Implemented by:

Nationwide Climate Vulnerability Assessment in Bangladesh

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Authors:

Dr. Hasse Goosen
Tanvir Hasan
Sanjib Kumar Saha
Dr. Nahid Rezwana
Md. Rejaur Rahman
Mohammad Assaduzzaman
Ashraful Kabir
Dr. Ghislain Dubois
Catharien Terwisscha van Scheltinga

Edited by:

Firdaus Ara Hussain
Md. Afjal Hossain
Md. Mahmudur Rahman

Special contribution from:

Abdullah Al Mohsin Chowdhury, Secretary, Ministry of Environment, Forest and Climate Change
Dr. Nurul Quadir, Additional Secretary, Ministry of Environment, Forest and Climate Change
Dr. Sultan Ahmed, Director General, Department of Environment
Shamshur Rahman Khan, Deputy Chief, Ministry of Environment, Forest and Climate Change
Mirza Shawkat Ali, Director (Climate change & International Convention (CC)), DoE

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List of abbreviations

AR4	IPCC Assessment Report 4
BBS	Bangladesh Bureau of Statistics
BCCSAP 2009	Bangladesh Climate Change Strategy and Action Plan (2009)
BDP2100	Bangladesh Delta Plan 2100
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
CAS	Climate Adaptation Services
CDMP	Comprehensive Disaster Management Programme
CEGIS	Center for Environmental and Geographic Information Services
CHT	Chittagong Hill Tracts
NCVA	Nationwide Climate Vulnerability Assessment
DoE	Department of Environment
DPP	Development Project Proforma
FCD	Flood Control and Drainage
FFWC	Flood Forecasting and Warning Centre
GED	General Economics Division, Planning Commission
GIS	Geographical Information Services
GIZ	German International Collaboration
GoB	Government of Bangladesh
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
IWM	Institute of Water Modelling
MoEF	Ministry of Environment,Forest and Climate Change
MoHFW	Ministry of Health and Family Welfare
NWRD	National Water Resources Database
RCP	Representative Concentration Pathway
SoB	Survey of Bangladesh
TPP	Technical Project Proforma

Abstract

Why a Nationwide Climate Vulnerability Assessment

Under the current climate conditions and due to its geographic location and topography, Bangladesh is exposed to a multitude of natural hazards such as floods, storm surges, droughts, riverbank erosion, etc. At the same time, new issues related to socio-economic factors and ongoing climate change impacts are emerging. Changes in temperature and precipitation patterns could affect, for instance, heat stress in the rapidly urbanising cities, groundwater depletion in rural productive areas, and so on. Emerging challenges from climate change include salinity intrusion and increasing coastal floods due to sea level rise. These impacts are threatening biodiversity, water resources, agriculture and settlements. A key question is, how to adjust development oriented planning to address issues triggered by climate change. There is a growing need for continuously updated and authentic information and data to enable the identification and monitoring of vulnerable areas and sectors in Bangladesh, and to design tailored adaptation strategies and measures. The elaboration of a Nationwide Climate Vulnerability Assessment (NCVA) is thus intended to provide the Government of Bangladesh with an evidence-based tool, prioritising adaptation funding and intervention within the country. This assessment was led by a team of international and national experts and was conducted through a systematic step by step approach applying participatory methods. The climate vulnerability was assessed for eight sectors at the Upazila level: Agriculture, Livestock, Fisheries, Navigation, Transport and Infrastructure, Water Resources, Biodiversity, Natural Disasters and Human Health. With this, the NCVA may serve as a tool to take on an integrated climate vulnerability perspective beyond the commonly regarded domains of flood risk and water management.

Current and future vulnerability: a climate change perspective

Climate change will increasingly expose the people of Bangladesh to natural hazards. What impacts will Bangladesh face by mid- and end-century? Which people, what areas, and sectors will be affected most? It is expected that the already intense and frequent hazards will intensify, such as riverine floods, flash floods, storm surges and cyclones. In addition, progressive changes such as rising sea levels will contribute to increased salinity intrusion, and rising temperatures will lead to an increase in heat wave and drought incidents. These changes will adversely affect Bangladesh. Some extreme events will occur more frequently, and the severity of events is likely to increase. This vulnerability assessment depicts the country's current vulnerability and future vulnerability under climate change, considering different scenarios, Representative Concentration Pathways (RCP) 4.5 and 8.5[1] and different temporal horizons (reference situation, 2050 and 2085). The vulnerability of a country can be represented as a complex interaction (**Error! Reference source not found.**) in which vulnerability is determined by the level of exposure to climate change, the degree of sensitivity to those changes, and the adaptive capacity of the system to cope with or moderate the negative impacts of climate change (IPCC AR4 2007). This NCVA assessed the current exposure, sensitivity and adaptive capacity of various sectors, and the resulting vulnerability, as well as the vulnerability under increased exposure due to climate change (future vulnerability). The overarching results are that the agriculture and water resource sectors in the country are considered highly vulnerable. The coastal zone is particularly vulnerable to natural disasters. Heat stress in cities will become a bigger issue in the coming decades. The results demonstrate the need to consider adaptation now in order to become resilient in the coming years. In summary, the results show that:

1. The exposure to climate change is increasing;
2. The sensitivity is increasing;
3. The adaptive capacity is low, though improving.

[1] Representative concentration pathways (RCP) or emission scenarios are greenhouse gas concentration trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) to describe four possible climate futures, depending on how much greenhouse gases are emitted in the years to come. In RCP 4.5, emissions peak around 2040, then decline. In RCP 8.5, emissions continue to rise throughout the 21st century.

Besides, there are other existing and emerging challenges in Bangladesh, like pressure on land use, governance, environmental protection, macro-economic development and globalisation. However, these are not part of the NCVA assessment. The need for taking integrated and long-term adaptation actions now becomes even more pertinent when considering these other emerging challenges in Bangladesh, which will exacerbate the impacts of climate change.

Routes to decrease vulnerability

There are many routes that can together decrease the vulnerability of Bangladesh. So far, most efforts have been sector oriented, and have concentrated on disaster risk reduction and water management, and have only regarded current climatic conditions. To increase the resilience of the country in the long run, an integrated approach is needed: decreasing sensitivity and increasing adaptive capacity of all sectors by elaborating strategies and implementing adaptation measures. A great potential for decreasing sensitivity lies in efforts focused on improving spatial planning, using nature-based solutions, enhancing gender equality, etc. Promising strategies to increase adaptive capacity are education and research, training, access to finance for investment, integration of local and regional initiatives into strategic plans, etc. In order to integrate local populations (community leaders, ethnic groups, etc.) in the different hotspots consideration, Focus Group Discussions have been conducted in those different climate hotspots. To summarise, the local communities stressed their lack of adequate information, knowledge and financial ability required to tackle climate change impacts.

Perspective of action for Bangladesh

This novel vulnerability assessment provides insight into the people, economic sectors and natural resources that may be most affected by climate change in a systematic, integrated and user-friendly manner. The produced maps allow for a spatio-temporal visualization of Bangladesh's vulnerability and provides an efficient tool for the prioritization of resource allocation for politicians and policy-makers to develop effective adaptation strategies, mainstream climate vulnerability with other policy domains, and enhance further research scope. This assessment will be integrated into the update of the Bangladesh Climate Change Strategy And Action Plan (BCCSAP) 2009 and can potentially contribute background information for project and policy documents addressing vulnerability, such as the National Adaptation Plan (NAP). Moreover, this assessment will facilitate access to funding sources (Green Climate Fund, World Bank, etc.) by providing clarifications on urgent adaptation needs of the country.

A continuous process and a national capacity

The nation-wide Climate Vulnerability Assessment came from recognition at the national level that an in-depth analysis is required for determining the vulnerability of different hotspots through an evidence-based study. The assessment of vulnerabilities per hotspot for the eight sectors were performed by a team of international and national experts, considering gender aspects as a cross-cutting issue. Top-down national data sets were combined with bottom-up inputs from regional workshops and focus group discussions. As new developments emerge and new (climate) data becomes available, the vulnerability assessment will need to be updated, making the assessment a living document. This systematic approach allows for replication in the future. The knowledge, capacity and ownership for the continuous development and use of the assessment lies within the country. Based on the experience of this assessment, it is vital to continuously and systematically improve the availability of climate change data in the country.This study is critical to keep track of the country's progress in addressing vulnerability through an index.

Potential adaptation options

The Nationwide Climate Vulnerability Assessment (NCVA) has intended to provide the Government of Bangladesh with a tool to assess climate change vulnerable areas.Other users, such as civil society organisations, research institutions and the private sector may be secondary beneficiaries of the NCVA. This assessment has prepared Geographical Information System (GIS) based maps of the country's vulnerability. These maps have outlined zones of high vulnerability and therefore, the identified zones should feed into political programming and public as well as private investment decisions. Decision makers and technical experts potentially use the map for designing adaptation programs for zones of high vulnerability. Amongst other applications, this tool will help the selection process and decision-making for funding allocation of new projects under various streams of climate finance, participatory identification of suitable adaptation options through impact chain for specific sectors/subsectors or spatial areas, identification of the baseline for M&E of climate change adaptation outcomes respectively.

1. Introduction

Internationally, Bangladesh is often considered to be one of the most vulnerable countries to climate change. It is threatened by both climate variability (of the current climate) and additional (future) change. To maintain economic growth and alleviate poverty, Bangladesh needs to adapt to climate risks and natural disasters, annual flooding, lack of water resources during the dry season, sea level rise, storm surges, coastal cyclones, etc. In addition to risks related to climate variability and change, many other challenges lie ahead of Bangladesh, including pressure on land use, governance, environmental protection, macroeconomic development and globalization (Ministry of Environment and Forests 2012). Given its ambition to achieve upper middle-income status by 2030, the government of Bangladesh takes a pro-active approach in addressing major challenges related to climate change and development (Ministry of Finance 2014). In support of this process, an integrated approach is needed to assess Bangladesh’s climate vulnerability in detail, with special regard to different regions and sectors (The World Bank Group 2011). Indeed, vulnerability assessments can help estimate the nature and extent of future threats to a given human or ecological system (Intergovernmental Panel on Climate Change, 2007), and they can provide the basis for devising measures to minimize or avoid harm.

The Nationwide Climate Vulnerability Assessment in Bangladesh was implemented by Bangladesh’s Ministry of the Environment, Forests and Climate Change (MoEFCC) and the Department of the Environment (DoE), with technical assistance from the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ). The process involved experts from high level, government officials from various departments, representatives of development partners, policy planners, researchers, and program managers. The Nation-wide Climate Vulnerability Assessment in Bangladesh focuses on the vulnerability related to agriculture, livestock, fisheries, biodiversity and environment, health, water resources, natural disasters, navigation, transport, and infrastructure. This assessment covers the entire country, with a specific resolution at the administrative level of Upazila. It is conducted for different time horizons, e.g. current vulnerability, vulnerability in the medium (2050) and long term (2085), and different emission scenarios: medium-optimistic scenario (RCP 4.5) and the most pessimistic one (RCP8.5). It follows the approach of the GIZ Vulnerability Sourcebook, providing a systematic step-by-step guidance, consistent with the Intergovernmental Panel on Climate Change’s (IPCC) approach and terminology. It examines vulnerability in an integrated way and emphasizes the importance of involving stakeholders in each step of the process (GIZ 2014).

The aim of the Nationwide Climate Vulnerability Assessment is to provide the Government of Bangladesh with a tool to assess vulnerable areas to climate change and identify the climate vulnerable populations of those areas. The identified zones can feed into political programming, and public as well as private investment decisions, supporting the development of suitable adaptation options. Moreover, the identification of vulnerable regions, sectors and populations can support the funding allocation of new projects under various streams of climate finance. Finally, the vulnerability assessment can be updated on a regular basis and can therefore also be used for monitoring and evaluating climate change adaptation efforts.

This synthesis report for policy makers summarizes in the first part the methodology which has been followed, with due consideration of challenges which have been encountered during the NCVA process. It may be noted that a technical annex to this synthesis report is provided, where the conceptual and technical (GIS) methodology is explained in more detail. A second part of this synthesis report focuses on the context and characteristics of Bangladesh regarding climate vulnerability and change. A third section presents the results obtained during this climate vulnerability assessment, with a selection of key maps resulting from the entire process. This section firstly gives an overview of the key results at the scale of Bangladesh (exposure, sensitivity and adaptive capacity to climate change). Then, regional differences regarding climate vulnerability are presented, and finally the sectoral climate vulnerabilities are summarized and illustrated with the final vulnerability maps. The sectoral findings are integrated into the assessment, with sectoral maps and indices in the annex. The fourth and final section of this synthesis report provides interesting perspectives to this innovative study while reflecting and discussing the approach and results.

2. Methodology

2.1 IPCC's conceptualization of vulnerability

Vulnerability is a concept used to express the complex interaction of climate change effects and the susceptibility of a system to its impacts. There exist manifold definitions and methods of operationalizing this concept. The Intergovernmental Panel on Climate Change (IPCC) sought to elaborate and advance an approach for understanding vulnerability in its Fourth Assessment Report (AR4) as:

"the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Intergovernmental Panel on Climate Change, 2007).

Within this perspective, vulnerability is understood to be the function of a system's climate change exposure, sensitivity and adaptive capacity to cope with climate change effects, as illustrated below:

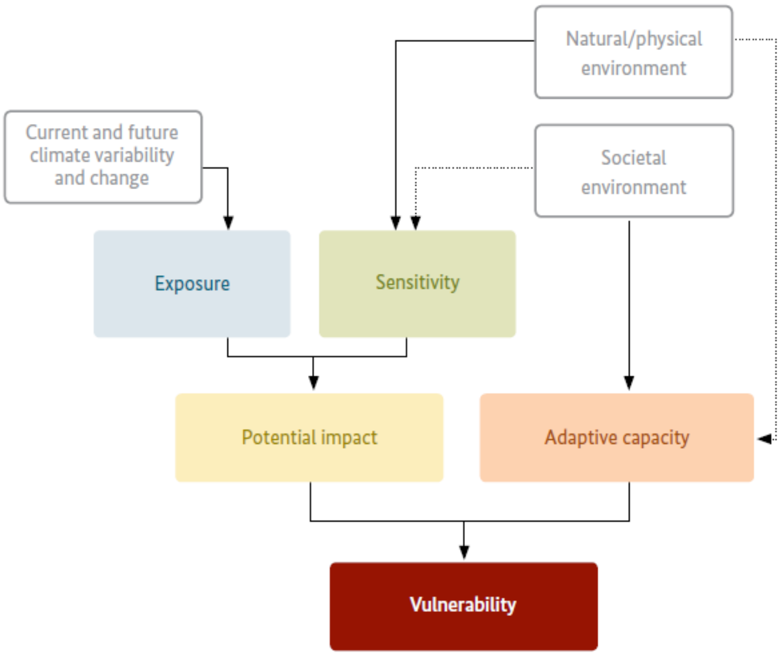


Figure 2.1: Vulnerability concept according to the IPPC AR4 (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2014)
Source: Vulnerability Sourcebook, 2014

Within this conceptual framework:

- **Exposure** refers to changes in climate parameters that might affect socio-ecological systems. Such parameters are for example temperature or precipitation, which climate change alters with regard to their quantity as well as their spatial and temporal distribution;
- **Sensitivity** tells about the status of the physical and natural environment of the affected systems that makes them particularly susceptible to climate change. For example, a sensitivity factor could be topography, land use, distribution and density of population etc.;
- **Potential Impact** is determined by combining exposure and sensitivity to climate change;
- **Adaptive capacity** refers, according to Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), to "the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

2.2 The GIZ Vulnerability approach tailored for application in Bangladesh

The Climate Vulnerability Assessment of Bangladesh is based on the Vulnerability Sourcebook approach (GIZ 2014). In line with IPCC AR4 conceptual framework, the Vulnerability Sourcebook advocates for an integrated approach of vulnerability assessments, looking at climatic, social, economic and environmental aspects of vulnerability with gender as a cross-cutting issue. It provides guidance on analysing vulnerability at different spatial levels like at the community, subnational or national levels, and can take different time horizons into account (e.g. current vulnerability, vulnerability in the medium to long term) (GIZ 2014).

The GIZ Vulnerability Sourcebook suggests a step-by step guidance for designing and implementing a Climate Vulnerability Assessment. The approach has been adapted to the context in which the Bangladesh NCVA took place and to stakeholders' needs and expectations. Six steps were implemented, from scoping to presentation of outcomes. The whole process was a result of integrative work between stakeholders and experts in order to ensure relevancy, validity, and accuracy through constant adjustments along the implementation of the Vulnerability Sourcebook methodology.

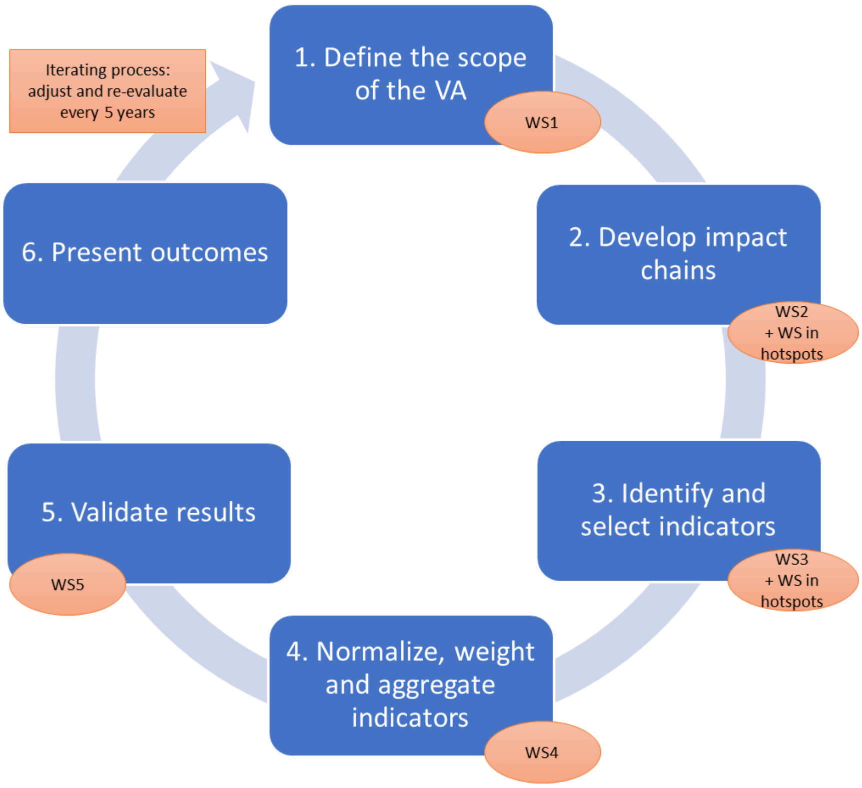


Figure 2.2: Workflow conducted for the Nationwide Climate Vulnerability Assessment in Bangladesh

Stakeholder engagement has been ensured through 10 workshops (5 in Dhaka and 5 in different climatic hotspots) and 37 focus group discussions, organized at crucial steps of the process, at both national and local levels.

Figure 2.3: Inception and Scoping workshop of the Nationwide Climate Vulnerability Assessment in Dhaka

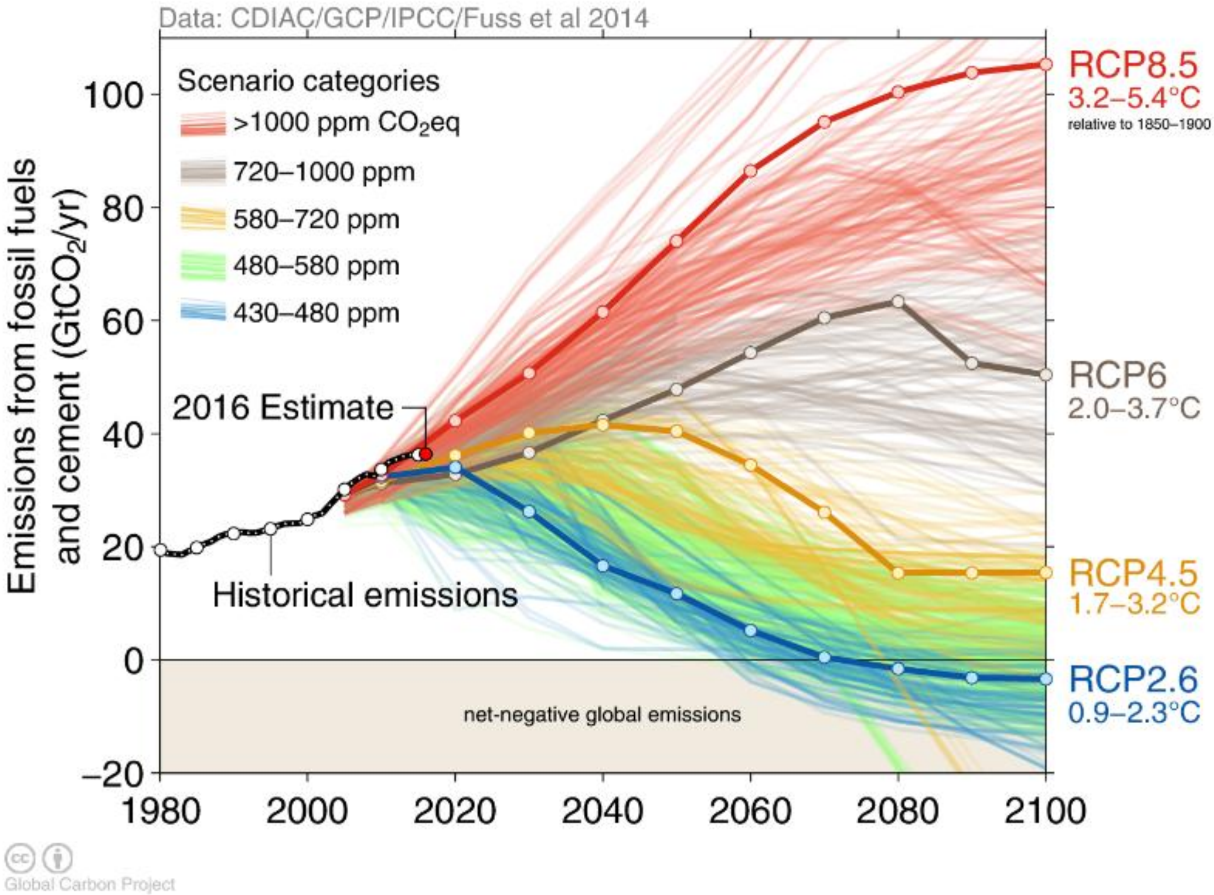


Figure 2.4: Representative Concentration Pathways
Source: Fuss et al 2014

The first workshop (November 2016), aimed to reach a common understanding of the objectives and the approach of the vulnerability assessment; to set the scope of the assessment and to make sure that the process would respond well to the needs of involved stakeholders (Work Package 1).

The workshop participants emphasized the need to develop the Climate Vulnerability Assessment at the administrative level of upazillas, i.e Bangladesh's sub-districts, in order to be able to visualize the vulnerability at the lowest sub-national level, based on data availability. However, challenges of data availability were faced throughout the study and proxies were selected based on consensus with stakeholders. A choice has been made to investigate two temporal horizons: **2050 and 2085**, according to two different climate scenarios: **RCP4.5 and RCP8.5**. The Representative Concentration Pathway RCP4.5 corresponds to a medium-optimistic projection, and the RCP8.5 to the most pessimistic one.

Once the priority climate change impacts were identified and approved, impact chains were developed together with stakeholders during a second workshop in Dhaka (February 2017) (Work Package 2). From May to October 2017, regional workshops took place in which the impact chains were validated and refined in different regions to incorporate the regional perspective regarding vulnerability. An extensive review of available data, along with stakeholders' consultations (December 2017) led to the selection of relevant indicators for the various components of vulnerability for all sectors (Work Package 3). Indicators treatment resulted once again from the combination of a participatory technical exercise (a four-day session held in Dhaka, February 2018) and technical deskwork to assign weights and implement the normalization methodology for each component of the various impact chains. All the required material was then available for implementing the vulnerability GIS mapping exercise, operationalized by the national experts (Work Package 4). A round-table discussion was arranged (May 2018) with the involvement of prominent experts to refine the findings and collect constructive feedback. A validation workshop in Dhaka was organized (May 2018) to present the vulnerability assessment outcomes. National experts and stakeholders were involved throughout the process, discussing the finalization and improvement of final results.

The NCVA outcomes combine some qualitative assessments (storylines and description of climate change impacts) with a quantitative analysis through vulnerability maps that allow visualizing vulnerability hotspots in Bangladesh, and the overview of vulnerability throughout the century under each climate scenario.

2.3 Understanding vulnerability through impact chains (IC)

One of the key elements of the methodology is the formalization of impact chains, identifying and prioritizing drivers of exposure, sensitivity and adaptive capacity. Impact chains normalize and aggregate information and knowledge in a simplified manner. It constitutes the basis for the quantitative vulnerability assessment. By breaking down vulnerability into specific components (exposure, sensitivity, potential impact and adaptive capacity), and de-segregating each component into explanatory factors, it facilitates the identification of relevant vulnerability indicators. The vulnerability assessment is supposed to follow the logic of the impact chain, assessing the exposure, sensitivity and adaptive capacity components, as presented in the AR4 of the Intergovernmental Panel on Climate Change (**Error! Reference source not found.**).

In accordance with the Vulnerability Sourcebook 2014, the objective of the Impact Chain Workshop led in Dhaka (February 2017) was to obtain shared and validated impact chains describing the cause-effect relationships that determine vulnerability. This workshop led to the elaboration of impact chains for each sector (one per sector), integrating several potential impacts shaping the vulnerability of the sectors.

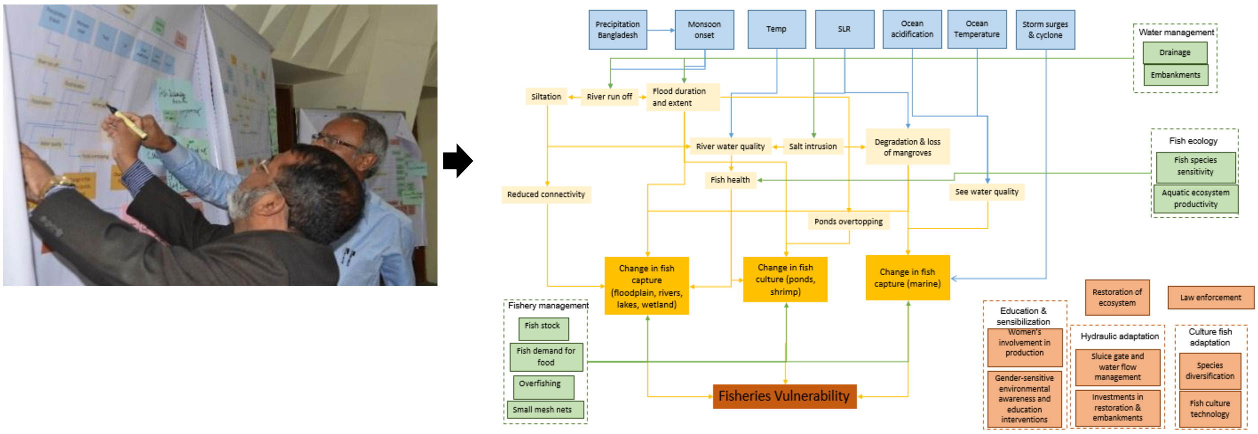


Figure 2.5: Elaboration of one impact chain per sector based on the workshop held in Dhaka (example of the fisheries sector)

The main climate indicators corresponding to exposure, sensitivity and adaptive capacity that are responsible for agricultural vulnerability to reduced water availability and quality are synthesized in a conceptual scheme. This scheme elaborates the causal links of vulnerability components and intrinsic factors. Consequently, an impact chain aims to detail how a specific change in climate (exposure factors) will drive the vulnerability of a specific sector.

Due to data gaps, the assessment does not include future projections for the sensitivity and adaptive capacity components.

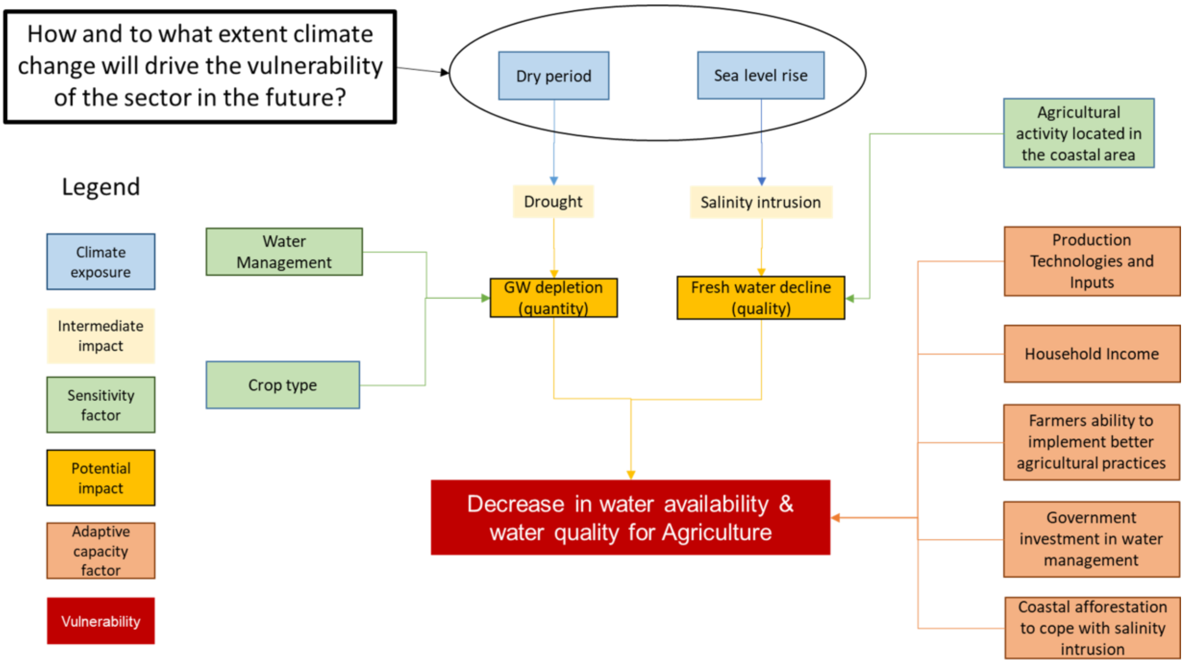
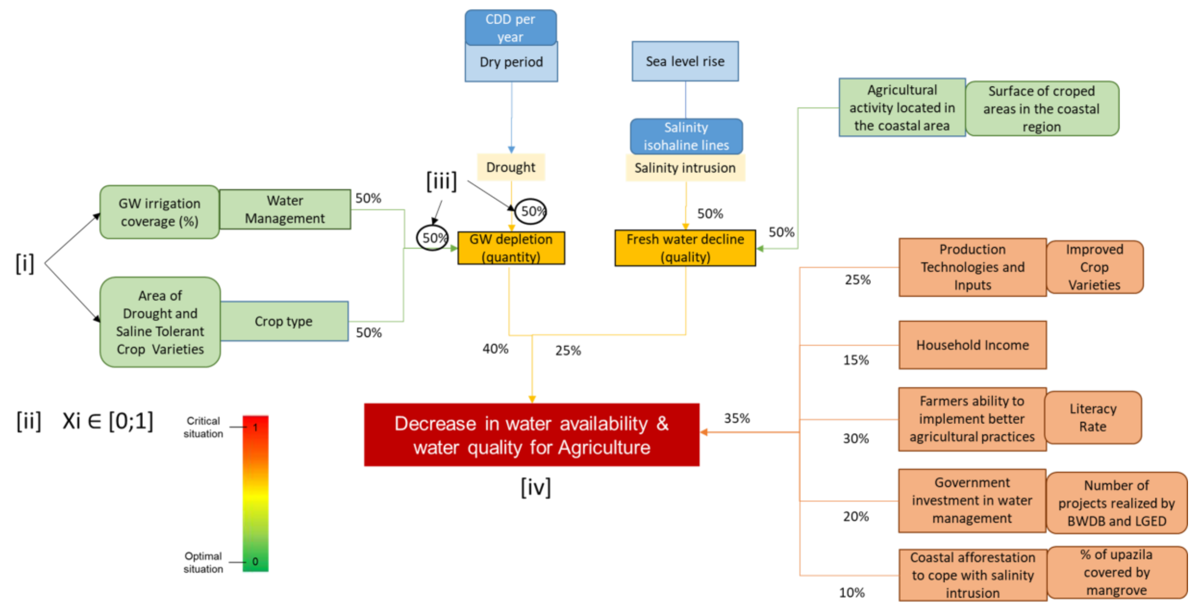


Figure 2.6: The impact chain: a conceptual tool for understanding sectoral vulnerabilities under climate change

Impact chains also constitute operational tools for conducting a Climate Vulnerability Assessment. When (i) indicators are selected for each composite factor of the impact chain; the data collected is (ii) normalized, (iii) weighted and (iv) aggregated; in order to finally produce vulnerability maps. The objective is to reach standardized vulnerability scores for each upazila, allowing comparison, hierarchization, and therefore allowing decision making on adaptation.

Based on the example of agricultural vulnerability to water availability and quality, this impact chain shows the step by step process conducted to produce vulnerability maps.



[iv] Index value $= \sum w_i X_i = (w_1 \cdot X_1 + w_2 \cdot X_2 + w_3 \cdot X_3 + \cdots + w_n \cdot X_n)$.

Figure 2.7: Impact chain: an operational tool for implementing a Climate Vulnerability Assessment

Table 2.1: Normalized data value with the corresponding vulnerability component

Scale	Climate exposure	Sensitivity	Potential impact	Adaptive capacity	Vulnerability
1	Adversely exposed	Highly sensitive	Adversely affected	Unable to adapt without substantially increased support and resources	Highly vulnerable
	↑	↑	↑	↑	↑
0	Not exposed	Not sensitive	Not affected	Able to adapt without problems	Not vulnerable

In addition to their usefulness for vulnerability mapping, impact chains are also valuable outcomes in themselves. They help create a comprehensive understanding of climate change vulnerability shared by various stakeholders, and they highlight issues in which adaptation actions can decrease vulnerability and increase climate resilience.

2.4 Scope of the vulnerability assessment

The decision to focus on vulnerabilities related to water, biodiversity, environment, agriculture (including livestock and fisheries), navigation, transport, infrastructure, health and security at the upazila level, was made keeping in mind Bangldaesh's climate and socioeconomic context, and having taken into consideration stakeholders expectations.

Within these sectors, the final choice of priority impacts (per sector) to investigate was based on a multicriteria analysis, assessing the relevance of the impacts (relation to climate change, link with other sustainable development goals, spatial scale and adaptation potential) and the operational feasibility of the mapping assessment (data availability, scientific knowledge, complexity and uncertainty).

This process led to the selection of 17 climate change impacts for investigation. For each impact, the assessment consisted of establishing an impact chain, selecting and treating relevant indicators to objectivize each vulnerability component and finally implementing the mapping exercise, for current and future vulnerability (2050 and 2085), for two RCP scenarios (RCP4.5 and 8.5).

Together with national experts, an updated list of 12 impact chains has been developed, based on data availability.

Table 2.2: Priority sectors and impacts covered by the NCVA

	Sectors	Impacts	Implemented Impact Chains
Natural capital (planet)	Water resources	1. Groundwater depletion and degradation 2. Degradation of surface water	X
	Biodiversity and environment	3. Mangrove forest degradation and loss 4. Char lands and islands degradation and loss	X
Production capital (profit)	Crop Agriculture	5. Land availability for agriculture 6. Water availability and quality for agriculture 7. Crops yield	X X X
	Livestock	8. Land availability for livestock 9. Livestock and poultry health	X X
	Fisheries	10. Change in fish culture (ponds and shrimp) 11. Change in fish capture (floodplain, rivers, lakes and wetlands)	X X
	Navigation, Transport & Infrastructures	12. Railway transport disruption 13. Road transport disruption	X
Human capital (people)	Human health	14. Heat-waves stress 15. Water-borne and communicable diseases	X
	Human security	16. People affected due to natural disasters	X

2.5 Stakeholders' involvement in the NCVA process

This climate vulnerability assessment covers the entire country. However, the perspectives of the people directly exposed to the adverse impacts of climate change in their daily lives are not always holistically incorporated in the assessment. This gap was addressed with the integration of community level participation in Focus Groups Discussions (FGD). The FGDs focused on community aspects in assessing climate vulnerabilities, providing deep insights into community opinions, ideas, plans, mechanisms, attitudes, perceptions, practice, knowledge, and expectations regarding highlighted climate vulnerabilities. Furthermore, the FGDs helped clarify the challenges and options identified by workshop participants in the initial stages of developing the impact chains.

Figure 2.8 – Focus group discussion in Bagaichhari Upazila, Rangmati Hill Districts, Farmer and Jhum Community (Chitagong Hill Tracts and Coast)

Figure 2.9: Focus group discussion in Amnura (Barind and Drought prone area)

2.6 Methodological and technical limitations of the NCVA

In the operationalization of the NCVA, several challenges emerged. The mapping exercise within this Nationwide Climate Vulnerability Assessment is an innovative approach, for which the technical team was supported by a national GIS expert. This step of GIS analysis is essential in building capacity to conduct an NCVA. The annex presents the technical approach to produce GIS maps.

Data gaps and/or unavailability

Due to missing/unavailable data, several proxies have been used. In some cases, (for e.g. fish culture and capture data), data was available at the district level which was then downscaled to the upazila level. Data availability for individual impacts remain a challenge and hence, impact chains were simplified or updated based on data availability and proxies. Several other techniques of normalization are available, however, for this assessment a single calculation method was used to maintain uniformity, as per expert judgement. In the future, other calculation methods may be explored. Future maps were produced taking only exposure data into consideration for the ensembled climate models, as predicted sensitivity and adaptive capacity data is not available in Bangladesh.

This assessment should be seen as a first attempt of systematically unraveling Bangladesh's vulnerability to climate change. The development of the Bangladesh NCVA has been an iterative process and consultative in nature. It is meant to be readjusted and updated periodically, in order to integrate knowledge developments, to expand the scope of analysis, to take account of dynamic and rapid socio-economic changes, and to support monitoring and evaluation of adaptation by showing how adaptation policies implemented through time succeed in reducing vulnerability. The NCVA followed a consultative approach because of its consultative nature. This is the first attempt in the world which was assessed prioritizing eight sectors and nationwide. The assessment has proven a challenging task, hampered by numerous limitations. In this section some of the highlights of the challenges will be underlined.

Data limitations

The impact chains, which were developed together with sectoral experts and stakeholders, provide valuable overviews of the causal relationships between climate change and the ultimate impacts on the sectors. However, the data inventory revealed that data was available only for a limited number of indicators. Hence, the study had to prioritize and narrow down the number of indicators to a more concise set of data layers.

Moreover, Bangladesh being such a dynamic country, the reliability of older data can be questioned. For example, soil salinity data originated from 2009, and groundwater depth from 2010. An updated and improved CVA would benefit from an updated database of spatial information about water resources and climate related hazards.

During the data selection process, several proxies have been used to assess exposure, sensitivity or adaptive capacity components in order to cope with the lack of data. Limitations associated with the use of proxies (approximations and lower representation of the assessed component) must be kept in mind. For some indicators, data are not available at the upazila level but only at the district level. In these cases information is thus less specific to each upazila, with a lower discrimination of data values among upazilas from a same district.

Weighting

By definition the weighing of indicators is a subjective matter. Ideally a series of consultations can be done or a specific method, such as the principle component analysis method can be used, to determine the weights. However, the NCVA exercise of this magnitude makes this practically very challenging. Having eight sectors, 12 impact chains consisting of over 20 indicators each, for multiple time horizons and climate scenario's would mean that thousands of weights would have to be determined in a stakeholder setting.

Projections of climate change

It proved to be difficult to find data sets that indicate projections of climate impacts into the future. In general some data are available on climatic exposure components, such as rainfall and temperature data. However, the systematic translation is missing of how climate change will have an impact on (flash) flood extent and frequency, drought and salinity. It therefore proved challenging to produce projections of future climate for these impacts.

Future projections have been prepared for some vulnerability maps. This was done only for two climate scenario's (RCP 4.5 and 8.5). The RCP8.5 combines assumptions about high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long term to high energy demand and GHG emissions in the absence of climate change policies. RCP8.5 thus corresponds to the pathway with the highest greenhouse gas emissions. Representative Concentration Pathway (RCP) 4.5 is a scenario that stabilizes radiative forcing of 4.5 W m^{-2} in the year 2100. The recent IPCC 1.5 degree report stresses the need of staying below a 1.5 degree Celsius of warming. The RCP 4.5 and 8.5 would well exceed the 1.5 degree warming level. The reasons for choosing the extremer RCP 4.5 and 8.5 is to demonstrate that exceeding the 1.5 degree level would push the vulnerability of Bangladesh up to critical levels. A recommendation for future improvement of the NCVA would be to perform an assessment for both 1.5 degree and > 2 degree warming, in line with the IPCC 1.5 degree report.

Projections of adaptive capacity and sensitivity

Future maps were produced taking only exposure data into consideration for the ensembled climate models, as predicted sensitivity and adaptive capacity data is not available for Bangladesh. The assessment does not include future projections for the sensitivity and adaptive capacity components. Projections of socio-economic indicators are probably even more challenging to produce than climate projections. However, some attempts have been made to develop future land use scenarios through land use modeling (Shaikh Shamim Hasan, et al., 2017).

Uncertainty analysis

Composite indicator development involves stages where subjective judgments have to be made: the selection of individual indicators, the treatment of missing values, the choice of normalization method, the weights of indicators, the choice of aggregation model, etc. All these subjective choices have to be made in order to aggregate the individual components into one vulnerability indicator. The methodological choices shape the message communicated by the aggregated vulnerability indicator. Thus, the quality of a vulnerability assessment strongly depends on the soundness of its assumptions. A scientifically good assessment practice would require that an expert provides an evaluation of the confidence in the vulnerability assessment process: firstly, by quantifying uncertainty in any step by step results (uncertainty analysis); and secondly, by evaluating how much each input is contributing to the final output uncertainty (sensitivity analysis).

Uncertainty analysis would allow investigating the uncertainty of variables that are imputed in the vulnerability assessment scheme. In a complementary way, sensitivity analysis would show how the uncertainty in the output of a mathematical model or system can be apportioned to different sources of uncertainty in its inputs. Ideally, uncertainty and sensitivity analysis should be run in tandem.

A combination of uncertainty and sensitivity analysis can help to gauge the robustness of the final vulnerability score, to increase its transparency, to identify which upazilas' vulnerabilities are favoured or weakened under certain assumptions and to help frame a debate around the final results. Literature shows that several ways exist to assess robustness of such indicators-based assessment. However, most of the time it requires a statistical work which is heavy and complex to implement, and not always feasible given the time provided for such study implementation.

Transboundary issues

One of the important drivers determining the water availability of the country is the amount of water entering through transboundary rivers. The NCVA study did not take this into account as information about transboundary river management is not available.

User-friendliness

The methodology resulted in a large number of indicators for current and future climate change scenarios. The number of maps produced may seem overwhelming and the results may be difficult to interpret. It is recommended to visualize the results through an interactive atlas to facilitate easy browsing through the results. Also it is recommended to develop training material to help users to understand and interpret the results.

3. Context and characterization of climate change in Bangladesh

3.1 Location and physical characteristics of Bangladesh

Bangladesh is a small country in terms of its territory, with an area of about 147,570 sq. km. Located in South Asia, it is bound by India on the west, the north and the northeast, and by Myanmar on the south-east. The Bay of Bengal demarcates the southern border with a long coastline. The Himalayan range is close to the northern border of Bangladesh.

The country primarily consists of low and flat land, except for the hilly regions in the northeast and southeast, and highlands in the north and northwest. Floodplains occupy about 80% of the country (Ministry of Environment and Forests 2012).

Three major rivers, the Ganges, Brahmaputra and the Meghna, which bring inflow from India, merge inside Bangladesh before discharging into the Bay of Bengal through a single outfall (Ministry of Environment and Forests 2012). The mean combined discharge is the third largest in the world, after the Amazon and the Congo. Seasonal flow variations in the rivers is characterized by abundant water during the monsoon and a much lower volume during the dry season.

Figure 3.1 : Bangladesh country location
Source: NOP, 2018

3.2 Socio-demographic and economic conditions

In 2017, the total population of the country was 163 million, with nearly 30% living in urban areas. The average population density is 1,252 inhabitants per sq. km. Gross Domestic Product (GDP) is rising at 7.1% (World Bank data, 2017). Poverty rates have steadily declined, from nearly 60% in 1991, to 25.1% in 2011 (Ministry of Environment and Forests 2012). The Human Development Index (HDI) for Bangladesh has risen from 0.328 in 1980, to 0.543 in 2007. A country, where 47 million people still live in poverty and 26 million people live in extreme poverty (World Bank 2013), natural hazards threaten to undo Bangladesh's development goals. Climate change goes beyond being only an environmental issue; rather, it is a development issue with implications on the socio-economic realities, i.e., population density, inequity and deprivation, poverty and per capita resource endowment, along with implications on development practices (Dastagir 2015). The high incidence of poverty and the heavy reliance of poor people on agriculture and natural resources increases their vulnerability to climate change (BCCSAP 2009).

Agricultural land dominates the land cover of the country, of which arable land occupies about 59% (Ministry of Environment and Forests 2012). In 2017, agriculture contributed 15% to the GDP (World Bank 2017), while the sector accounts for 45% of the labor force. With over 60% of Bangladesh's people dependent on agriculture, directly or indirectly, for their livelihoods, Bangladesh remains predominantly an agrarian nation (Ministry of Environment and Forests 2012).

3.3 Climate variability in Bangladesh

Bangladesh has typical monsoon climate characterized by rain-bearing winds, moderately warm temperatures, and high humidity. It receives heavy rainfall, 80% of which occurs during the southwest monsoon period (late May to mid-October). The mean annual temperature is about 25°C. Mean monthly temperature ranges from 18°C in January to 30°C from April to May. Highest temperatures in the year range between 38°C and 41°C. The average annual rainfall is about 2,200 mm a year with relatively high humidity all year around. Maximum humidity, over 80%, is recorded between June to September (Ministry of Environment and Forests 2012). Thus, the four major seasons and overall climate of Bangladesh is primarily influenced and defined by precipitation.

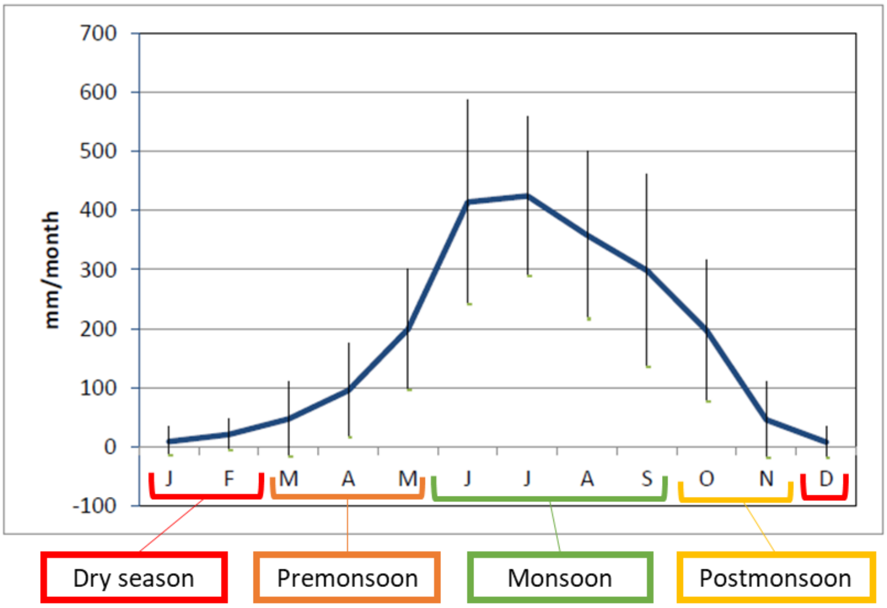


Figure 3.2: Seasonal istribution of mean precipitation in Bangladesh (1948-2004)
Source : BanDuDeltAS 2015

Under current climate conditions, Bangladesh is exposed to a multitude of natural hazards such as floods, cyclones, heat waves, river bank erosion, drought, storm surges and salinity intrusion. Heavy monsoon rain over the highlands and tropical storms in the coastal region trigger coastal floods. Sudden rain storms in April/May create immediate run-off, causing 'flash floods' in the north east (Hoar region). Every year cyclones hit the country's coastal region and on average a severe cyclone strikes the country once in 3 years. About 70% of Bangladesh is one meter or less above sea level, and consequently a large part of the country is flood plain. An 'average flood' causes about 20-25% of the country to be flooded. Rising sea level increases salinity intrusion, which in turn impedes fresh water availability. With a mix of flood plain and drought-prone areas, the country is faced with an abundance of water on one hand, and (agricultural) droughts on the other.

3.4 Climate change in Bangladesh

Every year, the country experiences a multitude of natural disasters which cause a heavy loss of life and property, and jeopardize development activities initiated by the government (Dastagir 2015). Bangladesh has a long history of severe floods, cyclones, storms, tidal surges, river and coastal erosion, etc. (Mc Granahan et al. 2007; IOM 2010, cited by Rahman and Rahman 2014). Climate change threatens to increase the country's exposure to these hazards in the near and distant future. This section presents climate change projections for Bangladesh, based on the baseline study (2015) and results generated under the HI-AWARE research project (2014-2018) on the Indus, Brahmaputra and Ganges river basins. The Bangladesh Climate Change Baseline study gives future climate projections for two scenarios: a relative low emission pathway "RCP4.5" and a high emission pathway

“RCP8.5” (BanDuDeltAS 2015). Future climate is projected based on 5 downscaled Global Climate Models (GCM). This study gives mid-century (2050) and end-century (2080) projections for the following climate indicators: average maximum temperature, duration of dry spells and precipitation intensity, with a baseline period of 1970-1999.

The International Centre for Integrated Mountain Development (ICIMOD) led regional and international partners in the HI-AWARE project on climate resilience and adaptation in the mountains and flood plains of the Indus, Ganges, and Brahmaputra river basins. In this project, the study by Wijngaard et al. (2017) considered hydrological extremes, such as floods and droughts, in the upstream domains of the Indus, Ganges and Brahmaputra. The hydrological fluxes were modelled using an ensemble of 8 downscaled General Circulation Models (GCMs) for both the RCP4.5, and the RCP8.5 scenarios. The results show an increase in both means and extremes of hydrological fluxes by the end of the century. Another study in the project by Lutz et al. (2016), described a method for climate model selection. It illustrates the outcomes for changes in mean air temperature, annual precipitation sum and climatic extremes for the river domains, for both scenarios, RCP4.5 and RCP8.5.The model is used to compare the changes between current (1971-2000) and future (2071-2100) climate. The study showed that while future climate is highly uncertain, changes are imminent.

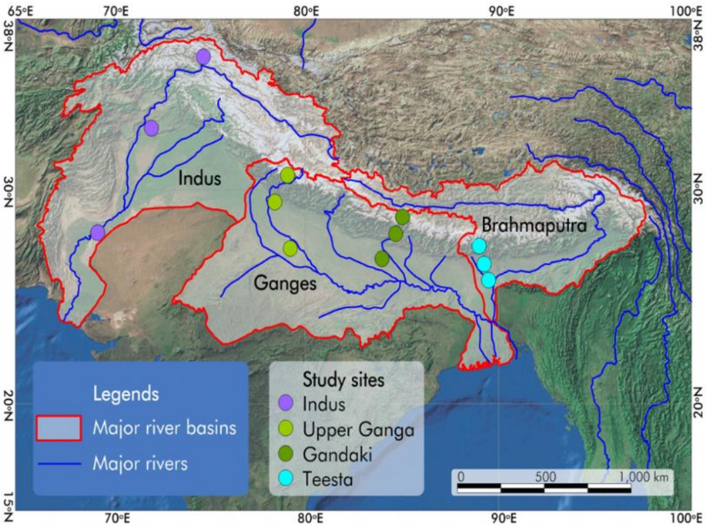


Figure 3.3: Study sites HI-AWARE project.
Source : Hi-AWARE project 2014

In the next section, climate change projections for Bangladesh are highlighted. The projections illustrate Bangladesh’s increasing exposure to climate-related hazards.

Temperature rise and increasing heat stress

Annual average temperature in Bangladesh has shown an increasing trend over the last few decades (Figure 3.4). Future temperature projections for the country are uncertain, in terms of magnitude of temperature increase, however, there is consensus over an increasing trend in temperature in Bangladesh.

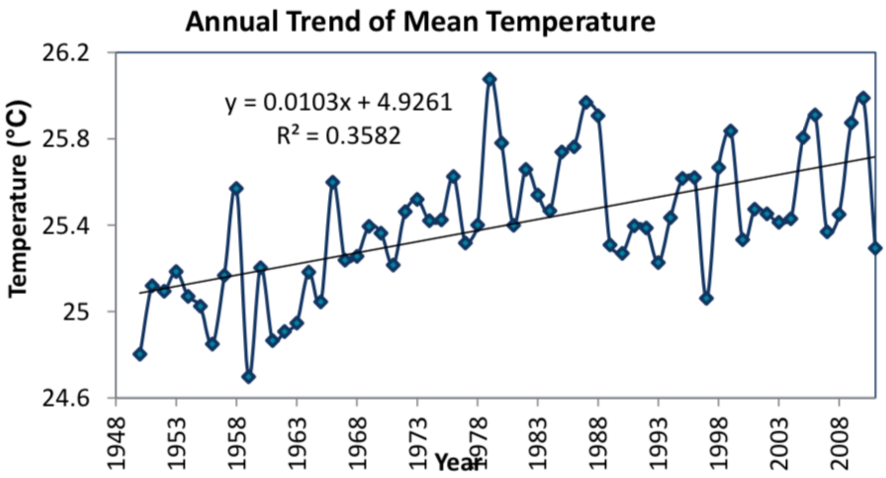


Figure 3.4: Historic annual trend mean temperature
Source : BanDuDeltAS 2015

The baseline study shows that both minimum and maximum temperature will further increase in the 21st century in Bangladesh (BanDuDeltAS 2015). By end-century, maximum temperature is projected to increase by 2°C to 2.5°C for the RCP 4.5 scenario, and by up to 4°C under the RCP 8.5 scenario. Higher temperatures may cause heat stress further inducing health risks. Under current climate conditions, the average number of days where maximum temperature exceeds 40°C is 20 to 25 days. Mid-century (2050) projections indicate an increase by 2.5 to 3.5 extreme heat days, while end-century (2085) projections indicate an increase of 3.5 to 5 extreme heat days for moderate (RCP 4.5) and extreme (RCP 8.5) emission scenarios respectively (see Figure 3.5).

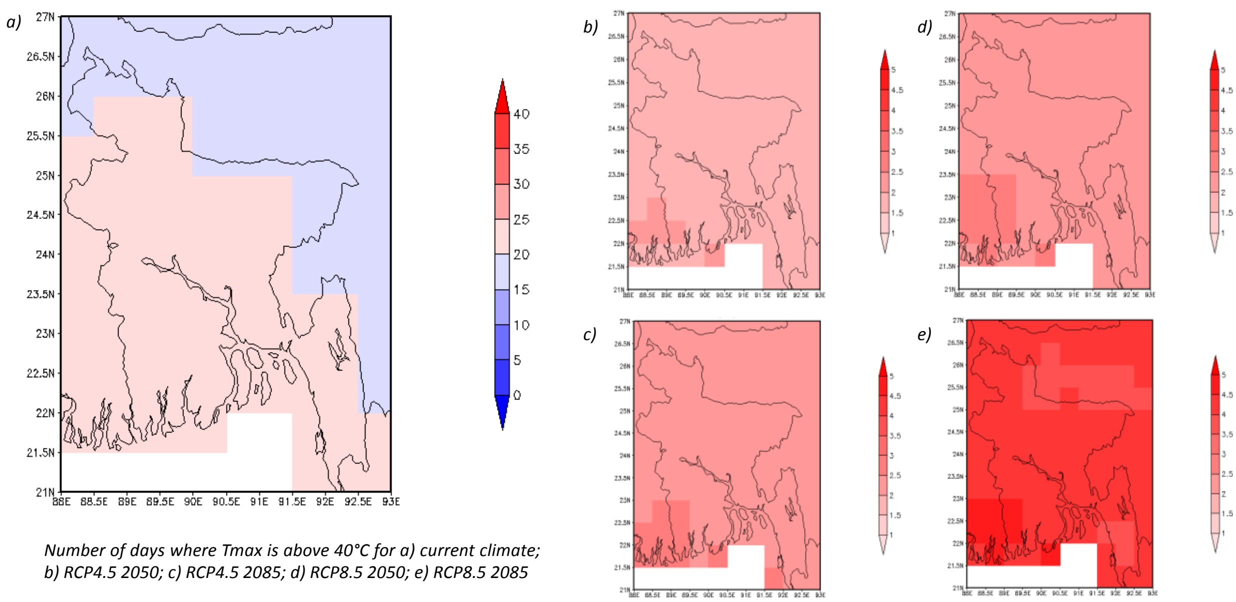


Figure 3.5: Number of days where the maximum temperature is above 40 degrees for current and future climate
Source : BDP, 2018

Lower night-time temperatures are required to recover from exposure to extreme heat during the day. High night-time temperatures exacerbate the risk of illness. Figure 3.6: Number of nights above 30 degrees per year for current climate (left), and for future climate under RCP 8.5 scenario for 2050 (right).

Source: http://www.cas-platform.com/hi-aware/)

shows current and future incidence of the number of nights per year that exceed temperatures of 30°C in Bangladesh. These maps were generated based on the study by Lutz et al. (2016). They cover most of Bangladesh, except for the southern coastal zone. In the current climate, there is no record of night-time temperature exceeding 30°C. It should be noted that values on the maps represent air temperature in rural areas. This means that in urban areas, where building materials retain the heat of the day, the actual night-time temperature may be higher, both in current and future climate scenarios. This phenomenon is referred to as the Urban Heat Island effect.

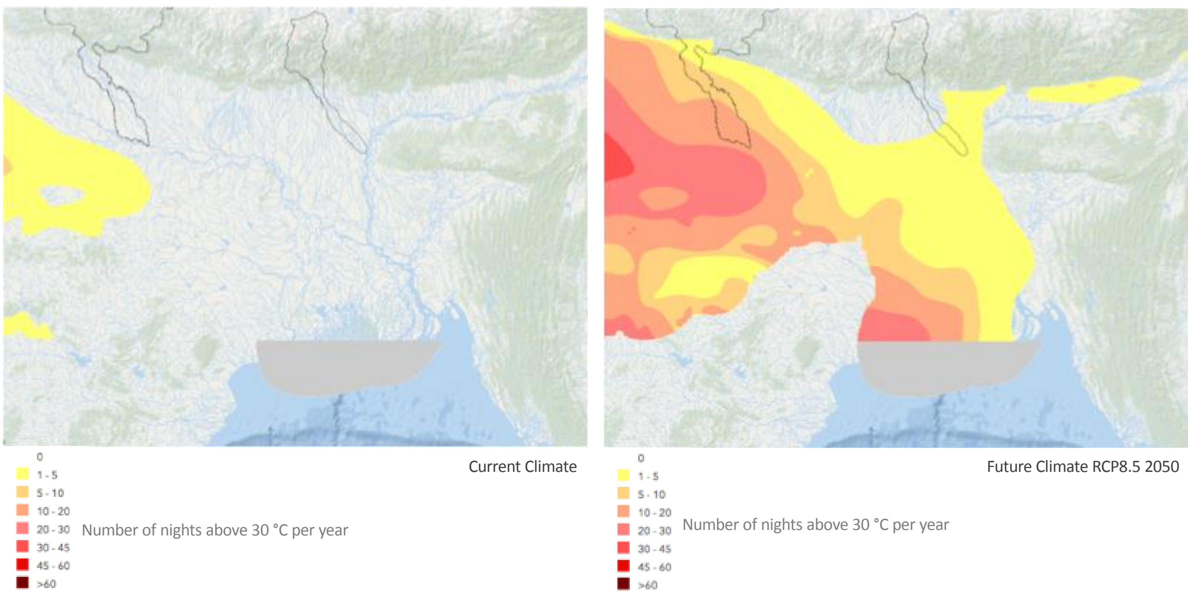
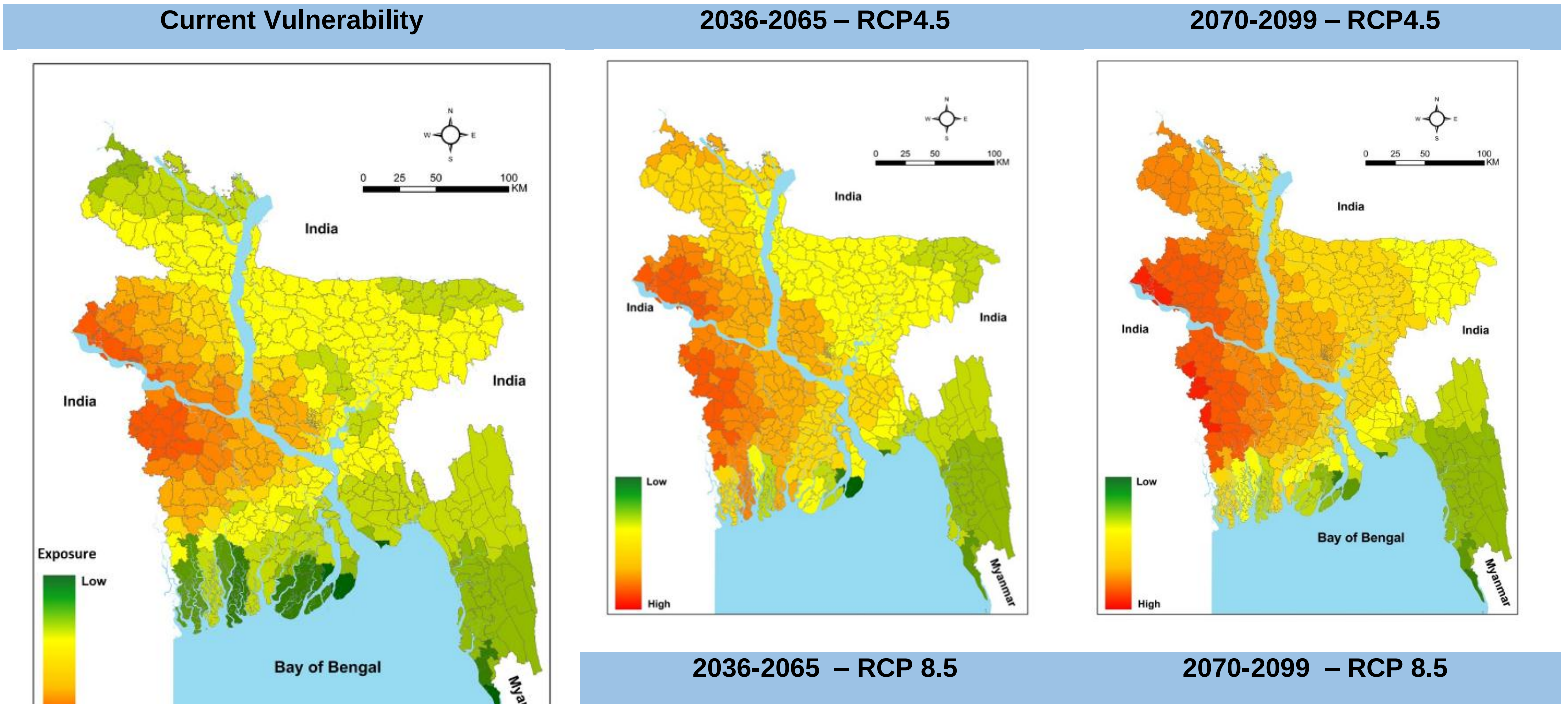
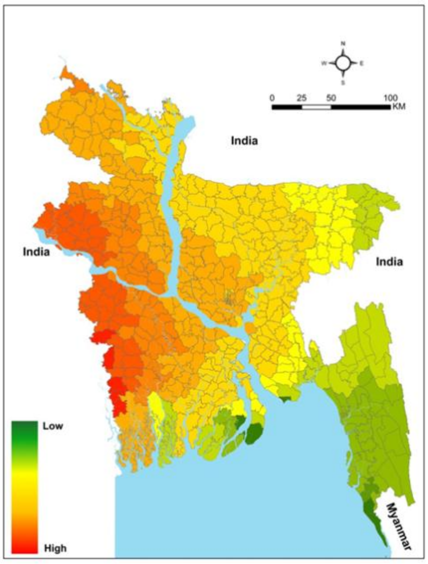


Figure 3.6: Number of nights above 30 degrees per year for current climate (left), and for future climate under RCP 8.5 scenario for 2050 (right) (Lutz A. F. 2016).
Source: http://www.cas-platform.com/hi-aware/)





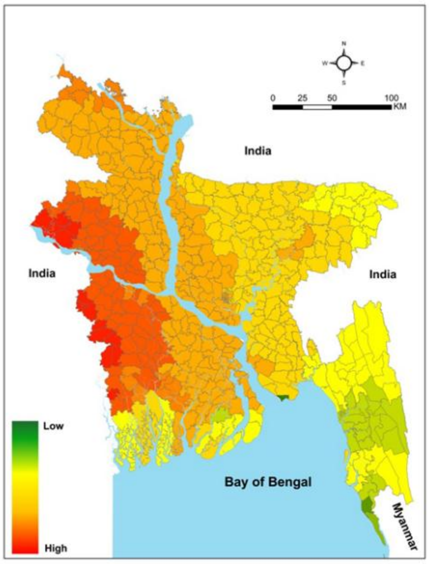


Figure 3.7: Assessment of Bangladesh's exposure to increase in heat stress (considering the following factors: increase in the number and duration of heat waves and the increase in heat level). Values are normalized between 0 and 1 to be included in the sectoral vulnerability assessment (chapter 4).

Increasing risk of droughts

The western parts of Bangladesh are prone to (agricultural) droughts during the dry season (Figure 3.8). The impact of climate change on rainfall patterns, especially during the dry season, is highly uncertain (BanDuDeltAS 2015). Some projections indicate an increase in the longest period of consecutive dry days (Figure 3.9) 3.15. Under current climate conditions, the largest period of consecutive dry days is up to 60 days. Under the RCP 8.5 scenario, by 2080, this may increase by 10-15 days. Studies indicate an increase in the severity of dry spells and increased risk of drought in Bangladesh.

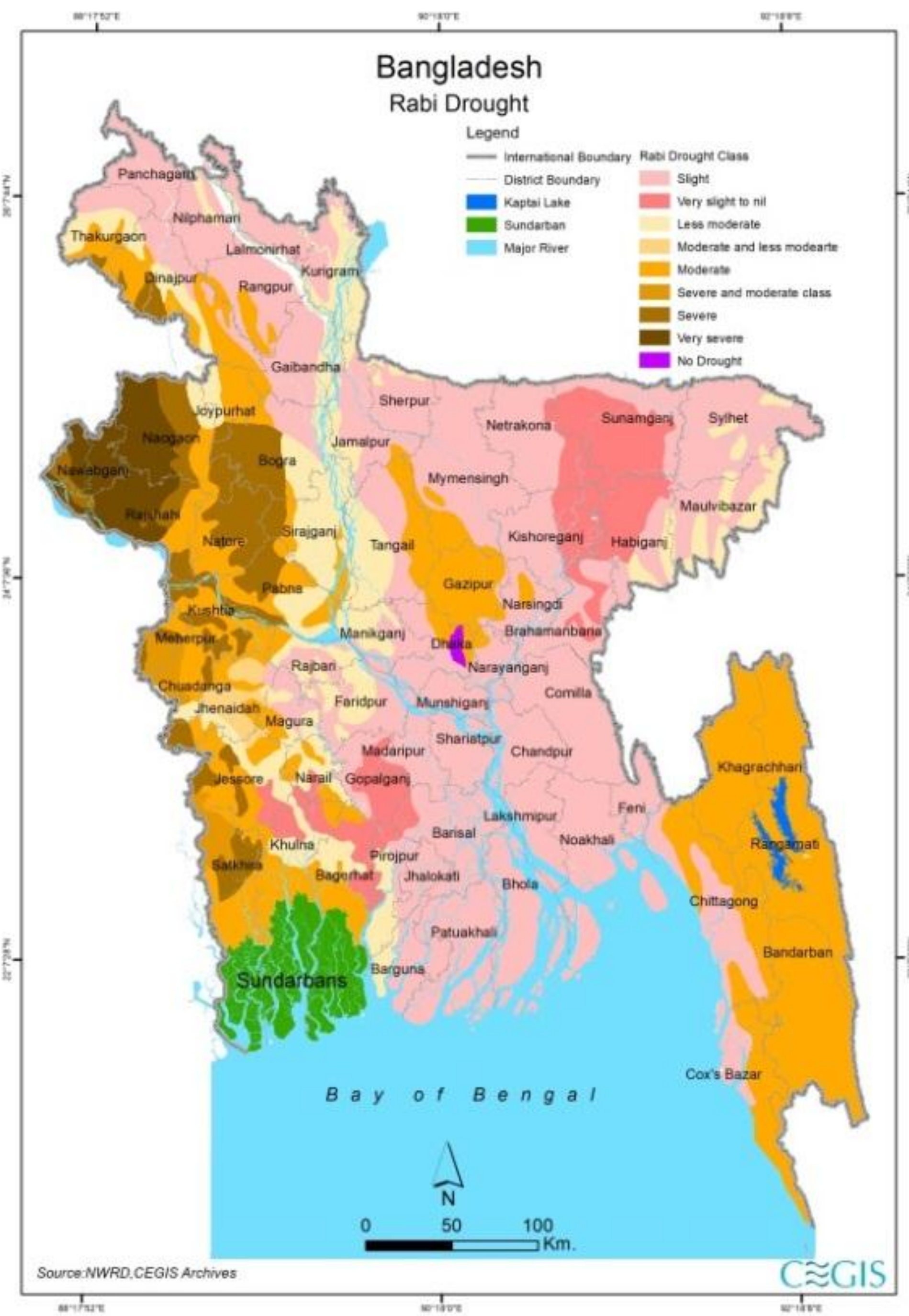


Figure 3.8: Drought prone areas in Bangladesh.
Source: BARC (2013)

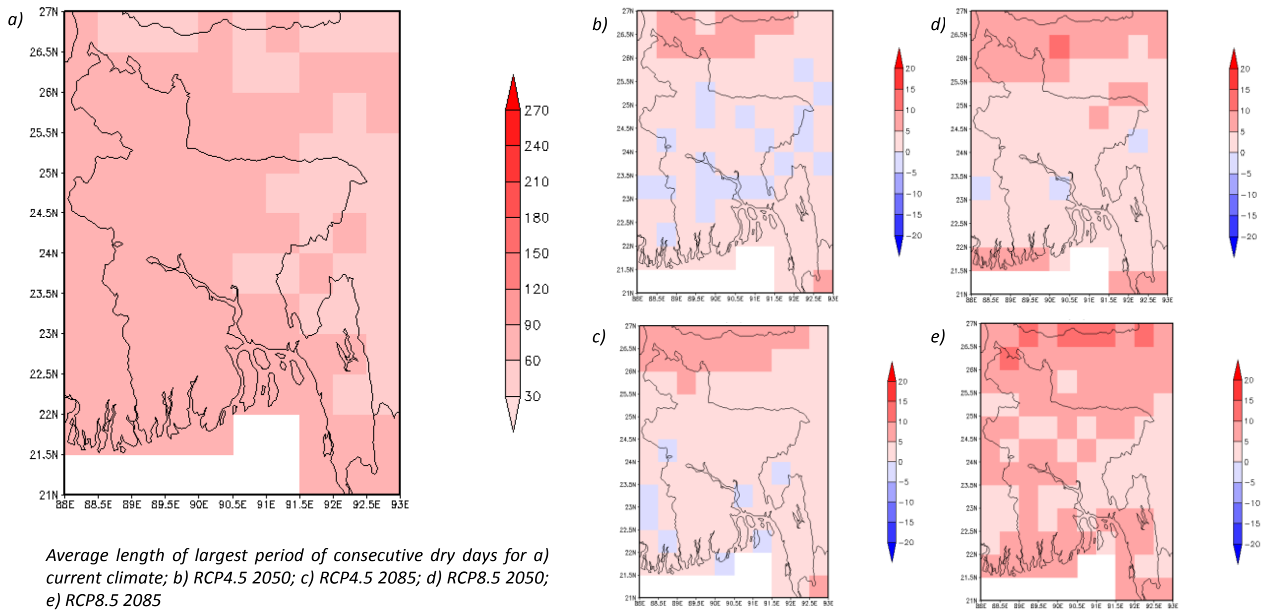


Figure 3.9: Average length of longest period of consecutive dry days for current and future climate
Source : BDP, 2018

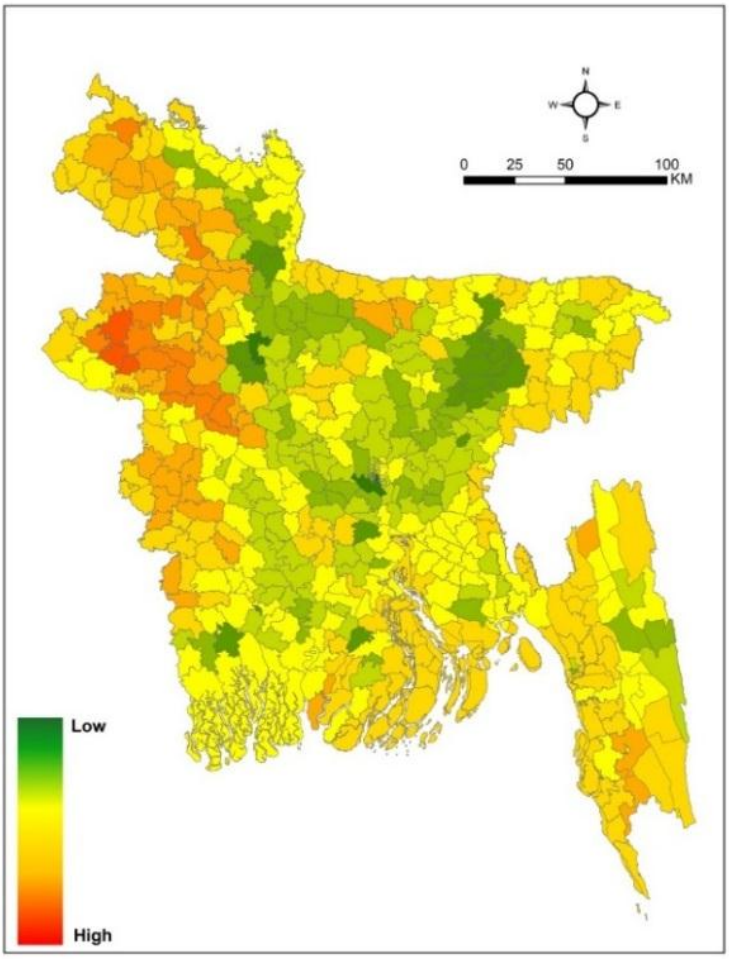


Figure 3.10: Normalized map of the current drought prone areas of Bangladesh (considering Rabi drought, Kharif drought and pre-Kharif drought)

Increase in rainfall intensity

Annual rainfall patterns vary widely each year in Bangladesh. This makes the detection of trends in rainfall difficult. Rainfall patterns may become more variable and erratic (BanDuDeltAS 2015); especially during the pre-monsoon and monsoon seasons, which will receive more rainfall. An increase in total rainfall accompanied by only a slight increase in total number of rainy days is indicative of an increase in rainfall intensity. **Error! Reference source not found.** illustrates the increase in rainfall intensity. The left side of the figure shows rainfall intensity per day that occurs once every 10 years. Under current climate conditions, this ranges from 50-100 mm in the West of Bangladesh, to more than 200 mm in the North. Climate change will increase the occurrence of these rainfall events. Under an RCP8.5 scenario, intense rainfall events are projected to occur every 3-5 years, and even more often than once every 3 years by 2055. These maps were generated based on the results from the study by Lutz et al. (2016).

Increase of high river flows and flood risk

Currently, a large area of Bangladesh is prone to flooding. Figure3.12 shows the flood prone areas along with the different types of flooding. Inland Bangladesh is particularly prone to moderate to severe riverine floods or flash floods.

Based on the projected rainfall increase, and consequently, an increase in river discharge, the risk of floods is expected to increase. Figure 3.13: Annual maximum discharge Upper Brahmaputra Basin (left) and Upper Indus Basin (right) under climate change adopted from Wijngaard et al. .
shows the annual maximum discharge for the Upper Brahmaputra Basin in the coming century, for the RCP 4.5 and RCP 8.5 scenarios (Wijngaard, et al. 2017). Subsequently, Figure 3.14: Increase of peak discharge of the Teesta river and rivers feeding the Brahmaputra in 2050 under RCP 8.5
Source: Wijngaard, et al. 2017 shows an increase of 25% - 75% in peak river discharge of the Teesta and other rivers feeding the Upper Brahmaputra basin by 2050, under the RCP 8.5 scenario. This map was created based on the results of Wijngaard et al. (2017).

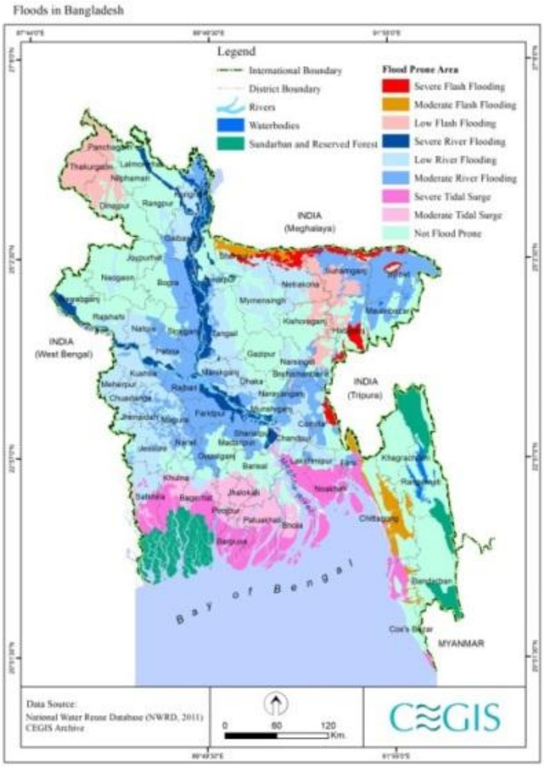


Figure3.12: Flood prone areas of Bangladesh. Source: BARC (2013)

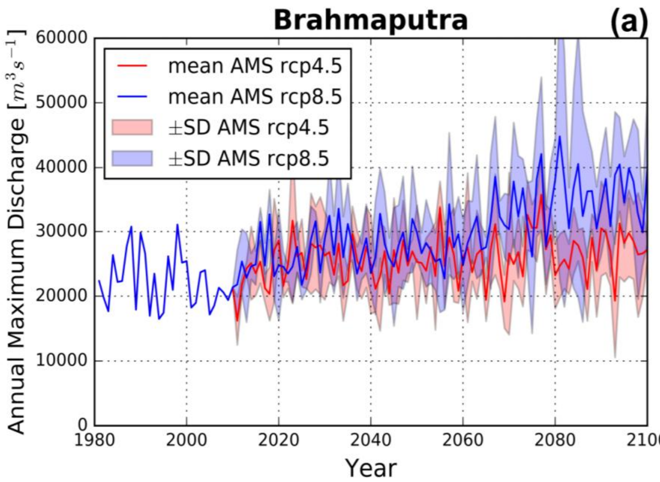


Figure 3.13: Annual maximum discharge Upper Brahmaputra Basin (left) and Upper Indus Basin (right) under climate change adopted from Wijngaard et al. (2017).

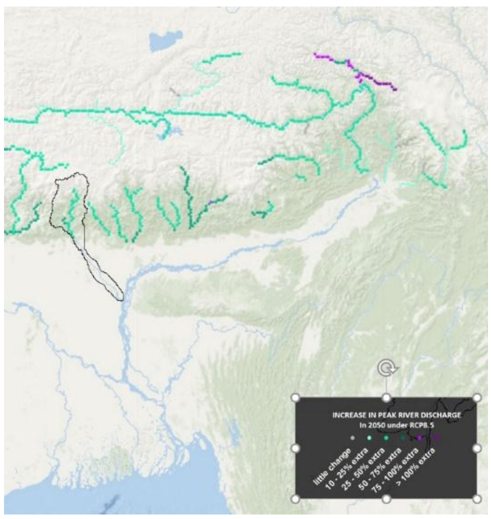


Figure 3.14: Increase of peak discharge of the Teesta river and rivers feeding the Brahmaputra in 2050 under RCP 8.5
Source: Wijngaard, et al. 2017

This increase in peak river discharge in the upper catchment area of the Brahmaputra indicates the potential increase of flood risk in Bangladesh, especially since river discharge from the Brahmaputra is often responsible for riverine floods in Bangladesh. However, actual flood risk depends on a variety of factors apart from rainfall intensity, including human interventions along the river systems. The above results show that the vulnerability to floods due to climate change may increase, assuming that sensitivity and adaptive capacity remain equal, which is unlikely.

A large area of Bangladesh is, thus, currently prone to flooding. Under climate change, rainfall is projected to increase in the river basins that feed the major rivers in Bangladesh (Wijngaard, et al., 2017). As a result, river discharges will further increase which may lead to increased flood risk.

Riverbank Erosion

Another implication of an increase in river discharge and peak flows due to climate change is an increase in river bank erosion. River bank erosion along the main rivers is a recurrent phenomenon (Hassan en Mahmud-ul-islam 2016). Figure 3.15 shows river erosion and accretion of the major rivers in Bangladesh for the period 1997-2015.

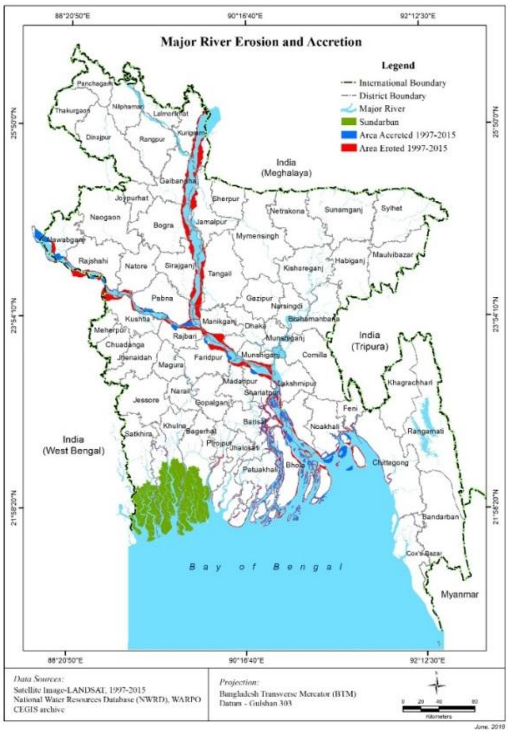


Figure 3.15: Major River erosion and accretion.
Source: National Water Resources Database, 2013

Sea Level Rise and Salinity Intrusion

Sea level rise and consequently, salinity intrusion are substantial problems for a low-lying delta such as Bangladesh. In the past few decades, the soil salinity line has shifted further inland (Figure3.16: Soil salinity boundary (minimum value of 2-4 ds/m) in 1973 (left), 2000 (middle) and 2009 (right)). Global warming increases the rate of melting of ice on land and the expansion of sea water, resulting in sea level rise. The sea level at the Bay of Bengal rises slightly higher than global average sea levels (BanDuDeltAS 2015). By 2100, the global mean sea level rise is projected to increase by 37 cm to 75 cm under the RCP 4.5 scenario, and between 55 cm to 123 cm under the RCP8.5 scenario. For Bangladesh, these values are often projected less than 5% higher (ibid).

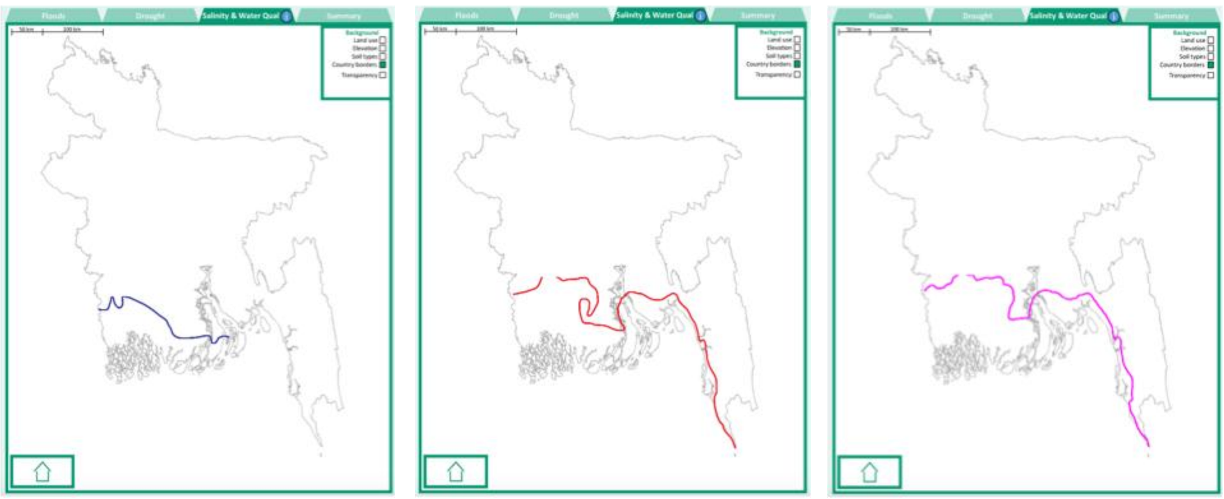


Figure3.16: Soil salinity boundary (minimum value of 2-4 ds/m) in 1973 (left), 2000 (middle) and 2009 (right) Source : BDP, 2018

Reference year (2010) Exposure to salinity intrusion 2018	2036-2065	2070-2099

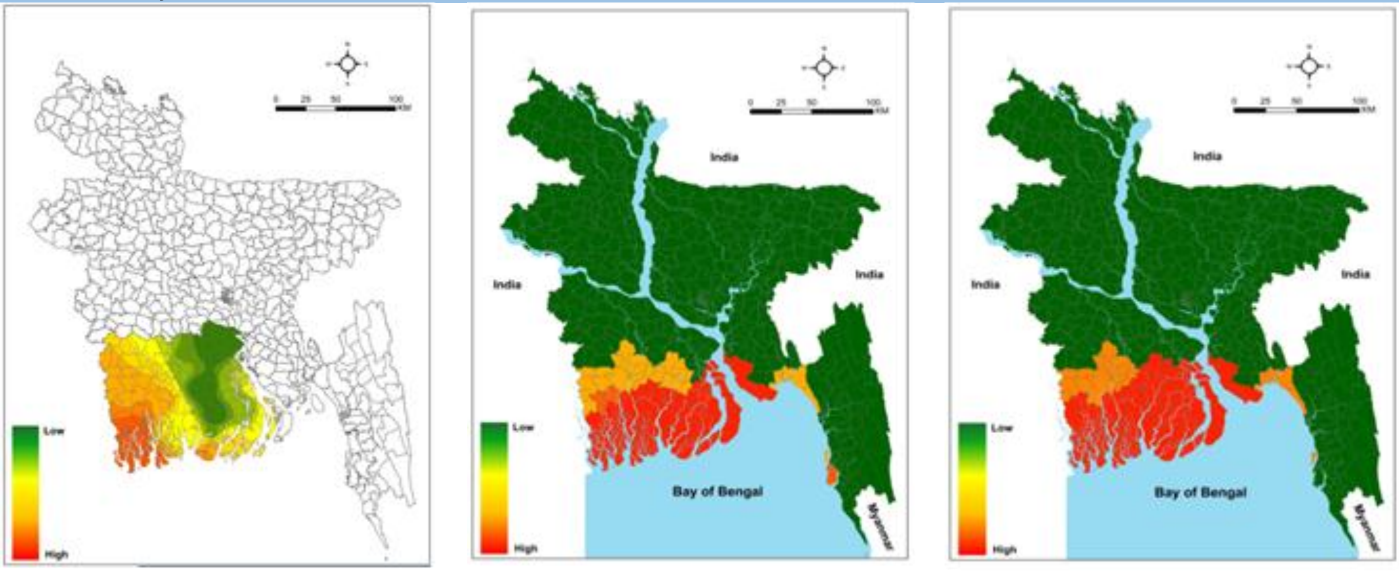


Figure 3.17: Current exposure to salinity intrusion (left); assessment of Bangladesh's exposure to sea level rise for 2050 (middle) and 2085 (right)
Source: IWM, 2015

Cyclones, Storm Surges and coastal flooding

The low-lying areas of the coastal region of Bangladesh are highly vulnerable to cyclones and storm surges, which can have devastating social and economic impacts. Historical analysis shows that tropical cyclone frequency has decreased in the past decades, yet the intensity has increased as the spatial position of the maximum intensity of cyclones has moved towards the east Asian coastline (BanDuDeltAS 2015). Further, the cyclones are often followed by devastating storm surges. Figure3.18 shows the inundated areas and depth of a storm surge with a 50-year and a 100-year return period.

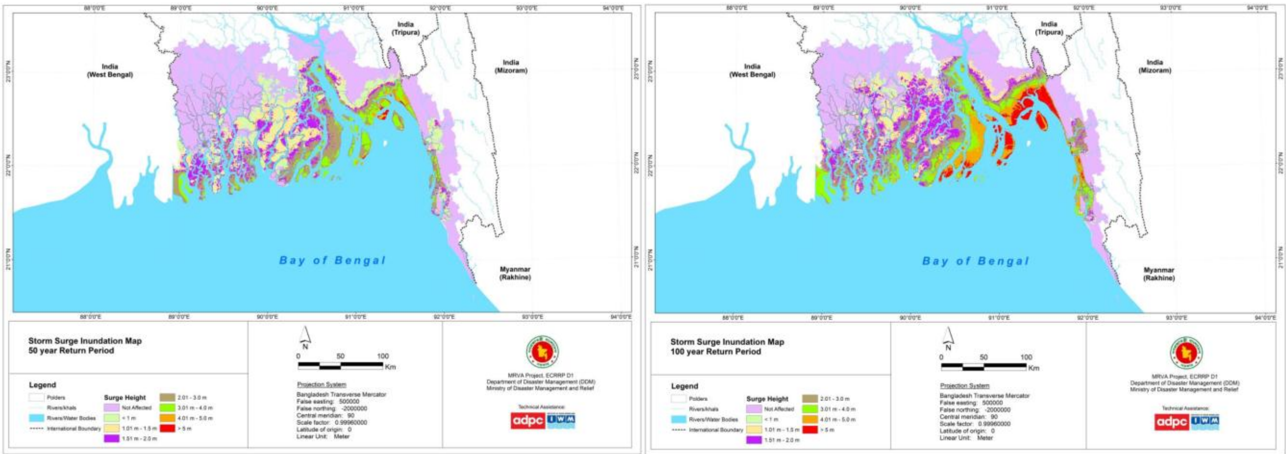


Figure3.18: Extent and depth-wise category of storm surge inundation at 50-year return period (left) and at 100-year return period (right) for the coastal area of Bangladesh
Source: MRVA, 2016

Under climate change, the intensity of both tropical cyclones and storm surges are likely to increase through the rising sea surface temperature and sea level. **Error! Reference source not found.**3.19 shows how storm surge inundation may increase as a result of climate change. .

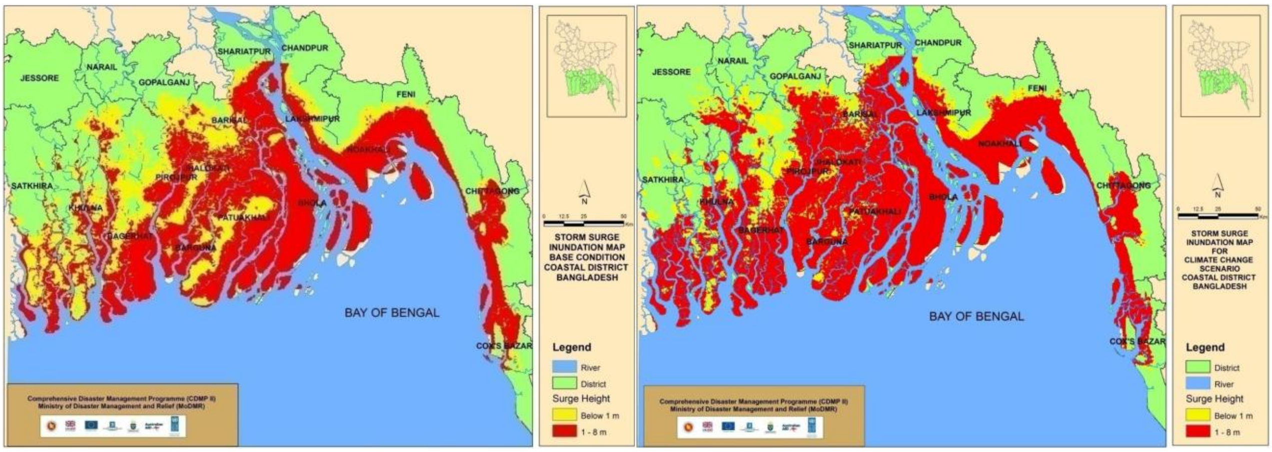


Figure3.19: Storm surge inundation map for current (left) and future (right) climate
Source: MRVA, 2016

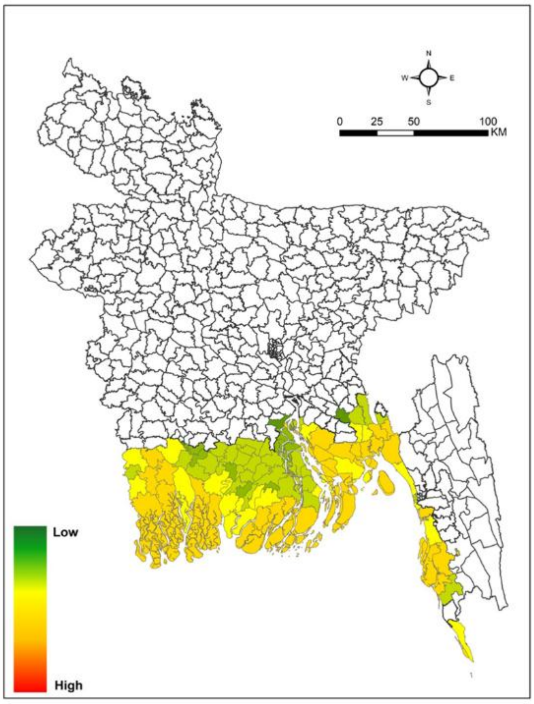


Figure3.20: Assessment of Bangladesh's current exposure to storm surges

The coastal zone of the country one of the most disaster-prone areas of the world (Anisuzzaman et al. 2013).

3.5 Regional differences of climate vulnerability

Bangladesh is divided in to several climatic regions. Each region is exposed to a different variety of climate hazards, and therefore, each region is differently vulnerable to climate variability and change. This section presents projections of the most prominent climate change impacts per region, with key maps from the assessment of Bangladesh's exposure to climate change.

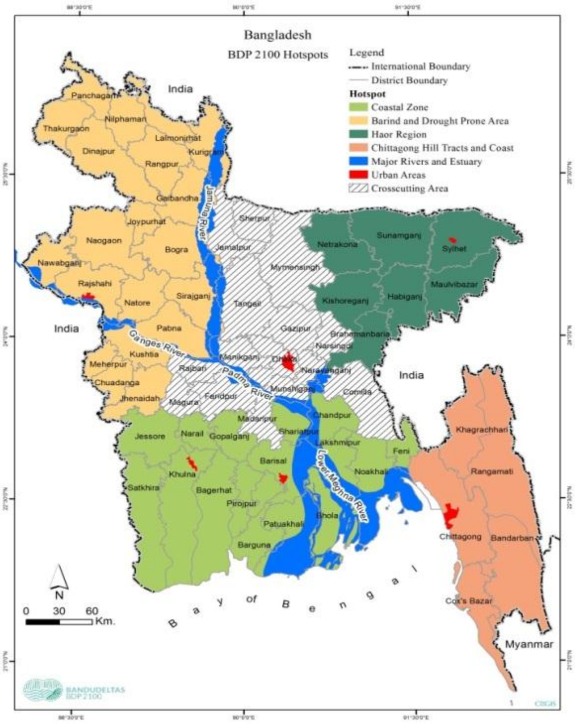


Figure 1: Climate hotspots of Bangladesh
(Source: BDP, 2018)

3.5.1 Central flood-prone area

The central flood-prone area is characterized by highly variable rainfall in the upstream region of the Himalayan river basins. Maximum precipitation occurs during monsoon, from west to east of the Hindu Kush Himalayan region. Mean annual precipitation ranges from 300 mm in Ladakh area (in India) in the west to 1400 mm in the center (Kathmandu) and 4000 mm in the east (Pasighat, India) in the Brahmaputra basin (ICIMOD, 2002).

The main climate change threat for Bangladesh is the potential increase in floods, notably flash floods, as a result of erratic precipitation, and the associated water scarcity issues during such events (e.g., Dhaka Tribune 2017; WHO-UNWater 2012). Flash floods cause surface water degradation, notably due to industrial effluents (e.g., Amin 2015) and the use of pesticides. Floods also cause sand deposition on banks and riverbeds, which decreases the water carrying capacity of large rivers. This results in the expansion of floodplains during monsoon, and thus, increasing riverbank erosion. Climate change is expected to increase rainfall intensity during the pre-monsoon and monsoon seasons, thereby increasing Bangladesh's exposure to river floods and flash floods in the future.

Flash floods and seasonal long-stay floods inundate an average of 26,000 km^2 or 18% of the total area of Bangladesh annually (FFWC-GOB 2015). Monsoon floods affect lives, livelihoods, drinking water, sanitation, health, energy and infrastructure, including houses. However, livelihoods, since they are largely agrarian, are the most impacted. Floods, and the accompanying river erosion and sand deposition negatively impact crop production and yield, which tend to decrease every year. Cattle and poultry often die or are lost during such events, further affecting local communities relying on livestock and agricultural resources. People living in these areas, the char in particular, have to cope with river erosion by shifting their habitat and personal belongings after each flood. In addition, some people lose lives, while the elderly, children and women often get sick because of the lack of access to clean drinking water. Most of the existing tube wells get submerged during floods, along with roads, further exacerbating the lack of good communication and transport facilities in the area. Flood-related vulnerabilities are likely to worsen in this region because of climatic and socio-economic factors impacting the exposure and sensitivity of people and systems.

3.5.2 Northwest drought-prone area

The driest region of the country is the North-west, which has been experiencing recurrent below-average rainfall. Perennial river flows are present in the major regional river systems, but many of the minor rivers lack sufficient flows in the dry period, exposing some regions of Bangladesh to drought. In the past, droughts have affected 47% of the country by area, and about 53% of the population (BanDuDeltAS 2015). Over the past few decades, drought has become a recurrent natural phenomenon in the Barind tract in northwest Bangladesh. This particular region is considered a semi-arid region.

Under climate change, expected rise in temperatures combined with lower and more erratic rainfall during the dry season, is projected to lead to an increase in droughts, especially in the northern and western regions of the country. Increase in droughts will cause soil dryness and hydrological imbalance, resulting in water shortage, groundwater depletion, very low stream flows leading to crop failure, scarcity of fodder for livestock, and scarcity of drinking water.

Climate change is already impacting the livelihoods of the poor who are largely involved in agriculture through the decreasing trends in crop production. Apart from the loss to agriculture, drought also causes abnormal increases in prices, increases the unavailability of jobs, and reduces access to food for rural people, especially the small and landless laborers (Habiba et al. 2012). The most significant problem for agriculture is the constantly decreasing groundwater levels. Besides crops, fish and domestic animals also face severe impacts due to the impacts of climate change. Local people grow fish in the available ponds, but maintaining required water-levels for fish cultivation during drought occurrences is challenging. In addition, domestic animals suffer from malnutrition and dehydration due to the inadequacy of grass and water.

While people of this region have been struggling with extreme temperatures and inadequate rainfall for a long time, malnutrition and sudden weather changes in recent years is increasing the frequency of diarrhea, fever, cough, flux and skin diseases, especially among children. The projected increase in drought intensity and duration, combined with higher temperatures would increase the exposure of the regional population to heat stress and increase their vulnerability in terms of negative impacts on health and food security in the future.

3.5.3 Southern coastal areas

The local climate of the coastal zone of Bangladesh, and notably the Meghna estuary, is largely dependent on factors like fresh water flows from rivers, tide penetration from the Bay of Bengal and meteorological conditions like cyclones, storm surges and wind. Sea level rise appears to be one of the most important causes of environmental and socio-economic vulnerabilities in the coastal areas due to salinity intrusion and coastal flooding (Seal A. and Baten M. A. 2012). Even though salinity intrusion in groundwater and the soil is a slow process, the associated impacts are already devastating. Saline water intrusion in coastal rivers and groundwater aquifers, is reducing freshwater availability for human consumption and agricultural irrigation. Salinity intrusion in the soil highly impacts crop yield, and under-nutrition, because of the lack of vegetable cultivation, appears to be an increasingly common health problem in all coastal areas. Stakeholders from the region also report that climate change impacts on the fisheries sector is huge. Both captured fish (Sundarbans) and farmed fish (shrimp) have been impacted in terms of their variety and availability, which has reduced over time due to the changing climate (salinity intrusion, sea and river surface temperatures, etc.)

Coastal areas of Bangladesh are also highly exposed to cyclones and storm surges, which have significant impacts on lives and livelihoods in the region. During the period 1960-2015, nineteen severe cyclones have hit the coast of Bangladesh (Baseline study Climate Change). Expected increase in the intensity of cyclones, storm surges and coastal flooding may affect lives, livelihoods, agricultural and livestock sectors, as well as infrastructure and transports facilities.

3.5.4 Northeast Haor basin

A haor is a wetland ecosystem in the northeastern part of Bangladesh. It is a bowl or saucer shaped shallow tectonic depression, also known as a ‘back swamp’. This region covers an area of 2 million ha, with 0.86 million ha as depression area. Around 19.37 million people depend on this region for their livelihoods (CEGIS 2012c). Annual rainfall ranges from 2,200 mm along the western boundary. to 5,800 mm in the northeast corner (CEGIS 2012b). Excess rainfall in the upstream hilly areas and subsequent runoff, river sedimentation, unplanned road and water management infrastructure, deforestation, hill cuts, landslides, improper drainage, and the effect of climate variability and change can be viewed as major contributors to the devastation caused by flash floods (CEGIS 2012b). During the monsoon (July-September), the haors turn into a vast inland sea within which the villages appear as islands.

The main climate change impact is the increase of flash flood risk in the pre-monsoon period. The haor region gets inundated for several months, threatening the cultivation of crops only cultivated during this period every year. Climate change in the future could thus have serious implications for the agriculture sector, health, and food security of the people in this region.

3.5.5 Eastern hilly region

The Eastern hilly region covers the Chittagong Hill Tracts (CHT) and the eastern coast of the country, i.e. the coast near Chittagong and Cox’s Bazar. CHT and the nearby coast are exposed to landslides, drying up of springs, cyclones and storm surges. All of these have huge impacts on, as well as increase uncertainty in, the lives and livelihoods in the region. The main climate change impact in the CHT region is perceived to be the drying up of streams and water sources due to low rainfall in the dry period (October – May). This affects drinking water and agriculture. Streams are changing due to landslides in the rainy season, largely as a result of overexploitation, as are the declining groundwater levels (for drinking water and irrigation). These pose major problems for the cities and surrounding areas. The region faces water quality issues as well, which may be exacerbated by climate change.

Groundwater degradation due to iron and salinity is a major problem for ensuring safe drinking water in the plain lands near the coast. Besides water scarcity and quality issues, water excess is also an issue in the region. Waterlogging is observed in low lands and plain lands where there are not enough structures (bridges/culverts) to drain out rain water. River siltation in major rivers is an increasing phenomenon due to increasing landslides, and this in turn increases water logging and sedimentation in the Chittagong port.

The vulnerable groups of this region are mostly people in the hills, who face food and water shortages, forcing them to collect water from distant places. People living in valleys near fragile hills face high risk of landslides. Women, children, the elderly and disabled are particularly vulnerable to water borne diseases, and people living in low-lying lands along rivers are vulnerable to flash floods and riverine floods.

3.5.6 Urban areas

One of the main issues encountered in urban areas over the last few years, is the increase in extreme temperatures, especially during the summer and winter seasons. As urban areas are very congested, higher temperatures during summer increases the incidence of diseases like dysentery, diarrhea and heat stroke. In addition to high temperatures, high air pollution in cities increases heat stress and health issues in urban populations.

Urban areas in Bangladesh are also highly vulnerable to an increase in natural disaster occurrences such as cyclones, storm surges, and floods, which are projected to increase with climate change. Most of the coastal towns and cities are situated on riverbanks of the low-lying tidal zones of Bangladesh, at an average elevation of 1.0–1.5m above sea level, increasing their vulnerability to multiple threats such as cyclones, storm surges, floods, earthquakes, tsunamis, and above all, climate change.

(Rahman and Rahman 2014). Bangladesh's cities are still very sensitive to such hazards, especially because of the huge and rapid development of urban areas, which remain poor and lacking in sufficient infrastructure to cope with extreme events.

3.5.7 Gender aspects of vulnerability

Different population groups are not equally vulnerable to climate change. Several factors, such as geographic location, socio-economic conditions, culture and tradition, induce different vulnerabilities between different groups of people. These factors especially make women more vulnerable to climate-related events than men (Haque et al. 2012; Sultana 2010; Nelson et al. 2002). Previous experiences show that among the other factors, gender, defined as 'socially learned behaviors and expectations associated with each sex' (Watkins and Whaley 2000 p 44), and cultural differences in gender identity and behavior, work as strong social factors creating differences between male and female members of society while increasing women's vulnerability to hazards and disasters (Weisman 1997; Bari 1998; Nahar et al. 2014; Nasreen 2004; MacDonald 2005; Alam and Collins 2010; Rahman 2013; Alam and Rahman 2014). According to the General Economics Division (GED), Government of Bangladesh, and other sources, women's vulnerability to climate change is different from men due to their reduced access and control over resources (GED 2014), limited opportunities for decent work, lower social status (Mitchell et al. 2014), and their dependency on men to get useful information (Saroar and Routray 2012). Bangladesh has a GII (Gender Inequality Index) value of 0.520, according to the 2015 index , and ranks 119 out of 159 countries. Only 43.1% of women participate in the labor market, compared to 81.0% of men. Only 20% of parliamentary seats are held by women. Around 176 women die from pregnancy related causes each year and the adolescent birth rate is 83 births per 1000 women of ages 15-19 (UNDP 2016).

Women are more affected by the natural disasters in Bangladesh (Mitchell et al. 2014) which increases their vulnerability to climate change, as climate change is expected to increase the number of disasters (Ali 1996; Agrawala et al. 2003; Karim and Mimura 2008; Sultana 2010). Disasters have gendered health impacts, with women's access to healthcare being more affected than men's (Rezwana 2018). Gender-based violence against women also increases during disasters (Rezwana and Pain 2017; MacDonald 2005; Houghton et al. 2010; Chan & Zhang 2011; MADRE et al. 2011; Patterson 2011 in Enarson 2012).

Several measures have been taken to reduce gender inequalities in the country, focusing on several sectors such as employment, education, disaster management, etc. However, even with these achievements many development challenges still remain (Mitchell et al. 2014). Gender has not yet received proper attention in development efforts, plans and policies to address climate change impacts. However, gender should be considered as the cross-cutting issue for all sectors that are strongly aligned to the prevailing culture, traditions, social attitude and norms. If gender sensitive development projects are not taken up in time, women would experience more violence, displacement and hunger, while facing additional burdens due to climate change and disasters. This nationwide climate vulnerability assessment aims at focusing on gender as the cross-cutting aspect, emphasizing how women, children, old people, etc. can be differently vulnerable to the same climate change issues. The sectoral narratives contain a section on gender vulnerability, and the quantitative assessments take into account some gender factors.

4. Results of the nationwide climate vulnerability assessment

Under current climate conditions, Bangladesh is exposed to a multitude of natural hazards such as floods, cyclones, heat waves, river bank erosion, drought, storm surges and salinity intrusion. Climate change in the future is projected to increase Bangladesh's exposure to these hazards. The most vulnerable area, in terms of natural disasters, is the coastal zone.

This report highlights both negative and positive key messages.

1) The bad news is that exposure to climate related impacts (both extreme and slow-onset events) is increasing.
2) Increasing environmental and socio-economic challenges could exacerbate these impacts.
3) The good news is that there is growing political attention and political will to cope with the adverse impacts of climate change. There is a general sense of urgency that the country needs to intensify its efforts to become less vulnerable to climate change. Funds are available and plans are in the making, such as the BCCSAP 2018 and the Bangladesh Delta Plan 2100.

The population of Bangladesh will continue to grow. The current population growth rate of Bangladesh is 1.37% (BBS, 2017). This indicates a potential increase in demand for food and water, and land claims resulting from that demand. Groundwater depletion and environmental pollution are likely to further increase in the coming years. Migration towards the cities results in the (informal) urban sprawl, with unplanned development and settlements in areas that are at high risk of flooding, erosion, cyclones, etc. Low-lying wetlands have already been converted from agricultural land and flood zones into urban areas. This development is further driven by the continuing tendency of people migrating from the rural areas to major cities. Indeed, the cities hold the promise of resources, employment and education. Approaching 2050, the country's population is expected to be predominantly urban (BDP, 2018). The urbanization process leads to expansion of urban areas into high risk zones while simultaneously encroaching on vulnerable hotspots: densely populated areas with little green space, little room for water drainage and storage and a large share of impermeable surfaces such as roads, pavements, and buildings. Heat stress in the densely populated areas leads to serious health impacts and may cause casualties. Moreover, water borne diseases may become prevalent, especially in the absence of well-planned sanitation and sewage systems.

Over the past 45 years Bangladesh has made significant progress across different socio-economic indicators of development:

- GDP growth has climbed from less than 4% in the early 1970s to around 7% in 2015;
- per capita income has surged from less than US$100 in 1972 to US$1400 in FY2016;
- poverty has fallen from more than 75% in the early 1970s to 24% in 2015;
- fertility rate has decelerated from 7.3 in 1974 to 2.1 in 2014;
- life expectancy has increased from 55 years in 1974 to 71 years in 2015;
- child mortality has declined from 240 per thousand from 1974 to 31 in 2014; and
- adult literacy has increased from 22% to 64% over the same period.

Bangladesh has achieved food self-sufficiency and the economy is transforming from an agrarian base towards a modern manufacturing and services economy. In 2015 Bangladesh crossed over from a World Bank classified low-income economy, to a lower middle-income economy. Despite these positive developments the fact remains that Bangladesh is persistently being to natural hazards which severly impact people and ecosystems.The intensity and frequency of these events will increase due to climate change. Hence a lot remains to be done, this is a huge task.

In this section, the results of the assessment are presented based on a sector-wise impact chain analysis driven by a deeply participatory apporach. The vulnerability maps indicate current and, wherever possible, future vulnerability. As noted in the methodology section, the maps depicting current vulnerability are based on an aggregation and computation of various climate, topographical and socio-economic indicators (categorized under exposure, sensitivity and adaptive capacity) per sub-sector (See Annex). The maps depicting future vulnerability, however, are derived from previous model-based studies, and focus on projections of current and future climate change (only incorporating indicators for exposure), under the RCP4.5 and RCP8.5 scenarios.
The details of the method that was followed can be found in the technical annex.

4.1 Human vulnerability to climate change

In Bangladesh, as with other developing countries, climate change is a major concern for human health and well being. Scientists agree that Bangladesh is particularly susceptible to climate-related impacts due to its geophysical position, demographic dynamics, poor public health infrastructure, and a high number of people with low level of resilience to economic shocks (Elahi, 2016; Patz et al., 2005). The changing climate is expected to expose the country to extreme and changing weather patterns that will both directly and indirectly impact population health. The direct and/or primary impact will be an increased incidence of water and vector borne diseases, extreme heat and cold related diseases, and malnutrition (Patz, Campbell-Lendrum, Holloway, & Foley, 2005). Indirect climate change impacts will be visible in the increase of seasonal distribution of some allergic diseases and infections, fatal accidental injuries due to flood and landslides, mental and other illness (Rahman 2008). The Intergovernmental panel on clime change (IPCC) released a report, which places Bangladesh at the top of its risk index to climate change, with 36 million peoples' lives and livelihoods vulnerable in just the coastal region alone (Banu et al., 2014; Kabir et al., 2016a; Kabir et al., 2016b).

Heat related illness will be more prevalent in the Barind tract and big city areas. Socio-economic and demographic dynamics will be a sensitive factor in this context, wherein the poor and people with low levels of resilience to economic shocks will be more vulnerable — the landless, elderly, children, disabled people, people dependent on daily wage labor, and women (Brouwer et al., 2007; Haines et al., 2006; Rahman, 2008). The potential adaptive options in this situation might be increasing access to safe water, electricity, and building the economic resilience of poor households. These findings are concordant with the existing literature (Anon, 2008; Rahman, 2008).

Focus Group Discussion Findings

(based on local communities' observations of climate change impacts)

In the Coastal zone, malnutrition is already a chronic health problem. Participants pointed out that vegetable intake is further decreasing among local people due to the increase in soil salinity as a result of sea level rise. As a participant from Shamnogor stated, "females suffer the most as they have to bear most pressure. They can't eat enough vegetables and milk. Milk has become very rare now". Groundwater scarcity (due to increased salinity clearly attributed to sea level rise) has caused people to drink less water, resulting in increased occurances of renal diseases. Participants also mentioned a rise in infectious diseases, citing a Chikungunya outbreak in 2017 (formerly very rare in this area). Some of them associated such diseases to an increase in mosquito populations, that they attributed to rising temperatures and a changing climate.

In the Barind area, recent and sudden weather changes, in addition to malnutrition, are causing more diarrhea, fever, cough, flux and skin diseases, among people of all ages, but especially among children.

In urban areas (Dhaka), participants mentioned that poor people, children, the elderly and pregnant women are suffering more from heat stress in Dhaka city (fever, asthma, dust allergy and high blood pressure are common and frequent). They are increasingly worried that extreme temperature in the future will greatly impact the entire population, especially the low-income inhabitants of Dhaka.

In flood prone areas (Jamalpur district), focus group discussions also highlighted the vulnerability of children, women and the elderly who suffer the most from water-borne diseases after flooding events due to the lack of access to clean drinking water.

Figure 4.1 – Focus group discussion in Urban area

Figure 4.2- Focus group discussion in the Coastal area

Two assessments have been prioritized and conducted in the scope of this nationwide climate vulnerability assessment: human vulnerability to increase in heat stress, and human vulnerability to increase in natural disasters.

4.1.1 Vulnerability to increase in natural disasters

The Current context

Bangladesh is one of the most densely populated countries in the world, with a population of over 160 million living in 147,570 square kilometer (56,977 square miles) (MoHFW, 2017). The country's economy is dominated by the agrarian sector which employs a majority of the rural labor force. Low-lying geo-physical features, combined with high population density, and low levels of resilience to economic shocks make the country highly vulnerable to a number of hazards including floods, droughts, cyclones, storm surges, tidal surges, heat and cold waves. Below we list some of the key climate-linked disasters.

Floods:Floods have a detrimental effect on peoples lives and livelihoods. It can result in the scarcity of drinking water; damage to sanitation systems; impact health facilities and services; loss of physical infrastructure such as houses, roads, and other facilities. The impact of floods in agriculture is expected to exacerbate human vulnerabilities. For example, in a rural setting, agriculture is the key source of employment and income. Agriculture contributes nearly 20% of the gross domestic production (GDP) and supports 45% of the total labor force. Human vulnerability is viewed to be high as, floods cause unemployment and/or underemployment. Besides, during the flood period, a number of vector and water borne diseases increase, resulting in morbidity and mortality among the affected population. Flooding is one of the most common natural disasters in Bangladesh that causes greater levels of human vulnerability. The incidence of flooding in Bangladesh is expected to increase in the future.

Cyclones**:** Cyclones and tidal surges are considerable natural disasters in Bangladesh. Due to its geophysical locations, demographic dynamics, and higher population density, Bangladesh's vulnerability to these phenomena is viewed to be higher. A study suggests that 26% of region is at risk of cyclones (Disaster Management Bureau, 2013). Although, the rate of death and injury from cyclone incidents has significantly fallen over the years (Fernandes and Zaman, 2012), unplanned interventions (e.g. urbanization), limited resources, inappropriate strategic plans, and the lack of adequate coping mechanisms can increase human vulnerabilities. The most common impact of cyclones might be the loss of lives, injuries, damage to infrastructure, and the loss of livelihoods. Further, in most cases, cyclones cause storm surges, leading to coastal flooding, which increases the vulnerability of the area and its people. Major cyclones in the past, such as cyclone Bhola (1070), Gorkey (1991), Sidr (2007), and Aila (2009) caused 2-10 metre storm surges (Cash, Halder, Husain, Islam, Mallick, May, Rahman, & Rahman, 2013). Studies suggest that cyclones and storm surges will likely affect infrastructure and livelihoods in greater scale, further increasing human vulnerability (Alam and Collins, 2010).

Landslides: Landslides have become a regular natural hazard in Bangladesh in recent years. In 2017, landslides claimed at least 152 lives in three hilly districts—Chittagong, Rangamati, and Bandarban. Although there are multiple causes of landslides, one study suggests that torrential rainfall in a short period of time triggers the occurrence of landslides, linking it to a changing climatic context (Ahmed, 2015). Intense extreme rainfall over a short period of time puts people (especially those living on the slope of hills) at greater vulnerability and risk to landslides (Ahmed, 2015). Landslides cause significant damage to road and communications infrastructure. Affected communities remain cut off and without basic utilities such as water, electricity, and food supplies. Further, landslides damage homes together with belongings, basic necessities, food stocks, and livelihoods.

Projected climate impacts based on existing assessments

Based on exsting studies, these natural events are expected to become more frequent and severe in the coming decades, as a result of human-induced global warming.

- Rainfall patterns may become more variable and erratic (BanDuDeltAS 2015).
- Rainfall intensity of 10-year return period is projected to occur every 3-5 years in 2055, under an RCP 8.5 scenario (Lutz et al., (2016)).
- The intensity of both tropical cyclones and storm surges are likely to increase with rising sea surface temperatures and sea level.
- Peak river discharge of the Teesta river and the rivers feeding the Brahmaputra basin is expected to increase by 25-75% in 2050, under the RCP 8.5 scenario (Wijngaard et al. (2017)

Natural disasters and climate change: Impact chain analysis and vulnerability map

The impact chain of human vulnerability to natural disaster specifically focuses on three prevalent climate hazards in Bangladesh, namely 1) cyclones and storm surges, 2) sea level rise (SLR), and 3) heavy rainfall resulting in riverine and flash floods (See Figure 4.3). The resultant impact is the vulnerability of people affected by mortality; morbidity; loss of houses, goods, services and livelihoods. The age of people across regions, gender, access to housing, health facilities, income, degree of education, access to flood protection infrastructure, etc. are formulated as key factors contributing to human vulnerability.

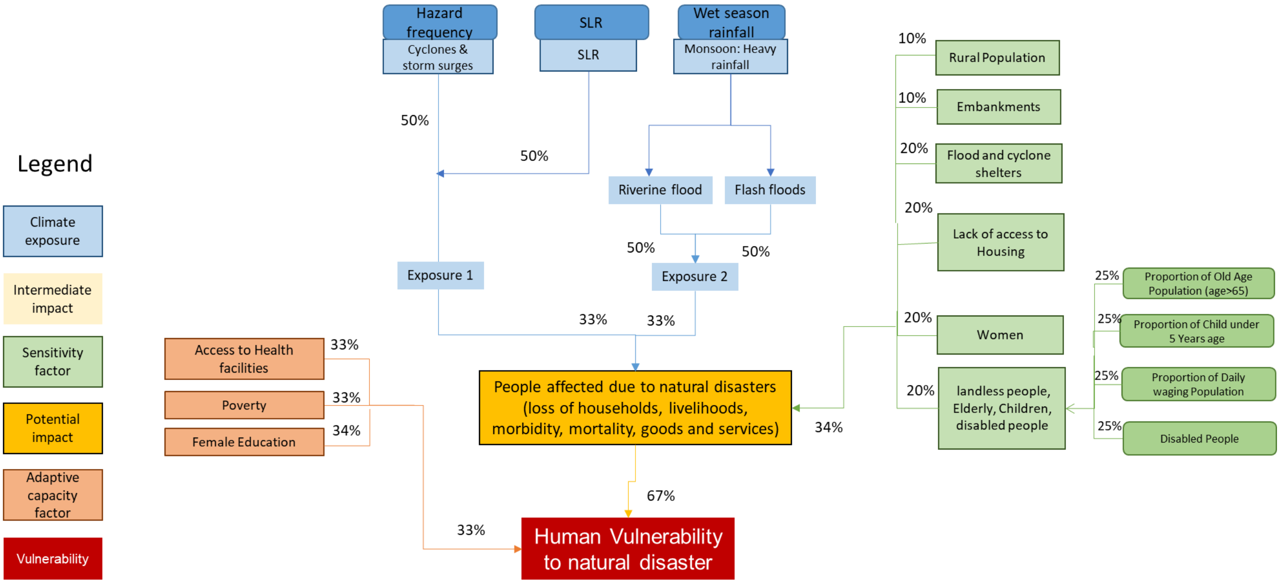


Figure 4.3- Impact chain of human vulnerability to natural disaster

The resultant composite vulnerability map (Figure 4.4) (incorporating multiple indicators), shows that the southern part of the country, especially the coastal region is relatively more vulnerable to natural disasters. This region is highly suseptible to a number of natural disasters such as tropical cyclones, tidal surges, and coastal floods. Additionally, the adaptive capacity of the region is perceived to be low. High level exposure and sensitivity combined with a low level of adaptive capacity puts this region at particular risk in the future.

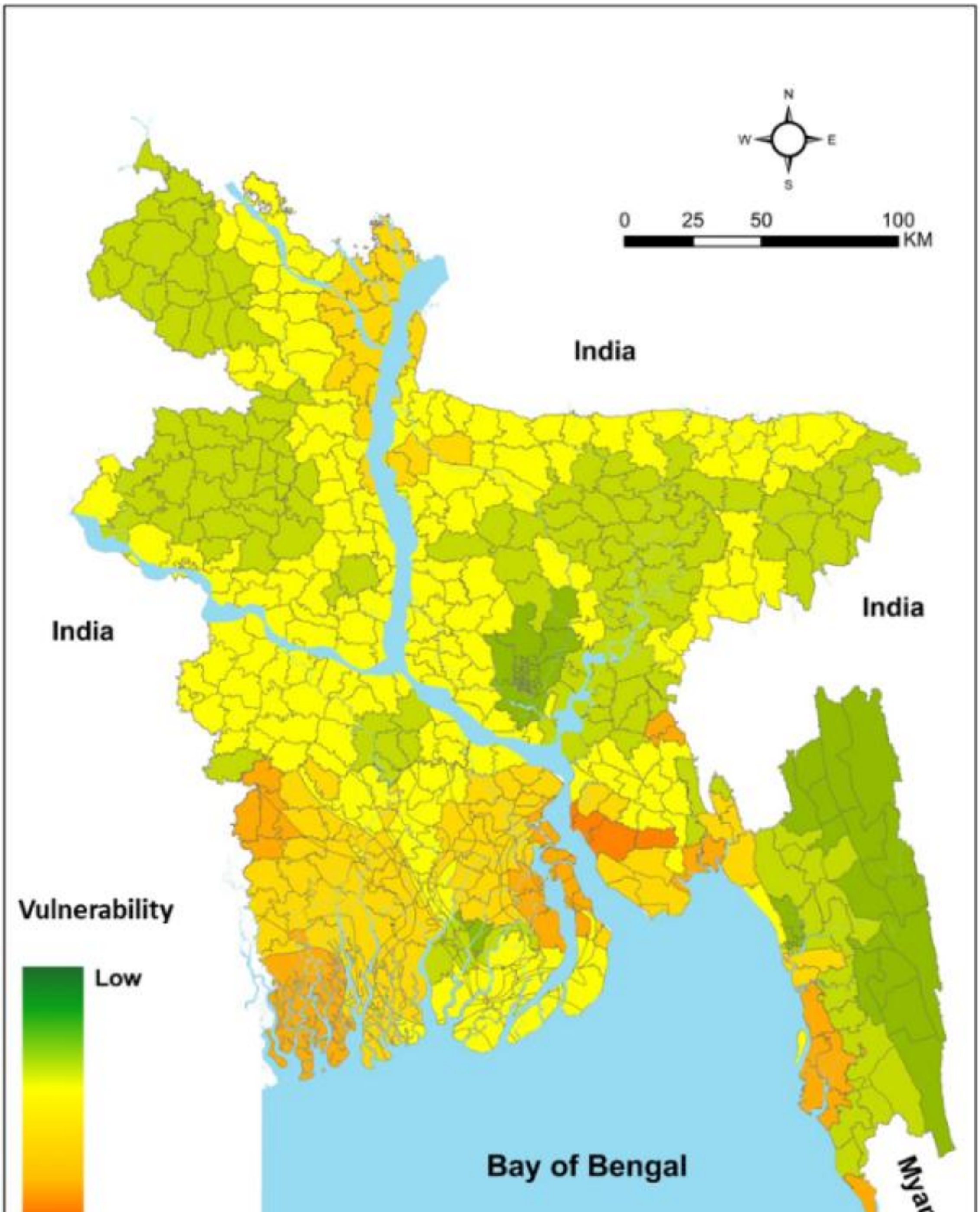


Figure 4.4: Assessment of the current vulnerability of human to natural disasters.

Community perceptions and experiences on natural disasters

Focus Group Discussion Findings
(based on local communities' observations of climate change impacts)

In the coastal zone, workshop participants observed that the weather, especially rainfall, has become inconsistent and unpredictable: "it doesn't rain when we expect to, but the excessive rainwater inundates the village when it's not meant to rain". Irregular rainfall makes it difficult to take appropriate protective measures against flooding. A participant from Rupsha observed that "it rains less during the monsoon but inundates during winter". The consequences from winter floods are particularly devastating for agriculture and fish farming.

Focus group discussions were held **in Saint Martin Island**, considered to be one of the most vulnerable areas to natural disasters and climate change. In this area, sea level rise causes further salinity intrusion and increases the likelihood of tidal surges. Overpopulation, isolation from the continent, and lack of options to sustain livelihoods are some of the main vulnerability factors pointed out during the discussions.

In flood prone areas (Islampur and Dewanganj upazilas), participants in the focus group discussions claimed that the frequency of floods has increased over the years due to the early onset of monsoon rainfall and heavy rainfall episodes. Whereas some years ago there was an interval of five to ten years between two floods, these episodes now occur every year or two. In the same way, river erosion has increased; each year, more area is eroded, more land is lost and an increasing number of people lose their lands, houses and assets.

Next steps

Policy interventions looking to maintream climate impacts in disaster risk response and management can use the spatial vulnerability analysis along with local responses as the first step in gathering more on-ground data in the vulnerable regions before prioritising interventions and resources for adaptation.

4.2 Health Vulnerability to Climate Change

The Current context

Over the past few decades Bangladesh has made significant advancements in select health indicators, especially compared to other South Asian countries. However, experts believe that climate change has the potential to stymie these developmental milestones. Increased temperatures, erratic precipitation and extreme weather events are expected to impact the frequency, extent and distribution of disease outcomes. Direct and indirect impacts include an increase in water and vector borne diseases, malnutrition, extreme heat and cold related stressors, change in the seasonal distribution of allergic diseases and infections, accidents and fatalities due to cyclones, floods, and landslides, as well as mental illness (Patz, Campbell-Lendrum, Holloway, & Foley 2005) (Rahman 2008).

4.2.1 Vulnerability to increase in heat-stress

Based on data availability, expert feedback and judgment, and emerging trends in South Asia, the NCVA focuses specifically on heat stress and its impacts. The assessment tries to bridge current information gaps on the subject with the aim of assisting policy planners to address this emerging health burden.

Projected climate impacts based on existing assessments

The intensity and frequency of heat stress is expected to drastically increase in the future. People have already been experiencing higher temperatures in recent years.

- In line with global mean temperature increase, Bangladesh has experienced considerable rise in temperature in the past decades;
- By the end of the century the maximum temperatures are projected to increase by 2 to 2.5°C under the RCP4.5 scenario, and by up to 4°C for the RCP8.5 scenario (DuDeltAS, 2015);
- Under current climate conditions, the average number of days where the maximum temperature exceeds 40°C is 20 to 25 days.
- In future climate, this may increase by 2.5 to 3.5 days in 2050, and by 3.5 to 5 days in 2085, for the RCP4.5 and RCP8.5 scenario's respectively (Bangladesh Delta Plan 2100 Project 2015).

An increase in the frequency and duration of extreme temperature is putting human health at risk, especially in the north-eastern part of Bangladesh.

Heat stress and climate change: Impact chain analysis and vulnerability map

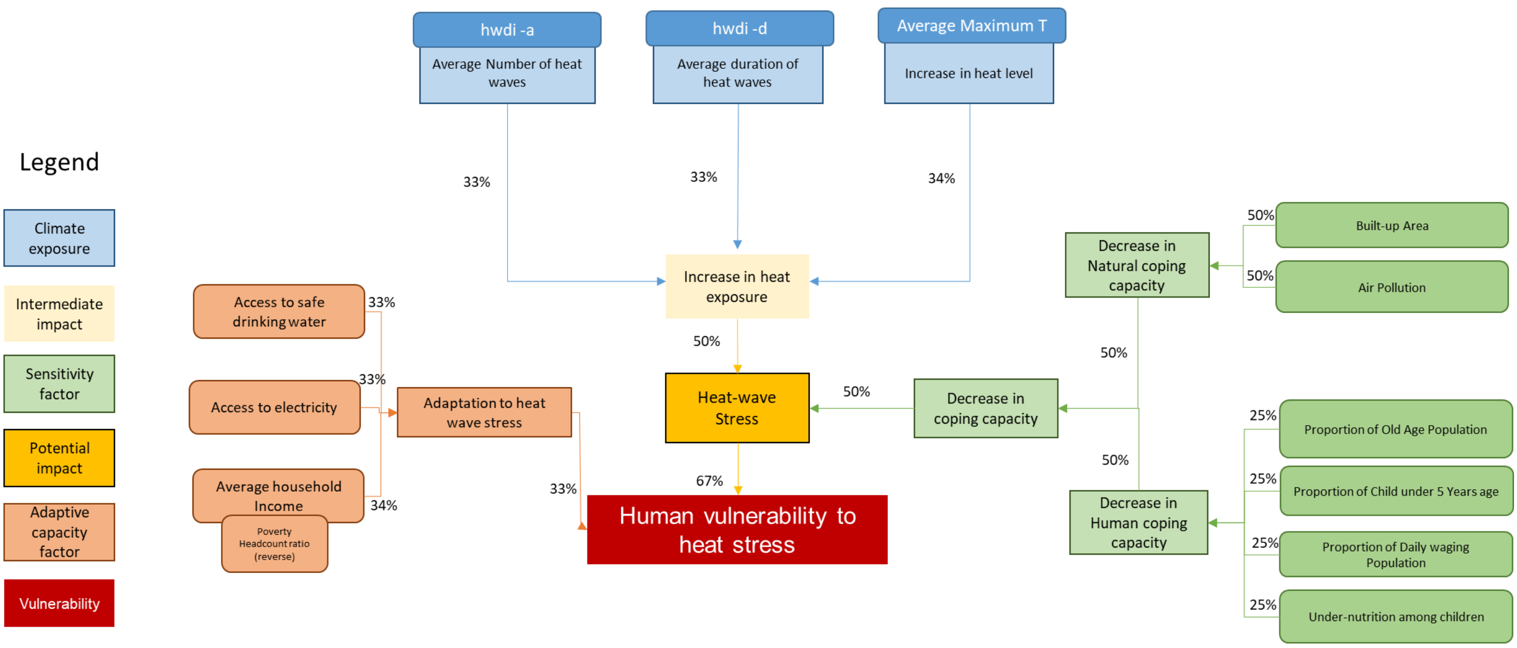


Figure 4.5: Impact chain related to the assessment of human vulnerability to increase in heat stress

The impact chain for human vulnerability to heat stress focusses on three components of exposure: 1) average number of heatwaves, 2) average duration of heatwaves, and 3) increase in heat levels (See Figure 4.3). A number of physical and socio-economic factors (constituting sensitivity and adaptive capacity) such as the age of people, their type of habitation, built-up area, access to electricity, clean drinking water, access to clean air, household income, etc. are also incorporated in assessing and mapping human vulnerability to extreme heat.

The vulnerability map (Figure 4.6) (based on model-based future projections of exposure to extreme heat under the moderate and extreme scenarios), indicates that the northwest region of Bangladesh, the central southwest, and areas adjacent to Dhaka city will experience high levels of heat stress specially in 2085, while the rest of the country may face relatively moderate and low levels of heat stress. There seems to be a higher degree of variability (in exposure to extreme heat) between timelines and scenarios in the drought prone (central northwestern) part of the country. The maps indicate that the southeastern (Chittagong Hill Tract) region, coastal region, and northeast hoar areas will likely have a lower level of vulnerability. These areas are covered by reserved forests and social forests that may provide canapoy cover and offset the impacts of extreme heat. The urban heat island effect will exacerbate heat stress in rapidly urbanizing areas. Plans, strengthening early warning systems, and amending labor and public health policies to address heat stress prevention and response are adaptation actions that may offset some of these vulnerabilities.

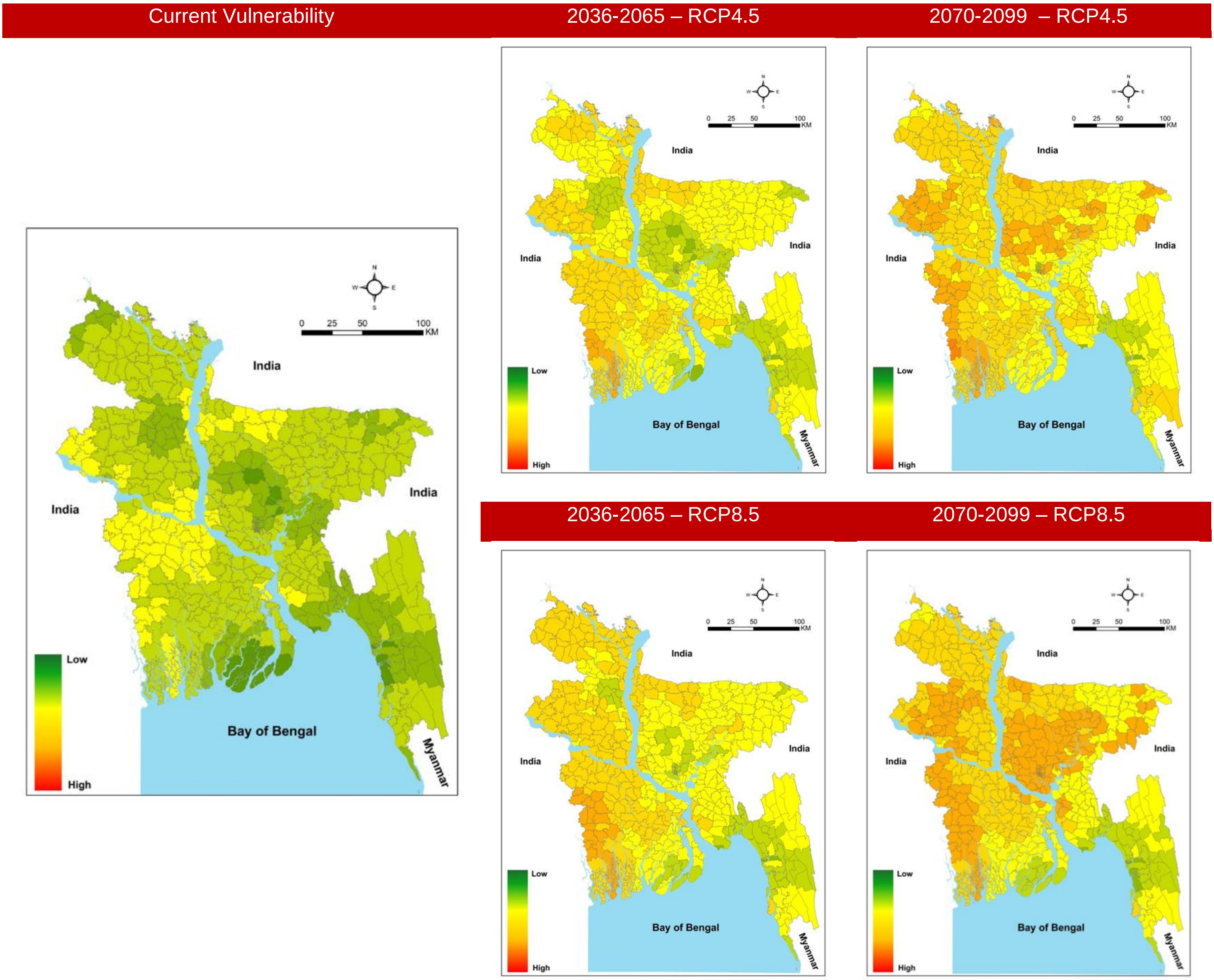


Figure 4.6: Assessment of the evolution of human vulnerability to increase in heat-stress in the future

Next steps

There is a growing body of evidence on national and sub-national responses to combat heat stress, globally and in South Asia[2]. Policy interventions on tackling heat stress typically include designing policies in collaboration with national and local disaster management agencies; developing heat action plans; designing early warning systems; as well as developing public health and labour management policies and advisories[3], that focus on extreme heat prevention and care.

4.3 Vulnerability of water sector to climate change

The Current context

Bangladesh lies in the downstream of the Ganges-Brahmaputra-Meghna (GBM) river basin which is a transboundary system with a total area of 1.7 million km^2 in India (64%), China (18%), Nepal (8%), Bangladesh (7%), and Bhutan (3%) (FAO, 2011). The GBM river system is the third largest freshwater outlet to the ocean, exceeded only by the Amazon and the Congo river systems (Chowdhury & Ward, 2004). To understand the impact of climate change on water resource availability in Bangladesh, it is helpful to note that five regions have been demarcated with different physiographic characteristics (based on hotspots identified in the Delta Plan 2100 by the Government of Bangladesh), namely flood-prone, drought-prone, coastal, haor, and eastern hilly regions.

Flood prone regions:

Current trend: In Bangladesh, floods hit every year. Flash floods and seasonal long-stay floods inundate an average of 26,000 km^2 or 18% of total area of Bangladesh annually (FFWC-GOB, 2015). **Error! Reference source not found.**4.5 summarizes the flood affected areas every year since 1954

Projected impact: Climate change is expected to increase incidence of both flash and seasonal long stay floods, resulting in further water scarcity during flood events (e.g., DhakaTribune, 2017; WHO-UNWater, 2012).

Impact on water resources: Flash floods cause surface water degradation, notably due to industrial effluents (Amin, 2015) and the use of pesticides, negatively affecting aquatic biodiversity (Siddique, 2017). Floods also cause sand deposition on river banks and riverbeds, decreasing the water carrying capacity of large rivers, while expanding the floodplain during monsoon due to riverbank erosion.

Drought-prone regions:

Current trend: Drought has become a recurrent natural phenomenon in the Barind tract in the northwest and southwestern region of Bangladesh in the recent decades. The Barind tract covers most parts of Dinajpur, Rangpur, Bogra, Joypurhat, Naogaon, Pabna, and Rajshahi districts. This particular region is considered a semi-arid region.

Projected impact: Climate change is expected to increase the variability of rainfall during the dry period (November-May). Droughts cause soil dryness, hydrologic imbalance resulting in water shortage, groundwater depletion, and very low stream flows that result in crop failure, scarcity of fodder for livestock, and even scarcity of drinking water (Rahman et al., 2007).

Impact on water resources: An increase in duration and intensity of droughts may result in greater irrigation needs for rabi (winter) crops and may also hamper crop production in the rabi season.

[2] http://www.euro.who.int/en/publications/abstracts/heathealth-action-plans

[3] For instance, incentiving local businesses to shifting labour work hours, to avoide peak heat hours; advising government hospitals to move maternity and children wards to lower floors to stay cooler etc.

Temperature increase during summer and winter could increase the risk of pest attacks to many crops, necessitating the use of more pesticide, with consequences to water quality.

Coastal regions:

Current trend: Coastal areas of Bangladesh are exposed to cyclones and storm surges, seawater intrusion, and sea level rise. During the period from 1960-2015, 19 severe cyclones hit the coast of Bangladesh. Another climate change impact in the coastal region is waterlogging in beels and low lying areas. Remote sensing studies indicate that the waterlogged areas in southwest Bangladesh have increased nearly eight times in the past 4.5 decades.[4]

Projected impact: Under climate change, the intensity of both tropical cyclones and storm surges are likely to increase with rising sea surface temperature, and sea level rise.

Impact on water resources: Cyclones, and resultant storm surges, affect the quality and availability of water for drinking and irrigation.

Haor region:

Current trend: This area is suseptible to flash floods during the pre-monsoon (April-May) season, as a result of excess rainfall in the upstream hilly areas and subsequent runoff. These flash floods are exacerbated by river sedimentation, unplanned road and water management infrastructure, deforestation, hill cuts, landslides, and improper drainage (CEGIS, 2012b).

Projected impact: The projected increase of flash flood risk in pre-monsoon period is a major concern in the haor basin.

Impact on water resources for cultivation: There are differing responses to floods in the region. Farmers prefer to cultivate the land as early as possible to ensure that the rabi crop can stay in the field. If flash floods hit before harvest the farmers' livelihoods are impacted. On the other hand, fish cultivators prefer the resulting inundation from floods as the water stays in the haors for as long as possible.

Eastern hilly regions:

Current trend: The Chittagong Hill Tract (CHT) and nearby coastal areas are suseptible to land slides, cyclones, storm surges and the drying up of springs.

Projected impact: Climate change is expected to increase the variability of rainfall during the dry period (November-May).

Impact on water resources: Low rainfall in the dry period is expected to further dry up streams and water sources. Over-extraction of groundwater (in cities and surrounding areas) will lead to further decline in ground water levels and a reduction in the capacity of surface water reservoirs, e.g., ponds, lakes, and rivers. Water quality issues will worsen as a result of unplanned waste management, industrial effluents, use of pesticides as well as increased iron and salinity in the ground water.

[4] Research by Space Research and Remote Sensing Organization (SPARRSO) of Government of Bangladesh showed that the waterlogged area in southwest Bangladesh increased from 6,279 ha in 1973 to 47,143 ha in 2016 (Correspondent, 2017).

Projected climate impacts based on existing scientific assessments

Current studies project that the availability and quality of water resources will be become more variable in the future owing to un-seasonal, high intensity precipitation events, increased floods, and greater salinity owing to sea water intrusion.

- Rainfall patterns may become more variable and erratic (BanDuDeltAS 2015);
- Rainfall intensity of a 10-year return period is projected to occur every 3-5 years in 2055, under the RCP 8.5 scenario (Lutz et al., (2016));
- Peak river discharge of the Teesta river and rivers feeding the Brahmaputra basin is expected to increase by 25-75% in 2050, under the RCP 8.5 scenario (Wijngaard et al., (2017));
- Under the RCP 8.5 scenario, the period of consecutive dry days may become 10-15 days longer (from the present 60 days) by end of the century (BanDuDeltAS 2015).

4.3.1 Groundwater depletion and degradation

Climate change threats on water resources in Bangladesh (as a result of the aforementioned impacts) can be aggregated into three key components: Groundwater resources depletion and degradation, wetlands and beels degradation, and river and water-bodies degradation. Out of these three components, the climate vulnerability assessment is focused on groundwater resources depletion and degradation. Groundwater resources depletion is expected as a result of an increase in drought intensity and frequency during the dry season and salinity intrusion in the coastal areas.

Groundwater depletion and degradation: Impact chain analysis and vulnerability map

The impact chain assessment of Bangladesh's vulnerability to groundwater depletion and degradation (Figure 4.10) focusses on three components of exposure, 1) annual consecutive dry days, 2) drought prone areas, and 3) salinization and saility intrusion (See Figure 4.3). A number of physical and socio-economic factors (constituting sensitivity and adaptive capacity), such as current ground water status, domestic water use and irrigation demand, institutional capacity on the planning, usage and control of ground water, size of surface water irrigation projects, etc., together contribute to the assessment and mapping of the country's vulnerability to groundwater depletion and degradation.

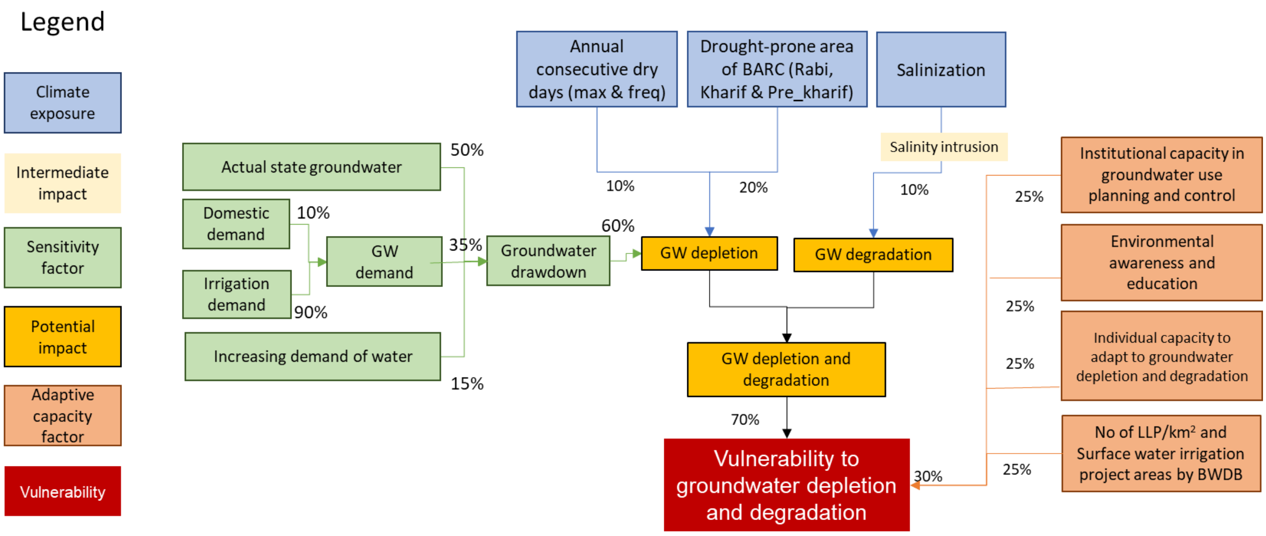


Figure 4.10: Impact chain related to the assessment of the vulnerability to groundwater depletion and degradation

The future vulnerability of groundwater depletion and degradation (GDD) to climate change was evaluated on the basis of two variables, namely drought and salinity intrusion due to sea level rise (Figure 4.11). To get the vulnerability maps of 2050 and 2085, two scenarios of RCP 4.5 and RCP 8.5 were averaged for drought. By 2050, the severity of groundwater depletion in the dry season is expected to increase beyond the present drought prone area to the whole country, except in Sylhet, the eastern hilly region, and a few pocket areas in the southern region. By 2085, the vulnerability to drought will expand to most of the upazilas of the country, except areas in CHT. However, the CHT region is less dependent on groundwater resources.

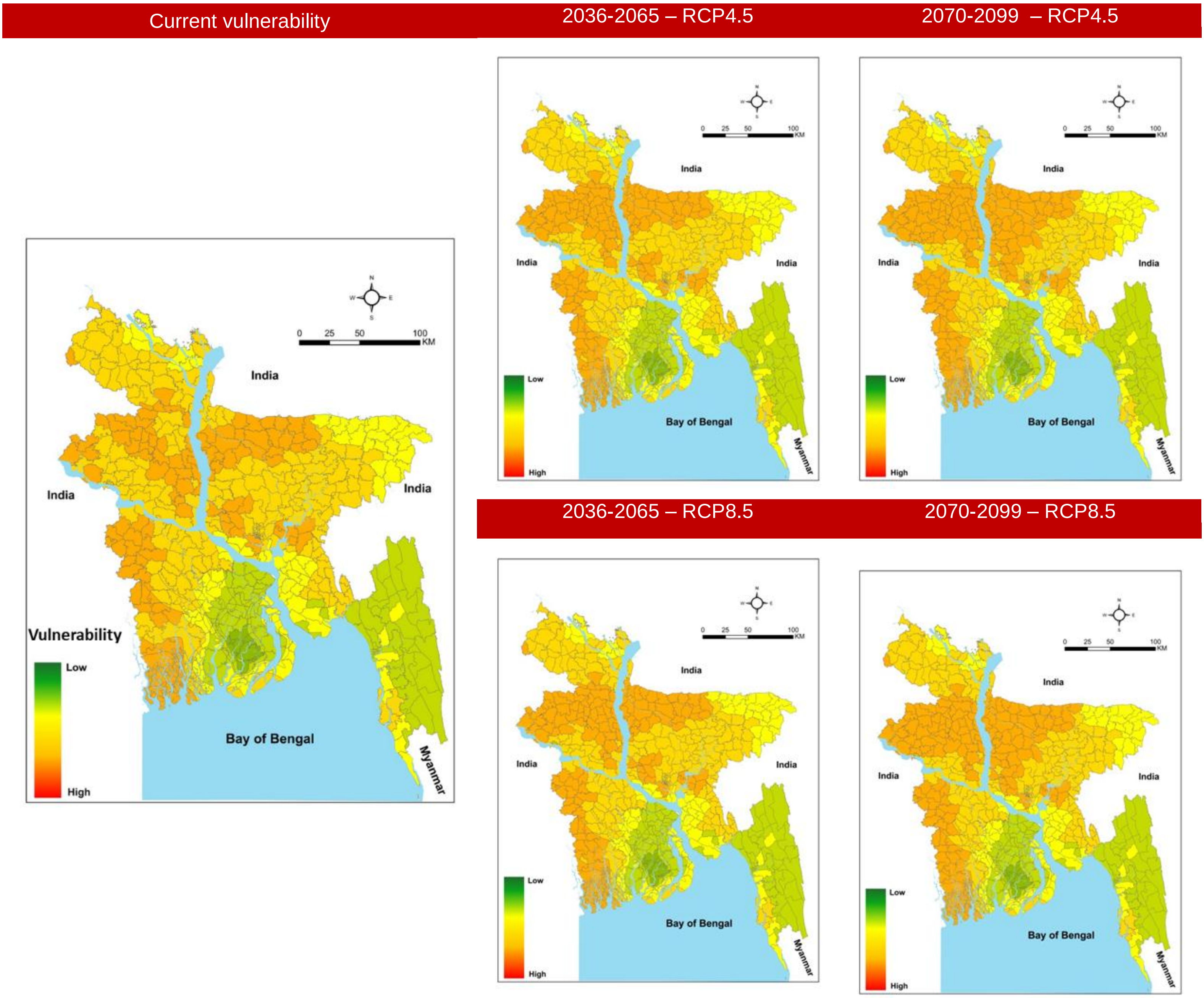


Figure 4.11: Assessment of the evolution of vulnerability to groundwater depletion due to expected increase in drought

Due to intensive and uncontrolled groundwater development, the groundwater table has already declined in the North-west and North-central regions, and specifically in Dhaka, where, in a number of locations, a decline up to 75 metres has occurred. In these areas, evidence indicates that groundwater recharge rates do not keep up with abstraction rates (BanDuDeltAS 2015). The North-east and central part of the country is also vulnerable to groundwater depletion due to the increase in drought preiods. The adaptive capacity of these regions is not high enough to compensate for the negative impacts of climate change.

Community perceptions and experiences on ground water depletion and degradation

Focus Group Discussion Findings

(based on local communities' observations of climate change impacts)

Some participants reported salinity intrusion **in coastal areas,** due to climate change (and sea level rise), resulting in scarcity of safe groundwater. Consequently, the quantity of safe water available for human consumption has decreased, resulting in health problems such as renal disease. A participant even mentioned "we can't drink an adequate amount of water".

In Chittagong, despite people having abundant water supplies during the monsoon season, they commented that changing conditions (reduced wetlands to store water, heavy rains) make it difficult to capture the waterflow or to maintain water in a proper manner in the only well ring. Hence, they suffer from both water scarcity and unsafe water.

Figure 4.8 – Focus Group Discussion in the Coastal area

Figure 4.9 – Focus group discussion in Bagaichhari Upazila, Rangmati Hill Districts, Farmer and Jhum Community (Chitagong Hill Tracts and Coast)

Gender considerations and next steps

Changes in water resources: quantity, quality and availability; all have direct impacts on agriculture, fisheries, biodiversity and navigation. However, all these changes have gendered health impacts on men and women. Household water collection and management is mostly conducted by female members of the family, so any change in water sources means a long walk for a woman, with heavy water pots, under scorching heat or rains, and at increased risk to gender-based violence. Participants in the drought prone region of Rajshahi mentioned their problems of water collection and expressed worry over future change in fresh water availability. Besides Rajshahi, participants from Banderban, Sylhet, and urban dwellers in Dhaka city mentioned that women and girls have to face several health proble, associated with water collection outside their homes. Women spend long working hours in collecting water from shared tube wells in tea gardens and urban houses for poor residents. After a long working day, garment workers (most of whom are female) have to stay awake late into the night for access to water supplies, or be in a queue to collect free water. These walks to collect water; carrying heavy loads, walking in the sun or rain, lack of sleep, are all carried out by women whose health status is cross-cut by several factors like age, pregnancy, new motherhood and other sickness. Besides these problems of water collection, water pollutions increase women's vulnerability to illness. This is evident in the fact that the number of women who are victims of arsenic poisoning is higher than that of the number of men. Apart from the health impacts, arsenic works as an indirect factor for domestic violence, like wife abandonment, divorce and social isolation. Saline water intrusion and increased salinity in fresh water sources in coastal regions increases reproductive health diseases among women. The impacts of climate change on water resources have gendered effects, increasing the vulnerability of women living in climate change hotspots of the country.

To increase adaptive capacity, more tube wells should be installed near residential areas, and prevailing water resources (ponds, rivers and swamps) should be maintained properly. Use of fertilizers and pesticides should be monitored, along with an increase in awareness programmes on the use of fertilizers, gender equality and disparity, and river water pollution at the regional level.

4.4 Vulnerability of the agricultural sector to climate change

The Current context

Bangladesh has over 160 million inhabitants with a population density of more than 1000 per sq km., on limited arable land (BBS, 2011). With its growing economy, Bangladesh predominantly depends on agriculture, which is strongly determined by seasonal weather patterns and climatic conditions. Therefore, supporting this huge population with food and fibre has always been challenging, especially since agriculture is highly vulnerable to climatic variability and climate extremes.

Based on socio-economic projections, geographical location and future hazards, Yohe et al. (2006) concluded that Bangladesh will be extremely vulnerable to climate change under all scenarios, including a scenario combining mitigation and enhanced national adaptive capacity. Although in the last four decades, the agriculture sector has attained significant progress in crop production and food security management through interventions (agricultural and fiscal), in the risk prone areas, these gains could be threatened with changes in climate, associated extreme hazards, as well as saline water intrusion in coastal areas due to sea level rise. Some reasons for concern in the agriculture sector in Bangladesh are briefly summarized below:

Global mean temperature increase can deplete water resource systems and cause agricultural yield losses: Due to glacier melt in the Nepal Himalayas, water supply during the dry season in the Ganges and Brahmaputra rivers will decline in the long run. Agriculture, and the supporting sectors, will be impacted by reduced surface water supplies. For agriculture in Bangladesh, water supply in the rivers in March and April is critical, as rainfall is very low, and the rate of evaporation (driven by temperature) is high. Research findings in Bangladesh, and other parts of the world, indicate that every 1°C increase in minimum temperature during the growing season would result in a 10% reduction in rice yields (Peng et al., 2004). (Error! Reference source not found.4.12).

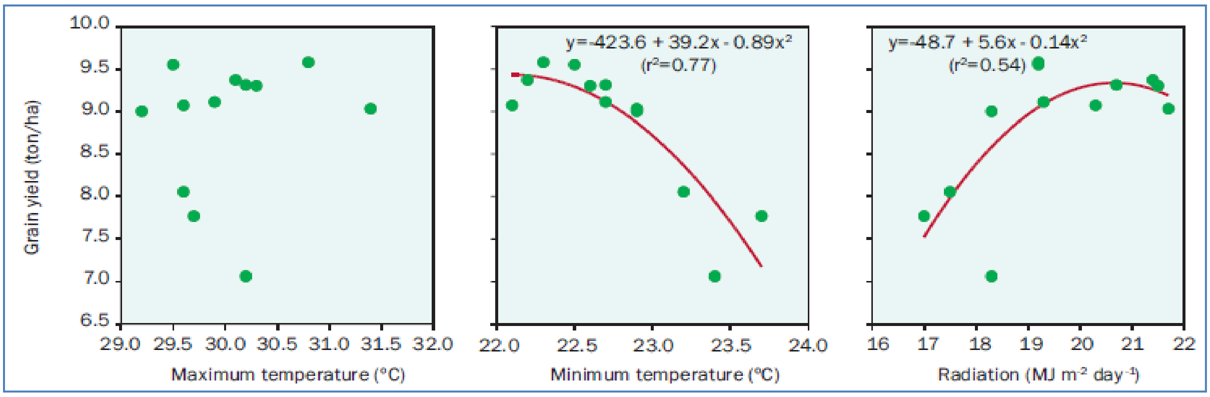


Figure 4.12: Relationship between crop yields and climate (Peng et al., 2004)

Temporal and spatial distributional changes of water resources can harm agriculture: At present, the greatest pressure on water resources results from rising human populations, particularly in urban areas. Increase in water requirements due to increased agricultural production to meet the growing needs of a burgeoning population, and rapid economic growth to tackle widespread poverty, would substantially increase total water requirements in Bangladesh. Simultaneously, climate change is expected to decrease freshwater availability in large river basins (IPCC, 2007). Projected changes in the timeline and distribution of rainfall will impact current cropping and harvesting patterns. The lack of potential water storage facilities means that the available water cannot be used to compensate for the seasonal requirements of freshwater for cultivation. Climate change is also projectedto further decrease dry season water flows in Bangladesh, which will impact groundwater storage and soil moisture content due to high evaporative losses.

There will be significant changes in land classes that are widely used for crop production: Mirza (2003 and 2005) estimated substantial changes in land categories (F1, F2, F3 and F4) (Table 4.1) due to an increase in the magnitude of floods and the extent of flooded areas. Changes in inundation categories may result in reduced cropping intensity in Bangladesh. The agricultural sector of Bangladesh may suffer substantially from this loss of land productivity. The World Bank (2010) also estimated similar trends in land class changes.

Table 4.1: Land classification for crop suitability

Land type of Inundation Class	Range of Inundation Depth	Crop suitability
Highland (F_0)	Less than 30 cm (Flood free)	Land suited to HYV T. Aman in wet season, wheat and HYV Boro in rabi season
Medium Highland (F_1)	30 cm to 90 cm (Shallow flooded)	Land suited to local varieties of aus and T. Aman in wet season; wheat and HYV Boro in Rabi season
Medium Lowland (F_2)	90 cm to 180 cm (Moderately flooded)	Land suited to B. Aman in wet season and wheat and HYV Boro in Rabi season
Lowland (F_3)	Greater than 180 cm (Deeply flooded)	Land suited to B. Aman in wet season and HYV Boro in Rabi season

Source: MPO (1986)

Extreme weather events can increase agricultural sector losses: As the global mean climate changes, the probability of extreme weather events such as days with high or very low temperatures, extreme precipitation, floods, droughts, tropical cyclones, and storms will also change (IPCC, 2007a; IPCC, 2001). Changes in the distribution of temperature and precipitation could also make extreme events much worse. An increase in the frequency and magnitude of these events can lead to further losses in the agriculture sector. For example, in Bangladesh, an extreme flood event of the magnitude of the 1998 flood could cause losses in over 2 million tons of rice crops.

Sea level rise and salinity intrusion can increase the loss of agricultural lands and food insecurity in the coastal region**:** Rising sea-level will permanently inundate vast agricultural lands, making them unsuitable for crop agriculture in the coastal area of Bangladesh. Saltwater intrusion could progress further inland in the future through tidal inflows, increasing soil salinity seasonally or permanently. A World Bank (2000) study suggests that increased salinity from a 30cm sea level rise would cause a net reduction of 0.5 million metric tons of rice production, which could feed about 3 million people for a year.

As noted above, multiple climatic factors are expected to impact agriculture in Bangladesh. In the NCVA, however, three main climate vulnerability assessments have been conducted with respect to agirculture, namely, vulnerability to land loss, vulnerability to decrease in water quality and availability, and vulnerability of crops (potential decrease in yields).

Projected climate impacts based on existing scientific assessments

- Rainfall patterns may become more variable and erratic (BanDuDeltAS 2015);
- Rainfall intensity of a 10-year return period is projected to occur every 3-5 years in 2055, under the RCP 8.5 scenario (Lutz et al., (2016));
- Peak river discharge of the Teesta river and rivers feeding the Brahmaputra basin are expected to increase by 25-75% in 2050, under the RCP 8.5 scenario (Wijngaard et al., (2017));
- Under the RCP 8.5 scenario, the period of consecutive dry days may become 10-15 days longer (from the present 60 days) by end of the century (BanDuDeltAS 2015);
- The IPCC (2007) predicts a 30% reduction Bangladesh, while rice and wheat production is predicted to fall by 8% and 32% respectively, by 2050.

4.4.1 Vulnerability to the decrease in land availability for agriculture

Agricultural crop lands are directly exposed to a number of climate induced hazards like precipitation increase, storms, cyclones, and sea-level rise, which can in turn impact the quality and availability of arable land.

Decrease in land availability for agriculture: Impact chain analysis and vulnerability map

The impact chain assessment of Bangladesh's vulnerability, in terms of land available for agriculture, (Figure 4.13) focuses on three components of exposure: 1) sea level rise leading to salinization, 2) storms and cyclones resulting in tidal floods, and 3) consecutive wet days causing flash floods and riverine floods. A number of geographical and socio-economic factors (encompassing sensitivity and adaptive capacity) such as soil type, presence of embankments, land ownership, land use changes (specifically towards urbanization), crop production technologies and inputs, farmer's access to education and institutional support together contribute to the assessment and mapping of the country's vulnerability to groundwater depletion and degradation.

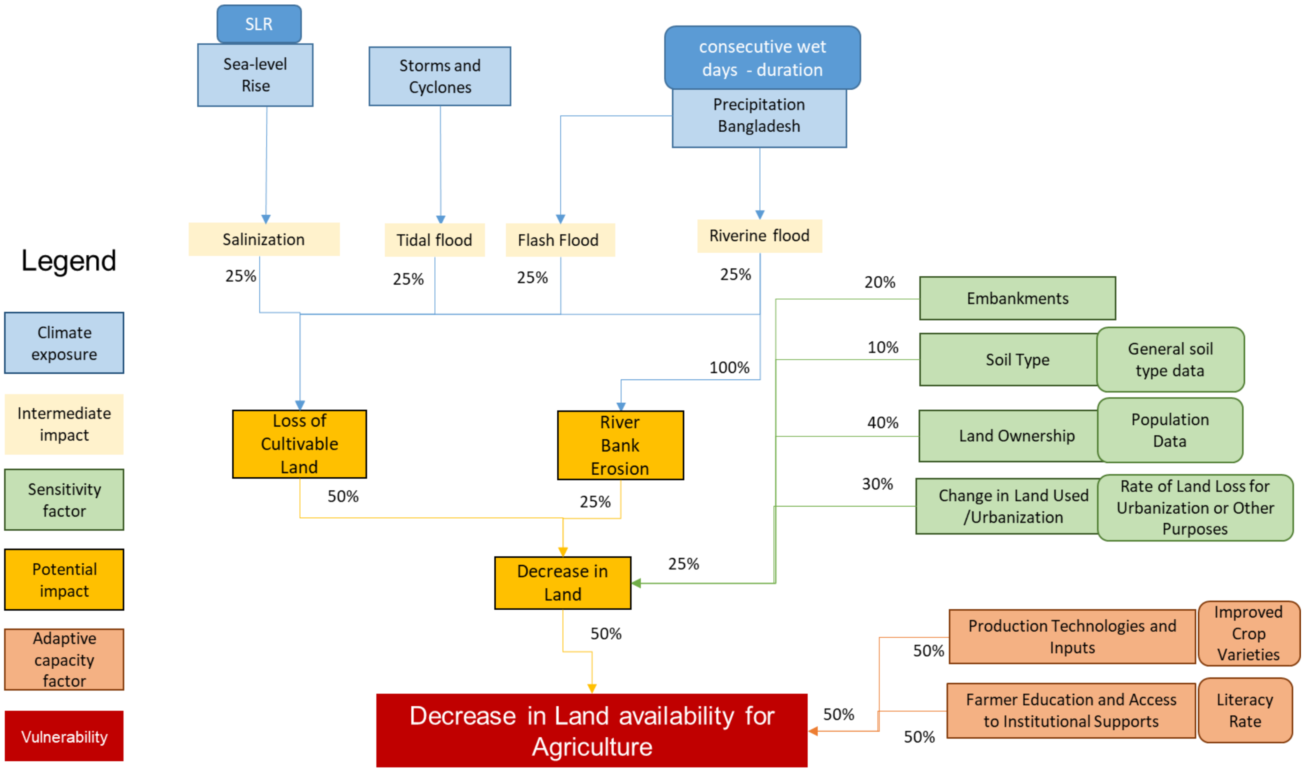


Figure 4.13: Impact chain related to the assessment of vulnerability to land loss for agriculture

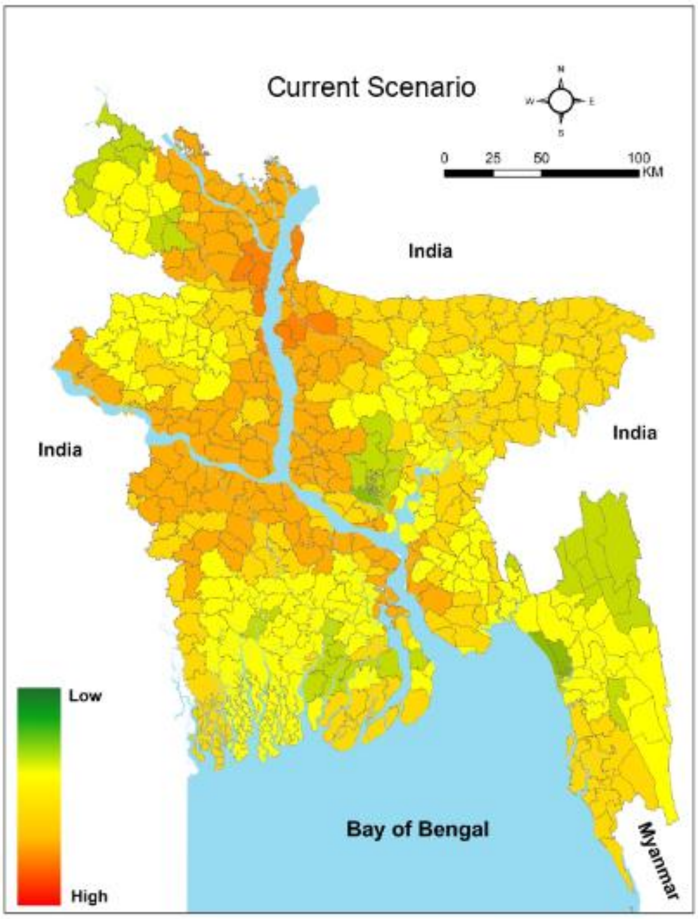


Figure 4.14: Assessment of the current vulnerability to agricultural land loss. See technical annex for the full sectoral NCVA analysis

The resultant composite vulnerability map (Figure 4.4) (including the aforementioned indicators), shows that land loss due to climatic hazards is expected to be greatest in the Teesta area and along the major rivers. This is due to an increase in runoff and land erosion because of more intense rainfall, causing flash floods and riverine floods. The south of Chittagong is also expected to be highly vulnerable to a potential increase in land slides, due to climate and development factors. The north-eastern part of Bangladesh, is expected to face increasing challenges related to land loss, especially because of water logging, and an increase in wet lands. Coastal areas are also expected to be more vulnerable to land loss with coastal flooding and salinity intrusion. Adaptive capacity to land loss appears to be very limited in most of regions of Bangladesh.

4.4.2 Vulnerability to the decrease of water availability and quality for agriculture

Water availability and quality for agriculture: Impact chain analysis and vulnerability map

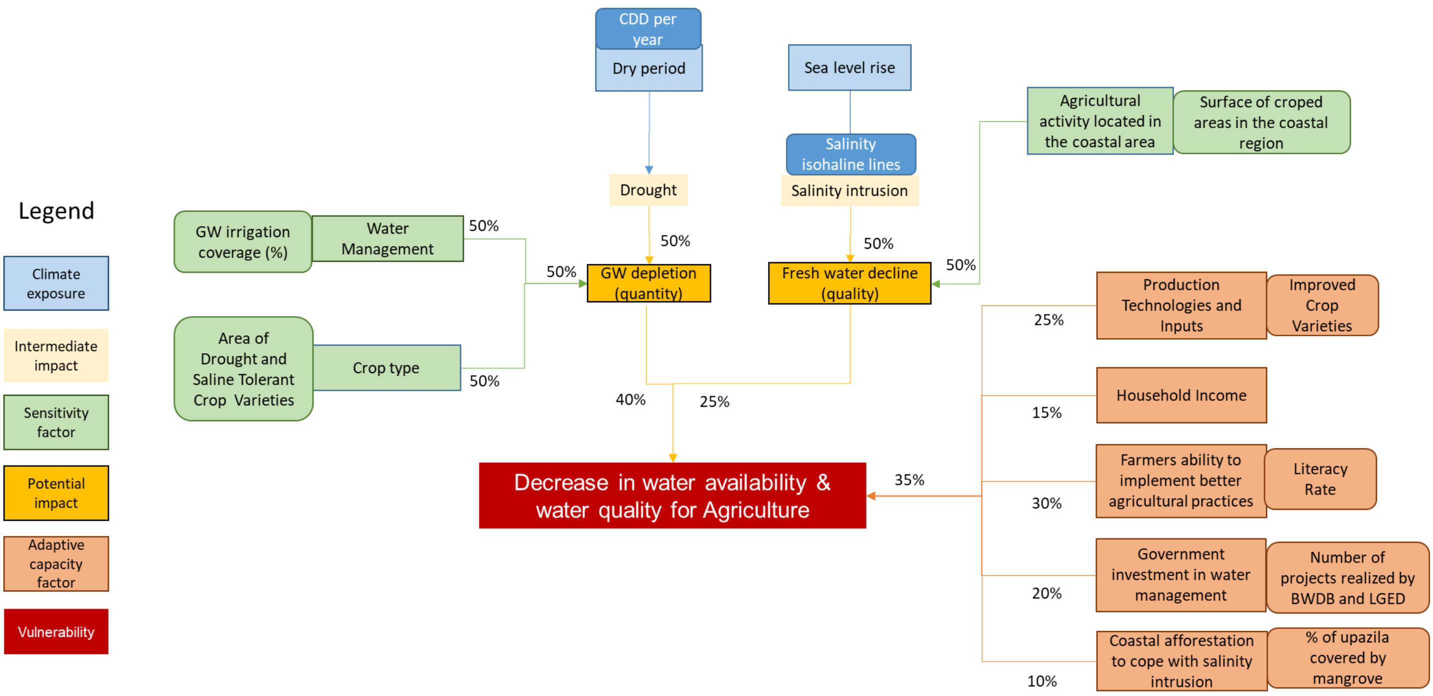


Figure 4.15: Impact chain related to the assessment of agricultural vulnerability to water quality and availability

The impact chain assessment of Bangladesh's vulnerability, in terms of water quality and availability for agriculture, (Figure 4.15) focuses on two components of exposure, 1) consecutive dry days leading to drought conditions, and 2) salinity intrusion resulting in fresh water decline. A number of geographical and socio-economic factors (encompassing sensitivity and adaptive capacity) such as ground water coverage, area of drought-resistent and saline-tolerant crop varieties, crop production technologies and inputs, extent of coastal afforestation, household income, etc. together contribute to the assessment and mapping of the country's vulnerability to groundwater depletion and degradation.

Map 4.11 in the previous section indicates the evolution of vulnerability to groundwater depletion due to expected increase in drought. It shows areas which are classified as highly sensitive because of the high rate of groundwater abstraction for extensive irrigation purposes. Currently, about 4.2 million ha of land are irrigated by groundwater (both shallow and deep tube wells), whereas only 1.03 million ha are irrigated by surface water, using low lift pumps (BanDuDeltAS 2015). Increased water availability encouraged farmers to grow irrigated boro rice during the dry winter season. Today, among the 80% of groundwater used for irrigation, 73% is exclusively used for boro rice, mostly cultivated in the North-west regions, where groundwater levels are declining much faster than many other areas. Despite clear evidence that groundwater is being over exploited, a large number of additional wells are being installed every year (Qureshi A.S. 2014).

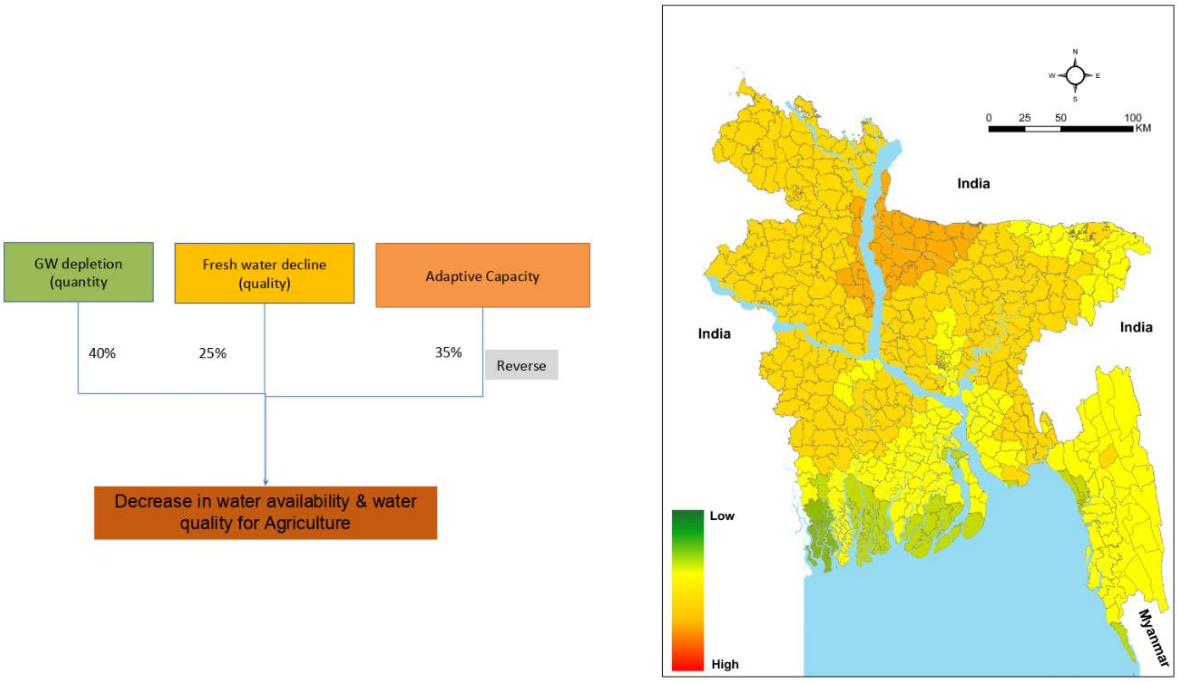


Figure 4.16: Current vulnerability of agricultural to water quality and availability

Community perceptions and experiences on water availability for agriculture

Focus Group Discussion Findings
(based on local communities' observations of climate change impacts)

In the Barind area, since there is little rainfall during the growing season and no nearby water ressources, farmers depend on groundwater for crop irrigation. Participants indicated that the most significant problem is the lack of groundwater for agricultural production and an increase in demand for water. Groundwater availability has shifted from a depth of 100 feet to current availability at 140 feet. Insufficient irrigation in rice fields has caused a decline in yield from 800 kg to 500 kg, leading to a shift to less water-intensive crops such as mustard and wheat.

In the Chittagong area, participants mentioned a "water crisis" involving two aspects: abundant rainfall and lack of rainfall in an unpredictable climate. Too much rain washes away the topsoil with it nutrients, making the land unsuitable for two seasonal crops, as in the past. On the other hand, too little rain and rising temperatures make it difficult for crops to grow and survive.

In flood prone areas, irregularities in rainfall, contrary to the usual seasonal cycle, hampers crop cultivation activities. Participants observed that groundwater resources have declined. Today, in some parts of Islampur and Dewanganj upazilas, there is not enough water to satisfy irrigation needs and other uses.

Figure 4.17 – Focus group discussion in Amnura (Barind and Drought prone area)

The combined effects of drought and water salinization will heavily affect fresh water availability, posing a major problem for agricultural purposes (Ghulam Hussain S., 2009). Shortages in fresh water is likely to become more pronounced, especially in the coastal belt and drought-prone areas in the north-west of the country.

4.4.3 Crop yield vulnerability to climate change

Crop yield vulnerability: Impact chain analysis and vulnerability map

The impact chain assessment of Bangladesh's crop yield vulnerability (Figure 4.19) focuses on four components of exposure: 1) consecutive dry days, 2) riverine floods, 3) flash floods, and 4) storm surge height. A number of geographical and socio-economic factors (encompassing sensitivity and adaptive capacity), such the variety of rice grown, crop production technologies and inputs, household income, land ownership, presence of embankments, etc. together contribute to the assessment and mapping of crop yield vulnerability.

Figure 24.18 – Focus group discussion in Kangli Ovoyasrom-Kulaura, Moulavibazar, Sylhet (Haor region)

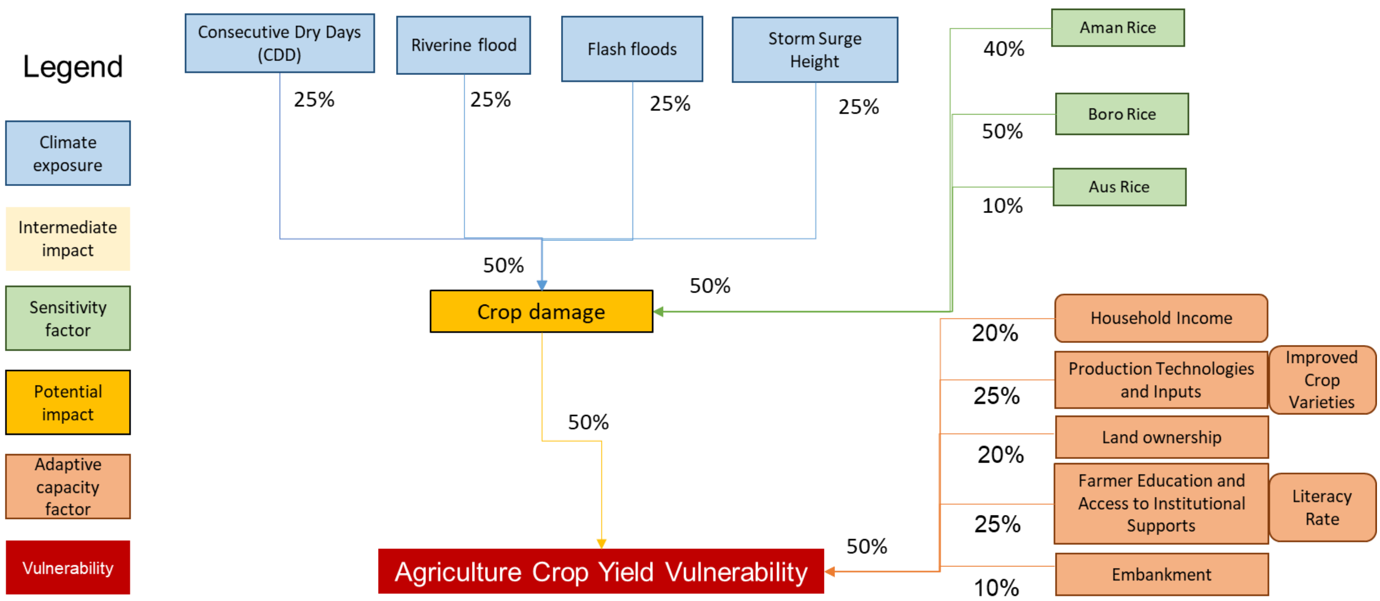


Figure 4.19: Impact chain related to the assessment of increase in damage to agricultural crops yields

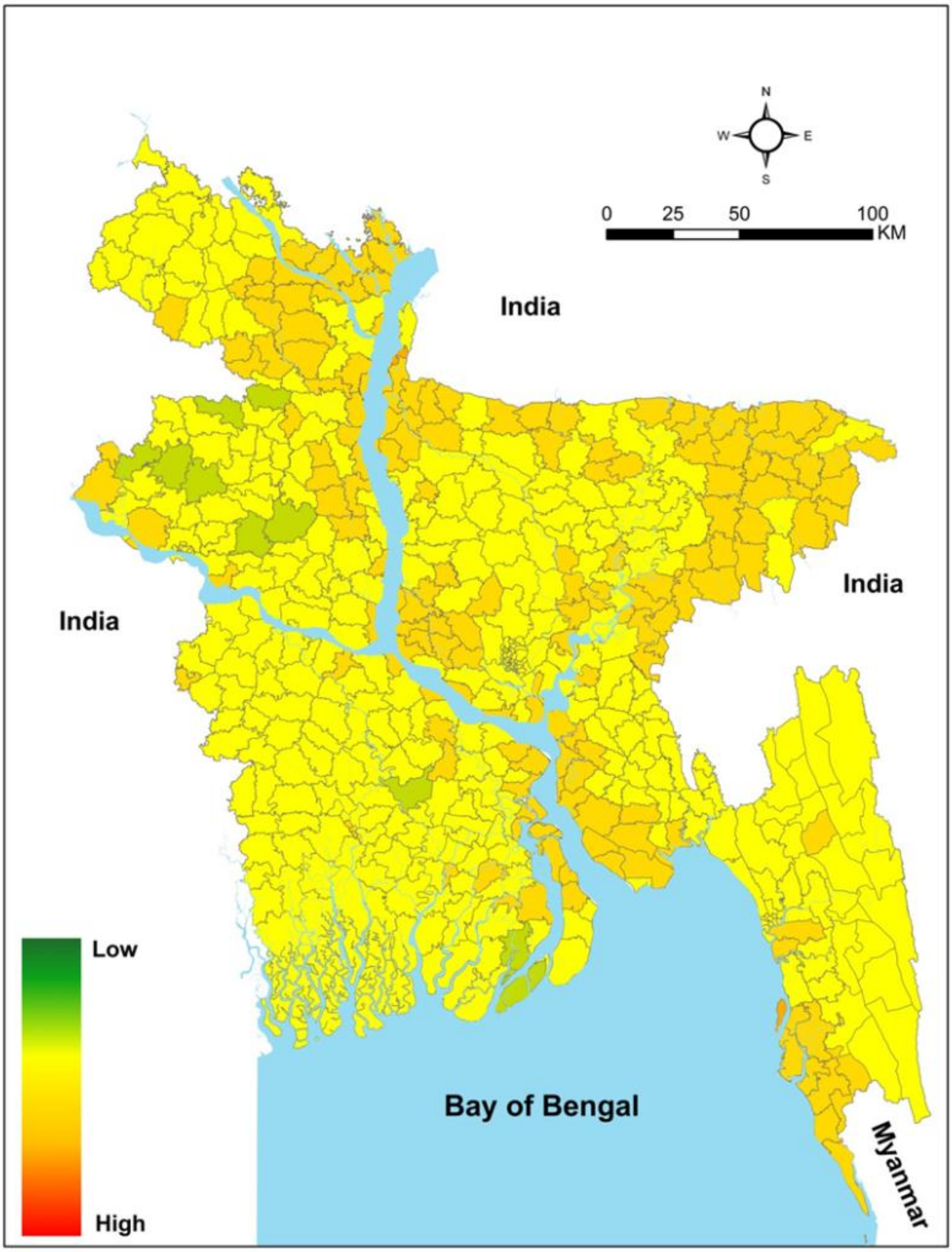


Figure 4.20: Assessment of the current vulnerability of the agricultural sector to crops yields degradation

The resultant composite vulnerability map (Figure 4.20) (including the aforementioned indicators), indicates that the vulnerability of crop yield is low to medium. This analysis corroborates the view of sectoral experts who participated in the national workshop, and argued that rice crops are growing well, and may not be particularly vulnerable. However, seasonal flash floods currently damage boro rice almost every year. Participants at the regional workshop in Sylhet raised this as a chronic problem for farmers of the area. There is concern that the yield of rice crops, in particular boro rice has been steadily declining. Findings from the regional workshop and the FGD sessions have recorded similar voices. In some southern coastal areas, crop yield may suffer due to increased salinity. As shown in the map, crops in the areas along the Meghna are flooded every year.

Community perceptions and experiences on crop yields

Focus Group Discussion Findings

(based on local communities' observations of climate change impacts)

In the Barind area (Kansat) where farmers mainly grow mango, participants mentioned a significant loss in production because of increased rain and storm, along with insufficient temperature. These changes were attributed to climate change. As an example, average rainfall during March and April escalated from 0.1mm and 12.7mm in 2010, to 26mm and 80mm in 2017 respectively. Such conditions result in the drop of flowers and immature mangoes during the blooming period, along with a decline in taste of mature mangoes during the growing period. Additionally, a pest, locally known as Ukune Poka, has massively spread over the last three years due to favourable climatic conditions. This pest attacks the mango plant more during damp weather after rainfall.

As a result, most farmers are facing a loss of income. Apart from mango plantations, other crops like rice, maize, and wheat also suffer from minor issues like bacterial attacks and burning out from an insect locally called Current.

In the Haor region (Judhistipur, Fenchuganj and Sylhet), climate change is already affecting rice crops. According to participants: recent irregularities in rainfall patterns and the amount of rainfall has resulted in higher water levels and increased delays in water recession. This results in a drop-in rice quality, impacting farmers' livelihoods. Farmers involved in litchi production in Judhistipur have also faced losses in production due to irregular rainfall and changing climatic conditions. One of them stated a loss of 50% of jackfruit crop due to drought.

In flood prone areas (Jamalpur district), floods and river erosion have increased over the years. As a result, more agricultural land is covered by sand each year. This hampers cultivation of some of the seasonal crops and also affects crop yields.

Gender considerations and next steps

The impacts of climate change on agriculture have differentiated effects on men and women. Men lose their livelihoods, food insecurity increases and their socio-economic condition changes. However, women are differentially affected by impacts on agriculture, from men. In recent years, poverty, women's empowerment and male migration have led to a change in gender aspects of the agricultural labor force (systematic "feminization") in Bangladesh. By 2008, 66% of all women participated in agricultural activities, and women constituted 45.6% of the total farming population (MoEF 2013, p 36). However, women generally do not own productive assets such as land or ponds. They also have limited access to information, services and other productive resources, along with limited decision-making power. Most women are also not involved in the marketing of their agricultural produce.

The present study recommends gender focused initiatives to increase women's adaptive capacity and decrease their sensitivity, based on data collected from the field. Increasing technological and logistical support for women involved in agro-farming would go a long way in increasing capacity of the local women. Inducing marketing systems for all goods produced by local men and women at the regional level (mangoes in Rajshahi regions and hand made products: cane products, hand-made fans, mattresses, etc.) will diversify their income sources. Arranging income generating trainings (handicrafts) will open up opportunities to participate in other employment options, while reducing their vulnerability to climate change impacts on agriculture. The Government of Bangladesh has already initiateddseveral programmes, e.g. inspiring and helping farmers to plant saline tolerant crops in coastal regions, stronger varieties of hybrid rice for flash flood prone regions, VCF, etc. While these initiatives help build adaptive capacity for farmers, they need to be inclusive, gender sensitive, women friendly, and more effectively monitored and evaluated.

With regard to crop yeild, a good number of options, technologies and measures have been suggested to maintain production and secure good yield. Among the technical measures and options, resilient crop types/varieties, improved cultivation technologies and access to other production inputs are important. Water management and the timely availability of fresh water for irrigation are critically important measures for quality yield. At the same time, management of embankments and other structures along with the facilitation of drainage play an important role for crop cultivation and subsequent yield. Farmers' education and awareness, regular technical and institutional support, and the enforcement of enabling policies are necessary as supportive options to improve adaptive capacity.

4.5 Vulnerability of the livestock sector to climate change

Climate change has both direct and indirect impacts on livestock. Temperature, humidity, rainfall, and other climate factors directly influence animal growth, milk production and reproduction (Hounghton et al., 2001). Indirect effects include impacts on the quantity and quality of feedstuff, such as pasture, forage and grain, as well as the severity and distribution of livestock diseases and parasites (Seo and Mendelsohn, 2006a). Climate change can also affect livestock biodiversity, genetics, breeding and rearing (Ahmed et al., 2013).

The Current context

The livestock sub-sector in Bangladesh is threatened by a number of climate parameters. Higher temperatures can result in heat stress and decreased livestock yields; sea level rise can inundate new coastal areas reducing grazing areas and fodder production; increased salinity can impact livestock rearing in the southern region; and an increase in the frequency and magnitude of droughts in the northern part of Bangladesh can further impact the livestock industry.

The main climate change impacts that have been assessed in the NCVA are the decrease in land availability for livestock and the increase in health issues of cattle and poultry.

Projected climate impacts based on existing scientific assessments

- By the end of the century, maximum temperature is projected to increase by 2 to 2.5°C, under the RCP 4.5 scenario and up to 4°C under the RCP 8.5 scenario. (DuDeltAS, 2015)
- Under current climate conditions, the average number of days where the maximum temperature exceeds 40°C is 20 to 25 days. In future climate, this number may increase by 2.5 to 3.5 days in 2050, and by 3.5 to 5 days in 2085, for the RCP 4.5 and RCP 8.5 scenario's respectively. (Bangladesh Delta Plan 2100 Project 2015)

4.5.1 Decrease in livestock and poultry health

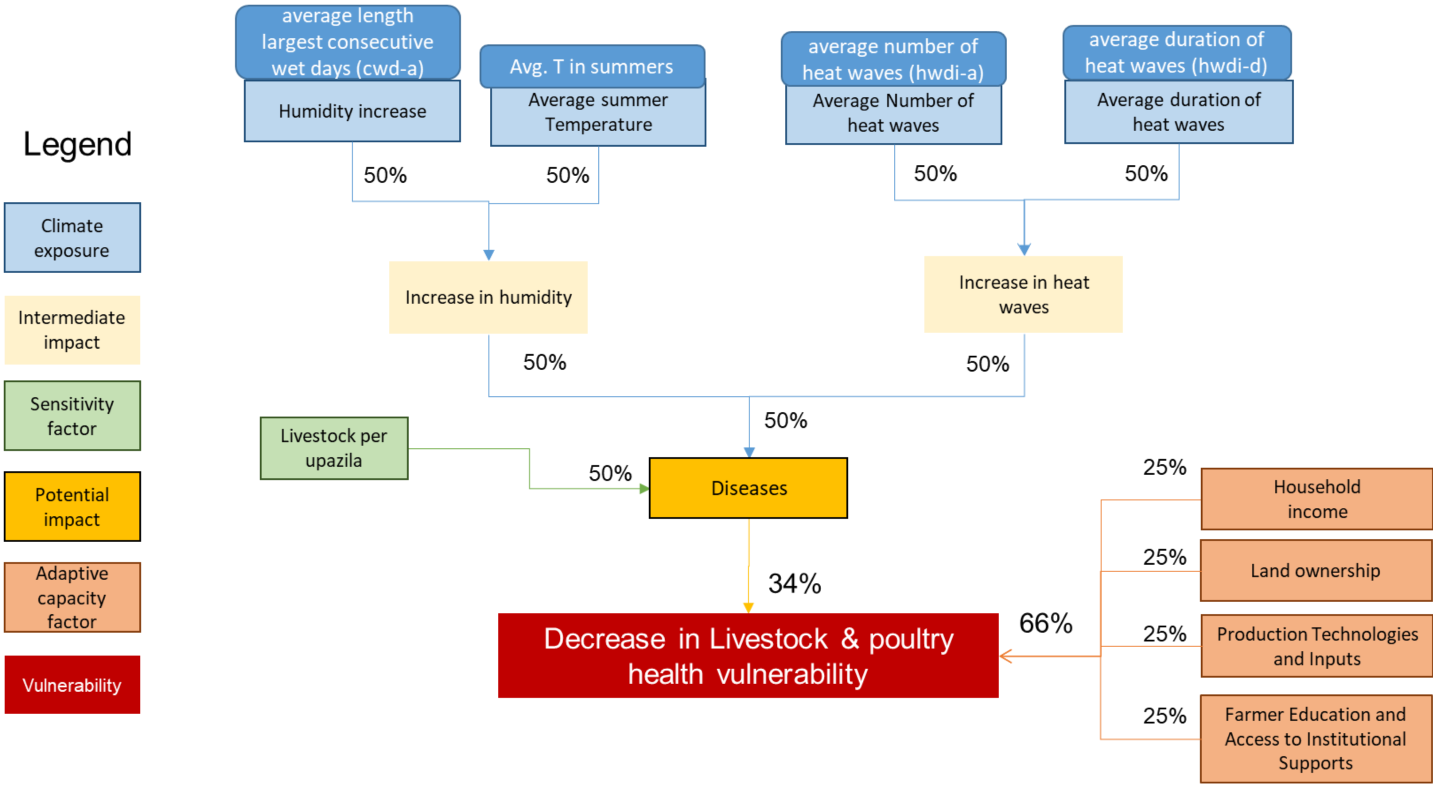


Figure 4.23: Impact chain related to the assessment of livestock and poultry vulnerability to health issues

The impact chain assessment of Bangladesh's vulnerability to decrease in livestock and poultry (Figure 4.23) focuses on four components of exposure: 1) increase in humidity; 2) average summer temperatures ; 3) average number of heat waves; and 4) average duration of heatwaves. A number of physical and socio-economic factors (encompassing sensitivity and adaptive capacity) such as livestock per upazila, household income, land ownership, production technology and inputs, farmers education, and access to institutional support together contribute to the assessment and mapping of the decrease in livestock and poultry.

The vulnerability map (Figure 4.24), based on model-based future projections of exposure to extreme heat under the moderate and extreme scenarios, indicates that vulnerability, in terms of decrease in livestock and poultry, is medium to medium-high overall. By 2085, under the high emissions (RCP 8.5) scenario, the entire western region of the country is projected to have the highest relative vulnerability. Stakehodder perceptions of vulnerability in the north east region seem to be aligned to the spatial vulnerability depicted in the maps, however, less so in the south-western areas.

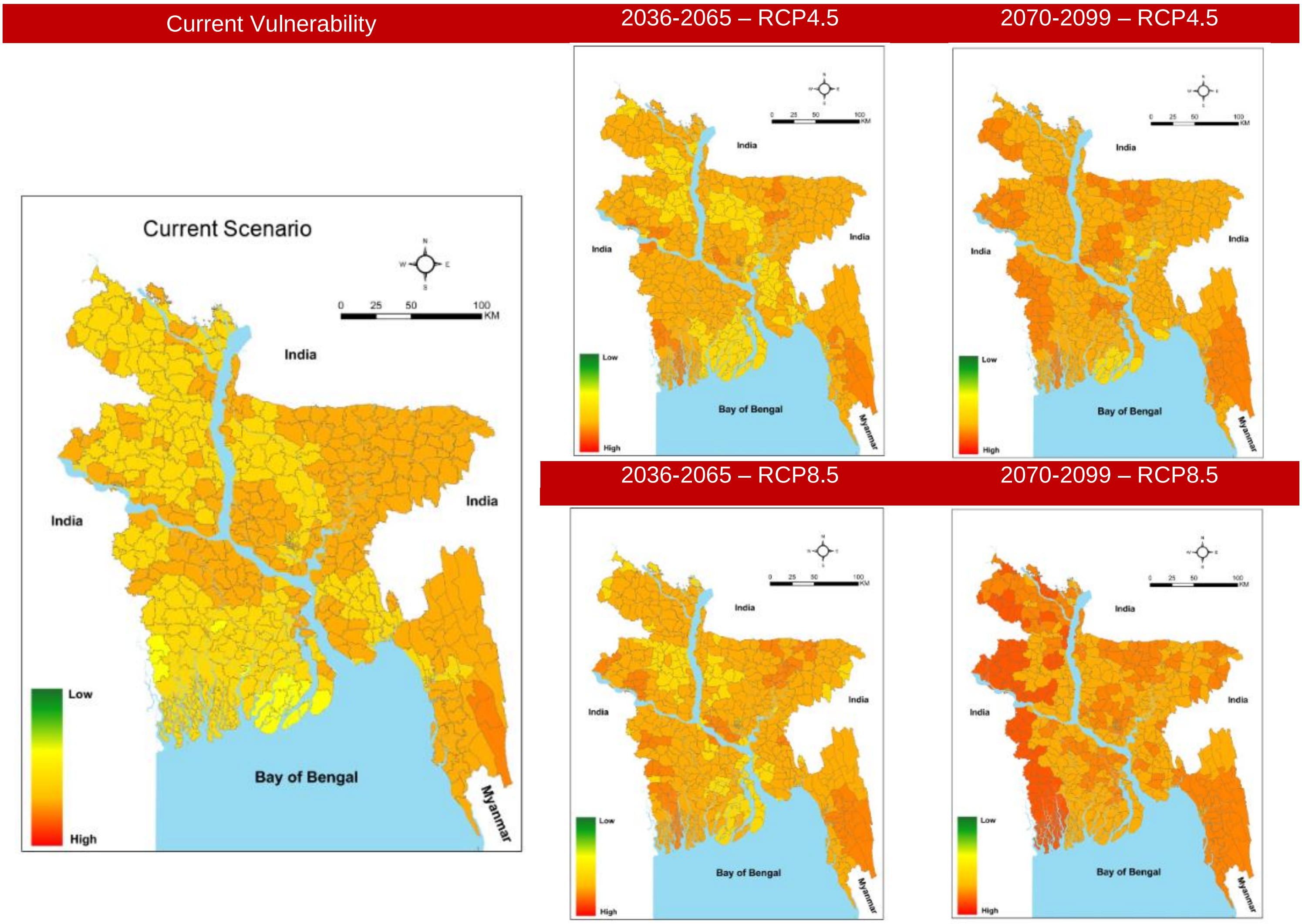


Figure 4.24: Assessment of the evolution of the vulnerability of livestock and poultry to increase in health issues

4.5.2 Loss of land availability for livestock

Similar to the agriculture sector, livestock is vulnerable to the decrease in land availability due of sea-level rise and coastal flooding, potential increase in flash floods and rivers floods, and potential increase in the frequency of storm surges.

Loss of land available for ivestock: Impact chain analysis and vulnerability map

The impact chain assessment of Bangladesh's vulnerability in terms of land available for livestock (Figure 4.25) focuses on three components of exposure, 1) sea level rise leading to salinization ; 2) storms and cyclones resulting in storm surges ; and 3) consecutive wet days causing floash floods and riverine floods. A number of geographical and socio-economic factors (encompassing sensitivity and adaptive capacity), such as livestock rearing as a primary occupation, livestock per upazilla, land owernship, extent of agricultural equipment per farm, etc. together contribute to the assessment and mapping of the country's vulnerability to loss of land for livestock.

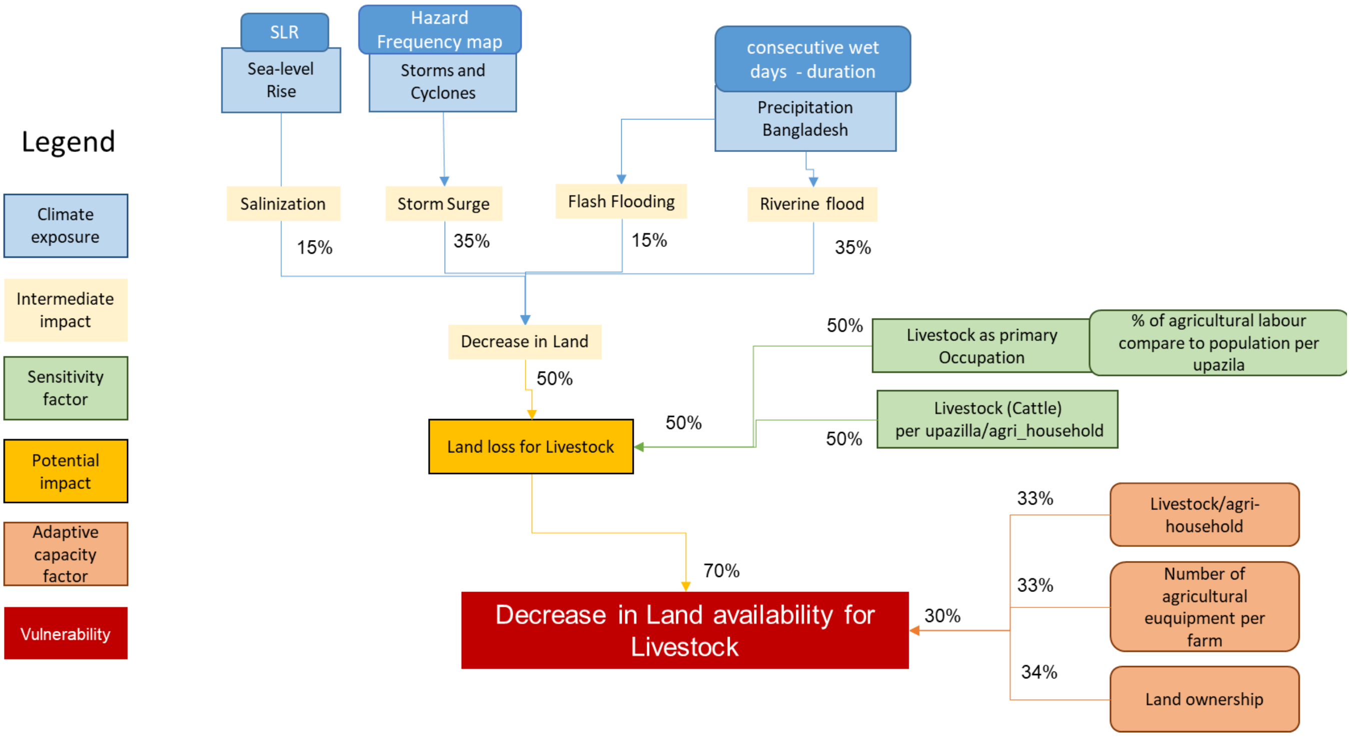


Figure 4.25: Impact chain related to the assessment of the livestock sector's vulnerability to decrease in land availability

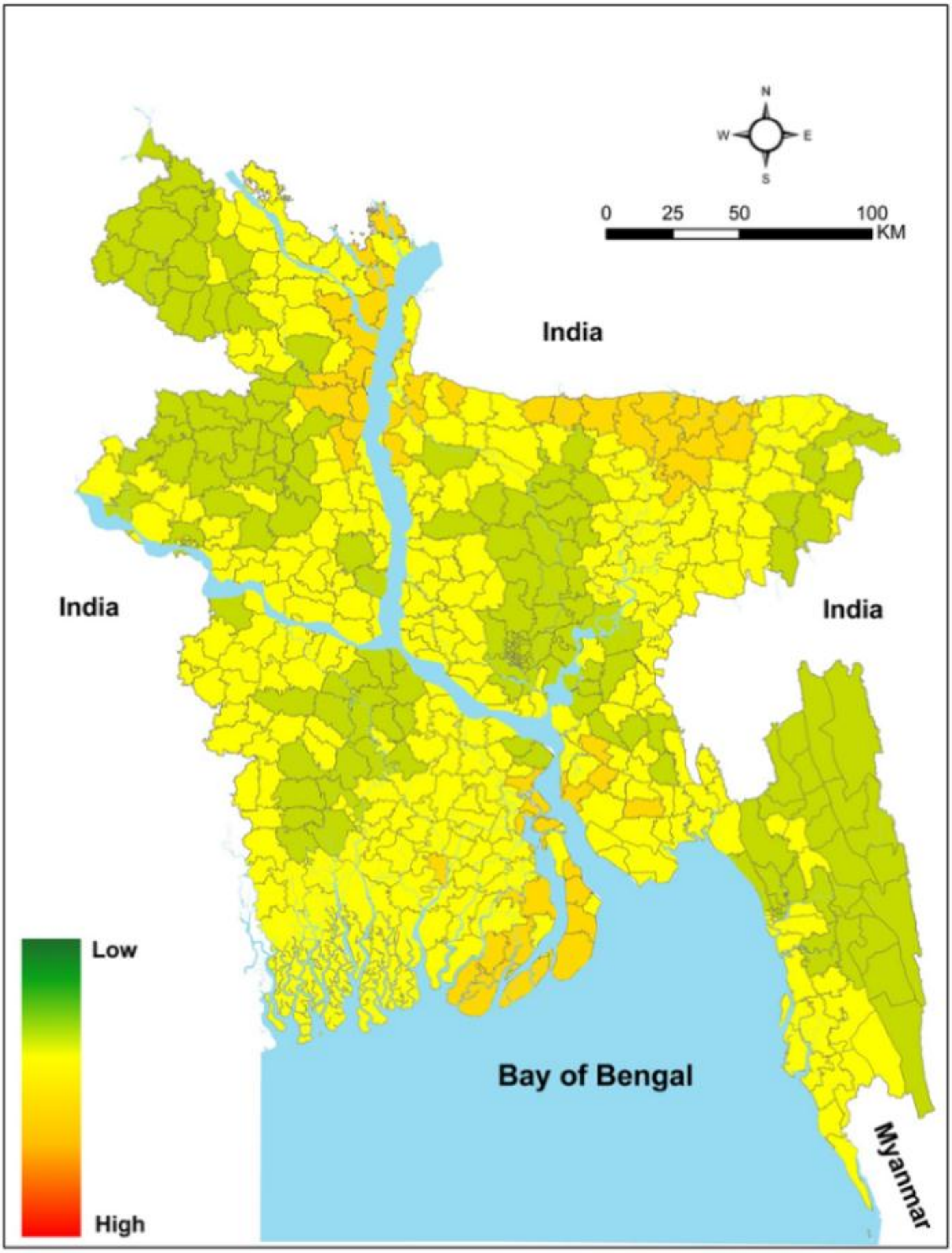


Figure 4.26: Assessment of the current vulnerability of the livestock sector to land loss

The resultant composite vulnerability map (Figure 4.26) (including the aforementioned indicators), indicates that, with regard to land availablity for livestock, the vulnerability of the country is medium to medium-low, with small areas in the north and south central regions being relatively more vulnerable. However, stakeholders at the regional workshops in south-west Bangladesh indicated more vulnerability to (reduced) land availability (likely because of addtional local factors).

Community perceptions and experiences on livestock vulnerability

Focus Group Discussion Findings

(based on local communities' observations of climate change impacts)

In the coastal zone, the prevalence and severity of animal diseases has increased over the past few years, which workshop participants have linked to climate change. Livestock breeding is highly impacted by water and pasture land depletion due to salinity intrusion. The older participants mentioned that when they were young (25-30 years ago), there were considerable pasture land available in the area. However, the current water and grass scarcity have forced some farmers to stop cattle rearing. As stated by a participant from Shyamnagor: "How can we raise cattle without water, grass and pastureland?"

The situation is similar **in Barind and drought prone areas**, where the decrease in water and graze land is seen as the main driver for animal health degradation and livestock breeding reduction. Participants observed that diseases locally known as 'Khura rog' are affecting cows, while goats are being affected by diarrhea in the winter season. As a result, there is tremendous economic impact on the local community, with women (who are largely involved in animal husbandry) being the worst affected.

In the Haor region (Dakkhin Protappur, Jaflong, Sylhet), the main concern is for poultry and ducks. The increase in diseases and associated mortality have severly affected the breeding of poultry.

In the flood prone areas, animals are lost by drowning and by flood-induced diseases. For example, participants noted that cattle were infected by anthrax after remaining in muddy places in areas with little access to veterinarians.

Figure 4.21: Focus group discussion in Amnura (Barind and Drought prone area)

Figure 4.22: Focus group discussion in Dakkhin Protappur, Jaflong, Sylhet (Haor region)

Gender considerations and next steps

As a result of the aforementioned climate impacts on the livestock sector, there is likely to be a greater economic impact on the local community, especially for women who are highly involved in animal husbandry. Small and marginal farmers particularly face a critical situation.

Experts during stakeholder consultations however, stressed that the sector has technological options (e.g. vaccination, feeds, improved fodder varieties, etc.) and facilities (e.g. training and education opportunities) to enhance adaptive capacity to offset this vulnerability.

4.6 Vulnerability of the fisheries sector to climate change

The Current context

Climate change is projected to affect fish production, biodiversity, habitat, physiology, reproduction, growth, and migration. It is also expected to impact fish cultivation and aquaculture related infrastructure. A brief account of climate change impacts on the fisheries sector is detailed below.

Impact of temperature rise on fisheries and aquaculture: Bangladesh already experiences high temperatures. Fish physiology (growth, reproduction, metabolism, etc.) is directly impacted by changing temperatures (Chowdhury et al., 2010). Extreme temperatures (extreme hot and extreme cold) as well as temperature fluctuations have a direct impact on fish physiology, growth, mortality, reproductive systems, feeding behaviour, production, and migration inland and in marine waters. High temperatures may induce the growth of aquatic microphytes. Higher production of microphytes can cause habitat degradation and oxygen depletion. Climate change also indirectly impacts fish cultivation through its effects on habitat/ecology, on which fish depend for food and shelter (Mustafa, 2010).

Impact of erratic rainfall: High temperature with irregular/insufficient rainfall might affect the spawning activity of fin-fish, particularly the major carp which needs very specific environmental, ecological and biological conditions for spawning. In 2009, due to high and fluctuating temperatures, and low rainfall, aquaculture activity, including fish hatchery performance, was seriously affected in the Mymensingh region of Bangladesh (Mustafa, 2009). Akhter Z. Nasrin (National fish week – 2016, DoF) reported that erratic rainfall and temperature fluctuations have already negatively impacted the spawning performance of major carp in its only natural spawning ground in Halda river in Bangladesh. In the Halda river, spawning of major carp usually occurs during April-May, under favourable environmental conditions (rainfall, temperature, water flow, water quality, etc).

Impact of floods: Almost every year, 20-30% of the country is flooded. River bank erosion, mainly due to floods, causes river siltation. This reduced the water holding capacity of rivers, degrades fish habitats, and reduces water availability in winter for fish production and the conservation of biodiversity. But as floods inundate more areas in the floodplain, there may be some beneficial effects for open water fisheries/flood plain fisheries, as fish get more grazing area, nutrients, and sometimes, a longer time to grow.

Observed impacts of drought: Droughts associated with high temperature and low rainfall have adverse impacts on aquaculture and inland open water fisheries in the drought prone area in Bangladesh. In the north and north-west regions of Bangladesh, particularly in Barind, droughts have been found to affect aquaculture due to insufficient water and the drying up of the water bodies. Ponds, rivers, canals and beels dry up or retain insufficient water during the dry/drought period, affecting fish production in aquaculture, and in open water systems in the north-east region (Haor area in Sylhet basin). Fish growth, reproductive systems, survivability, biodiversity, etc. are adversely affected by droughts, making fish more vulnerable to diseases. Connectivity between different water bodies, particularly between rivers and floodplain/beel, has also been lost due to the drying up of water bodies and connecting channels. This affects migration, breeding and growing of fish and other aquatic animals.

Impacts of sea level rise and salinity intrusion**:** Salinity intrusion is likely to affect fresh water aquaculture, as well as species distribution and biodiversity in the coastal region. Due to climate change, water salinity will exceed the desired levels for fresh water fish cultivation. Salinity intrusion is already affecting freshwater fish culture. With sea level rise, salinity will intrude further inland, reducing fresh water area for fish production.

The inundation of low lying areas as a result of sea level rise has some positive impacts, in terms of an increase in area for production of fish and shrimp in coastal zones. Salinity increase and intrusion may create opportunity for bleakish water/estuarine aquaculture and fisheries (brackish water and marine fish/shrimp culture). Increasing salinity can enhance culture of Tiger shrimp (P. monodon) in coastal areas, up to a certain threshold. Growth of tiger shrimp is optimum at 2-25 ppt. of water salinity. Beyond this threshold, growth may be affected. P. indicus, already cultivated in Bangladesh, can tolerate salinity levels up to 42 ppt, and P. venname can grow better in up to 45 ppt of salinity.

Impacts of cyclone and tidal surge: In the last few decades, the occurrence and intensity of tropical cyclones have increased in the Bay of Bengal region, particularly in Bangladesh (Chowdury et al., 2010). This has resulted in aquatic resource losses. Cyclones Sidr (November 2007) and Aila (May 2009) destroyed coastal aquaculture infrastructure and fishing equipment (boats and nets), and caused the loss of numerous fishers' lives. Recently, cyclones Mahasen (16 May 2013) and Roanu (April 2016) have impacted fishers, their assets, aquaculture infrastructure, fish and the fish ecology (Table 4.2).

An account of the damage/loss to fisheries due to different cyclones is provided in Table 4.2.

Table 4.2 – Impacts of past cyclones on fisheries

Cyclone/ Surge		**Year**	**Wind speed (km/hr)**	**Surge height (m)**	**Total loss/damage (fish/shrimp) (Million USD)**
1	Sidr	2007	260	5.5	300
2	Aila	2009	120	3.0	126
3	Mahasen	2013	120	1.1	1.0
4	Roanu	2016	54	1.0-1.5	20.1

Source: GoB, 2008

Projected climate impacts based on existing scientific assessments

- Rainfall intensity of 10-year return period is projected to occur every 3-5 years in 2055 under the RCP 8.5 scenario (Lutz et al., (2016)).
- Peak river discharge of the Teesta river and the rivers feeding the Brahmaputra basin are expected to increase by 25-75% in 2050, under the RCP 8.5 scenario (Wijngaard et al., (2017)).
- The intensity of tropical cyclones and storm surges are likely to increase due to rising sea surface temperature and sea level
- Under the RCP 8.5 scenario, the period of consecutive dry days may increase by 10-15 days (from the present 60 days), by the end of the century (BanDuDeltAS 2015).

4.6.1 Change in fish culture (ponds and shrimps)

Change in fish culture: Impact chain analysis and vulnerability map

The impact chain assessment of Bangladesh's vulnerability in terms of change in fish culture (Figure 4.28) focuses on three components of exposure : 1) sea level rise leading to salinization; 2) storms and cyclones resulting in increased height of storm surges; and 3) consecutive wet days causing flash floods and riverine floods. A number of geographical and socio-economic factors (encompassing sensitivity and adaptive capacity), such as the presence of embankments, area of fish ponds, rates of poverty and literacy, together contribute to the assessment and mapping of the country's vulnerability to change in fish culture.

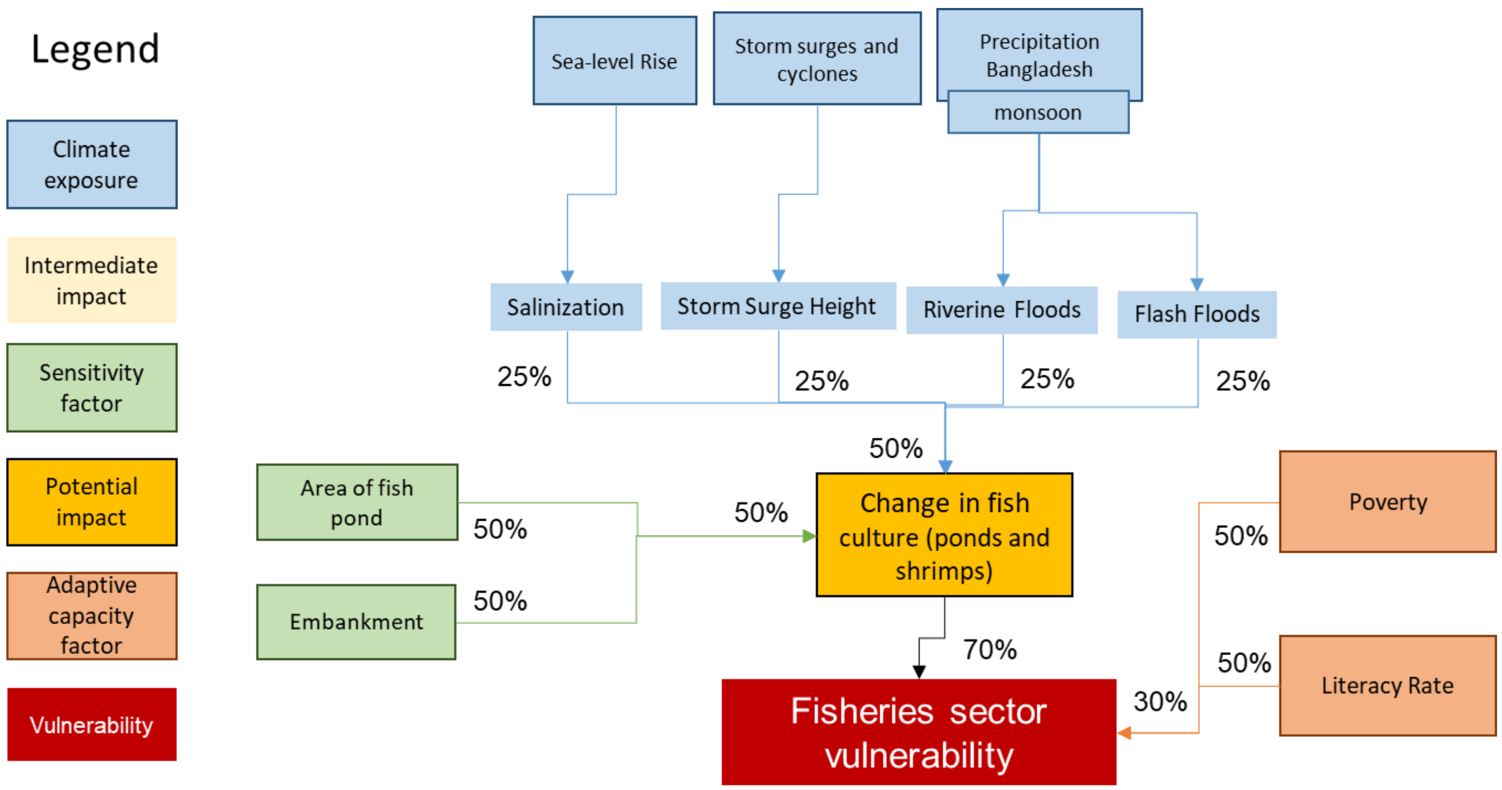


Figure 4.28: Impact chain related to the assessment of vulnerability in the fisheries due to changes in fish culture (ponds and shrimps)

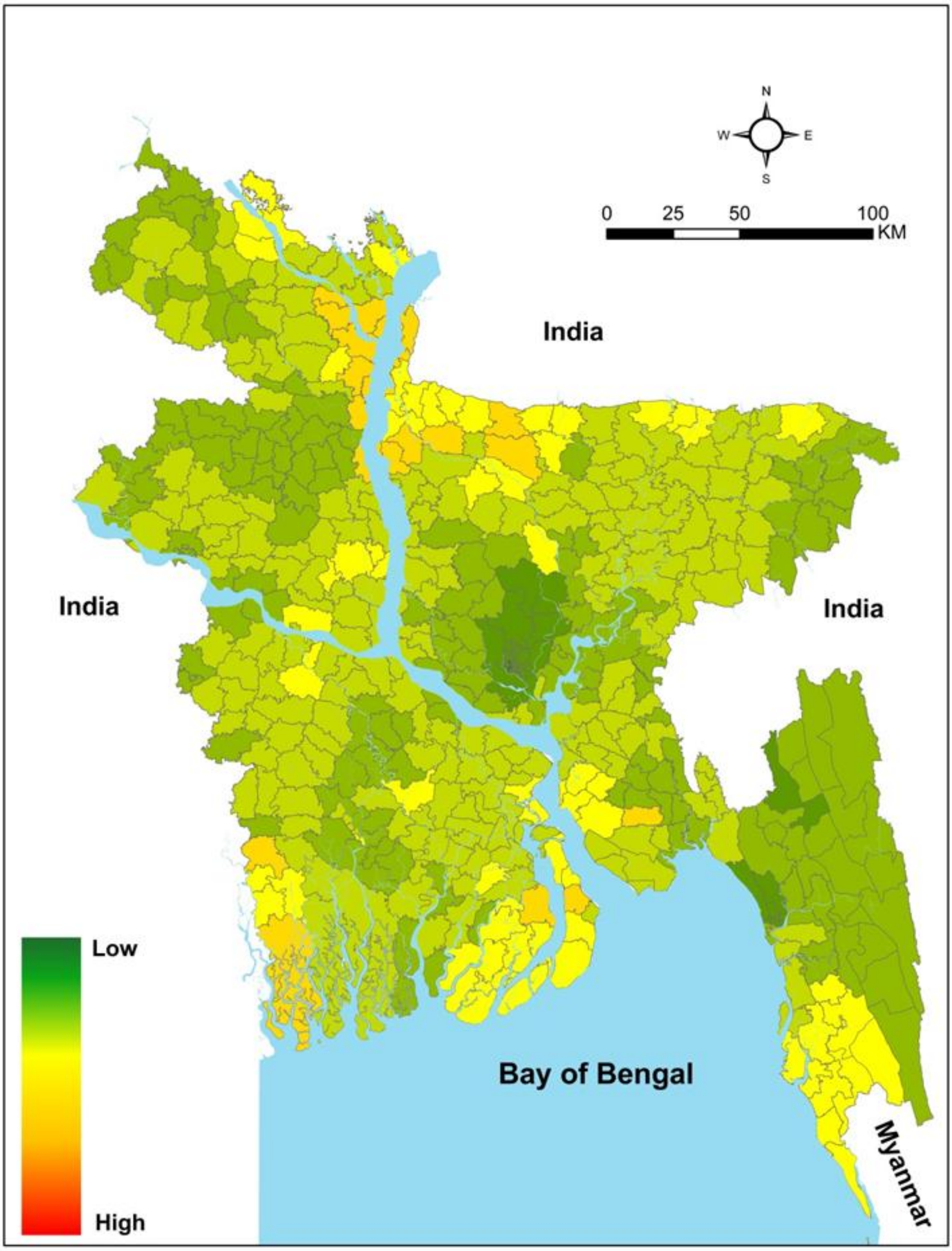


Figure 4.29: Assessment of the current vulnerability of the fisheries sector to changes in fish culture

The resultant composite vulnerability map (incuding the aforementioned indicators), indicates that overall vulnerability of Bangladesh to change in fish culture is low, with pockets of medium to medium-high vulnerability in interspersed areas of Rangpur, Mymensingh and Khulna (Figure 4.29). The map is indicative of the on-ground experience that, some climate impacts can present opportunities for certain aspects of the fisheries sector.

4.6.2 Change in fish capture (floodplains, rivers, lakes and wetlands)

Change in fish capture: Impact chain analysis and vulnerability map

The impact chain assessment of Bangladesh's vulnerability in terms of change in fish capture (Figure 4.30) focuses on three components of exposure : 1) sea level rise leading to salinization ; 2) storms and cyclones resulting in increased height of storm surges; and 3) consecutive wet days causing flash floods and riverine floods. A number of geographical and socio-economic factors (encompassing sensitivity and adaptive capacity), such as the presence of fishermen, availability of embankments, area of fish ponds, rates of poverty and literacy, together contribute to the assessment and mapping of the country's vulnerability to change in fish capture.

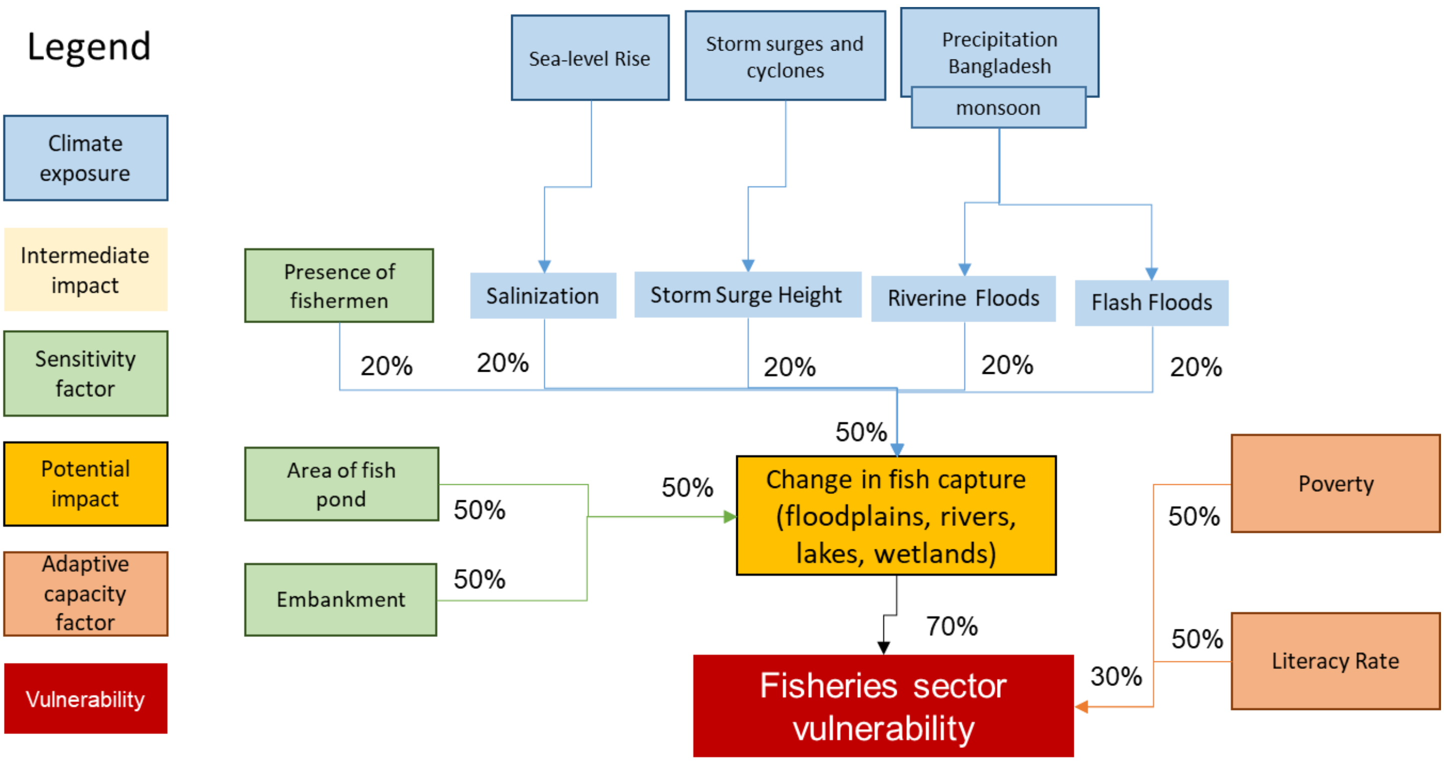


Figure 4.30: Impact chain related to the assessment of fisheries sector vulnerability to changes in fish capture

The resultant composite vulnerability map (incuding the aforementioned indicators), indicates that overall vulnerability of Bangladesh to change in fish culture is low, with pockets of medium to medium-high vulnerability in areas of Rangpur, Mymensingh, Khulna, Barisal and Chittagong (Figure 4.31).

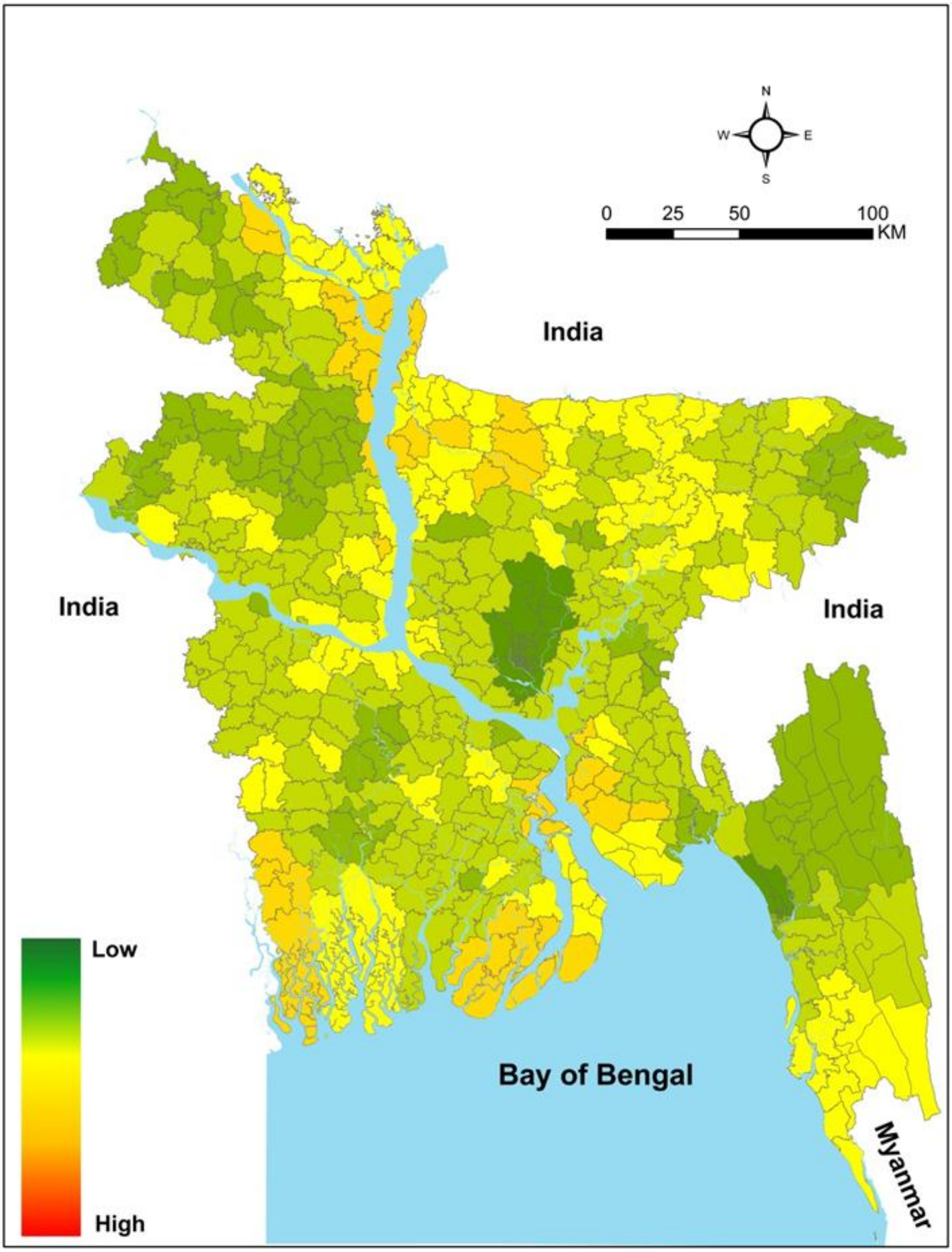


Figure 4.31: Assessment of the current vulnerability of the fisheries sector to changes in fish capture

Community perceptions and experiences on fish culture and capture

Focus Group Discussion Findings

(based on local communities' observations of climate change impacts)

In coastal areas, participants have already observed impacts of climate change on the entire fish industry regarding captured fish (Sundarban) and fish farming (Shrimp). There has been a reduction, over time, of both variety and quantity of captured fish, which has been attributed to more frequent and intense heavy rains and hail storms. These factoes have been responsible for the degradation of water quality. As a participant stated, "extreme rainfall and storms like Sidr, Aila, damage fish in open water bodies: the water rises up and washes the rotten leaves into the water, thereby degrading its quality. Additionally, fish die due to the hail during severe storms." Shrimp cultivation and production require a moderate water temperature. If temperatures are too high, as already experienced by participants from Shyamnagor, it triggers virus attacks and mortality. If temperatures are too low, it slows shrimp growth. As a result, shrimp cultivation is becoming more difficult, possibly due to climate change.

In the Barind area, because local people engage in fish culture in available ponds, it has become increasingly difficult to maintain a sufficient amount of water. Decreasing rainfall trends has induced farmers to use pond water for irrigation because of depleting groundwater, and rising temperatures have made some ponds water too hot for fish culture.

In the Haor region, participants observed a reduction in fish quantity over the last 10 years, due to early flooding, an increase in fish mortality in the paddies (due to a pH increase) and a trapping of fish in paddies due to inconsistent rain. They are worried that fish could disappear in the Hakaluki over the next 10 years.

In Judhistipur, Fenchuganj, **Sylhet**, fishermen noted that fish suffer from several diseases, which may be attributed to changes in temperature, amount of rainfall, and availability of water in the haor.

In flood prone areas, the respondents (especially the elderly) have perceived a decrease in the amount of fish (particularly indigeneous species) in rivers, beel/lakes, ditches, canals, etc., over the past few years.

Figure 4.27 – Fishermen Chorpara, Kutub bazar, Cox'sBazar (Chitagong Hill Tracts and Coast)

Gender considerations and next steps

Millions of people and their families depend on fish capture in Bangladesh. Any change in fish capture affects fishermen and their family members. Women tend to be most affected as they depend on the family income. Further, according to the FGD participants, decreasing availability of local varieties of fish directly affects the health of expecting mothers and their children. Poor inhabitants living near rivers and haors depend on fish capture to fulfil their protein needs. Changes in fish capture also lead to an increase in domestic violence and family conflicts. Increasingly, fishermen are changing their occupations, migrating, and leaving their families in an insecure condition, enhancing women's vulnerability to gender-based violence (GBV). Proper training on fish capture and providing modern fishing tools (boats, nets, life saving equipments, etc.) for both men and women involved in fishing can help increase their adaptive capacity. However, trainings (agro-based), loans and donations to start a new business or occupation (tailor shops, grocery shops, etc.) would also be helpful for these fishermen, especially the women of these families.

Contrary to popular belief, women are heavily involved in fish production systems in Bangladesh. Feed preparation, fertilization of ponds, feeding fish and shrimp, as well as post-harvest activities are often women's responsibilities. According to the Department of Fisheries Report, 2015, about 1.4 million women are employed in this sector. However, most of the people (male and female) involved in fish culture lack any training or education. Arranging trainings for both men and women on fish culture, enabling access to small loans, especially for women, would increase their adaptive capacity to cope with changes in natural fish capture due to climate change, ensure their employment, economic stability, and food security. Current adaptation strategies used by farmers, such as using saline tolerant species like Tilapia and Parsey (Mugil) ; fresh water giant prawn (M. rosenbergii) which can tolerate salinity up to 6 ppt ; can be scaled up and supported institutionally.

4.7 Vulnerability of infrastructure to climate change

Transport infrastructure and assets play a dual role with regard to climate impacts. On the one hand, roads and railway infrastructure is synonymous with development. It is known to impove the adaptive capacity of people by improving access to schools, factories, markets for goods, etc. In case of extreme weather events, transport infrastructure and systems also facilitate easy evacuation, provision of post disaster response and access to medical facilities. On the other hand, inadequately planned and poorly contructed transport infrastructure can further exacerbate climate events through damaged assets, accumulated debris, distruptions in transport and post disaster response.

The Current context

The vulnerability of transport to climate change in the NCVA is principally focused on transport infrastructure, specifically road transport and rail transport vulnerability.

The navigation, transport, and infrastructure vulnerability is evaluated combining potential impact of each sub-sector, i.e., (i) roads, riverports and railways; (ii) river navigability and aviation; (iii) critical infrastructure (electricity, seaport, telecom, and water); and (iv) damage and operations of industries.

Projected climate impacts based on existing scientific assessments

- Rainfall patterns may become more variable and erratic (BanDuDeltAS 2015)
- Rainfall intensity of 10-year return period projected to occur every 3-5 years in 2055 under RCP 8.5 (Lutz et al. (2016).

- The intensity of both tropical cyclones and storm surges are likely to increase through the rising sea surface temperature and sea level
- Peak river discharge of the Teesta river and the rivers feeding the Brahmaputra basin expected to increase by 25-75% in 2050 under the RCP 8.5 scenario (Wijngaard et al. (2017)

4.7.1 Road transport vulnerability to climate change

Road transport vulnerability: Impact chain analysis and vulnerability map

The impact chain assessment of Bangladesh's vulnerability in terms of road trasnport (Figure 4.34) focuses on three components of exposure: 1) sea level rise leading to salinization; 2) storms and cyclones resulting in increased height of storm surges; and 3) precipitation causing flash floods and riverine floods. A number of geographical and socio-economic factors (encompassing sensitivity and adaptive capacity) such as, the presence of national and regional highways, presense of district, upazilla, and village roads, availability of critical infrastructure, household incomes, literacy rates, etc. together contribute to the assessment and mapping of the country's vulnerability to road transport.

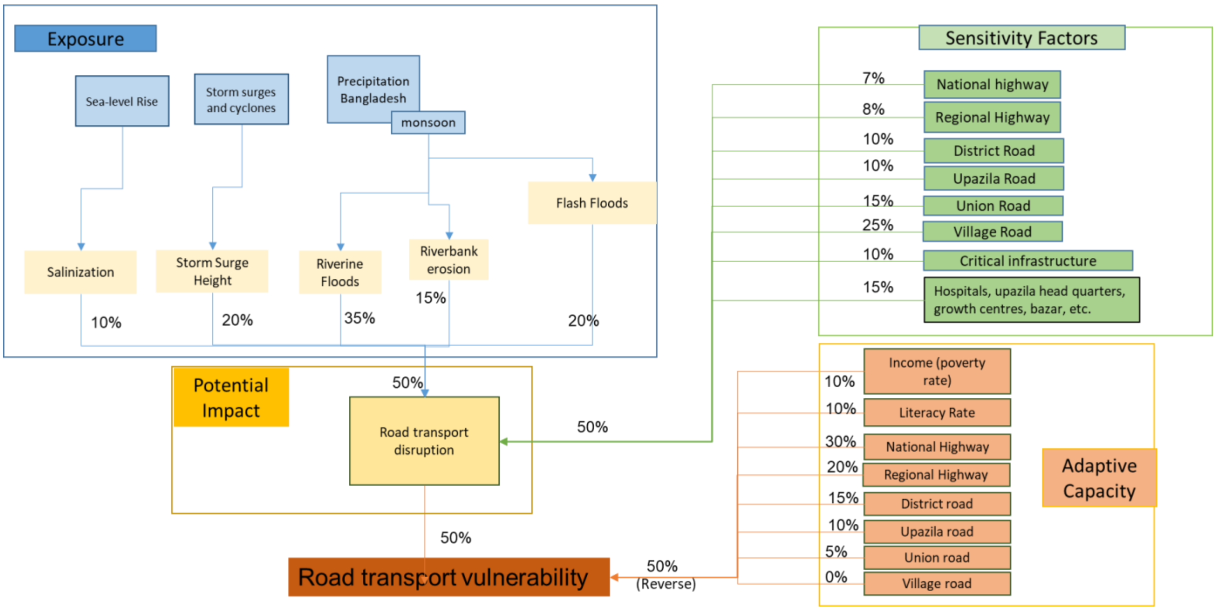
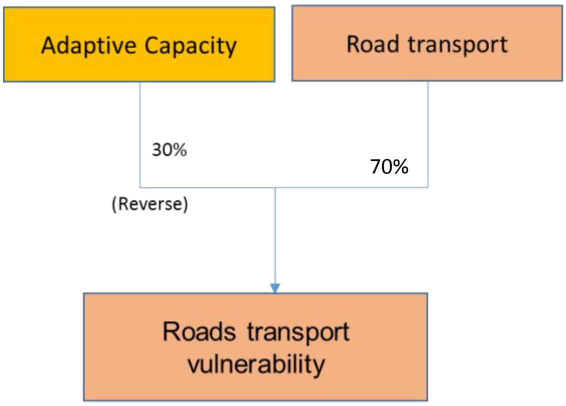


Figure 4.34: Road transport vulnerability to climate change

The resultant composite vulnerability map (including the aforementioned indicators) ascribes 70% weightage to potential impacts and deducts 30% in terms of adaptive capacity factors, which offset the overall vulnerability (Figure 4.35). The map shows that areas of north-central Sherpur, Jamalpur and Gaibandha districts, and southwest Satkhira, Barisal and Pirojpur districts are more vulnerable than other parts of the country. However, Barisal, Pirojpur and other coastal districts are connected to alternative commercial navigation routes. Most areas of the country are moderately vulnerable except for some pockets like Dhaka and its surroundings, and Chittagong areas where better road network service is available.



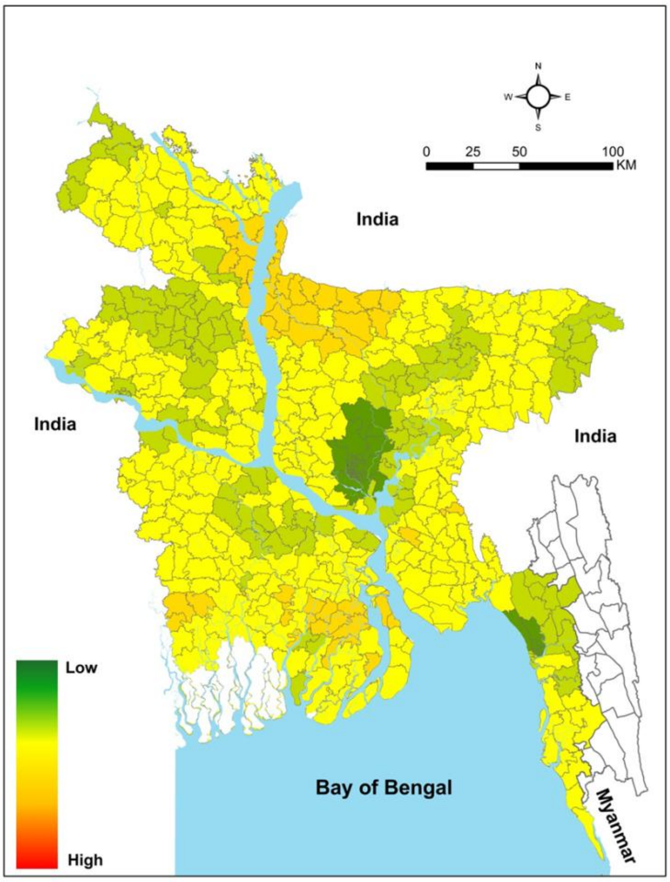


Figure 4.35: Current road infrastructure vulnerability to climate change

4.7.1 Vulnerability to rail transport disruption

Vulnerability to rail transport disruption: Impact chain analysis and vulnerability map

The impact chain assessment of Bangladesh's vulnerability in terms of rail transport disruption (Figure 4.36) focuses on three components of exposure : 1) sea level rise leading to salinization ; 2) storms and cyclones resulting in increased height of storm surges ; and 3) precipitation causing flash floods and riverine floods. A number of geographical and socio-economic factors (encompassing sensitivity and adaptive capacity), such as railway infrastructure, railway network, availability of critical infrastructure, hospitals, bazaars, upazilla head quarters, household income, literacy rates, etc. together contribute to the assessment and mapping of the country's vulnerability to rail transport disruption.

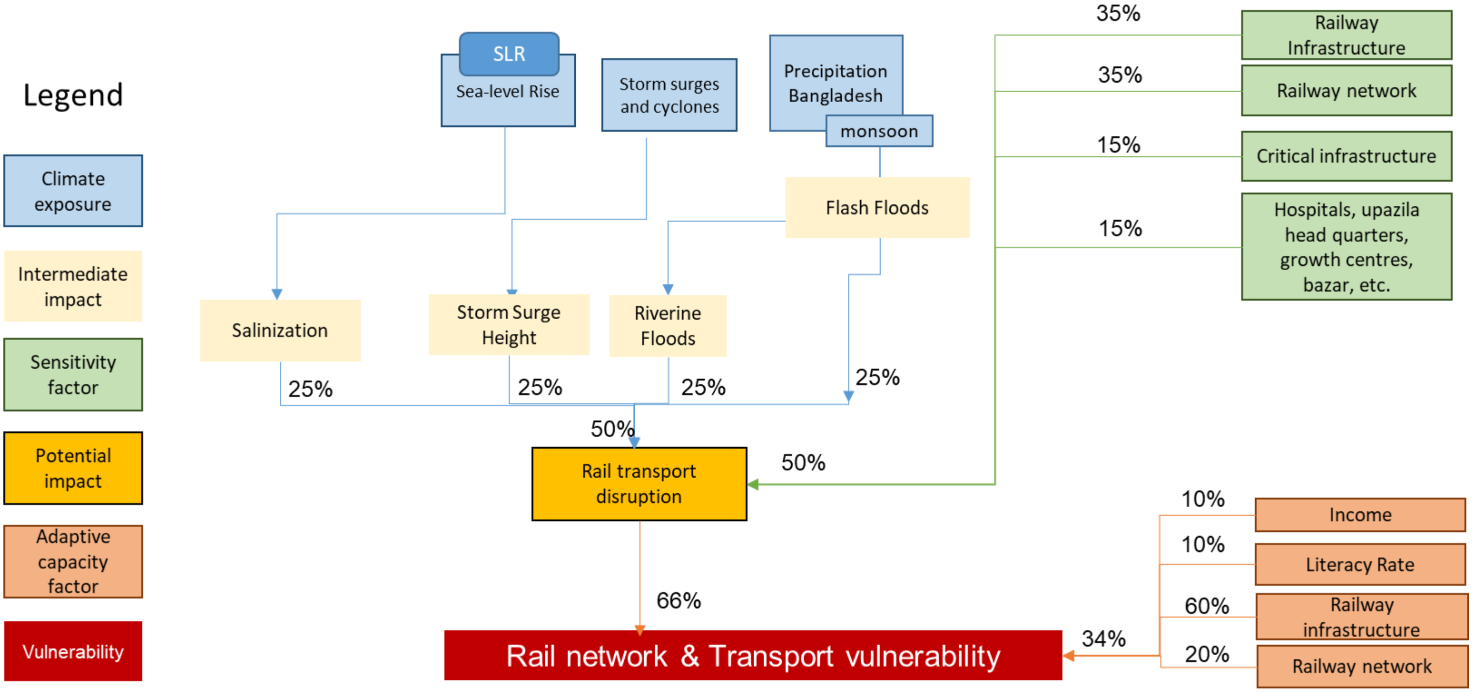


Figure 4.36: Impact chain related to the assessment of the vulnerability to rail transport disruption

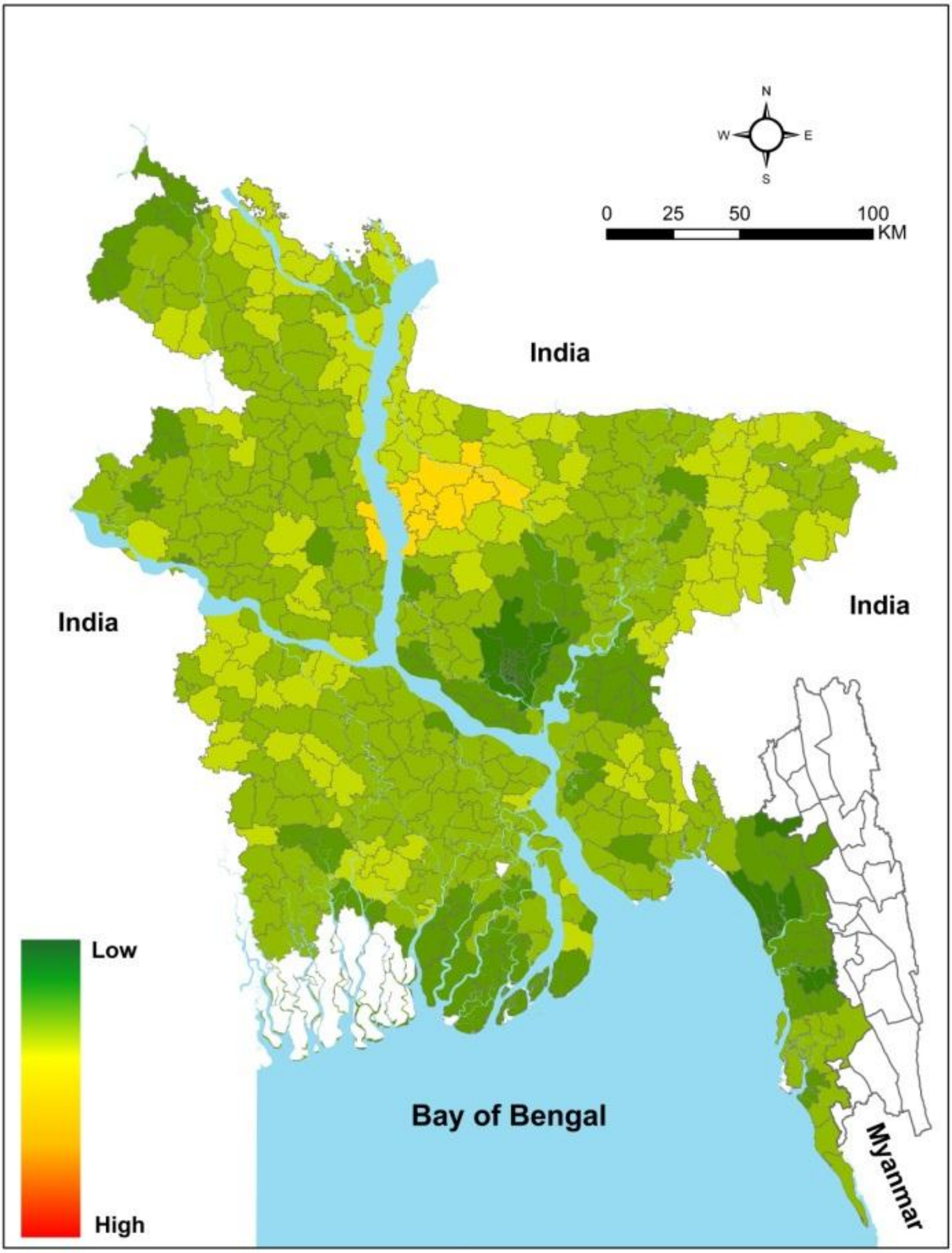


Figure 4.37: Current vulnerability map of rail infrastructure

Figure 4.37 shows the final vulnerability map of railway transport disruption in Bangladesh where the left side map shows all the upazilas except Sundarbans and CHT areas, while right side map shows only the upazilas which are connected to railway network. It has been observed that, north of Dhaka near and surrounding the Jamuna bridge, is the most vulnerable to railway transport disruption.

Community perceptions and experiences on transport vulnerability

Focus Group Discussion Findings

(based on local communities' observations of climate change impacts)

The participants to the focus group discussions held in different parts of **Chittagong Hill Tracts and the coastal region** discussed the impacts of road and marine network disruption following natural disasters, which result in isolation (especially for people living on the islands), inaccesibility to safer places, as well as lack of access to food and safe water supplies. Electricity network shutdown also prevents people from properly storing food, which amplifies the health impacts of natural disasters. For fishing communities, road and connectivity disruptions make it impossible to continue selling fish in the market, depriving them of their livelihoods during the disaster period. The discussions also shed light on the vulnerability of women during natural disasters, especially pregnant women, when access to emergency transport and medical facilities is lacking.

In Kutubdia para, participants mentioned a lack of adequate cyclone shelters for the local population, increasing their vulnerability during natural events.

In flood prone areas, roads are often inundated, so people have to use boats as their usual means of transport during the flood season. Road network disruptions also prevent children from going to school.

Figure 4.32: Transporting materials in Kutubdia para (Chitagong Hill Tracts and Coast)

Figure 4.33: Focus group discussion in Kutubdia Para (Chitagong Hill Tracts and Coast)

The exposure factors include five components. Four exposure components are common with railway transport disruption, the fifth component is riverbank erosion prone areas. The weights assigned were salinization (10%), storm surge height area (20%), riverine floods (35%), flash floods (20%), and riverbank erosion prone area (15%). Details are described in the map section.

There are eight sensitivity factors for road transport vulnerability: national highway (7% weight), regional highway (8%), district road (10%), upazila road (10%), union road (15%), village road (25%), critical infrastructure (10%), and locations of hospitals, upazila head quarter, growth centres, and bazars (15%).

Next steps

The key conclusions of railway disruption are: (i) north of Dhaka, near and surrounding the Jamuna bridge, is most vulnerable to railway transport disruption; and (ii) other areas where railway services are available are more or less vulnerable. However, as an easy and cheap transport service, railway services should be expanded to each upazila in the near future for uniform development of the country.

The key conclusions of roads disruption are: (i) areas of north-central Sherpur, Jamalpur and Gaibandha districts and southwest Satkhira, Barisal and Pirojpur districts are more vulnerable than other parts of the country. However, Barisal, Pirojpur and other coastal districts are connected to alternative commercial navigation routes; and (ii) most other areas of the country are moderately vulnerable, except for some pocket areas of Dhaka and its surroundings, and the Chittagong area where very good road network services are available. National and regional highways quality should be regularly maintained and kept smooth to ensure uninterrupted access across the country. Rail and road networks should be maintained with the same priority, as alternatives to each other.

4.8 Mangrove forest degradation and loss

Biodiverstiy in Bangladesh: The Current context

Biodiversity is one of the key issues to plan and design sustainable development strategies. For Bangladesh, biodiversity and environment is not only important to achieve the 2030 agenda for sustainable development, but also important for a balanced ecosystem and as an important driver of food security. Needless to say, a large portion of the population in Bangladesh is directly dependent on natural resources.

Recent studies reveal that different regions of this country are losing their local varieties of birds, fish, trees and animals. For example, the Haor region has lost local varieties of fish (Rani, Kheua, Rui, Katla, Baush, Rita. Elong, Vacha). Fruit trees are also affected by different diseases. For example, production of litchi and jackfruit, along with their taste, has been affected. There is a decresae in the number of birds, particularly sparrows, vultures and migratory birds. Changes in rainfall, temperature, water flow in the rivers, and flash floods, along with man-made factors like the use of pesticides, fertilizers and deforestation, have huge impacts on chaning the biodiversity in this region. Urban areas are also losing biodiversity. Data collected from the field reveals that Badda, Mohammadpur in Dhaka have different types of trees and birds. Over the last few years, there is an increase in new diseases affecting trees and animals of this region.

With regard to biodiversity vulnerablity, the NCVA has focused mainly on the Sundarbans mangrove forest. People living in this area are dependent on natural resources for their livelihoods. Over-exploitation, deforestation, habitat change, pollution and invasive species are the most important problems causing biodiversity loss and environmental degradation in Bangladesh, while climate change is expected to increase vulnerability of this region.

Climate vulnerability and the Sundarbans: The Sundarbans in Bangladesh is the largest mangrove forest in the world and is home to a vast array of biodiversity. It is well known for its forest resources and wild life, including the famous Royal Bengal tiger. Although, there are no permanent settlements inside the Sundarbans, a large number of people living in its periphery directly or indirectly depend on the mangrove ecosystem for their livelihood. People (Sundarbans resource users) enter the forest to harvest natural resources including fish, crabs, nypa palm and honey. In the Sundarbans, some species of flora and fauna have already become extinct (http://www.iucnredlist.org/), while several others are threatened and on the verge of extinction. Biodiversity vulnerability to climate change in the Sundarbans is increasing. Biodiversity and natural resource conservation for a healthy ecosystem should be a priority sector for building climate resilience in Bangladesh.

Due to its special status as a reserved forest, the assessment focused on the Sundarbans. This specific mangrove ecosystem is highly threatened by human activities, as well as by climate change impacts, especially sea level rise and salinity intrusion.

The map below shows that the Sundarbans contains a very specific ecosystem, with endemic and diverse species of mangrove adapted to water with high salinity rates.

However, this unique ecosystem is highly sensitive to human pressure, notably because of the increasing degradation of water quality for several reasons:

Domestic and industrial waste generated by Khulna: Khulna City Generates 300-380 tons of solid waste per day, that includes 70% - 80% solid waste (Murtaza, 2002);

The Mongla port, with high traffic of boats crossing the Sundarbans, with some registered oil accidents;

High concentrations of Silicate resulting from the shrimp-farm effluents, and nutrient export from the harbor;

Tourist activities and plastic waste ;

Emissions of sulphur dioxide, nitrogen oxides, dust and mercury from industrial and power generation activities.

Therefore, combined with the impact of climate change (sea level and salinity intrusion), the Sundarbans mangrove forest is highly vulnerable to biodiversity degradation and loss.

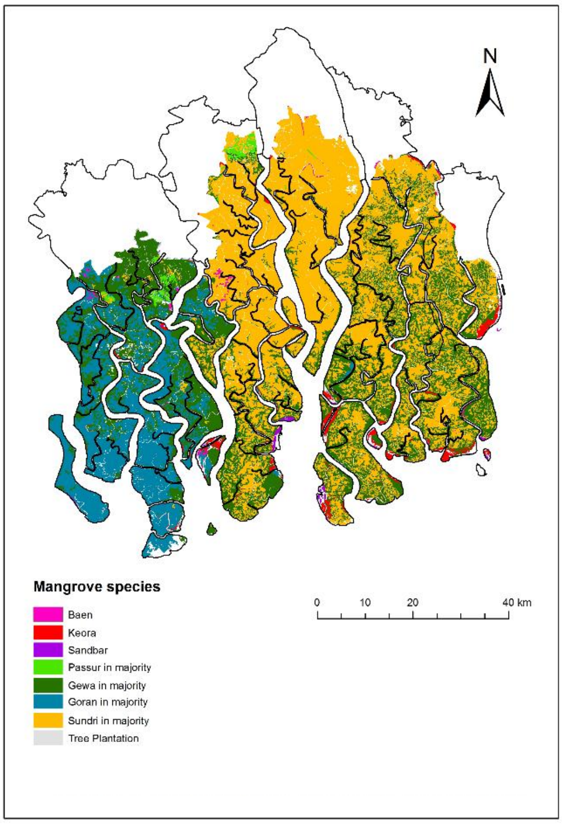


Figure4.39: Mangrove species diversity within the Sundarbans forest

Projected climate impacts based on existing scientific assessments

- The intensity of both tropical cyclones and storm surges is expected to increase through rising sea surface temperature and sea level rise leading to further salinization.

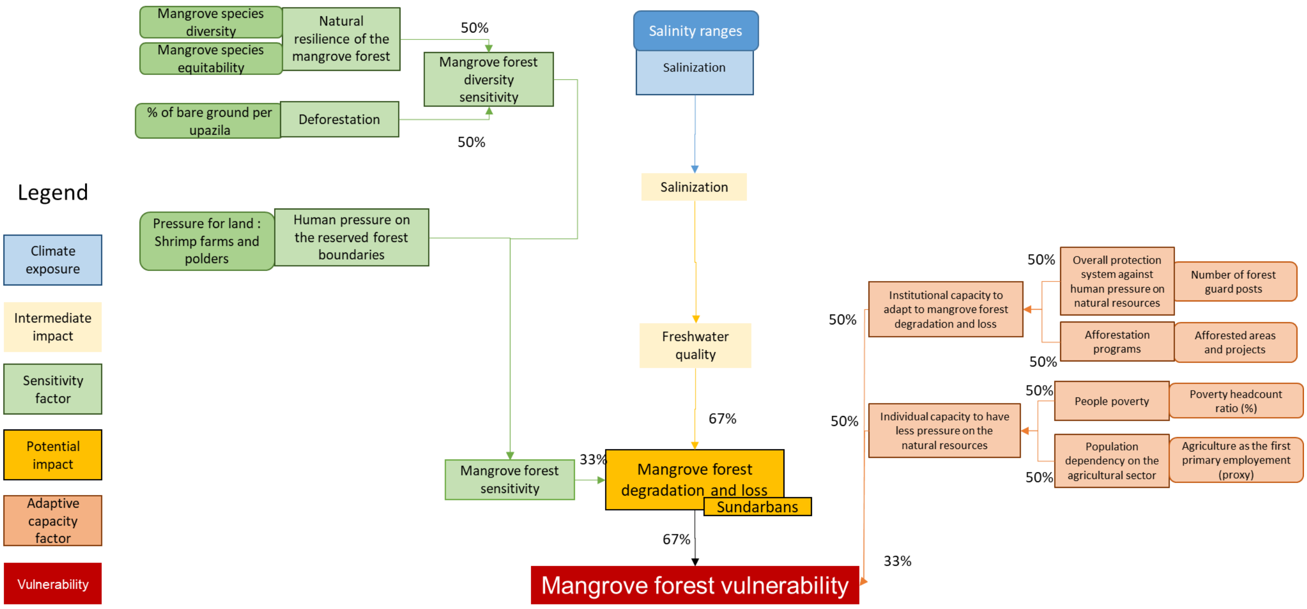


Figure 4.40: Impact chain related to the assessment of the mangrove forest vulnerability to climate change

The impact chain assessment of Bangladesh's mangrove forest vulnerability (Figure 4.40) focuses on one key component of exposure : salinization and its impact on freshwater quality. A number of physical and socio-economic factors (constituting sensitivity and adaptive capacity), such as mangrove species diversity, species equitability, percentage of bare ground per upazilla, pressure on land use, institutional capacity to adapt to mangrove forest degradation and loss; and individual capacity to ease dependence on natural resources, have been considered.

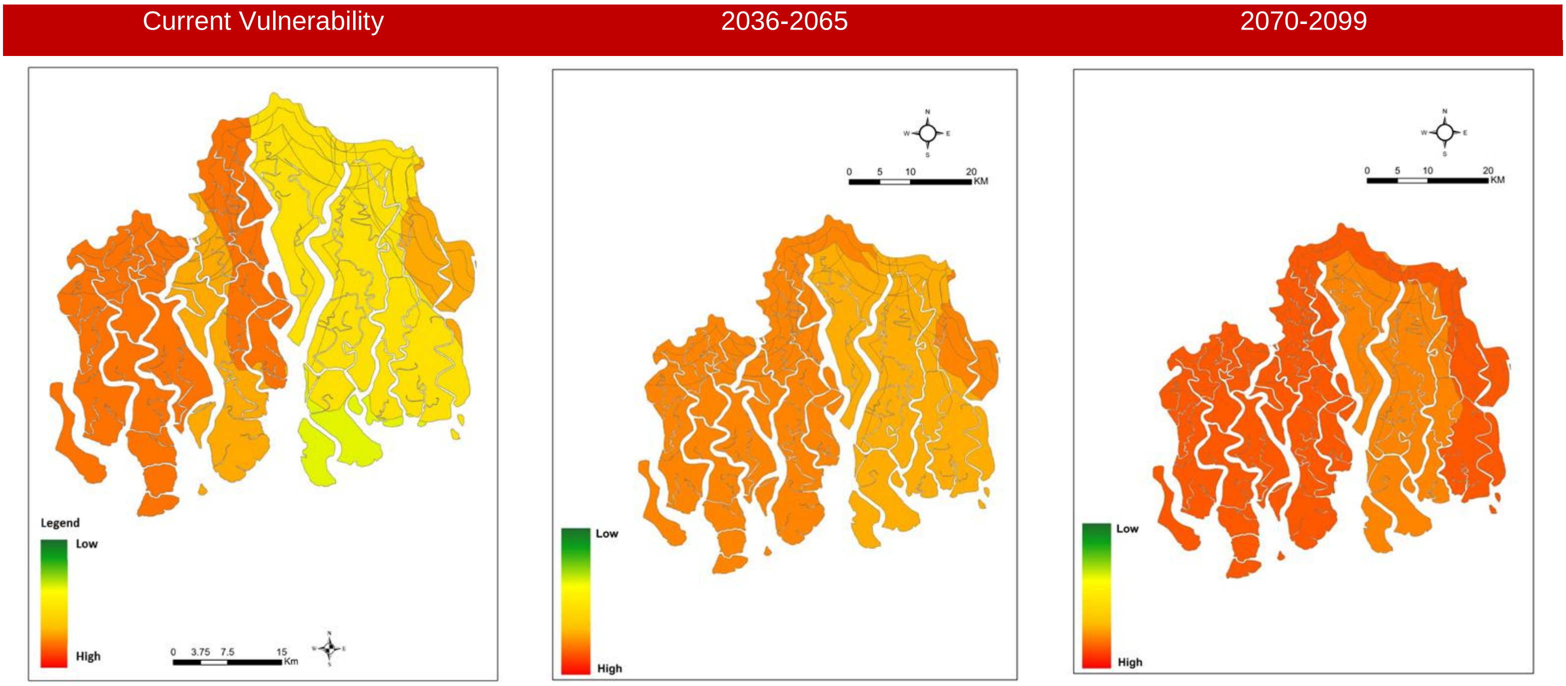


Figure 4.41: Evolution of the mangrove forest vulnerability to degradation and loss: current situation (left), in 2050 (middle) and in 2100 (right)

Coastal biodiversity (natural resources) and ecosystem services play an important role in the socio-economic development, the lives, and livelihoods of the coastal region of Bangladesh (Islam, 2016). The vulnerability of the Sundarbans mangrove forests is interconnected with the vulnerability of the coastal zone as a whole, where land meets the sea. This vulnerability study considers several factors like hyper-salinity, natural hazards, agricultural crop production, urbanization, commercial shrimp cultivation and the administrative and institutional capacity to adapt to the mangrove forests degradation and loss. Figure 4.41 shows the current and projected vulnerability of Sundarbans mangrove forests in 2050 and 2100. Almost all mangrove forests need a freshwater supply from the upstream source. In the Sundarbans, two potential rivers, namely Passur in Mongla and Chunar in Munshiganj carry high rates of salinity intrusion, along with the coastal Sundarbans shown in the maps (Figure 4.41). Salinity intrusion in the upstream coastal zone is a major challenge to maintaining water quality for fresh water ecosystems and mangrove biodiversity. As a result, coastal biodiversity is facing serious threats from salinity intrusion, environmental changes and thus, socio economic impacts for people living in these areas.

Community perceptions and experiences on local biodiversity

Focus Group Discussion Findings
(based on local communities' observations of climate change impacts)

In the coastal area, there has been a drastic decrease in biodiversity. Participants commented on the disappearance of birds and wild animals, attributing these changes to climate change.

In Chittagong, the 1999 major cyclone destroyed the natural environment (especially sand dunes protecting the island from waves and salinity intrusion), and resulted in a major loss of biodiversity. Since that event, this fragile island ecosystem, which has always been vulnerable to natural disasters, is more and more susceptible to the impacts of climate change such as sea level rise, salinity intrusion, storm surges, further threatening its inhabitants and the economy. Bleaching of the coral reefs around St. Martin Island has also been reported.

In flood prone areas (Jamalpur district), people, especially the elderly, acknowledged a decline in biodiversity: wild birds (owl, vulture, eagle) and local indigeneous fish species (Koi, Magur, Puti, Meni, Shol, Gojar) are disappearing. According to participants, climate change, along with anthropogenic pressures (use of pesticides for instance) could explain this decline.

Figure 4.38: Focus group discussion in Bagaichhari Upazila, Rangmati Hill Districts, Farmer and Jhum Community (Chitagong Hill Tracts and Coast)

Gender considerations and next steps

All these changes have direct impacts on the health of the inhabitants. However, women, children and the eldery are most vulnerable. Pregnant rural women mostly depend on local varieties of fish, vegetables, fruits and dairy products. Changes in the local environment and biodiversity has affected production of local varieties of food and livestock products, impacting the nutritional intake of all, but especially women and children. Decline in the number and variety of trees and plants affects the availability of food, local medicine, and firewood. Women and children eir girls and young boys are involved in collecting fire woods from these natural resources. Now they have to go a long way to get these woods which increases health hazards and social insecurity. Above all, psychological health impacts of changing biodiversity have been revealed among inhabitants of different regions. In several settings; regional workshops, FGDs, and national workshops, participants mentioned that they feel sad and depressed seeing these changes in nature in their regions. They could have taken refuge under the trees during hot summer days, they loved the greenery, and they saw natural animals like foxes, bedgers, squerrels, birds, frogs, oysters all around their home and gardens, now these animals are not seen easily. Residents feel frustrated and worried for the future. According to the residents, planting more trees, maintaining quality of the natural wetlands, ponds and rivers would help to improve the conditions. Following proper urban plans will also help to improve the greenery of the cities. However, involvement of more women in social forestry and traditional institute of hilly regions, and arranging trainings for tree plantations, use of pesticides and maintaining natural wet lands will be helpful to combat impacts of climate change on biodiversity and improve the life of the residents.

Given the findings of the NCVA, a management plan of biodiversity and environmental conservation and climate change adaptation is required for strategy formulation for climate resilience Bangladesh.

5. Potential Adaptation options

The Nationwide Climate Vulnerability Assessment (NCVA) has intended to provide the Government of Bangladesh with a tool to assess climate change vulnerable areas.Other users, such as civil society organisations, research institutions and the private sector may be secondary beneficiaries of the NCVA. This assessment has prepared Geographical Information System (GIS) based maps of the country’s vulnerability. These maps have outlined zones of high vulnerability and therefore, the identified zones should feed into political programming and public as well as private investment decisions. Decision makers and technical experts potentially use the map for designing adaptation programs for zones of high vulnerability. Amongst other applications, this tool will help the selection process and decision-making for funding allocation of new projects under various streams of climate finance, participatory identification of suitable adaptation options through impact chain for specific sectors/subsectors or spatial areas, identification of the baseline for M&E of climate change adaptation outcomes respectively.

5.1 Drought Prone Areas

Drought is a prolonged, continuous period of dry weather along with abnormally insufficient rainfall. It occurs when evaporation, transpiration and water demand exceed the amount of rainfall and water availability over a reasonable period of time. Drought impacts are diverse and may be broadly classified into economic, environmental and social impacts (Paul 1998; Wilhite et al. 2000). Drought prone areas include the Rajshahi and Rangpur division in the northwest, and some parts of Khulna division in the southwest regions of Bangladesh. Habiba et al. (2012) summarized water-related adaptation practices in Rajshahi and Chapai Nawabganj districts as: (i) water harvesting by re-excavation of ponds, khari and canals; (ii) groundwater exploitation by using deep tubewells and shallow tubewells; (iii) crop diversification (drought tolerant crop varieties); and (iv) alternative livelihoods (e.g., fish cultivation, cottage industries, poultry, dairy farms, etc.). Potential adaptation options for these regions may include: (i) adaptation governance to be improved for strengthening the interrelationships between stakeholders to achieve an effective adaptation plan or policy; (ii) early warning of climate extremes (e.g., droughts and floods); (iii) small/tenant farmers may be supported with sprinkler or drip irrigation services; (iv) improved water saving farm practices, for e.g., drought resistant crop varieties, short duration crops; (v) water conservation through small reservoirs instead of large dams; and (vi) rain water harvesting for drinking and domestic water use.

5.1.1 Potential impacts and adaptation options for water

The Government of Bangladesh has already taken different initiative to enrich adaptive capacity, e.g Enhancement of Irrigation Efficiency Through Construction of Sub-surface Irrigation Channel. Drought may result in decreased crop yields, a decrease in the quantity and quality of water resources, while increasing the risk of forest fires (Rahman et al. 2007). The present water-related adaptation include water harvesting by re-excavation of ponds, khari, canals; water resources exploitation by deep and shallow tube wells; crop intensification (diversification of crops and cropping pattern); alternative livelihoods (mango cultivation with rice/wheat, homestead gardening, jujube cultivation, fodder cultivation and cottage industries) (Habiba et al. 2012). Groundwater for irrigation is extracted using 1306 DTWs and 2563 STWs in Rajshahi division, and 438 DTWs and 2732 STWs in Rangpur division (2014-15) (BBS 2016). Drought tolerant and short duration rice varieties are widely cultivated in the region.

During stakeholder consultations, the following adaptation options were highlighted and prioritized: i). Increasing surface water use while controlling groundwater extraction; ii). Increaing surface water storage and artificial recharge; and iii). Including the planned use of water resources (water resource management) in land use planning/zoning.

The government of Bangladesh has two long-term, large projects planned to construct barrages on the Ganges and Brahmaputra rivers so that excess water received during the monsoon may be reserved for use during the dry season. Surface water storage facilities may be increased to recharge groundwater aquifers during the monsoon by constructing small and medium sized reservoirs in the high Barind tract, where groundwater exploitation is high. Table 5.1 and Figure 5.1 provide the ranking of climatic impacts and potential adaptation options, based on stakeholder consultations, for the resilient development of water resources in drought prone hotspots.

Table 5.1: Ranking of climatic impacts and potential adaptation options

Potential impacts	**Adaptation options**
1. Drought 2. Heat wave and dust storm 3. Nor'wester 4. Hail storm 5. Tornado 6. Flood 7. Arsenic contamination 8. Riverbank erosion	1. Groundwater use control and surface water use increase 2. Surface water storage and artificial recharge 3. Land use planning/zoning 4. Development of drought tolerant varieties 5. Increase of scientific research 6. Planned water management infrastructure and maintenance 7. Waste and effluent management 8. Wetland and drainage system restoration

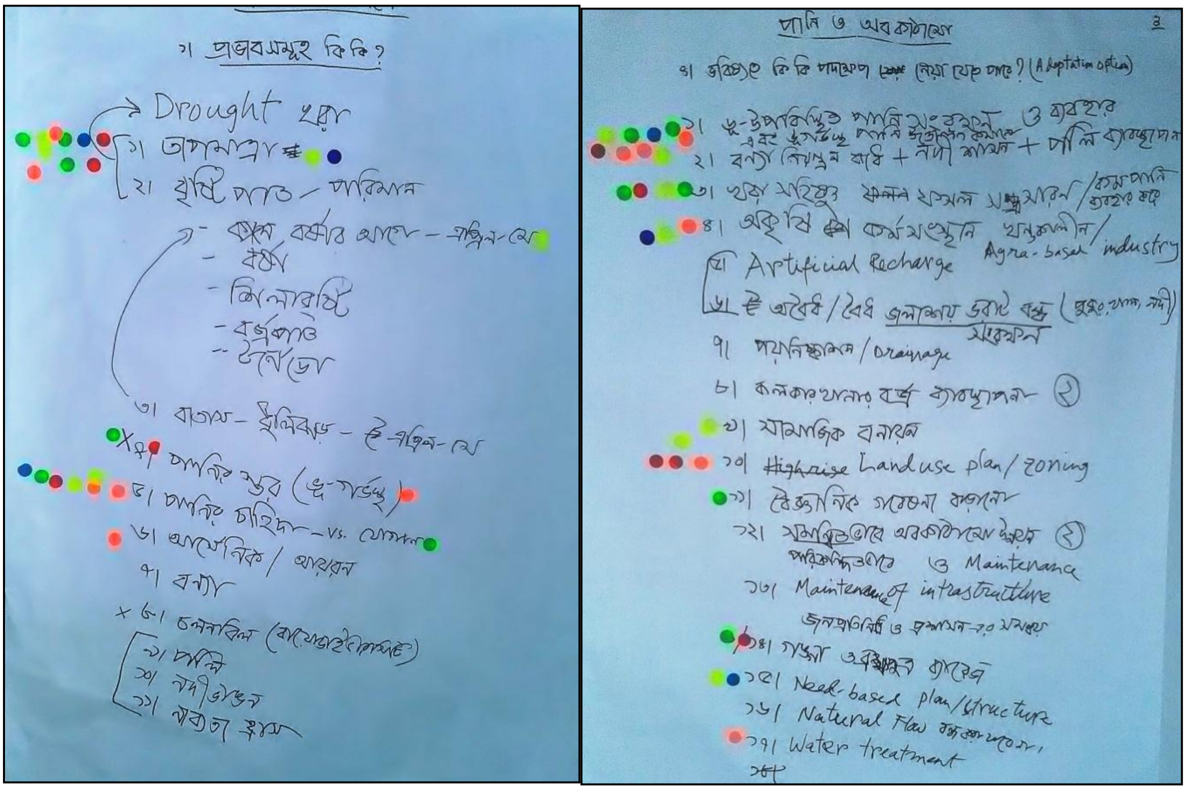


Figure 5.1: Photos of ranking of impact and potential adaptation options

5.1.2 Potential impact and adaptation options for navigation, transport and infrastructure

In the Rajshahi region, drought occurrence is the most pertinent climate impact. To increase the adaptive capacity of the people in the region, land use and development planning has been given highest priority as an adaptation option. The government of Bangladesh has recognized the Rajshahi master plan (recently implemented by the Rajshahi Development Authority) as a good example of urban planning and development control in a metropolitan city. However, land use zoning and development control in the context of integrated water resource management, and related infrastructural development at the regionallevel, may be some of the most effective adaptation practices in all sectors. It should be noted, however, that governance and funding of such large-scale implementation is a challenge in the Bangladesh context.

Climate resilient infrastructure development has been ranked as the 2nd most important adaptation option by stakeholders. The need to include stakeholders' perspectives in the planning and design stage of infrastructure projects has been stressed, along with the consideration of climate conditions. Emphasis has also been placed on the regular maintenance of infrastructure.

Other adaptation options that have been emphasized include research in infrastructure needs, sediment management for navigability, flood management, flood control infrastructure, industrial water and effluent management to mitigate degradation, drainage system restoration, early warning, control over construction regulations, and construction skills development. Since economic development of the region depends on basic infrastructure development and proper maintenance, the consideration of changing climatic conditions in the future cannot be understated.

Table 5.2: Ranking of climatic impacts and potential adaptation options for the resilient development of navigation, transport, and infrastructure in drought prone areas

Potential impacts	**Adaptation options**
1. Drought 2. Heat wave and dust storm 3. Nor'wester 4. Hail storm 5. Tornado 6. Flood 7. Arsenic contamination 8. Riverbank erosion 9. River siltation and decrease of navigability	1. Land use planning and development control 2. Climate resilient infrastructure development 3. Research on infrastructure needs 4. Sediment management for navigability 5. Flood control infrastructure 6. Industrial water and effluent management 7. Planned infrastructure maintenance 8. Drainage system restoration 9. Early warning 10. Construction regulations and skills

5.1.3 Potential impacts and adaptation options for health

One of the major health-related climate change impacts perceived has been the increase in allergens, causing an increase in incidence of air-borne diseases such as chronic obstetric pulmonary disease and asthma. The second major impact of changing climatic conditions observed, has been the increase in heat waves, and subsequently heat strokes in this region, particularly during the dry season. The increase in prolonged and frequent heat waves causes heat-related ailments, and even death. Bangladesh has recorded some of its highest temperatures in recent years. Studies show that the Ganges delta has been experiencing extreme events during summer, resulting in further depletion of surface water resources. Changing climate conditions have enforced limitations on crop cultivation, affecting food security and restricting the availability of nutritious food choices. These factors contribute to the incidence of malnutrition and chronic diseases such as diabetes.

Other potential impacts of a changing climate are increased arsenic concentration and thus, poisoning in drinking water, influenza transmission, skin infections and diseases (especially during winter), psychological stress and/or depression due to the loss of agricultural production and/or an increase in production costs.

Climate change has differential impacts on different groups of people. Women, children, the elderly, and disabled are particularly vulnerable to the increased risk of diseases and heat strokes. Lack of access to nutritious food will not only directly impact the health of women and children, but also have varying effects on the mental and reproductive health of both men and women.

Table 5.3: Ranking of climatic impacts and potential adaptation options for health in drought prone areas

Potential impacts	Adaptation options
1. Increased allergens (air-borne disease, asthma, COPD) 2. Heat stroke 3. Water-borne diseases (diarrhea, jaundice, typhoid, skin diseases) 4. Decreased crop diversity and changing food habits (resulting in malnutrition and chronic diseases such as diabetes) 5. Mental stress/depression (loss of productivity) 6. Compromised immunity 7. Poor WASH 8. Under nutrition 9. Arsenic contamination	1. Reserve surface water 2. Build awareness to WASH 3. Ensure access to clean water 4. Improve navigation 5. Promote plantations 6. Research and monitoring 7. Improve access to health care 8. Decentralization (planning, service provision) 9. Strengthen community health care 10. Increase health education 11. Curricula development (school, college) 12. Strengthen training program

Increasing surface water storage infrastructure will increase water availability for irrigation (and other purposes) during the dry summer season while also reducing dependency on, and over-exploitation of groundwater. Other potential adaptation options recommended were promoting plantations and improving navigation, increasing access to health care, decentralization of planning and service provision, community-based health interventions, increasing health and climate change impact awareness through health education, curricula development and training .

5.1.4 Potential impacts and adaptation options to natural disasters

With regard to human vulnerabilities, increased production costs in agriculture, coupled with the loss of production caused by extreme events (droughts, intensity of fog), water shortages impacting irrigation and household use, the increased incidence of thunder, lightning, intense fog, influenza, and snake bites have been identified as potential impacts on the lives and livelihoods of the people of Bangladesh, particularly those dependent on agriculture. Influenza like illness (ILI) was noticed, both in response to high and low temperatures, significantly increasing human vulnerabilities.

Table 5.4: Ranking of potential climatic impacts and adaptive capacity of humans due to natural diaster

Potential impacts	Adaptation options
1. Increase in production costs 2. Loss of production 3. Scarcity of water for agriculture & household use 4. Damage of goods 5. Increase in thunder and lightning 6. Increase in snake bites 7. Influenza, fog intensity 8. Increased morbidity	**1.** Crop insurance **2.** Increase support to vulnerable groups (ethnic groups, the elderly, children, disabled, extreme poor) **3.** Increase awareness **4.** Increase social protection coverage

Adaptation options to overcome some of these challenges include: i) crop insurance, ii) increased support to most vulnerable individuals and/or groups such as ethnic minorities, elderly people, children, the disabled, and extremely poor, iii) increase awareness about the changing climatic conditions and potential responses, and iv) increase coverage of social protection systems (various allowances).

5.1.5 Potential impacts and adaptation options for biodiversity

As climate change is destroying habitats of fauna and flora, it is necessary to protect existing habitats and create new suitable habitats. Drought is a major barrier for the development of the region. Expanding surface water infrastructure and reservoirs should replace the heavy dependence on groundwater sources. Organic agriculture practices can be introduced to minimize the destructive effects of chemical fertilizers and pesticides on soil fertility and productivity.

Table 5.5: Ranking of potential climatic impacts and adaptive capacity of biodiversity

Potential impacts	Adaptation options
1. Destruction of species in flora and fauna 2. Damage to habitats of flora and fauna 3. Reduced yield 4. Disturbance to cultivation of normal crop varities and crop cycles 5. Extinction of country fish 6. Introduce high yielding varieties 7. Reduced snails, oysters, frogs and birds 8. Invasive alien species	1. Innovate drought resistant varieties by the government and NGOs 2. Introduce various varieties suitable to the area (maize) 3. Increase active participation of women in agriculture sector 4. Introduce crop insurance 5. Awareness raising 6. Arrange training 7. Reduce chemical fertilizers and pesticides by the cooperation of government 8. Strengthen quarantine system (seed) 9. Establish a corruption free society

5.1.6 Potential impacts and adaptation options for agriculture

Participants observed a decreasing trend in crop yield dut to increasing temperatures and reduced rainfall. Irrigation from natural water sources has also been impacted over time due to the drying up of ditches, leading to increased dependence on pump/underground irrigation, especially for Aman rice cultivation.

Changing rainfall patterns has impacted the normal crop calendar. Heavy and continuous rainfall, damages standing crops, creating problems for the drying and marketing of crops. Heavy rainfall induced floods cause river erosion. Participants have noted a change in land use patterns over time, where rice fields are being converted into mango orchards in many areas of the Barind tract.

Participants noted that climate change will have a direct impact on agriculture which will further increase gender based vulnerabilities. It will affect family incomes, increasing mental stress, which will increase gender based violence due to lack of money, food, etc. This was a strong opinion of the most participants in Rajshahli. Soil sensitivity to temperature and rainfall would lead to a reduction in soil fertility, impacting crop growth and yield. These factors would result in a loss of income for women, and thus a loss in their decision-making power within their families.

Marginal communities, particularly the plain-land indigenous communities are worst impacted by changes in temperature and rainfall patterns, due to their direct dependence on agriculture as farmers or farm labourers. Similarly, the elderly and children who are involved in crop production, management and marketing, are also sensitive to changing temperature and precipitation patterns. It should be noted that the elderly (men and women) in agriculture are most vulnerable to climatic impacts.

Given that the area is drought prone, water management has been regarded as the most important area for adaptation. Adaptation options include the establishing of cross dams, rubber dams, etc. Participants recommended increasing water use efficiency in almost all aspects of farm production, daily life and other activities.

The current adaptation strategy adopted by the poor dependent on daily wage labour is internal/seasonal migration. Participants felt that arranging training and capacity building programmes for people in technical areas of crop production, management andmarketing could enhance their adaptive capacity. Arranging trainings for specific crops like mango growers would be helpful for both men and women in Rajshahi. Further, particiapnts mentioned that introducing alternative sources of income or job opportunities for women would be helpful. New types of crops could be introduced. For instance, at present, corn and mung bean are being grown in Rajshahi and more women are getting work, compared to previous times.

5.1.7 Potential impacts and adaptation options of fisheries

Given the natural characteristics of the northern/drought prone areas, participants referred to the drying up of natural water sources like rivers, canals, ponds and ditches as an immediate impact of increased temperatures. As a result, fish sanctuaries were reportedly being lost, while fishermen/women are not permitted to catch natural fish.

The many local and indigenous varieties of fish, reptiles and frogs are almost extinct, or becoming extinct due to increased temperatures and low or irregular rainfall. According to the workshop participants, all of the above reasons and factors negatively impact aquaculture in the drought prone areas.

People who belong to marginal communities, the plain land indigenous communities, are particularly vulnerable to changing temperature and rainfall patterns, due to their dependence on natural fish catch. Local and indigenous fish, frog and reptile varieties (local/indigenous ones) have been found to be more sensitive to the changes in temperature and rainfall.

Natural water reservoirs used to be the source of natural protein for local communities. Due to their extreme sensitivity to climatic changes, the conservation, preservation and excavation of natural and local water reservoirs and sanctuaries has been identified as an important potential solution to address the vulnerability of the fisheries sector to climate change, along with the development of knowledge and skills training for the local officers, fishers and other stakeholders. Internal and seasonal migration has been adopted as a local coping/adaptation strategy, since alternative sources of livelihood are not available during the lean period.

5.1.8 Potential impacts and adaptation options of livestock

High temperature along with low and uneven rainfall patterns have caused major health problems for livestock and poultry in drought prone areas. These climatic patterns are responsible for the loss of grazing and pasture land in the area, impacting livestock rearing as a livelihood option for local farmers. This has further caused reductions in milk and egg production, with farmers facing maximum losses due to loss of revenue. The marginal and indigenous livestock farming communities, along with exotic varieties of livestock and poultry are particularly sensitive to changing climate trends which impact water reservoirs and grasslands.

Training to livestock and poultry farmers and owners could work as the best adaptation strategy, combined with the introduction of improved varieties of livestock and poultry that can withstand high temperatures and low rainfall.

5.2 Haor Region

A haor is a wetland ecosystem in the northeastern part of Bangladesh which is a bowl- or saucer-shaped shallow tectonic depression, also known as a backswamp (Nishat et al., 2002). A total of 373 haors are located in Sylhet (105), Kishoreganj (97), Sunamganj (95), Netrakona (52), Habiganj (14), Brahmanbaria (7), and Moulvibazar (3) districts, covering 2 million ha area with 0.86 million ha depression area. Around 19.37 million people are dependent on this area for their livelihoods (CEGIS, 2012c). The unique physical setting and hydrology of the haor areas create a lot of opportunities as well as constraints for its inhabitants. Annual average rainfall ranges from 2200 mm along the western boundary, to 5800 mm in the northeastern corner (CEGIS, 2012b). The wettest area of the world, Cherrapunjee in Meghalaya (India), which receives an average rainfall of 12000 mm/year is located about 30 km upstream of the northern boundary of haor basin. The haor basin receives runoffs from the upstream catchment slopes of the Shillong Plateau in Meghalaya in the north, from the highlands in Manipur to the east, and from the hills of Tripura and Mizoram (all in India) in the southeast. Flash floods during the pre-monsoon season (April-May) is the main disaster which largely affects agriculture (boro rice or other rabi crops) in the region. Excess rainfall in the upstream hilly areas and subsequent runoffs, river sedimentation, unplanned road and water management infrastructure, deforestation and hill cuts, landslides, improper drainage, and last but not least, the effect of climate variability are major contributors to the devastation caused by flash floods (CEGIS, 2012b).

5.2.1 Potential impacts and adaptation options for water

The boro rice crop (rabi crop) is the only crop sown every year in the haro region as the haors remain inundated for 7-8 months in a year. It is during the pre-monsoon season that this crop is in the fields. The occurrence of flash floods before the harvesting of rabi crops thus causes sever damage to farmers livelihoods, for e.g., in 2017, flash floods started on March 28, affecting six districts (Sylhet, Moulavibazar, Sunamganj, Habiganj, Netrokona and Kishoreganj) in the northeast region, causing water overflow and breeched embankments in many places. The flashfloods destroyed nearly-ready-for-harvesting boro rice in about 160,170 ha (Reliefweb, 2017).

The main cause of flash floods during the pre-monsoon season is the early onset of excess rainfall in upstream hilly areas. As we have no control on rainfall variability, we need to have control over other contributing factors such as river sedimentation, unplanned road and water management infrastructure, deforestation, hill cuts, and improper drainage, as listed by CEGIS (2012b). However, different stakeholder groups in the region have conflicting flood control options. For example, farmers prefer to cultivate the land as soon as possible and as long as the rabi crop can stay in the field. On the other hand, fishers group prefer to live with floods and stay water in the haors as long as possible.

The Government of Bangladesh has already taken different initiative to enrich adaptive capacity, e.g Haor Flood Management and Livelihood Improvement Project, Haor Flood and Livelihood Improvement Project, Pre-Monsoon flood Protection and Drainage Improvement in Haor Areas, Construction of Submersible Roads at Haor Regions under Mithamoin & Astagram Upazila of Kishoregonj District, Community Based Sustainable Management of Tanguar Haor, etc.

The adaptation strategies currently employed by farmers in the haor region is to use short-duration crop varieties that require less water, for e.g., pumpkin, mustard, vegetables in floating gardens, deep water rice varieties, and even fish cultivation. The government has opened juvenile fish cultivation centers as well (table 5.6). However, more effective adaptation options required include the regular drediging of rivers, perennial haors; and the implementation of the Master plan of Haor basin (Table 5.6).

Table 5.6: Ranking of climatic impacts and potential adaptation options for the resilient development of water resources in haor and wetland hotspots in northeast Bangladesh, by workshop participants

Potential impacts	Adaptation options
6. Pre-monsoon flash floods 7. Erratic/abnormal weather (rainfall, temperature) 8. Drinking water scarcity 9. Groundwater level depletion 10. Declining river flows during the dry season 11. Soil moisture decrease/ irrigation demand increase during dry season 12. Drought 13. Water quality (both surface & ground water) degradation 14. Ecosystem degradation 15. Water logging increase 16. Riverbank erosion 17. Siltation in river/ haor bed	1. Regular dredging of rivers, haors, and khals 2. Implementation of the master plan of haor basin 3. Protection of beel area (perennial haor) by dredging for fishery 4. Strengthen the Department of Bangladesh Haor and Wetlands Development 5. Enhance alternative livelihoods in non-agricultural sector 6. Increase surface water use during dry season 7. Deep tubewell installation for meeting irrigation demands during dry season 8. Expedite rain water harvesting 9. Raise platform of tubewells 10. Purification of drinking water during floods

Multiple stakeholders including government representatives, NGOs and community leaders in Sylhet identified pre-monsoon flash floods as the main climatic impact.

5.2.2 Potential impacts and adaptation options for navigation, transport and infrastructure

Navigation, in this context, is the process of monitoring and controlling the movement of a craft or vehicle on land, in air or in water. Navigation may be hampered due to low flows in the river or low visibility, due to climatic factors like dense fog. Transport refers to the movement of people or goods from one place to another by means of a vehicle, aircraft or ship. Infrastructure includes the basic physical structure facilities, e.g. water management infrastructure (regulators, irrigation canals, sluices, dams, barrages, embankments, etc.); all type of roads and highways; buildings and power supplies.

Flash floods have been ranked as the number one climate impact in the northeast haor and wetlands region. Planned development of infrastructure in this region has been prioritized as the most important adaptation option by workshop participants. Unplanned development in this area has exacerbated problems such as water-logging, inundation and landslides. All stakeholders during the workshop stressed the need for the consideration of climate change during all stages of infrastructure planning and development, along with regular maintenance of infrastructure facilities. Governance, funding and implementation of large infrastructure projects were recognized as challenges present in developing the adaptive capacity of this region.

The next priority was given to the building of crop processing and storage centres, to preserve the harvested rabi crops, especially boro rice, from flash floods and consequent inundation. Other adaptation options include the construction of embankments to protect flood prone villages from wave erosion; construction of roads; installation of electric poles; ferry boat services for school children; seed storage facilities for farmers; and encouraging the use of solar power at the household level. Since economic development of the region depends on the availability of basic infrastructure, priority must be given to regular maintenance of infrastructure, along with the consideration of changing climatic conditions and their potential impacts in the future, during the planning and development stage of infrastructure projects.

The workshop participants also emphasized options to increase gender-based adaptive capacity in the region. Residential schools, especially for girls, would minimize the restrictive impact of floods on continuing education; increasing the number of women-friendly sanitation facilities in flood prone areas and new communication and transport infrastructure facilities can improve the adaptive capacity of both women and men in this area.

Table 5.7: Ranking of climatic impacts and potential adaptation options for the resilient development of navigation, transport, and infrastructure in the haor and wetlands hotspot in northeast Bangladesh, by the workshop stakeholders

Potential impacts	Adaptation options
1. Damage to school, roads, embankments and other infrastructure due to inundation 2. Riverbank erosion 3. Road (and other infrastructure) damage due to erratic rainfall 4. Damage to houses, schools and power facilities due to tornadoes 5. Landslides, due to erratic rainfall 6. Decline in the longevity of infrastructure due to fog and cold waves 7. Power failure due to thunderstorm and lightning	1. Stop the unplanned development of infrastructure 2. Build crop processing centres in the haor basin 3. Flood proof infrastructure and villages by raising the platform of schools; installing tubewells; and building embankments to ensure protection from wave erosion 4. Ferry boat service for school children 5. Seed storage facilities for farmers 6. Enhance the use of solar power at the household level

5.2.3 Potential impacts and adaptation options of health

One of the major impacts of changing climatic patterns, noted during the workshop, is the high rate of malnutrition. Changing rainfall patterns along with incidence of extreme rainfall and drought conditions has led to crop losses, directly impacting food consumption patterns. Insufficient food consumption and/or starvation has contributed to a higher prevalence of malnutrition in Bangladesh, with women and children being most affected. Participants also emphasized the negative impacts of malnutrition on newborns and infants.

Flash floods affect sanitation systems, leading to several health problems, especially for women. The increase in household work as a result of flash floods further increases the burden on women, who are largely responsible for running the household, affecting both their mental and physical health.

Water shortages, especially of clean drinking water, has been identified as one of the major climate change impacts in Bangladesh. Water shortages largely occur in the region due to the occurrence of floods and/or drought. During the monsoon season, tubewells get submerged in flood water, thus becoming dysfunctional, while the drought season impacts groundwater levels, leading to water scarcity for domestic use, agriculture and other purposes. There has also been a noticeable increase in infectious diseases, particularly of water borne diseases (such as diarrhea, jaundice, typhoid and skin diseases); vector-borne diseases leading to outbreaks; and air-borne diseases (such as asthma, COPD, etc.). Increasing incidence of these diseases has been linked with high temperatures and heavy rainfall, associated with climate change. Women are more vulnerable to new diseases, along with increased psychological and mental stress, due to prevailing malnutrition, poor health and their role in reproduction.

The haor region remains largely inundated during the monsoon. This affects health and family service operations in the region. Lack of access to family planning (FP) services and supplies contribute to an increase in fertility rates in the region. An increase in unnatural deaths due to snake bites, storms, thunder storms may be attributed to changing climate conditions. Inspite of a lack of scientific data, an increase in the incidence of thunder in recent years has been recorded and observed leading media reports. Thunder storms cause damage to trees and also affect the fish and animal population. Animals and fish are also affected by the increasing toxicity in soil and water due to the use of chemical fertilizers. The use of chemical fertilizers in the haor region has increased to ensure crop harvests in the shortest period of time, to avoid inundation due to early flash floods. The increasing level of toxicity has resulted in the death of fish and other species, causing damage to the ecosystem.

Table 5.8: Ranking of climatic impacts and potential adaptation options

Potential impacts	**Adaptation options**
1. Malnutrition [due to crops loss] 2. Clean/drinking water scarcity 3. Increase in water-borne diseases (diarrhea, jaundice, typhoid, skin diseases) 4. Decreasing immunity 5. Increase in disease out-breaks [vector-borne diseases] 6. Increasing fertility rates (due to lack of FP supplies) 7. Fatigue (due to high temperatures) 8. Increased allergens (air-borne diseases such as asthma, COPD) 9. Unnatural death [due to snake bite, drowning, thunder] 10. Deforestation [up-rooting of tress due to storms] 11. Earthquake 12. Arsenic contamination 13. Water level dropping 14. Loss of animal population/habitat 15. Increase in pollution/toxicities/ pesticide	1. Enhancing human resources (awareness, training, education) 2. Strengthening early weather forecasting 3. Intensive homestead gardening 4. Strengthening out-break investigation **5.** Tree plantation (hijol, chors, nalkhagra, binnapati, ukul, singar)

In the discussion about potential adaptive mechanisms, particpants emphasized the need for enhancing human capacity through awareness building, training programmes and education. Low levels of awareness and education restrict access to information and reduce the understanding of a healthy lifestyle. There is also a need to strengthen weather forecasting systems in order to improve the dissemination of early warnings with regard to climate-related events. In order to improve malnutrition, participants recommended promoting homestead vegetable gardening, which can be a good source of family nutritional requirements, especially since the haor rergion lacks in vegetable supplies.

In order to reduce the incidence of disease outbreaks among livestock, duck, goats, poultry, fish and wild species, participants highlighted the need for strengthening outbreak investigation, which can examine the root cause of these deaths, while suggesting effective measures to control the incidence of outbreaks. Awareness building initiatives carried out simultaneously would go a long way in building the adaptive capacity of people in this region. Particiapnts also stressed the need to enhancing indigenous tree plantations which are a key element in maintaining the ecosystem of the haor region, and balancing harsh weather and unfavourable climate-related extreme events. The drastic reduction in the number and variety of indigenous trees in recent years hCas affected the health and wellbeing of the haor people. Prioritising indigenous tree plantation can contribute to the increased wellbeing of the people of this region.

5.2.4 Potential impacts and adaptation options of Humans to natural disasters

Changing weather patterns (temperature and rainfall in particular) have increased human vulnerabilities to climate change and natural disasters. Changing climatic patterns have affected agriculture, health, the ecosystem and many other sectors, thus directly impacting lives and livelihoods. Increasing vulnerability and sensitivity to potential impacts result in unemployment, social unrest, conflict, crime, communal tension, mental stress and physical health problems. These factors further reduce the adaptive capacity of people, impacting their ability to cope with natural disasters and climate-relaed events. The loss in agricultural production due to changing climatic indicators has led to increased malnutrition, while simultaneously affecting the habitat of fish and othe wild species, thus further impacting th ecosystem. Changing climatic patterns particularly affect people dependent on natural resources (fish and other species) for their livelihoods.The lack of adequate job opportunities and alternative sources of income leads to begging. The physical impacts of heavy rainfall, floods, storms, and associated river bank ero**Pote**sion induce migration and climate-related dislocation. This further increases social vulnerabilities, with women and adolescent girls being most vulnerable. Damage to physical infrastructure from climate-related events and natural calamities also impacts the regular operation of schools and other social services. Discontinuation of education and an increase in school dropout rates has been observed during periods of prolonged flooding.

Climate change and its associated impacts will increase women’s insecurity (social, economic and health). There may be increased incidence of gender-based violence, domestic violence and early marriage, along with an increase in gender-based discrimination.

Table 5.9: Ranking of climatic impacts and potential adaptation options

Potential impacts	Adaptation options
1. Changing weather patterns [temperature, rainfall] 2. Thunderstorms 3. Increase in unemployment 4. Discontinuation of education/school drop-outs 5. Migration/displacement 6. Begging 7. Psycho-somatic stress 8. Increase in debt/poverty 9. Damage to infrastructure (increase in transportation costs→price hikes) 10. Changing food habits (skip meals/less food) 11. Loss of animal population 12. Loss of fish habitat and population 13. Damage to houses and household property 14. Social tension/conflicts/crimes	1. Enhancing education 2. Better planning for construction (embankments, improved school infrastructure) 3. Improve drainage system in up-stream areas 4. Improve electricity supply 5. Improve access to information

Participants emphasized the following adaptation options: i) enhancing education; ii) better planning for construction works such as embankments, bridges, culverts, and roads; iii) Improving drainage systems in up-stream areas; and iv) promoting greater access to information. Increased access to education (for both men and women) can enhance information and awareness of climate change and related impacts. Simultaneous investments into quality construction can act as a safeguard during flash floods and other extreme events.

Awareness programmes (for both men and women) to improve social awareness with regard to gender roles, women's empowerment, religious education, health, and hygiene would go a long way towards increasing adaptive capacity. Besides, arranging and improving programmes on micro capital, microcredit and Government Bhata for older men, women and poor women would be very helpful. Law enforcement needs to be improved in order to reduce gender-based violence.

5.2.5 Potential impacts and adaptation options of biodiversity

The low-lying, bowl-shaped haor basin in Sylhet Division of northeastern Bangladesh is subject to wealthy fisheries in the monsoon period, and bumper boro rice production in winter. Its geographical elevation is lower than the normal plain lands with most of the region lying below 8 meters. This area remains flooded for 7- 8 months in a year, to depths of 5 meters or more during the monsoon (NERP, 1995). The haor area is endowed with a vast variety of flora and fauna, but due to tremendous population pressure, rural poverty and unemployment, the biodiversity of this region has been decreasing at an alarming rate. Biodiversity is strongly associated with intact ecosystems and natural landscapes. However, transformation of land use patterns, expansion of agricultural lands, change in cropping patterns, introduction of high yield crop varieties (HYV), urbanization, expansion of road networks, unplanned embankments, and other manmade factors have caused immense damage to habitats in the ecosystem. Shrinking of the haor area due to expansion of agricultural fields; decreasing water flows; use of herbicides, chemical fertilizers and pesticides in agricultural fields which are drained into the haor area threaten the animal life in water, further decreasing the breeding capacity of fish; unauthorized hunting of waterfowls and other migratory birds; depletion of water plants due to widespread collection of fire wood; massive introduction of invasive alien plants, e.g., Eichhornia crassipes (Kachuripana) and fish, e.g., Clarius gariepinus (African magur), Oreochromis mossambicus (telapia), Cyprinus carpio (common carp); lack of awareness; the 'Jalmohal' leasing system; decreasing area of wetlands; over exploitation of swamp forests; absence of a legal institution for preservation of biodiversity; disregard of local people's needs in the haor management system, etc. have contributed to making the haor area of Bangladesh most vulnerable to climate change and its impacts.

Although Bangladesh is rich in biodiversity (species), Rahman (2004) has identified 12 species of wildlife as extinct in Bangladesh. In 1992, Hussain found 18 species of wildlife to be extinct. A number of indigenous species of mammals, birds, reptiles, etc. are now under tremendous pressure. IUCN (2000) listed 40 species of inland mammals, 41 species of birds, 58 species of reptiles, and 8 species of amphibians under various degrees of risk in Bangladesh. According to a recent exercise completed by the Bangladesh National Herbarium, 106 vascular plant species face risks of various degrees of extinction in Bangladesh (Reza, 2004). In addition, Dey (2006) listed 167 plant species as vulnerable or endangered in Bangladesh.

Table 5.10: Ranking of potential climatic impacts and adaptation options for biodiversity

Potential impacts	Adaptation options
1. Some fish and aquatic species are vulnerable and on the verge of extinction 2. The ecosystem is being destroyed 3. Change in species 4. Destruction of indigenous species 5. Loss of habitat 6. Decrease in the area under wetlands	1. Re-excavation of canals, beels and rivers 2. Awareness raising initiatives 3. Improve inter-governmental coordination 4. Restoration of swamp forests 5. Swamp tree plantation, conservation, protection and management 6. Water shed management 7. Establish wetland sanctuaries 8. Arrange livelihood by organizing communities 9. Increase research 10. Manage waste 11. Use organic manure 12. Control the use of herbicides in tea plantations 13. Not stop open natural water flow

Adaptive capacity refers to the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, and to respond to consequences. Climate change is destroying habitats of fauna and flora, especially in haor area. It is thus necessary to protect the existing habitat and create new suitable habitats for the endangered species. Flood/flash flood is a major barrier for development of the haor region; therefore, proper flood management should be strengthened. Further, the use of herbicides, chemical fertilizers, and pesticides are destroying soil fertility and micro-organisms. Introducing organic manure and organic forms of agriculture will go a long way in supporting the ecosystem of this region. The swamp forest area needs to be expanded (hijol, koroch, barun etc.) as it works both as an adaptation and mitigation option. Swamp forests get submerged by up to 20-30 feet of water during the monsoon season, making the expansion, governance, protection, conservation and management practices for this swamp area a priority. Creating a sanctuary for the protection of endangered species is a good adaptation option for the biodiversity, along with increasing research and cultivation of flood tolerant species; crop insurance for farmers to help them cope with floods and flood related losses; enhancing women's participation in agricultural production; applying traditional knowledge and indigenous practices to protect the biodiversity. The government of Bangladesh has already developed a village conservation group and co-management committee to support protection and management of the biodiversity of the haor region. There is a need to increase capacity within the Haor and Wetlands Development Department, along with increasing abilities to protect the region; need for proper implementation of the Ecologically Critical Area (ECA) Management Rules-2016, the Biodiversity Rule-2012, and Act 2017, along with the Haor Master Plan.

5.2.6 Potential impacts and adaptation options of agriculture

Decreasing crop yields, changing climatic patterns in the greater Sylhet division and flash floods have resulted in reduced crop yields, affecting the food security of poorer sections of society. Food needs for these sections have been identified as unstable over the years, particularly during the flood season. Flash floods also impact the cost of production, of seeds, and other input costs. Increase in production costs result in an increase in produce costs, thus raising the daily expenditure of people in the flood prone areas.

Damage to standing crops due to excess and/or heavy rainfall and flash floods causes an instant loss of food security for a period of up to one year. A decreasing trend in crop diversity observed by workshop participants indicates an increasing loss of local crop varieties. Due to water logging in the fields (as a result of heavy rainfall), farmers in the region have been forced to change their cropping patterns and sowing time.

The community at large, including farmers, farm holders, labourers, and even the business community have been directly or indirectly impacted by the occurrence of floods and flash floods. Impacts from climate-related events are notably higher in the elderly, women, children and disabled people.

Table 5.11: List of climate change impacts and adaptation options for agriculture

Potential impacts	**Adaptation options**
1. Reduction of crop yield 2. Damage of standing crops (during flash flood) 3. Increase in price of seeds 4. Decrease in the diversity of crops (loss of traditional varieties) 5. Food insecurity (especially during flood season) 6. Increase in production costs 7. Increase in livelihood expenditure 8. Change in seed sowing time due to water logging in the monsoon and water shortage during dry season 9. Siltation of the rivers, haor, canals, etc. 10. Arsenic contamination	1. Cultivation of resilient (short duration and flood tolerant) crop varieties 2. Introduce mechanized cultivation methods (e.g. Combined harvester) 3. Revert to traditional cultivation practices 4. Cultivate vegetables on the river/haor/pond bank 5. Establish seed storage units 6. Revise cropping patterns 7. Revise agro-ecological zone (AEZ) 8. Dredging of canals, lakes, and rivers 9. Amend land leasing policies

Workshop participants recommended a shift to flood resilient crop varieties with a shorter life span, along with the cultivation of vegetables on the banks of rivers, the haor, ponds, and canals. Many participants raised the need for the introduction of mechanized cultivation technologies in the flash flood prone area, as mechanization can enhance the efficiency of agricultural work, saving crops from the impacts of flash floods. Participants also noted the need for establishing silo/seed storage for the area and reiterated the urgency of dredging of the water bodies.

5.2.7 Potential impacts and adaptation options of fisheries

The north-eastern region is predominantly a terrestrial wet land and the largest natural fish habitat of Bangladesh. Over the years, loss in biodiversity and integrity of the wetlands has resulted in reduced fish production in this region. As a result of hanging climatic patterns, water bodies have been shrinking and the breeding zone of fish has shifted to the upper riparian area. Fish varieties, especially the local/indigenous species have noticeably reduced in recent years.

Table 5.12: Ranking of climate change impacts and adaptation options

Potential impacts	Adaptation options
1. Loss of fish varieties (especially local/indigenous varieties) 2. Reduced fish yield 3. Decrease in fish breeding due to flash floods in the monsoon and shortage of water in the dry season 4. Change of breeding zone (shift to the upper riparian area) 5. Loss of terrestrial water bodies/fish habitat	1. Save/protect fish with net/bana (bamboo mat) during floods 2. Establish a wetland sanctuary 3. Introduce case aquaculture (crab) 4. Re-excavation of rivers, ponds, canals, haor 5. Management/restoration of swamp forest 6. Introduce silvo-fisheries (forest+fish)

Potential adaptation options identified by workshop participants include the use of bamboo mats (bana), to restrict fish migration during the flood season; crab culture; re-excavation of water bodies; and the restoration of swamp forests to enable fish regeneration and growth.

5.2.8 Potential impacts and adaptation options of livestock

Seasonal floods, flash floods and other climate-related hazards severly impact livestock, poultry rearing, and production in this region. Of primary concern is the spread of diseases, which increases the cost of medicine. Coupled with the increase in costs of fodder, decrease in the availability of grazing land (due to expanding agriculture and development), the livestock farming has been severely affected in the region. Further, the lack/absence of shelter or killa make it extremely difficult to manage and save livestock and poultry, especially during flood occurrences in the haor area.

Table 5.13: Ranking of climate change impacts and adaptation options

Potential impacts	Adaptation options
1. Increase in disease, illness and death of livestock 2. Increase in cost of fodder 3. Increasing cost of medicine (vaccine) 4. Decrease in grazing land availability 5. Problem of animal shelters during flash floods	1. Duck rearing in ponds/haor 2. Introduce fodder cultivation and storage 3. Establish animal shelters/killa 4. Introduce bathan (open grazing) management 5. Land zoning to encouraging livestock rearing

Duck rearing has been identified as a profitable venture and potential adaptation option by a large number of stakeholders. Some participants proposed food cultivation in the suitable/marginal land to support farmers during the hazard/flood season. Other options include establishing animal/livestock shelters in the area; land zoning; and bathan management.

5.3 Coastal Region

The coastal areas of Bangladesh are exposed to frequent cyclones and storm surges, seawater intrusion, and sea level rise, which severely impact the lives and livelihoods of people in this region. Between 1960-2015, 19 severe cyclones hit the coast of Bangladesh. A sea surface temperature of ≥28˚C is an important threshold for the development of major cyclones/hurricanes (categories 3, 4, or 5) (Knutson & Tuleya, 2004; Michaels et al., 2005). The coastal zone of Bangladesh also faces safe drinking water scarcity and a lack of fresh water for irrigation, further compounded by the long term water-logging in the beels of Khulna and Jessore districts. A number of adaptation strategies to reduce climate vulnerabilities are already in practice in this area. These include coastal polders network, tidal river management to elevate the bed of the beels, rainwater harvesting, and managed aquifer recharge. However, more planned adaptation actions in the water and infrastructure sectors in coastal areas are necessary to reduce vulnerabilities to climatic change and climate variability.

5.3.1 Potential impacts and adaptation options of water

In terms of climate-related impacts, water logging in the beels and polders has been prioritized by stakeholders in Khulna. Waterlogging is a major problem in large parts of the coast, especially in the southwest (Satkhira, Jessore, Khulna, and Bagerhat) and southeast (Noakhali, Feni), however, their causes are different (BanDuDeltAS, 2015). Research by the Space Research and Remote Sensing Organization (SPARRSO) of the Government of Bangladesh showed an increase in the waterlogged area in southwest Bangladesh from 6,279 ha in 1973 to 47,143 ha in 2016 (Correspondent, 2017). The primary causes of waterlogging in the southwest are: (i) silting up of rivers, with riverbeds higher than polders preventing natural draining out; (ii) badly planned or executed infrastructure projects such as roads which block drainage; (iii) improper maintenance of water infrastructure; and (iv) aquaculture and other economic activities which may obstruct drainage (Kabir & Robson, 2015). The Feni and Noakhali districts in the southeast have been historically prone to water logging (due to heavy rains) (Kamal, 2006). Problems and shortcomings in the drainage system has further exacerbated water logging in the following districts: Comilla, Noakhali, Laksmipur, Chandpur, and Feni (BanDuDeltAS, 2015). The major causes of waterlogging in these areas are: (i) the area is almost flat with very little slope; (ii) the existing rivers/khals provide insufficient drainage; and (iii) existing water control structures are inadequate for draining out the water logged due to heavy rains (BanDuDeltAS, 2015).

The Government of Bangladesh has already taken different initiative to enrich adaptive capacity, e.g Development of roads damaged by floods and waterlogged under Chittagong City Corporation and construction / reconstruction of canal, resistance walls, bridges and culverts, Development of safe water supply and sanitation system in neighboring habitations including the important markets of Bandhban Hill District, Safe Drinking Water Supply & Sanitation system Development at Different Important Bazar with Surrounding Locality under Khagrachari and Rangamati District, etc.

The ranking of climatic impacts and adaptation options by the stakeholders is listed in Table 5.14 and shown in Figure 5.2

Table 5.14: Ranking of climatic impacts and potential adaptation options for the resilient development of water resources in coastal areas in southern Bangladesh, by the workshop stakeholders

Potential impacts	Adaptation options
1. Waterlogging in beels and polders 2. Increased salinity – surface water degradation 3. Drinking water scarcity due to pond salinity 4. Floods – tidal and seasonal 5. Drought 6. Sea level rise 7. River siltation 8. Increased salinity leading to groundwater degradation 9. Declining groundwater levels 10. Decline in upstream freshwater flows 11. Erratic (or abnormal) rainfall 12. Riverbank erosion	1. Increase fresh water flows in upstream rivers to reduce salinity 2. Enhance rainwater harvesting at the household level 3. Re-excavation/dredging of rivers, ponds (near Bay of Bengal) to enhance drainage and drinking water storage 4. Land use planning/zoning 5. Integrated coastal management projects like 'Blue Gold' water management (http://www.bluegoldbd.org) 6. Control/zoning of saline water intrusion due to shrimp culture 7. Enhance groundwater recharge with fresh water 8. Improve access to non-farm based alternative livelihoods 9. Awareness building on climate issues and solution

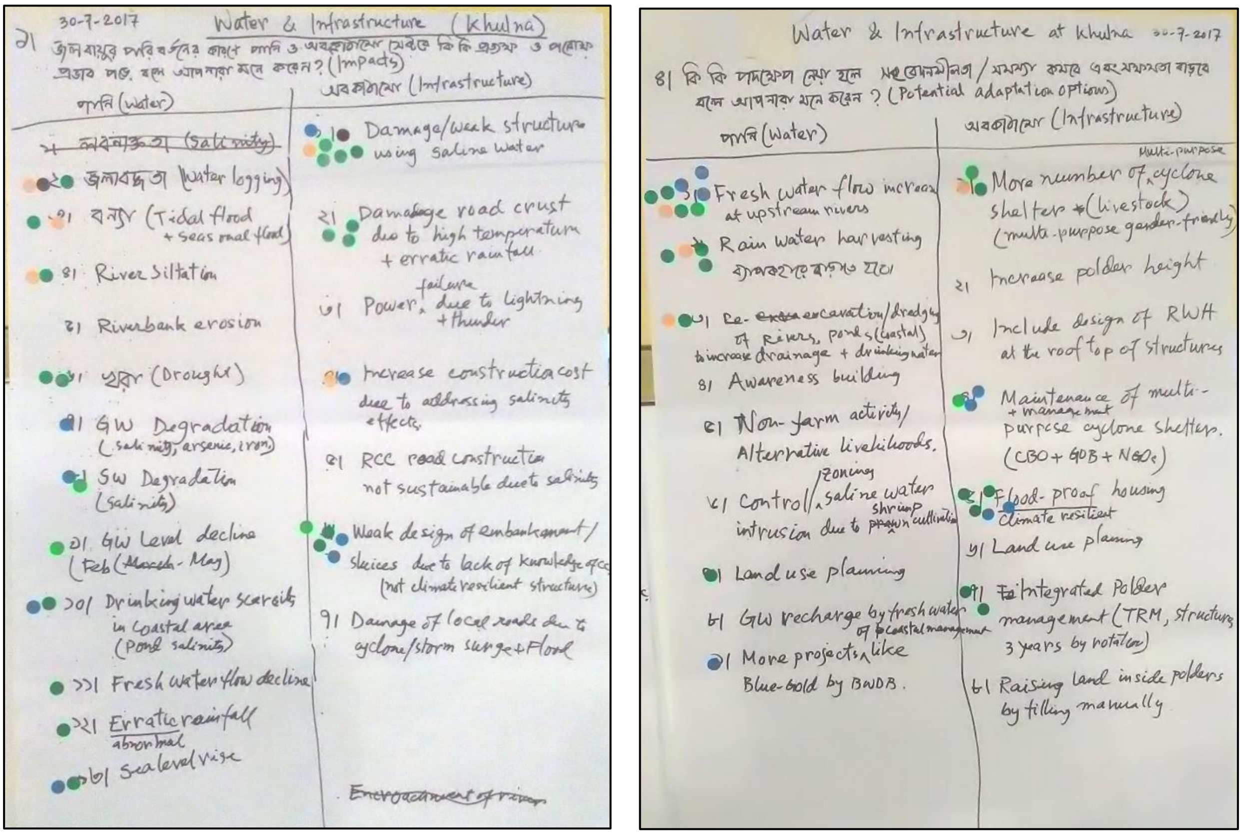


Figure 5.2: Photos of ranking of impacts (question 1) and potential adaptation options (question 4) and their prioritization in both water resources and infrastructure vulnerability

5.3.2 Potential impacts and adaptation options of navigation, transport and infrastructure

Salinity intrusion has been ranked as the most important climatic impact in the southwest coastal region of Bangladesh. The top priority to enhace adaptive capacity in the region is the construction of flood proof/resilient houses in this region using moreTcli:. According to BanDuDeltAS (2015), salinity concentration in rivers generally increases linearly during the dry period from October (post-monsoon) to late May (pre-monsoon), concurring with the gradual seasonal reduction in upstream fresh water inflow. A reduction in freshwater inflows from the transboundary Ganges river, siltation of its tributaries, and other rivers following the construction of polder system, resulted in a large increase of river and groundwater salinity up to 100 km inland from the sea. For example, in the Rupsa river at Khulna, salinity concentrations in May increased from 0.7 ppt in 1962 to 16.8 ppt in 2011 (BanDuDeltAS, 2015). Rahman et al. (2015) projected that 25 ppt isoline of river water salinity would encroach more areas in the southwest coastal region during dry periods, by the end of this century. The adaptation strategies in practice to reduce infrastructure vulnerability to salinity intrusion are using stone instead of brickmate vu, Sylhet sand instead of local sand, and thick iron rods for weight bearing as construction materials. However, more adaptation options need to be practiced at a larger scale to reduce climate vulnerabilities.

The unplanned development of infrastructure has exacerbated problems such as seawater intrusion, waterlogging, and cyclone impacts. It is imperative to take into consideration multiple stakeholder persepctives and climate data (current and future) from the planning stage of infrastructure projects, and across all stages, in order to minimize climate impacts on infrastructure. This must be accompanied by regular maintenance of infrastructure facilities. While governance, funding and implementation of large scale infrastructure projects remain challenging in this area, changing climatic conditions need to be taken into consideration to maintain economic development in this region and to build resilience.

Table 5.15: Ranking of climatic impacts and potential adaptation options for the resilient development of navigation, transport, and infrastructure in coastal areas in Bangladesh, by the workshop stakeholders

Potential impacts	Adaptation options
1. Damage to/weakening of structures due to saline water 2. Weak embankment design due to lack of consideration of climate impacts 3. Damage of road crust due to high temperature and erratic rainfall 4. Increase in construction costs due to salinity 5. Power failure due to thunderstorm and lightning 6. Concrete roads are not salinity tolerant 7. Damage of local roads due to cyclones/storm surges and floods	1. Flood proof/resilient housing 2. Increase the number of multi-purpose cyclone shelters (MPCS) 3. Maintenance of existing MPCS and management by participatory approach, including GoB, NGOs, and CBOs 4. Integrated polder management (IPM) by participatory approach e.g., tidal river management in the polders 5. Increase polder height 6. Include design of rainwater harvesting at the rooftop of structures 7. Land use planning/ zoning 8. Raising land elevation inside polders by filling up with sediments

5.3.3 Potential impacts and adaptation options of health

Observed key health impacts induced by changing climatic features is the incidence of emerging infectious diseases (skin diseases, hair fall, nail dystrophies) and water-borne diseases (diarrhea, jaundice, typhoid). While there is little evidence to support these observations, changing temperature and rainfall patterns, accompanied by salinity intrusion and extreme weather events has impacted agricultural production (especially rice and vegetables). Reductions in agricultural produce has resulted in malnutrition, most severely impacting the poor and disadvantaged/vulnerable groups of society. Women, children and the elderly are most vulnerable to these impscts.

Chronic conditions, such as renal disease and cardiovascular disease are on the rise. Increasing incidence of these events may be indirectly linked to climate change. The indirect consumption of salt has increased due to increase in salinity intrusion, affecting vegetables, food grains and water resources. Excess salt consumption can result in non-communicable chronic diseases such as renal diseases. Recent research has found that the people living in coastal districts have a greater amount of salt consumed [1]. Other intermediary and immediate impacts of climate change in coastal areas is the scarcity of drinking and/or clean water, especially due to salinity intrusion, frequent coastal floods and tidal surges. Reproductive health has also been impacted, with low-borth weight and premature births on the rise. While there is little evidence to support this, some participants noted the linkages between psychosomatic illnesses and comorbidity and chaging climatic patterns.

Flood and cyclone occurrences hinder routine school and health service operations in affected areas. The loss of plant and animal species, including domestic animals have also been linked with climate change. Climate-related events result in increased water logging, affecting water, sanitation and hygiene systems (WASH), access to safe and clean drinking water, access to water for domestic cooking and cleaning purposes, and access to water for irrigation. The multiple impacts across sectors most severly affects the poor, marginalized, women, the elderly, children and the disabled, resulting in physical and mental illnesses, forced migration, increased vulnerabilities and death.

Table 5.16: Ranking of climatic impacts and potential adaptation options for health

Potential impacts	Adaptation options
1. Emerging and reemerging infectious diseases [skin diseases, hair fall, nail dystrophies] 2. Waterborne diseases (diarrhea, jaundice, typhoid, skin diseases) 3. Malnutrition 4. Increasing incidence of chronic disease 5. Increased allergens (airborne diseases such as asthma, COPD) 6. Clean/drinking water scarcity 7. Dental diseases 8. Low-birth weight/ pre-matured birth 9. Psychosomatic illness 10. Comorbidity/double burden of diseases 11. Micro-toxicities/ pollution	1. Good governance 2. Greater level of awareness building 3. Better resource management 4. Strengthening education system 5. Increase access to quality services 6. Diversified income generating activities 7. Focusing and enhancing regional/contextual planning 8. Better natural resource management 9. Enhancing research and planning

Participants emphasized the need for establishing good governance practices; enhancing awareness programs focusing on the possible impacts of climate change and its consequences on health; better management of natural resources, as well as of physical infrastructure to improve the adaptation mechanism; strengthening education to increase health care access and healthy behaviors. Enhancing access to quality health care services can play a bigger role in this aspect. Quality health care services may include the management of emerging and reemerging diseases (as mentioned by participants). New interventions can be introduced with greater coverage of diseases linked to salinity. Access to multiple income generating activities will improve livelihood options for the poor, which will consequently help in improving their health. In the course of emerging and reemerging disease burdens, high quality research and planning would be a beneficial adaptation option as this will broaden the likelihood of identifying etiology and disease epidemiology, while offering plausible healthcare interventions.

5.3.4 Potential impacts and adaptation options of humans to natural disasters

Participants emphasized the need to increase the number of cyclone shelters in the coastal zone, along with the building of higher embankments. Embankments should be constructed so as to cover the major areas affected by tidal surges and floods. The current height of embankments is ineffective in providing protection from floods or tidal surges. There is a need for well planned, sustainable construction of coastal infrastructure to build climate resilience in the area.

With regard to water scarcity, rainwater harvesting has been prioritized as an adaptation option, along with the promotion of awareness building activities to increase peopl's participation in maintaining and preserving their environment. Maintaining water flows in the river has also been identified as an important action to build adaptive capacity. Other potential actions include controlling corruption and ensuring accountability, initiating high level advocacy and diplomacy for claiming climate change compensation from industrial nations. The following table (Table 5.17) presents the prioritisation of climate impacts and adaptation options by workshop participants.

Table 5.17: Ranking of climatic impacts and potential adaptation options for Human vulnerabilities

Potential impacts	Adaptation options
1. Loss of livelihood/production capital 2. Damage to homes/shelters/living places 3. Decrease in food production 4. Damage to drinking/clean water sources 5. Damage to infrastructure 6. Break in schooling 7. Increased morbidity 8. Loss of flora and fauna 9. Migration/displacement 10. Water logging/coastal floods 11. Forced change of occupation 12. Cultural shocks/gender-based violence 13. WASH	1. Enhance capacities for rain water harvesting 2. Increase cyclone salters 3. Increase number and height of embankments 4. Sustainable construction 5. Enhance awareness 6. Advocacy for compensation from foreign nations 7. Maintain natural water flows 8. Control corruption and ensure accountability

5.3.5 Potential impacts and adaptation options of biodiversity

There are multiple implementing agencies (government and NGOs) working to protect the biodiversity of Bangladesh. However, there is a severe lack of coordination both within and among different agencies and departments. There is, thus, a need for awareness and capacity building across these different agencies in order to build climate resilience in the region. Water bodies (ponds, canals, rivers, and the sea) are contaminated by various types of waste, particularly solid wastes. While the government of Bangladesh has undertaken various initiatives to protect the biodiversity by establishing buffer zones such as a sanctuaries, national parks, community conservation areas, safari parks, eco-parks, mangrove forests, special biodiversity conservation area, breeding places, etc., there is a need to implement water pollution control actions and biodiversity protection rules and regulations along with the establishment of new buffer zones. Community participation in these initiatives is paramount to enhance protection of the buffer zones. Community participation can be enhanced through trainings, awareness campaigns, workshops, meetings, IEC material distribution, etc.

The opinions of the stakeholders/participants on climatic impacts and the adaptive capacity of biodiversity have been prioritized and highlighted in Table 5.18.

Table 5.18: Ranking of potential climatic impacts and adaptive capacity

Potential impacts	Adaptation options
1. Damage to ecosystems 2. Change in patterns of ecosystems 3. Penetration by invasive alien species which threaten existing indigenous species. 4. Change of habitats 5. Destruction of micro-organisms due to the use of chemical fertilizers and pesticides 6. Deforestation 7. Species migration or extinction due to lack of food 8. Forced change in livelihood otions 9. Change in the breeding process and life cycle of species 10. Possible increase of epidemic diseases 11. Wildlife endangered by natural disasters 12. Decrease in water flows 13. Change in food habits of wildlife	1. Increase the coordination and capacity of implementing agencies 2. Prepare and implement plan for the conservation of biodiversity 3. Control pollution 4. Establish buffer zones 5. Implement different rules and regulations 6. Build awareness of the people 7. Incorporate biodiversity in all development planning 8. Ensure accountability of concerned institutions 9. Increase the flow of fresh water 10. Stop the entry of people in breeding places 11. Increase the forest lands

5.3.6 Potential impacts and adaptation options of agriculture

Participants had conflicting opinions regarding the status of agricultural yield in the area. Some participants noted a decrease in crop yield due to changing climatic patterns, while others (from the Department of Agricultural Extension (DAE) in particular), demonstrated an increase in overall production due to the introduction of resilient rice varieties and other high yielding crop varieties. It must be noted, however, that the overall vulnerability of the agriculture sector is on an increasing trend due to the increase in soil and water salinity, along with other climate-induced problems such as sea upsurges, drought, scarcity of irrigation/sweet water during the dry/winter season, etc.

Participants noted changes in rainfall patterns, increasing intensity of rainfall, longer drought periods and a decrease in availability of water for irrigation during the dry season. These factors have negatively impacted overall crop cultivation and crop yield. Participants linked changes in land use patterns to climate change induced salt water intrusion, facilitated by the introduction of shrimp/fish (Gher) culture. This practice, though commercially viable, caused more damage to and degradation of agricultural land. The increased salinity along with the introduction of high yielding crop varieties has led to the loss of local/indigenous crop varieities. There has also been an increase in insects and diseases, associated with the increase in soil and water salinity.

Table-5.19: List of climate change impact and adaptation options

Potential impacts	**Adaptation options**
1. Change of land use patterns – from crop cultivation to fish culture (Gher) 2. Scarcity of irrigation water during the winter/dry season 3. Lack of sweet/potable water especially during the dry season 4. Heavy rainfall in a short period of time 5. Loss of local/indigenous crop varieties 6. Increased soil salinity and saltwater intrusion in the main land 7. Increased tendency of drought 8. Increase in infestation of insect, diseases	1. Re-excavation of (already dried-up) river, canal and pond and excavation/linking of canals 2. Cultivation and dissemination of resilient crop varieties 3. Innovation, promotion and cultivation of more saline tolerant crop varieties (rice) 4. Change cultivation techniques and cropping pattern 5. Introduce and teach people about the proper land use for saline prone areas 6. Prepare a master plan for the saline prone areas, covering crops, fisheries, infrastructure, other aspects

As a spontaneous response, all participants felt that the introduction and cultivation of resilient crop varieties should be the number one option to combat the climate change induced salinity problems, specifically for rice, sun flower and water melon, among others. Changing cultivation methods and techniques to adapt to the changing ecological conditions (due to increases salinity) was also stressed. Re-excavation of dried up rivers, canals of the area and preparing a master plan for the area were came as an option for the long-term and policy level adaption. Participants recommended educating local people on land use practices to enhance awareness and local capacities in proper decision making (with regard to land use).

5.3.7 Potential impact and adaptation options of fisheries

Although the coastal region has a good number of saline tolerant fish varieties, there are some sweet/fresh water varieties that grow in less saline areas, and/or in the monsoon season when salinity concentrations decrease. Due to the increase in water salinity over the years, sweet/fresh water fish are threatened. Increasing temperatures have led to an increase in drought conditions, further drying up canas, ponds and water bodies. There has been an observed change in the breeding season of fish as well.

Table 5.20: List of climate change impact and adaptation options

Potential impacts	Adaptation options
1. Drying up of canals, ponds and small water bodies due to drought 2. Increased salinity has reduced the production of sweet/fresh water fish 3. Increase in fish diseases due to the climate change induced salinity 4. Change in fish breeding season (early breeding) 5. Change in habitat of Hilsa fish 6. Change in the fishing ground in the Bay of Bengal	1. Re-excavation of canals, ponds and water bodies to restore and retain sweet water 2. Innovation and dissemination of resilient fish varieties 3. Execution of policies with regard to the management of net-pata 4. Arrange training for the fishers on fish culture and management 5. Undertake fisheries resource inventory to create baseline data

With regard to potential adaptation options, workshop participants felt that the execution of policy and laws were critical. They emphasized management of local net-pata for fish production in coastal areas. They recommended regular and massive training for fishermen so that they are educated and skilled enough to capture and culture fish in a more environmentally sound and sustainable manner. They also indicated the need for re-excavation of canals, ponds and water bodies; innovation and dissemination of resilient fish varieties; and undertaking a fisheries inventory to create a baseline status of the coastal area.

5.3.8 Potential impact and adaptation options of livestock

Climate change induced salinity has caused damage to local fodder/grass land. Deficiencies in natural grass/fodder availability have increased difficulties in cattle and livestock rearing in coastal areas. Workshop participants have observed an increase in the incidence of livestock diseases, which may be linked to increasing temperatures, increasing salinity and uneven rainfall patterns. These factors have impacted milk production and meat production (especially broiler), affecting livelihoods and food security. Table 5.21 summarizes the impacts and adaptation options ranked and identified through participants'

Table 5.21: List of climate change impacts and adaptation options

Potential impacts	Adaptation options
1. Decrease in natural fodder availability due to the increased salinity 2. Loss of grazing/grass land in saline areas 3. Decrease in milk production 4. Increased incidence of livestock diseases 5. High temperatures might impact the production of broiler	1. Introduction and promotion of improved fodder cultivation in the coastal saline area 2. Fodder cultivation on the side/edge of embankment and gher 3. Rearing improved varieties of cow, poultry, goat and sheep 4. Raise awareness on the use of vaccination 5. Introduce and apply the feed import law

Most of the participants felt that the introduction, promotion and cultivation of improved fodder could play an important and critical role to encourage the livestock production in the coastal saline area. Potential options for fodder cultivation are along the embankments and gher. Workshop participants recommended rearing of improved livestock and poultry in the area so as to enhance milk, meat and egg production.

5.4 Flood Prone Areas

Monsoon floods affect lives, livelihoods (mainly agriculture), drinking water, sanitation, health, energy, and infrastructure. Flood prone areas in Bangladesh have a large agrarian economy. The health impacts after floods are tremendous, with increase in incidence of water-borne diseases, diarrhea and snake bites. During 2007 monsoon floods in Bangladesh, snake bites were estimated to be the second cause of death after drowning, and caused more deaths than diarrhea and respiratory diseases (Dewan, 2015). Other major impacts floods include the loss of employment and unavailability of fuel-wood for cooking. Day laborers often starve to death due to lack of a source of income, or sickness. During the floods in 1988, 1998, and 1999, hundreds of industries, especially garment factories went under water, causing destruction to raw materials and machinery worth millions of dollars. Some factories never recovered and thousands of people were rendered jobless (Dewan, 2015).

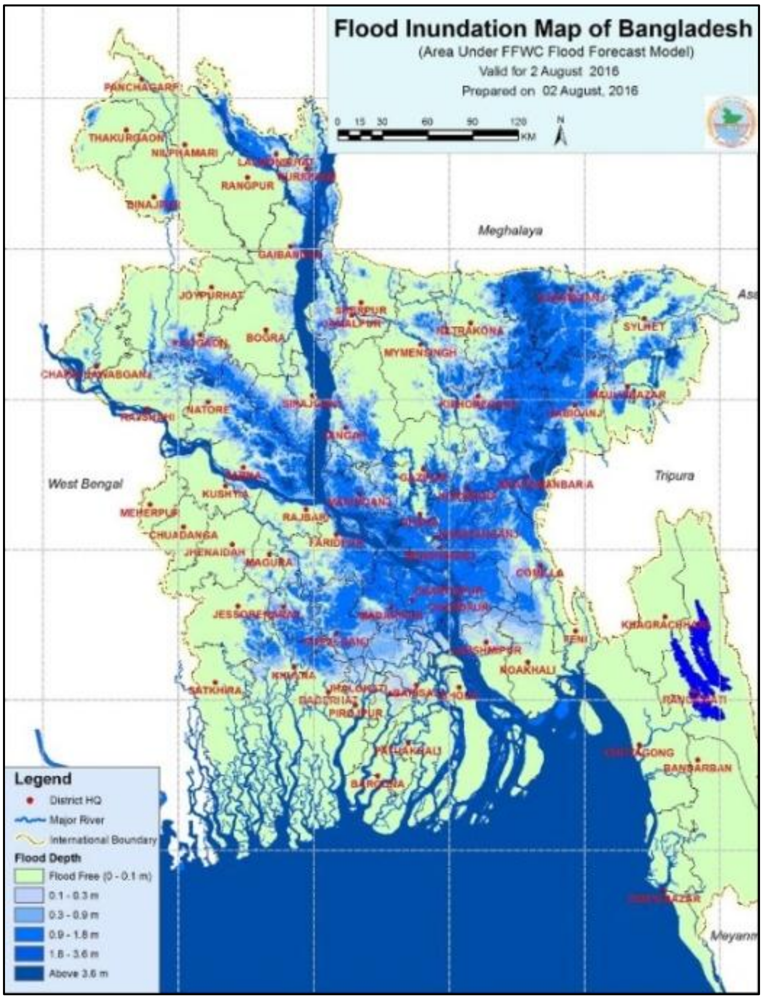


Figure 5.3: Flood depth map of Bangladesh on 2 August 2016 prepared by Flood Forecasting & Warning Centre of Bangladesh; the area inundated in this map is representative of flooded areas every year (26,000 km^2, 18% area)

Shimi et al. (2010) listed current adaptation practices in flood prone areas of Bangladesh (Goalanda, Rajbari) as: (i) drinking water: 43% HH collects water from a distant place using boats; 32% protect tubewells from inundation by raising the tubewell platform or adding an extra pipe; 17% use flood water after purification; 8% use flood water without purification; (ii) sanitation: only 3% HH use safe toilets by raising platforms; 42% use hanging latrines; 28% resort to open defecation; 20% defecate into flood water from boats; and 7% use other unhygienic latrines; (iii) food storage: 55% HH don’t store food at all; 32% store dry food that can be directly eaten (chira-muri-gur); 13% store dry food to cook (chal-dal-tel-nun); (iv) health: due to water borne diseases 55% have no access to treatment; 18% visit the village doctor; 17% go to health centres; and 10% visit allopathic doctors. There is need for planned adaptation actions in the water and infrastructure sectors in flood prone areas of Bangladesh to reduce vulnerability to recurrent monsoon floods caused by climatic change and variability.

The Government of Bangladesh has already taken different initiative to enrich adaptive capacity, e.g. Establishment of Jamalpur Economic Zone, Road Improvement Works in Jamalpur & Maderganj Paurashava, Distt. Jamalpur, Establishment of Jamalpur Medical College and Hospital and Jamalpur Nursing College, Rural infrastructure development of Jamalpur and Sherpur districts, River bank protection pilot project for the protection of the area of Jamalpur Sadar Melandah upazila, due to the breakdown of the old Brahmaputra river of Jamalpur district through the Bamboo Bandeling, Protection of Bhuapur-Tarakandi road through Protection of Left Bank of Jamuna River in Sharishabari Upazila of Jamalpur District, Greater Mymensingh Rural Infrastructure Development, Construction of Inter-district Roads: Mymensingh and Netrokona, Widening & Improvement of Important Regional Highways to appropriate standard, etc.

5.4.1 Potential impact and adaptation options of water

Stakeholders from Mymensingh prioritized flash floods as the main climatic impact in flood prone areas. Drinking water scarcity during floods is a major problem (DhakaTribune, 2017; WHO-UN Water, 2012), compounded by surface water degradation due to industrial effluents (Amin, 2015), use of pesticides, etc. These factors cause damage to aquatic life, wildlife and the ecosystem at large (Siddique, 2017). Sand deposition on banks and riverbeds due to floods, decrease the water carrying capacity of large rivers, causing the floodplain area to expand during monsoon, thereby increasing riverbank erosion. Uneven rainfall during the dry period (November-May) necessitates irrigation for rabi crops. Increasing temperatures during summer and winter months has also increased water requirements for crop cultivation, thereby increasing overall water demand.

Table 5.22: Ranking of climatic impacts and potential adaptation options for the resilient development of water resources in flood prone areas in Bangladesh (by the stakeholders' consultation workshop)

Potential impacts	Adaptation options
1. Drinking water scarcity 2. Surface water degradation due to industrial effluents, pesticides, etc. 3. Harm to aquatic life 4. Sand deposition on riverbanks and riverbeds 5. Uneven rainfall in the dry season 6. Heavy metal pollution 7. Higher temperatures in summer and winter 8. Shortening of winter months 9. River siltation 10. Riverbank erosion	1. Build small scale surface water reservoirs (excavating ponds, etc.) 2. Surface water treatment plant for water supply in big cities 3. Planned fish culture which will not block surface water flow during floods 4. Water pollution control by increasing awareness and executing rules 5. Enhance rainwater harvesting at the household level 6. Need-based drinking water distribution points (tubewells) 7. Raising plinth of tubewells and latrines 8. Re-excavation/dredging of rivers to increase water carrying capacity 9. Land use planning/zoning 10. Embankments for flood protection and other structures

People living near rivers, the poor, slum dwellers, women, the elderly and the disabled are most vulnerable to climate change impacts in the water sector. Adaptation strategies currently in pratcice for irrigation include the use of submersible water pumps, shallow engine water pumps, deep tubewells (DTW), shallow tubewells (STW), and low lift pumps (LLP). River excavation/dredging is practiced mainly for navigation purposes and not to augment the flow of large rivers, however, small rivers and channels are excavated regularly. Potential adaptation options include the construction of small-scale surface water reservoirs (e.g. excavating ponds, dighi, etc.); surface water treatment plants for water supply in large cities; a planned fish culture which will not block surface water flows during floods; water pollution control by increasing awareness and executing rules; enhancing rain water harvesting at the household level where there is lack of safe drinking water; need based drinking water distribution points (tubewells); raising plinths of tubewells and latrines (necessary during floods); re-excavation/dredging of large rivers to increase water carrying capacity; land use planning/zoning of flood prone areas; and construction of embankments for flood protection and other structures.

5.4.2 Potential impacts and adaptation options of navigation, transport and infrastructure

In flood prone areas, recurrent flash floods and seasonal long stay floods hit every year, which damage bituminous road crust, weak embankments, educational institutions, bridges, culverts, houses, and local earthen roads, which are inundated or blocked by high flood water current. Sensitive groups include women, children, elderly people, poor people, day laborers, students, and low income people. Current adaptation strategies include embankments in Mymensingh, Jamalpur, Netrokona, and Sherpur; two rubber dams at Chellakhali and Ghogai rivers in Sherpur. However, many more adaptation options need to be practiced at a larger scale to reduce climate risk and vulnerability.

Table 5.23: Ranking of climatic impacts and potential adaptation options for the resilient development of navigation, transport, and infrastructure vulnerability in flood prone areas in Bangladesh (by the workshop participants)

Ranks of climatic impacts	Ranks of potential adaptation options
1. Damage of bituminous road crust due to floods, high temperature and erratic rainfall 2. Damage of weak embankments 3. Impact of water control structures on other sectors 4. Damage of educational institutions 5. Loss due to land slide in some areas 6. Damage to bridges, culverts and roads 7. Loss due to riverbank erosion 8. Damage of low and mud houses 9. Damage to local roads due to floods	1. Dredging of major rivers and canals to increase flow and navigability 2. Enhance flood protection infrastructure (e.g., embankments, spur) 3. Build rubber dams, where feasible and appropriate 4. Road construction using CC/RCC 5. More bridges or culverts for increasing flow in the floodplains 6. Raising plinth levels of educational institutions, which may also be used as flood shelters 7. Increase the number of multi-purpose flood shelters and highland for livestock 8. Flood proof/resilient housing 9. Land use planning/ zoning

To increase the adaptive capacity of the people in the region, stakeholder opinions and climate data (both current and future) should be incorporated from the beginning of the planning stage of infrastructure projects, and across all staged of planning and implementation. Regular maintenance of infrastructure has been emphasized by workshop participants. Since the economic development of these areas is dependent on basic infrastructure development, governance, funding and implementation of small and large-scale infrastructure projects needs to be improved in order to enhance climate and economic resilience.

5.4.3 Potential impacts and adaptation options of health

Malnutrition has been identified as the most potential impact of changing climatic features. Climate change impacts on the agriculture sector reducing crop production and yield, directly affects food security and nutritional intake, especially of the poor and lower income groups. Climate-related ecents such as floods and flash floods further impact food security, while giving rise to a number of other water- and vector-borne infectious diseases (diarrhea, jaundice, skin diseasesm dengue, chikungunya, etc.).

Participants also observed an increase in chronic conditions such as renal and cardiovascular disease as an indirect impact of climate change, along with an increase in psychosomatic illnesses. Literature and data to support these observations is however, limited. Climate change has also negative impacts on the occurrence of the thunder, posing greater health risks to individuals. However, it remains to be seen how climate change influences greater occurrence of thunder.

Table 5.24: List of climate change impacts and adaptation options

Potential impacts	**Adaptation options**
1. Malnutrition 2. Heat stock/ excessive sweating 3. Emerging and reemerging infectious diseases [dengue, chikungunia, malaria] 4. Water-borne diseases (diarrhea, jaundice, typhoid, skin diseases) 5. Increase in chronic disease 6. Thunder 7. Psycho-somatic illness	1. Improve modern technology and medical equipment 2. Raising funds for climate-induced disease response 3. Enhance waste management capacity 4. Control and check corruption, monitoring and supervision 5. Introduce and promote ingenious/ traditional crop varieties 6. Improve coordination between stakeholders [NGO, Govt., communities] 7. Reforestation 8. Develop human resources and skills

In discussions relating to adaptive mechanisms, the participants emphasized the need for establishing good governance and raising separate funds to address climate-induced illnesses and health shocks. There is a need to improve the waste management system, especially in cities, as waste material can possibly influence vector breeding, leading to vector-borne diseases. Introducing and promoting indigenous/traditional crop varieties can increase flood tolerance of crops and improve nutritional intake as well. Developing human capital, such as health care providers; improving coordination and cooperation between communities and service providers are important actions to address the negative impacts of climate change.

5.4.4 Potential impacts and adaptation options of Humans to natural disaster

Changing climatic features influence the occurrence of floods that damage home/shelter/living places; decrease agriculture production, and damage infrastructure. It enhances human vulnerabilities health, agriculture, education, and the ecosystem. The most obvious impact of climate change is the loss of livelihood and productive capital, resulting in poverty. River bank erosion was observed to be frequent in the greater Mymensingh region, especially in the haor areas. People dependent on agriculture, fisheries and livestock are forced to migrate and/or change occupations. Prolonged floods pose health hazards, affect economic growth and development and increase food insecurity.

Table 5.25: List of climate change impacts and adaptation options for humans to natural disasters

Potential impacts	Adaptation options
1. Flood 2. Poverty 3. Occupation change 4. River bank erosion 5. Damage to natural property/infrastructure 6. Emergence of diseases 7. Unemployment 8. Price hikes 9. Under nutrition and food insecurity	1. Enhancing capacities for rain water harvesting 2. Construction of mounds 3. Strengthening relief & rehabilitation programs 4. Distribute lime, finger links 5. Strengthening early warning systems 6. Enhance coordination between the government, NGOs and other agencies 7. Arrange quick relocation mechanisms for affected people and animals during disaster 8. Build and repair embankment in hoars

Improving water management practices can facilitate better control of flood water. Other potential adaptive options include constructing mounds in the haor and low-lying areas, enhancing outreach of relief and rehabilitation programs, and improving current infrastructure facilities.

5.4.5 Potential impacts and adaptation options of biodiversity

Bangladesh is one of the most flood prone countries in the world. There are 230 rivers which occupy about 7% of the total land area of Bangladesh. Each year in Bangladesh, 25% of the country is flooded. When a simultaneous rise in water level occurs in the three rivers, theGanges, Brahmaputra and Meghna, the flood event become devastating. The floods of 1987, 1988, 1998 and 2007 were extensive. Floods cause enormous economic loss to the country, destroy infrastructure, standing crops, livestock and human lives. The flood prone areas of Bangladesh are rich in flora and fauna, however, tremendous population pressure, along with high rates of unemployment have resulted in increased dependence on natural resources, causing a steady decline in the biodiversity of the region. Impacts on the ecosystem have resulted in loss of species (especially local/indigenous species) of plants, trees, birds, insects, aquatic life, wildlife and others. Beneficial insects such as the damsel bug, earwig, lady bugs, bees, etc. are becoming extinct due to imbalances caused by the use of chemical fertilizers and pesticides. Further, many factories producing fish and poultry feed produce toxic waste. Thirty species of fishes have been listed as extinct in inland water bodies (Hossain, 2014). The flora and fauna species of Bangladesh are also undergoing genetic mutations due to anthropogenic pressures, uncontrolled dredging, hydrological interventions, pollution and chemical fertilizers, the transformation of land use patterns, change in cropping patterns, expansion of agricultural lands, encroachment, shifting cultivation, expansion of road networks, urbanization, unplanned embankments, etc. Massive introduction of invasive alien plants e.g., Eichhornia crassipes (Kachuripana)) and fish e.g., Clarius gariepinus (African magur), Pangasius sutchi (Pangas), Oreochromis mossambicus (telapia), Cyprinus carpio (common carp), Oreochromis niloticus (Nilotica) etc. are responsible for the sensitivity of biodiversity.

Table 5.26: Ranking of potential climatic impacts and adaptive capacity

Potential impacts	Adaptation options
1. Ecosystem is being destroyed 2. Decrease in/extinction of aquatic animals due to drying up of water bodies 3. Increase adulterate food (Fish and poultry feed) 4. Genetic changes in local flora and fauna 5. Increase in diseases due to use of chemical fertilizers and pesticides 6. Loss of habitats of flora and fauna 7. Increase in invasive alien species 8. Local crop varieties (especially) are becoming extinct	1. Increase awareness 2. Protect existing forests 3. Protect natural wetlands 4. Increase social forestry 5. Switch to manure and organic pesticides 6. Improve drainage systems 7. Establish sanctuary for waterfowls and birds 8. Implement government policies and acts and create new policies

Massive new plantations are needed, along with existing plantations to protect the biodiversity. Bangladesh is rich in wetland habitats, however, increasing human population and unplanned development exert tremendous pressure on these ecosystems. Potential adaptation options include: increasing the use of organic manures and fertilizers to replace chemical pesticides and fertilizers; improve drainage systems for better collection and disposal of water; creating sanctuaries to protect sensitive habitats and ecosystems. The Government of Bangladesh declared the Biodiversity Rule 2012 and Act 2017. Implementation of this Act needs to be strengthened along with the facilitation of new policies to protect and preserve the biodiversity.

5.4.6 Potential impacts and adaptation options of agriculture

The sudden on-set of floods leads to tremendous crop damage, soil damage and damage to seeds and seedlings as well. Subsequent water logging further exacerbates damage to crops. River erosion, as a result of flooding, causes severe damage to roads, embankments, and crop land, thereby affecting crop production, yield, transport and marketing. These impacts particularly cause critical and life-threatening damage to those dependent on agriculture for sustenance, the poor, landless labourers, women, the elderly, children and the disabled, resulting in unemployment, food insecurity, malnutrition, mental and physical health problems, and further poverty.

Participants felt that changing climatic patterns have affected groundwater quantity, thus affecting water availability for irrigation needs. These patterns have also caused an increase in pest infestations, affecting crop production and yield negatively.

Table 5.27: List of climate change impacts and adaptation options

Potential impacts	Adaptation options
1. Crop damage due to sudden/flash floods (standing rice, vegetables) 2. Reduce crop land due to the river erosion, resulting from heavy floods 3. Damage of seed beds due to early floods 4. Increase in unemployment because of loss of land and cultivation 5. Increase in insect and diseases in the crops 6. Prolonged water logging creates problems for seedling production 7. Loss of ground water and irrigation water during winter	1. Construct roads and embankment with a view to protect crop land 2. Research, develop and promote resilient crop varieties 3. Stop sand collection from rivers (this induces river bank erosion and thus crop land loss) 4. Introduce floating seed beds during flood season 5. Promote the flood tolerant traditional rice variety (Joli Aman) 6. Enhance capacity of the private sector/NGOs who work directly with community people

Most participants emphasized the construction of roads and embankments which are critical to protect crop land and thus facilitate crop production, ensuring livelihood and food security. Participants recommended further research, development and promotion of resilient crop varieties, especially those that can tolerate flood and water logging.

5.4.7 Potential impacts and adaptation options of fisheries

Floods, especially flash floods cause severe damage to fish and other aquatic life, especially to cultured fish in ponds. The loss is largely a result of over flow of water, damage of pond bank, and the failure of other protection measures. Many fish and fish varieties get lost due to heavy and prolonged floods. Loss in local fish varieties due to recurrent floods have been noted by workshop participants.

Table 5.28: List of climate change impacts and potential adaptation options

Potential impacts	Adaptation options
1. Loss of fish, fish resources and fish species (indigenous varieties in particular) 2. Fishers/fishing communities are the most serious victims due to the loss of fish stock. 3. Fish diseases (originated in the pond) spread to the open water. 4. Natural breeding is affected due to climate change and flood 5. Drying up of rivers during the winter season resulting in loss of fish	1. Increase the number of and area under 'Fish Sanctuary' 2. Construct roads/embankments to protect fishery resources from the loss of flood 3. Execution of policies to stop using the small mesh net (current jaal) 4. Fish production in a planned manner 5. Introduce rice cum fish culture 6. Introduce the case culture technique

Indiscriminate fishing in open water and the gaps in policy implementation have resulted in a massive loss of natural fish. Enhancing the establishment of 'Fish Sanctuary' is considered a good way to conserve and make fish available for the whole year. Strong steps are required to execute policies to stop use of the small mesh net (current jaal) and vigilance of the concerned agencies is highly critical. This can potentially save fish resources, small fish in particular, and ensure year around availability.

Construction of road/embankment was also found to be important to protect fishery resources from flood water.

5.4.8 Potential impacts and adaptation options of livestock

Workshop participants explained that the extensive flood created a serious crisis of fodder and grass across the area. They flagged that rearing of livestock had been difficult, due to the lack or deficiency of natural grass/fodder in the flood affected area. Given that flood occurrences are very severe, the impacts on and losses of livestock resources are huge. Participants also noted the increase in diseases in livestock, which may be linked to higher temperatures, and increased rainfall and floods.

Table 5.29: List of climate change impacts and potential adaptation options

Potential impacts	Adaptation options
1. Serious fodder crises during the flood period	1. Introduction and promotion of dry/solid feed during the flood period
2. Direct loss of livestock resources due to sudden and prolonged flood	2. Construction of Killa (raised land) in most flood affected areas
3. Increased incidence of livestock diseases	3. Impart vaccination to livestock during the flood months
4. Space constraints for livestock during the flood period	4. Prepare and store Silage for the flood months

Almost all of the participants observed that the preparation, introduction and promotion of solid/dry cattle feed could play an important role in saving livestock resources from the impact of floods. They also recommended preparation and storage of silage for the flood season that could save their livestock, which is urgently needed by the poor farmers.

5.5 Chittagong Hill Tracts and Coasts

The Chittagong hill tracts (CHT) and nearby coast is exposed to land slides, drying up of springs, cyclones and storm surges every year. These events increase vulnerability and uncertainty of lives and livelihoods in this region. Planned adaptation actions in water and infrastructure sectors in CHT and the nearby coast are necessary to reduce risk and vulnerability to climatic change and variability.

The Government of Bangladesh has already taken different initiative to enrich adaptive capacity, e.g. Development of roads damaged by floods and waterlogged under Chittagong City Corporation and construction / reconstruction of canal, resistance walls, bridges and culverts, Development of safe water supply and sanitation system in neighboring habitations including the important markets of Bandhban Hill District, Safe Drinking Water Supply & Sanitation system Development at Different Important Bazar with Surrounding Locality under Khagrachari and Rangamati District, etc.

5.5.1 Potential impact and adaptation options of water

The main climatic impacts in the CHT region is the drying up of streams and water resources due to low rainfall in the dry period (October – May) as stated and ranked by stakeholders from government organizations, NGOs, and community leaders in Bandarban. Groundwater levels are declining due to over exploitation of both drinking water and irrigation, while surface water capacities are reducing due to increased water pollution, unplanned waste management, industrial effluents, use of chemicals, pesticides, etc. Lack of relevant water infrastructure to drain water leads to waterlogging in the low lands, while groundwater degradation due to iron and salinity is a major problem for ensuring safe drinking water in the plain lands. Siltation in major rivers is an increasing phenomenon due to increasing landslides. Already many sources of drinking water/streams have dried up due to low rainfall during dry periods or changing streams due to landslides, increasingly frequent flash floods have been observed by the stakeholders in recent years.

Table 5.30: Ranking of climatic impacts and potential adaptation options for the resilient development of water resource vulnerability in CHT and nearby coastal areas

Potential climatic impacts	Adaptation options
1. Drying up of streams and sources of water 2. Groundwater level declining 3. Reducing the capacity of surface water reservoirs e.g., ponds, lakes, and rivers 4. Water pollution due to unplanned waste management and use of pesticide 5. Waterlogging due to erratic rainfall 6. Groundwater degradation due to iron and salinity 7. River siltation 8. Many sources of drinking water dried up fully 9. Increased frequency of flash floods	1. Protection of natural and reserve forest for reviving sources of streams and drinking water 2. Increase VCF – village common forest 3. Controlling stone and sand collection from water sources 4. Increase plantation of trees which enhances infiltration and store water for recharging water sources 5. Increase rubber dams and water treatment plants where feasible 6. Social afforestation program by the government 7. Public awareness raising on climatic issues and adaptation options 8. Enhance rainwater harvesting at the

during May - August	household level 9. Preservation of natural water sources and pollution control 10. Control (no) monoculture 11. Excavation/dredging of rivers, canals, stream, and other surface water reservoirs 12. Planned sustainable development in the CHT 13. Balancing population over the ecosystem services/natural resource availability in the CHT

The sensitive groups are mostly people in the hills facing food and water shortages, people who collect water from distant places, people who are at high risk of landslides e.g., those residing in valleys near a fragile hill, children, women, the elderly and disabled, people living low lands near rivers. The present adaptation strategies include protection of natural and reserve forest, village common forests, enhance rain water harvesting at the household level, use of gravity flow system, deep tube wells, and dug wells, traditional watershed management system, and water treatment plant in Chittagong city. Potential adaptation options include the protection of natural and reserve forests for reviving sources of streams and drinking water, more village common forest, controlling the collection of stone and sand from water sources, increase plantation of trees which enhance infiltration and store water, construction of rubber dams and water treatment plants where feasible, social afforestation programs by the government, public awareness building on climatic issues and adaptation options, enhance rain water harvesting at household level, preservation of natural water sources and pollution control, discouraging monoculture, excavation/dredging rivers and other water sources, planned sustainable development in the CHT, and balancing population over the ecosystem services/ natural resources availability in the CHT.

5.5.2 Potential impacts and adaptation options of navigation, transport and infrastructure

In the CHT and eastern coast, frequent landslides occur every year in many hills which interrupt road services, communication, and other infrastructure like power supply, educational institutions, bridges, culverts, houses, local earthen roads, etc. As the hills of CHT are mainly underlain by consolidated shales, siltstones and sandstones, landslide erosion occurs very easily when these materials are loosened by high intensity rainfall. This landslide process is expedited when deforestation takes place on top of the hills, and the valleys receive flash floods when torrential rain occurs. In Chittagong city, in recent years, waterlogging occurs more frequently due to torrential rainfall and lack of capacity of drainage systems to handle torrential rainfall. The sensitive groups include marginal indigenous people, students, patients, and people near rivers/streams and low lands. The present adaptation measures so far found may be listed as building traditional lofty houses without cutting hills which reduces landslide erosion and maintenance of loads by local people. However, more adaptation options need to be practiced at a larger scale to reduce the climate risk and vulnerability.

Table 5.31: Ranking of climatic impacts and potential adaptation options for the resilient development of navigation, transport, and infrastructure in CHT and nearby coastal area (by the workshop stakeholders)

Potential impacts	Adaptation options
1. Damage of road and communication infrastructure due to landslides 2. Interruption of power due to landslide 3. Damage of road due to loose topsoil in hilly areas 4. Damage to bridges/culverts due to erratic rainfall 5. Damage of infrastructure inundated in flash floods 6. Damage of irrigation canals of drainage channels due to erratic rainfall	1. Planning and construction of infrastructure considering environmental protection and climate change impacts 2. Regular maintenance of roads, bridges/culverts 3. Enhancing capacity of traditional institutions and coordination with other institutions 4. Underground electric lines up to sub-district level 5. Increase afforestation and control deforestation 6. Control hill cutting 7. Prohibition of use and extraction of local stone and sand 8. Green structure should be used for infrastructure development 9. Increase reserve forest

To increase the adaptive capacity of the people in the region, adaptation options as of stakeholders' priority include planning and construction of infrastructure considering environmental protection and climate change impacts; maintenance of roads, bridges/ culverts regularly; enhancing capacity of traditional administrative institutions and coordination to other institutions; underground electric lines up to upazila level to reduce the risk of damaging from the landslide; increase afforestation and control deforestation; control hill cutting; prohibition of use and extraction of local stone and sand; more green structure for infrastructure development; increase reserve forest; and increase coordination of government departments. From the beginning of planning of each infrastructure project, the stakeholders' opinion and changing climatic conditions should be considered at all stages of infrastructure planning and implementation.

5.5.3 Potential impacts and adaptation options of health

Increase of vector-borne diseases (dengue, malaria, chikungonia) was frequently mentioned climate induced health impact. However, the existing literature is scarce to support dengue and chikungonia. Emerging and reemerging infectious diseases (skin diseases, infections). The rise of non-communicable disease [cancer, diabetes, cardiovascular, renal] was also viewed as the negative impact of changing climatic feature. However, the scientific information, offers less and/or no evidence to establish this statement. Further increase of morbidity (respiratory diseases, common cold, and fever) was mentioned to be high as a result of extreme climatic events that has not also been established by the existing literature. Participants stated that changing climate conditions also negatively impacted reproductive and sexual health, especially for women and adolescent girls. The women and girls are experiencing irregular menstruation and are developing complications during pregnancy. However, these claims have not been supported by existing literature. Psychosomatic illness and low level of physical strength were observed as a climate induced health impact in the region.

Table 5.32: List of climate change impacts and adaptation options

Potential impacts	Adaptation options
1. Increase in vector-borne diseases [dengue, malaria, chikungonia] 2. Emerging and reemerging infectious diseases [skin diseases, infections] 3. Increase in non-communicable disease [cancer, diabetes, cardio-vascular, renal] 4. Increase in morbidity [respiratory diseases, common cold, fever] 5. Complications in reproductive health [irregular menstruation, infertility, pregnancy related complication] 6. Lower physical stamina 7. Psychosomatic illnesses	1. Promote awareness 2. Protect and promote traditional/indigenous socio-political organizations in CHT [headman, women, VCF network] 3. Improve WASH 4. Promote community based health care system 5. Promote agriculture/food security 6. Increase health providers 7. Improve Government and NGO collaboration and coordination 8. Strengthen vaccination 9. Improve communication facilities 10. Establish mobile hospitals 11. Improve referral system (supply ambulance) 12. Promote access to information 13. Repair and protect water bodies 14. Tree plantation and reforestation 15. Protect hills 16. Protect Eco system

5.5.4 Potential impact and adaptation options of Humans to natural disaster

With regard to the major climate change impacts, the majority of participants revealed that the key health impact induced by the changing climate feature is the incidence of landslide in Chittagong Hill Tracts (CHT). Although there is limited scientific information to support this claim, participants laid their own explanations on how changing climatic feature resulted in repeated landslide in the region. Changing rainfall patterns (increasing incidence of high intensity rainfall) has resulted in increased landlide occurrence, which often claims life and damages productive assets and the ecosystem, further affecting traditional practice, skills, and knowledge relating to medicine. Further, participants mentioned a decrease in natural water resources thus threatening availability of clean water for hill communities.

Table 5.33: List of climate change impact and adaptation options

Potential impacts	Adaptation options
1. landslide 2. Loss of livelihood 3. Loss of traditional/indigenous practice, skills, knowledge 4. Loss of natural water bodies 5. Erosion 6. Loss of natural forest and habitat for wildlife 7. Migration/displacement 8. Lack of access to clean water 9. Damage to flora and fauna 10. Changing agricultural systems [jhum→tobacco cultivation] 11. Emerging and re-emerging diseases [malaria]	1. Promote education program 2. Build cold storage 3. Promote social forestry 4. Improve water, road and communication infrastructure 5. Introduce modern jhum cultivation 6. Promote natural forest [reforestation] 7. Access to land [ethnic people] 8. Promote and strengthen awareness programs 9. Promote market access 10. Improve WASH 11. Review social policy (the policy should be framed in consultation with ethic people) 12. Revise definition of forest

5.5.5 Potential impact and adaptation options of biodiversity

The Chittagong Hill Tracts are undergoing deforestation and land degradation arising from environmentally unsuitable activities such as tobacco cultivation and shifting cultivation (slash and burn). The area is rich of flora, which is now depleting at an alarming rate, owing to illegal felling, cutting, massive soil erosion, jhum/shifting cultivation, and other anthropogenic activities. Among the species of fauna are elephants, monkeys, foxes, wild pigs, lightning-bites, plexus-oysters, rats, birds, snakes, lizards and amphibians like frogs, which are decreasing gradually due to crisis of food, wild habitat loss, prey, etc. Indigenous people, who are living in hilly areas, are practicing shifting cultivation, which is locally called jhum cultivation. Jhum cultivation can cause top soil loss, degradation of soil quality, loss of habitats of wild animals, decrease in environmental balance and crop yield. Beneficial insects such as the damsel bug, earwig, lady bugs, bees, etc. are becoming extinct due to imbalances caused by the use of chemical fertilizers and pesticides. Further, many factories producing fish and poultry feed produce toxic waste. Thirty species of fishes have been listed as extinct in inland water bodies (Hossain, 2014). The flora and fauna species of Bangladesh are also undergoing genetic mutations due to anthropogenic pressures, uncontrolled dredging, hydrological interventions, pollution and chemical fertilizers, the transformation of land use patterns, change in cropping patterns, expansion of agricultural lands, encroachment, shifting cultivation, expansion of road networks, urbanization, unplanned embankments, etc. Massive introduction of invasive alien plants e.g., Acacia (Acacia auriculaeformisn), Mangium (Acacia mangium), Eycalyptus (Eucalyptus brassiana), Mahogany (Swietenia macrophylia) etc. are making vulnerability of biodiversity. Acacia and Eucalyptus trees produce leaves that are not easily degradable. So, the soil becomes less fertile and the existence of thousands of humus-dependent species including herbs and earthworms become threatened. These trees absorb large amounts of water and hence even the indigenous trees cannot properly grow around it. These trees do not support any wildlife since these do not produce edible fruit or nectar for them. Moreover, the pollen produced by the flowers of these trees harm the respiratory tracts of human beings and lead to allergic diseases (Ameen, 1999). Medicinal plants play a significant role in providing primary health care services to the people. They serve as important therapeutic agents, as well as important raw materials for the manufacture of traditional and modern medicines. But these plants are becoming extinct due to the shrinking of land resource base, deforestation, climate change, over exploitation and lack of appropriate management. The clearing of forests in the hilly areas is threatening biodiversity, especially wild animals due to shortage of food. People, especially the indigenous people are habituated to eat natural fruits from the forest. Many indigenous tribes consume locally grown herbs and spices for food and medicine. But due to decreasing the forest products people are changing their food habits.

Table 5.34: Ranking of potential climatic impacts and adaptive capacity

Potential impacts	**Adaptation options**
1. Extinct flora and fauna. 2. Decrease in forest cover because of unplanned Jhum (slash and burn) cultivation. 3. Extinct beneficial insects. 4. Decrease flora and fauna by using chemical fertilizers and pesticides. 5. Habitat loss of wild animals. 6. Invasive alien plants. 7. Decrease in medicinal plant species. 8. Decrease in food for animals. 9. Change food habit of local people.	1. Increase village conservative forest (VCF) and take VCF under rules and regulations. 2. Preserve natural forests. 3. Ensure participation of various stakeholders to protect the forests. 4. Prepare law for uplifting stones and sands. 5. Stop environmental pollution. 6. Preserve grazing lands. 7. Cultivate Jhum in a planned way. 8. Afforest in consideration of birds food, e.g. fruits trees 9. Increase alternative income source. 10. Decrease dependence on the forest. 11. Increase awareness. 12. Apply existing laws to protect the forest. 13. Closely monitor the saw mills and brick fields. 14. Preserve mother trees.

Indigenous communities in the Chittagong Hill Tracts of Bangladesh are managing forests around their homesteads in a sustainable way, despite exclusion of the customary rights of government managed reserved forests. Community managed Village Common Forest (VCF) represents an influential model of forest management, serving multi-functions to the dependent of indigenous communities. As per the decision of the key stakeholders, VCFs are enriched with more biodiversity than that of Government forests. Indigenous management of resources in VCFs is sustaining a balance between exploitation and conservation. Halting degradation of forest resources in Bangladesh, VCF could be used widely as an effective instrument. According to international standards, any country needs at least 25 percent forest cover to maintain ecological balance. Now, only 5% area of the country is covered with natural forests. Forests are fast depleting due to illegal logging, unemployment, conversion to non-forestry uses and by the government's inability to suitable policies to regulate cutting of trees. Necessary initiative should be taken to preserve the existing forests. All people's participation (Tribal, NGOs, Government, etc.) is important to conserve the forests. Reorientation of government policies, easy access to institutional support and the active participation of local people in developing interventions are of the utmost importance in order to find alternative land uses for sustainable hill farming, improve the farmer's living standards and conserve forests. Dependency on forest should be decreased by increasing awareness among the stakeholders to preserve forests. The government of Bangladesh has declared Biodiversity Rule 2012 and Act 2017, hence the enforcement is necessary. It is also suggested to create new policies to protect and preserve biodiversity.

5.5.6 Potential impacts and adaptation options of agriculture

Climate change induced increased temperature and uneven rainfall has huge impact on the hilly uplands of Bangladesh. The impact goes across horizontally and longitudinally to various sectors and sections of the communities living there. According to the participants's view in the workshop impact of heavy rainfall cause severe soil erosion and landslides in the lands and thus incur direct loss of the crops and fruit/timber trees. The bottom of the hills and surrounding area, crop lands, water bodies, homesteads are immediately covered with the sand and silt eroded from the upper hills.

The workshop participants reported that heavy rainfall caused water logging as well in some areas and farmers could not cultivate crops in time. Due to prolonged rain and landslides, some years, the farmers could not maintain the schedule of crop cultivation and things get delayed. Due to uneven temperature there are emergence of new/more insects and diseases and the crops and the farmers had to spend more money to control insects and diseases. Loss of crops due to insect infestation becomes very regular in the areas. Some of the participants raised the problem of scarcity of irrigation water, especially in the dry season of the year. They told that they had to arrange additional effort and incur more money for irrigation water. Sometimes, according to them, they could not save crops and harvest the yield. The impact and adaptation options are ranked as per the identification through participants' vote and thus presented hereunder (Table 5.35).

Table 5.35: List of climate change impact and adaptation options

Rank of Climate change impact	Rank of Potential adaptation option
1. Land erosion and hill slides due to incessant rainfall in the hilly areas 2. Delay in crop cultivation due to prolonged rainfall 3. Scarcity of irrigation water during dry season 4. Flash flood and water logging in some areas of the upland areas 5. Sand/silt deposition in the crop land at the hill bottom due to soil erosion 6. Increase the incidence of insects and diseases due to variable temperature 7. Delayed fruit setting in mango and litchi	1. Plant trees to arrest and reduce hill slides, soil erosion 2. Enhance research to generate new technologies and varieties which could adapt to the hilly environment 3. Increase the mixed cultivation practice (tree+crops) in the hilly upland areas 4. Raise community awareness on the forest management 5. Facilitate and support the indigenous community institution/networks (headman, karbery etc.) 6. Introduce the cultivation of Mushroom and Honey 7. Construct the Rubber Dam to efficiently manage the water sources

During the group discussion, majority of the participants recommended the research initiatives for the generation, introduction and cultivation of resilient crops those could withstand in the flood, flash flood of the hilly areas. They also advised to go for mixed cultivation with crops and trees together in the same piece of land, especially in the hilly uplands and hill slopes. Plantation of trees across the hill slopes was also suggested to arrest/reduce the soil erosion and thus landslide. Participants felt the need for providing support to the most vulnerable hilly indigenous community and their networks. They raised the issue to capacity building and awareness raising of the hilly communities.

5.5.7 Potential impacts and adaptation options of fisheries

Participants of the Chittagong Hill Tracts workshop exclaimed that canal, streams were dried up due to high temperature and siltation from the hilly soil erosion. They informed that the overall fish production of the hilly area was decreasing due to the natural as well as man-made reasons like over extraction.

While most of them observed that the local fish varieties were getting extinct due to the lack of water, they also claimed that fish cultivation was also gaining momentum in some areas. Some of them thought that the natural fish sanctuaries were getting reduced in the areas due to variable rainfall and high temperature. Economic loss was incurred by the producers and the community who used to depend on fish production, management and business

Table 5.36: List of climate change impact and adaptation options

Rank of Climate change impact	Rank of Potential adaptation option
1. Canal, streams are dried up due to high temperature	1. Enhance research and improve resilient fish varieties for the hilly areas
2. Extinction of local fish varieties due to the lack of water	2. Establish natural sanctuary where the local and indigenous fish could breed and propagate easily
3. Decrease in overall fish production in the hilly areas due to variable rainfall and high temperature	3. Raising awareness so that people are responsible and maintain a sustainable extraction and consumption
4. Reduction of natural fish sanctuaries in the areas	4. Improve the capacity of the fisher, producer and fish trader
5. Economic loss to the producers and the community who used to depend on fish production, management and business	5. Fish cultivation in pond, lake and stream (by constructing cross band)

Almost all participants recommended to enhance research in order improve resilient fish varieties in the hilly area. The current practice of fish cultivation and management needed to be upgraded so that the production is increased. They also called to establish natural sanctuaries where the local and indigenous fish could breed and propagate easily. Although the hilly districts are surrounded by a number of lakes, the community people seemed to be reluctant for the proper management. Improvement of the capacity of the fisher, producer and fish traders were also suggested by the participants while they felt that fish cultivation might be enhanced in the pond, lake and stream if by cross band was constructed.

5.5.8 Potential impacts and adaptation options of livestock

According to the hilly participants the heavy rainfall, hill slides caused consequential damage and loss of grassland along the hill and uplands. As a result, local farmer/farm owners confronted with the scarcity of green grass, fodder and trees in the entire area. Ultimately, that impacted the overall livestock and poultry resources. The participants reported the emergence of some new diseases for the livestock, which according to them, might have caused due to high and variable temperature and prolonged rainfall. They felt as a consequence, overall production of milk, meat and egg were reduced. Extinction of forest animals and birds due to loss of forest was observed by the participants and they also argued that there was less appearance of the migratory birds due to the change in the season, temperature and rainfall pattern.

Table 5.37: List of climate change impact and adaptation options

Rank of Climate change impact	Rank of Potential adaptation option
1. Loss of Livestock and Poultry Resources in the hilly uplands 2. Damage and loss of grassland due to hill slides as a result of heavy rainfall 3. Scarcity of green grass, fodder and trees in the entire area 4. The emergence of some new diseases for the livestock 5. Extinction of forest animals and birds due to loss of forest 6. The less appearance of the migratory birds due to the change in the season, temperature and rainfall pattern	1. Raise the awareness level of the community and the consumers 2. Save the forest resources (plants, animals and birds) 3. Enhance research to generate new varieties of animals, birds and technologies those could adapt in the hilly environment 4. Introduce and intensify the rearing and production of Goyal, Goat, Ship, Poultry 5. Improve the capacity of the farmers and the owners

The workshop participants suggested to raise the awareness level of the community and the consumers so that they became responsible and take part to save the forest resources (plants, animals and birds). All of them recommended to enhance research to generate new varieties of animals, birds and technologies those could adapt in the hilly environment. Intensification of rearing and production of goyal, goat, ship, poultry, etc. were also stressed by the local participants. They also advocated for the improvement of the capacity of the farmers and the owners.

5.6 Crosscutting urban areas

The Government of Bangladesh has already taken different initiative to enrich adaptive capacity, e.g. Urban Resilience Project, Dhaka Environmentally Sustainable Water Supply Project, Development of Dhaka Water Supply Network, Clean Air and Sustainable Environment, Greater Dhaka Sustainable Urban Transport Project, Improvement of Important Regional Highways to appropriate level and Width, Dhaka Mass Transit Development Project, etc.

5.6.1 Potential impact and adaptation options of water

The vulnerability of water resources is characterized by the depletion and degradation of ground water resources, the degradation of wetlands and beels and the degradation of rivers and waterbodies. Lower precipitation can lead to less groundwater recharge on the long term. Also sensitivity factors, such as a high water demand from irrigation or domestic and industrial water use can cause groundwater depletion. The release of pollutants from agriculture, sewage and from chemical industry negatively influences the water quality. Higher temperatures and low precipitation in the dry season can lead to a higher concentration of these pollutants in water bodies. Coastal floods influenced by sea level rise and storm surges and cyclones can increase salinization of water.

During the monsoon season, extreme precipitation from February to May (also coming from India) can lead to flash floods. River bank erosion and riverine floods can lead to siltation and water logging, which can be mitigated through water management (drainage, dredging or embankments).

Adaptive capacity factors include education and sensibilization, and water use planning and control. The latter includes water governance, investments for water management infrastructures, groundwater use control and integrated water resource management.

Table 1 Ranking of the climate change impacts and optention adaptation options

Rank of Climate change impact	**Rank of Potential adaptation option**
1. Domestic and industrial water demand in urban areas 2. Sanitation and water supply in rural areas 3. Irrigation demand 4. Landuse pressure 5. Water use allocation 6. Irrigation efficiency 7. Water management infrastructure 8. Sewage and water treatment in urban area and water scarce areas	1. Investment for water management infrastructure 2. Integrated water resources management by increasing water use efficiency 3. Water governance 4. Environmental awareness and education 5. Groundwater use control in groundwater critical areas

Although adaptive capacity factors are prioritized, they are all interlinked and should be considered as a system for reducing overall water resources vulnerability.

Adaptation options to reduce water resources vulnerability:

- Surface water preservation for dry period in large reservoirs e.g., Ganges barrage, Brahmaputra barrage;
- Riverbank protection and river dredging for flood control, drainage, and water uses;

- Alternate water supply in groundwater depletion and degradation area e.g., piped water supply, rain water harvesting, tara pump, deep set shallow tubewell, or deep tubewell with pump, etc.;
- Pollution control and use of surface water where available; and
- Use of Ganges river water for Barind area

5.6.2 Potential impact and adaptation options of navigation, transport and infrastructure

Potential climate change impacts on navigation, transport and infrastructure include the damage of roads, riverports and railways, reduced river navigability and aviation and the damage of critical infrastructure (electricity, sea port, telecom, water) and industries. In particular floods (flash floods, riverine and coastal floods) caused by higher precipitation during the monsoon in Bangladesh and India, sea level rise and cyclones and storm surges would harm this sector. Water management, like the presence of embankments, drainage and dredging can reduce the sensitivity of the system. The quality, climate resilience and the maintenance of infrastructure also determines its sensitivity, as well as socio-economic pressure coming from transport and energy demand. The adaptive capacity is influenced by the level of education and sensibilization, and existent national strategy and planning mechanism, like investments, construction regulations and skills, climate resilient planning, land use planning and research efforts on infrastructure needs.

Table 5.39: Ranking of the climate change impacts and optention adaptation options

Rank of Climate change impact	**Rank of Potential adaptation option**
1. International water treaty 2. Presence and maintenance of infrastructure 3. People dependent on critical infrastructure 4. Quality of infrastructure 5. Climate resilient infrastructure 6. Transport and energy demand 7. Dredging capacity	1. Climate resilient planning of infrastructure 2. Investments 3. Maintenance of infrastructure 4. Construction regulations and skills 5. Landuse planning & development control 6. Early warning of climatic disasters* 7. Awareness raising on early warning and disaster preparedness 8. Local governance improvement 9. Research on infrastructure needs

5.6.3 Potential impacts and adaptation options for health

The participants agreed with the impact chain framework, and proposed to add few elements in the areas of intermediary impacts, potential impacts, sensitivity factors, and adaptive capacity factors. They additionally mentioned new intermediary factors such as ground water lowering, arsenic concentration, poisoning in drinking water, and influenza transmission. Following the discussion, the participants pointed out the increasing rates of skin infections and diseases especially in the winter as potential impacts of changing climatic feature. In addition, they identified psychological shocks and trauma as potential outcomes of changing climatic conditions. In regard to psychological impacts of disasters, it is to be noted that women are more affected compared to male victims. Nahar and her colleagues revealed in their research on Bangladeshi disaster-affected people that a large proportion of the survivors who were women and poor were found to be traumatized and needed psychological support after disasters (Nahar et al. 2014). In this perspective, gendered psychological impacts may be included in sensitivity factors.

During the discussion on adaptive capacity issue, the participants emphasized the importance of reforestation and of behavior change communication (BCC). They additionally mentioned the occurrence of psychological shocks as one of potential impacts during and post disaster and as an obstacle to adaptive capacity. Although natural disasters' impact on community resilience to cope up with adverse situation remain largely unexplored in Bangladesh, several studies support evidence that extreme events generate unexpected shocks that lead to erosion of resilience among the communities (Adger and Vincent 2005). Additionally, few studies conducted in Bangladesh and south-Asian context showed that severe damage of household assets and community resources due natural calamities resulted in psychological shocks that further deteriorated health status of household members (Mazumdar et al. 2014; Saha 2016; Uddin and Mazur 2015).

Regarding the arsenic concentration and poisoning of drinking water, the existing literature suggests that vibrio infections, which result in bacterial diarrhea, are likely to increase due to global warming (Alter et al. 2011). Moreover, global literature stresses that a change in climatic conditions, and especially global warming, accelerates the rates of influenza and disease outbreaks in many countries (Brown and Rohani 2012; DE et al. 2016; Mirsaeidi et al. 2016; Vandegrift et al. 2010; Wang et al. 2015). Although the existing studies show little and/or no evidence on how climate change influences flu transmission, climate variability and extreme events are likely to affect the spread of microbes favoring the spread of flu under warm and humid conditions (Mani and Wang 2014). Furthermore, interspecies influenza transmission is likely to increase due to veterinary interactions (Donatelli et al. 2016). Such conditions will be perpetuated by a redistribution of infectious agents and some other social determinants of health, which are highly susceptible to climate change (Shahid 2010).

Following the identification of additional vulnerability components in each area of the impact chains, participants were asked to attribute a vote to the components they identified as key elements of vulnerability. The table below presents their priorities and ranking. For each component, the number of votes is presented in brackets.

Table 5.40: Human vulnerabilities and Health: Prioritization

Potential impact	**Adaptive options**
1. Change distribution of vector-borne insects [malaria & dengue] 2. Psychological shocks and trauma	1. Behavior change communication [BCC] 2. Investment in WatSan

Regarding health vulnerabilities, the participant highlighted two major adaptive actions of equal importance: Investment in WatSan and Behavior change communication (BCC). In particular, BCC should be very helpful for improving health conditions and healthcare accessibility of the inhabitants. Research shows that attitude and behaviour at the personal and social level have a strong relation with health conditions of women (Fikree and Pasha 2004& Story et al. 2012).

In addition, the participants identified several adaptation measures including awareness building, promoting environment friendly infrastructure, monitoring water quality & finding out alternative option, developing curriculum and integrating climate related health issues into community clinic, as well as priorities action oriented training and monitoring.

5.6.4 Potential impact and adaptation options of Human due to natural disaster

In regard to human vulnerabilities, the participants also identified some additional aspects in the areas of intermediary and potential impacts, sensitivity factors and adaptive capacity. Concerning intermediary factors, the participants supplemented siltation, water logging, rural sanitation, and salinity intrusion. Damages to physical communication infrastructures were identified as additional potential impacts of climate change. Regarding sensitivity factors, the participants mentioned "residential pattern" and "technical need assessment" as sensitive aspects. Effective communication among stakeholders, communities and actors was identified as an essential means of adapting to climate change. Among others, salinity intrusion was found to be crucial for human vulnerability. Yet, literature suggests that salinity intrusion is likely to increase due to the climate change, with key vulnerabilities in various aspects of lives and livelihoods (Huyakorn et al. 1987; Werner and Simmons 2009).

Following the identification of additional vulnerability components in each area of the impact chains, participants were asked to attribute a vote to the components they identified as key elements of vulnerability. The table below presents their priorities and ranking. For each component, the number of votes is presented in brackets.

Table 5.41: Human vulnerabilities and Health: Prioritization

Potential impact	**Adaptive options**
1. Damage and loss of household assets and livelihood	**1.** Effective communication between stakeholders, communities and actors during and post disaster
2. Infrastructure and physical communication damage	2. Local government improvement

the participants emphasized on two major adaptation options: i) Effective communication between stakeholder's communities and actors during and post disaster and ii) local government improvement. Ensuring an effective communication between stakeholder's communities and actors during and post disaster appears to be the key priority for adapting to climaplanned ways", "promoting gender sensitive infrastructure (e.g. separate room for female with toilets in cyclone shelter)", "ensure highest technical support to construct infrastructure", "promoting alternative livelihood option" and "taking preventive measures to reduce massive loss and damage".

Promoting gender sensitive infrastructure measure appears particularly important, as according to some research, damaged sanitation becomes a great problem for women after disasters (Rashid and Michaud 2000: CCC 2009).

5.6.5 Potential impact and adaptation options of biodiversity

The main updates to the draft impact chain on biodiversity were comprehensively discussed by the participants. The main conclusions are presented hereafter.

Regarding intermediate impacts, the participants added a component, "interconnection between wetlands and rivers", and left all other factors unchanged. Four potential impacts were submitted to the group: degradation and loss of forest and vegetation, degradation of char lands, wetlands and beels degradation and loss of marine biodiversity. After discussion, the participants proposed to reformulate the impacts as: "degradation and loss of forest and vegetation, wetlands and rivers degradation, degradation of char lands and island, and loss of marine biodiversity".

In regard to adaptive capacity, the participants reformulated "environmental and knowledge awareness raising" as "environmental capacity development and awareness raising" and "funds for ecosystem restoration” as “ecosystem restoration”. They deleted “efforts for developing ecotourism” and added two adaptive capacity factors: “strategic environmental assessment” and “real time monitoring of pollution”.

Table 5.42: Biodiversity: Prioritization

Potential impact	Adaptive capacity
1. Degradation and loss of forest and vegetation 2. Wetlands and river degradation 3. Loss of marine biodiversity 4. Degradation of char lands and island	1. Strategic environment assessment 2. Environmental capacity development and awareness raising 3. Species diversity 4. Ecosystem connectivity 5. Ecosystem restoration 6. Efforts for developing ecotourism 7. Protected areas and enforcement of laws 8. Real time monitoring of pollution

Biodiversity resilience is crucial to cope with climate change impacts. The adaptation options discussed by the group are presented hereafter: I. Update the threatened wildlife and undertake necessary steps for prevention of habit loss, II. Restore and rehabilitate forest (mangrove, non-mangrove and swamp), III. Monitor and maintain forest health, vitality and diversity, IV. Implement integrated forest fire management, V. Enhance landscape connectivity and reduce forest fragmentation, VI. Monitor and remove invasive species and address pest and disease threats, VII. Select appropriate species for use in planted forests, VIII. Community based adaptation to climate change through coastal afforestation, IX. Afforest and reforest by climate resilient participatory process, X. Re-vegetate forests through rehabilitation of forest dependent local and ethnic community, XI. Establish coastal greenbelt, XII. Develop agro-forestry, XII. Introduce alien species, XIII. Reduce habit fragmentation and promote establishment of migration corridors and buffer zones, and XIV. Integrate ecosystem planning and management.

5.6.6 Potential impacts and adaptation options of agriculture

One of the main climate impacts on agriculture is the change in precipitation in the dry season and during the monsoon due to the strong influence on water availability for agriculture and the influence on floods (riverine and flash floods). Floods and riverbank erosion can cause the degradation of soil quality and land loss. For flash floods, extreme precipitation in February and May in Bangladesh and India play a crucial role.

Sea level rise can increase the damage caused by coastal floods, storm surges and cyclones and can lead to land loss. Salinization because of relative sea level rise and lower discharge of rivers in the dry season can negatively influence soil quality.

Higher temperatures would particularly harm agriculture in combination with lower precipitation in the dry season and could lead to drought. Higher humidity levels would increase the likelihood of pest and crop diseases.

Whether these climate impacts are going to harm the agricultural sector also depends on the sensitivity of the agricultural system. The participants identified land pressure caused by urbanization and changes in land ownership as a sensitivity factor. Deforestation would lead to higher surface run off and could increase the likelihood of riverine and flash floods. High population density and the displacements of people add more pressure to the agricultural sector. Water management (existing embankments, irrigation and drainage efficiency and infrastructure) has the potential to mitigate climate impacts on the agricultural sector. Other important sensitivity factors are those related to agronomy (soil type, crop type/variety, chemicals/fertilizers/pesticides and intensive vs. extensive practices). With more woman working in agriculture, their role and empowerment in the agricultural sector needs to be considered.

The adaptive capacity of the agricultural sector is driven by education and sensibilization of farmers including gender sensitive vocational training. The adaptive capacity further depends on existing agronomic techniques such as quality of farm practices and technology or production inputs. National planning mechanism, such as governmental support, access to markets and fertilizers or insurance programs, also play a role in the adaptive capacity of the agricultural sector.

Several adaptation options/technologies were identified by the participating officers. They were categorized according to major production/cultivation essentials. While many of the options proposed are commonly known, the participants found them relevant and supported their promotion given the impending risks posed by climate change in various hotspots of Bangladesh. The options are provided in the tables below.

Table 5.43: Agriculture: Adaptation options

Quality of Farm Practices	Cropping Pattern	Degradation of Soil Quality	Irrigation and Water Use Efficiency	Soil Salinization
1. Flood/Drought/ Saline Tolerant Crop Varieties 2. Floating Agriculture 3. Sarjan (method) Cultivation 4. Water Reservoir 5. Rain Water Harvester	1. Zone/area based multiple cropping practices	1. Use Organic Manure 2. Cultivate Leguminus Crops	1. Alternative Wetting and Drying (AWD) Method 2. Plastic (fita) Pipe Irrigation	1. Improve and Maintain Embankment (at the coastal area)

5.6.7 Potential impacts and adaptation options for fisheries

The main potential impacts in the fisheries sector are the change in fish capture in floodplains, rivers, lakes, wetlands, ponds and the marine environment. The change in fish capture is driven by climate impacts, such as precipitation and the monsoon onset due to their influence on the river run off and consequently river connectivity. River water quality and fish health depends on the change in temperature and also on salt intrusion, which is also a result of sea level rise. This would also lead to a degradation and the loss of mangroves. Marine fish could be adversely affected by ocean acidification, higher ocean temperatures and storm surges and cyclones.

Whether these climate impacts are going to impact the fisheries sector also depends on the sensitivity of the system. The sensitivity is mainly driven by water management (drainage and embankments) and fishery management, which includes factors like overfishing, small mesh nets and the fish demand for food.

The adaptive capacity describes the ability of the system to adjust to these changes. It is mainly influenced by the availability of education and sensibilization, which also includes the involvement of woman in the fisheries sectors and environmental awareness. Moreover, law enforcement and existing hydraulic adaptation measures, such as sluice gates or investments in restoration and embankments play a role.

In addition to the above-mentioned options, Gender focused government loan would be helpful to increase equity and equality among the receivers of the agricultural sectors. This would be helpful to decrease the disparity among men and women involved in agricultural sectors.

Table 5.44: Fisheries: Adaptation options

Species Diversification	Change in Capture Fish	Water Quality	Restoration of Ecosystem
1. Establish hatchery to produce fingerlings of rear species	1. Community based wetland management	1. Maintain proper water depth in coastal/shrimp cultivation area	1. Establish zone based fish culture facility/system

5.6.8 Potential impacts and adaptation options for the livestock sector

Livestock vulnerability is characterized by land availability and water and feed availability, which impacts the productivity (or mortality) in the livestock sector. The main climate impacts on the livestock sector are temperature and precipitation in the dry season and during the monsoon due to their influence on feed production. Apart from climate impacts, also sensitivity factors have an impact on feed availability, such as water management and agricultural practices.

Sea level rise, coastal floods and riverine floods in combination with riverbank erosion could lead to land loss for the livestock sector. This also depends on socio-economic pressure on land due to urbanization or population growth.

Heatwaves, storm surges and cyclones could negatively impact cattle health and wellbeing and also lead to higher mortality rates. Also, pests and diseases could increase because of higher humidity levels. Sensitivity factors, such as the availability of early warning systems, killa, trees shading or vaccinations influence how susceptible the livestock sector is in terms of pests and diseases and cattle health in general.

The adaptive capacity of the livestock sector is characterized by the availability of education and sensibilization programs, including gender sensitive vocational training. Moreover, the improvement of agronomic techniques, and national planning mechanism, such as access to markets, finance and insurance programs have an impact on the adaptive capacity of the fisheries sector. The institutional setting, like for example the existence and enforcement of property rights also determines the adaptive capacity.

Table 5.45: Livestock: Adaptation options

Quality of Farm Practices and Technologies	Water and Feed Availability	Cattle Health and Wellbeing	Mortality	Storm Surge and Cyclone
1. Establishment of Model Farm for livestock 2. Safe production of milk and egg (for market) 3. Introduce ICT in cattle farming	1. Establish Quality Feed Mills/industries	1. Ensure balanced feed for livestock 2. Plantation of fodder trees 3. Cultivation of fodder crops (integrated with agriculture)	1. Improve and enact vaccination, medication and deworming	1. Establishment of Killa (with water availability) 2. Saline tolerant livestock rearing (buffalo, duck, sheep) 3. Ensure fresh drinking water 4. Cyclone tolerant cattle shed

6. Vulnerability Index

The decision to focus on vulnerabilities related to water, biodiversity, environment, agriculture (including livestock and fisheries), navigation, transport, infrastructure, health and security at the upazila level, was made keeping in mind Bangldaesh's climate and socioeconomic context, and having taken into consideration stakeholders expectations.

Within these sectors, the final choice of priority impacts (per sector) to investigate was based on a multicriteria analysis, assessing the relevance of the impacts (relation to climate change, link with other sustainable development goals, spatial scale and adaptation potential) and the operational feasibility of the mapping assessment (data availability, scientific knowledge, complexity and uncertainty).

This process led to the selection of 17 climate change impacts for investigation. For each impact, the assessment consisted of establishing an impact chain, selecting and treating relevant indicators to objectivize each vulnerability component and finally implementing the mapping exercise, for current (30 years average) and future vulnerability (2036-2065 and 2070-2099), for two RCP scenarios (RCP4.5 and 8.5).

Together with national experts, an updated list of 12 impact chains has been developed, based on data availability (see Table 2.2).

Table 6.1 : Nationwide Climate Vulnerability Index (0 means no vulnerability, 1 means highly vulnerable)

Division	District	Upazila	People Affected Due to Natural Disaster	Heat Stress	Ground Water Quality Depletion and Degradation	Mangrove Forest Vulnerability	Land Availabilty for Livestock	Water Availability	Crop Yield Vulnerability	Decrease in Livestock & Poultry Health Vulnerability	Land Availability for Agriculture	Change in Fish Culture	Change in Fish Capture	Rail Network Vulnerability	Road Network Vulnerability
Barisal	Barguna	Amtali	0.58	0.23	0.35		0.34	0.36	0.48	0.53	0.58	0.39	0.48	0.35	0.45
Barisal	Barguna	Bamna	0.50	0.30	0.45		0.43	0.51	0.51	0.64	0.42	0.27	0.29	0.21	0.38
Barisal	Barguna	Barguna Sadar	0.57	0.24	0.00		0.36	0.37	0.56	0.53	0.55	0.37	0.46	0.32	0.43
Barisal	Barguna	Betagi	0.35	0.30	0.31		0.43	0.51	0.51	0.64	0.42	0.27	0.29	0.21	0.38
Barisal	Barguna	Patharghata	0.56	0.37	0.38		0.42	0.51	0.58	0.62	0.47	0.22	0.29	0.28	0.31
Barisal	Barisal	Agailjhara	0.57	0.43	0.37		0.41	0.48	0.52	0.62	0.53	0.33	0.34	0.30	0.36
Barisal	Barisal	Babuganj	0.56	0.37	0.36		0.42	0.50	0.63	0.63	0.54	0.33	0.32	0.27	0.43
Barisal	Barisal	Bakerganj	0.59	0.32	0.31		0.41	0.53	0.52	0.59	0.57	0.31	0.29	0.29	0.45
Barisal	Barisal	Banari Para	0.57	0.42	0.36		0.42	0.48	0.51	0.62	0.50	0.30	0.31	0.28	0.41

Division	District	Upazila	People Affected Due to Natural Disaster	Heat Stress	Ground Water Quality Depletion and Degradation	Mangrove Forest Vulnerability	Land Availabilty for Livestock	Water Availability	Crop Yield Vulnerability	Decrease in Livestock & Poultry Health Vulnerability	Land Availability for Agriculture	Change in Fish Culture	Change in Fish Capture	Rail Network Vulnerability	Road Network Vulnerability
Barisal	Barisal	Barisal Sadar (Kotwali)	0.54	0.37	0.41		0.41	0.50	0.52	0.58	0.52	0.33	0.34	0.27	0.47
Barisal	Barisal	Gaurnadi	0.57	0.41	0.37		0.42	0.48	0.53	0.62	0.53	0.33	0.34	0.30	0.36
Barisal	Barisal	Hizla	0.80	0.45	0.46		0.47	0.49	0.50	0.68	0.67	0.42	0.58	0.44	0.39
Barisal	Barisal	Mehendiganj	0.80	0.40	0.46		0.45	0.44	0.50	0.66	0.67	0.33	0.49	0.33	0.39
Barisal	Barisal	Muladi	0.57	0.38	0.38		0.41	0.50	0.52	0.61	0.54	0.31	0.32	0.27	0.36
Barisal	Barisal	Wazirpur	0.57	0.32	0.37		0.41	0.48	0.56	0.62	0.53	0.33	0.34	0.30	0.37
Barisal	Bhola	Bhola Sadar	0.75	0.39	0.51		0.41	0.49	0.55	0.57	0.57	0.43	0.39	0.29	0.46
Barisal	Bhola	Burhanuddin	0.58	0.38	0.51		0.51	0.53	0.54	0.71	0.45	0.45	0.42	0.32	0.44
Barisal	Bhola	Char Fasson	0.56	0.23	0.41		0.37	0.38	0.64	0.52	0.64	0.39	0.53	0.39	0.41
Barisal	Bhola	Daulatkhan	0.59	0.38	0.55		0.52	0.53	0.51	0.58	0.47	0.39	0.42	0.36	0.46
Barisal	Bhola	Lalmohan	0.50	0.32	0.52		0.55	0.53	0.58	0.57	0.51	0.38	0.43	0.34	0.39
Barisal	Bhola	Manpura	0.61	0.26	0.00		0.43	0.39	0.51	0.59	0.57	0.43	0.52	0.29	0.40
Barisal	Bhola	Tazumuddin	0.60	0.40	0.44		0.43	0.53	0.54	0.70	0.53	0.32	0.39	0.30	0.35
Barisal	Jhalokati	Jhalokati Sadar	0.56	0.37	0.36		0.42	0.50	0.45	0.62	0.54	0.32	0.32	0.31	0.47
Barisal	Jhalokati	Kanthalia	0.35	0.31	0.31		0.43	0.51	0.54	0.62	0.42	0.25	0.29	0.21	0.34
Barisal	Jhalokati	Nalchity	0.56	0.37	0.33		0.42	0.49	0.49	0.64	0.54	0.36	0.36	0.25	0.48
Barisal	Jhalokati	Rajapur	0.56	0.46	0.31		0.43	0.53	0.51	0.59	0.40	0.27	0.24	0.19	0.49
Barisal	Patuakhali	Bauphal	0.72	0.37	0.40		0.49	0.49	0.55	0.57	0.44	0.47	0.44	0.19	0.44
Barisal	Patuakhali	Dashmina	0.50	0.23	0.52		0.40	0.39	0.59	0.54	0.58	0.42	0.49	0.32	0.46
Barisal	Patuakhali	Dumki	0.43	0.36	0.33		0.52	0.49	0.49	0.61	0.44	0.36	0.43	0.19	0.47
Barisal	Patuakhali	Galachipa	0.58	0.23	0.41		0.33	0.36	0.46	0.53	0.58	0.40	0.49	0.35	0.45
Barisal	Patuakhali	Kala Para	0.56	0.23	0.35		0.35	0.37	0.54	0.53	0.58	0.39	0.48	0.35	0.44
Barisal	Patuakhali	Mirzaganj	0.43	0.32	0.31		0.43	0.48	0.64	0.57	0.39	0.19	0.27	0.17	0.47
Barisal	Patuakhali	Patuakhali Sadar	0.47	0.39	0.31		0.36	0.37	0.56	0.55	0.48	0.40	0.48	0.22	0.44
Barisal	Pirojpur	Bhandaria	0.35	0.34	0.30		0.39	0.48	0.54	0.63	0.40	0.24	0.29	0.14	0.34
Barisal	Pirojpur	Kawkhali	0.56	0.34	0.36		0.44	0.50	0.55	0.60	0.40	0.30	0.26	0.24	0.49

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Barisal	Pirojpur	Mathbaria	0.44	0.31	0.45		0.40	0.51	0.51	0.62	0.42	0.29	0.31	0.21	0.39
Barisal	Pirojpur	Nazirpur	0.50	0.42	0.36		0.40	0.48	0.52	0.62	0.51	0.31	0.31	0.28	0.42
Barisal	Pirojpur	Nesarabad (Swarupkati)	0.56	0.41	0.36		0.43	0.48	0.53	0.59	0.40	0.33	0.30	0.25	0.49
Barisal	Pirojpur	Pirojpur Sadar	0.50	0.40	0.37		0.48	0.46	0.51	0.55	0.48	0.24	0.27	0.24	0.44
Barisal	Pirojpur	Zianagar	0.57	0.42	0.48		0.44	0.47	0.48	0.55	0.57	0.33	0.28	0.30	0.48
Chittagong	Bandarban	Alikadam	0.46	0.43	0.44		0.42	0.47	0.49	0.66	0.57	0.35	0.36	0.39	0.34
Chittagong	Bandarban	Bandarban Sadar	0.35	0.32	0.44		0.32	0.51	0.47	0.74	0.43	0.17	0.31	0.19	0.26
Chittagong	Bandarban	Lama	0.44	0.43	0.44		0.42	0.48	0.48	0.70	0.58	0.40	0.41	0.36	0.44
Chittagong	Bandarban	Naikhongchhari	0.44	0.43	0.44		0.44	0.48	0.52	0.70	0.58	0.40	0.41	0.36	0.43
Chittagong	Bandarban	Rowangchhari	0.35	0.48	0.44		0.28	0.50	0.51	0.77	0.49	0.17	0.31	0.19	0.30
Chittagong	Bandarban	Ruma	0.35	0.33	0.44		0.29	0.50	0.51	0.78	0.49	0.17	0.31	0.19	0.31
Chittagong	Bandarban	Thanchi	0.35	0.39	0.44		0.29	0.47	0.54	0.81	0.49	0.23	0.37	0.26	0.31
Chittagong	Brahamanbaria	Akhaura	0.46	0.35	0.59		0.44	0.61	0.48	0.67	0.52	0.27	0.28	0.37	0.38
Chittagong	Brahamanbaria	Ashuganj	0.41	0.33	0.60		0.37	0.59	0.48	0.71	0.52	0.23	0.25	0.27	0.32
Chittagong	Brahamanbaria	Banchharampur	0.44	0.34	0.68		0.35	0.64	0.51	0.67	0.62	0.24	0.27	0.33	0.40
Chittagong	Brahamanbaria	Bijoynagar	0.46	0.35	0.59		0.42	0.61	0.48	0.69	0.52	0.29	0.30	0.37	0.38
Chittagong	Brahamanbaria	Brahmanbaria Sadar	0.46	0.35	0.59		0.42	0.61	0.49	0.69	0.52	0.29	0.30	0.39	0.38
Chittagong	Brahamanbaria	Kasba	0.44	0.35	0.59		0.35	0.60	0.61	0.67	0.62	0.21	0.23	0.34	0.40
Chittagong	Brahamanbaria	Nabinagar	0.44	0.31	0.66		0.34	0.61	0.59	0.65	0.62	0.21	0.23	0.29	0.40
Chittagong	Brahamanbaria	Nasirnagar	0.45	0.36	0.61		0.37	0.62	0.54	0.66	0.57	0.26	0.32	0.27	0.36
Chittagong	Brahamanbaria	Sarail	0.45	0.42	0.60		0.38	0.59	0.44	0.69	0.59	0.24	0.30	0.26	0.35
Chittagong	Chandpur	Chandpur Sadar	0.54	0.45	0.49		0.40	0.53	0.63	0.64	0.66	0.28	0.33	0.48	0.37
Chittagong	Chandpur	Faridganj	0.57	0.37	0.49		0.45	0.53	0.54	0.67	0.53	0.40	0.55	0.26	0.42
Chittagong	Chandpur	Haim Char	0.80	0.45	0.46		0.48	0.49	0.54	0.66	0.67	0.42	0.58	0.44	0.38
Chittagong	Chandpur	Hajiganj	0.48	0.38	0.49		0.45	0.53	0.54	0.62	0.54	0.34	0.36	0.36	0.45

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Chittagong	Chandpur	Kachua	0.47	0.42	0.46		0.33	0.50	0.49	0.58	0.63	0.26	0.36	0.47	0.39
Chittagong	Chandpur	Matlab Dakshin	0.55	0.38	0.49		0.42	0.53	0.51	0.62	0.66	0.31	0.46	0.49	0.36
Chittagong	Chandpur	Matlab Uttar	0.45	0.39	0.49		0.35	0.53	0.49	0.67	0.54	0.26	0.30	0.26	0.33
Chittagong	Chandpur	Shahrasti	0.47	0.50	0.46		0.36	0.51	0.46	0.62	0.52	0.26	0.29	0.40	0.36
Chittagong	Chittagong	Anowara	0.64	0.25	0.47		0.43	0.50	0.49	0.66	0.50	0.31	0.32	0.24	0.36
Chittagong	Chittagong	Bakalia	0.38	0.26	0.41		0.34	0.46	0.51	0.68	0.47	0.13	0.22	0.22	0.23
Chittagong	Chittagong	Banshkhali	0.67	0.25	0.47		0.42	0.50	0.47	0.68	0.58	0.32	0.33	0.24	0.44
Chittagong	Chittagong	Bayejid Bostami	0.29	0.26	0.41		0.30	0.44	0.55	0.65	0.34	0.07	0.07	0.12	0.19
Chittagong	Chittagong	Boalkhali	0.40	0.19	0.42		0.35	0.46	0.49	0.64	0.47	0.16	0.19	0.28	0.31
Chittagong	Chittagong	Chandanaish	0.43	0.32	0.44		0.31	0.52	0.48	0.70	0.54	0.19	0.26	0.29	0.27
Chittagong	Chittagong	Chandgaon	0.29	0.30	0.41		0.30	0.45	0.64	0.65	0.33	0.08	0.09	0.14	0.18
Chittagong	Chittagong	Chittagong Port	0.61	0.31	0.38		0.42	0.43	0.54	0.63	0.37	0.17	0.23	0.16	0.26
Chittagong	Chittagong	Double Mooring	0.38	0.24	0.38		0.41	0.43	0.53	0.61	0.37	0.17	0.23	0.16	0.25
Chittagong	Chittagong	Fatikchhari	0.43	0.30	0.43		0.33	0.52	0.62	0.66	0.48	0.21	0.24	0.27	0.31
Chittagong	Chittagong	Halishahar	0.61	0.24	0.38		0.42	0.43	0.54	0.61	0.37	0.17	0.23	0.16	0.26
Chittagong	Chittagong	Hathazari	0.29	0.33	0.41		0.28	0.44	0.60	0.63	0.33	0.08	0.09	0.21	0.19
Chittagong	Chittagong	Khulshi	0.29	0.26	0.41		0.30	0.44	0.48	0.65	0.33	0.07	0.07	0.12	0.18
Chittagong	Chittagong	Kotwali	0.38	0.42	0.68		0.34	0.60	0.57	0.62	0.47	0.13	0.22	0.22	0.23
Chittagong	Chittagong	Lohagara	0.44	0.46	0.59		0.43	0.56	0.49	0.70	0.58	0.36	0.37	0.29	0.44
Chittagong	Chittagong	Mirsharai	0.62	0.30	0.43		0.43	0.53	0.46	0.65	0.53	0.30	0.27	0.39	0.42
Chittagong	Chittagong	Pahartali	0.38	0.50	0.38		0.43	0.44	0.48	0.61	0.40	0.15	0.21	0.21	0.27
Chittagong	Chittagong	Panchlaish	0.29	0.38	0.41		0.29	0.44	0.52	0.65	0.33	0.07	0.07	0.12	0.19
Chittagong	Chittagong	Patenga	0.61	0.32	0.38		0.42	0.43	0.54	0.63	0.37	0.17	0.23	0.16	0.26
Chittagong	Chittagong	Patiya	0.64	0.31	0.47		0.42	0.50	0.63	0.66	0.50	0.32	0.34	0.28	0.37
Chittagong	Chittagong	Rangunia	0.43	0.42	0.44		0.34	0.50	0.51	0.63	0.48	0.23	0.27	0.32	0.27
Chittagong	Chittagong	Raozan	0.43	0.33	0.48		0.34	0.52	0.51	0.66	0.48	0.19	0.22	0.27	0.27

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Chittagong	Chittagong	Sandwip	0.65	0.46	0.51		0.40	0.55	0.51	0.63	0.53	0.30	0.31	0.21	0.39
Chittagong	Chittagong	Satkania	0.43	0.41	0.44		0.30	0.52	0.49	0.70	0.54	0.19	0.26	0.26	0.28
Chittagong	Chittagong	Sitakunda	0.52	0.41	0.41		0.29	0.43	0.63	0.65	0.33	0.08	0.09	0.24	0.19
Chittagong	Comilla	Barura	0.47	0.41	0.54		0.35	0.51	0.55	0.62	0.52	0.27	0.30	0.40	0.36
Chittagong	Comilla	Brahman Para	0.44	0.34	0.63		0.36	0.60	0.49	0.67	0.62	0.20	0.23	0.32	0.39
Chittagong	Comilla	Burichang	0.70	0.36	0.63		0.36	0.62	0.48	0.66	0.54	0.25	0.34	0.31	0.37
Chittagong	Comilla	Chandina	0.44	0.41	0.54		0.36	0.51	0.64	0.65	0.62	0.27	0.30	0.37	0.40
Chittagong	Comilla	Chauddagram	0.45	0.33	0.59		0.35	0.61	0.52	0.63	0.55	0.23	0.26	0.37	0.45
Chittagong	Comilla	Comilla Adarsha Sadar	0.75	0.39	0.56		0.37	0.60	0.49	0.63	0.55	0.24	0.32	0.39	0.47
Chittagong	Comilla	Comilla Sadar Dakshin	0.47	0.39	0.56		0.35	0.60	0.51	0.62	0.52	0.25	0.28	0.47	0.37
Chittagong	Comilla	Daudkandi	0.46	0.42	0.54		0.33	0.51	0.52	0.66	0.53	0.27	0.33	0.37	0.30
Chittagong	Comilla	Debidwar	0.44	0.37	0.63		0.35	0.62	0.57	0.67	0.62	0.26	0.29	0.29	0.40
Chittagong	Comilla	Homna	0.46	0.34	0.68		0.34	0.63	0.51	0.66	0.53	0.24	0.30	0.33	0.30
Chittagong	Comilla	Laksam	0.47	0.38	0.56		0.36	0.60	0.56	0.62	0.52	0.24	0.27	0.47	0.36
Chittagong	Comilla	Manoharganj	0.47	0.38	0.56		0.36	0.60	0.52	0.62	0.52	0.24	0.27	0.39	0.36
Chittagong	Comilla	Meghna	0.46	0.41	0.58		0.34	0.59	0.49	0.69	0.53	0.24	0.29	0.37	0.30
Chittagong	Comilla	Muradnagar	0.44	0.34	0.68		0.34	0.64	0.48	0.65	0.62	0.28	0.31	0.33	0.40
Chittagong	Comilla	Nangalkot	0.47	0.33	0.59		0.35	0.61	0.61	0.62	0.52	0.23	0.26	0.40	0.36
Chittagong	Comilla	Titas	0.46	0.43	0.58		0.34	0.59	0.53	0.66	0.53	0.24	0.29	0.37	0.30
Chittagong	Cox'S Bazar	Chakaria	0.67	0.42	0.56		0.42	0.52	0.52	0.69	0.58	0.40	0.41	0.36	0.44
Chittagong	Cox'S Bazar	Cox'S Bazar Sadar	0.67	0.37	0.55		0.43	0.50	0.49	0.69	0.58	0.37	0.38	0.31	0.44
Chittagong	Cox'S Bazar	Kutubdia	0.55	0.35	0.57		0.40	0.54	0.53	0.70	0.63	0.28	0.44	0.42	0.37
Chittagong	Cox'S Bazar	Maheshkhali	0.67	0.45	0.55		0.43	0.50	0.54	0.69	0.58	0.37	0.38	0.31	0.43
Chittagong	Cox'S Bazar	Pekua	0.67	0.23	0.52		0.43	0.54	0.50	0.68	0.58	0.33	0.34	0.28	0.43
Chittagong	Cox'S Bazar	Ramu	0.44	0.33	0.54		0.43	0.48	0.48	0.67	0.58	0.41	0.42	0.36	0.44

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Chittagong	Cox'S Bazar	Teknaf	0.68	0.34	0.53		0.41	0.40	0.55	0.67	0.58	0.37	0.40	0.36	0.39
Chittagong	Cox'S Bazar	Ukhia	0.44	0.32	0.54		0.44	0.48	0.49	0.68	0.57	0.37	0.38	0.36	0.41
Chittagong	Feni	Chhagalnaiya	0.62	0.29	0.58		0.45	0.56	0.63	0.65	0.53	0.29	0.26	0.30	0.42
Chittagong	Feni	Daganbhuiyan	0.45	0.32	0.59		0.37	0.61	0.52	0.61	0.55	0.22	0.25	0.35	0.44
Chittagong	Feni	Feni Sadar	0.62	0.29	0.58		0.44	0.56	0.52	0.65	0.53	0.29	0.26	0.37	0.42
Chittagong	Feni	Fulgazi	0.62	0.33	0.56		0.45	0.54	0.55	0.68	0.52	0.31	0.28	0.29	0.42
Chittagong	Feni	Parshuram	0.41	0.41	0.55		0.44	0.55	0.53	0.67	0.43	0.30	0.27	0.32	0.42
Chittagong	Feni	Sonagazi	0.69	0.41	0.58		0.39	0.56	0.41	0.62	0.47	0.22	0.23	0.17	0.38
Chittagong	Khagrachhari	Dighinala	0.33	0.38	0.44		0.29	0.49	0.47	0.65	0.42	0.15	0.19	0.17	0.32
Chittagong	Khagrachhari	Khagrachhari Sadar	0.33	0.38	0.44		0.29	0.49	0.57	0.65	0.43	0.15	0.19	0.17	0.32
Chittagong	Khagrachhari	Lakshmichhari	0.43	0.30	0.43		0.36	0.52	0.53	0.67	0.48	0.17	0.21	0.27	0.30
Chittagong	Khagrachhari	Mahalchhari	0.33	0.35	0.44		0.29	0.47	0.55	0.67	0.42	0.15	0.19	0.15	0.28
Chittagong	Khagrachhari	Manikchhari	0.43	0.30	0.43		0.35	0.52	0.55	0.66	0.48	0.17	0.21	0.27	0.30
Chittagong	Khagrachhari	Matiranga	0.33	0.36	0.44		0.28	0.47	0.50	0.65	0.42	0.15	0.19	0.15	0.29
Chittagong	Khagrachhari	Panchhari	0.33	0.35	0.44		0.29	0.49	0.48	0.65	0.42	0.15	0.19	0.17	0.32
Chittagong	Khagrachhari	Ramgarh	0.43	0.37	0.43		0.35	0.52	0.53	0.66	0.48	0.17	0.21	0.27	0.30
Chittagong	Lakshmipur	Kamalnagar	0.61	0.34	0.47		0.40	0.54	0.54	0.69	0.58	0.31	0.38	0.30	0.37
Chittagong	Lakshmipur	Lakshmipur Sadar	0.80	0.45	0.46		0.43	0.49	0.61	0.66	0.67	0.44	0.60	0.44	0.40
Chittagong	Lakshmipur	Ramganj	0.57	0.41	0.46		0.47	0.51	0.51	0.67	0.58	0.42	0.58	0.26	0.44
Chittagong	Lakshmipur	Ramgati	0.61	0.30	0.44		0.39	0.51	0.49	0.68	0.58	0.30	0.37	0.26	0.37
Chittagong	Lakshmipur	Roypur	0.80	0.41	0.46		0.47	0.49	0.51	0.66	0.67	0.42	0.58	0.44	0.39
Chittagong	Noakhali	Begumganj	0.81	0.43	0.44		0.46	0.52	0.45	0.67	0.58	0.45	0.61	0.35	0.43
Chittagong	Noakhali	Chatkhil	0.47	0.38	0.56		0.36	0.59	0.56	0.60	0.47	0.24	0.27	0.34	0.39
Chittagong	Noakhali	Companiganj	0.69	0.33	0.51		0.39	0.56	0.51	0.61	0.47	0.24	0.24	0.18	0.38
Chittagong	Noakhali	Hatiya	0.60	0.23	0.39		0.38	0.37	0.51	0.62	0.53	0.32	0.39	0.26	0.36
Chittagong	Noakhali	Kabirhat	0.49	0.32	0.43		0.45	0.49	0.56	0.62	0.57	0.27	0.28	0.33	0.59

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Chittagong	Noakhali	Noakhali Sadar (Sudharam)	0.61	0.33	0.47		0.38	0.54	0.49	0.69	0.58	0.31	0.38	0.31	0.38
Chittagong	Noakhali	Senbagh	0.47	0.37	0.56		0.35	0.58	0.56	0.59	0.48	0.23	0.26	0.34	0.39
Chittagong	Noakhali	Sonaimuri	0.47	0.29	0.56		0.35	0.58	0.54	0.59	0.47	0.23	0.26	0.37	0.40
Chittagong	Noakhali	Subarnachar	0.61	0.49	0.53		0.39	0.58	0.52	0.68	0.58	0.32	0.40	0.30	0.37
Chittagong	Rangamati	Baghai Chhari	0.33	0.38	0.44		0.29	0.49	0.46	0.65	0.42	0.15	0.19	0.17	0.32
Chittagong	Rangamati	Barkal	0.33	0.38	0.44		0.29	0.47	0.50	0.74	0.42	0.16	0.20	0.18	0.36
Chittagong	Rangamati	Belai Chhari	0.35	0.32	0.44		0.28	0.50	0.45	0.73	0.49	0.17	0.31	0.25	0.25
Chittagong	Rangamati	Jurai Chhari	0.33	0.40	0.44		0.30	0.49	0.58	0.75	0.46	0.17	0.23	0.19	0.27
Chittagong	Rangamati	Kaptai	0.43	0.32	0.43		0.35	0.52	0.55	0.64	0.49	0.18	0.21	0.31	0.27
Chittagong	Rangamati	Kawkhali (Betbunia)	0.43	0.30	0.43		0.35	0.52	0.50	0.66	0.48	0.17	0.21	0.27	0.30
Chittagong	Rangamati	Langadu	0.33	0.37	0.44		0.29	0.49	0.48	0.67	0.42	0.15	0.19	0.17	0.32
Chittagong	Rangamati	Naniarchar	0.43	0.32	0.46		0.35	0.56	0.62	0.66	0.49	0.20	0.24	0.34	0.30
Chittagong	Rangamati	Rajasthali	0.35	0.43	0.44		0.29	0.50	0.51	0.72	0.49	0.17	0.31	0.19	0.25
Chittagong	Rangamati	Rangamati Sadar	0.33	0.37	0.44		0.29	0.49	0.46	0.71	0.47	0.17	0.23	0.19	0.25
Dhaka	Dhaka	Adabor	0.34	0.36	0.63		0.32	0.57	0.48	0.65	0.40	0.09	0.11	0.14	0.22
Dhaka	Dhaka	Badda	0.34	0.33	0.56		0.30	0.55	0.61	0.62	0.39	0.09	0.10	0.15	0.22
Dhaka	Dhaka	Bangshal	0.33	0.34	0.68		0.33	0.52	0.44	0.62	0.58	0.07	0.09	0.29	0.18
Dhaka	Dhaka	Biman Bandar	0.33	0.32	0.57		0.32	0.50	0.49	0.61	0.35	0.05	0.10	0.10	0.19
Dhaka	Dhaka	Cantonment	0.34	0.33	0.56		0.31	0.55	0.51	0.62	0.39	0.09	0.10	0.17	0.22
Dhaka	Dhaka	Chak Bazar	0.33	0.34	0.68		0.33	0.52	0.51	0.68	0.40	0.07	0.09	0.12	0.18
Dhaka	Dhaka	Dakshinkhan	0.33	0.32	0.57		0.32	0.50	0.53	0.63	0.35	0.05	0.10	0.10	0.19
Dhaka	Dhaka	Darus Salam	0.34	0.36	0.63		0.30	0.57	0.50	0.68	0.40	0.09	0.11	0.14	0.22
Dhaka	Dhaka	Demra	0.35	0.35	0.57		0.32	0.54	0.51	0.66	0.38	0.10	0.12	0.15	0.23
Dhaka	Dhaka	Dhamrai	0.50	0.36	0.66		0.37	0.62	0.54	0.67	0.70	0.23	0.28	0.40	0.37
Dhaka	Dhaka	Dhanmondi	0.32	0.33	0.59		0.34	0.70	0.54	0.54	0.32	0.03	0.07	0.07	0.18

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Dhaka	Dhaka	Dohar	0.50	0.38	0.52		0.37	0.56	0.55	0.69	0.64	0.20	0.25	0.37	0.37
Dhaka	Dhaka	Gendaria	0.35	0.35	0.66		0.33	0.53	0.62	0.67	0.39	0.07	0.12	0.12	0.20
Dhaka	Dhaka	Gulshan	0.34	0.33	0.56		0.30	0.55	0.60	0.60	0.39	0.09	0.10	0.15	0.22
Dhaka	Dhaka	Hazaribagh	0.32	0.33	0.59		0.36	0.70	0.48	0.56	0.31	0.03	0.07	0.07	0.18
Dhaka	Dhaka	Jatrabari	0.35	0.35	0.57		0.31	0.54	0.44	0.64	0.39	0.10	0.12	0.15	0.24
Dhaka	Dhaka	Kadamtali	0.35	0.35	0.57		0.32	0.54	0.57	0.64	0.39	0.10	0.12	0.15	0.23
Dhaka	Dhaka	Kafrul	0.35	0.33	0.55		0.30	0.53	0.48	0.64	0.39	0.07	0.12	0.10	0.22
Dhaka	Dhaka	Kalabagan	0.32	0.33	0.59		0.36	0.70	0.54	0.58	0.32	0.03	0.07	0.07	0.21
Dhaka	Dhaka	Kamrangir Char	0.33	0.34	0.69		0.32	0.57	0.54	0.64	0.40	0.08	0.09	0.13	0.18
Dhaka	Dhaka	Keraniganj	0.32	0.35	0.68		0.30	0.52	0.56	0.63	0.33	0.07	0.09	0.12	0.19
Dhaka	Dhaka	Khilgaon	0.34	0.33	0.56		0.30	0.55	0.48	0.62	0.39	0.09	0.10	0.15	0.22
Dhaka	Dhaka	Khilkhet	0.34	0.33	0.56		0.31	0.55	0.47	0.62	0.39	0.09	0.10	0.15	0.22
Dhaka	Dhaka	Kotwali	0.33	0.26	0.68		0.33	0.46	0.56	0.62	0.58	0.07	0.09	0.29	0.18
Dhaka	Dhaka	Lalbagh	0.32	0.34	0.69		0.32	0.57	0.57	0.60	0.33	0.08	0.09	0.13	0.18
Dhaka	Dhaka	Mirpur	0.34	0.36	0.63		0.30	0.57	0.57	0.68	0.40	0.09	0.11	0.14	0.22
Dhaka	Dhaka	Mohammadpur	0.34	0.36	0.63		0.31	0.57	0.48	0.65	0.40	0.09	0.11	0.14	0.22
Dhaka	Dhaka	Motijheel	0.34	0.33	0.57		0.32	0.55	0.53	0.60	0.39	0.09	0.10	0.14	0.21
Dhaka	Dhaka	Nawabganj	0.50	0.38	0.52		0.36	0.56	0.56	0.69	0.64	0.20	0.25	0.37	0.37
Dhaka	Dhaka	New Market	0.32	0.33	0.59		0.36	0.70	0.55	0.59	0.32	0.03	0.07	0.07	0.18
Dhaka	Dhaka	Pallabi	0.35	0.38	0.55		0.29	0.53	0.43	0.62	0.38	0.07	0.12	0.10	0.22
Dhaka	Dhaka	Paltan	0.35	0.33	0.56		0.32	0.53	0.43	0.66	0.40	0.08	0.12	0.11	0.22
Dhaka	Dhaka	Ramna	0.35	0.33	0.56		0.32	0.53	0.48	0.60	0.40	0.08	0.12	0.11	0.22
Dhaka	Dhaka	Rampura	0.34	0.35	0.56		0.31	0.55	0.49	0.62	0.39	0.09	0.10	0.15	0.22
Dhaka	Dhaka	Sabujbagh	0.35	0.36	0.57		0.32	0.54	0.54	0.66	0.38	0.10	0.12	0.15	0.23
Dhaka	Dhaka	Savar	0.34	0.38	0.63		0.29	0.57	0.53	0.66	0.40	0.09	0.11	0.14	0.22
Dhaka	Dhaka	Shah Ali	0.34	0.36	0.63		0.32	0.58	0.53	0.68	0.41	0.10	0.14	0.15	0.14

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Dhaka	Dhaka	Shahbagh	0.33	0.41	0.68		0.34	0.51	0.55	0.66	0.40	0.07	0.09	0.12	0.21
Dhaka	Dhaka	Sher-e-bangla Nagar	0.34	0.46	0.62		0.32	0.56	0.46	0.68	0.40	0.04	0.06	0.10	0.22
Dhaka	Dhaka	Shyampur	0.35	0.37	0.66		0.33	0.53	0.54	0.65	0.39	0.07	0.12	0.12	0.20
Dhaka	Dhaka	Sutrapur	0.35	0.44	0.68		0.33	0.52	0.52	0.65	0.39	0.07	0.12	0.12	0.21
Dhaka	Dhaka	Tejgaon	0.35	0.33	0.55		0.31	0.53	0.53	0.61	0.39	0.07	0.12	0.10	0.22
Dhaka	Dhaka	Tejgaon Ind. Area	0.34	0.33	0.56		0.32	0.54	0.58	0.60	0.39	0.06	0.11	0.15	0.22
Dhaka	Dhaka	Turag	0.33	0.43	0.57		0.32	0.50	0.53	0.63	0.35	0.05	0.10	0.10	0.19
Dhaka	Dhaka	Uttar Khan	0.33	0.44	0.57		0.33	0.51	0.53	0.65	0.35	0.10	0.12	0.10	0.21
Dhaka	Dhaka	Uttara	0.33	0.32	0.57		0.31	0.50	0.52	0.61	0.35	0.05	0.10	0.12	0.19
Dhaka	Faridpur	Alfadanga	0.44	0.46	0.59		0.35	0.56	0.49	0.70	0.56	0.21	0.25	0.30	0.32
Dhaka	Faridpur	Bhanga	0.51	0.43	0.57		0.39	0.57	0.55	0.67	0.70	0.26	0.31	0.43	0.34
Dhaka	Faridpur	Boalmari	0.44	0.46	0.59		0.34	0.56	0.51	0.70	0.56	0.21	0.25	0.38	0.32
Dhaka	Faridpur	Char Bhadrasan	0.50	0.39	0.52		0.38	0.56	0.62	0.69	0.64	0.20	0.25	0.37	0.37
Dhaka	Faridpur	Faridpur Sadar	0.44	0.48	0.60		0.33	0.57	0.52	0.71	0.68	0.25	0.29	0.57	0.36
Dhaka	Faridpur	Madhukhali	0.44	0.48	0.60		0.35	0.57	0.56	0.69	0.68	0.23	0.27	0.57	0.35
Dhaka	Faridpur	Nagarkanda	0.51	0.43	0.57		0.38	0.57	0.62	0.67	0.71	0.26	0.31	0.46	0.34
Dhaka	Faridpur	Sadarpur	0.50	0.35	0.52		0.36	0.56	0.59	0.69	0.64	0.20	0.25	0.37	0.37
Dhaka	Faridpur	Saltha	0.44	0.31	0.60		0.33	0.57	0.53	0.68	0.68	0.23	0.27	0.49	0.35
Dhaka	Gazipur	Gazipur Sadar	0.33	0.32	0.57		0.29	0.51	0.61	0.66	0.36	0.12	0.14	0.25	0.15
Dhaka	Gazipur	Kaliakair	0.50	0.35	0.66		0.37	0.62	0.51	0.67	0.70	0.25	0.30	0.45	0.37
Dhaka	Gazipur	Kaliganj	0.34	0.33	0.56		0.31	0.55	0.57	0.63	0.39	0.11	0.13	0.18	0.23
Dhaka	Gazipur	Kapasia	0.34	0.21	0.59		0.29	0.57	0.51	0.64	0.58	0.12	0.13	0.41	0.21
Dhaka	Gazipur	Sreepur	0.38	0.38	0.58		0.29	0.52	0.55	0.64	0.39	0.12	0.13	0.33	0.19
Dhaka	Gopalganj	Gopalganj Sadar	0.56	0.40	0.54		0.37	0.61	0.46	0.57	0.50	0.35	0.36	0.27	0.42
Dhaka	Gopalganj	Kashiani	0.44	0.46	0.59		0.33	0.56	0.55	0.70	0.55	0.23	0.27	0.33	0.33

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Dhaka	Gopalganj	Kotali Para	0.57	0.43	0.37		0.39	0.48	0.65	0.62	0.53	0.33	0.34	0.30	0.37
Dhaka	Gopalganj	Muksudpur	0.51	0.43	0.57		0.38	0.57	0.52	0.67	0.70	0.28	0.32	0.43	0.34
Dhaka	Gopalganj	Tungi Para	0.54	0.32	0.44		0.40	0.49	0.58	0.57	0.47	0.33	0.35	0.27	0.40
Dhaka	Jamalpur	Bakshiganj	0.51	0.44	0.65		0.45	0.68	0.51	0.66	0.67	0.40	0.40	0.38	0.50
Dhaka	Jamalpur	Dewanganj	0.51	0.44	0.65		0.45	0.68	0.56	0.66	0.67	0.40	0.40	0.40	0.50
Dhaka	Jamalpur	Islampur	0.51	0.45	0.65		0.44	0.68	0.51	0.66	0.67	0.40	0.40	0.40	0.50
Dhaka	Jamalpur	Jamalpur Sadar	0.56	0.41	0.73		0.34	0.67	0.51	0.55	0.72	0.32	0.37	0.76	0.45
Dhaka	Jamalpur	Madarganj	0.56	0.46	0.66		0.44	0.67	0.54	0.66	0.76	0.52	0.53	0.56	0.50
Dhaka	Jamalpur	Melandaha	0.56	0.46	0.66		0.44	0.67	0.50	0.64	0.77	0.52	0.53	0.61	0.50
Dhaka	Jamalpur	Sarishabari	0.56	0.46	0.73		0.37	0.67	0.49	0.57	0.72	0.32	0.37	0.66	0.44
Dhaka	Kishoreganj	Austagram	0.45	0.42	0.58		0.38	0.61	0.47	0.66	0.57	0.29	0.35	0.30	0.36
Dhaka	Kishoreganj	Bajitpur	0.45	0.42	0.58		0.38	0.61	0.52	0.66	0.57	0.29	0.35	0.34	0.36
Dhaka	Kishoreganj	Bhairab	0.45	0.33	0.58		0.39	0.63	0.51	0.71	0.59	0.22	0.28	0.31	0.35
Dhaka	Kishoreganj	Hossainpur	0.40	0.40	0.64		0.35	0.64	0.53	0.68	0.53	0.21	0.23	0.28	0.31
Dhaka	Kishoreganj	Itna	0.41	0.40	0.62		0.35	0.61	0.55	0.68	0.55	0.27	0.36	0.29	0.34
Dhaka	Kishoreganj	Karimganj	0.41	0.41	0.62		0.35	0.61	0.60	0.68	0.55	0.27	0.36	0.29	0.35
Dhaka	Kishoreganj	Katiadi	0.45	0.43	0.59		0.37	0.61	0.54	0.69	0.59	0.27	0.34	0.37	0.35
Dhaka	Kishoreganj	Kishoreganj Sadar	0.40	0.40	0.64		0.33	0.64	0.62	0.68	0.53	0.21	0.23	0.34	0.31
Dhaka	Kishoreganj	Kuliar Char	0.45	0.43	0.59		0.39	0.61	0.56	0.69	0.59	0.27	0.34	0.37	0.35
Dhaka	Kishoreganj	Mithamain	0.45	0.43	0.60		0.38	0.62	0.45	0.66	0.57	0.29	0.35	0.33	0.37
Dhaka	Kishoreganj	Nikli	0.45	0.43	0.60		0.38	0.62	0.49	0.66	0.57	0.29	0.35	0.33	0.36
Dhaka	Kishoreganj	Pakundia	0.49	0.41	0.59		0.34	0.60	0.53	0.59	0.55	0.23	0.28	0.26	0.27
Dhaka	Kishoreganj	Tarail	0.41	0.38	0.62		0.36	0.61	0.48	0.68	0.55	0.27	0.36	0.29	0.35
Dhaka	Madaripur	Kalkini	0.57	0.43	0.38		0.40	0.49	0.58	0.62	0.53	0.34	0.35	0.30	0.37
Dhaka	Madaripur	Madaripur Sadar	0.58	0.44	0.38		0.38	0.48	0.55	0.61	0.46	0.34	0.35	0.28	0.38
Dhaka	Madaripur	Rajoir	0.51	0.39	0.57		0.39	0.57	0.45	0.67	0.70	0.26	0.31	0.43	0.34

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Dhaka	Madaripur	Shib Char	0.51	0.46	0.57		0.38	0.57	0.56	0.67	0.71	0.28	0.32	0.43	0.34
Dhaka	Manikganj	Daulatpur	0.52	0.49	0.62		0.37	0.64	0.50	0.71	0.73	0.30	0.37	0.45	0.37
Dhaka	Manikganj	Ghior	0.52	0.49	0.62		0.38	0.64	0.62	0.71	0.73	0.30	0.37	0.45	0.37
Dhaka	Manikganj	Harirampur	0.50	0.39	0.52		0.37	0.56	0.59	0.69	0.64	0.20	0.25	0.37	0.37
Dhaka	Manikganj	Manikganj Sadar	0.50	0.38	0.66		0.37	0.62	0.53	0.69	0.70	0.23	0.28	0.40	0.37
Dhaka	Manikganj	Saturia	0.50	0.51	0.66		0.38	0.62	0.53	0.67	0.70	0.23	0.28	0.40	0.37
Dhaka	Manikganj	Shibalaya	0.52	0.42	0.62		0.38	0.64	0.54	0.71	0.73	0.30	0.37	0.45	0.38
Dhaka	Manikganj	Singair	0.50	0.35	0.66		0.37	0.62	0.52	0.66	0.70	0.23	0.28	0.40	0.37
Dhaka	Munshiganj	Gazaria	0.46	0.41	0.47		0.34	0.53	0.54	0.66	0.54	0.23	0.29	0.34	0.30
Dhaka	Munshiganj	Lohajang	0.51	0.42	0.57		0.41	0.56	0.48	0.67	0.71	0.27	0.32	0.44	0.35
Dhaka	Munshiganj	Munshiganj Sadar	0.45	0.41	0.47		0.36	0.54	0.61	0.67	0.54	0.23	0.28	0.27	0.33
Dhaka	Munshiganj	Serajdikhan	0.33	0.39	0.71		0.31	0.63	0.55	0.62	0.58	0.11	0.12	0.33	0.24
Dhaka	Munshiganj	Sreenagar	0.50	0.39	0.52		0.37	0.56	0.46	0.67	0.64	0.20	0.25	0.37	0.37
Dhaka	Munshiganj	Tongibari	0.52	0.40	0.51		0.40	0.55	0.53	0.66	0.71	0.27	0.35	0.42	0.35
Dhaka	Mymensingh	Bhaluka	0.39	0.22	0.62		0.30	0.61	0.54	0.57	0.51	0.24	0.26	0.38	0.37
Dhaka	Mymensingh	Dhobaura	0.51	0.48	0.68		0.42	0.65	0.60	0.66	0.58	0.44	0.45	0.37	0.48
Dhaka	Mymensingh	Fulbaria	0.42	0.32	0.59		0.30	0.65	0.56	0.56	0.56	0.32	0.34	0.27	0.42
Dhaka	Mymensingh	Gaffargaon	0.49	0.30	0.59		0.31	0.60	0.54	0.61	0.55	0.35	0.40	0.34	0.28
Dhaka	Mymensingh	Gauripur	0.44	0.44	0.68		0.32	0.64	0.51	0.64	0.54	0.34	0.36	0.44	0.41
Dhaka	Mymensingh	Haluaghat	0.51	0.49	0.68		0.41	0.65	0.52	0.66	0.58	0.48	0.48	0.37	0.48
Dhaka	Mymensingh	Ishwarganj	0.44	0.44	0.68		0.32	0.64	0.53	0.64	0.54	0.34	0.36	0.44	0.42
Dhaka	Mymensingh	Muktagachha	0.56	0.41	0.73		0.37	0.67	0.52	0.55	0.72	0.41	0.46	0.59	0.45
Dhaka	Mymensingh	Mymensingh Sadar	0.56	0.41	0.73		0.36	0.67	0.50	0.55	0.72	0.43	0.48	0.76	0.45
Dhaka	Mymensingh	Nandail	0.40	0.40	0.64		0.31	0.64	0.61	0.68	0.53	0.32	0.34	0.33	0.32
Dhaka	Mymensingh	Phulpur	0.51	0.43	0.68		0.37	0.65	0.52	0.66	0.58	0.55	0.55	0.37	0.49

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Dhaka	Mymensingh	Trishal	0.42	0.41	0.59		0.30	0.65	0.57	0.56	0.56	0.30	0.33	0.32	0.42
Dhaka	Narayanganj	Araihazar	0.46	0.35	0.68		0.33	0.63	0.49	0.67	0.53	0.23	0.28	0.33	0.31
Dhaka	Narayanganj	Bandar	0.55	0.39	0.47		0.36	0.52	0.45	0.68	0.67	0.26	0.30	0.45	0.34
Dhaka	Narayanganj	Narayanganj Sadar	0.35	0.35	0.57		0.31	0.54	0.54	0.64	0.39	0.10	0.12	0.19	0.24
Dhaka	Narayanganj	Rupganj	0.34	0.32	0.56		0.30	0.55	0.55	0.64	0.39	0.09	0.10	0.15	0.23
Dhaka	Narayanganj	Sonargaon	0.46	0.39	0.61		0.34	0.61	0.52	0.66	0.54	0.22	0.27	0.35	0.25
Dhaka	Narsingdi	Belabo	0.41	0.35	0.58		0.36	0.63	0.45	0.73	0.52	0.25	0.28	0.27	0.32
Dhaka	Narsingdi	Manohardi	0.49	0.30	0.59		0.33	0.60	0.59	0.61	0.54	0.25	0.30	0.26	0.27
Dhaka	Narsingdi	Narsingdi Sadar	0.44	0.35	0.68		0.33	0.64	0.53	0.69	0.62	0.24	0.30	0.35	0.30
Dhaka	Narsingdi	Palash	0.34	0.30	0.59		0.33	0.57	0.54	0.66	0.58	0.10	0.11	0.43	0.21
Dhaka	Narsingdi	Roypura	0.41	0.45	0.58		0.34	0.63	0.50	0.73	0.52	0.24	0.27	0.34	0.32
Dhaka	Narsingdi	Shibpur	0.49	0.48	0.59		0.33	0.60	0.51	0.61	0.55	0.25	0.30	0.26	0.27
Dhaka	Netrakona	Atpara	0.42	0.41	0.69		0.39	0.64	0.46	0.67	0.58	0.27	0.29	0.29	0.37
Dhaka	Netrakona	Barhatta	0.42	0.41	0.69		0.39	0.64	0.55	0.67	0.58	0.27	0.29	0.34	0.37
Dhaka	Netrakona	Durgapur	0.51	0.48	0.68		0.45	0.65	0.48	0.68	0.58	0.37	0.38	0.37	0.48
Dhaka	Netrakona	Kalmakanda	0.48	0.41	0.68		0.37	0.62	0.54	0.68	0.61	0.28	0.36	0.42	0.38
Dhaka	Netrakona	Kendua	0.41	0.38	0.62		0.35	0.62	0.55	0.69	0.57	0.25	0.34	0.27	0.36
Dhaka	Netrakona	Khaliajuri	0.41	0.40	0.62		0.36	0.61	0.65	0.68	0.55	0.27	0.36	0.29	0.34
Dhaka	Netrakona	Madan	0.41	0.40	0.62		0.35	0.61	0.48	0.68	0.55	0.27	0.36	0.29	0.35
Dhaka	Netrakona	Mohanganj	0.42	0.41	0.69		0.39	0.64	0.46	0.67	0.58	0.27	0.29	0.30	0.37
Dhaka	Netrakona	Netrokona Sadar	0.44	0.43	0.68		0.32	0.64	0.54	0.64	0.54	0.25	0.27	0.44	0.41
Dhaka	Netrakona	Purbadhala	0.51	0.42	0.68		0.41	0.65	0.52	0.66	0.58	0.37	0.38	0.47	0.48
Dhaka	Rajbari	Balia Kandi	0.52	0.49	0.63		0.33	0.55	0.53	0.65	0.68	0.30	0.35	0.55	0.32
Dhaka	Rajbari	Goalandaghat	0.53	0.49	0.63		0.33	0.55	0.60	0.67	0.70	0.32	0.37	0.52	0.33
Dhaka	Rajbari	Kalukhali	0.51	0.48	0.63		0.39	0.56	0.53	0.66	0.66	0.31	0.36	0.51	0.40

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Dhaka	Rajbari	Pangsha	0.54	0.26	0.62		0.40	0.56	0.58	0.69	0.69	0.35	0.40	0.51	0.38
Dhaka	Rajbari	Rajbari Sadar	0.53	0.32	0.63		0.30	0.55	0.50	0.67	0.70	0.34	0.39	0.58	0.34
Dhaka	Shariatpur	Bhedarganj	0.55	0.38	0.49		0.34	0.54	0.54	0.66	0.67	0.30	0.34	0.43	0.34
Dhaka	Shariatpur	Damudya	0.58	0.37	0.38		0.43	0.51	0.49	0.61	0.56	0.28	0.29	0.34	0.41
Dhaka	Shariatpur	Gosairhat	0.56	0.46	0.46		0.47	0.49	0.54	0.66	0.67	0.40	0.56	0.44	0.39
Dhaka	Shariatpur	Naria	0.55	0.39	0.47		0.35	0.52	0.54	0.66	0.67	0.27	0.31	0.45	0.34
Dhaka	Shariatpur	Shariatpur Sadar	0.58	0.47	0.38		0.42	0.51	0.49	0.61	0.56	0.30	0.31	0.34	0.41
Dhaka	Shariatpur	Zanjira	0.52	0.35	0.51		0.40	0.53	0.46	0.58	0.66	0.25	0.24	0.45	0.37
Dhaka	Sherpur	Jhenaigati	0.52	0.38	0.63		0.48	0.62	0.59	0.63	0.65	0.39	0.40	0.37	0.50
Dhaka	Sherpur	Nakla	0.56	0.41	0.73		0.39	0.67	0.51	0.55	0.72	0.31	0.35	0.59	0.44
Dhaka	Sherpur	Nalitabari	0.51	0.48	0.67		0.40	0.63	0.61	0.64	0.56	0.37	0.38	0.35	0.48
Dhaka	Sherpur	Sherpur Sadar	0.56	0.41	0.66		0.42	0.67	0.55	0.64	0.77	0.52	0.53	0.56	0.51
Dhaka	Sherpur	Sreebardi	0.51	0.27	0.65		0.45	0.68	0.59	0.66	0.67	0.40	0.40	0.38	0.50
Dhaka	Tangail	Basail	0.49	0.35	0.64		0.39	0.64	0.52	0.69	0.69	0.25	0.31	0.42	0.36
Dhaka	Tangail	Bhuapur	0.56	0.41	0.74		0.37	0.67	0.47	0.57	0.70	0.31	0.36	0.60	0.43
Dhaka	Tangail	Delduar	0.49	0.36	0.64		0.39	0.64	0.57	0.69	0.69	0.25	0.31	0.39	0.36
Dhaka	Tangail	Dhanbari	0.56	0.41	0.73		0.39	0.67	0.57	0.55	0.72	0.31	0.35	0.59	0.44
Dhaka	Tangail	Ghatail	0.42	0.33	0.59		0.29	0.65	0.56	0.58	0.57	0.21	0.24	0.27	0.42
Dhaka	Tangail	Gopalpur	0.56	0.40	0.74		0.37	0.67	0.56	0.55	0.70	0.31	0.36	0.58	0.43
Dhaka	Tangail	Kalihati	0.49	0.35	0.64		0.38	0.64	0.60	0.67	0.69	0.25	0.31	0.44	0.36
Dhaka	Tangail	Madhupur	0.56	0.41	0.73		0.37	0.67	0.54	0.57	0.72	0.32	0.37	0.59	0.45
Dhaka	Tangail	Mirzapur	0.50	0.36	0.66		0.36	0.62	0.60	0.67	0.70	0.25	0.30	0.46	0.37
Dhaka	Tangail	Nagarpur	0.50	0.38	0.66		0.37	0.62	0.62	0.67	0.70	0.25	0.30	0.40	0.37
Dhaka	Tangail	Sakhipur	0.50	0.40	0.64		0.35	0.58	0.50	0.68	0.50	0.22	0.27	0.21	0.38
Dhaka	Tangail	Tangail Sadar	0.49	0.45	0.64		0.37	0.64	0.60	0.69	0.69	0.25	0.31	0.42	0.36
Khulna	Bagerhat	Bagerhat Sadar	0.45	0.35	0.46		0.40	0.49	0.59	0.58	0.48	0.25	0.26	0.34	0.42

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Khulna	Bagerhat	Chitalmari	0.54	0.42	0.47		0.39	0.49	0.55	0.57	0.46	0.32	0.33	0.27	0.47
Khulna	Bagerhat	Fakirhat	0.45	0.36	0.46		0.42	0.49	0.55	0.58	0.48	0.25	0.26	0.32	0.42
Khulna	Bagerhat	Kachua	0.50	0.39	0.46		0.42	0.50	0.55	0.58	0.53	0.33	0.29	0.41	0.47
Khulna	Bagerhat	Mollahat	0.56	0.38	0.51		0.39	0.61	0.47	0.57	0.47	0.32	0.34	0.24	0.40
Khulna	Bagerhat	Mongla	0.63	0.35	0.45	0.67	0.41	0.35	0.48	0.58	0.47	0.31	0.36	0.26	0.36
Khulna	Bagerhat	Morrelganj	0.45	0.36	0.48		0.39	0.51	0.55	0.56	0.48	0.26	0.27	0.25	0.42
Khulna	Bagerhat	Rampal	0.45	0.34	0.46		0.41	0.49	0.60	0.58	0.48	0.25	0.26	0.29	0.42
Khulna	Bagerhat	Sarankhola	0.60	0.32	0.42	0.70	0.41	0.43	0.48	0.61	0.47	0.23	0.29	0.18	0.36
Khulna	Chuadanga	Alamdanga	0.50	0.48	0.66		0.35	0.59	0.51	0.63	0.68	0.26	0.31	0.51	0.41
Khulna	Chuadanga	Chuadanga Sadar	0.50	0.48	0.66		0.36	0.59	0.52	0.63	0.68	0.26	0.31	0.51	0.41
Khulna	Chuadanga	Damurhuda	0.50	0.48	0.66		0.36	0.59	0.58	0.63	0.68	0.26	0.31	0.55	0.40
Khulna	Chuadanga	Jiban Nagar	0.50	0.47	0.65		0.37	0.60	0.57	0.65	0.58	0.25	0.30	0.38	0.41
Khulna	Jessore	Abhaynagar	0.44	0.42	0.58		0.33	0.60	0.50	0.63	0.51	0.25	0.28	0.38	0.35
Khulna	Jessore	Bagher Para	0.53	0.47	0.64		0.37	0.63	0.50	0.64	0.67	0.32	0.36	0.44	0.42
Khulna	Jessore	Chaugachha	0.53	0.48	0.65		0.40	0.63	0.51	0.65	0.69	0.32	0.37	0.44	0.41
Khulna	Jessore	Jhikargachha	0.53	0.46	0.65		0.39	0.63	0.57	0.65	0.69	0.34	0.39	0.49	0.41
Khulna	Jessore	Keshabpur	0.46	0.45	0.61		0.34	0.62	0.57	0.63	0.54	0.28	0.32	0.33	0.42
Khulna	Jessore	Kotwali	0.44	0.34	0.68		0.30	0.52	0.56	0.62	0.52	0.28	0.31	0.46	0.37
Khulna	Jessore	Manirampur	0.53	0.42	0.63		0.30	0.60	0.54	0.63	0.51	0.32	0.31	0.33	0.40
Khulna	Jessore	Sharsha	0.46	0.37	0.67		0.37	0.63	0.46	0.65	0.55	0.29	0.38	0.42	0.36
Khulna	Jhenaidah	Harinakunda	0.50	0.47	0.66		0.37	0.59	0.47	0.63	0.68	0.26	0.31	0.47	0.41
Khulna	Jhenaidah	Jhenaidah Sadar	0.50	0.47	0.65		0.34	0.60	0.45	0.65	0.58	0.27	0.32	0.33	0.44
Khulna	Jhenaidah	Kaliganj	0.53	0.47	0.56		0.37	0.63	0.59	0.63	0.67	0.28	0.33	0.50	0.42
Khulna	Jhenaidah	Kotchandpur	0.50	0.47	0.65		0.38	0.60	0.56	0.65	0.58	0.25	0.30	0.38	0.41
Khulna	Jhenaidah	Maheshpur	0.43	0.45	0.68		0.36	0.62	0.54	0.67	0.56	0.23	0.26	0.35	0.43
Khulna	Jhenaidah	Shailkupa	0.54	0.38	0.62		0.36	0.55	0.50	0.69	0.69	0.37	0.43	0.49	0.43

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Khulna	Khulna	Batiaghata	0.45	0.36	0.47		0.40	0.50	0.56	0.56	0.42	0.24	0.25	0.30	0.40
Khulna	Khulna	Dacope	0.63	0.37	0.49	0.74	0.40	0.35	0.52	0.59	0.49	0.33	0.36	0.26	0.36
Khulna	Khulna	Daulatpur	0.53	0.36	0.62		0.44	0.55	0.56	0.71	0.48	0.27	0.26	0.30	0.35
Khulna	Khulna	Dighalia	0.44	0.41	0.59		0.35	0.60	0.46	0.63	0.51	0.19	0.23	0.33	0.34
Khulna	Khulna	Dumuria	0.46	0.39	0.59		0.31	0.60	0.48	0.63	0.51	0.19	0.23	0.33	0.35
Khulna	Khulna	Khalishpur	0.53	0.36	0.52		0.44	0.55	0.64	0.66	0.48	0.27	0.26	0.30	0.35
Khulna	Khulna	Khan Jahan Ali	0.58	0.41	0.61		0.35	0.60	0.57	0.65	0.49	0.26	0.23	0.31	0.41
Khulna	Khulna	Khulna Sadar	0.59	0.41	0.55		0.41	0.54	0.46	0.59	0.53	0.37	0.32	0.36	0.47
Khulna	Khulna	Koyra	0.69	0.46	0.46	0.59	0.43	0.46	0.56	0.58	0.48	0.35	0.40	0.26	0.40
Khulna	Khulna	Paikgachha	0.40	0.23	0.49		0.38	0.54	0.65	0.59	0.46	0.33	0.32	0.25	0.39
Khulna	Khulna	Phultala	0.58	0.49	0.61		0.36	0.60	0.55	0.63	0.49	0.26	0.23	0.31	0.41
Khulna	Khulna	Rupsa	0.45	0.33	0.47		0.41	0.50	0.48	0.56	0.42	0.24	0.25	0.33	0.40
Khulna	Khulna	Sonadanga	0.59	0.28	0.55		0.41	0.54	0.51	0.59	0.54	0.37	0.32	0.35	0.47
Khulna	Khulna	Terokhada	0.45	0.30	0.56		0.38	0.58	0.55	0.53	0.45	0.24	0.28	0.34	0.38
Khulna	Kushtia	Bheramara	0.46	0.39	0.58		0.38	0.57	0.59	0.69	0.67	0.19	0.24	0.48	0.33
Khulna	Kushtia	Daulatpur	0.46	0.40	0.62		0.34	0.57	0.58	0.71	0.67	0.21	0.26	0.40	0.34
Khulna	Kushtia	Khoksa	0.54	0.50	0.62		0.40	0.55	0.48	0.69	0.69	0.36	0.41	0.51	0.43
Khulna	Kushtia	Kumarkhali	0.54	0.48	0.62		0.37	0.58	0.51	0.70	0.71	0.27	0.33	0.51	0.44
Khulna	Kushtia	Kushtia Sadar	0.50	0.48	0.66		0.36	0.59	0.53	0.63	0.68	0.26	0.31	0.50	0.41
Khulna	Kushtia	Mirpur	0.50	0.48	0.63		0.36	0.59	0.56	0.68	0.68	0.26	0.31	0.56	0.41
Khulna	Magura	Magura Sadar	0.52	0.49	0.63		0.31	0.55	0.55	0.67	0.68	0.30	0.35	0.48	0.33
Khulna	Magura	Mohammadpur	0.44	0.47	0.63		0.34	0.56	0.47	0.65	0.56	0.21	0.25	0.30	0.32
Khulna	Magura	Shalikha	0.53	0.30	0.64		0.38	0.63	0.49	0.64	0.67	0.26	0.31	0.44	0.41
Khulna	Magura	Sreepur	0.52	0.34	0.58		0.34	0.55	0.51	0.64	0.68	0.28	0.33	0.48	0.32
Khulna	Meherpur	Gangni	0.50	0.49	0.66		0.36	0.59	0.55	0.63	0.68	0.26	0.31	0.47	0.41
Khulna	Meherpur	Meherpur Sadar	0.50	0.49	0.66		0.36	0.59	0.50	0.63	0.68	0.25	0.29	0.47	0.41

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Khulna	Meherpur	Mujib Nagar	0.50	0.48	0.68		0.39	0.61	0.52	0.64	0.58	0.25	0.30	0.39	0.40
Khulna	Narail	Kalia	0.44	0.40	0.58		0.38	0.61	0.53	0.57	0.52	0.29	0.34	0.31	0.37
Khulna	Narail	Lohagara	0.44	0.32	0.59		0.33	0.51	0.48	0.70	0.55	0.21	0.25	0.30	0.32
Khulna	Narail	Narail Sadar	0.53	0.42	0.64		0.31	0.60	0.53	0.63	0.62	0.23	0.23	0.43	0.39
Khulna	Satkhira	Assasuni	0.69	0.40	0.46		0.40	0.37	0.48	0.55	0.47	0.39	0.48	0.28	0.40
Khulna	Satkhira	Debhata	0.54	0.50	0.47		0.41	0.50	0.56	0.55	0.59	0.45	0.47	0.33	0.45
Khulna	Satkhira	Kalaroa	0.46	0.45	0.67		0.38	0.63	0.54	0.65	0.55	0.24	0.32	0.37	0.36
Khulna	Satkhira	Kaliganj	0.66	0.48	0.56		0.39	0.50	0.59	0.63	0.59	0.41	0.49	0.33	0.45
Khulna	Satkhira	Satkhira Sadar	0.54	0.32	0.47		0.38	0.50	0.49	0.55	0.59	0.46	0.49	0.33	0.46
Khulna	Satkhira	Shyamnagar	0.77	0.30	0.45	0.62	0.39	0.34	0.53	0.55	0.56	0.51	0.55	0.33	0.41
Khulna	Satkhira	Tala	0.62	0.42	0.67		0.34	0.62	0.59	0.62	0.54	0.32	0.28	0.33	0.50
Rajshahi	Bogra	Adamdighi	0.37	0.34	0.65		0.30	0.64	0.47	0.66	0.47	0.22	0.24	0.37	0.31
Rajshahi	Bogra	Bogra Sadar	0.48	0.30	0.61		0.36	0.62	0.55	0.64	0.63	0.20	0.24	0.39	0.30
Rajshahi	Bogra	Dhunat	0.50	0.40	0.69		0.39	0.67	0.47	0.64	0.74	0.28	0.33	0.43	0.41
Rajshahi	Bogra	Dhupchanchia	0.37	0.34	0.65		0.30	0.64	0.49	0.64	0.47	0.22	0.24	0.32	0.31
Rajshahi	Bogra	Gabtali	0.48	0.30	0.61		0.36	0.62	0.56	0.62	0.63	0.20	0.24	0.39	0.31
Rajshahi	Bogra	Kahaloo	0.37	0.33	0.65		0.29	0.64	0.51	0.64	0.47	0.22	0.24	0.32	0.31
Rajshahi	Bogra	Nandigram	0.37	0.34	0.65		0.29	0.64	0.60	0.64	0.47	0.22	0.24	0.29	0.31
Rajshahi	Bogra	Sariakandi	0.56	0.31	0.66		0.44	0.67	0.47	0.66	0.76	0.54	0.55	0.56	0.50
Rajshahi	Bogra	Shajahanpur	0.48	0.50	0.61		0.36	0.62	0.52	0.62	0.63	0.20	0.24	0.35	0.31
Rajshahi	Bogra	Sherpur	0.50	0.35	0.69		0.38	0.67	0.57	0.66	0.74	0.28	0.33	0.43	0.42
Rajshahi	Bogra	Shibganj	0.48	0.49	0.61		0.35	0.62	0.55	0.60	0.63	0.20	0.24	0.35	0.31
Rajshahi	Bogra	Sonatola	0.48	0.37	0.64		0.38	0.65	0.62	0.61	0.63	0.19	0.23	0.48	0.36
Rajshahi	Joypurhat	Akkelpur	0.37	0.34	0.65		0.30	0.64	0.53	0.64	0.47	0.22	0.24	0.36	0.31
Rajshahi	Joypurhat	Joypurhat Sadar	0.37	0.36	0.65		0.31	0.64	0.61	0.63	0.47	0.25	0.27	0.28	0.33
Rajshahi	Joypurhat	Kalai	0.48	0.30	0.64		0.40	0.64	0.55	0.55	0.61	0.19	0.24	0.40	0.35

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Rajshahi	Joypurhat	Khetlal	0.36	0.34	0.66		0.32	0.64	0.57	0.64	0.65	0.16	0.18	0.40	0.32
Rajshahi	Joypurhat	Panchbibi	0.39	0.29	0.65		0.30	0.61	0.52	0.64	0.48	0.26	0.28	0.31	0.30
Rajshahi	Naogaon	Atrai	0.43	0.41	0.63		0.36	0.65	0.48	0.63	0.60	0.30	0.33	0.39	0.36
Rajshahi	Naogaon	Badalgachhi	0.37	0.37	0.65		0.31	0.64	0.63	0.65	0.47	0.25	0.27	0.23	0.33
Rajshahi	Naogaon	Dhamoirhat	0.39	0.38	0.65		0.30	0.61	0.54	0.64	0.48	0.24	0.27	0.26	0.30
Rajshahi	Naogaon	Mahadebpur	0.39	0.39	0.66		0.29	0.66	0.55	0.65	0.50	0.22	0.24	0.24	0.30
Rajshahi	Naogaon	Manda	0.43	0.41	0.63		0.34	0.65	0.54	0.64	0.60	0.30	0.33	0.34	0.37
Rajshahi	Naogaon	Naogaon Sadar	0.37	0.35	0.65		0.27	0.64	0.53	0.64	0.47	0.22	0.24	0.29	0.31
Rajshahi	Naogaon	Niamatpur	0.42	0.44	0.63		0.33	0.64	0.53	0.64	0.54	0.26	0.30	0.21	0.38
Rajshahi	Naogaon	Patnitala	0.39	0.35	0.66		0.30	0.66	0.59	0.67	0.50	0.22	0.24	0.24	0.30
Rajshahi	Naogaon	Porsha	0.37	0.38	0.63		0.32	0.59	0.47	0.62	0.50	0.18	0.20	0.21	0.29
Rajshahi	Naogaon	Raninagar	0.37	0.33	0.65		0.29	0.64	0.50	0.64	0.47	0.22	0.24	0.31	0.31
Rajshahi	Naogaon	Sapahar	0.37	0.47	0.65		0.32	0.57	0.51	0.62	0.47	0.18	0.20	0.20	0.29
Rajshahi	Natore	Bagati Para	0.51	0.45	0.64		0.41	0.60	0.59	0.64	0.66	0.26	0.30	0.49	0.37
Rajshahi	Natore	Baraigram	0.51	0.45	0.64		0.39	0.60	0.56	0.64	0.66	0.26	0.30	0.46	0.39
Rajshahi	Natore	Gurudaspur	0.51	0.44	0.65		0.39	0.61	0.59	0.65	0.67	0.27	0.31	0.42	0.35
Rajshahi	Natore	Lalpur	0.46	0.40	0.58		0.36	0.57	0.58	0.67	0.67	0.21	0.26	0.48	0.34
Rajshahi	Natore	Natore Sadar	0.43	0.41	0.63		0.34	0.65	0.54	0.63	0.61	0.31	0.35	0.42	0.37
Rajshahi	Natore	Singra	0.36	0.36	0.66		0.27	0.63	0.63	0.59	0.50	0.20	0.22	0.28	0.33
Rajshahi	Nawabganj	Bholahat	0.49	0.47	0.67		0.42	0.57	0.46	0.70	0.69	0.23	0.29	0.40	0.35
Rajshahi	Nawabganj	Gomastapur	0.37	0.46	0.66		0.34	0.64	0.46	0.66	0.47	0.16	0.19	0.28	0.40
Rajshahi	Nawabganj	Nachole	0.37	0.46	0.66		0.36	0.64	0.55	0.59	0.47	0.16	0.19	0.29	0.40
Rajshahi	Nawabganj	Nawabganj Sadar	0.38	0.49	0.65		0.29	0.65	0.53	0.64	0.68	0.18	0.20	0.52	0.33
Rajshahi	Nawabganj	Shibganj	0.49	0.30	0.61		0.35	0.57	0.59	0.60	0.70	0.25	0.30	0.40	0.36
Rajshahi	Pabna	Atgharia	0.51	0.44	0.65		0.40	0.61	0.47	0.66	0.67	0.27	0.31	0.44	0.35
Rajshahi	Pabna	Bera	0.52	0.49	0.62		0.38	0.64	0.51	0.71	0.74	0.32	0.39	0.45	0.38

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Rajshahi	Pabna	Bhangura	0.46	0.45	0.67		0.37	0.64	0.52	0.69	0.63	0.38	0.45	0.44	0.34
Rajshahi	Pabna	Chatmohar	0.51	0.44	0.65		0.38	0.61	0.59	0.65	0.66	0.27	0.31	0.47	0.36
Rajshahi	Pabna	Faridpur	0.52	0.47	0.67		0.39	0.62	0.56	0.63	0.68	0.27	0.32	0.47	0.38
Rajshahi	Pabna	Ishwardi	0.46	0.39	0.58		0.37	0.57	0.51	0.69	0.67	0.21	0.26	0.47	0.34
Rajshahi	Pabna	Pabna Sadar	0.54	0.41	0.62		0.36	0.55	0.59	0.69	0.69	0.39	0.44	0.49	0.44
Rajshahi	Pabna	Santhia	0.52	0.33	0.67		0.37	0.62	0.54	0.61	0.68	0.27	0.32	0.47	0.39
Rajshahi	Pabna	Sujanagar	0.54	0.32	0.62		0.37	0.56	0.55	0.69	0.69	0.35	0.40	0.48	0.38
Rajshahi	Rajshahi	Bagha	0.46	0.41	0.59		0.39	0.58	0.46	0.66	0.70	0.21	0.26	0.39	0.36
Rajshahi	Rajshahi	Baghmara	0.43	0.41	0.63		0.34	0.65	0.52	0.63	0.61	0.31	0.35	0.34	0.37
Rajshahi	Rajshahi	Boalia	0.48	0.41	0.61		0.35	0.56	0.52	0.73	0.58	0.21	0.26	0.35	0.28
Rajshahi	Rajshahi	Charghat	0.51	0.46	0.64		0.41	0.60	0.54	0.64	0.65	0.26	0.30	0.51	0.37
Rajshahi	Rajshahi	Durgapur	0.42	0.45	0.68		0.36	0.65	0.55	0.68	0.54	0.30	0.34	0.22	0.41
Rajshahi	Rajshahi	Godagari	0.51	0.50	0.70		0.36	0.65	0.47	0.66	0.70	0.32	0.38	0.59	0.48
Rajshahi	Rajshahi	Matihar	0.48	0.41	0.61		0.36	0.56	0.50	0.71	0.58	0.21	0.26	0.35	0.28
Rajshahi	Rajshahi	Mohanpur	0.42	0.43	0.63		0.36	0.65	0.56	0.64	0.54	0.28	0.31	0.22	0.38
Rajshahi	Rajshahi	Paba	0.48	0.41	0.61		0.33	0.56	0.54	0.66	0.58	0.22	0.28	0.37	0.29
Rajshahi	Rajshahi	Puthia	0.51	0.48	0.64		0.40	0.60	0.49	0.66	0.66	0.26	0.30	0.47	0.38
Rajshahi	Rajshahi	Rajpara	0.48	0.42	0.61		0.35	0.56	0.50	0.71	0.57	0.21	0.26	0.35	0.28
Rajshahi	Rajshahi	Shah Makhdum	0.48	0.36	0.61		0.36	0.56	0.53	0.66	0.58	0.21	0.26	0.34	0.28
Rajshahi	Rajshahi	Tanore	0.42	0.36	0.63		0.36	0.65	0.59	0.64	0.54	0.28	0.31	0.22	0.38
Rajshahi	Sirajganj	Belkuchi	0.51	0.33	0.66		0.39	0.67	0.52	0.68	0.72	0.36	0.41	0.43	0.34
Rajshahi	Sirajganj	Chauhali	0.52	0.49	0.62		0.38	0.64	0.63	0.69	0.73	0.30	0.37	0.45	0.37
Rajshahi	Sirajganj	Kamarkhanda	0.51	0.40	0.62		0.40	0.66	0.53	0.64	0.74	0.41	0.46	0.44	0.38
Rajshahi	Sirajganj	Kazipur	0.56	0.41	0.74		0.36	0.67	0.46	0.57	0.70	0.31	0.36	0.58	0.43
Rajshahi	Sirajganj	Royganj	0.50	0.32	0.69		0.39	0.67	0.51	0.64	0.74	0.26	0.31	0.43	0.42
Rajshahi	Sirajganj	Shahjadpur	0.52	0.34	0.62		0.34	0.63	0.51	0.72	0.73	0.34	0.41	0.44	0.36

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Rajshahi	Sirajganj	Sirajganj Sadar	0.56	0.35	0.74		0.36	0.67	0.63	0.55	0.70	0.31	0.36	0.63	0.44
Rajshahi	Sirajganj	Tarash	0.50	0.40	0.67		0.36	0.63	0.56	0.63	0.72	0.27	0.32	0.41	0.39
Rajshahi	Sirajganj	Ullah Para	0.46	0.40	0.67		0.33	0.64	0.53	0.69	0.63	0.38	0.45	0.48	0.36
Rangpur	Dinajpur	Biral	0.41	0.42	0.60		0.32	0.60	0.48	0.66	0.48	0.25	0.26	0.41	0.37
Rangpur	Dinajpur	Birampur	0.51	0.38	0.62		0.38	0.58	0.48	0.61	0.66	0.25	0.30	0.49	0.37
Rangpur	Dinajpur	Birganj	0.42	0.39	0.58		0.32	0.60	0.49	0.58	0.49	0.26	0.27	0.26	0.39
Rangpur	Dinajpur	Bochaganj	0.42	0.40	0.58		0.35	0.60	0.51	0.60	0.49	0.24	0.24	0.30	0.39
Rangpur	Dinajpur	Chirirbandar	0.41	0.41	0.63		0.31	0.60	0.59	0.60	0.44	0.23	0.25	0.30	0.35
Rangpur	Dinajpur	Dinajpur Sadar	0.41	0.41	0.60		0.31	0.60	0.46	0.62	0.48	0.25	0.26	0.33	0.37
Rangpur	Dinajpur	Fulbari	0.51	0.38	0.62		0.38	0.58	0.51	0.61	0.66	0.25	0.30	0.49	0.37
Rangpur	Dinajpur	Ghoraghat	0.38	0.35	0.66		0.33	0.60	0.55	0.60	0.63	0.15	0.17	0.44	0.35
Rangpur	Dinajpur	Hakimpur	0.38	0.35	0.66		0.34	0.60	0.55	0.60	0.63	0.15	0.17	0.48	0.35
Rangpur	Dinajpur	Kaharole	0.42	0.40	0.58		0.35	0.60	0.55	0.60	0.49	0.24	0.24	0.25	0.39
Rangpur	Dinajpur	Khansama	0.42	0.39	0.58		0.35	0.60	0.55	0.58	0.49	0.25	0.25	0.26	0.39
Rangpur	Dinajpur	Nawabganj	0.51	0.38	0.52		0.37	0.58	0.50	0.69	0.66	0.27	0.32	0.50	0.37
Rangpur	Dinajpur	Parbatipur	0.41	0.49	0.63		0.30	0.60	0.54	0.60	0.44	0.23	0.25	0.41	0.36
Rangpur	Gaibandha	Fulchhari	0.56	0.45	0.65		0.46	0.68	0.54	0.66	0.79	0.53	0.54	0.56	0.50
Rangpur	Gaibandha	Gaibandha Sadar	0.56	0.45	0.65		0.44	0.68	0.50	0.66	0.79	0.53	0.54	0.63	0.51
Rangpur	Gaibandha	Gobindaganj	0.48	0.29	0.64		0.36	0.64	0.57	0.55	0.61	0.19	0.24	0.44	0.36
Rangpur	Gaibandha	Palashbari	0.50	0.22	0.65		0.33	0.63	0.50	0.55	0.65	0.26	0.31	0.42	0.29
Rangpur	Gaibandha	Sadullapur	0.58	0.38	0.58		0.44	0.63	0.49	0.66	0.79	0.45	0.52	0.59	0.50
Rangpur	Gaibandha	Saghatta	0.56	0.44	0.66		0.44	0.67	0.53	0.64	0.76	0.51	0.51	0.62	0.50
Rangpur	Gaibandha	Sundarganj	0.58	0.42	0.58		0.43	0.63	0.51	0.66	0.79	0.47	0.53	0.61	0.50
Rangpur	Kurigram	Bhurungamari	0.57	0.45	0.57		0.39	0.61	0.61	0.63	0.71	0.35	0.40	0.58	0.43
Rangpur	Kurigram	Char Rajibpur	0.56	0.45	0.65		0.47	0.68	0.54	0.67	0.79	0.51	0.52	0.55	0.50
Rangpur	Kurigram	Chilmari	0.56	0.40	0.64		0.47	0.63	0.63	0.64	0.74	0.45	0.51	0.55	0.52

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Rangpur	Kurigram	Kurigram Sadar	0.56	0.43	0.53		0.40	0.59	0.53	0.63	0.69	0.32	0.38	0.53	0.42
Rangpur	Kurigram	Nageshwari	0.57	0.45	0.57		0.37	0.61	0.63	0.63	0.71	0.36	0.42	0.53	0.43
Rangpur	Kurigram	Phulbari	0.56	0.27	0.53		0.41	0.59	0.49	0.63	0.68	0.32	0.38	0.50	0.42
Rangpur	Kurigram	Rajarhat	0.56	0.32	0.53		0.41	0.59	0.49	0.63	0.69	0.32	0.38	0.55	0.42
Rangpur	Kurigram	Raumari	0.58	0.37	0.58		0.44	0.65	0.53	0.66	0.77	0.53	0.59	0.52	0.47
Rangpur	Kurigram	Ulipur	0.56	0.37	0.64		0.44	0.63	0.56	0.64	0.74	0.47	0.52	0.60	0.53
Rangpur	Lalmonirhat	Aditmari	0.53	0.38	0.59		0.39	0.60	0.48	0.67	0.73	0.31	0.36	0.53	0.37
Rangpur	Lalmonirhat	Hatibandha	0.54	0.38	0.54		0.38	0.58	0.49	0.63	0.72	0.40	0.45	0.57	0.39
Rangpur	Lalmonirhat	Kaliganj	0.53	0.38	0.56		0.38	0.60	0.59	0.63	0.73	0.31	0.36	0.55	0.36
Rangpur	Lalmonirhat	Lalmonirhat Sadar	0.56	0.44	0.53		0.39	0.59	0.58	0.63	0.69	0.35	0.40	0.60	0.43
Rangpur	Lalmonirhat	Patgram	0.54	0.31	0.54		0.38	0.58	0.53	0.65	0.72	0.40	0.45	0.57	0.39
Rangpur	Nilphamari	Dimla	0.54	0.37	0.54		0.37	0.58	0.46	0.63	0.72	0.42	0.47	0.49	0.39
Rangpur	Nilphamari	Domar	0.53	0.38	0.54		0.38	0.57	0.55	0.65	0.74	0.28	0.32	0.56	0.42
Rangpur	Nilphamari	Jaldhaka	0.54	0.38	0.54		0.38	0.58	0.54	0.63	0.72	0.42	0.47	0.49	0.39
Rangpur	Nilphamari	Kishoreganj	0.53	0.39	0.56		0.39	0.60	0.63	0.64	0.74	0.29	0.34	0.47	0.43
Rangpur	Nilphamari	Nilphamari Sadar	0.42	0.39	0.59		0.33	0.61	0.49	0.61	0.48	0.27	0.27	0.34	0.36
Rangpur	Nilphamari	Saidpur	0.41	0.46	0.63		0.33	0.60	0.55	0.58	0.44	0.21	0.23	0.30	0.35
Rangpur	Panchagarh	Atwari	0.38	0.29	0.56		0.33	0.56	0.45	0.63	0.43	0.16	0.18	0.22	0.34
Rangpur	Panchagarh	Boda	0.38	0.29	0.56		0.32	0.56	0.53	0.63	0.44	0.16	0.18	0.22	0.35
Rangpur	Panchagarh	Debiganj	0.42	0.39	0.58		0.34	0.60	0.58	0.60	0.49	0.25	0.25	0.26	0.39
Rangpur	Panchagarh	Panchagarh Sadar	0.38	0.34	0.56		0.32	0.56	0.47	0.63	0.44	0.18	0.20	0.24	0.35
Rangpur	Panchagarh	Tentulia	0.38	0.26	0.57		0.33	0.56	0.55	0.64	0.44	0.18	0.20	0.24	0.32
Rangpur	Rangpur	Badarganj	0.51	0.38	0.63		0.38	0.62	0.62	0.62	0.66	0.27	0.32	0.51	0.40
Rangpur	Rangpur	Gangachara	0.53	0.38	0.59		0.38	0.60	0.56	0.67	0.73	0.31	0.36	0.48	0.37
Rangpur	Rangpur	Kaunia	0.58	0.44	0.53		0.41	0.59	0.54	0.65	0.74	0.49	0.54	0.57	0.41

Division	District	Upazila	People Affected Due to Natural Disaster	Heat Stress	Ground Water Quality Depletion and Degradation	Mangrove Forest Vulnerability	Land Availabilty for Livestock	Water Availability	Crop Yield Vulnerability	Decrease in Livestock & Poultry Health Vulnerability	Land Availability for Agriculture	Change in Fish Culture	Change in Fish Capture	Rail Network Vulnerability	Road Network Vulnerability
Rangpur	Rangpur	Mitha Pukur	0.51	0.38	0.63		0.35	0.62	0.55	0.62	0.67	0.27	0.32	0.45	0.41
Rangpur	Rangpur	Pirgachha	0.56	0.41	0.64		0.45	0.63	0.53	0.64	0.74	0.45	0.51	0.60	0.53
Rangpur	Rangpur	Pirganj	0.50	0.40	0.65		0.29	0.63	0.55	0.57	0.65	0.28	0.33	0.42	0.30
Rangpur	Rangpur	Rangpur Sadar	0.52	0.40	0.61		0.36	0.62	0.68	0.60	0.71	0.32	0.37	0.54	0.44
Rangpur	Rangpur	Taraganj	0.48	0.43	0.61		0.42	0.58	0.61	0.63	0.62	0.28	0.31	0.32	0.44
Rangpur	Thakurgaon	Baliadangi	0.38	0.29	0.56		0.32	0.56	0.51	0.63	0.43	0.18	0.20	0.20	0.34
Rangpur	Thakurgaon	Haripur	0.39	0.39	0.67		0.32	0.60	0.60	0.65	0.47	0.21	0.23	0.24	0.32
Rangpur	Thakurgaon	Pirganj	0.42	0.38	0.65		0.33	0.60	0.55	0.57	0.49	0.26	0.27	0.31	0.39
Rangpur	Thakurgaon	Ranisankail	0.38	0.35	0.58		0.32	0.58	0.53	0.63	0.44	0.18	0.20	0.22	0.31
Rangpur	Thakurgaon	Thakurgaon Sadar	0.42	0.36	0.58		0.27	0.60	0.54	0.60	0.49	0.28	0.28	0.36	0.40
Sylhet	Habiganj	Ajmiriganj	0.41	0.40	0.62		0.36	0.61	0.52	0.68	0.55	0.27	0.36	0.29	0.34
Sylhet	Habiganj	Bahubal	0.48	0.39	0.56		0.43	0.57	0.51	0.66	0.57	0.31	0.34	0.39	0.39
Sylhet	Habiganj	Baniachong	0.45	0.43	0.60		0.36	0.62	0.47	0.66	0.57	0.30	0.36	0.33	0.38
Sylhet	Habiganj	Chunarughat	0.48	0.39	0.56		0.42	0.57	0.52	0.68	0.57	0.33	0.36	0.44	0.39
Sylhet	Habiganj	Habiganj Sadar	0.48	0.39	0.56		0.42	0.57	0.52	0.66	0.57	0.31	0.34	0.42	0.39
Sylhet	Habiganj	Lakhai	0.45	0.42	0.58		0.38	0.61	0.58	0.66	0.57	0.29	0.35	0.30	0.37
Sylhet	Habiganj	Madhabpur	0.48	0.36	0.61		0.41	0.62	0.54	0.67	0.57	0.30	0.33	0.55	0.39
Sylhet	Habiganj	Nabiganj	0.48	0.38	0.56		0.41	0.57	0.62	0.66	0.57	0.33	0.36	0.34	0.39
Sylhet	Maulvibazar	Barlekha	0.44	0.39	0.46		0.35	0.49	0.49	0.66	0.57	0.20	0.24	0.44	0.33
Sylhet	Maulvibazar	Juri	0.44	0.39	0.46		0.36	0.49	0.54	0.68	0.57	0.20	0.24	0.39	0.33
Sylhet	Maulvibazar	Kamalganj	0.44	0.39	0.51		0.34	0.50	0.57	0.68	0.59	0.23	0.26	0.41	0.36
Sylhet	Maulvibazar	Kulaura	0.44	0.39	0.46		0.34	0.49	0.55	0.72	0.57	0.22	0.26	0.49	0.33
Sylhet	Maulvibazar	Maulvi Bazar Sadar	0.42	0.38	0.56		0.42	0.57	0.50	0.68	0.55	0.30	0.27	0.25	0.38
Sylhet	Maulvibazar	Rajnagar	0.44	0.49	0.51		0.34	0.50	0.47	0.68	0.59	0.23	0.26	0.35	0.36
Sylhet	Maulvibazar	Sreemangal	0.48	0.44	0.56		0.43	0.57	0.44	0.66	0.57	0.33	0.36	0.41	0.39
Sylhet	Sunamganj	Bishwambarpur	0.49	0.42	0.51		0.44	0.55	0.48	0.68	0.60	0.35	0.37	0.33	0.44

Division	District	Upazila	People Affected Due to Natural Disaster	Heat Stress	Ground Water Quality Depletion and Degradation	Mangrove Forest Vulnerability	Land Availabilty for Livestock	Water Availability	Crop Yield Vulnerability	Decrease in Livestock & Poultry Health Vulnerability	Land Availability for Agriculture	Change in Fish Culture	Change in Fish Capture	Rail Network Vulnerability	Road Network Vulnerability
Sylhet	Sunamganj	Chhatak	0.47	0.36	0.47		0.42	0.53	0.62	0.67	0.61	0.32	0.34	0.38	0.44
Sylhet	Sunamganj	Dakshin Sunamganj	0.47	0.36	0.47		0.44	0.53	0.51	0.65	0.61	0.32	0.34	0.33	0.44
Sylhet	Sunamganj	Derai	0.41	0.40	0.62		0.33	0.59	0.56	0.66	0.57	0.28	0.37	0.31	0.34
Sylhet	Sunamganj	Dharampasha	0.48	0.41	0.68		0.38	0.62	0.58	0.68	0.61	0.28	0.36	0.42	0.37
Sylhet	Sunamganj	Dowarabazar	0.47	0.35	0.47		0.43	0.53	0.52	0.67	0.61	0.32	0.34	0.33	0.44
Sylhet	Sunamganj	Jagannathpur	0.42	0.38	0.56		0.42	0.57	0.55	0.68	0.55	0.30	0.27	0.25	0.38
Sylhet	Sunamganj	Jamalganj	0.41	0.40	0.62		0.34	0.59	0.52	0.66	0.57	0.28	0.37	0.31	0.31
Sylhet	Sunamganj	Sulla	0.41	0.49	0.62		0.36	0.61	0.51	0.68	0.55	0.27	0.36	0.29	0.34
Sylhet	Sunamganj	Sunamganj Sadar	0.49	0.40	0.51		0.43	0.55	0.54	0.68	0.59	0.35	0.37	0.33	0.44
Sylhet	Sunamganj	Tahirpur	0.49	0.35	0.51		0.43	0.55	0.60	0.69	0.60	0.35	0.37	0.33	0.44
Sylhet	Sylhet	Balaganj	0.42	0.38	0.56		0.42	0.57	0.52	0.68	0.55	0.30	0.27	0.25	0.38
Sylhet	Sylhet	Beani Bazar	0.44	0.39	0.46		0.36	0.49	0.47	0.66	0.57	0.20	0.24	0.36	0.33
Sylhet	Sylhet	Bishwanath	0.47	0.35	0.47		0.44	0.53	0.49	0.67	0.60	0.32	0.34	0.38	0.44
Sylhet	Sylhet	Companiganj	0.47	0.35	0.51		0.44	0.53	0.50	0.61	0.61	0.32	0.34	0.33	0.44
Sylhet	Sylhet	Dakshin Surma	0.45	0.38	0.52		0.43	0.55	0.53	0.65	0.58	0.23	0.27	0.37	0.45
Sylhet	Sylhet	Fenchuganj	0.44	0.39	0.46		0.37	0.49	0.51	0.70	0.57	0.20	0.24	0.41	0.32
Sylhet	Sylhet	Golabganj	0.44	0.39	0.46		0.35	0.49	0.46	0.68	0.57	0.20	0.24	0.36	0.33
Sylhet	Sylhet	Gowainghat	0.47	0.35	0.47		0.41	0.55	0.60	0.67	0.59	0.36	0.37	0.34	0.47
Sylhet	Sylhet	Jaintiapur	0.49	0.35	0.46		0.44	0.48	0.55	0.73	0.65	0.26	0.29	0.25	0.45
Sylhet	Sylhet	Kanaighat	0.44	0.35	0.46		0.34	0.48	0.54	0.67	0.57	0.20	0.24	0.28	0.32
Sylhet	Sylhet	Sylhet Sadar	0.47	0.34	0.47		0.43	0.53	0.49	0.67	0.61	0.32	0.34	0.34	0.44
Sylhet	Sylhet	Zakiganj	0.44	0.40	0.46		0.34	0.48	0.48	0.67	0.57	0.20	0.24	0.28	0.32

7. Conclusions and wayforward

7.1 Conclusion

The nation-wide climate vulnerability assessment (CVA) is a key step in reviewing, summarizing and understanding the climate change vulnerabilities that people in different regions of Bangladesh face. The NCVA has been conducted in 6 climatic hotspots, namely: urban areas, flood-prone areas, drought areas, coastal areas, hill tracts and wetlands. This is an essential step to establish an index which will help decision-makers better understand the vulnerabilities of different areas, and inform planning, fund allocation and implemention of development interventions accordingly. The maps and analysis of the nation—wide climate vulnerability assessment indicate that the country is highly vulnerable to the impacts of climate change, across the selected sectors. Water resources are fast depleting, agriculture and livestock sectors are heavily affected, and people, especially in coastal areas are highly disaster prone. Heat stress will be a major issue in the coming decades. The vulnerability maps presented highlight the regional differences in climate vulnerability, while giving an outlook towards the future. If the country does not adapt to climate change, vulnerability will be pushed to critical levels.

Despite these positive developments, the fact remains, that Bangladesh is persistently exposed to natural hazards, and the intensity and frequency of those events will increase due to climate change. Besides investments in more obvious measures to reduce exposure to hazards, (for e.g. investments in the water sector), the study emphasizes the importance of increasing the adaptive capacity of the country. The adaptive capacity of people and sectors can be increased through education, technology, access to water, electricity, healthcare, and so on. Investing in increasing the adaptive capacity of the country is critical for reducing vulnerability, while at the same time, reducing gender imbalances and poverty.

The method of impact chains is a valid approach for an in-depth assessment of climate change vulnerability and risks. It proposes an inclusive, consistent, normalized and rigorous approach, which allows comparability and hierarchization of risks and territories. This is increasingly needed to mobilize climate finance. It is however very technical and requires a large amount of quality and accessible data, along with sound expertise in data management and processing (GIS). Small assumptions can strongly impact the results, and the method must be carefully implemented, with frequent checks. It must be implemented through a participatory approach to validate the results and build ownership. Moreover, for sustainability of the process, the country must continue capacity building activities towards conducting NCVAs in the future, on regular basis, and disseminate more widely in the country this capacity to understand and tackle climate change vulnerability and adaptation.

The Nationwide Climate Vulnerability Assessment in Bangladesh identified climate vulnerable areas and sectors. This information can support the Government of Bangladesh in making the country more climate resilient, and in addressing current and future climate variability and change. The challenges are complex and sustainable solutions that contribute to climate resilience and the ambitious development goals of Bangladesh are required. Sound information about climate vulnerability, obtained in a transparent process, is needed to support decision making for adaptation planning. The assessment can serve as a decision support tool for the Government of Bangladesh, that should feed into political programming and inform public as well as private investment decisions. The assessment covers the whole country and therefore, provides the possibility to compare the climate vulnerability of different regions and sectors so that funding allocation of new projects under various streams of climate finance can be supported.

The results obtained in the Nationwide Vulnerability Assessment in Bangladesh built upon existing studies and climate information obtained from the BCCSAP, CDMP-II, NAP, 5yr plan, the Bangladesh

Delta Plan 2100, the Knowledge Portal, and many other sources. Combining these efforts and ensuring that the results will be used for future studies and assessments is crucial for contributing to this goal and using research resources efficiently. The results obtained from the Nationwide Climate Vulnerability Assessment in Bangladesh need to be used and integrated with other sources of information and policy-making. The results should inform, for e.g., the Project Approval Process Integration (TPP/DPP) of the Planning Commission and Planning wing of the Sectoral Ministry. This study also identified knowledge gaps that need to be addressed in future studies: obsolete data; unavailable spatialized data not covering the entire country; lack of existing modeling on future risks (such as river floods, flash floods, storm surges, erosion, etc.) all contribute to abandon impact chain assessment, leading to numerous assumptions during the implementation process.

This assessment should be seen as a first – and essential – step in understanding Bangladesh's vulnerability to climate change, with the objective to prioritize adaptation interventions. The Bangladesh NCVA is an iterative process. It is meant to be readjusted and updated periodically, in order to integrate knowledge developments, to expand the scope of analysis, to take account of dynamic and rapid socio-economic changes, and to support monitoring and evaluation of adaptation by showing how adaptation policies implemented through time succeed in reducing vulnerability.

In the process of conducting the Nationwide Climate Vulnerability Assessment many stakeholders consultations and regional workshops took place. High level government officials from various departments, representatives of development partners, policy planners, researchers, local planners and program managers were involved in this process for the purpose of including different perspectives to capture the complexity of climate vulnerability. Representatives from MoEF, DoE, BWDB, BMD, BBS, SoB, GED Planning Commission, Ministry of Agriculture, etc. contributed to the National Climate Vulnerability Assessment in Bangladesh and provided valuable input and support. The regional workshops that took place revealed the high degree of local specifics that influence the vulnerability of different zilas and upazilas. The results obtained from the regional workshops are summarized in the sectoral annexes and were incorporated, to the highest degree possible, to refine and validate the results of the national vulnerability assessment. However, national maps cannot provide the degree of detail required for local vulnerability assessments and consequently local adaptation planning. The local scale is of particular importance when addressing climate risks because this is the scale at which climate risks manifest, and where solutions need to be found in practice (Cutter 2003; Masselink et al. 2017; Laudien et al. 2018; Wilson 2006; van den Berg and Coenen 2012; Mees et al. 2014; Hoppe et al. 2016). As there is a high demand for local vulnerability assessments, we recorequire the involvement of local stakeholders. This is particularly important for the development and design of local adaptation options.

A precondition for the use of the results obtained from the Nationwide Climate Vulnerability Assessment is that the final outcomes and the background map layers become publicly available. Often, limited access to spatial data is one of the major constraints in public planning. Open information services need to be available to enable quick and easy access to multiple sources of spatial information. Government institutions should work together towards sharing and opening data. Having climate change information, as well as other relevant spatial data, about the sensitivity and adaptive capacity of the area of interest are essential for scenario inclusive and robust planning.

7.2 The way forward

The Nationwide Climate Vulnerability Assessment (NCVA) is intended to map out the vulnerable areas or 'hot spots' in the country to inform the policy makers for adaptation planning. There are several on-going activities in the field of adaptation where these results could feed in to:

- the Bangladesh climate change strategy and action plan (BCCSAP), first adopted in 2009, which should be updated for 2018 by the MoEF;
- the National Adaptation Plan (NAP), that is a requirement of the UNFCCC, and will be more and more necessary to access climate finance;
- the implementation of the recently adopted Bangladesh Deltaplan 2100, an overarching vision for the country, which is accompanied by an investment plan;
- the elaboration of the third national communication on climate change (the second one was issued in 2012), which writing process should start soon;
- the Nationally Determined Contribution (NDC) provided at the COP21, which will be regularly updated, and includes a chapter on adaptation;
- the 8^{th} five-year plan
- the sectoral policies and plans.

For those activities listed above, the NCVA can provide input for and support:

- **The provision of a knowledge base** that is regularly updated and can feed the elaboration of the policy documents listed above. Such a knowledge base will fasten the writing process of such documents and make them more consistent. Keeping the NCVA up to date can foster a consistent response to the vulnerabilities identified by the NCVA;
- **The allocation of climate finance.** The NCVA will also serve the wider policy objective to improve the allocation of funds, which at present are not sufficiently aligned with the national climate strategy of Bangladesh. The NCVA can provide a basis for allocating resources and coordinating donor actions, for instance for the elaboration of a multi-sectoral investment on climate resilience and disaster risk management by the World Bank. Identifying populations, regions and sectors that may be most affected by climate change helps to prioritize research activities and relevant financial and technical assistance. Thus, the NCVA can improve the selection process and decision-making for funding allocation of new projects under various streams of climate finance.
- **The increase of capacity of the sectoral ministries to perform, update and monitor vulnerability to climate change, and to mainstream climate change vulnerability into their policy domains.** This objective may require further tailoring of the NCVA results to the needs and knowledge of the sectoral ministries. The current NCVA was a first attempt to map the vulnerability across multiple sectors. In future, sectoral ministries should be involved more closely. This can improve sectoral ownership and will improve the quality of the assessment by including sectoral information and data sets, determining weights and choosing normalization methods by sectoral experts.

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ANNEXES :

A. Guideline for the preperation of the Nationwide Climate Vulnerability Assessment in Bangladesh

This guideline aims at giving a deeper understanding of the GIZ methodology of impact chains, which have been followed for this Nationwide Climate Vulnerability Assessment of Bangladesh. They provide an in-depth analysis of the step by step approach advocated and give an overview of the underlying challenges of data analysis and processing under GIS. Indeed, the methodological part is followed by guidelines on the NCVA application under ArcGIS. These annexes provide the methodological framework that can be used for the implementation of other vulnerability assessments.

1. Methodology

1.1 The concept of vulnerability

Vulnerability is a concept used to express the complex interaction of climate change effects and the susceptibility of a system to its impacts. There exist manifold definitions and methods of operationalizing this concept. The Intergovernmental Panel on Climate Change (IPCC) sought to elaborate and advance an approach for understanding vulnerability in its Fourth Assessment Report (AR4) as:

“the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity” (Intergovernmental Panel on Climate Change 2007).

Within this perspective, vulnerability is understood to be the function of a system’s climate change exposure, sensitivity and adaptive capacity to cope with climate change effects, as illustrated below:

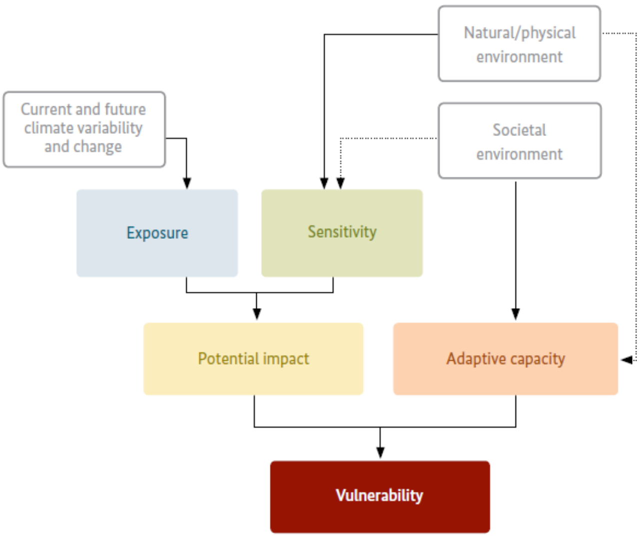


Figure A1: Vulnerability concept according to the IPPC AR4
Source : Vulnerability Sourcebook, 2014

Exposure refers to changes in climate parameters that might affect socio-ecological systems. Such parameters are, for example, temperature or precipitation, which climate change alters with regard to their quantity and quality, as well as their spatial and temporal distribution.

Sensitivity refers to the status of the physical and natural environment of the affected systems that makes them particularly susceptible to climate change. For example, a sensitivity factor could be topography, land use, distribution, density of population, etc.

Potential Impact is determined by combining exposure and sensitivity to climate change, on a system.

Adaptive capacity refers to, according to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), "the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences".

The Vulnerability Sourcebook provides a step-by step guidance for designing and implementing a Vulnerability Assessment.

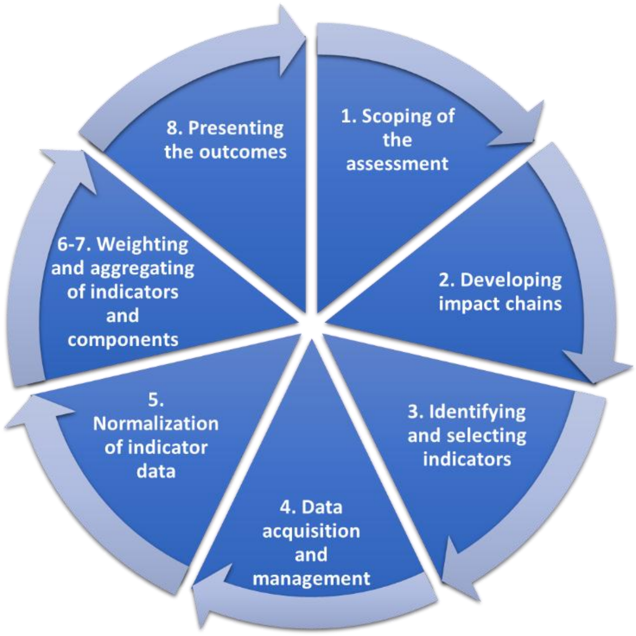


Figure A2: The NCVA workflow: a step by step approach

1.2 Defining the scope of the Vulnerability Assessment

Defining the scope of the Vulnerability Assessment aims to set the framework of the study by probing several essential points:

- Which resources are available and will be available in the future in order to quantitatively implement the NCVA?
- Which sectors should the NCVA cover?
- Which geographical regions should the NCVA cover?
- To which administrative units should the NCVA refer?
- To which time horizon(s) will the NCVA refer?

A scoping workshop was conducted in Bangladesh in December 2016 to prioritize the selected sectors and topics, which have been specifically assessed. Participants suggested undertaking the assessment for the entire country, since the project claims to be a nationwide outcome. Moreover, a specific request was formulated to implement the Climate Vulnerability Assessment at the administrative level of upazila, Bangladesh's sub-districts.

Bangladesh is divided into 7 divisions, 64 districts and 492 upazilas (sub-districts).

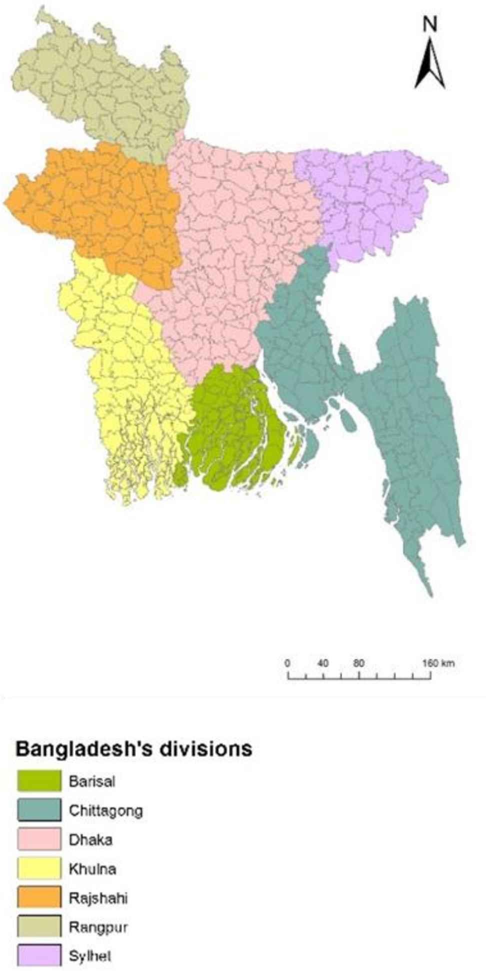


Figure A3: Administrative map of Bangladesh

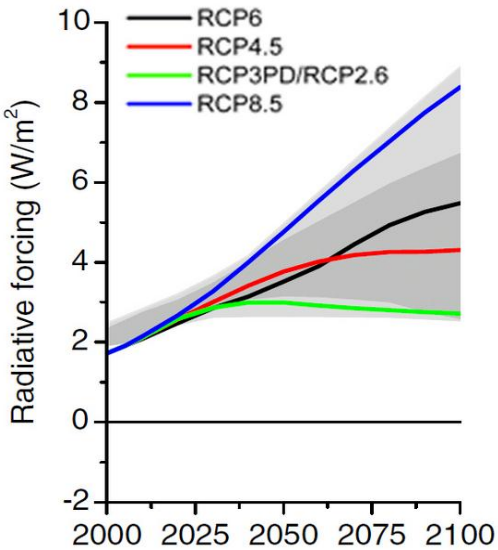


Figure A4: Representative Concentration Pathways Source : IPCC, 2017

Based on these outcomes, the technical experts (from GIZ) and national consultants decided to investigate two temporal horizons: **2050 and 2085**, according to two different climate scenarios: **RCP4.5 and RCP8.5**.

The Representative Concentration Pathway, RCP 4.5 corresponds to a medium-optimistic future scenario, and RCP 8.5 to the most pessimistic (extreme) scenario.

1.3 Developing impact chains

An impact chain is an analytical tool that helps to better understand, systemize and prioritize the factors that drive vulnerability in the system under review. Impact chains are valuable outcomes in themselves, since they create a comprehensive understanding of climate change vulnerability shared by various stakeholders and also help in the identification of suitable adaptation activities. **The entire vulnerability assessment is supposed to follow the logic of the impact chain, by assessing the exposure, sensitivity and adaptive capacity components, as presented in the fourth report of the Intergovernmental Panel on Climate Change.**

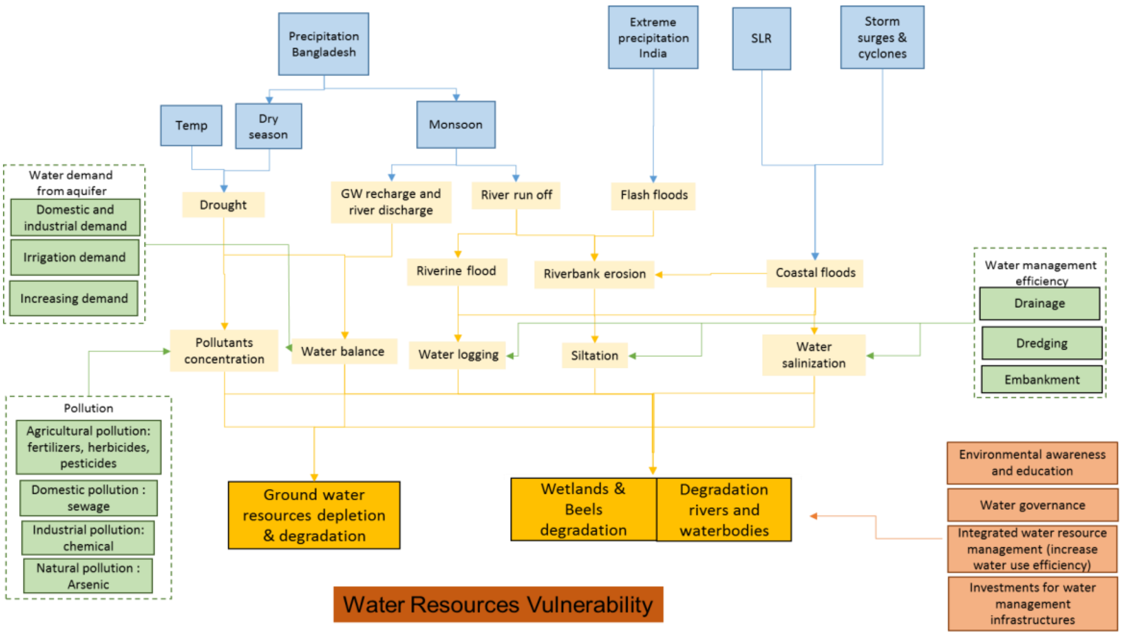


Figure A5: Example of the conceptual impact chain of water resources vulnerability to climate change

<u>Challenge of this step</u>

The impact chain framework presented above is a conceptual representation of the cause-consequence effects of climate change. The impact chain details 'how' a specific change in climate will drive the vulnerability of a specific sector. Temporal dimensions are highlighted within the scope of the exercise. The way to assess vulnerability may differ for this strict framework, owing to the lack of data and technical issues for implementation. These issues and choices have to be explained in order to ensure transparency in the assessment process.

1.4 Identifying and selecting indicators

Identifying and selecting indicators furthers the implementation of the impact chain by giving it a quantitative dimension and thus an operational utility. In practice, selecting indicators is an iterative process whereby a list of ideal choices is slowly thinned out, with indicators rejected where they are unfeasible or – in particular – where there is insufficient data to substantiate them (Vulnerability Sourcebook, 2014).

A good indicator has the following characteristics:

It is **valid and relevant**, i.e. it represents well the factors we want to assess.

It is **reliable** and **credible**, and also allows for data acquisition in the future.

It has a **precise meaning**, i.e. stakeholders agree on what the indicator is measuring in the context of the vulnerability assessment.

It is **clear in its direction**, i.e. an increase in value is unambiguously positive or negative with relation to the factor and vulnerability component.

It is **practical and affordable**, i.e., it comes from an accessible data source.

It is **appropriate**, i.e., the temporal and spatial resolution of the indicator is right for the vulnerability assessment.

However, most of the time indicators selection is driven by the availability of data and resources.

Challenge of this step

The indicators selection step is crucial in the process as it impacts the accuracy and relevance of the whole vulnerability assessment.

At this step of the exercise, some shifts may have appeared, compared to the initial version of the impact chains. These modifications mainly depend on data availability, quality, and on the methodological implementation which is already foreboded.

As shown in the data selection process, several proxies have been used to assess exposure, sensitivity and the adaptive capacity components, in order to cope with the lack of data. Limitations associated with the use of proxies (approximations and lower representation of the assessed component) must be kept in mind. Given the importance of this step for the overall VA process, we emphasize the added value that could be brought by local expertise to validate choices and thus, limit bias for the forthcoming vulnerability assessment.

Finally, for some indicators, data are not available at the upazila level but just at the district level. Information is thus less specific to each upazila, with a lower discrimination of data values among upazilas from the same district. The aggregation of data coming from different sources, and consequently, with different spatial accuracy can lead to results providing information with a different level of accuracy.

By the end of this step, the implementer should have completed the following:

- Checked the quality of the available indicators.
- Discussed the strengths and weaknesses of each selected indicator.
- Created a summary table on data characteristics: availability, source, type, time period, etc.

1.5 Normalizing

In the literature, the term 'normalization' refers to the transformation of indicator values measured on different scales and in different units into unit-less values on a common scale (OECD 2008). Using different units without a step of normalization doesn't allow for indicators aggregation.

In the Vulnerability Sourcebook, normalized values, between 0 and 1 get a score which ranges from 1 to 10, aiming to depict different states of vulnerability.

Table A2: Correspondence between the normalized value and its qualitative meaning according to each vulnerability component

Scale	Climate exposure	Sensitivity	Potential impact	Adaptive capacity	Vulnerability
1	Adversely exposed	Highly sensitive	Adversely affected	Unable to adapt without substantially increased support and resources	Highly vulnerable
0	Not exposed	Not sensitive	Not affected	Able to adapt without problems	Not vulnerable

The Vulnerability Sourcebook advocates several techniques for normalization:

Normalization of metric indicator values

Indicators measured using a metric scale can be normalized by applying the min-max method. This method transforms all values to scores ranging from 0 to 1 by subtracting the minimum score and dividing it by the range of the indicator values. The following formula is used to apply min-max:

$$X_{nv} = \frac{X_{ov} - X_{min}}{X_{max} - X_{min}}$$

Equation A1 - Min-max normalization

where, X_{nv} is the normalized value within the range of 0 to 1;
X_{ov} is the original value of a data point to be normalized;
X_{min} is the minimum value of all data points corresponding to the worst situation; and
X_{max} is the maximum value of all data points corresponding to the optimal situation.

When standardizing indicator values on a scale of 0 to 1, the value 0 is automatically allocated to the lowest number and the value 1 is allocated to the highest. However, this default range does not always reflect the 'reality' of the vulnerability occurring in a specific context. A min-max normalization using defined thresholds can be applied to better represent the reality. These thresholds can be based on literature or on an expert judgement.

$$X_{nv} = \frac{X_{ov} - Min}{Max - Min}$$

Equation A2 - Min-max normalization using defined bounds

where, X_{nv} is the normalized value within the range of 0 to 1;
X_{ov} is the original value of a data point to be normalized;
Min is the set minimum value and Max is the set maximum value.

A reference such as an existing and widely accepted index can be used to allocate the indicator values into classes. The Standardization method (or z-scores) (OECD 2008) allows data normalization according to their distance to the dataset mean, while building intervals that contain an equal number of values.

$$I_{qc} = \frac{x_{qc} - x_{qc=\bar{c}}}{\sigma_{qc=\bar{c}}}$$

Equation A3: Standardization for values normalization

I_{qc} is the normalized value within the range of 0 to 1;
X_{qc} is the original value of a data point to be normalized;
$X_{qc=c}$ is the average across the country;
σ qc=c is the standard deviation.

Normalization of non-metric indicator values

By defining classes in negative or positive terms, we can also give the quantitative or qualitative indicator a meaning applicable to the vulnerability assessment.

Table A3: Classification of non-metric indicator values

Class	Description
0.9 ->0.10	Critical
0.7 -> 0.8	Rather negative
0.5 -> 0.6	Neutral
0.3 -> 0.4	Rather positive
0.1 -> 0.2	Optimal

It is highly recommended to allocate scores to indicator values on the basis of the best knowledge available – be it from existing literature, local experts or any other reliable source.

<u>Challenge of this step</u>

This step is probably the most difficult one. Local expertise is required to make and validate choices, as

By the end of this step, the implementer should have:

- Selected the appropriate normalization procedure(s) with reference to the properties of the data.
- Made scale adjustments, if necessary.
- Transformed highly skewed indicators, if necessary.
- Documented and explained the selected normalisation procedure and the results.

results are highly sensitive to the normalization method chosen. The selection of a suitable method is not trivial and deserves **special attention to eventual scale adjustments, transformation** or highly skewed indicators. The normalisation method should take into account data properties, as well as the objectives of the composite indicator. Robustness tests might be needed to assess the impact of the chosen methodology on the outcomes.

1.6 Weighting and aggregation

The objective here is to **obtain a composite indicator of vulnerability, combining all indicators selected to represent vulnerability factors**. However, most of the time, vulnerability factors and components do not have the same influence on vulnerability, with some of them affecting vulnerability more than others. Therefore, an essential step of weighting is required before aggregating all indicators and components into a single composite indicator.

Weighting

If certain factors are more important than others, different weights should be assigned to them and to their corresponding indicators. This means that indicators that receive a greater (or lesser) weight thus have a greater (or lesser) influence on the respective vulnerability component and on overall vulnerability. The different weights assigned to indicators can be derived from existing literature, stakeholder information or expert opinion. However, there might also be valid reasons for assigning equal weights to all indicators, such as a lack of information, consensus or resources for defining different weights. This might be the case, for instance, where a large number of indicators for different vulnerability components make meaningful weights unfeasible. Participatory methods to obtain weighting factors seem to be the most appropriate to ensure that stakeholders' views are reflected and local expertise included in the process. As the final result is sensitive to the choice of weighting, weighting must be based on stakeholders' views and experts' judgment.

Aggregation

There are 2 types of aggregation: arithmetic (linear aggregation technique) and geometric (non-linear aggregation technique) with advantages and drawbacks.

Arithmetic aggregation is widely used due to its simplicity and ease of understanding. However, it presents the main drawback of full compensability, which means that a deficit in one dimension can be offset (compensated) by a surplus in another.

Contrary to arithmetic aggregation, **geometric aggregation** has the property of partial compensability, meaning that a poor performance in some indicators cannot be easily compensated for by high values in other indicators (Figure A5).

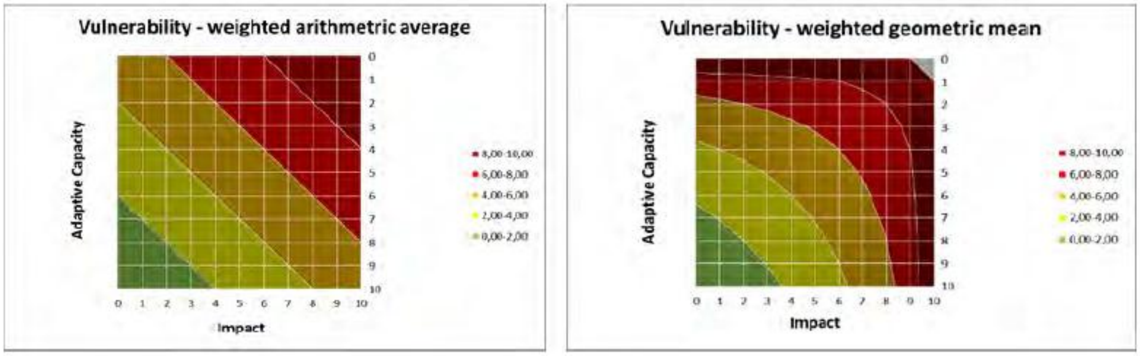


Figure A3 - Arithmetic and geometric aggregation approach comparison

The arithmetic aggregation method should be used for indicators, dimensions, or components that are independent to each other. This assumes that the indicators, dimensions, or components have no influence on one another. This statistical property of 'no interaction' can be regarded as problematic in socio-economic vulnerability assessments, as many vulnerability indicators and dimensions, most notably those related to adaptive capacity, and to some extent, to the sensitivity dimension, vary according to socio-economic characteristics. The geometric aggregation method appears to be better suited for correlated indicators, dimensions or components.

Arithmetic Aggregation

Individual **independent** indicators or vulnerability components should be multiplied by their weights, summed, and subsequently divided by the sum of their weights to calculate the composite indicator (index value) of a vulnerability component, as indicated in the following formula:

$$\text{Index value} = \sum w_i X_i = (w_1 \cdot X_1 + w_2 \cdot X_2 + w_3 \cdot X_3 + \cdots + w_n \cdot X_n).$$

Equation A4: Weighted arithmetic aggregation

Where, n= number of indicators; w_i= weight for indicator i, with $0 \leq wi \leq 1$ and $\Sigma\, w_i = 1$;
X_i = normalised value of indicator i

Geometric Aggregation

For individual **dependent** indicators or vulnerability components, the weighted geometric mean should be calculated as presented below:

$$\text{Index value} = \pi\, X_i^{wi} = (X_1)^{w1} \cdot (X_2)^{w2} \cdot (X_3)^{w3} \cdot \cdots \cdot (X_n)^{wn}$$

Equation A5: Weighted geometric aggregation

Where, n= number of indicators; w_i= weight for indicator i, with $0 \leq w_i \leq 1$ and $\Sigma\, w_i = 1$;
X_i = normalised value of indicator i

To enable meaningful aggregation of individual indicators, all indicators of the three vulnerability components must be aligned in the same way. This means that a low or high score represents a 'low' or 'high' value in terms of vulnerability.

Challenge of these steps

Weighting and aggregation, as explained above, are also challenging as the results are highly sensitive to the choices made.

Ideally, applied weights should reflect the contribution of each indicator or sub-component to the following composite. Alternatively, participatory methods that incorporate various stakeholders – experts, citizens and politicians – can be used to assign weights. This approach is feasible when the impact chain is drawn up in consultation with local stakeholders, and also during the GIS implementation for possible adjustments. This work should occur through a continuous interaction between actors in the field and the GIS expert. However, the scientific accuracy of this method is questionable. Statistical models such as principal components analysis (PCA) or factor analysis (FA) could be used to group individual indicators according to their degree of correlation, and weighting them according to their correlation strength. Weights, however, cannot be estimated with these methods if no correlation exists between indicators.

The other main issue highlighted in this impact chain implementation is the dilution of impacts along the aggregation process. The bigger the impact chain, the more the indicators of exposure, sensitivity and adaptive capacity will be diluted because of indicators' compensability resulting from aggregation. Impact chains constitute very relevant tools, as conceptual models, to represent and describe the cause-consequence links of climate change impacts. However, the complexity of the impact chain models cannot be reproduced in the mapping process without a loss of information. Therefore, before implementing the GIS work, we highly recommend restricting the number of indicators for exposure, sensitivity and adaptive capacity, by selecting those that are known to have a major impact on the vulnerability of the sector being assessed.

By the end of this step, the implementer should have:

- Selected the appropriate weighting and aggregation procedure(s).
- Discussed whether correlation issues among indicators should be accounted for.
- Discussed whether compensability among indicators should be accounted for.
- Documented and explained the weighting and aggregation procedures selected.

2. Robustness of a vulnerability assessment

The development of composite indicators involves stages where subjective judgements have to be made: the selection of individual indicators, the treatment of missing values, the choice of normalization method, the weights of indicators, the choice of aggregation model, etc. All these subjective choices are the bones of the composite indicator, here, the final vulnerability score given to each upazila. Together these methodological choices shape the message communicated by the composite indicator. Thus, the quality of a vulnerability assessment strongly depends on the soundness of its assumptions.

A scientifically good assessment practice would require an expert to provide an evaluation of the confidence in the vulnerability assessment process: firstly, by quantifying uncertainty in any step and the results (uncertainty analysis); and secondly, by evaluating how much each input is contributing to the final output uncertainty (sensitivity analysis).

Uncertainty analysis would allow for the investigation of the uncertainty of variables that are imputed in the vulnerability assessment scheme. In a complementary way, the **sensitivity analysis** would show how the uncertainty in the output of a mathematical model or system can be apportioned to different sources of uncertainty in its inputs. Ideally, an uncertainty and sensitivity analysis should be run in tandem.

The combination of an uncertainty and sensitivity analysis can help gauge the robustness of the final vulnerability score, to increase its transparency, identify which upazilas' vulnerabilities are favoured or weakened under certain assumptions, and to help frame a debate around the final results. The literature shows that several ways exist to assess the robustness of such an indicators-based assessment. However, most of the time it requires statistical work which is heavy and complex to implement, and not always feasible given the time usually provided for such a study implementation.

3. Building maps to assess vulnerability: GIS application

Mapping enables depiction of the temporal and spatial distribution of different aspects or determinants of vulnerability – i.e. hazards, biophysical features or processes, socio-economic conditions, etc. (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) 2013). Climate and its impacts vary over space, and this pattern of variation is likely to change as the climate changes. These aspects are of crucial importance for policy makers operating at regional, national or international scale, because **changes in vulnerability may affect regional equity, with consequent implications for planning** (Intergovernmental Panel on Climate Change 1994). Will the evolution be the same for all territories, or will climate change lead to new disparities? Will the consequences be the same for all issues in the same territory, or will some of them suffer a more worrying aggravation? As stated before, the mapping step in this study is an innovative approach which is essential to assess vulnerability at a regional scale.

This section details key GIS implementation steps for execution of the vulnerability assessment exercise. The first section familiarizes the reader with the basics of input data used in a GIS analysis. The second section discusses steps involved in setting up a project-related GIS environment. The third section is dedicated to discussions on GIS tools used for the assessment. It may be noted that the GIS implementation was done in ESRI's licensed software, Arc GIS 10.3.1.

4. Data formats and types

This section provides descriptions for **raster and vector data type**, the two basic data types used to store geospatial data. The understanding of data types is important for proper manipulation of the data.

Vector data

The vector data format represents the real world as objects. These objects can be points, lines or polygons (Figure 14).

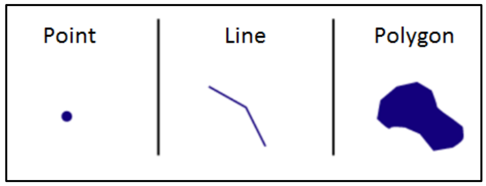


Figure A4 - Vector data GIS type

The data format of upazilas is vector type (**Error! Reference source not found.**), where each upazila is a polygon object with many qualities (called attributes). **Error! Reference source not found.** shows the upazila file where one object (upazila called Baghai Chaari) is highlighted in blue. All information about Baghai Chaari's qualities (attributes) like THACODE (Zipcode), DIVNAME (Province), DISTNAME (District), THANAME (upazila name) is shown in the left and is saved in a table called 'attribute table' of the vector file.

The vector data format can store information about many qualities of each object. Each object in a vector data (attribute) file is placed in a row, and the values corresponding to its qualities/attributes are placed in corresponding columns (**Error! Reference source not found.**).

Location: 722,179.008 2,580,251.971 Meters

Field	Value
FID	142
Shape	Polygon
THACODE	208407
DIVNAME	Chittagong
DISTNAME	Rangamati
THANAME	Baghai Chhari
Income_mil	212
Shape_Length	278401.545723
Shape_Area	1615675180.40625

Figure A5 - Vector file of upazila (left), attributes of one polygon object (in blue), Baghai Chaari (right)

FID *	Shape *	THACODE	DISTNAME	THANAME	Shape_Length	Shape_Area
1	Polygon	100409	Barguna	Amtali	197474.134029	515273615.294637
2	Polygon	100419	Barguna	Bamna	61124.611651	100987247.905049
3	Polygon	100428	Barguna	Barguna Sadar	104012.379281	324722084.838169
4	Polygon	100447	Barguna	Betagi	97402.211705	164855337.885623
5	Polygon	100485	Barguna	Patharghata	110189.000502	238769284.892955

Figure A6 - Snapshot of an attribute table of vector file with upazilas as polygon objects

The data format for all of the human sensitivity and adaptive capacity indicators is a vector type.

Raster data

Raster data, on the other hand, is a location-based data structure (**Error! Reference source not found.**). Space is partitioned into equal sized cells, grids or pixels. Only one value can be assigned to each cell (e.g. land-use type, temperature, elevation, etc.). This data type is the most suited for information that is continuous in nature. Unlike vector data, raster data does not have an attribute table.

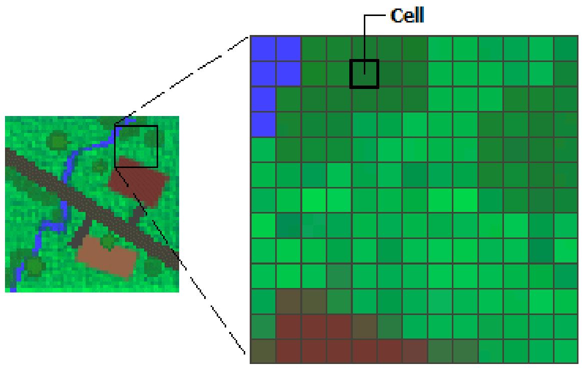


Figure A7 - Example of land-use type raster

The data format for all exposure indicators, along with an indicator for air pollution of the sensitivity component is a raster type.

5. Measurement scale of indicator data

The value of an attribute of an object in a vector data type can have three scales of measurement: nominal, ordinal and metric. The **nominal and ordinal scales are qualitative** in nature. In the nominal scale, all values are different in nature and equal in terms of importance (e.g. land-use type, Zip-code, name of sub-districts). Values in the ordinal scale are different, but there is a single way to order the values (e.g. level of arsenic concentration in groundwater described as high, low or moderate). The attributes of ordinal scale are never absolute numbers, but always ordered.

The **metric scale is always quantitative** in nature. Metric scale measurement values are different and are determined by an apparatus (e.g. Celsius temperature scale, population of an upazila, etc.). An understanding of the scale of measurement is crucial for the normalization step. The three types of measurement scale dictate the use of the specific set of GIS tools.

By this step, the implementer should be familiarized with :

- The two data types ;
- The three scales of measurement.

6. Setting up a GIS environment

At the start of a GIS project, a work environment with the correct settings needs to be established. The following steps were taken for setting up a work environment:

1. Source data, final results, and an intermediary results geodatabase was established. The nomenclature of the database is necessary to avoid confusion and allow for the easy transfer of project ownership from one person/team to another (**Error! Reference source not found.**).
2. Intermediary results geodatabase was set as the workspace and scratch workspace, which will allow overwriting of results every time a GIS tool/model is run.
3. Projections for the workspace were defined as the Bangladesh National grid projection: Gulshan-303.

4. A toolbox was created with subfolders. Each subfolder contained the tools concerning each step of the process, as described in the following section.

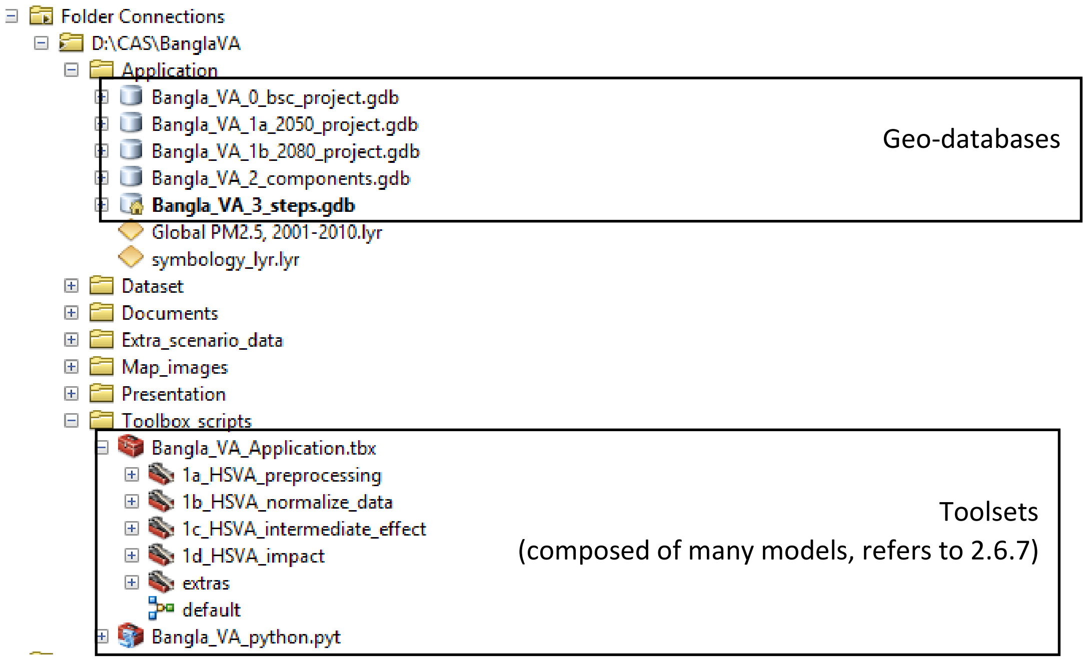


Figure A8 - Geodatabases and Toolbox set for vulnerability assessment exercise in ArcMap

7. Geographic Information System (GIS) tools

This section presents the tools used to compute the vulnerability of Bangladesh sub-districts to heat stress.

Pre-processing steps

After establishment of the workspace, data for each indicator was pre-processed. Pre-processing involved the following steps:

Clipping data to Bangladesh border extent

All data was clipped to the extent of Bangladesh's national border (**Error! Reference source not found.**). Exposure data used in the project was an outcome of global climate models and therefore, had to be clipped down to the area of interest.

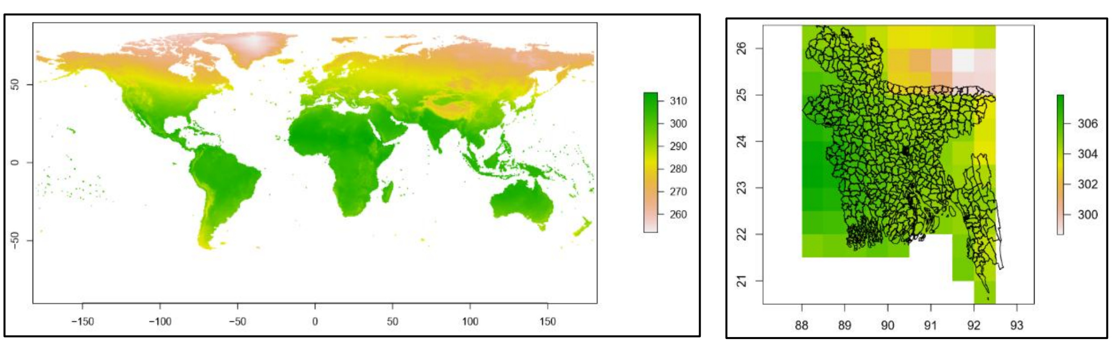


Figure A9 - From global data on temperature (in Kelvin) projections for 2050, RCP 4.5 (left), the data was clipped to the extent of Bangladesh (right)

Filling the data gaps

Most data used in the project was complete, with the exception of some exposure data which was missing (part of the marshy Sundarbans regions in the South[5]). However, for the computation of vulnerability at the sub-district level, to provide fair comparison between sub-districts, missing data for the southern sub-districts had to be computed. Based on the data type, there are two methods of filling data gaps:

Areal Interpolation

This method is suitable for vector type data. The tool will interpolate the values to a defined extent. **Error! Reference source not found.** shows the execution of areal interpolation, which fills the missing data gaps (in red circles), while simultaneously changing the output data type from vector to raster.
[Note: In this step, the user can choose to generate the output in vector format as well]

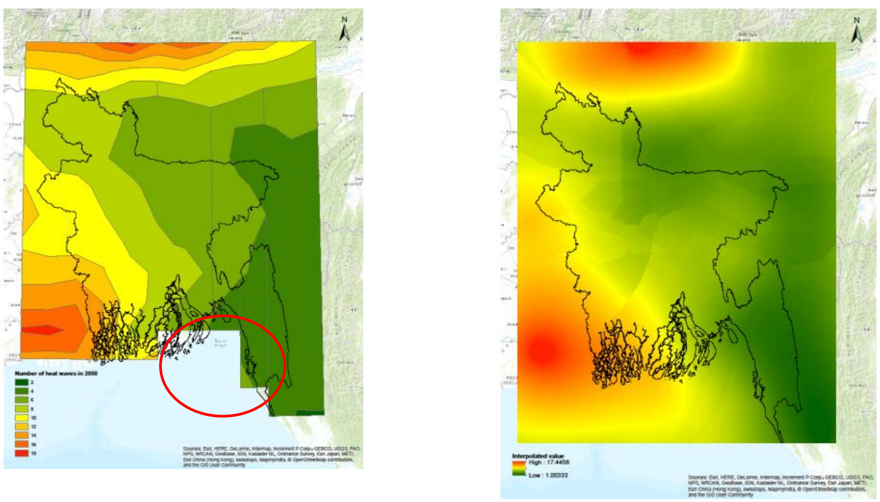


Figure A10 - Missing data gap (in red) is filled by performing areal interpolation on the vector file of climate indicators (left). The output of operation is a raster data-type (right)

Focal Mean

This method is best suited for raster data-type. The value of a missing cell is computed by applying a function (e.g. mean) to the cells of a specified window-size (e.g. 3 by 3) around the cell (**Error! Reference source not found.**).

[5] The climate model created projections of the climatic conditions for land. The marshy regions in the South of Bangladesh are not categorized as land, and therefore, data for these locations was missing.

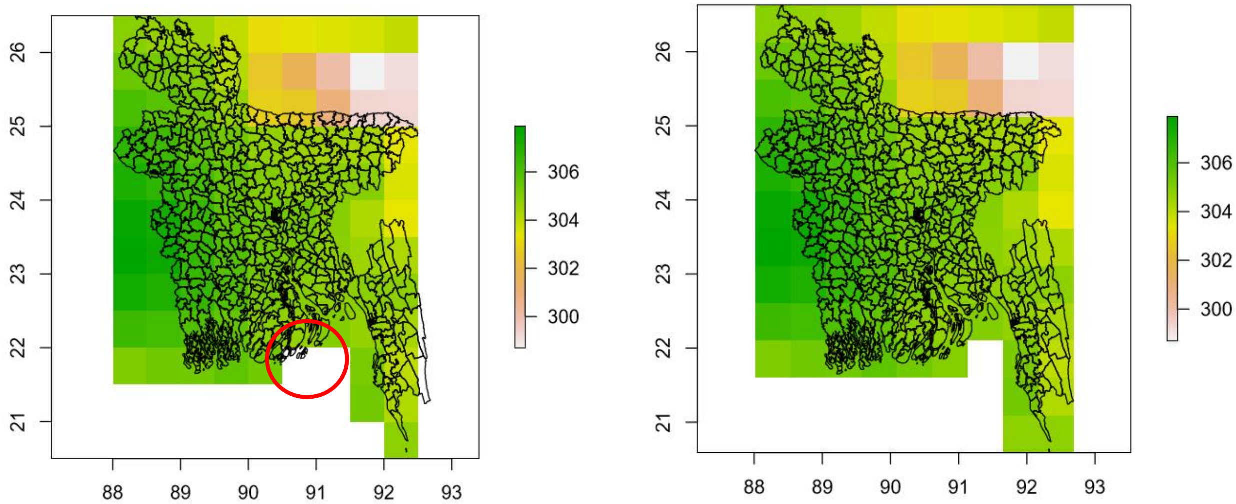


Figure A11 - Raster file of temperature projections for 2050 (in Kelvin) with missing data (left), output of focal mean operation (right)

Once the data is pre-processed, the next step is to transfer indicator values to each upazila.

By the end of this step, all input data should be:

- Pre-processed
    - Projected to Bangladesh national grid ;
    - Create its working environment by assembling all required data under project geodatabase ;
    - Complete and clipped to Bangladesh's extent.
- Ready for transfer to the upazila level.

Transferring indicator data to upazila

Most data for the adaptive capacity and human sensitivity indicators were available at the upazila level. All exposure indicators were available as raster type data, which needed to be transferred to each upazila. As discussed in the previous section, the indicator data may be available in different data formats and can have different measurement scales. This section focuses on GIS tools used for the transfer of indicator values to upazilas for different data types and scales of measurement.

Raster data-type (metric scale)

Data for all three exposure indicators: annual average maximum temperature, consecutive wet day events in summers, and summer days above 40 degrees, along with one sensitivity indicator: PM2.5, were available as raster. This means each cell in the raster had one value of the corresponding indicator. To make use of this data for the vulnerability assessment, all data available at the cell level had to be transferred to each upazila.

For instance, if five cells with different values of average maximum temperature fall within an upazila boundary, the transferring process consisted of calculating and allocating the corresponding average maximum temperature projections to each upazila.

This was achieved by using the following sequence of tools:
Step 1: Apply Zonal statistics as Table. This operation uses upazila boundary as a cookie cutter to extract all the values of cells falling within the boundary and then, returns the “MEAN” value of all these cells.

Step 2: Use operation Join Field. This operation adds a new attribute (e.g. average maximum temperature in 2050 for RCP scenario 4.5) from the table created in step 1, to the upazila vector file.

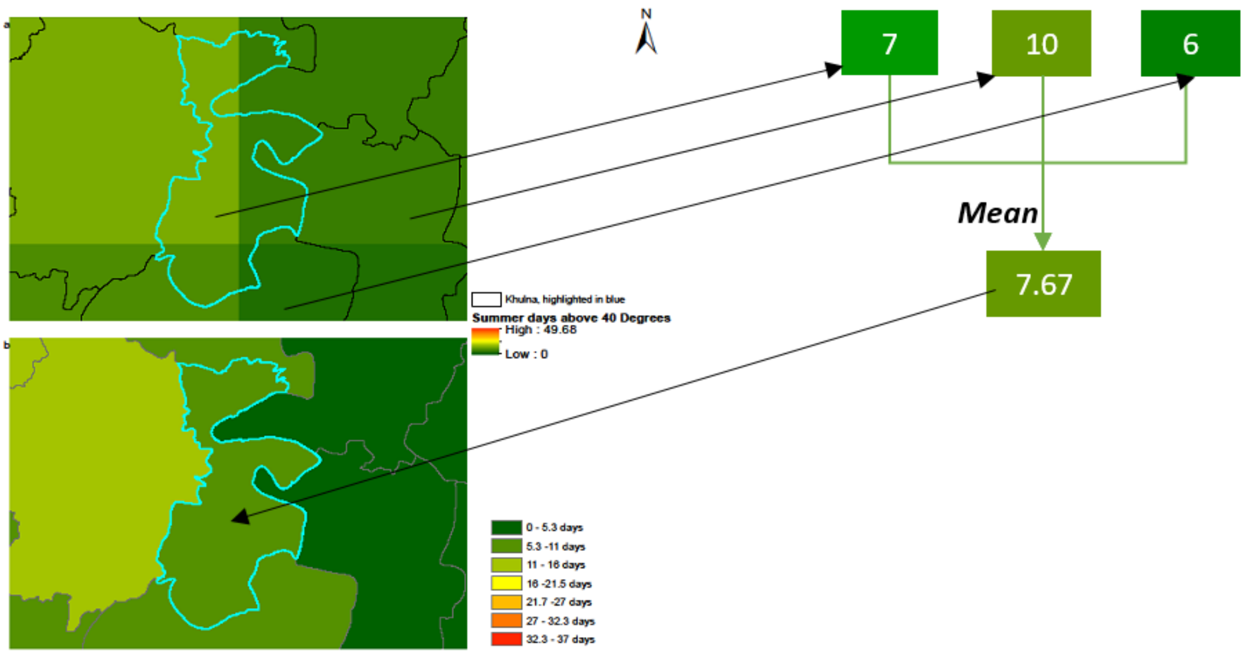


Figure A12 - Transfer of values to upazila from raster data type

‘Zonal Statistics as Table’ tool extracted all cells falling within the Khulna border (shown as blue border in **Error! Reference source not found.**). The cells of three unique values fell within Khulna’s border. Therefore, the number of summer days above 40 degrees for Khulna is given by the mean of the values of the cells inside Khulna’s border.

The computed mean value was then transferred to the upazila file by ‘Join Table’ tool.

Vector data type (nominal or ordinal scale)

Some vector data type (land-use type) was not available at the upazila level and therefore had to be transferred to the upazila. Also, some of this data followed the nominal scale of measurement (e.g. for land use type vector file, the attribute values were agriculture, forest, etc. and not a number). The nominal measurement scale was converted to metric measurement scale by assigning numerical values to each land-use type.

Manipulation of available data

As expected, not all data was available. Therefore, data had to be manipulated to create a desired indicator. For example, for the adaptive capacity component, income data was available at the upazila level. However, this data does not provide any relevant information about the adaptive capacity of a person in the upazila. Since per capita income is a more suitable indicator, the desired indicator (per capita income) was created using two different data (Income data and population density data).

Step 1 Join table: The population density data and income data are joined to the upazila vector file, resulting in the creation of two new attributes (qualities: income and population) for each upazila.

Step 2 Add field: A new (empty) attribute column is added to the upazila vector file.

Step 3 Calculate Field: The newly created attributes are calculated using an equation (Income/Population) in this step.

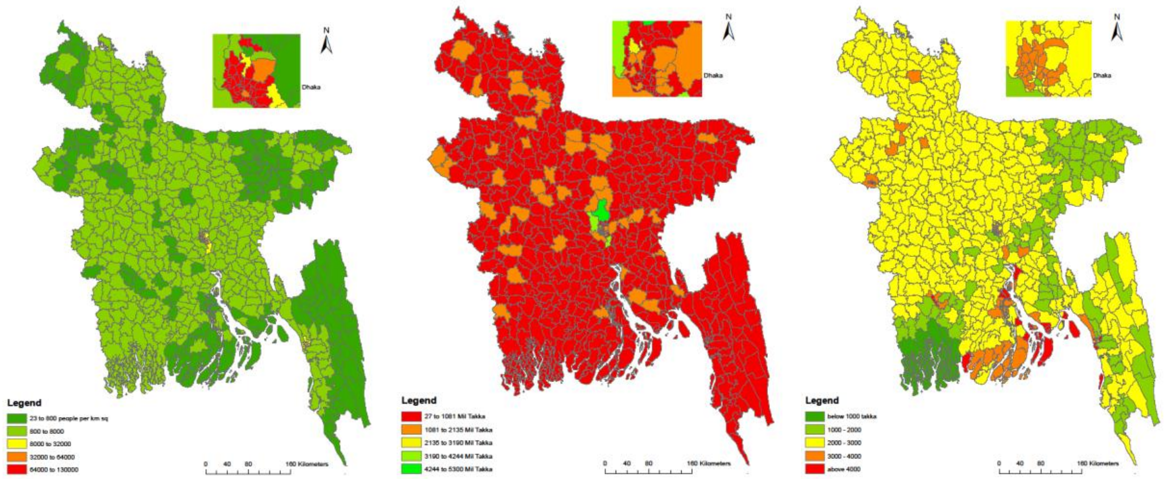


Figure A13 - Population density (left) with income per upazila (middle) and computed Per Capita Income (right)

By the end of this step,

- All indicator information (data) should be available at the upazila level.

The tool sequence used in the manipulation of available data should be well understood as it is the basis of all further GIS implementation steps.

8. Use of model builder

All maps in this exercise are created using a set of models. Use of models lead to near automation of the vulnerability exercise. Any desired changes in the weighting, aggregation type and normalization type can be accommodated to produce new results. The main benefit of modelling is the scope of repeatability of the assessment in future. For fair comparison of a vulnerability assessment exercise conducted today and tomorrow, it is important that the model, and the process applied for assessment is conserved, which is possible by using model building tools.

ModelBuilder in ArcMap is a visual programming language for building geoprocessing workflows. Models are represented as diagrams that chain together sequences of processes and geoprocessing tools. ModelBuilder in ArcMap allows to:

1. Build a model by adding geoprocessing tools, map layers, datasets, and other data types, and connecting them to a process.
2. Iteratively process every feature class, raster, file, or table in a workspace.
3. Visualize our workflow sequence as an easy-to-understand diagram.
4. Run a model step-by-step, up to a selected step, or run the entire model.

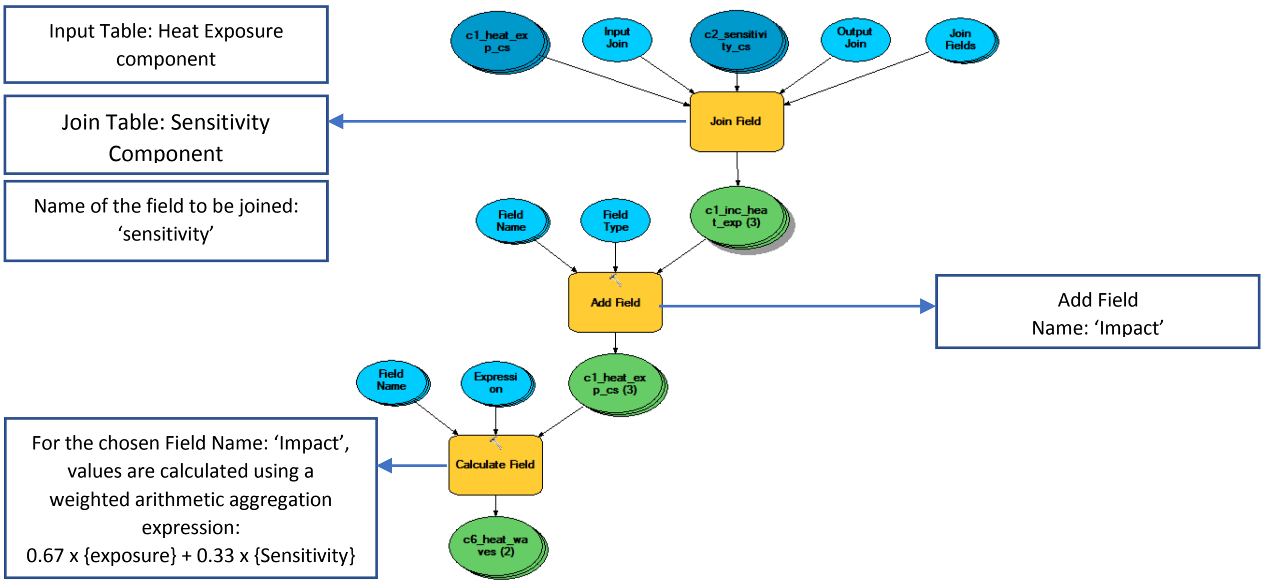


Figure A14 - Illustration of the Model Builder

In this example, the aim of the model is to reiterate five times the aggregation of heat exposure and the sensitivity component for the following timelines and scenarios: current; 2050, RCP 4.5; 2050, RCP 8.5; 2085, RCP 4.5; and 2085, RCP 8.5, to compute potential impact maps. Finally, being able to build a model is a very strong requirement as it.

B. Human Vulnerability to Climate Change

1. Impact chain

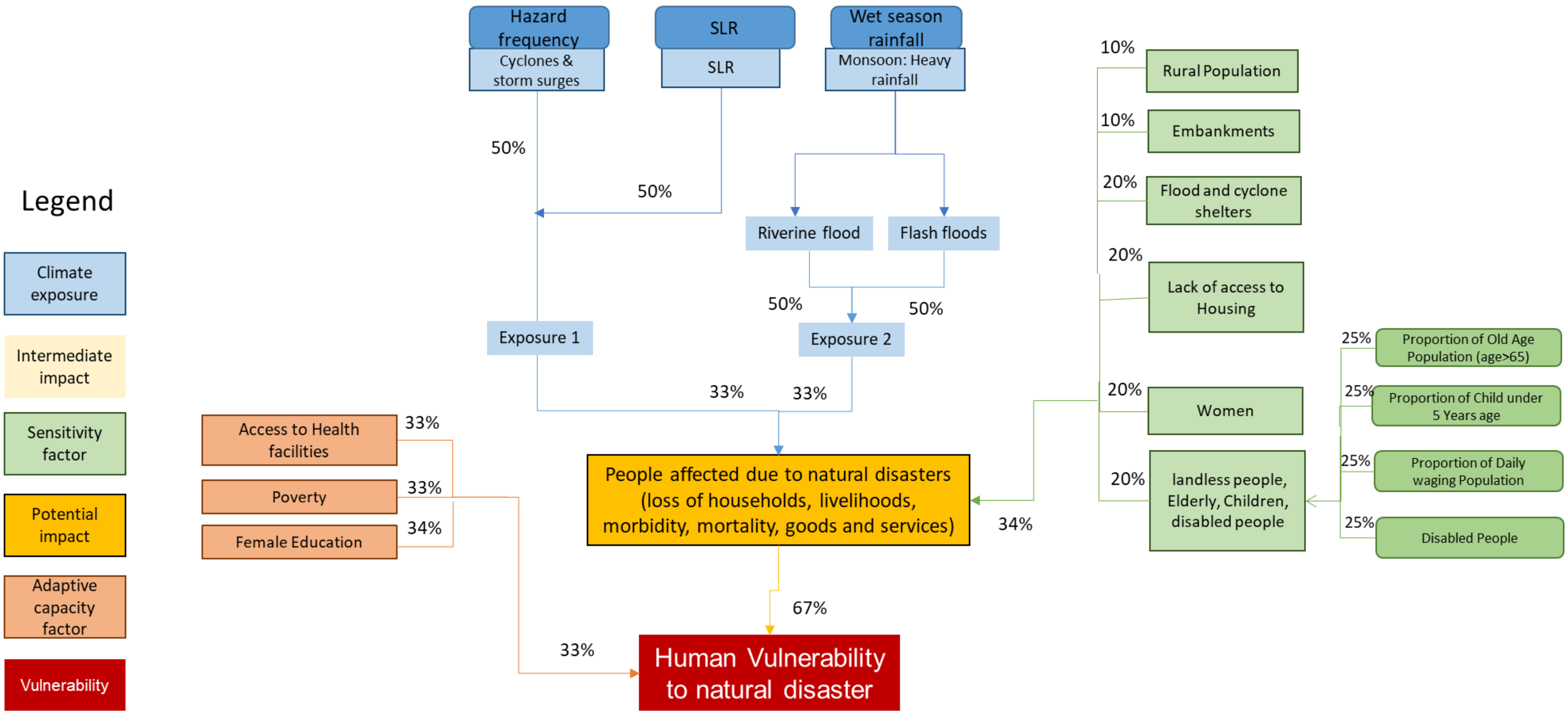


Figure B1: Simplified impact chain for human vulnerability to natural disasters assessment

2. Current exposure of human due to natural disasters

[Cyclone and storm surgeas] [Sea level rise] [Riverine flood] [Flash flood]

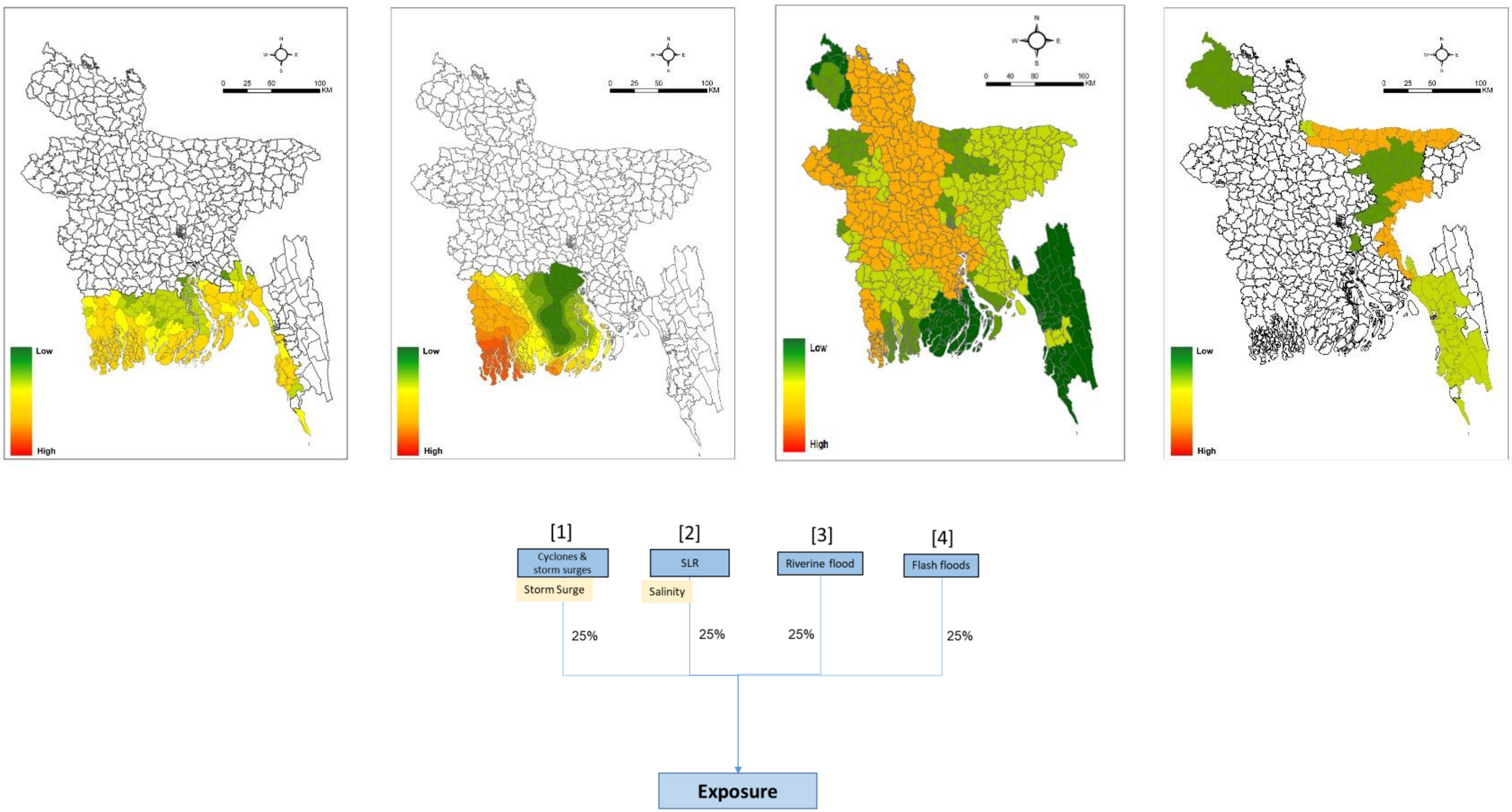


Figure B2: Intermediate maps of exposure to natural disasters

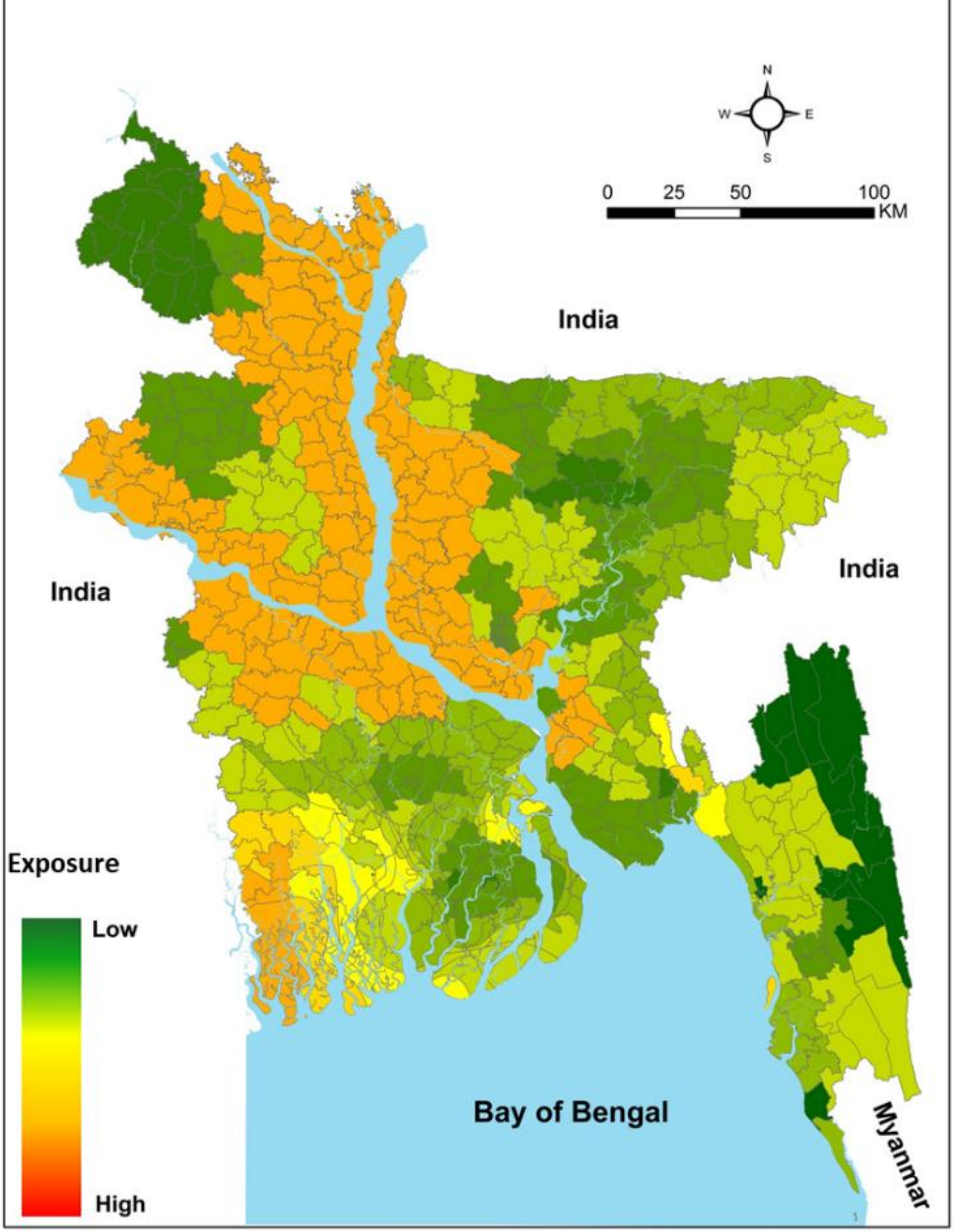
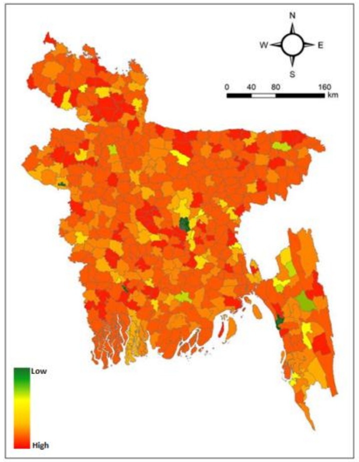


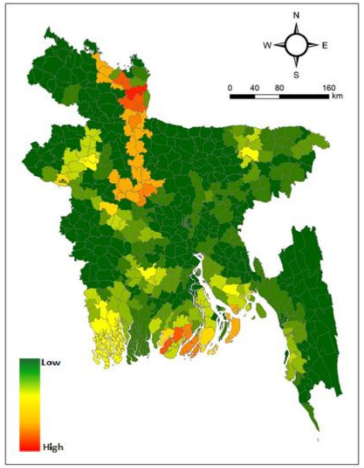
Figure B3: Map of current exposure to natural disasters in Bangladesh

3. Current Sensitivity of human due to natural disasters

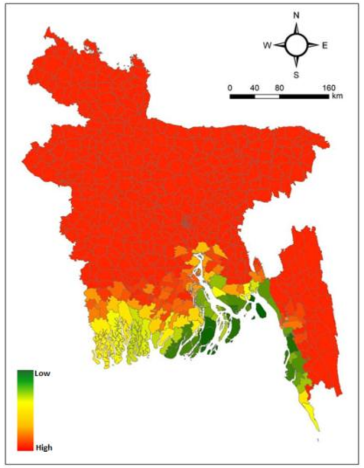
[Rural population]



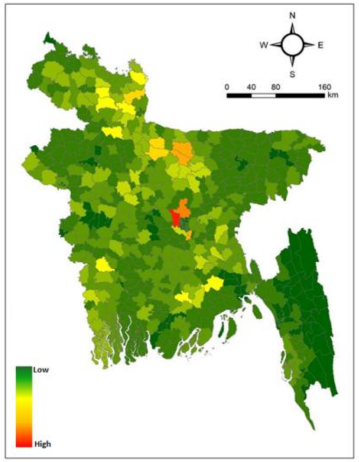
[Embankments]



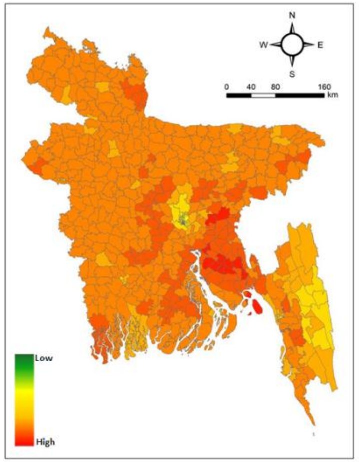
[Flood and cyclone shelters]



[Absence of climate resilience housing]



[Women]



[landless people, elderly, disable, and children]

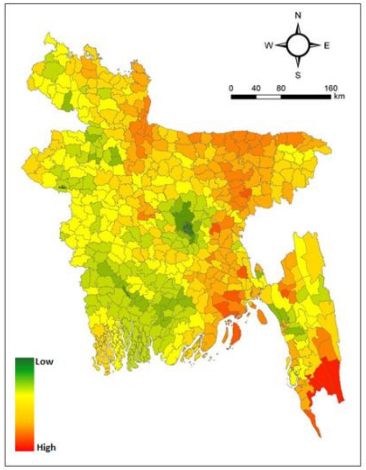
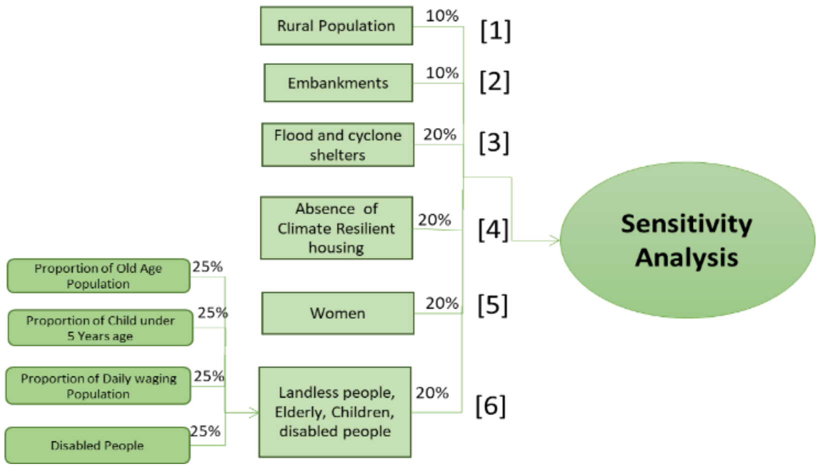


Figure B4: Intermediate maps of human sensitivity to natural disasters



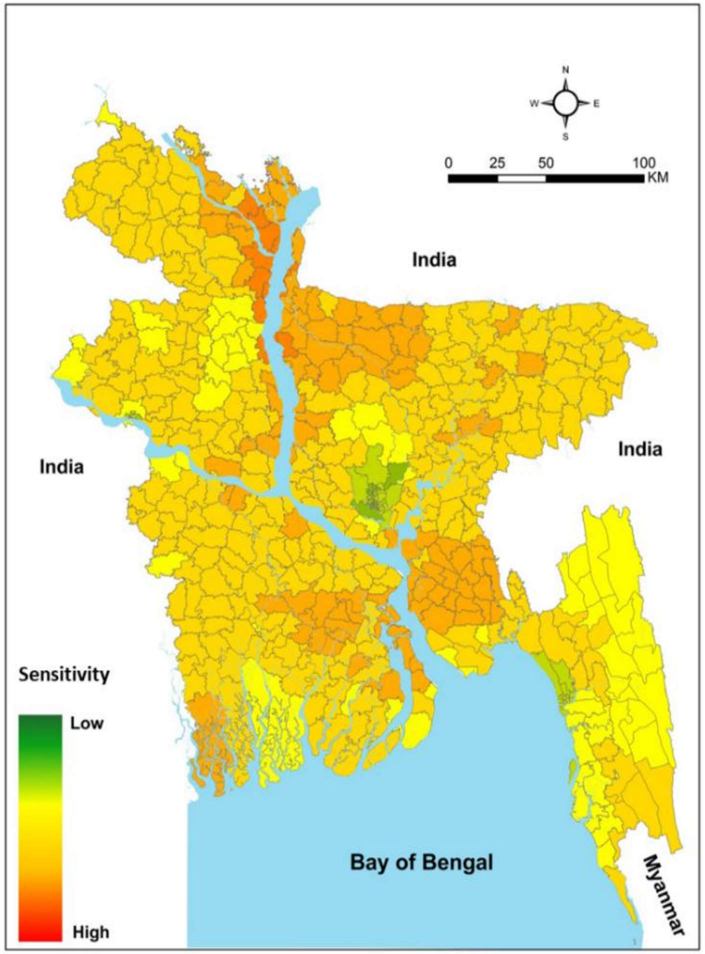
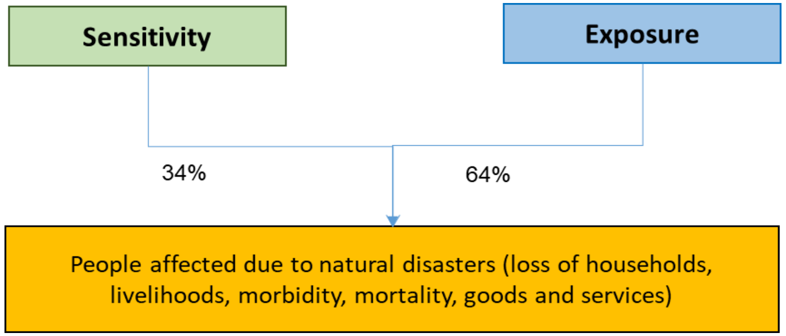


Figure B5: Final map of human sensitivity to natural disasters

4. Potential impact



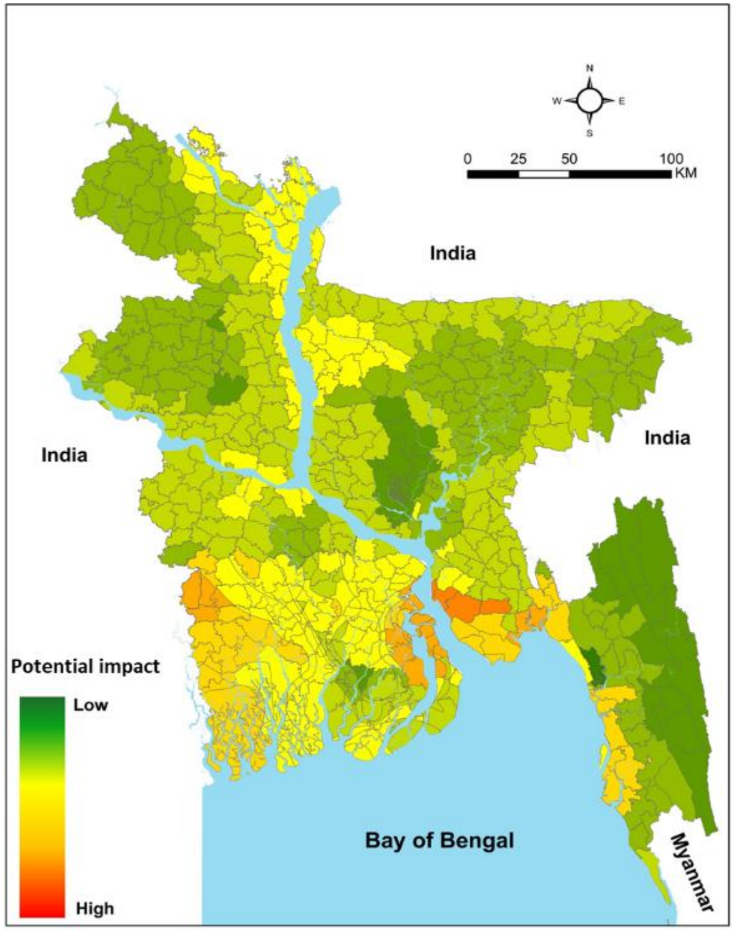


Figure B6: Potential impact of human due to natural diaster

5. Adaptive capacity

[Access to health facilities] [Poverty] [Female education]

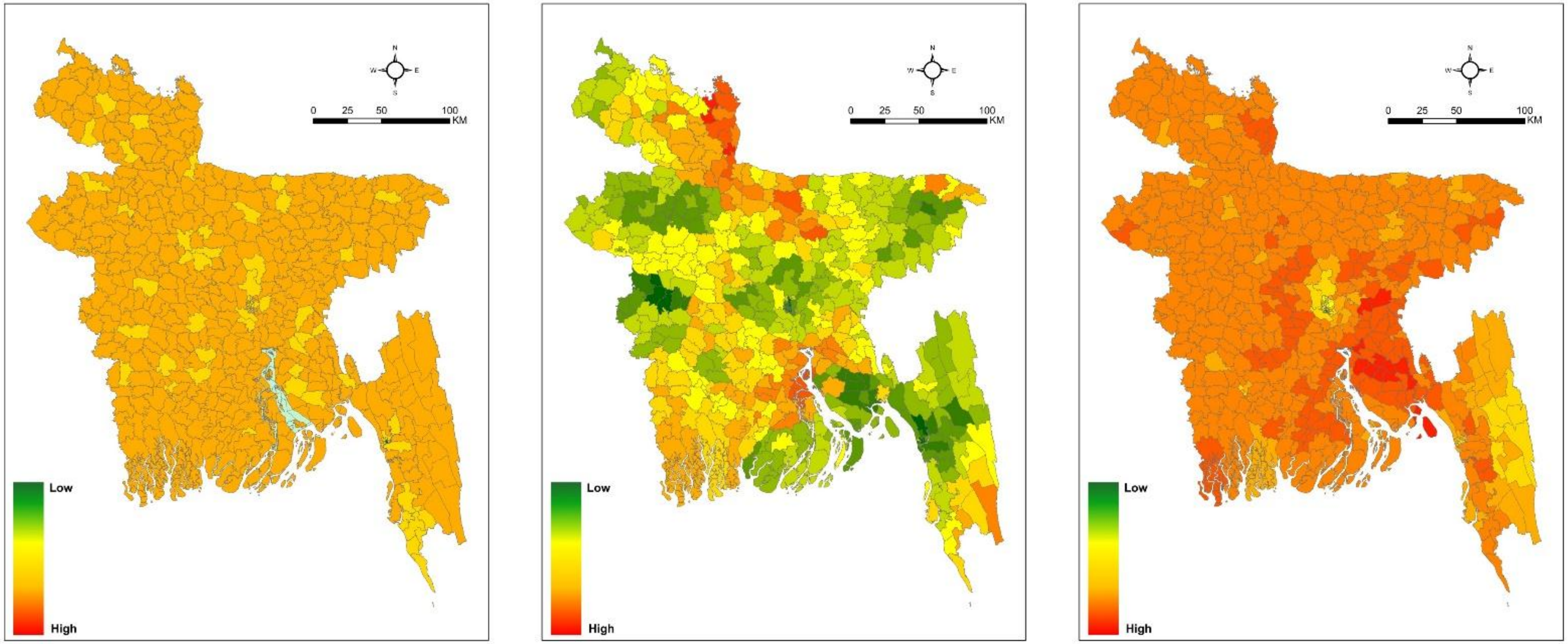
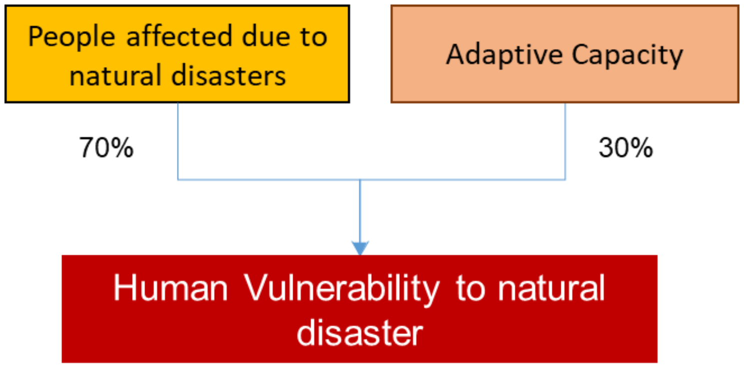


Figure B7: Intermediate maps of human ability to cope with the natural disaster’s impacts

6. Human vulnerability to natural disasters



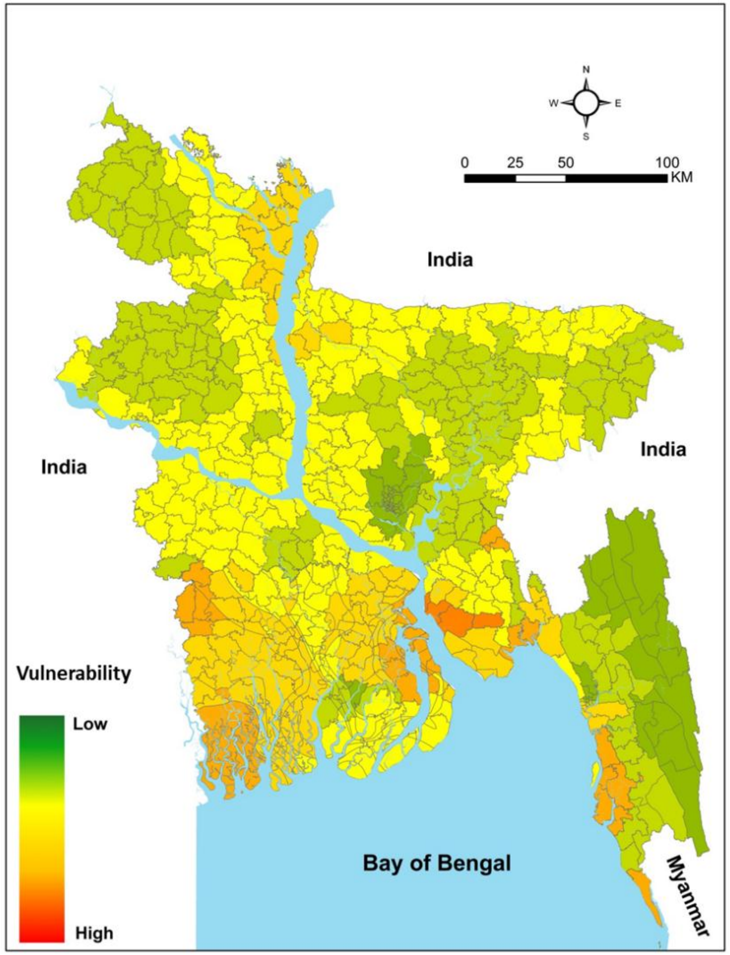


Figure B8: Map of current vulnerability to natural disasters in Bangladesh (considering flash flood, river flood and sea level rise)

A. Health Vulnerability due to Climate Change

1. Imapct chain

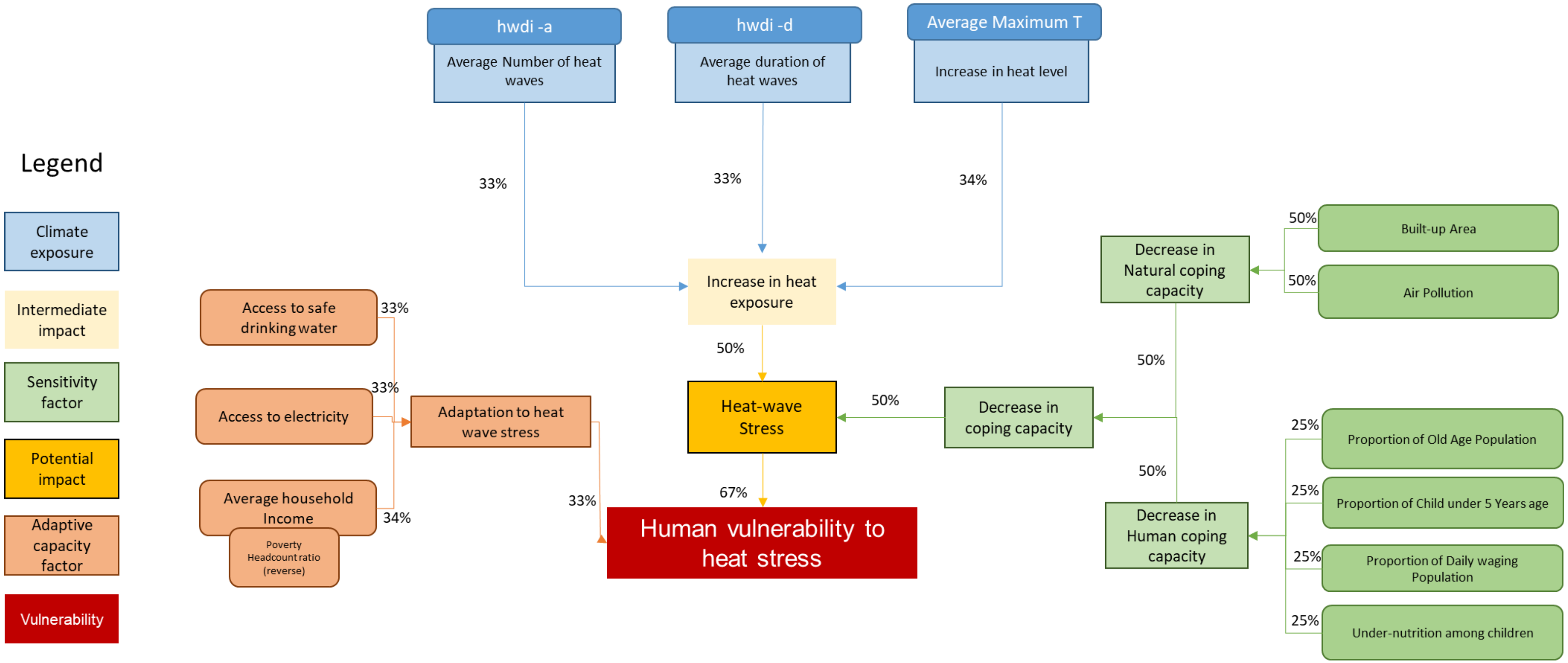


Figure C1: Impact chain of human vulnerability to heat stress

2. Current exposure

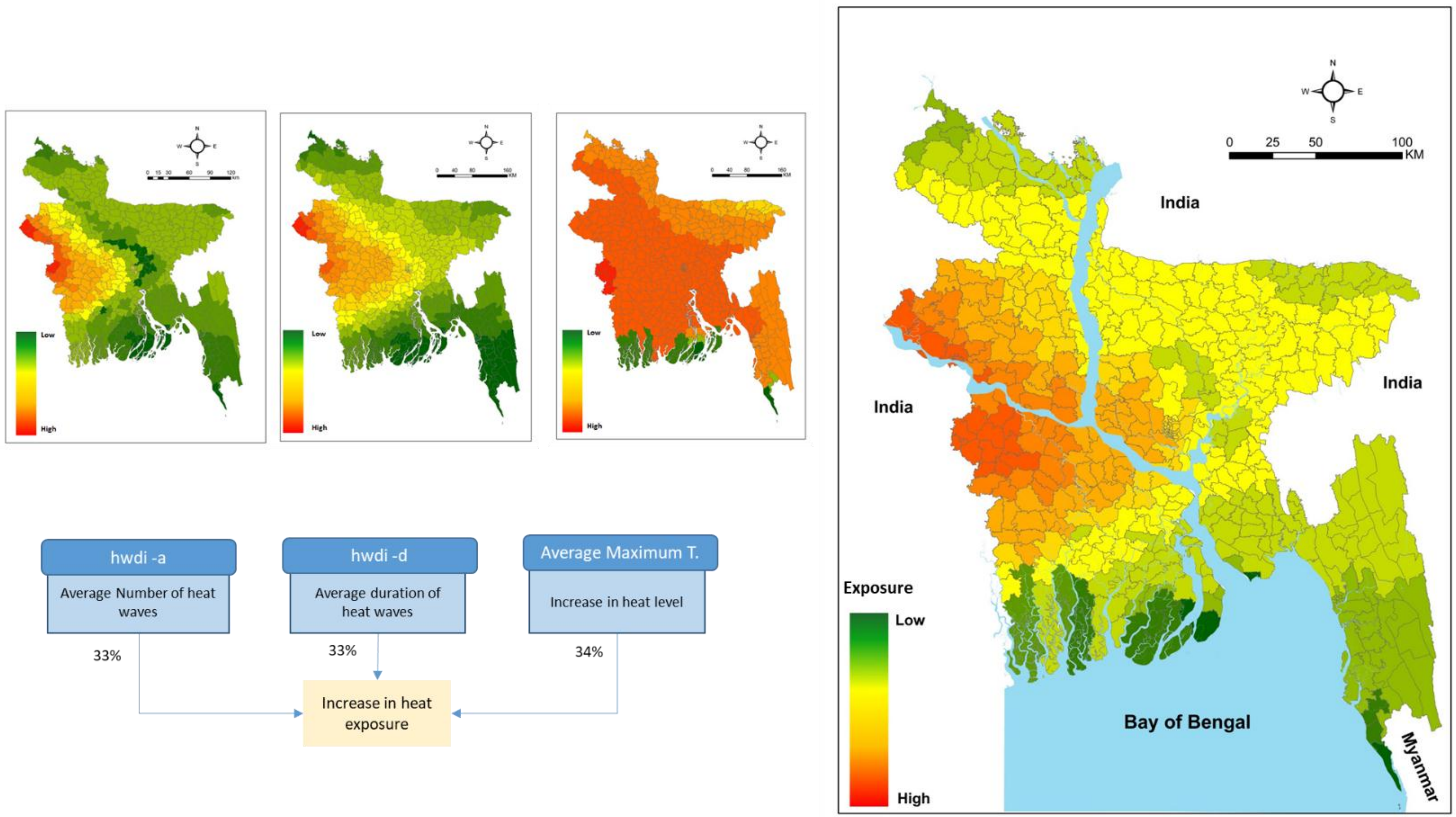


Figure C2: Map of current exposure to heat stress in Bangladesh

3. Evolution of the exposure to heat stress in the future

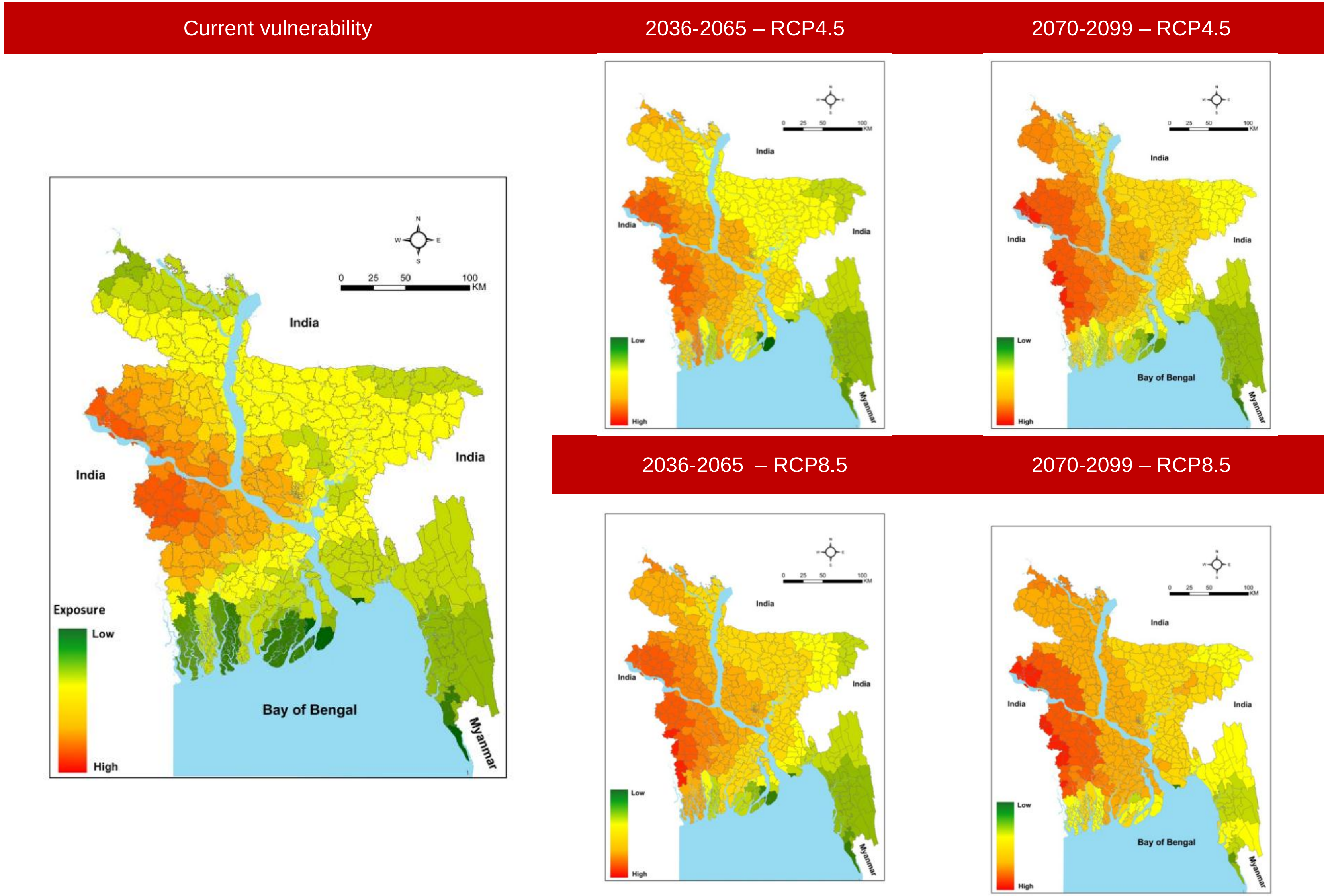


Figure C3: Evolution of the exposure to heat stress in the future

4. Sensitivity

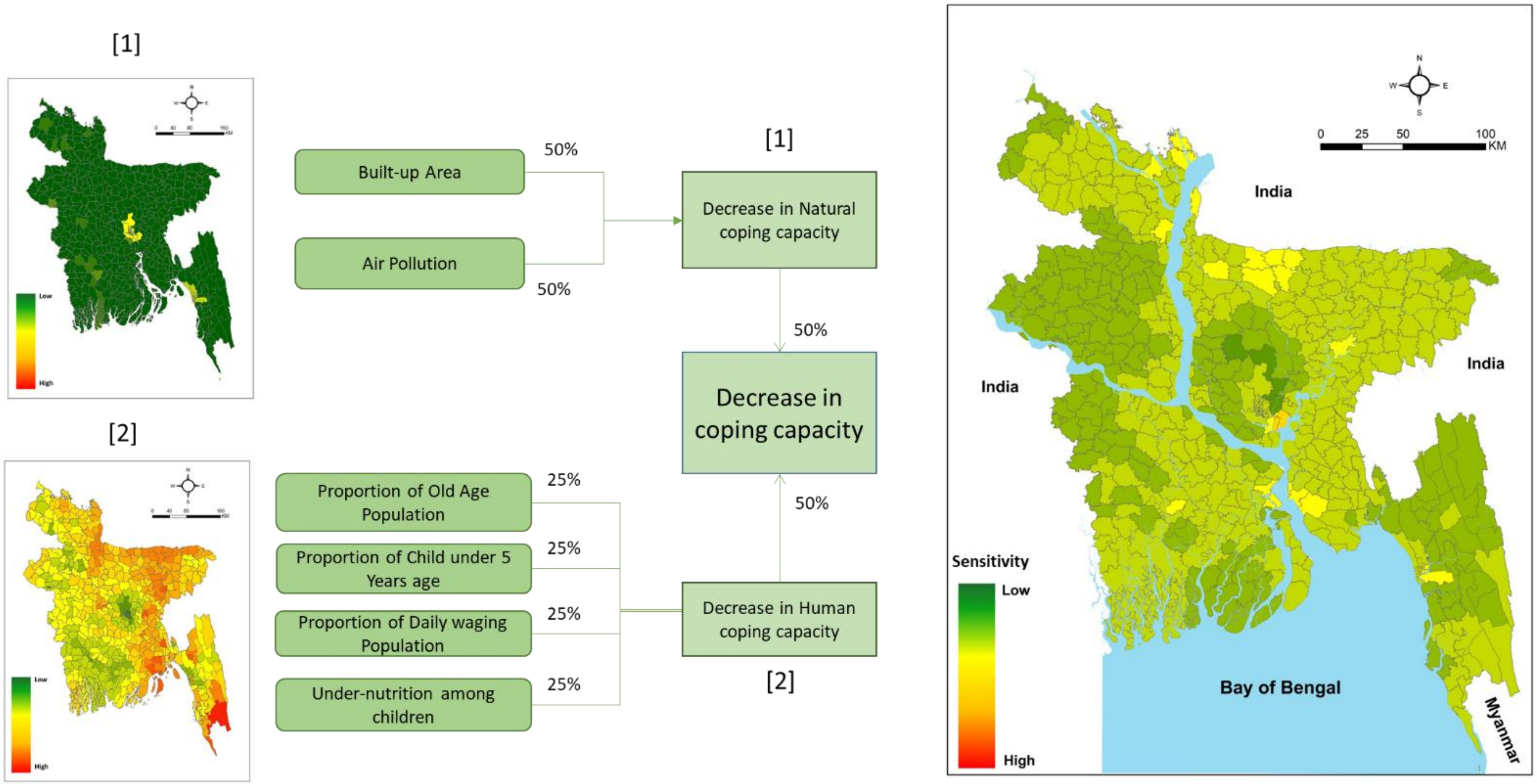


Figure C4: Sensitivity of health due to heat stress

5. Potential impact

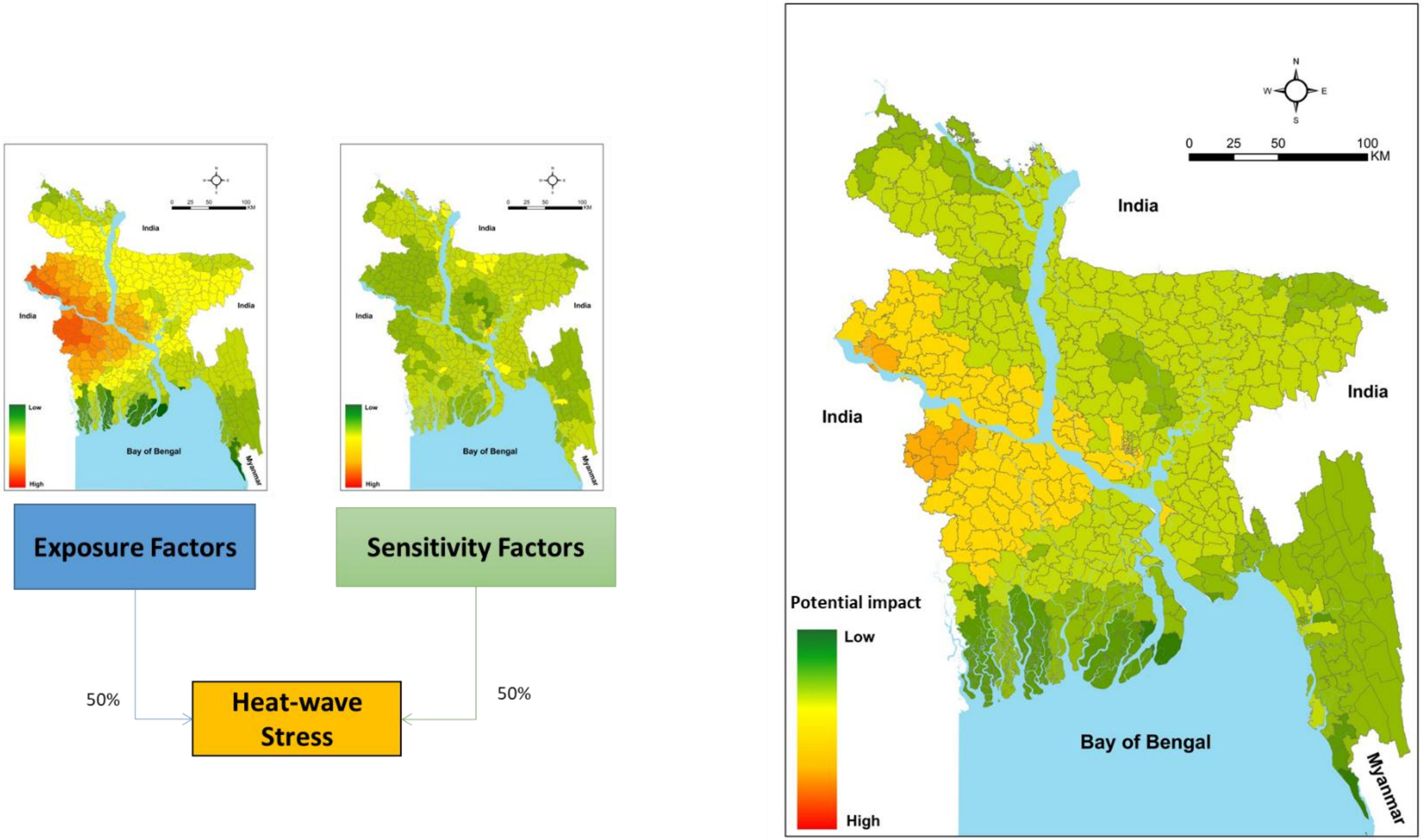


Figure C5: Potential impact of health due to heat stress

6. Adaptive capacity

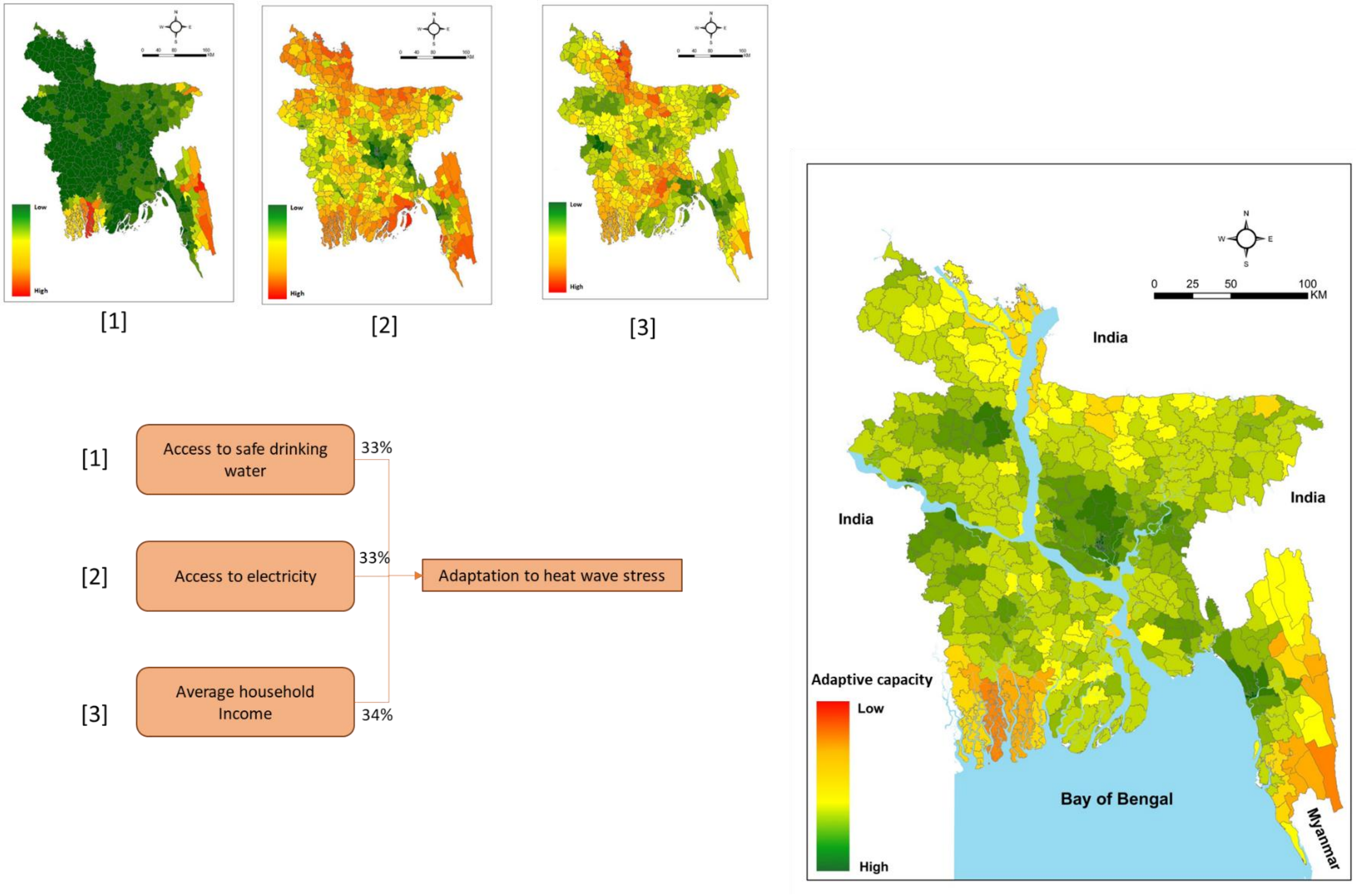


Figure C6: Adaptive capacity to cope with heat-waves stress

7. Present health vulnerability to heat stress

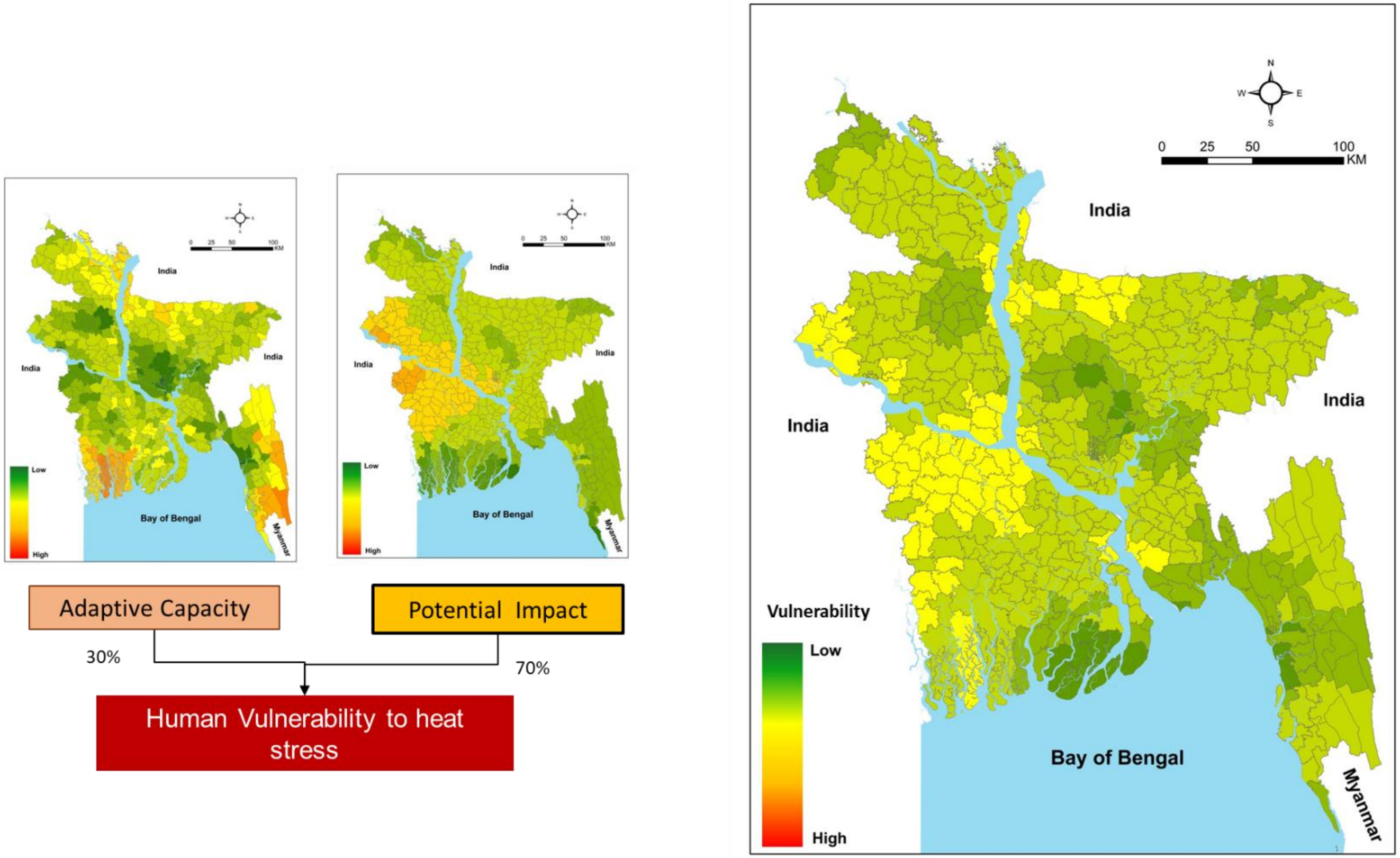


Figure C7: Present vulnerability of health due to heat stress

8. Current and future vulnerability to heat-waves stress

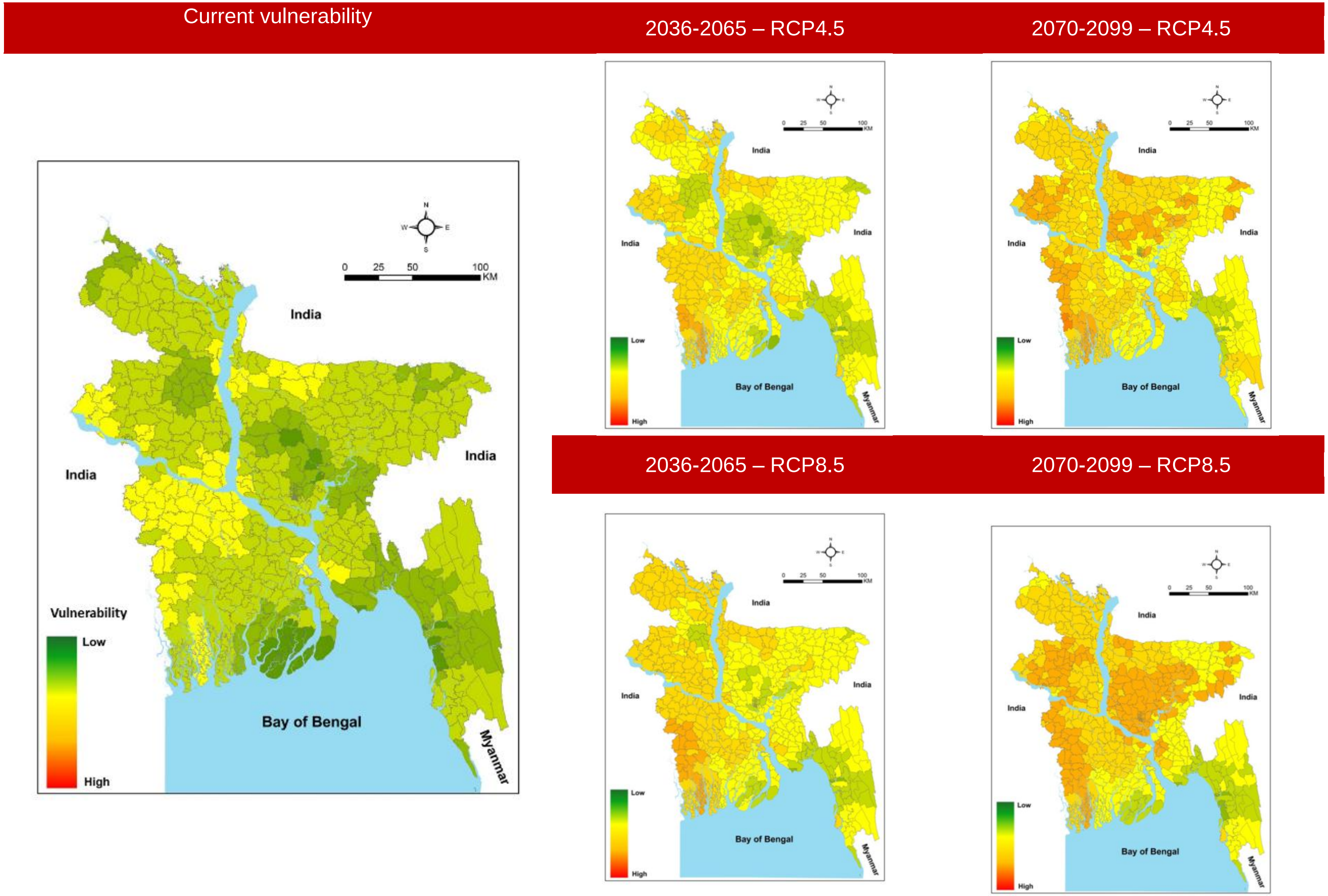


Figure C8: Evolution of health vulnerability due to heat-waves stress in the future

B. Water resources vulnerability to climate change

1. Impact chain

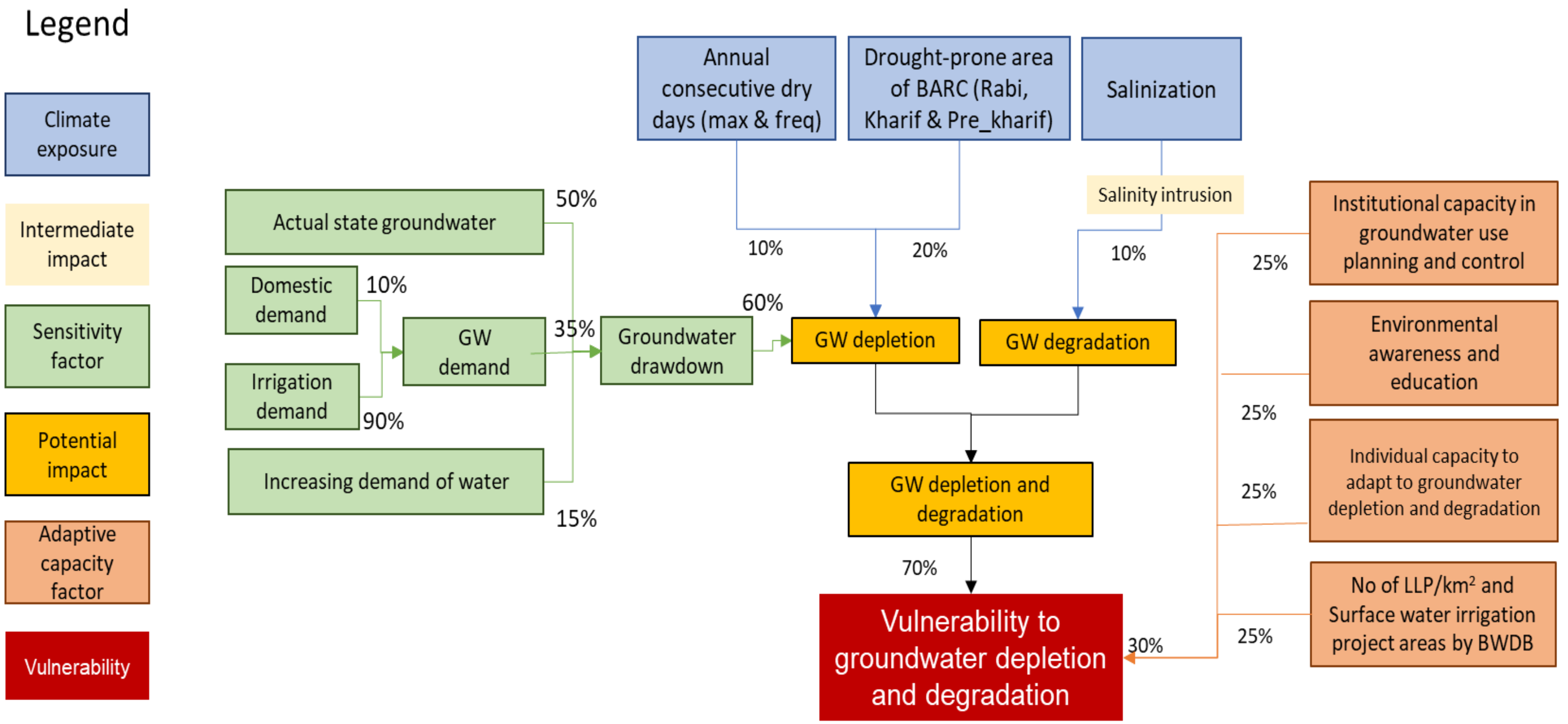


Figure D1: Impact chain for vulnerability to groundwater resources depletion and degradation

2. Exposure to drought and salinization

[Consecutive dry days] [Drought-prone area] [Salinity intrusion area]

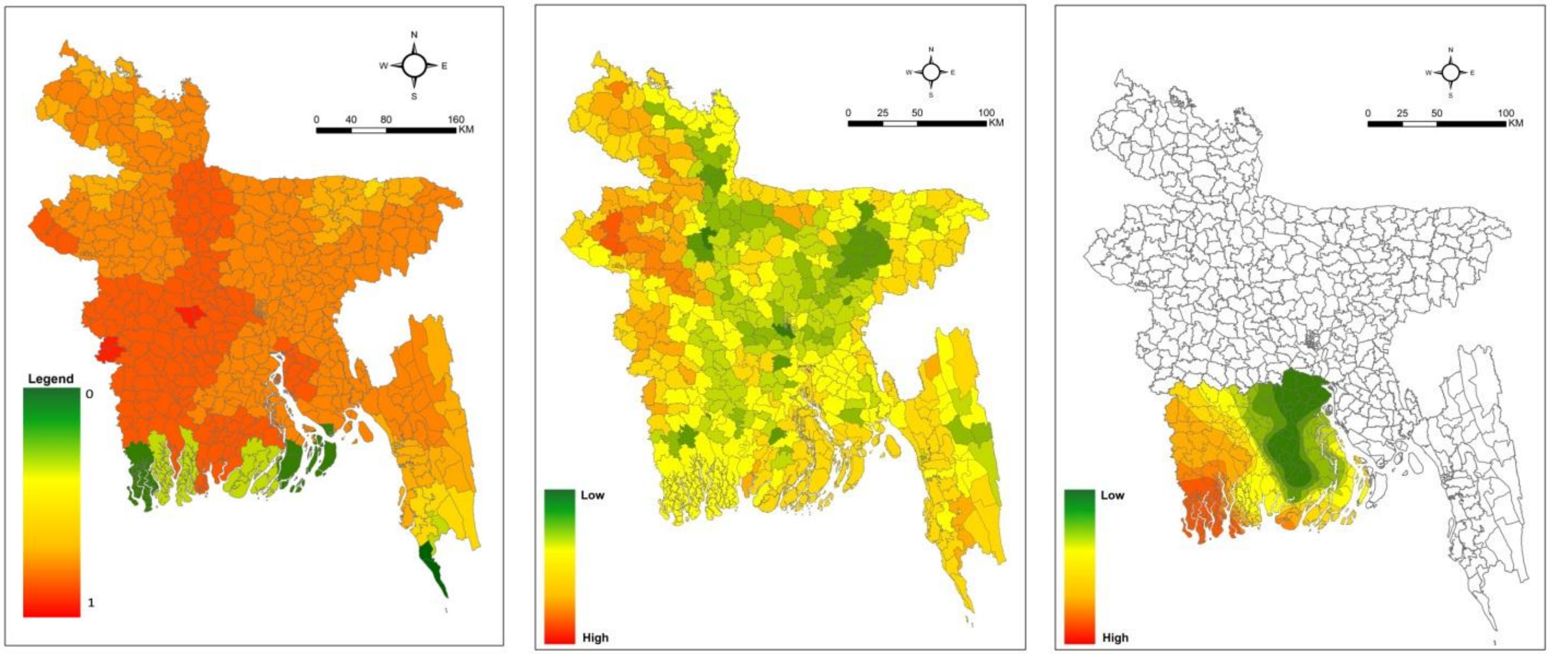


Figure D2: Exposure maps for groundwater depletion and degradation (GDD)

3. Sensitivity

[Actual state of ground water] [Domestic demand] [Irrigation demand] [Increasing demand of water]

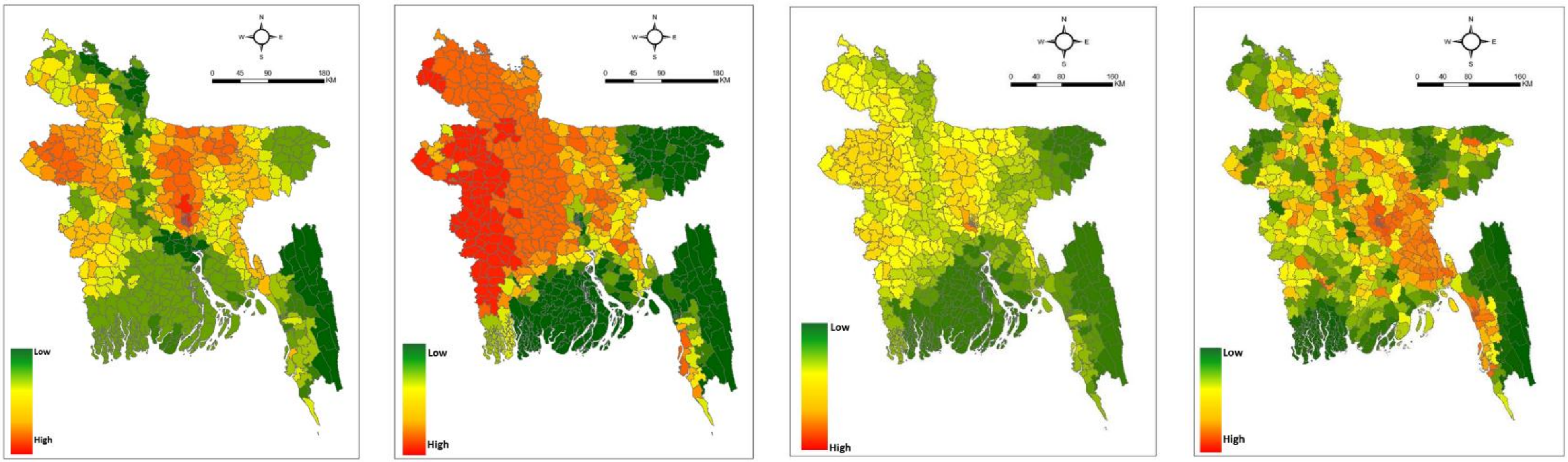
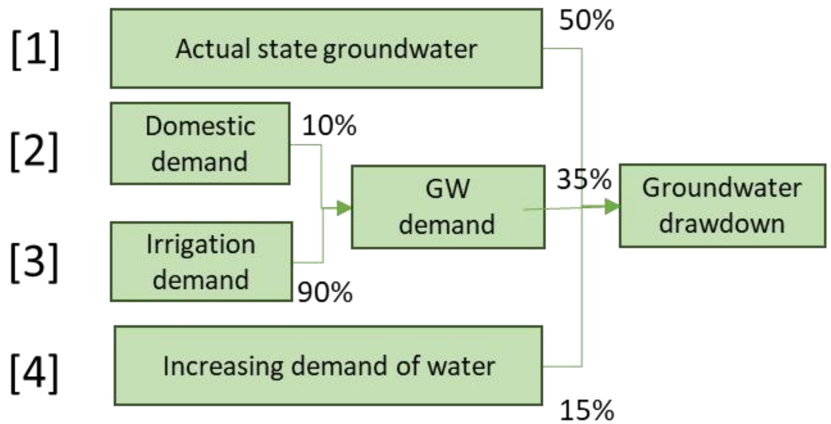


Figure D3: Sensitivity maps of groundwater



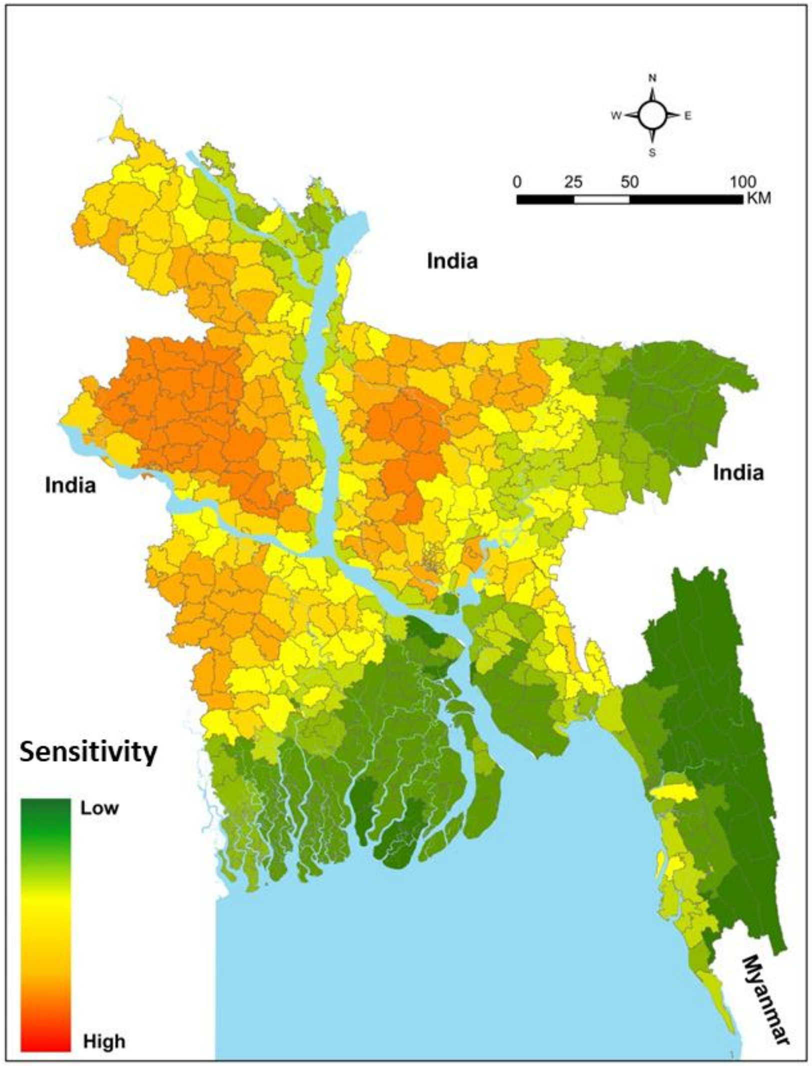


Figure D4: Sensitivity maps of groundwater

4. Potential impact on groundwater depletion and degradation

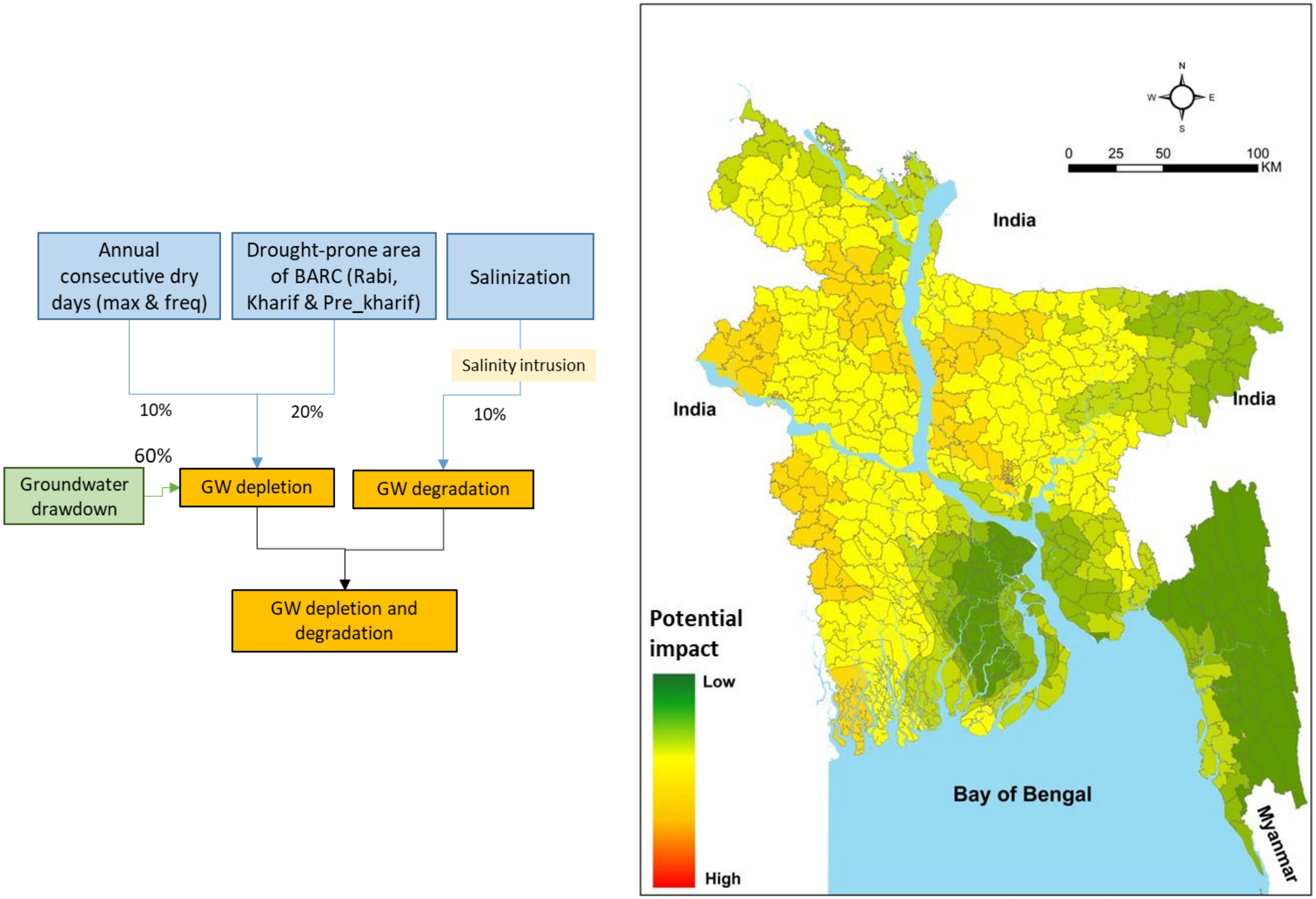


Figure D5: Map of potential impact of groundwater depletion and degradation

5. Adaptive capacity

[Institutional capacity in ground water use and control] [Individual capacity to adapt to ground water resources depletion and degradation] [Environmental awareness and education] [Surface water irrigation project by BWDB]

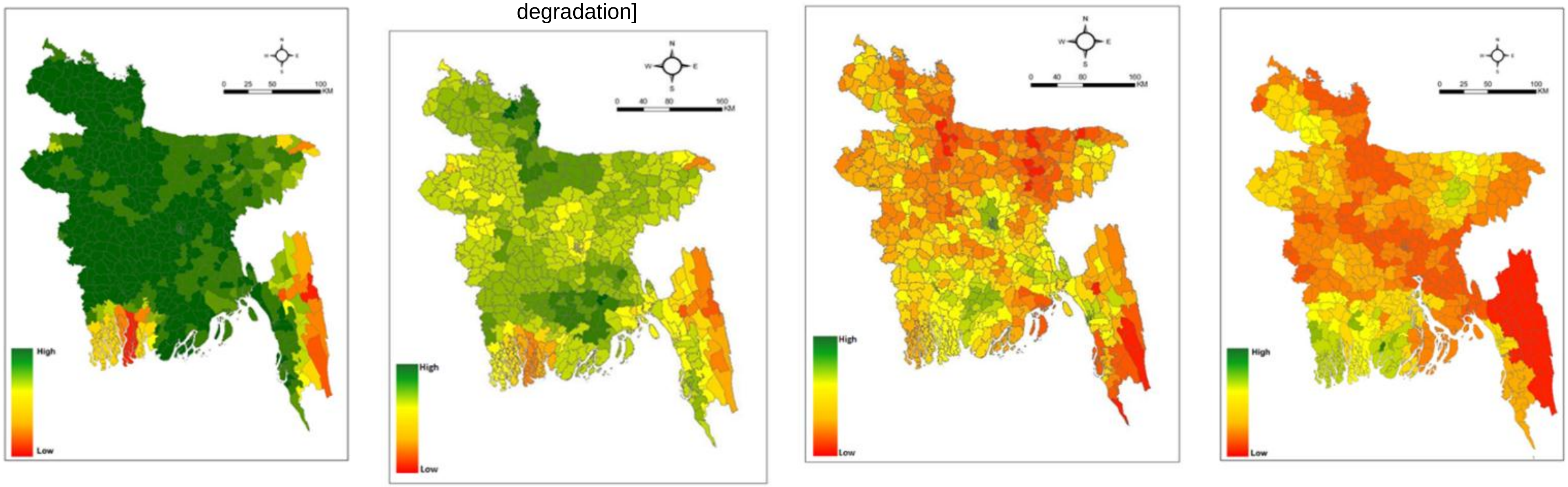


Figure D6 : Intermediate factors of adaptive capacity to groundwater resources depletion and degradation

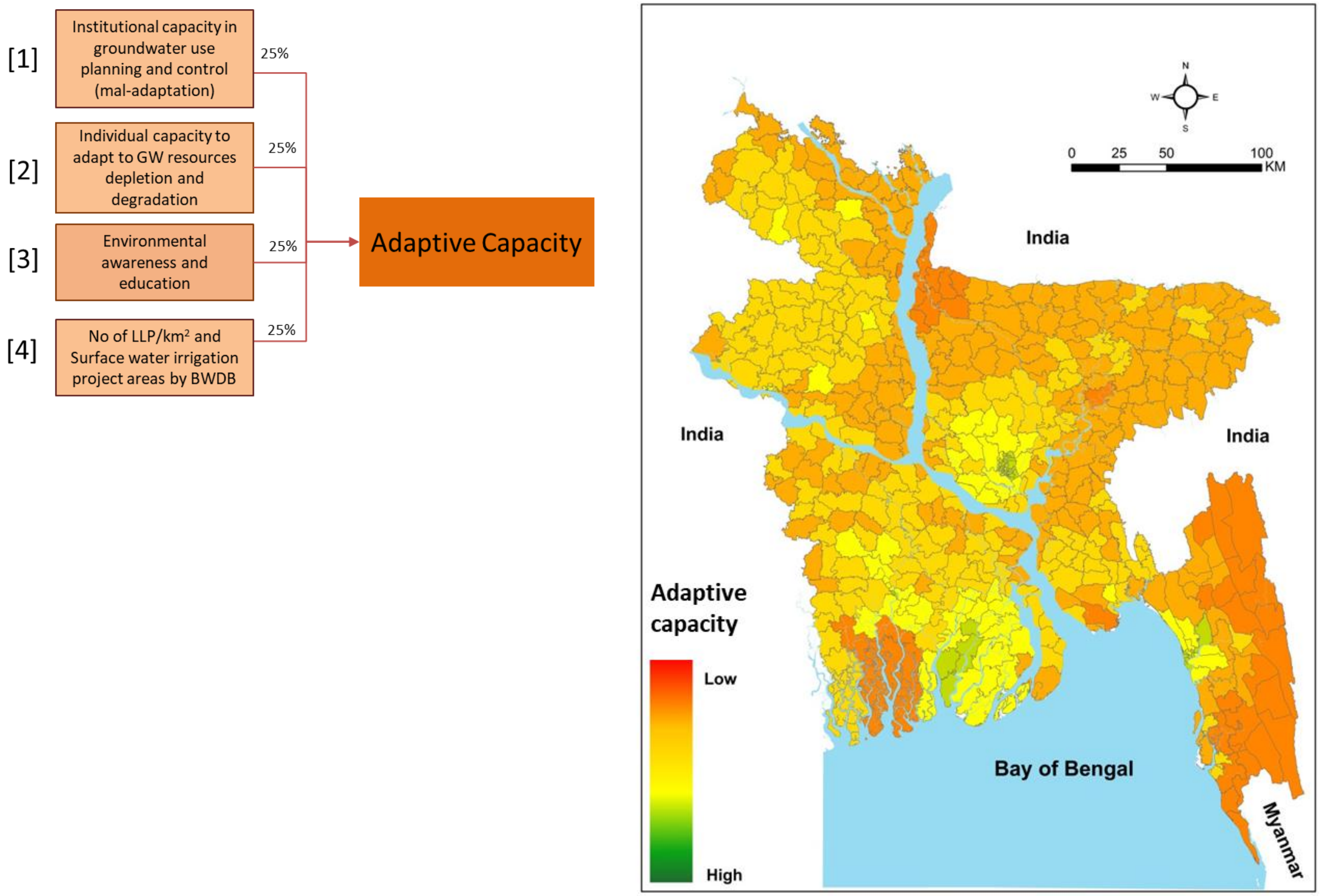


Figure D7 : Map of adaptive capacity to groundwater resources depletion and degradation

6. Vulnerability to groundwater depletion and degradation

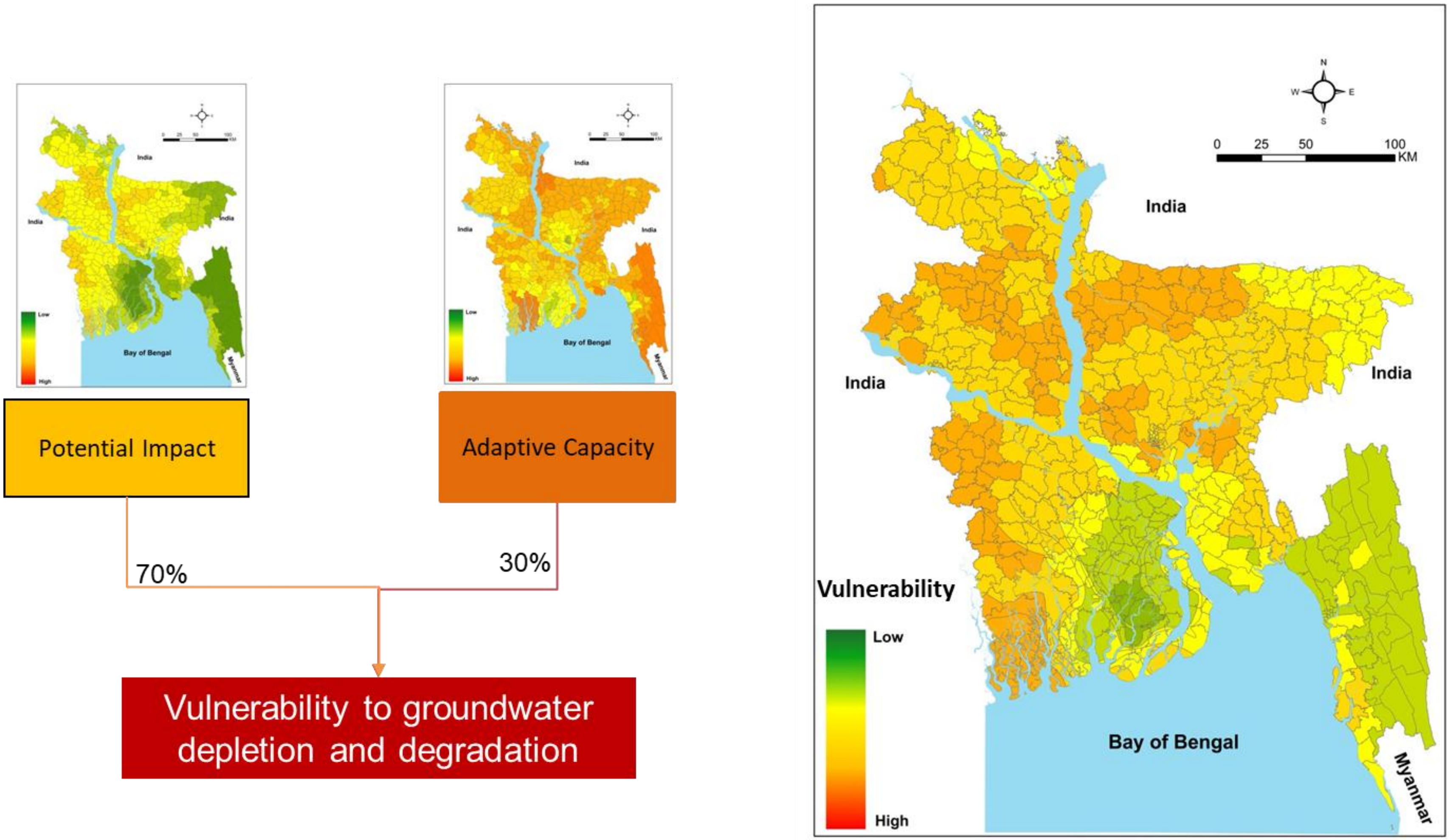


Figure D815: Final vulnerability to groundwater depletion and degradation map

7. Current and future vulnerability to groundwater depletion and degradation

.

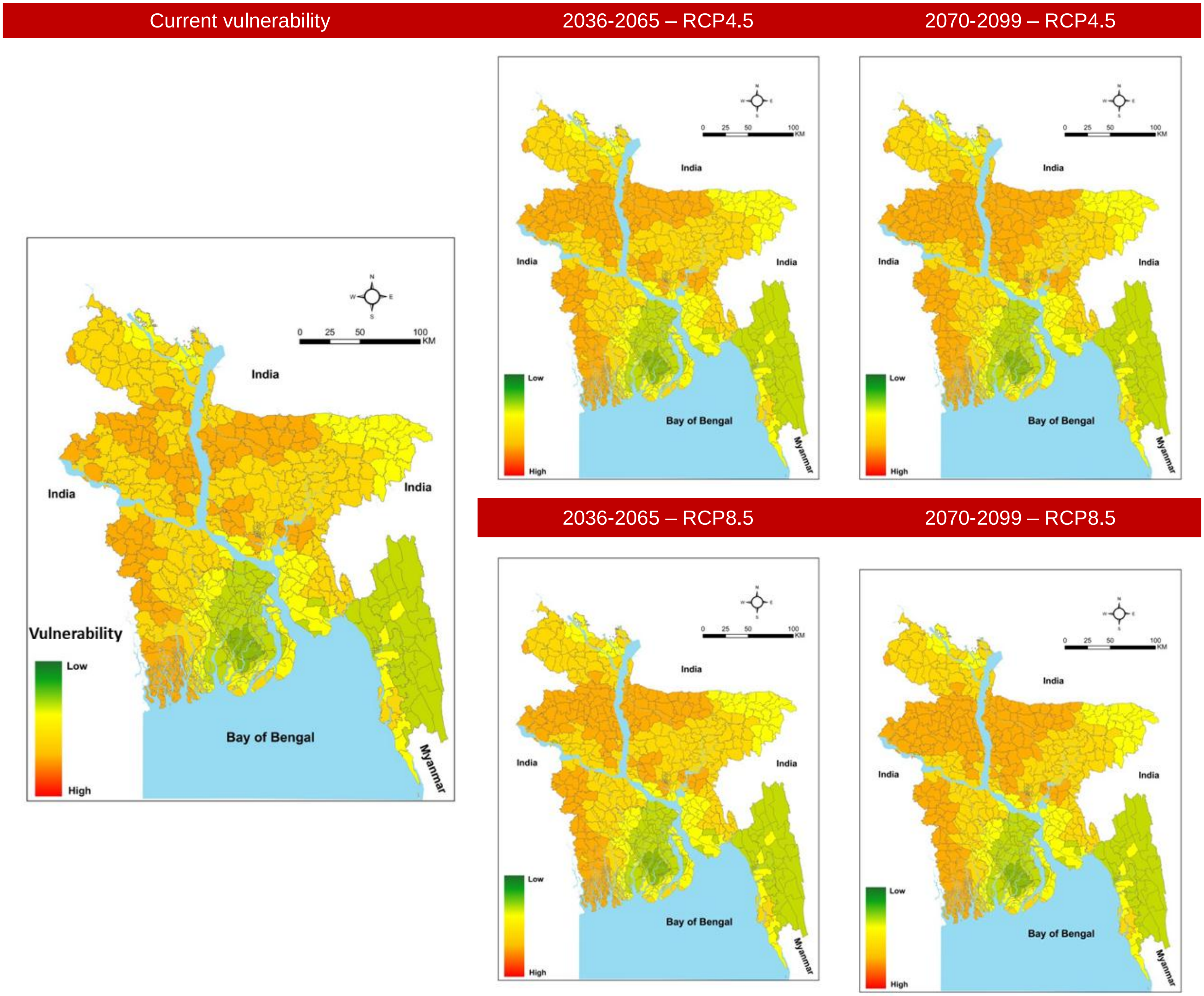


Figure D9: Future vulnerability to groundwater depletion

C. Vulnerability of agriculture

E.1 Agriculture sector's vulnerability to decrease in land availability under climate change

1. Impact chain

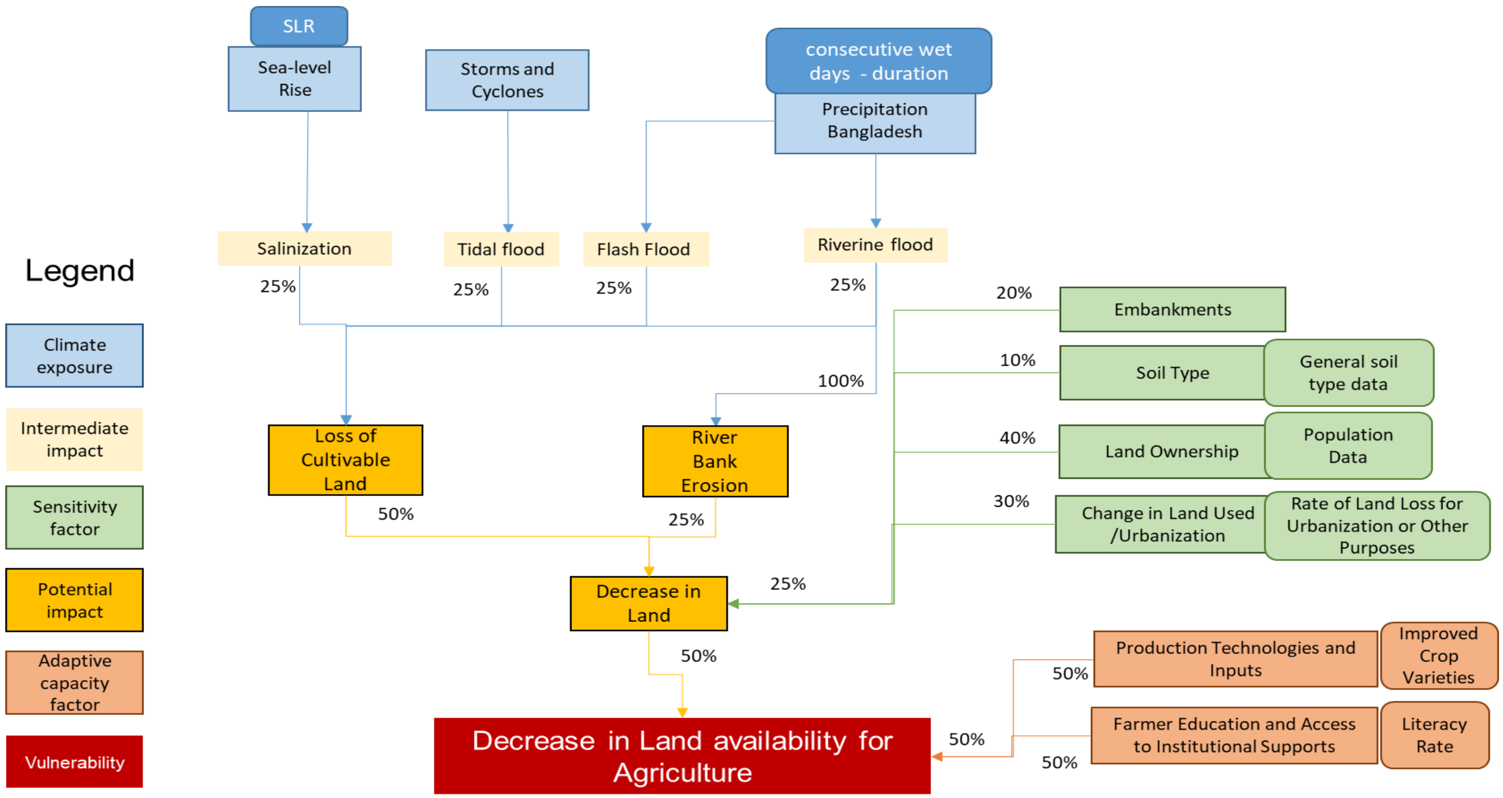


Figure E.1.1 : Impact chain on Land availability for Agriculture

2. Exposure

[Salinization] [Storm surge] [Flash flood] [River flood]

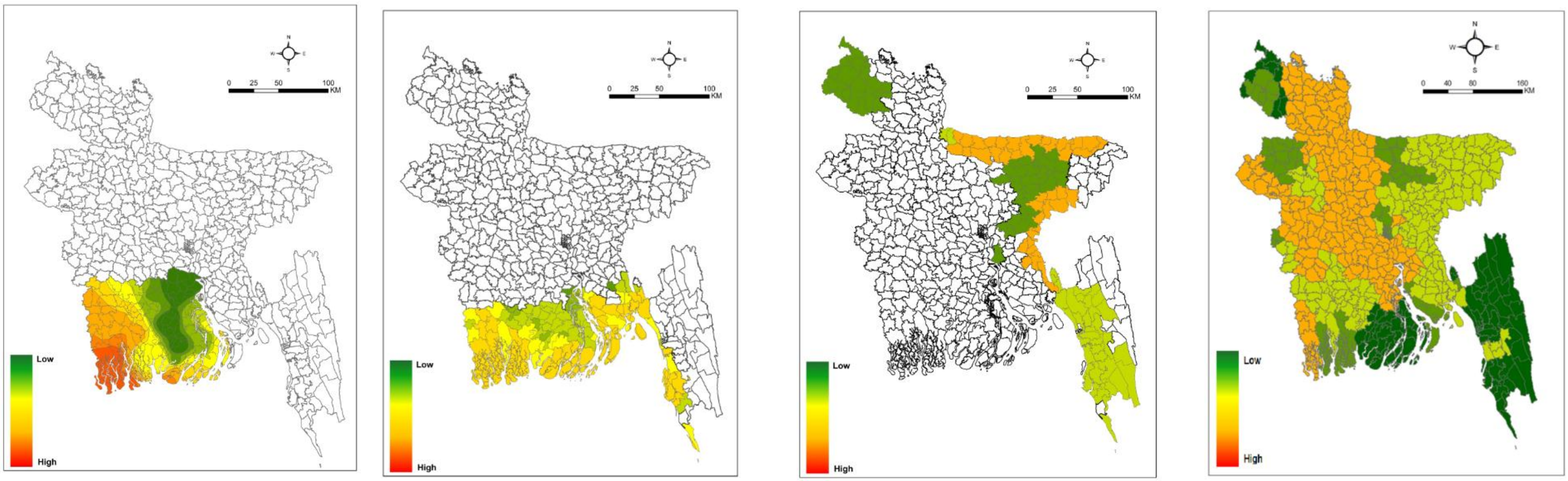
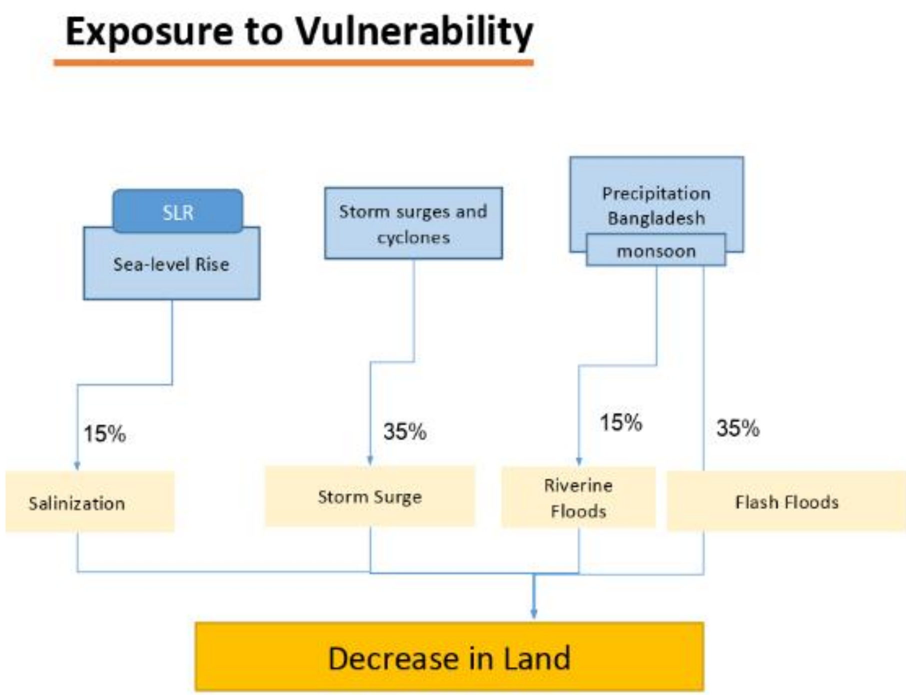


Figure E.1.2 : Exposure of agriculture on Land availability



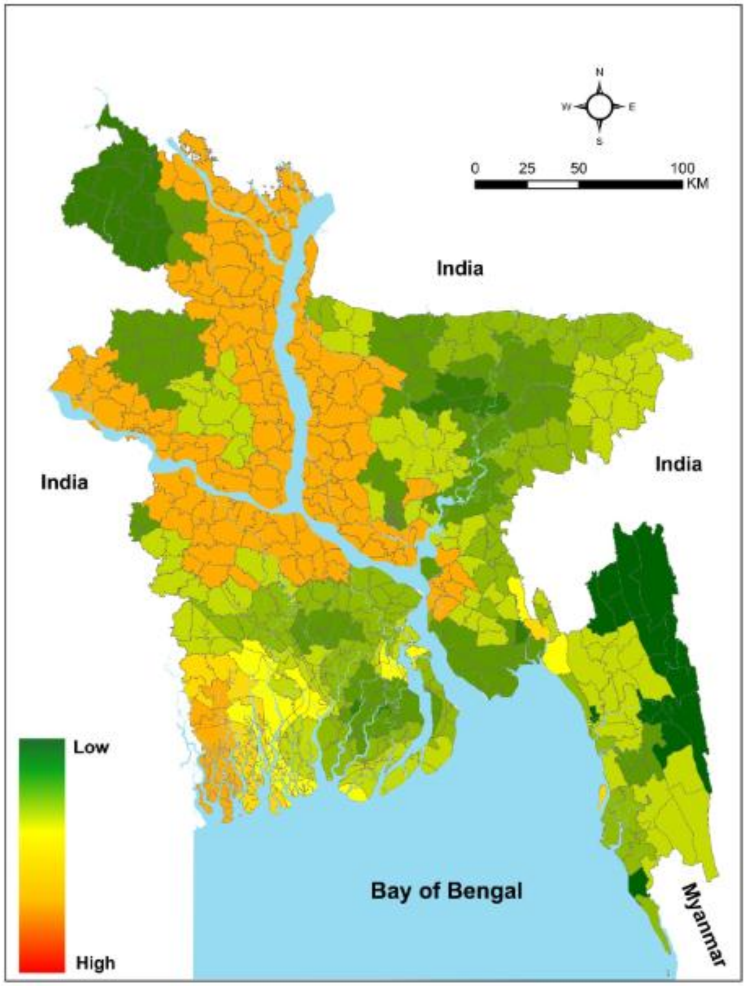
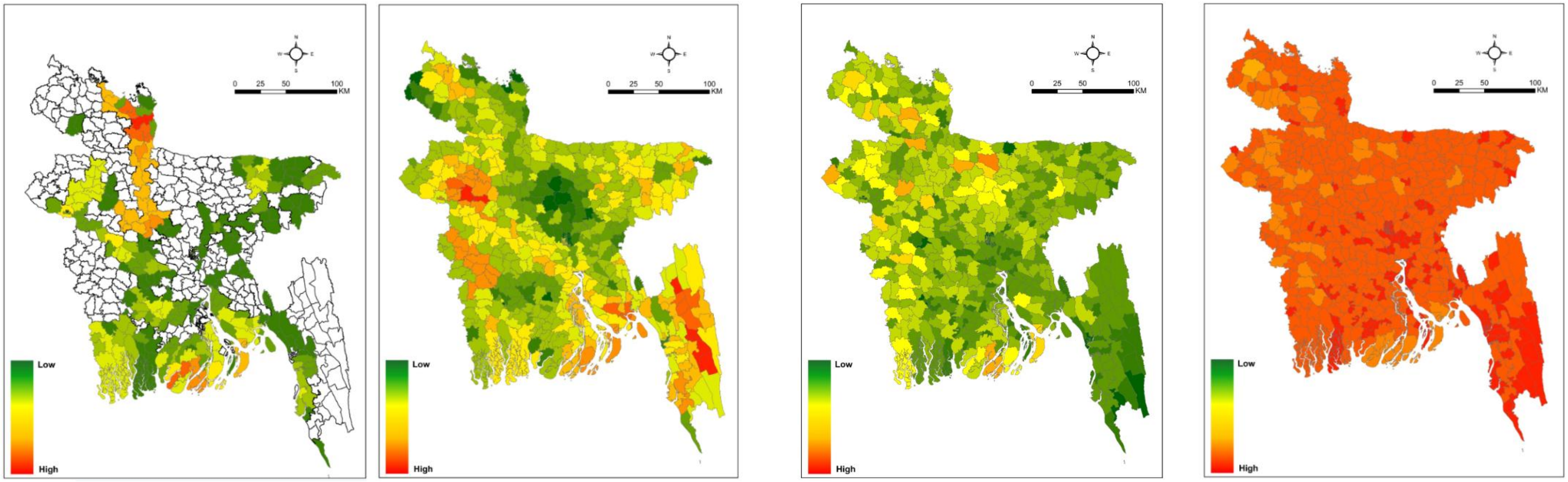


Figure E.1.3 : Exposure of agriculture on Land availability

3. Sensitivity

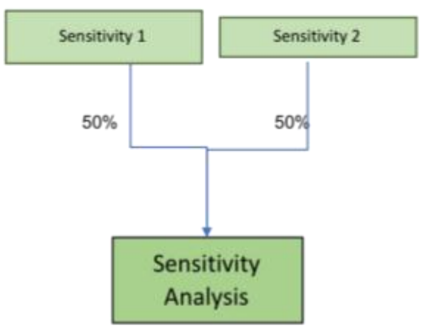
[Embankment] [Soil type] [Land ownership] [Changed in land use]



Sensitivity 1 Sensitivity 2

Figure E.1.4 : Sensitivity maps of agriculture on Land availability

Sensitivity Analysis



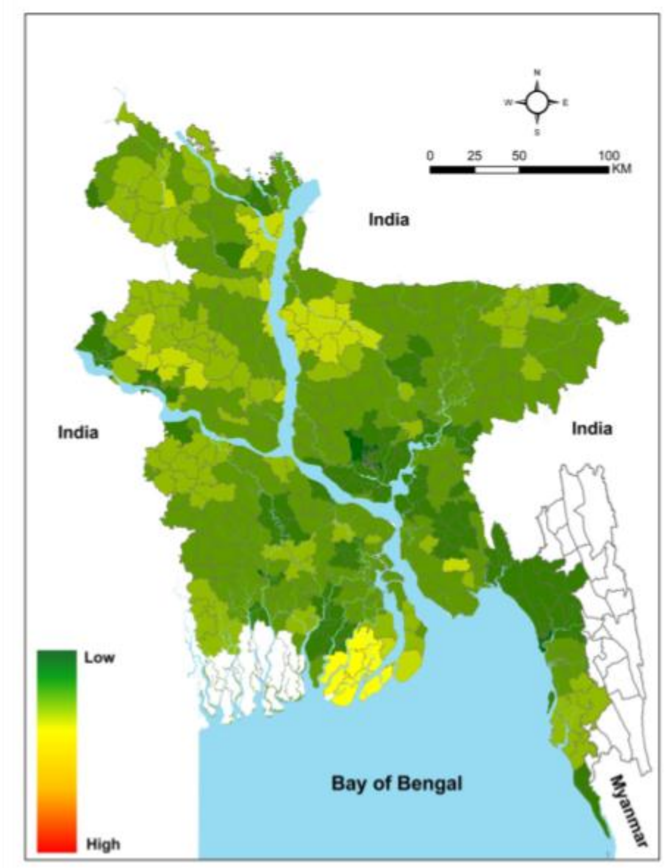


Figure E.1.5 : Sensitivity maps of agriculture on Land availability

4. Potential Impact

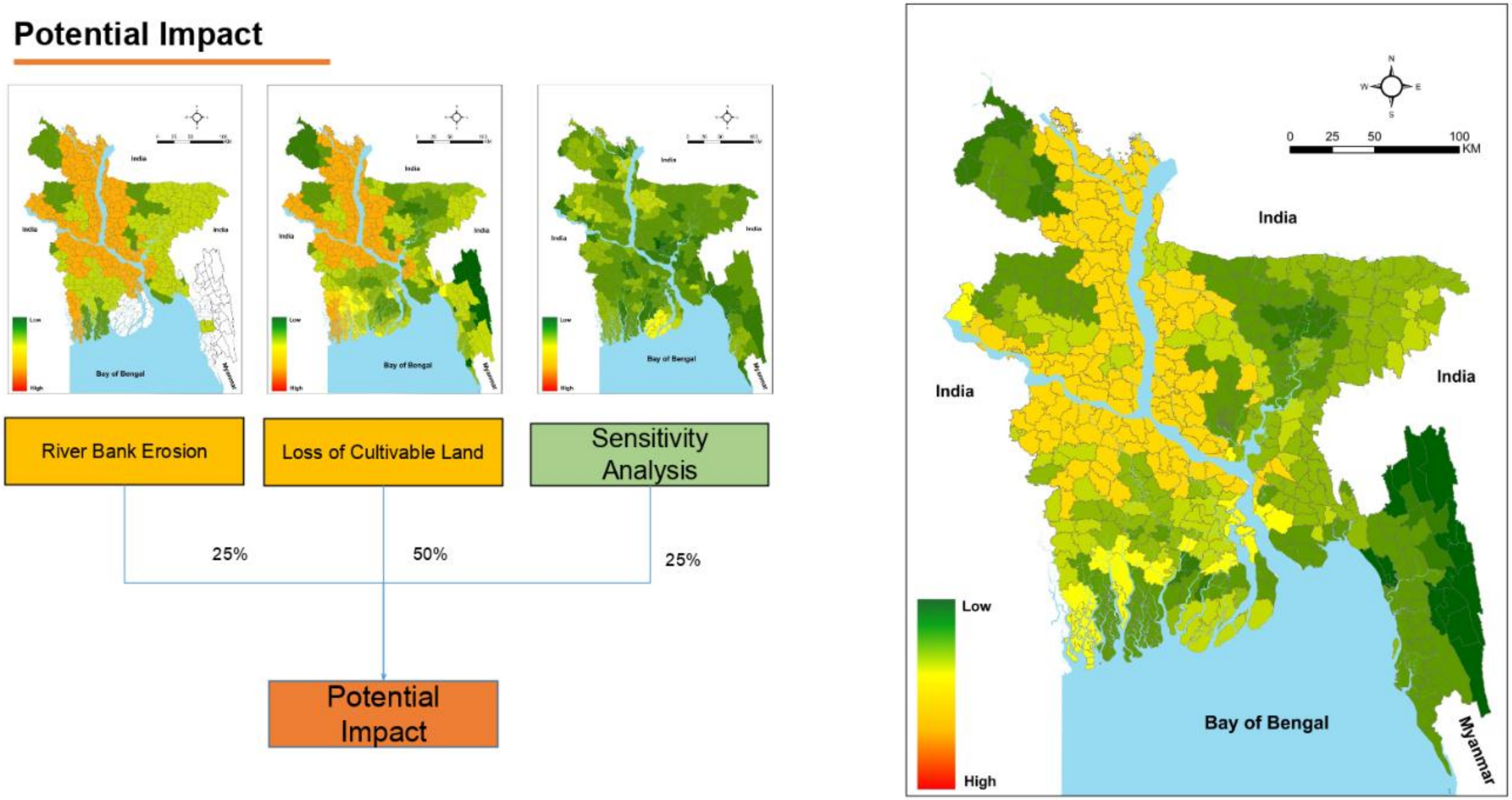


Figure E.1.6 : Potential impact of agriculture on Land availability

5. Adaptive capacity

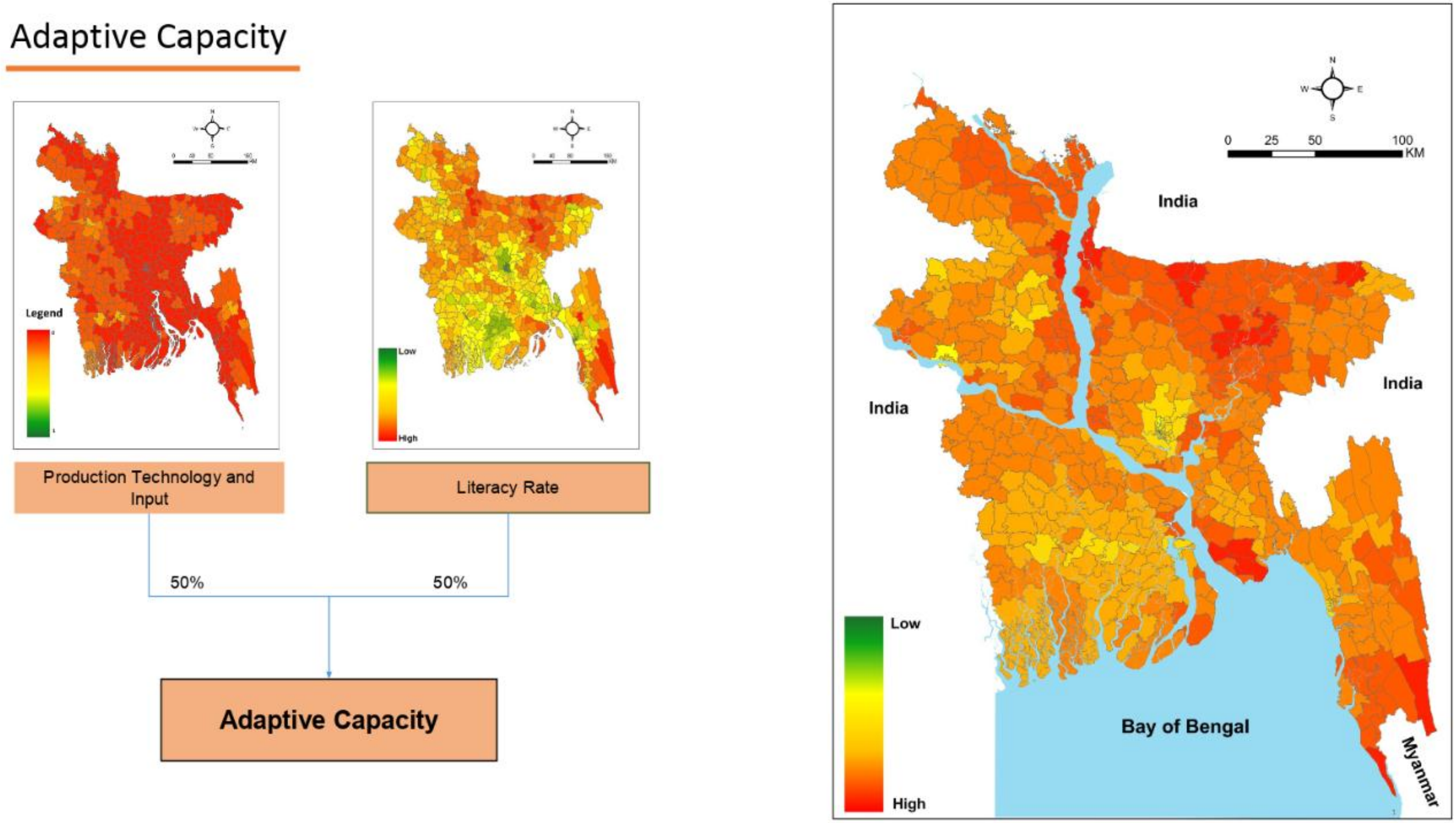


Figure E.1.7 : Adaptive capacity map on agriculture on Land availability

6. Current Vulnerability of agriculture on Land availability

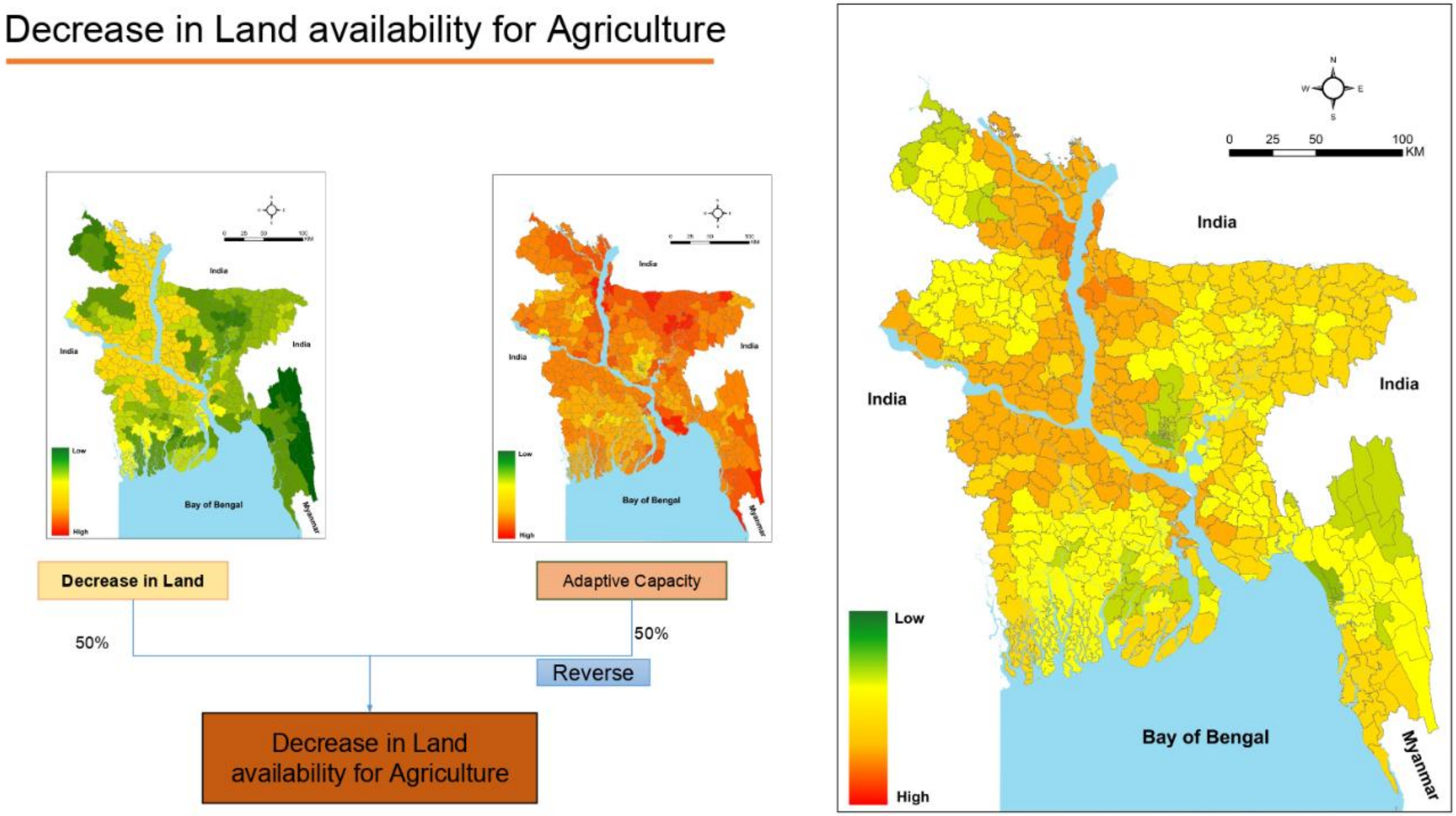


Figure E.1.8 : Current vulnerability of agriculture on Land availability

E.2 vulnerability of crop agriculture

1. Impact chain

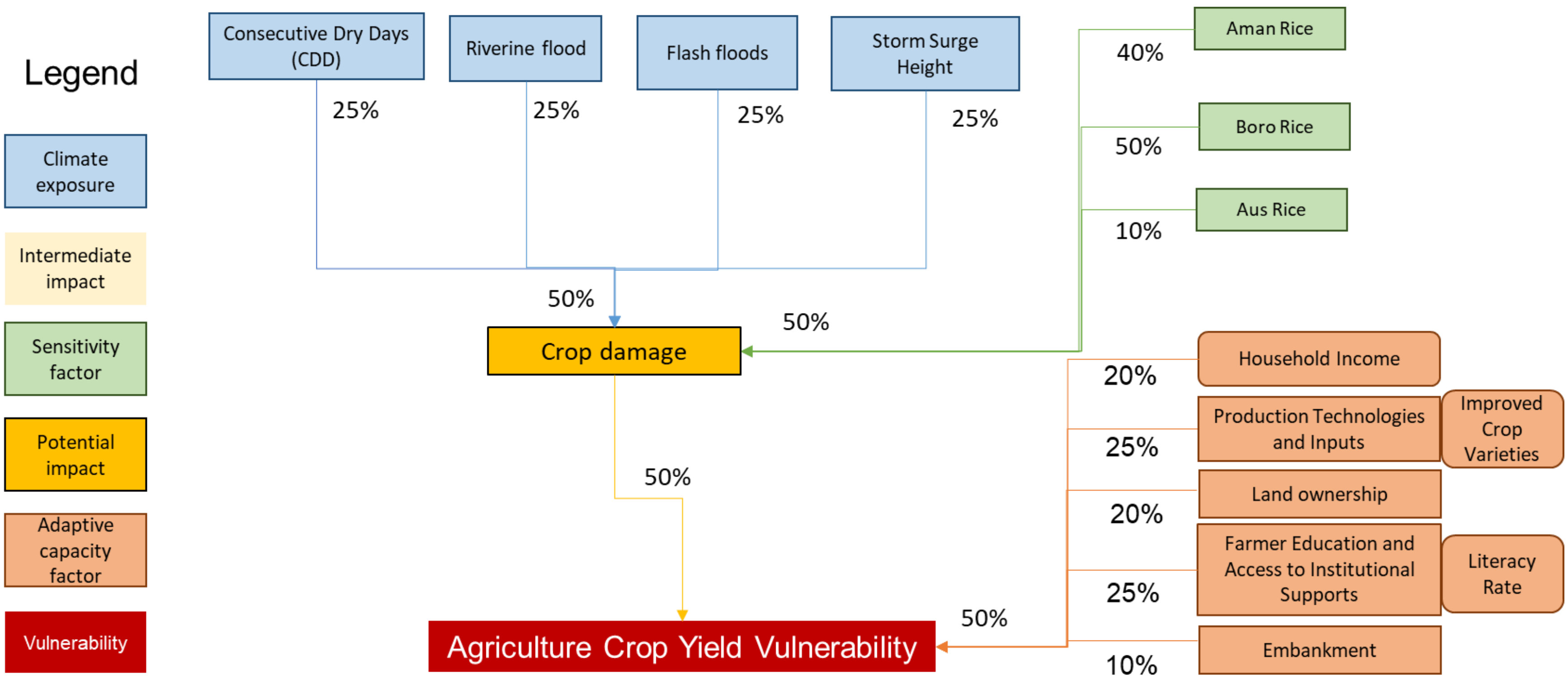


Figure E.2.1 : Current vulnerability of crop agriculture

2. Exposure

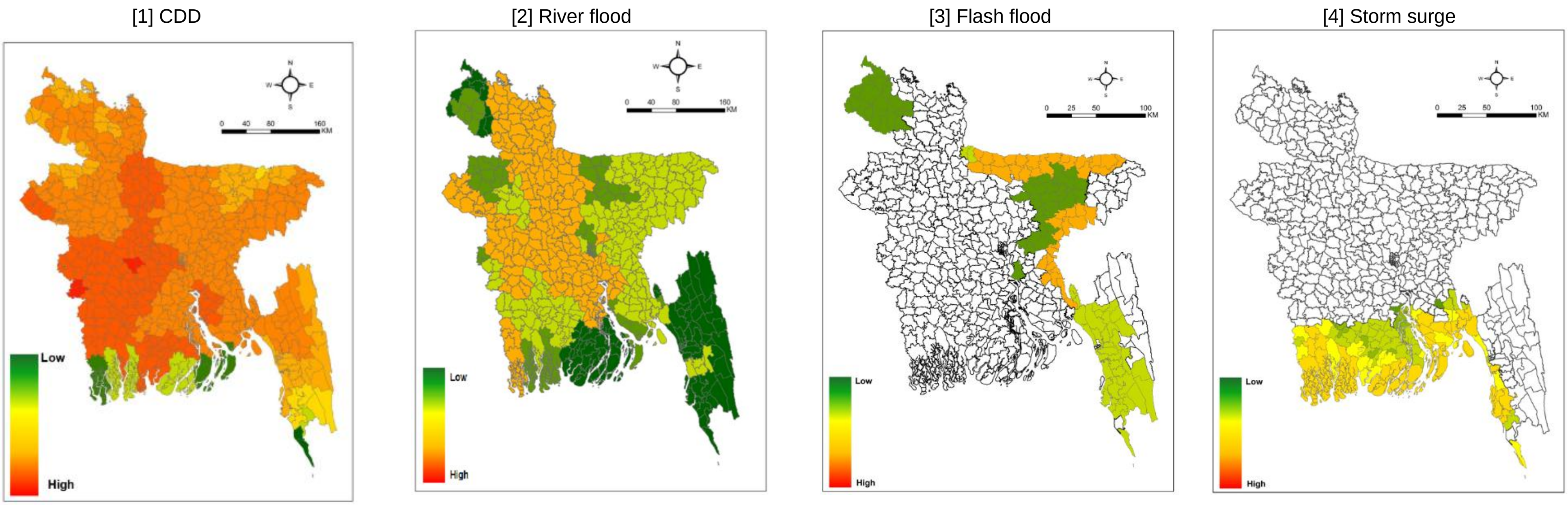
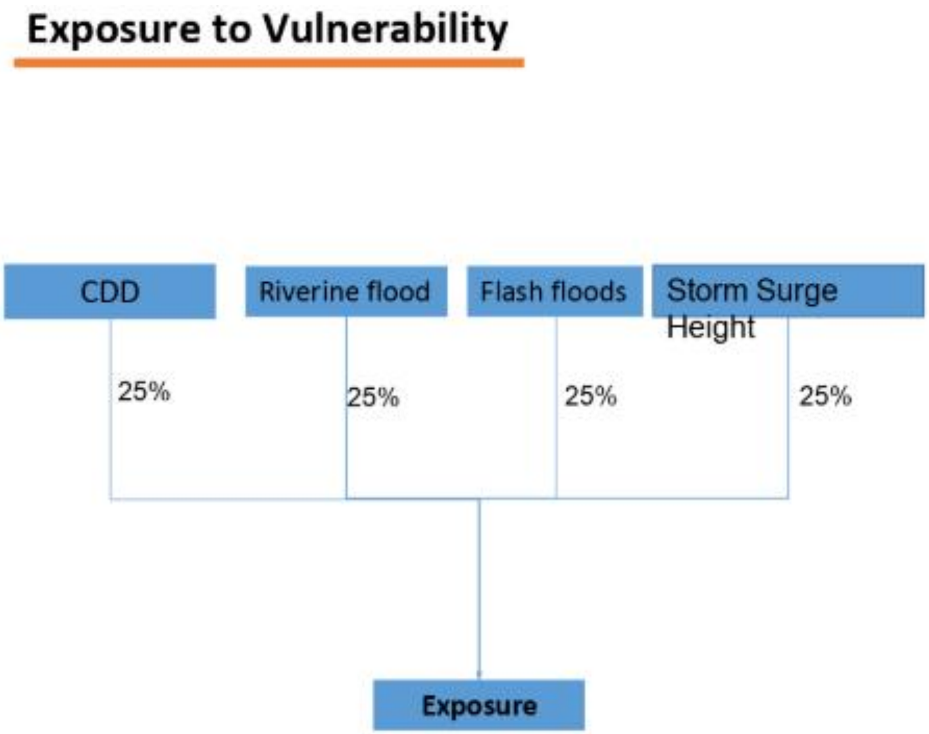


Figure E.2.2 : Exposure to crop agriculture



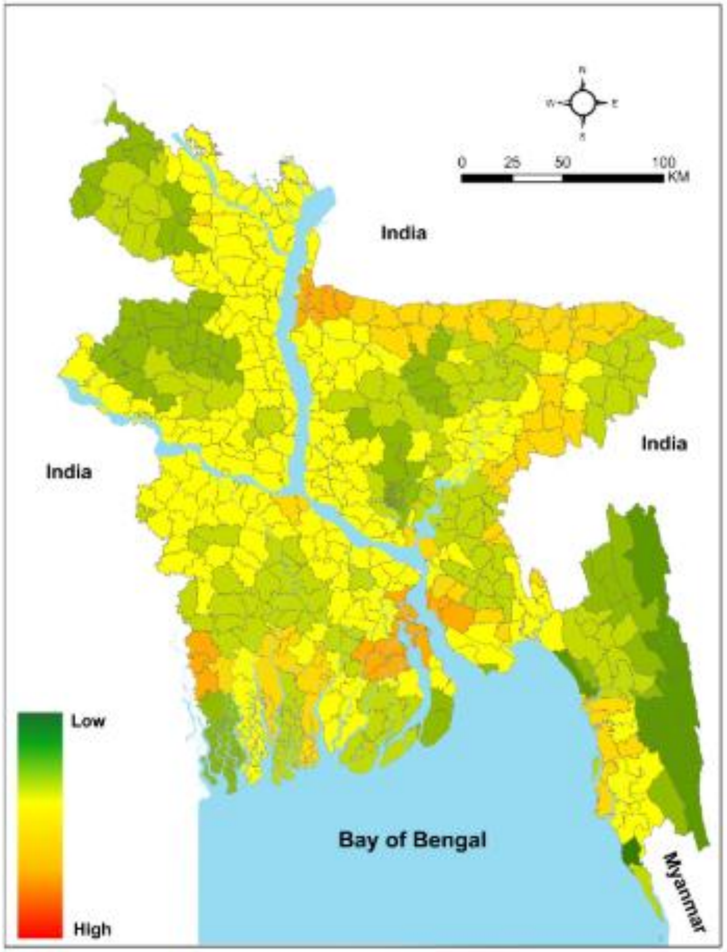
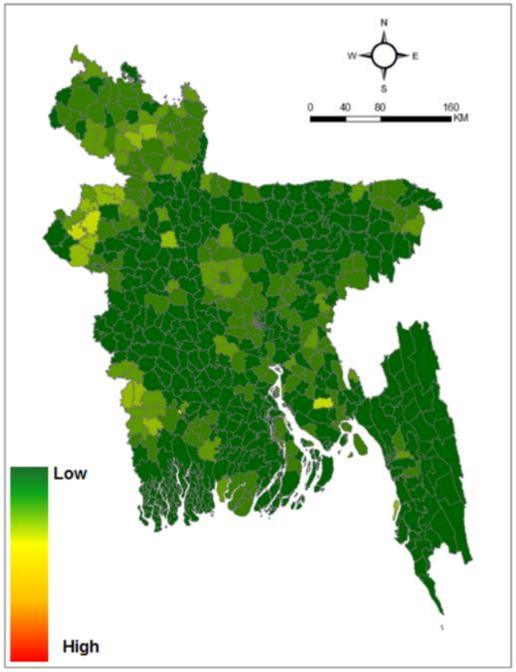


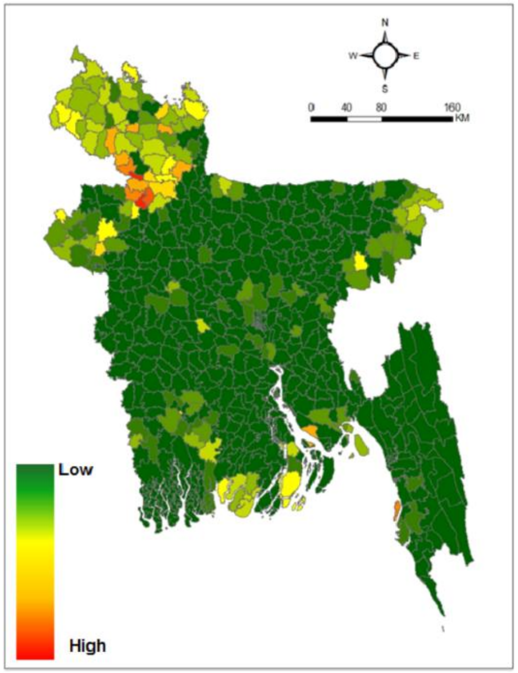
Figure E.2.3 : Exposure to crop agriculture

3. Sensitivity

[1] Aman rice



[2] Boro rice



[3] Aus rice

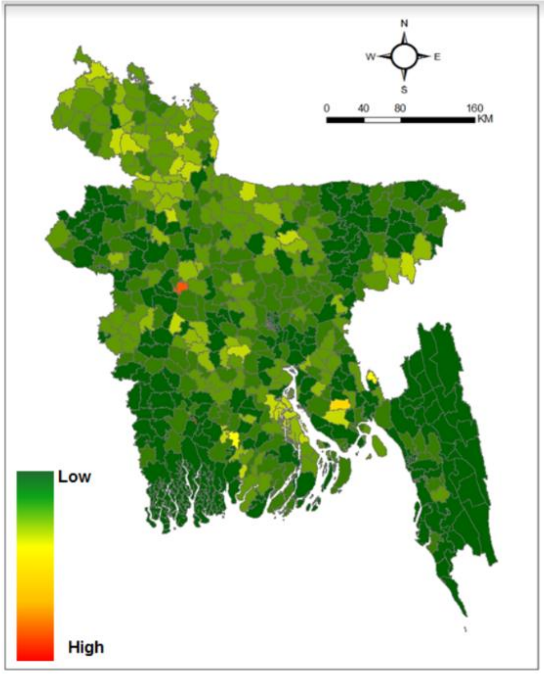
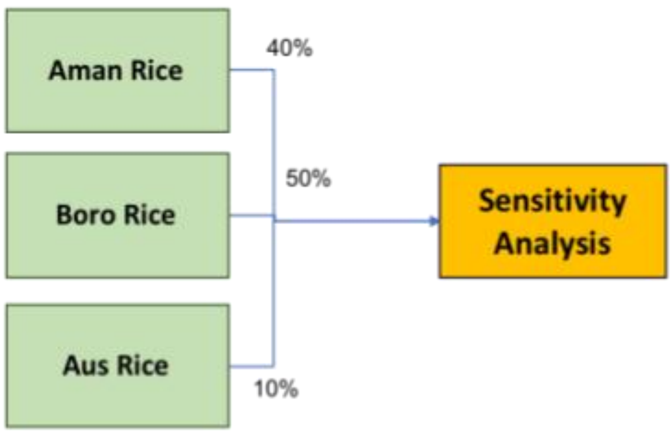


Figure E.2.4 : Sensitivity map of crop agriculture

Sensitivity Analysis



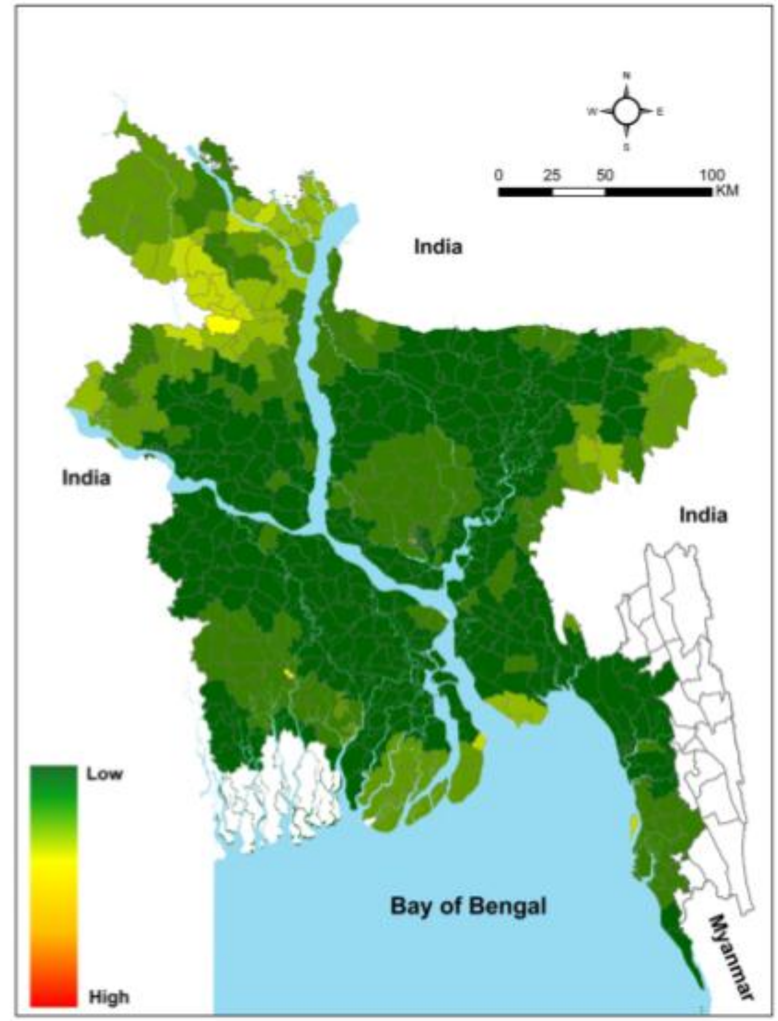


Figure E.2.5 : Sensitivity map of crop agriculture

4. Potential Impact

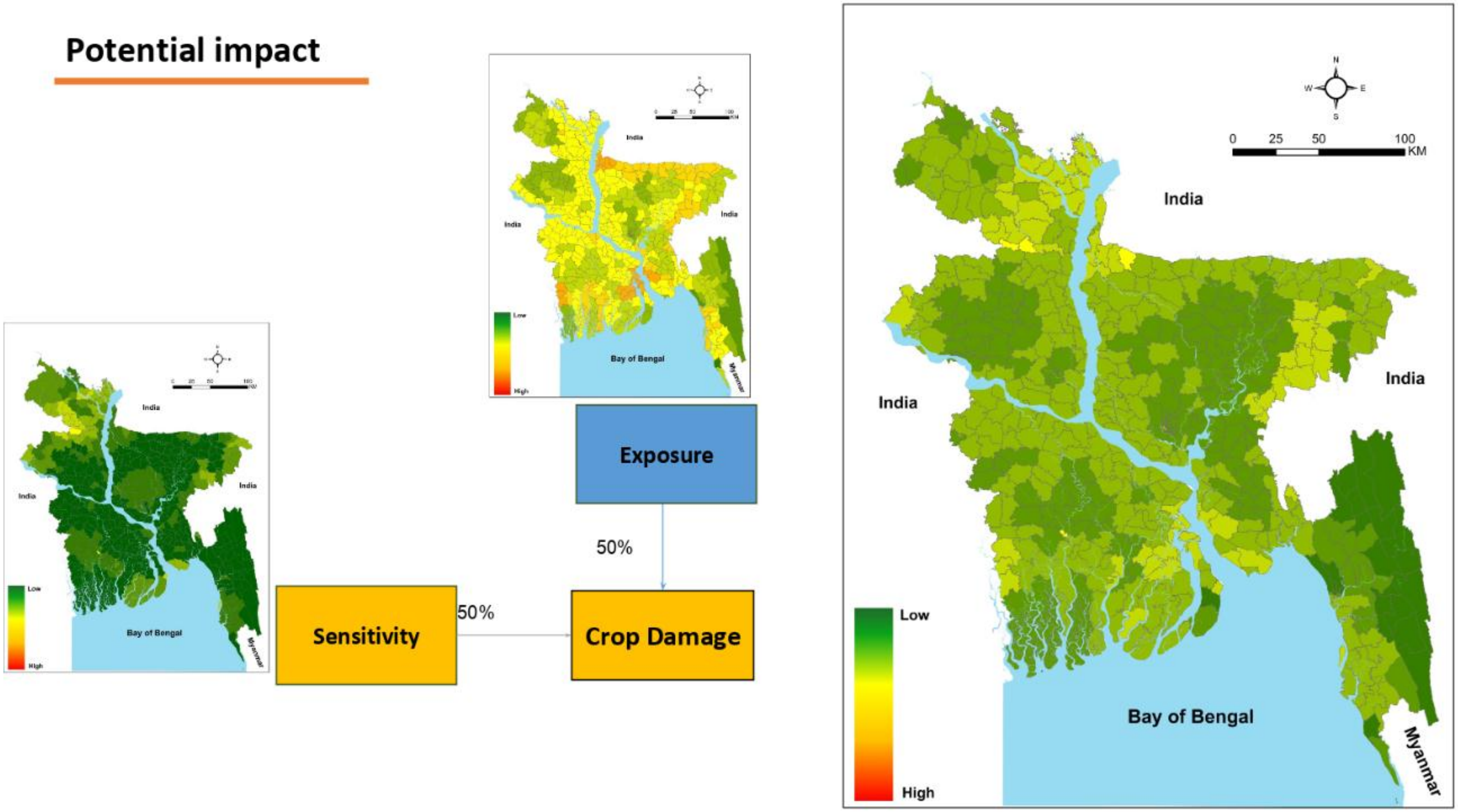


Figure E.2.6 : Potential impact map of crop agriculture

5. Adaptive capacity

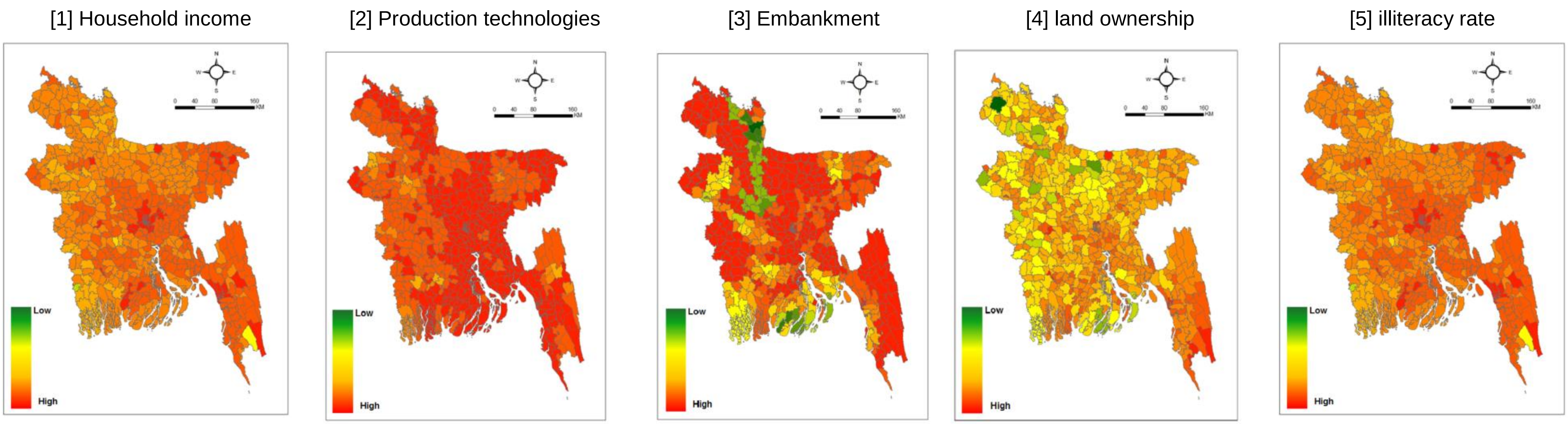
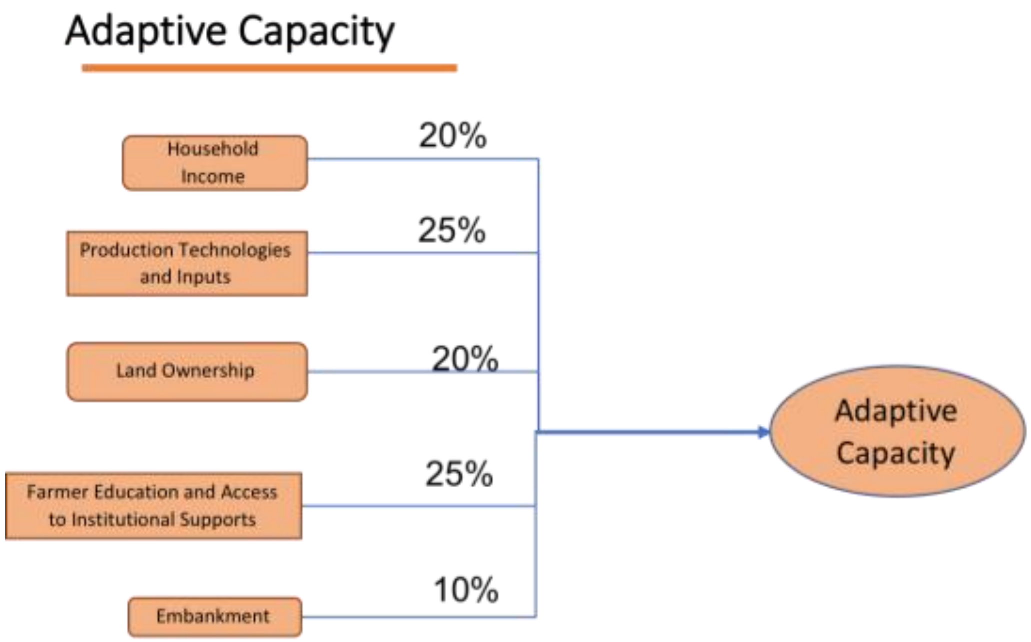


Figure E.2.7 : Adaptive capacity to crop agriculture vulnerability



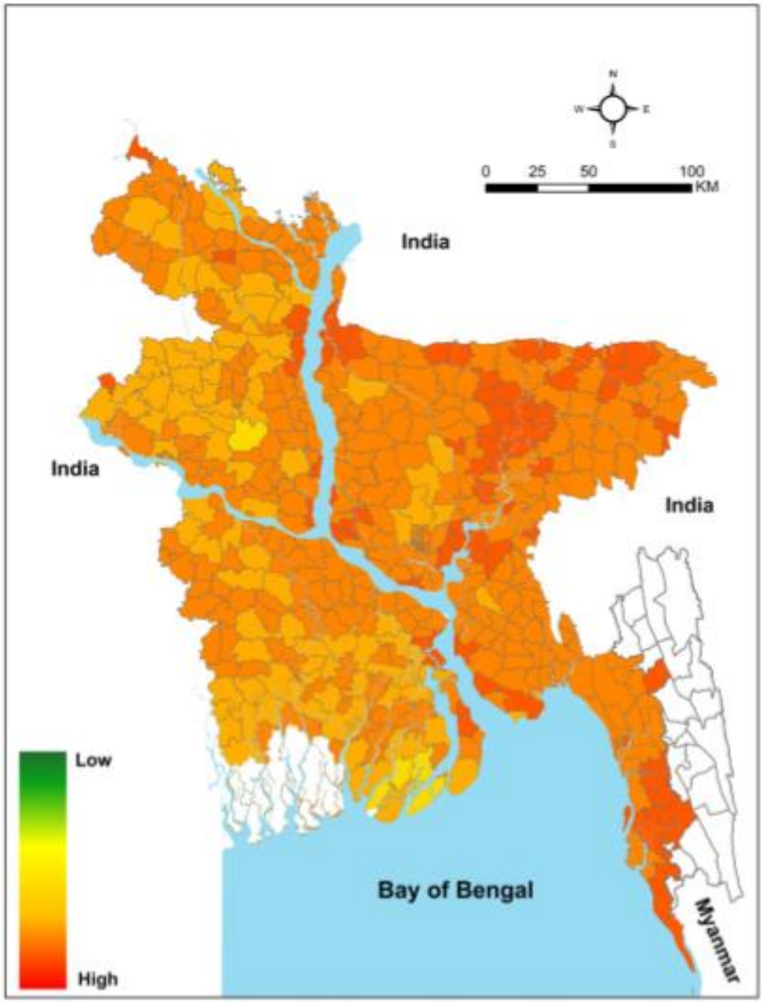


Figure E.2.8 : Adaptive capacity to crop agriculture vulnerability

6. Current vulnerability of crop agriculture

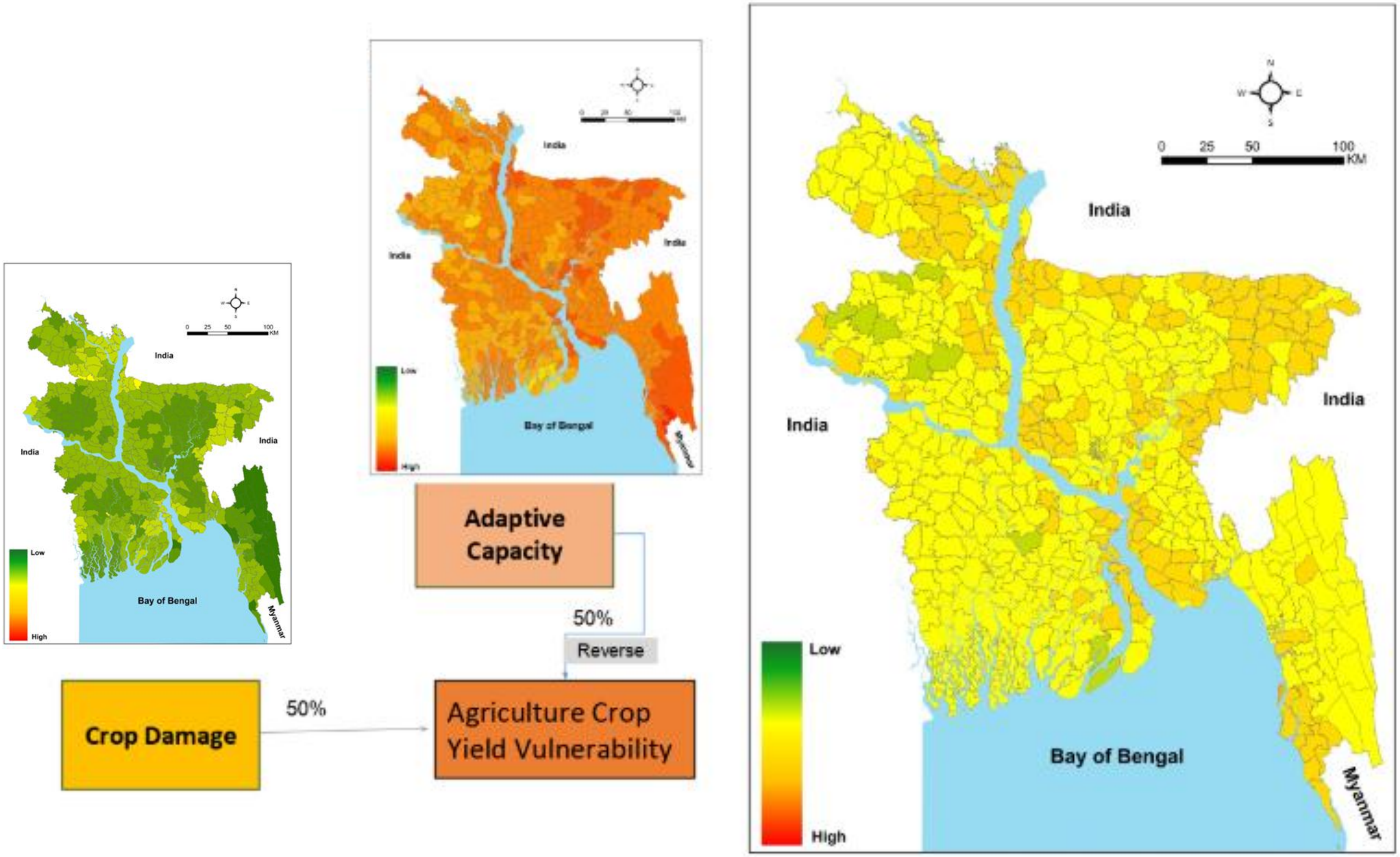


Figure E.2.9 : Current vulnerability to crop agriculture vulnerability

E.3 Vulnerability of agriculture due to lack of Water availability

1. Impact chain

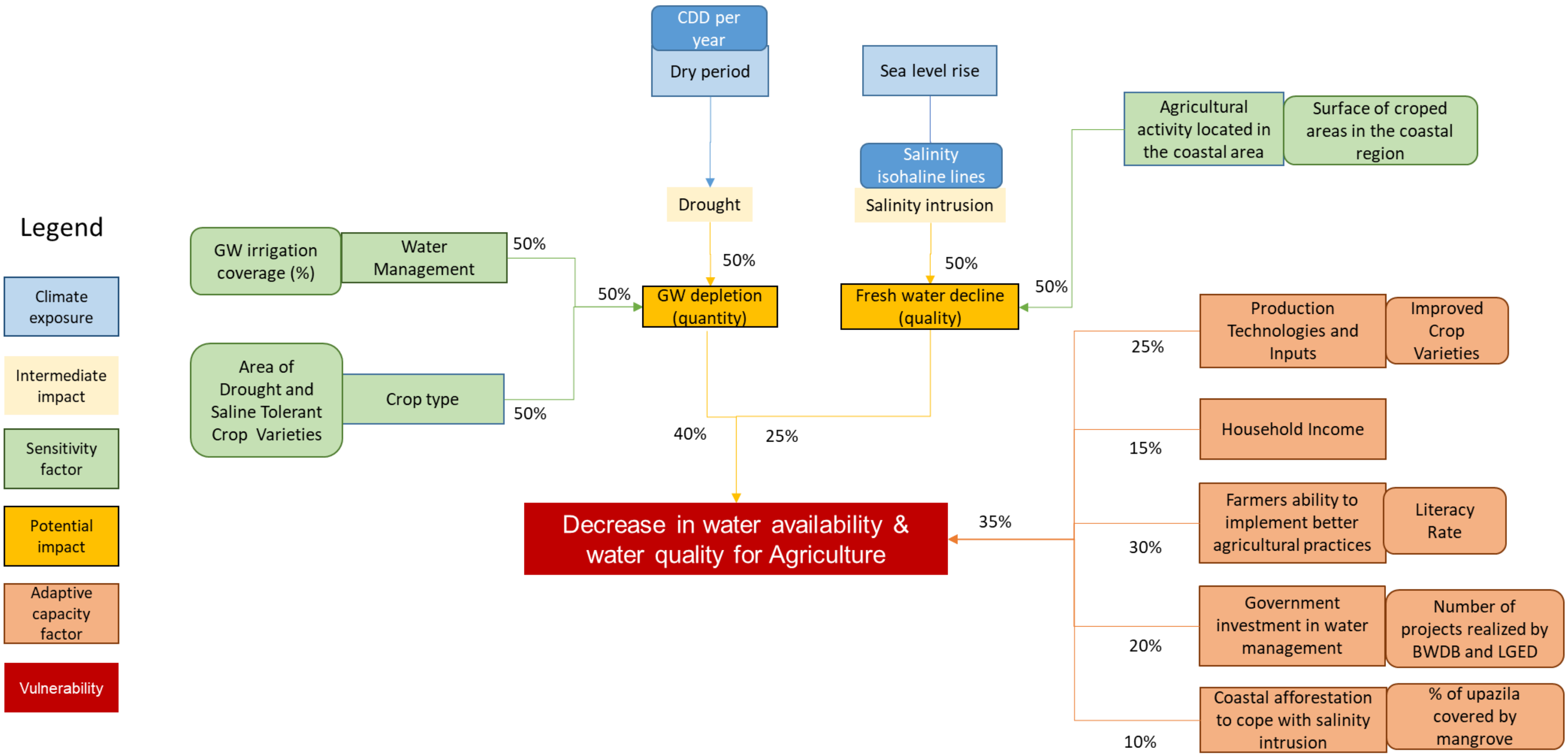


Figure E.3.1 : Impact chain of vulnerability of agriculture due to lack of water availability

2. Exposure

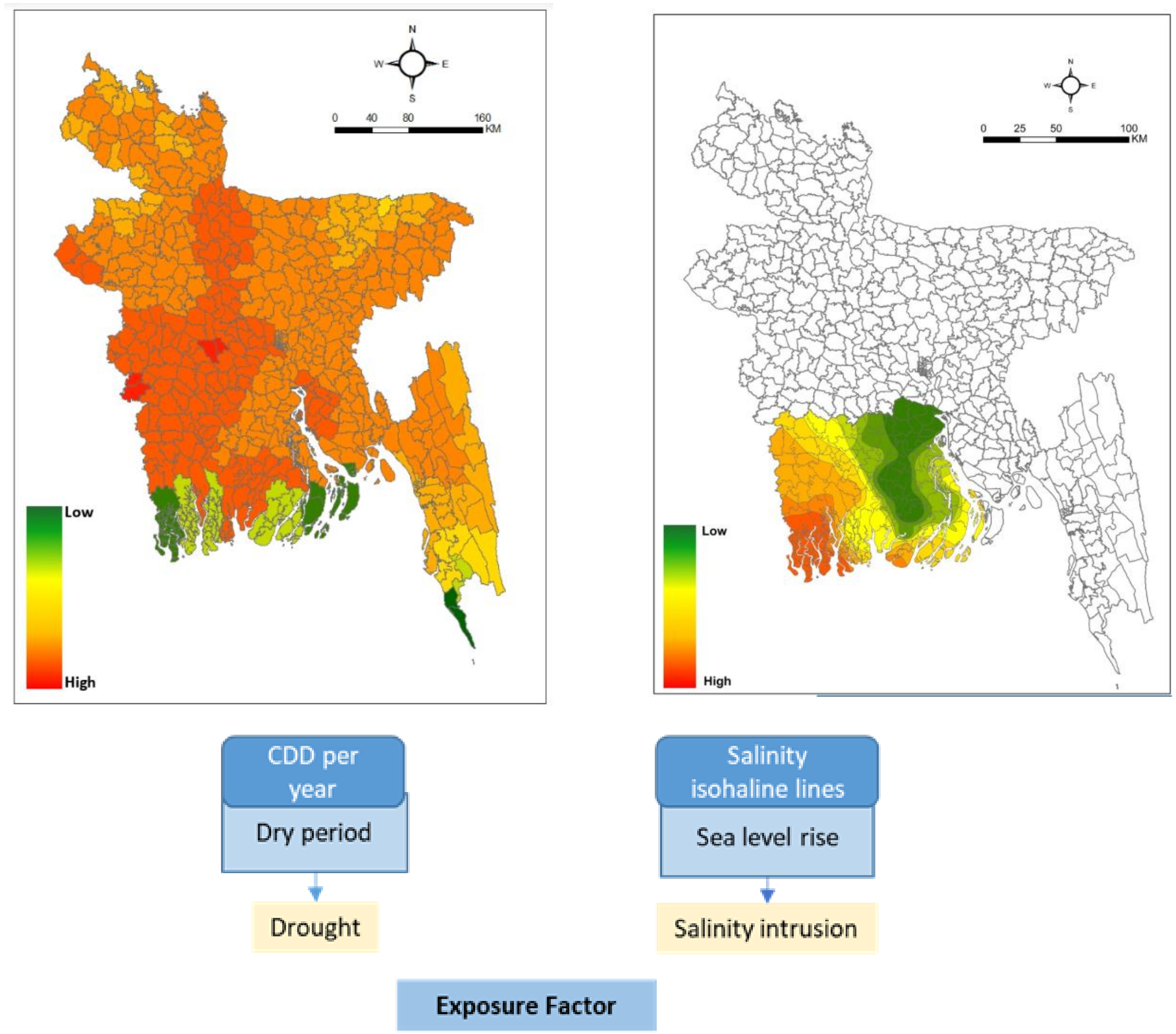


Figure E.3.2 : Exposure on agriculture on lack of water availability

3. Sensitivity

[1] Agricultural activity [2a] Irrigation coverage [2b] Crop type

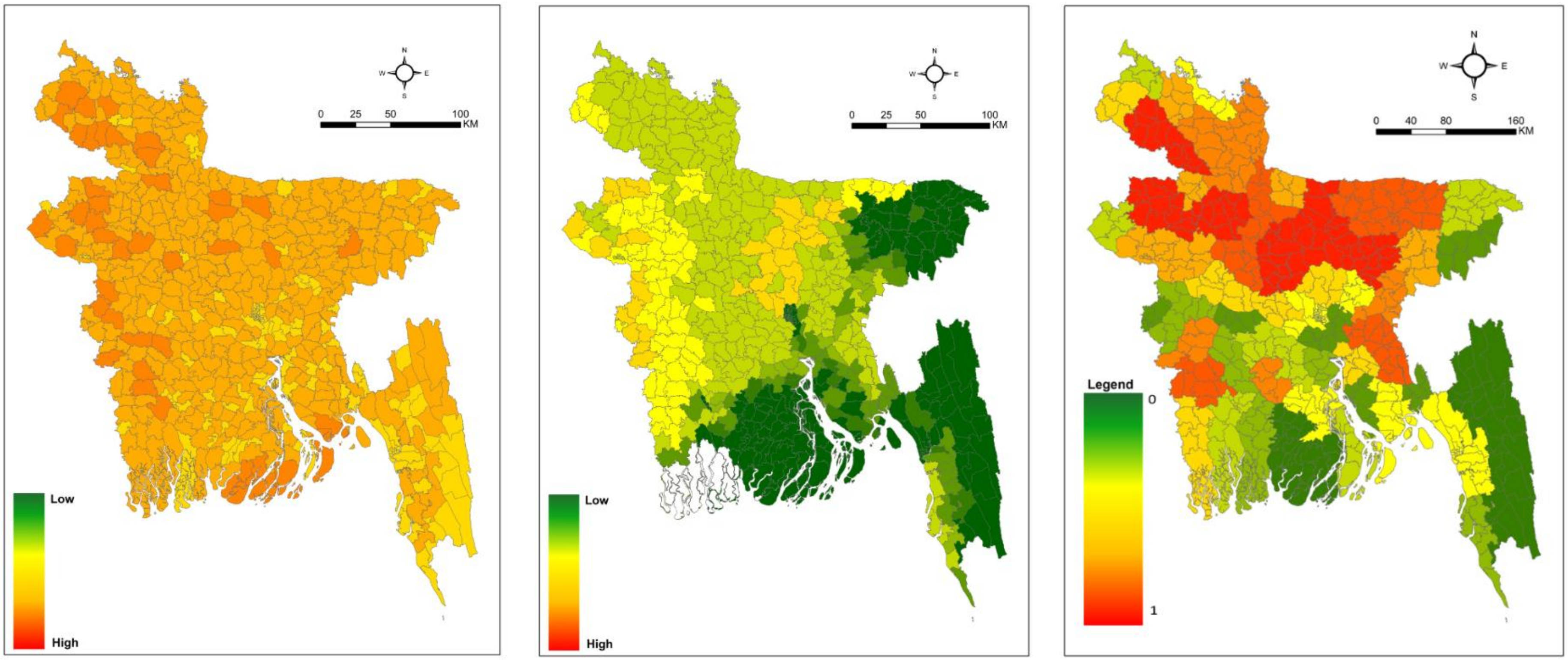
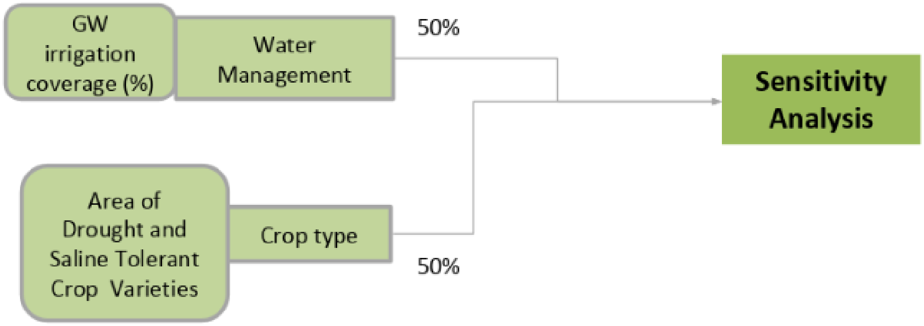


Figure E.3.3 : Sensitivity of agriculture on lack of water availability



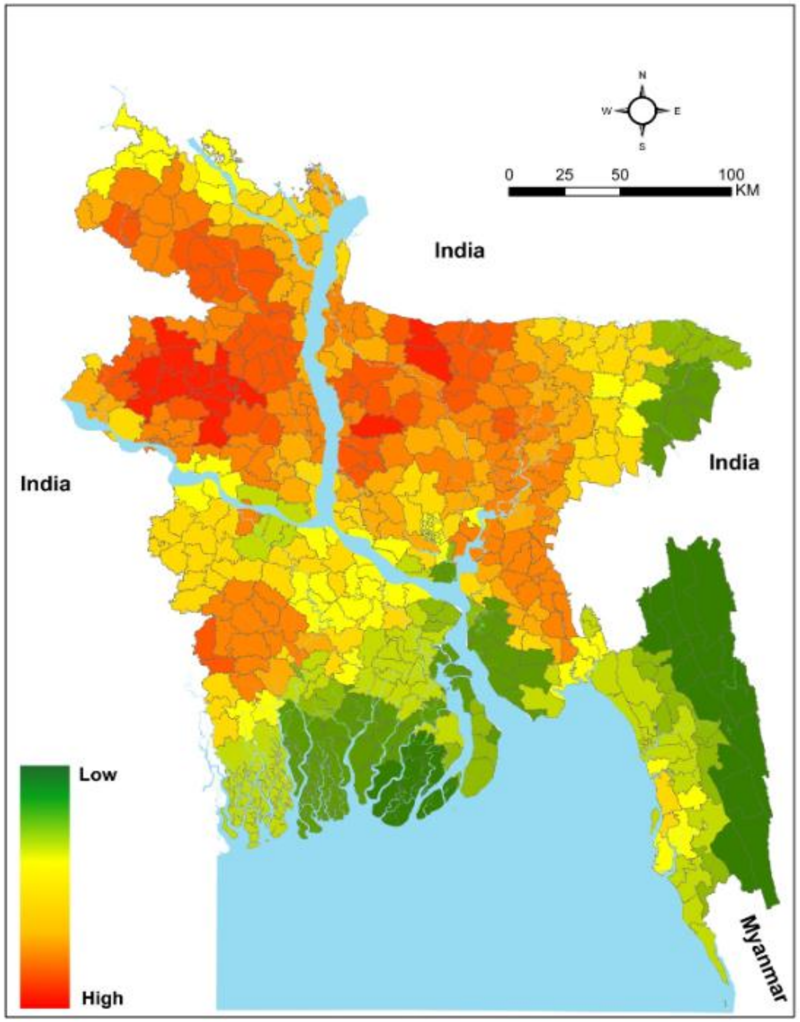


Figure E.3.4 : Sensitivity of agriculture on lack of water availability

4. Potential Impact

Ground water depletion

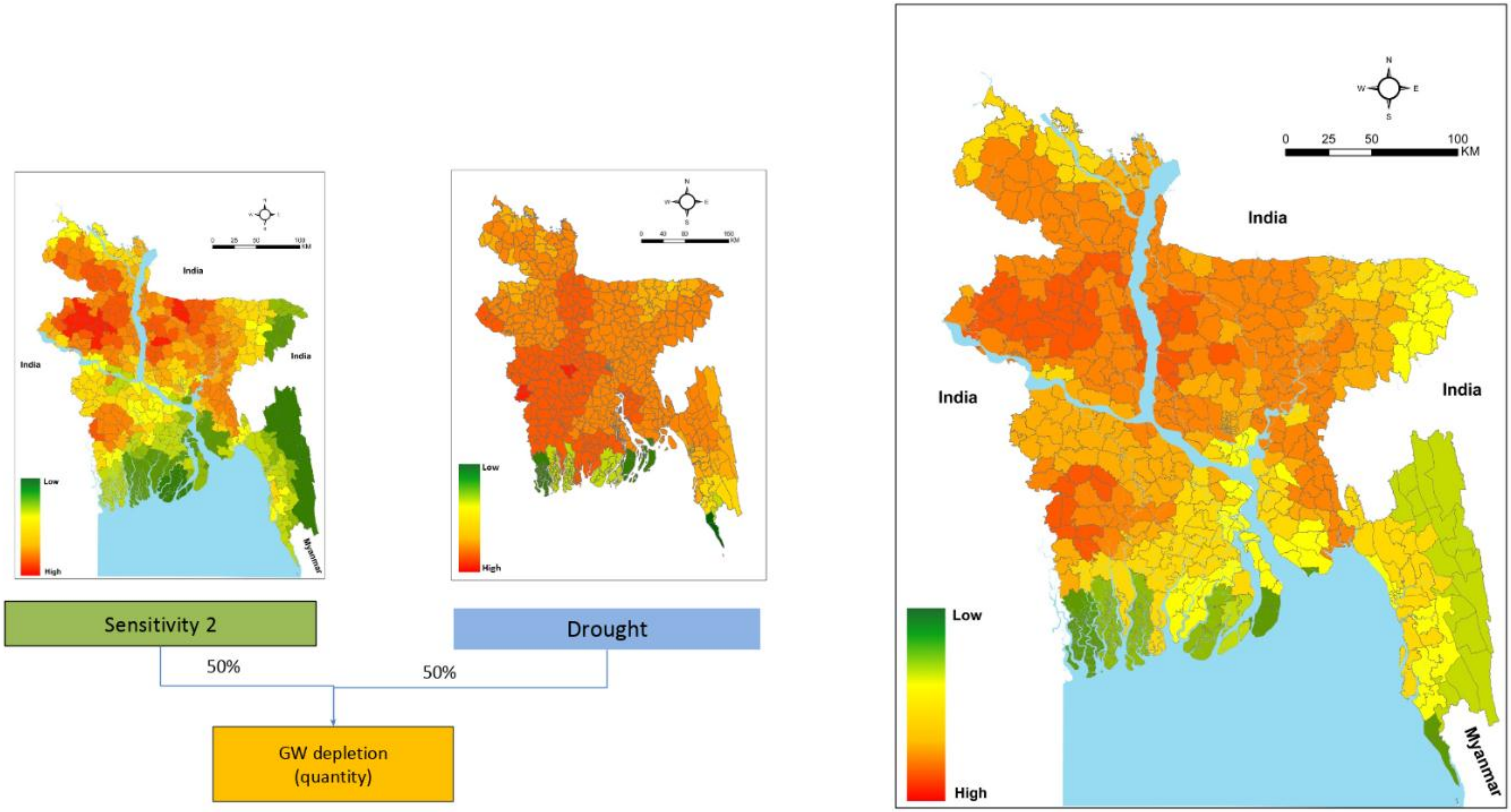
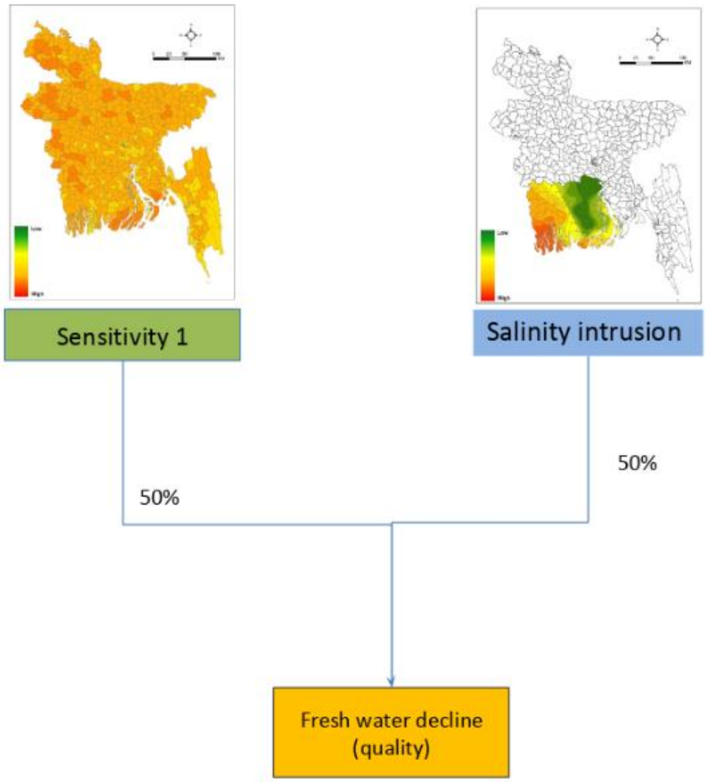


Figure E.3.5 : Potential impact of agriculture on lack of water availability

Potential Impact



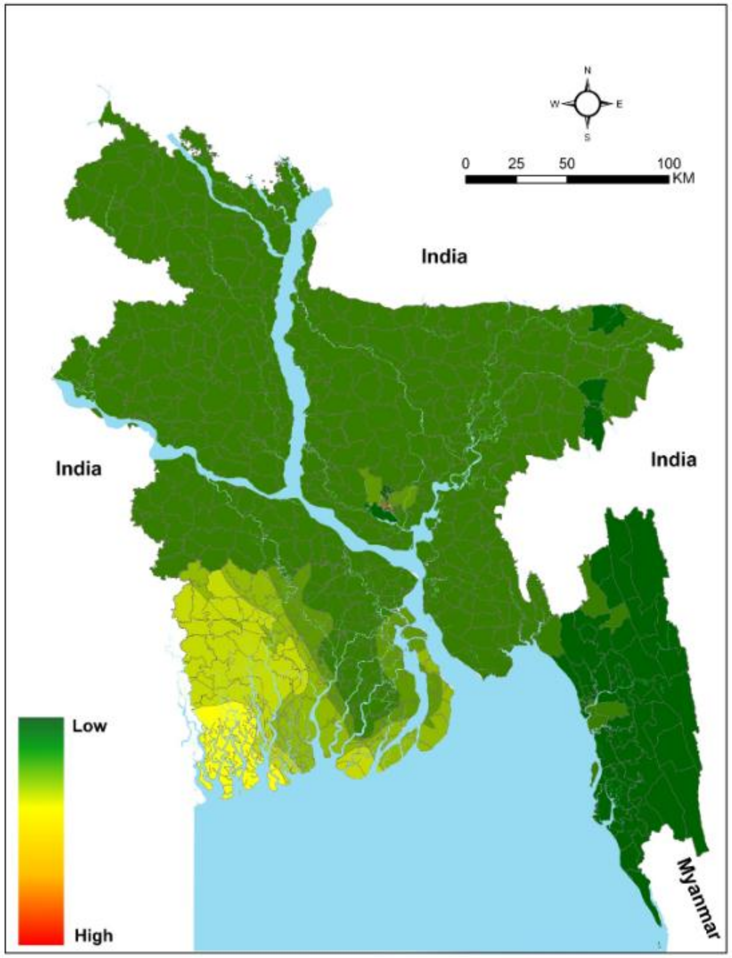
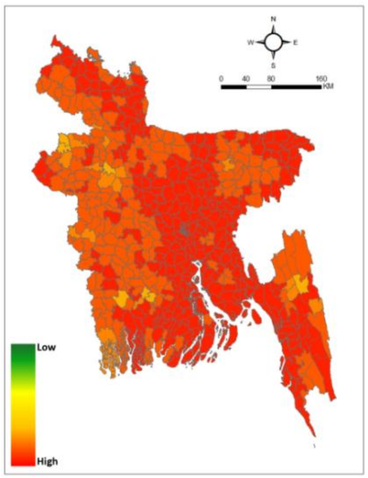


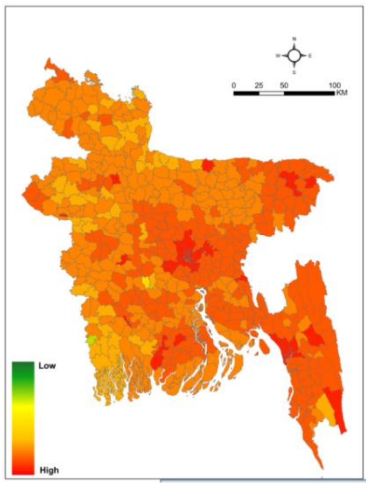
Figure E.3.6 : Potential impact of agriculture on lack of water availability

5. Adaptive capacity

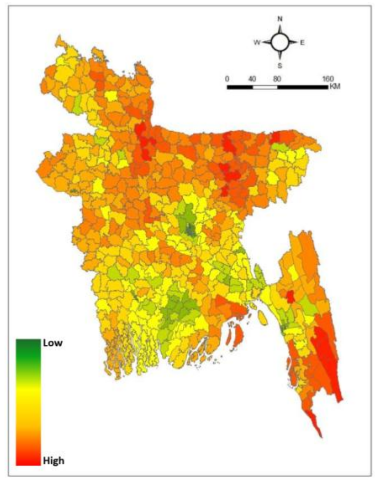
[1] Production technology



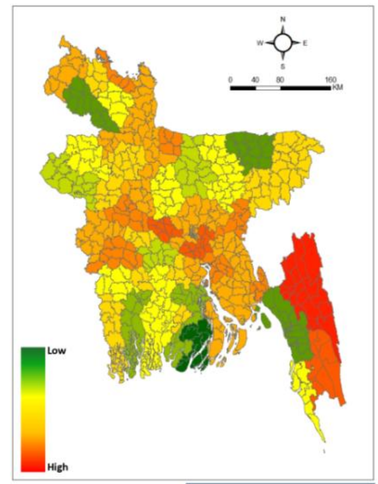
[2] Household income



[3] Literacy rate



[4] Governmental investment in water management



[5] Coastal afforestation to cope with salinity intrusion

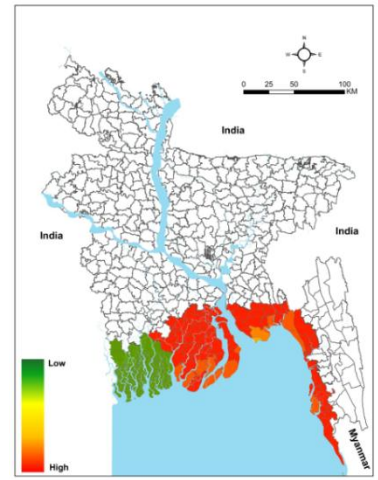
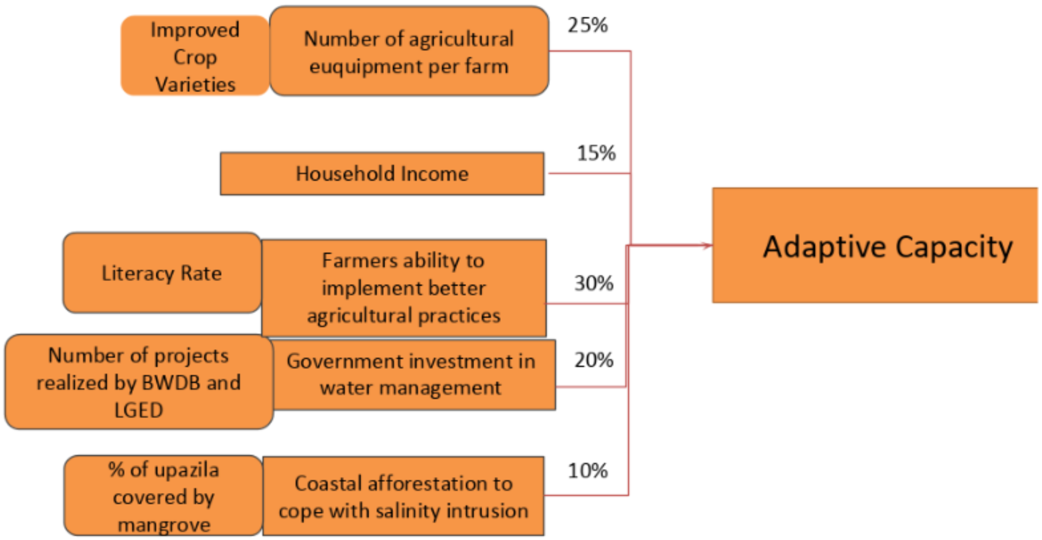


Figure E.3.7 : Adaptive capacity in agriculture for lack of water availability



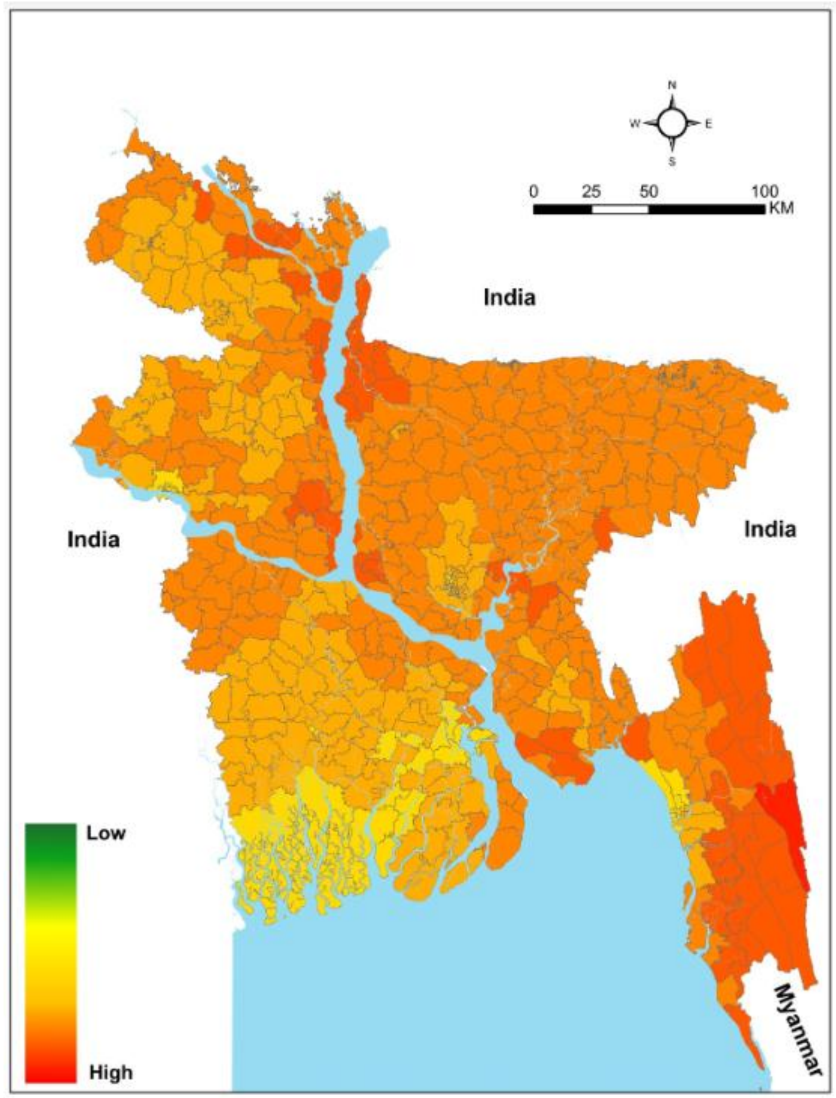
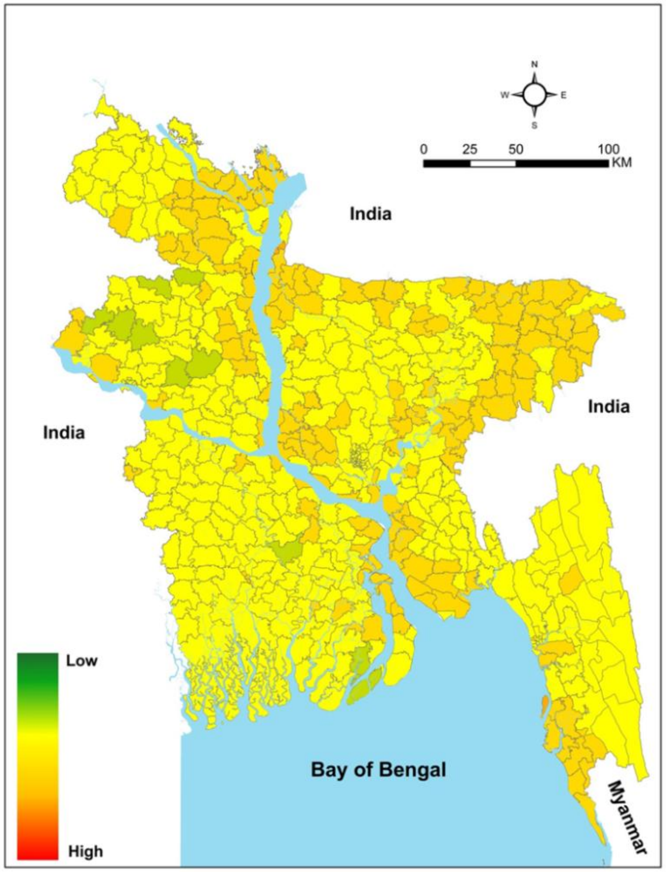


Figure E.3.8 : Adaptive capacity in agriculture for lack of water availability

6. Current vulnerability of crop agriculture



E.3.9 : Assessment of the current vulnerability of the agricultural sector to crops yield degradation

F. Vulnerability of livestock and poultry

F.1. Livestock Sector's Vulnerability to Decrease in Land Availability due to Climate Change

1. Impact chain

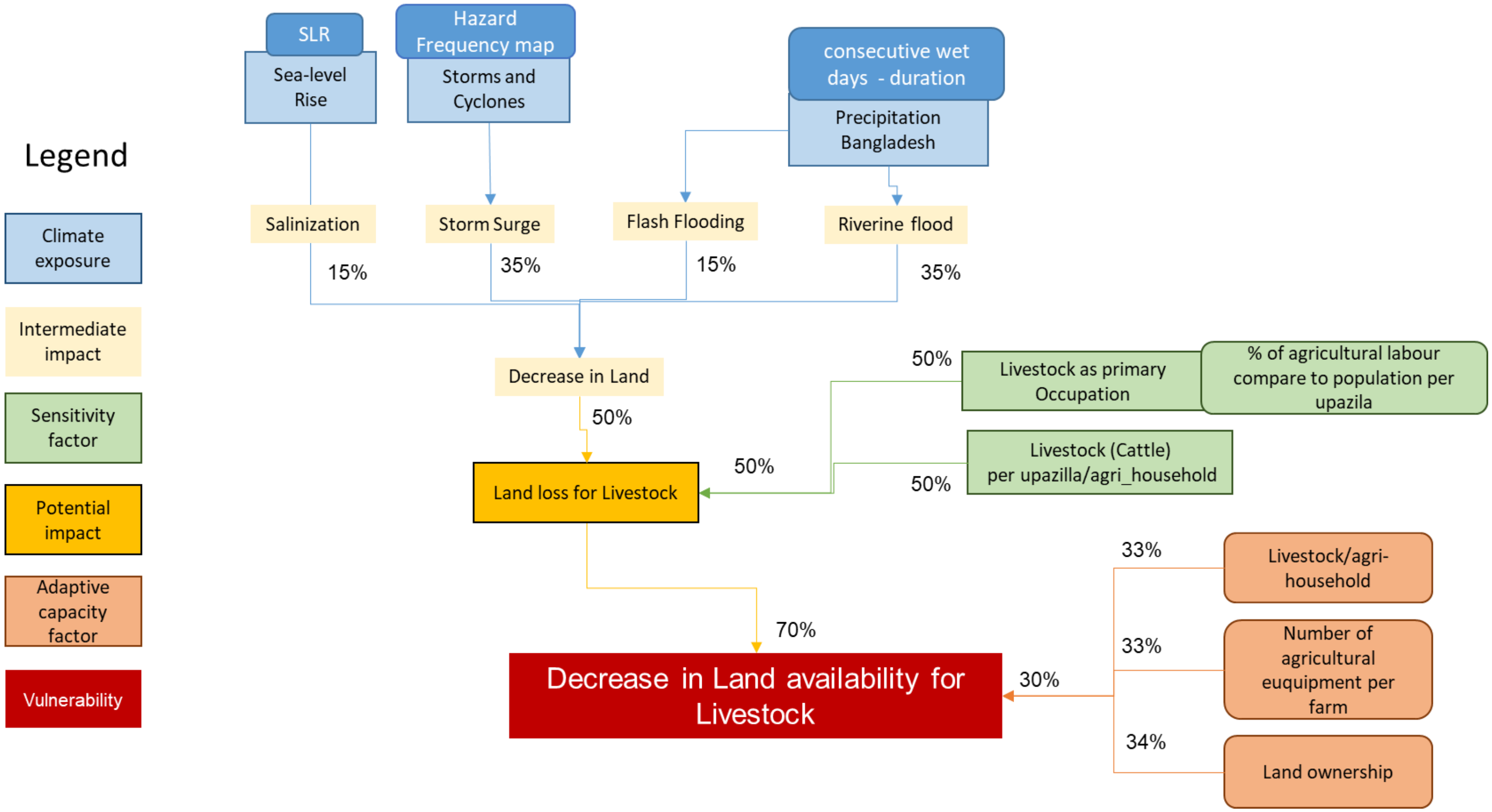


Figure F.1.1 : Impact chain of Livestock Sector's Vulnerability to Decrease in Land Availability due to Climate Change

2. Exposure

[1] Salinization [2] Storm surge [3] River flood [4] Flash flood

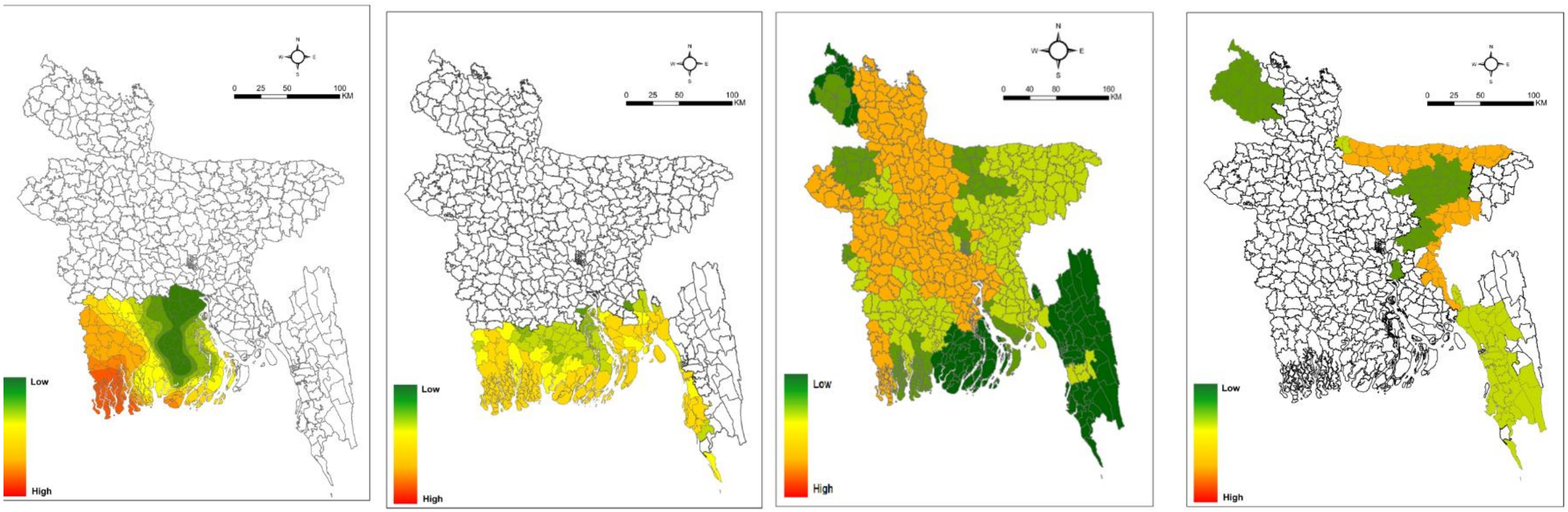
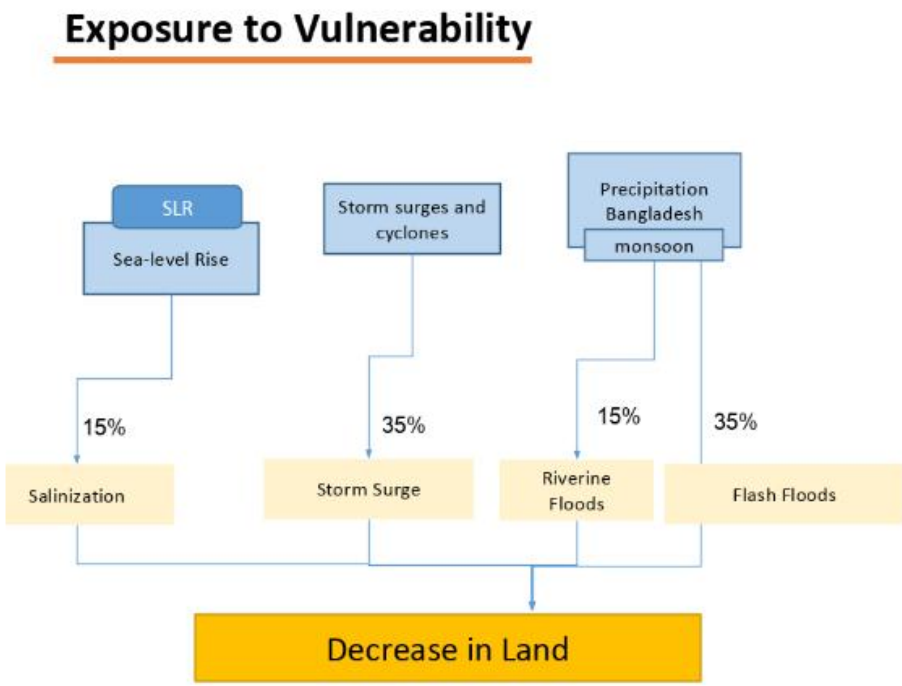


Figure F.1.2 : Exposure of Livestock to Decrease in Land Availability



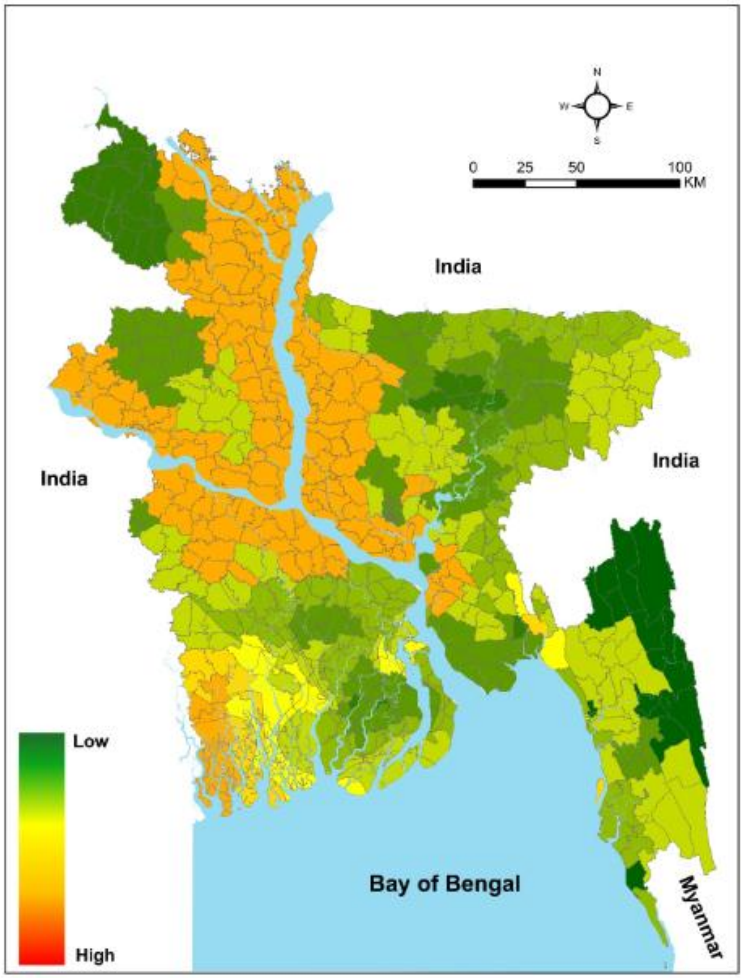


Figure F.1.3 : Exposure of Livestock Sector to Decrease in Land Availability

3. Sensitivity

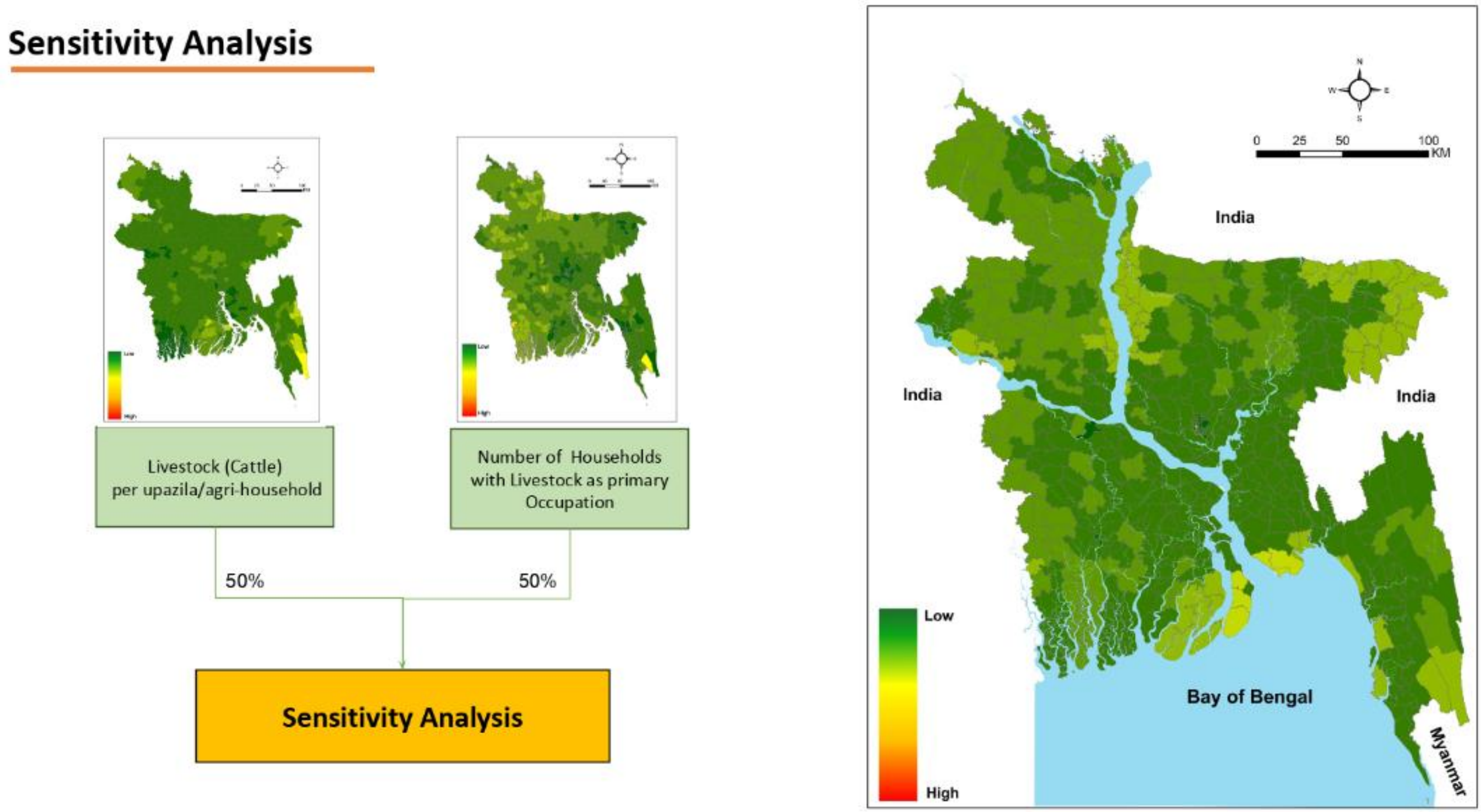


Figure F.1.4: Sensitivity of Livestock to Decrease in Land Availability

4. Potential Impact

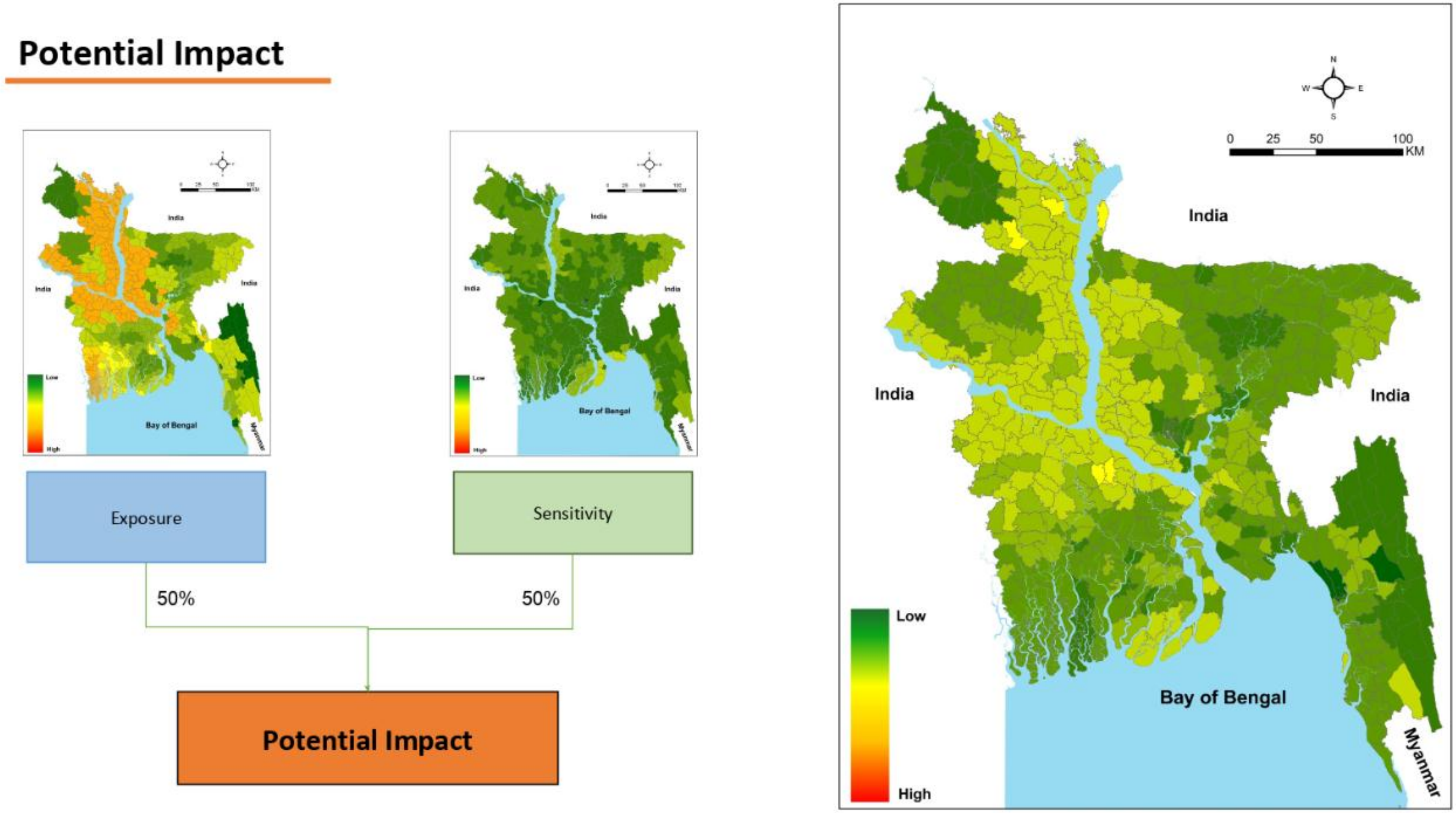


Figure F.1.5: Sensitivity of Livestock to Decrease in Land Availability

5. Adaptive capacity

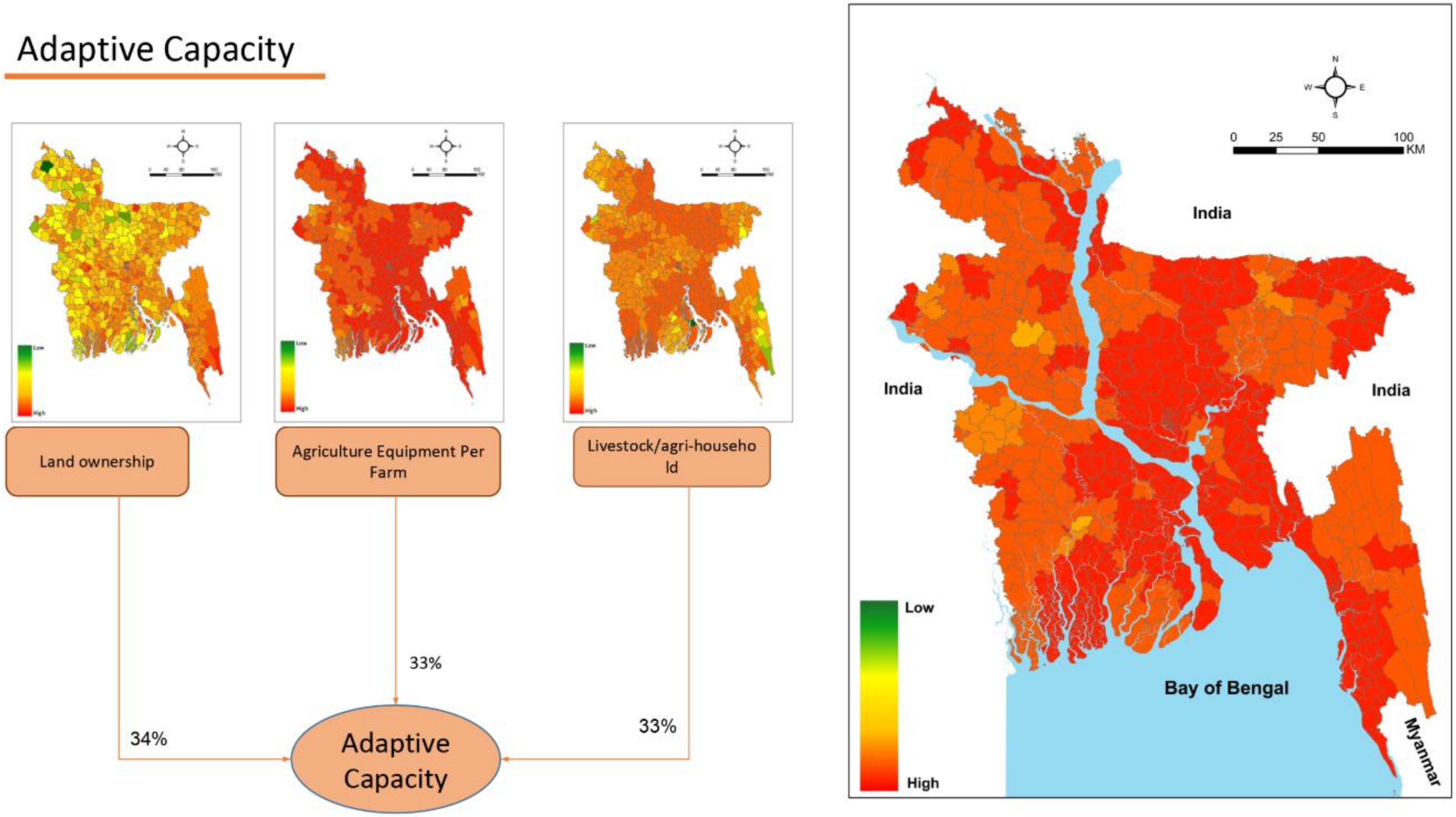


Figure F.1.6: Adaptive capacity of Livestock to Decrease in Land Availability

6. Vulnerability of livestock due to decrease in land availability

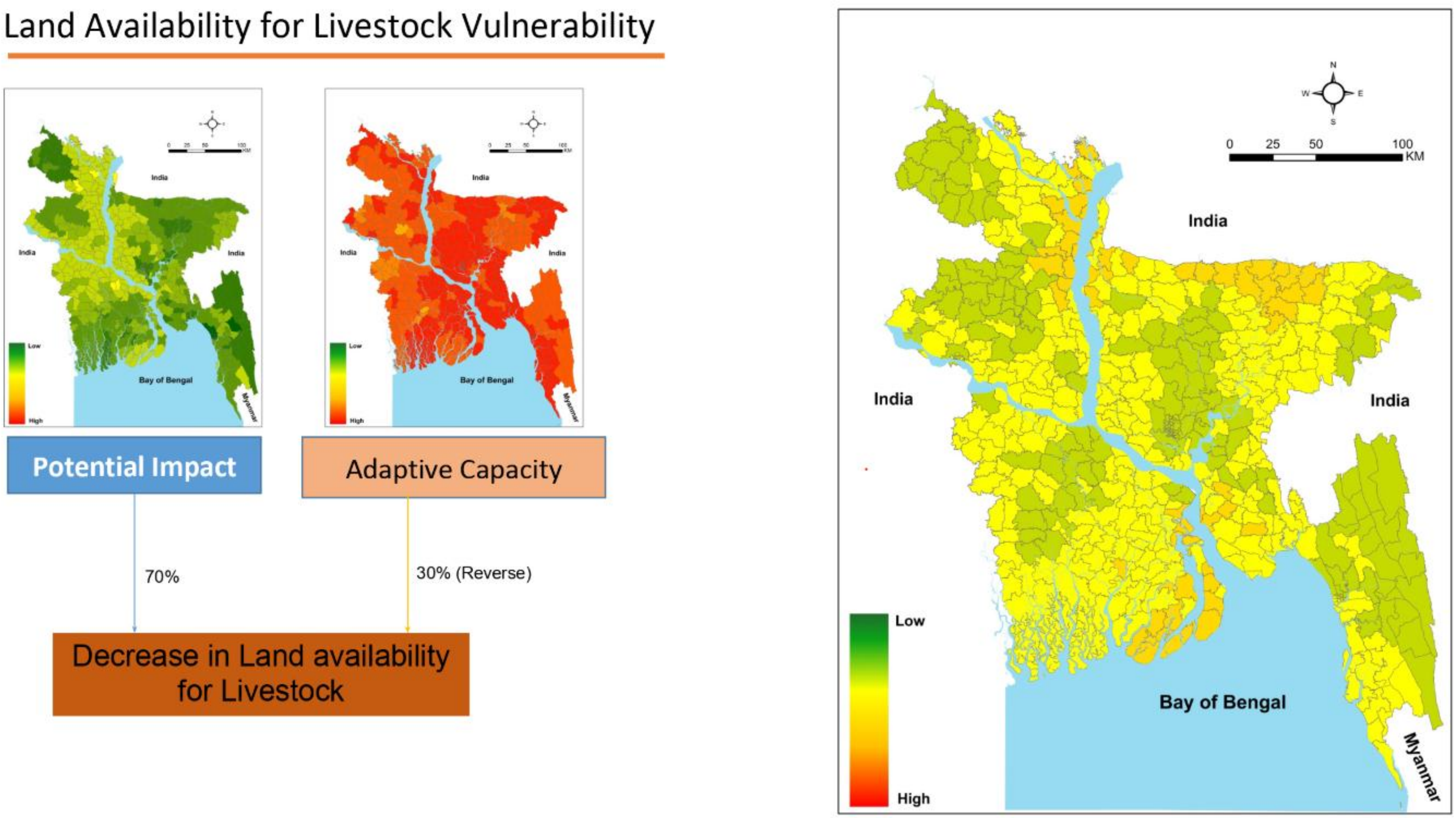


Figure F.1.7: Current vulnerability of Livestock to Decrease in Land Availability

F.2. Livestock and Poultry Health Vulnerability due to Climate Change

1. Impact chain

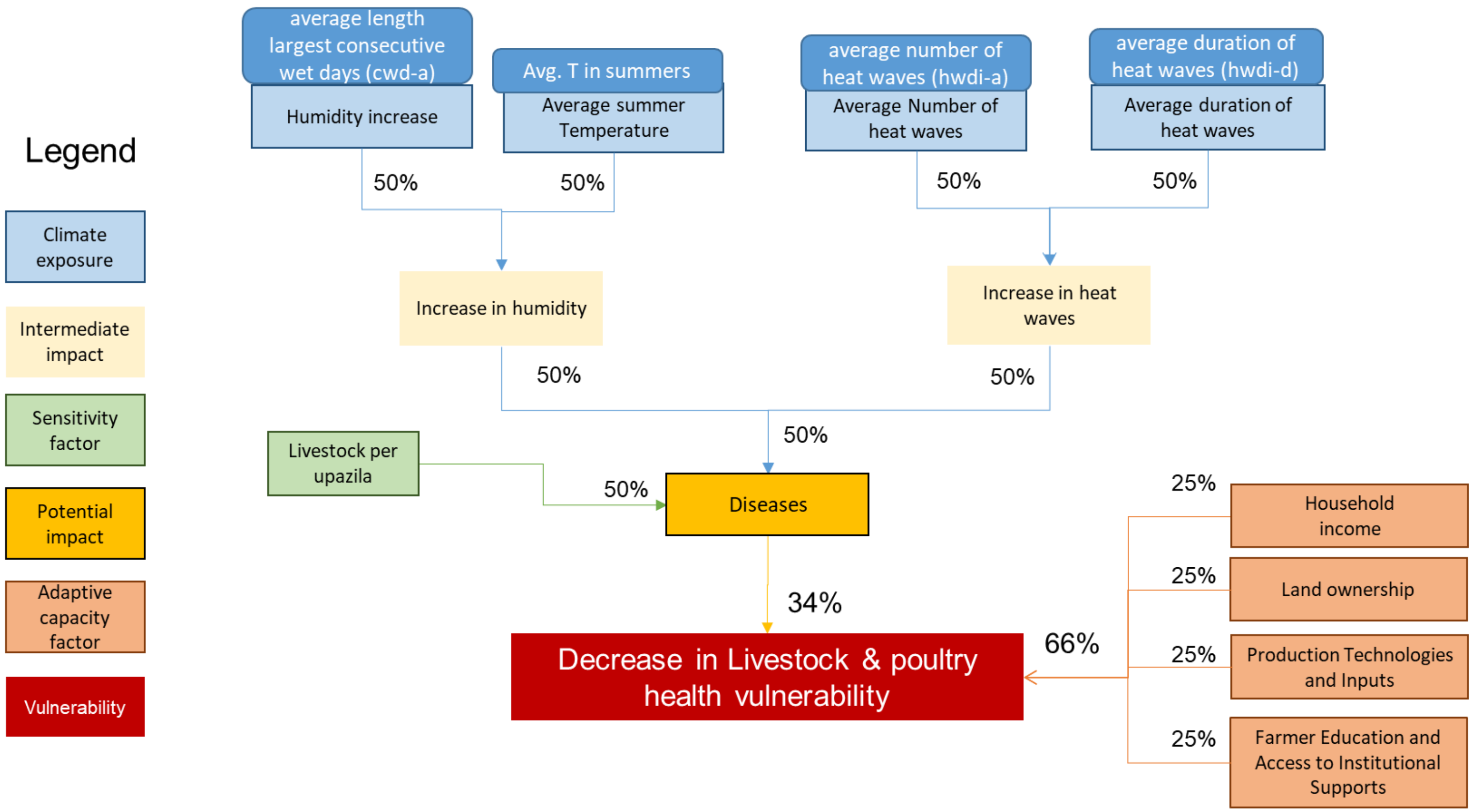


Figure F.2.1: Impact chain of Livestock and Poultry Health Vulnerability due to Climate Change

2. Exposure

[1] Consecutive wet days [2] average summer temperature [3] Number of heat waves [4] Duration of heat waves

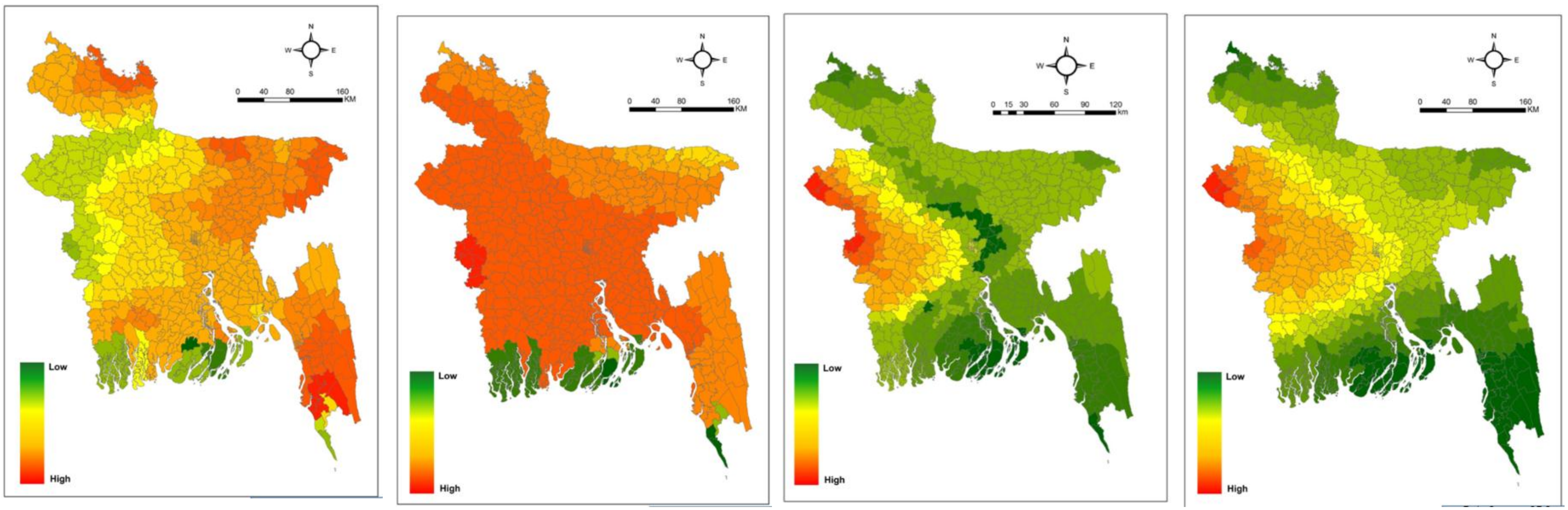


Figure F.2.2: Exposure of Livestock and Poultry Health

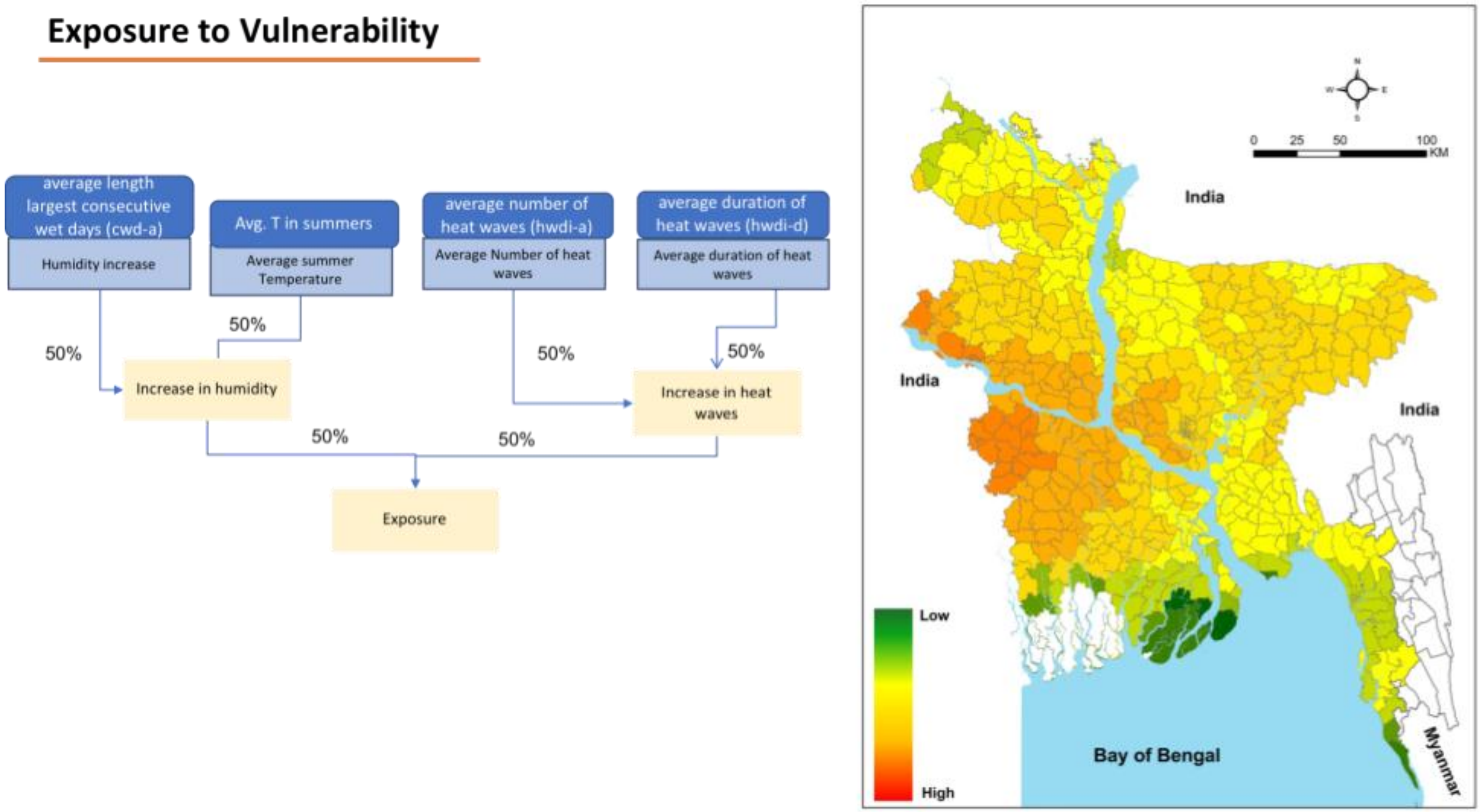


Figure F.2.3: Exposure of Livestock and Poultry Health

3. Sensitivity

[Livestock per Upazila]

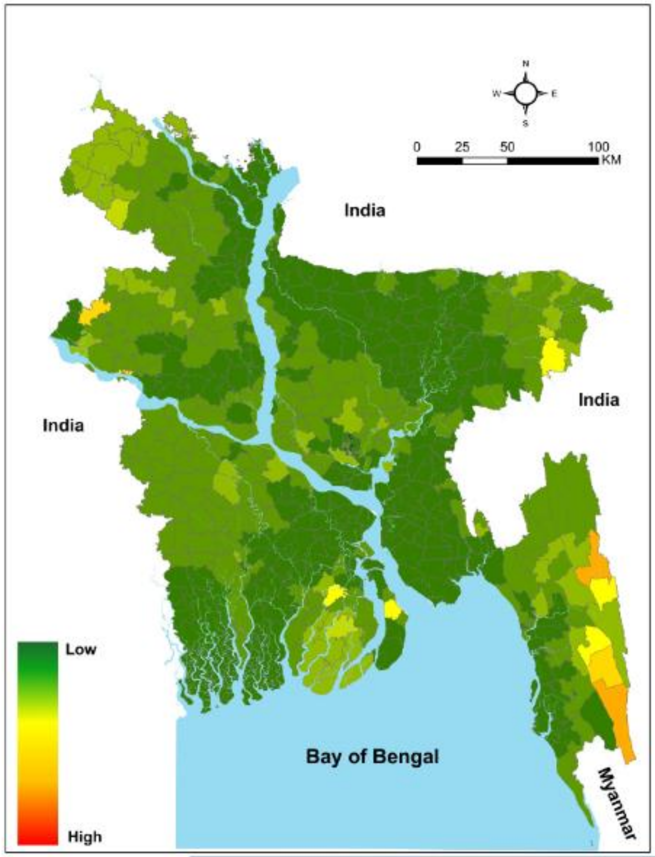


Figure F.2.4: Sensitivity of Livestock and Poultry Health

4. Potential Impact

Potential Impact

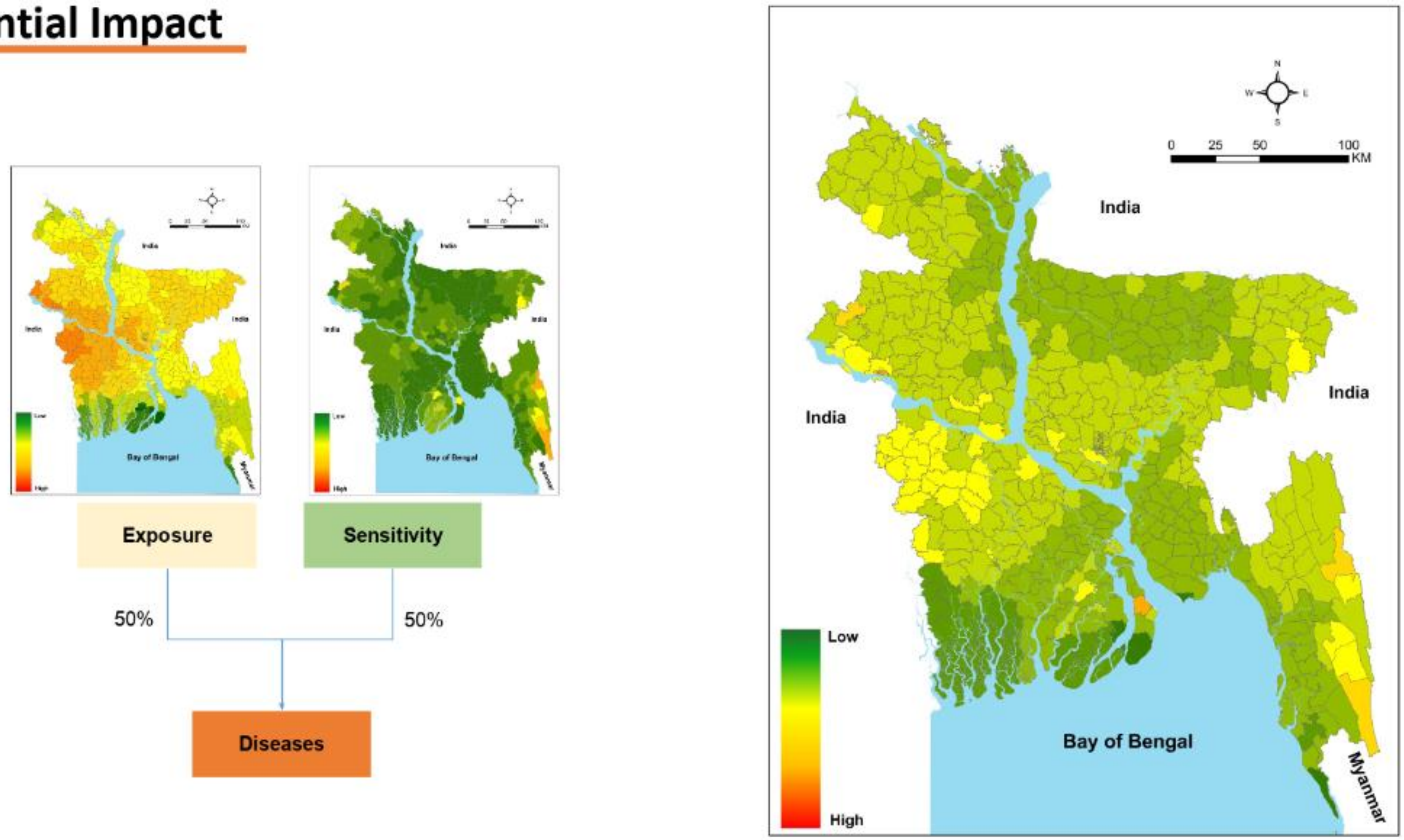


Figure F.2.5: Potential impact of Livestock and Poultry Health

5. Adaptive capacity

[1] Production technology and input

[2] Household income

[3] Farmer education and access to institutional support

[4] Land ownership

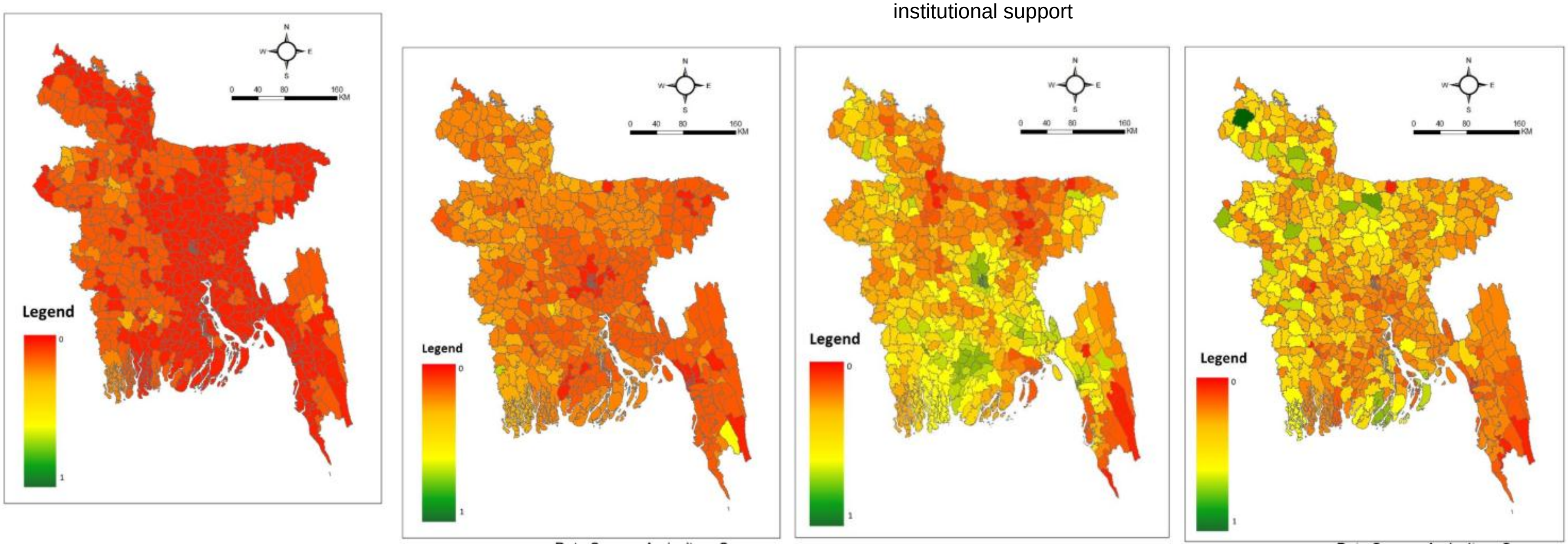
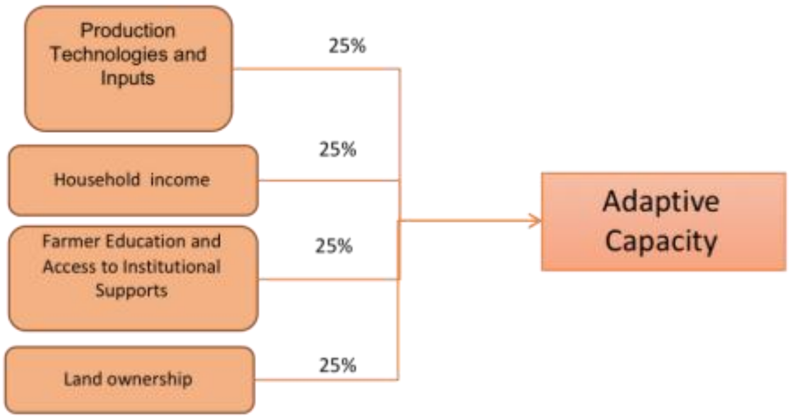


Figure F.2.5: Adaptive capacity of Livestock and Poultry Health

Adaptive Capacity



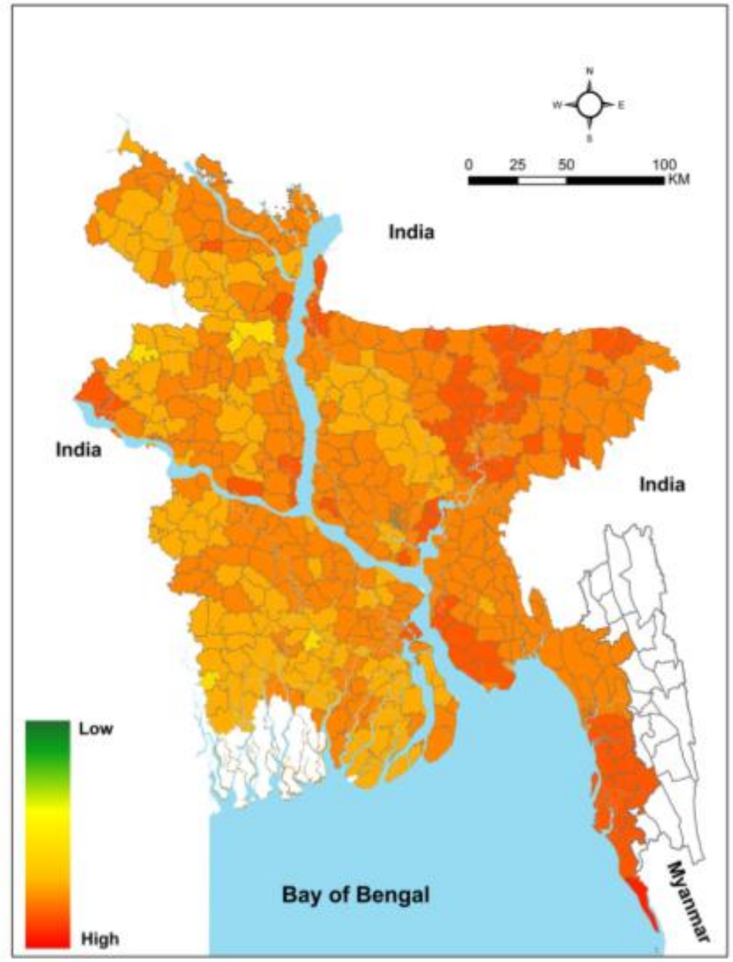


Figure F.2.6: Adaptive capacity of Livestock and Poultry Health

6. Vulnerability of live stockdue to decrease in land availability

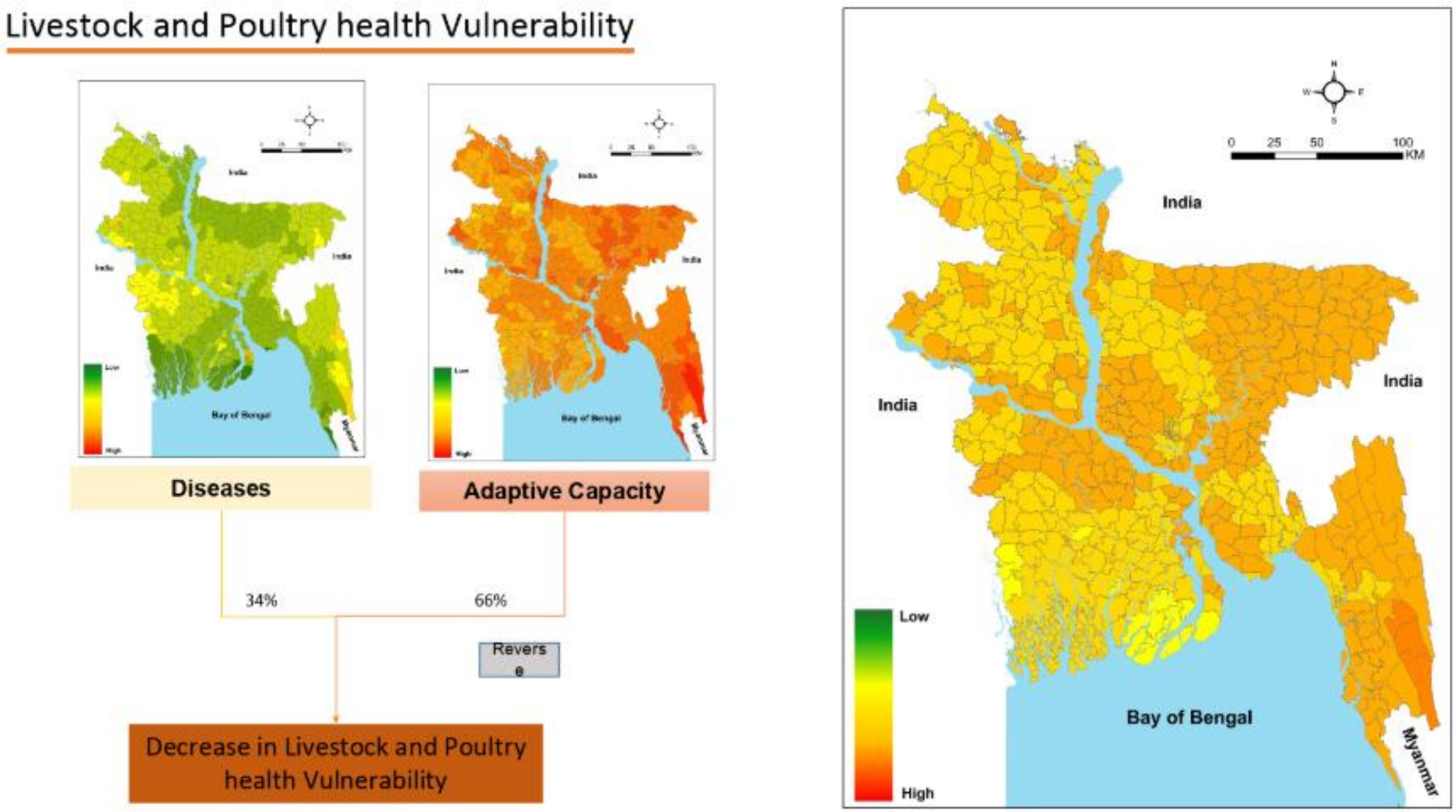


Figure F.2.7: Current vulnerability of Livestock and Poultry Health due to climate change

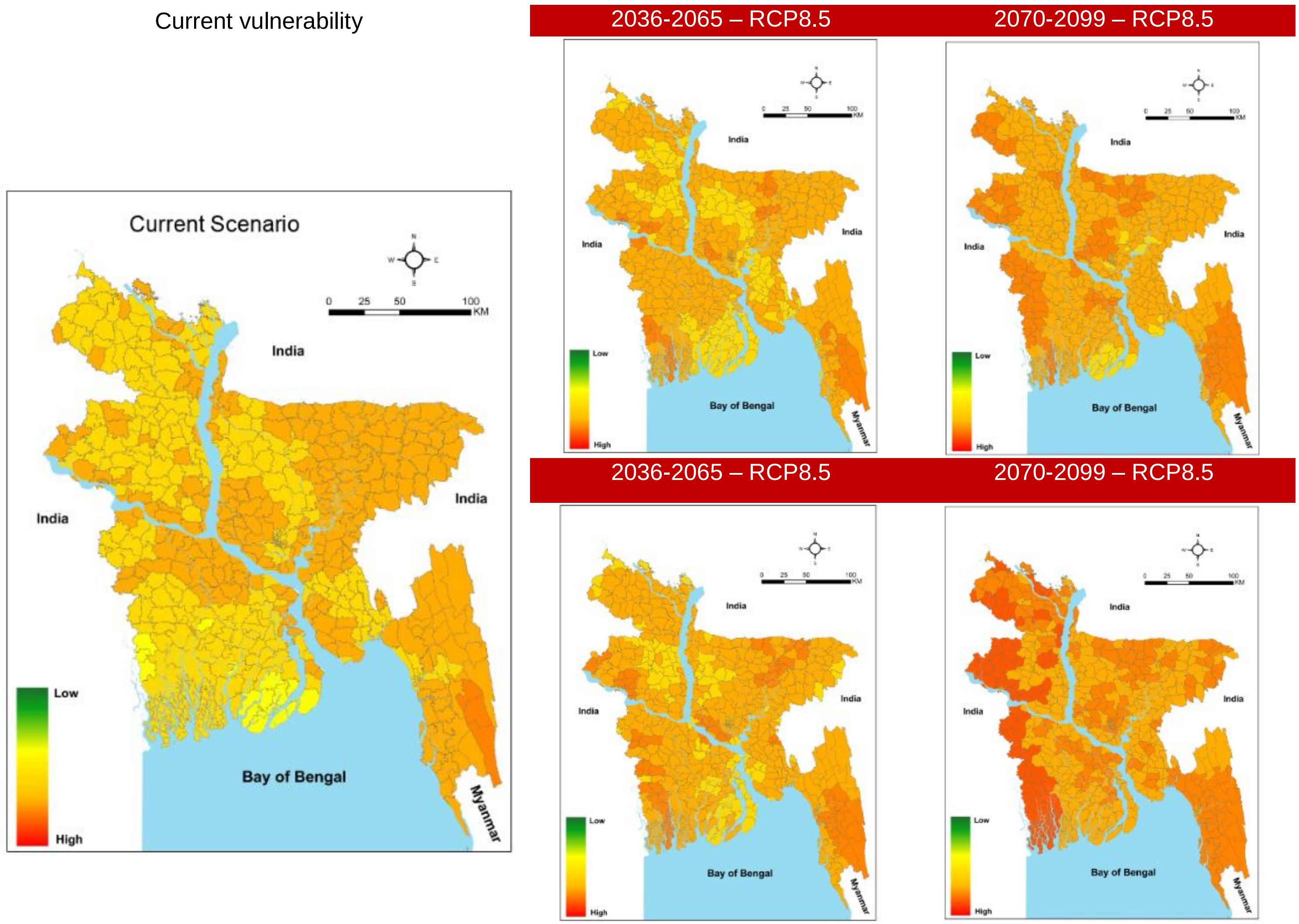


Figure F.2.7: Current and future vulnerability of Livestock and Poultry Health due to climate change

G. Vulnerability of Fisheries

G.1 Vulnerability of Cultured Fish due to climate change

1. Impact chain

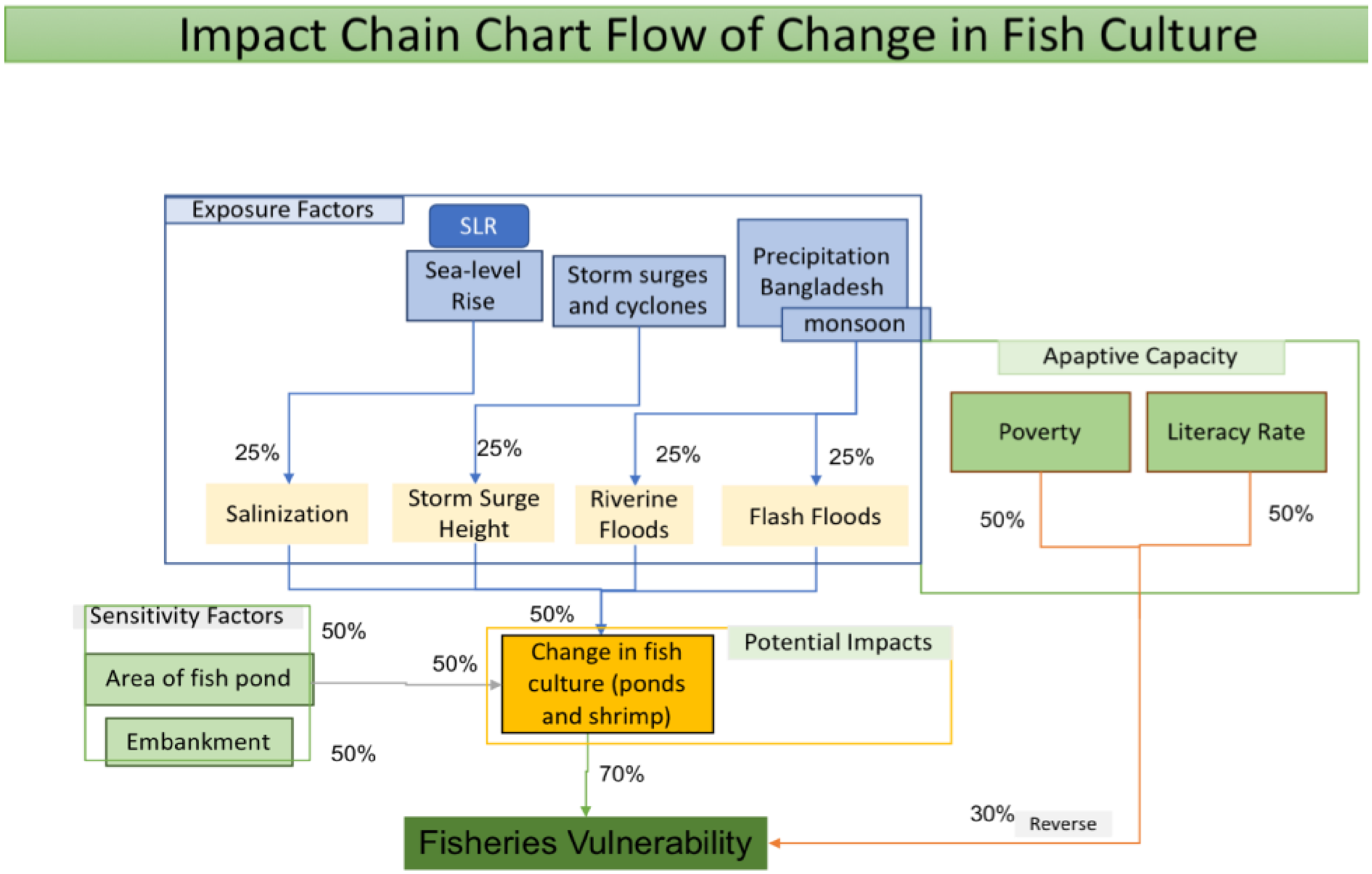


Figure G.1.1: Impact chain of vulnerability of cultured fish due to climate change

2. Exposure

[1] Salinization [2] Storm surge [3] River flood [4] Flash flood

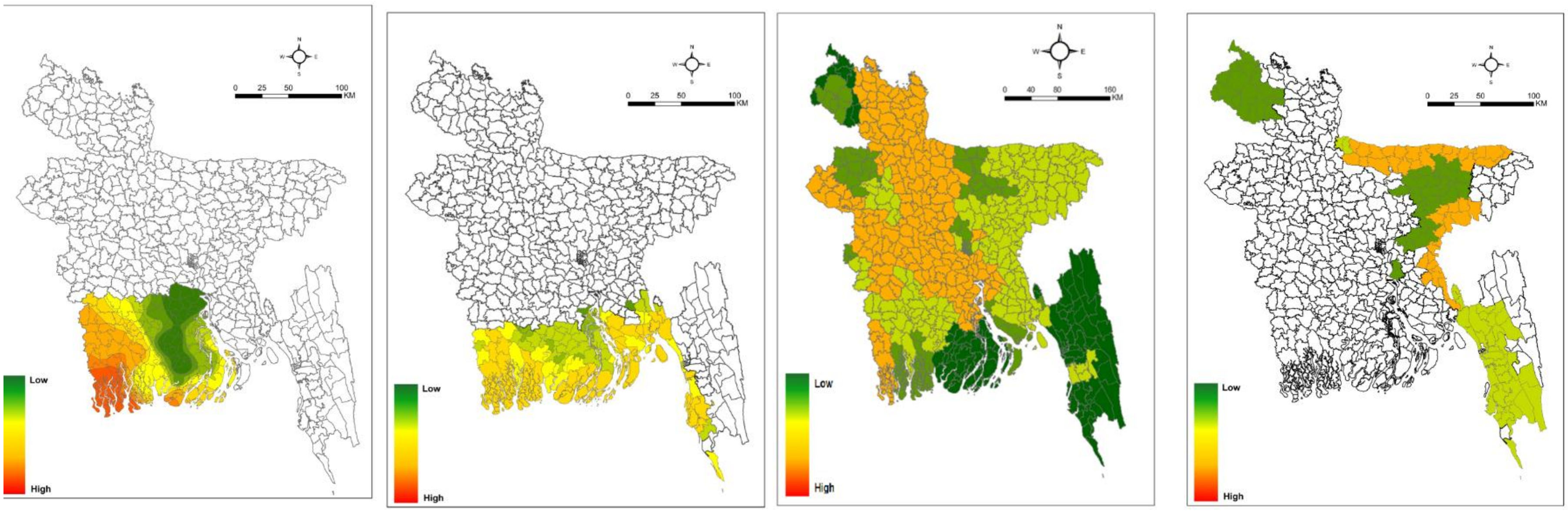
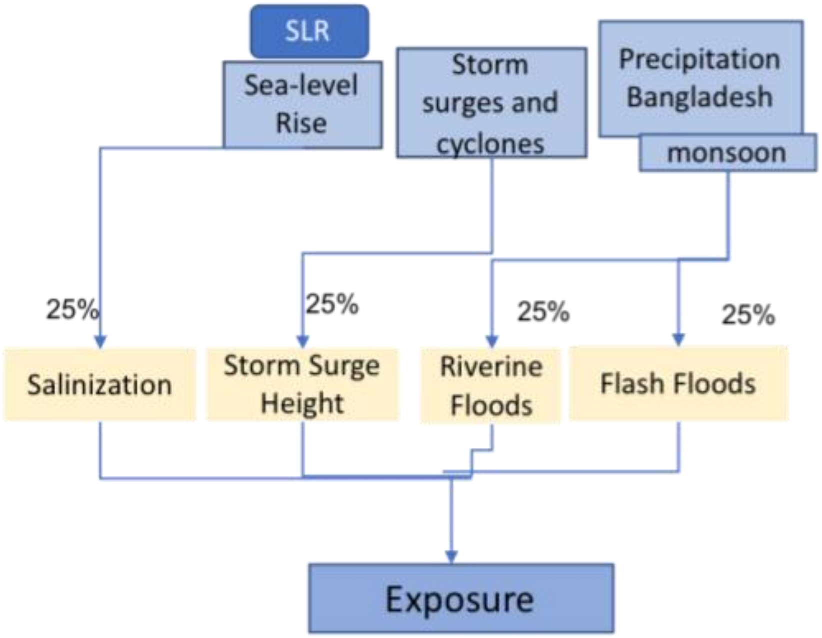


Figure G.1.2: Exposure of cultured fish due to climate change

Exposure to Vulnerability



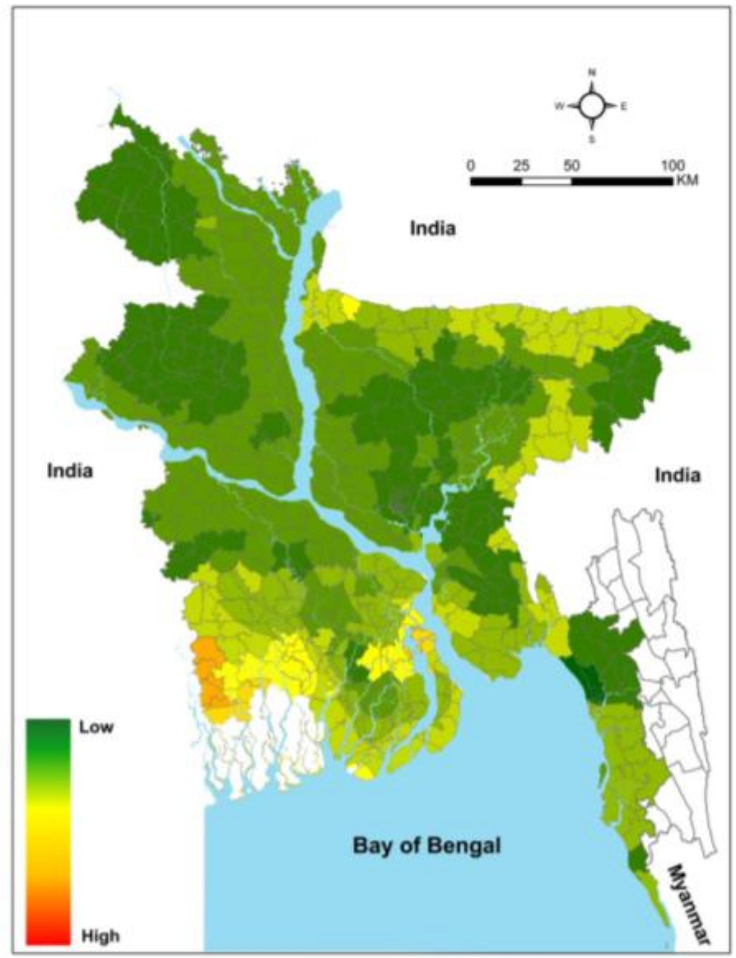


Figure G.1.3: Exposure of cultured fish due to climate change

3. Sensitivity

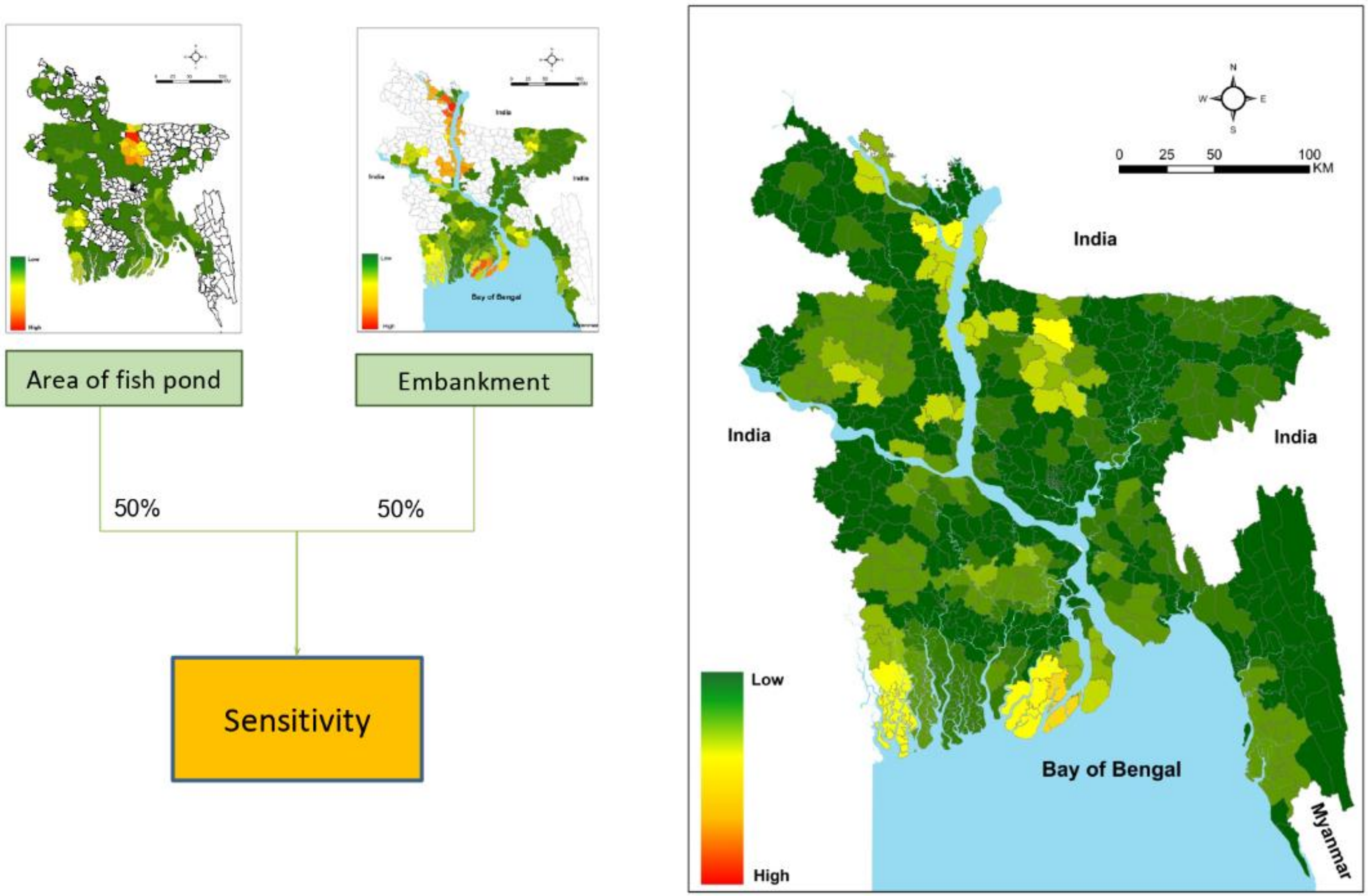


Figure G.1.4: Sensitivity of cultured fish due to climate change

4. Potential Impact

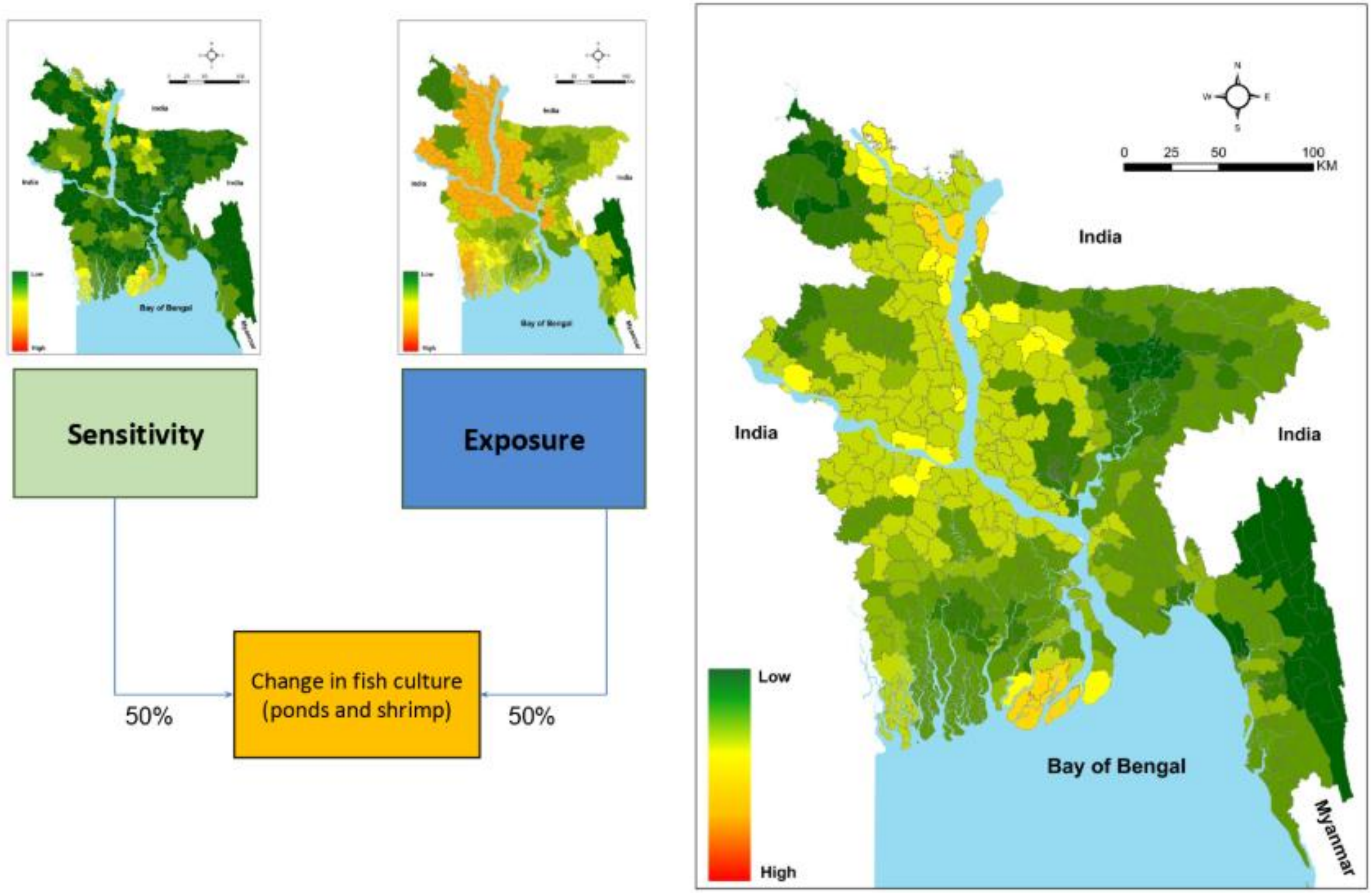


Figure G.1.5: Potential impact on cultured fish due to climate change

5. Adaptive capacity

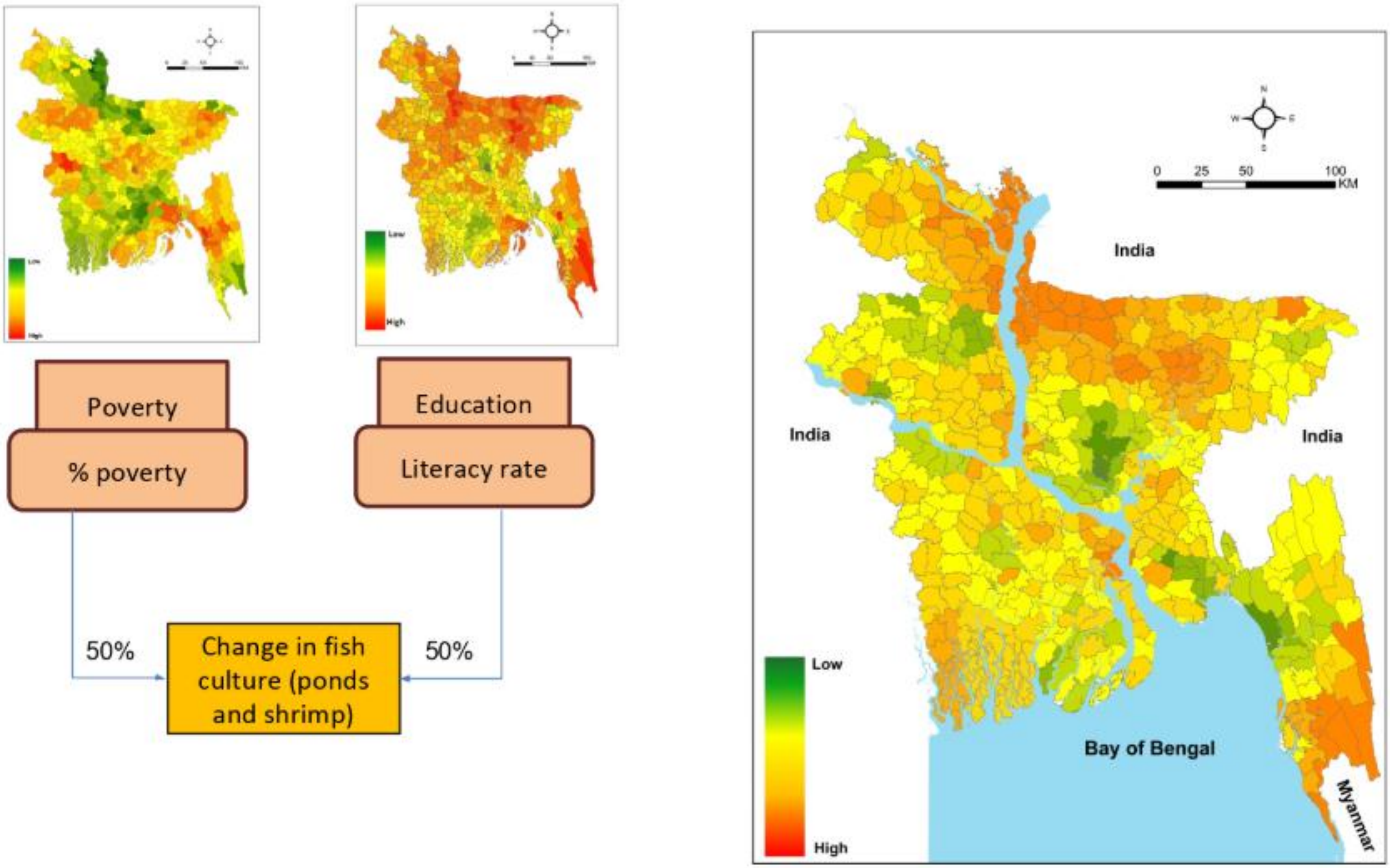


Figure G.1.6: Adaptice capacity of cultured fish due to climate change

6. Vulnerability of cultured fisheries

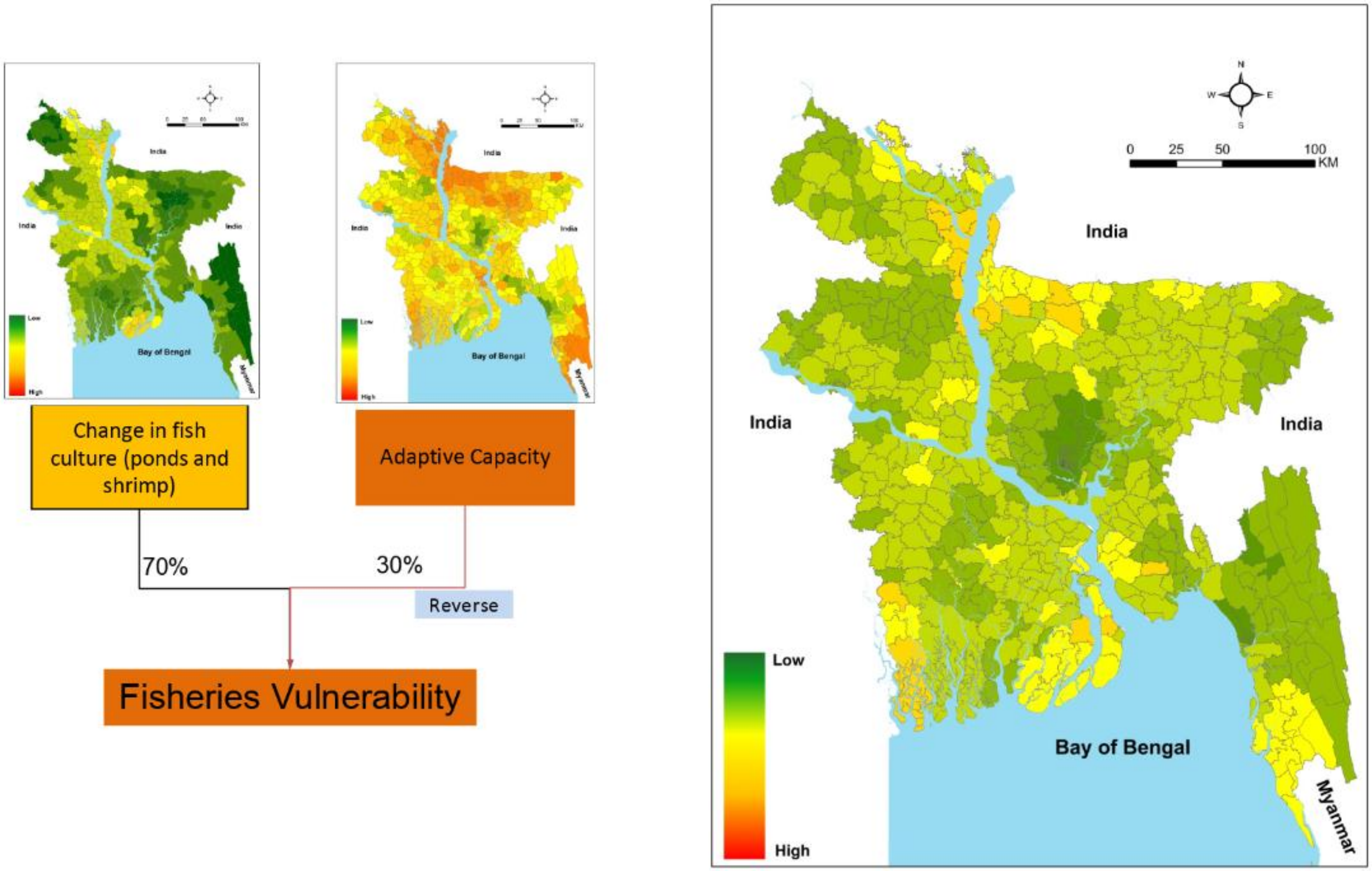


Figure G.1.6: Current vulnerability of cultured fish due to climate change

G.2 Vulnerability of captured Fish due to climate change

1. Impact chain

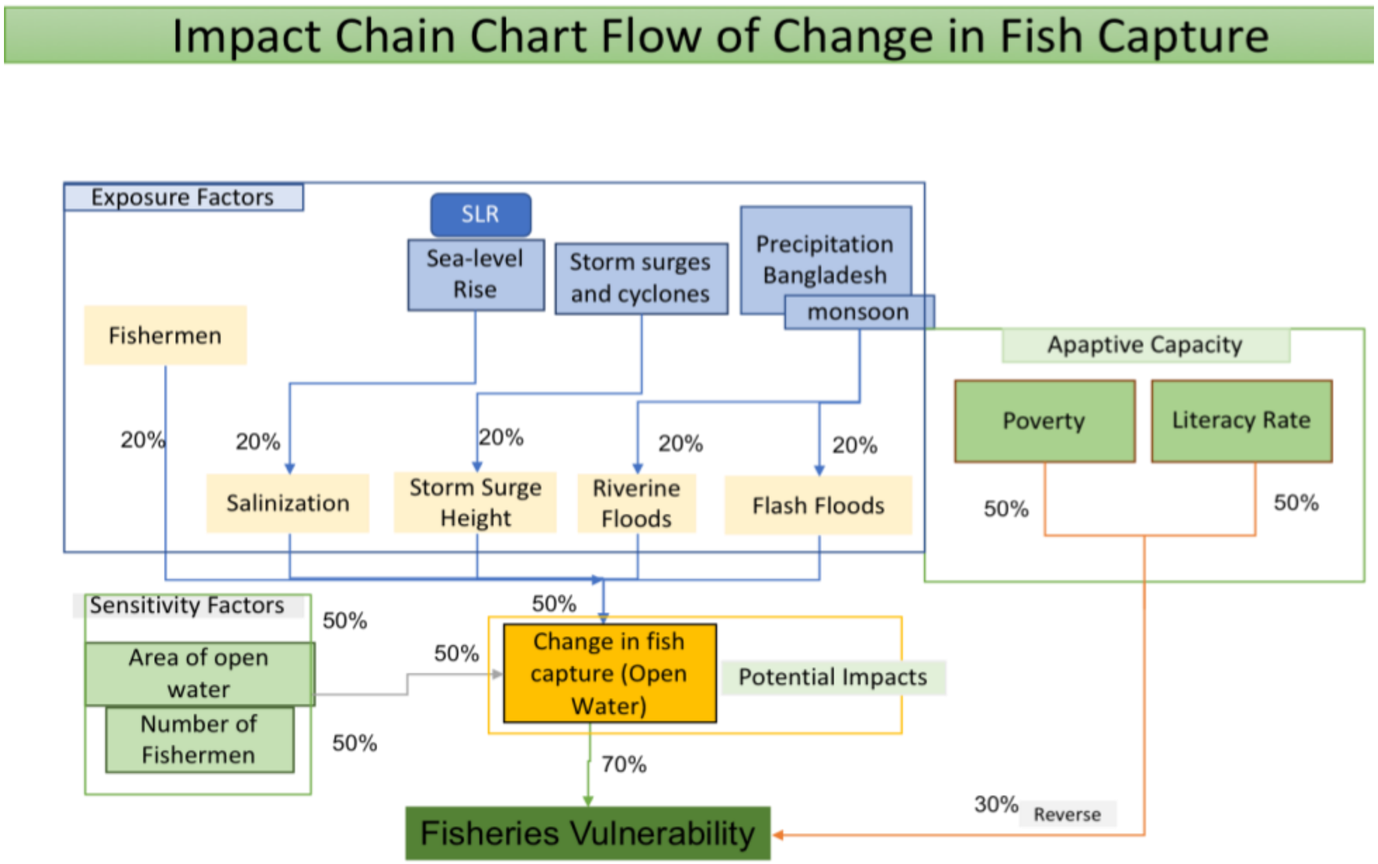


Figure G.2.1: Impact chain of vulnerability of captured fish due to climate change

2. Exposure

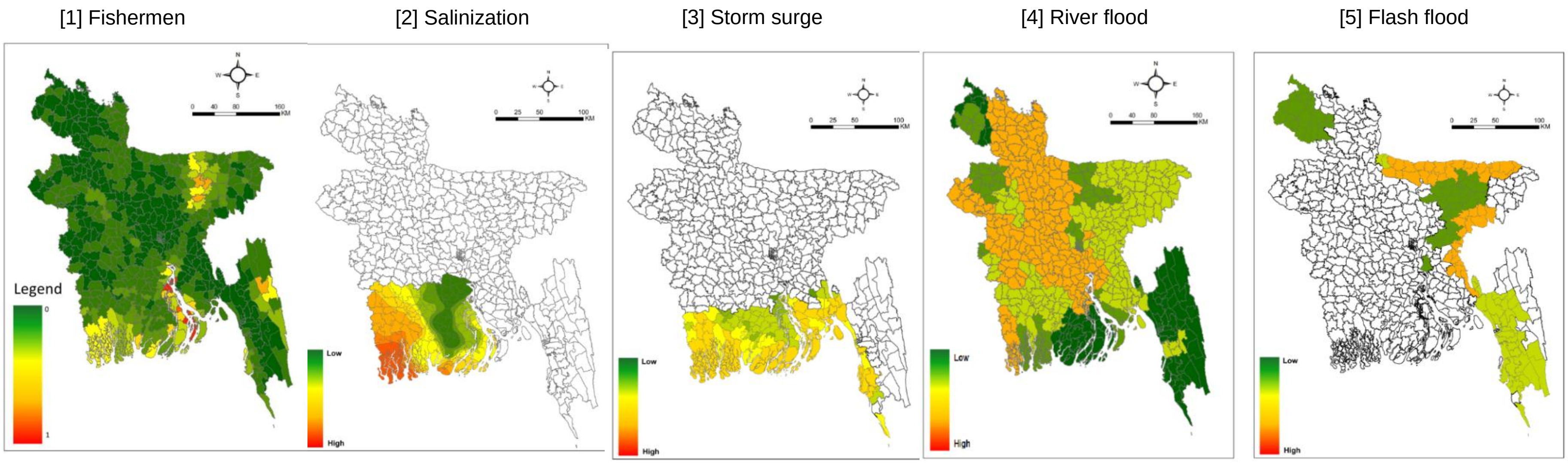


Figure G.2.2: Exposure of captured fish due to climate change

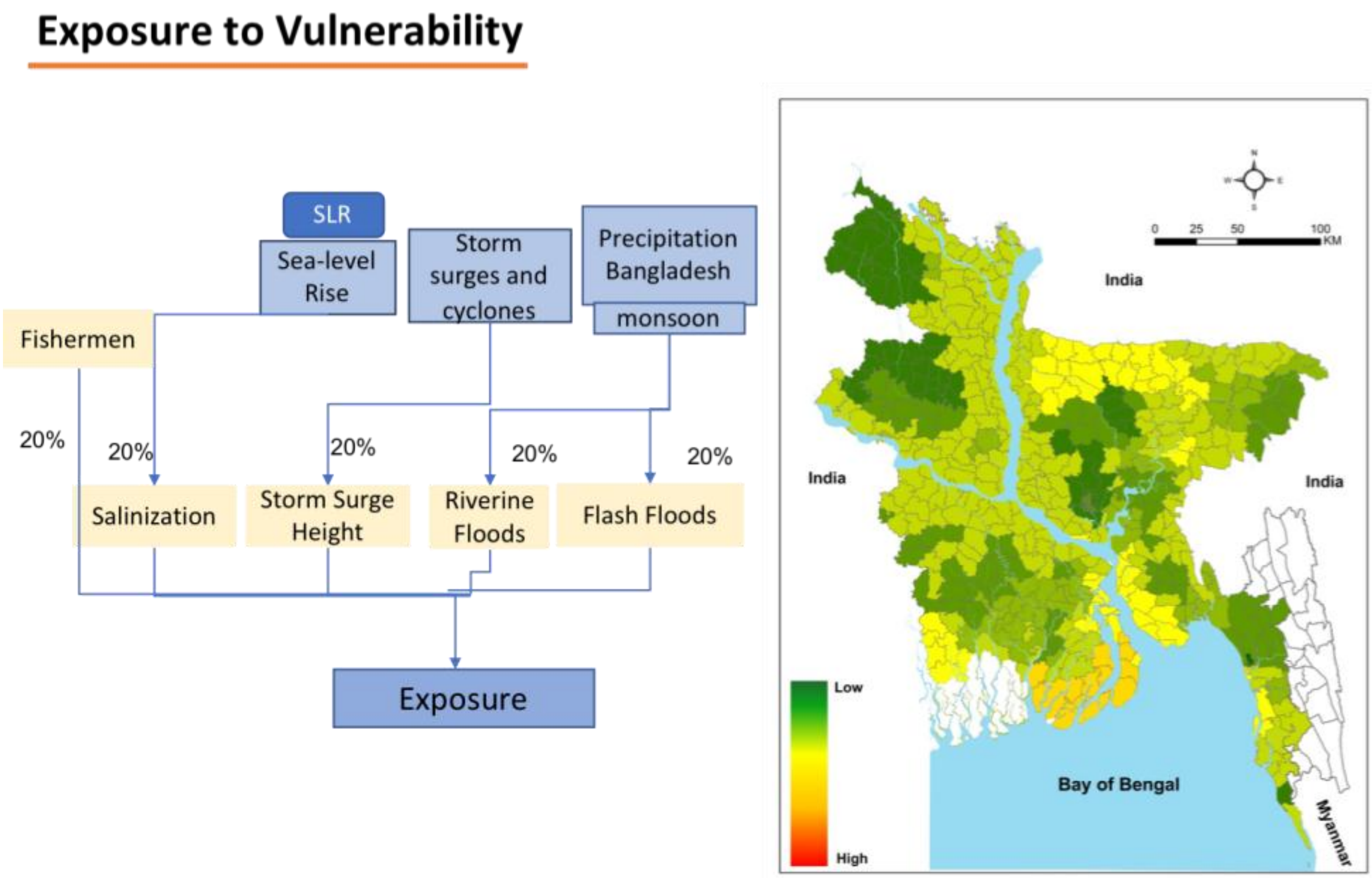


Figure G.2.3: Exposure of captured fish due to climate change

3. Sensitivity

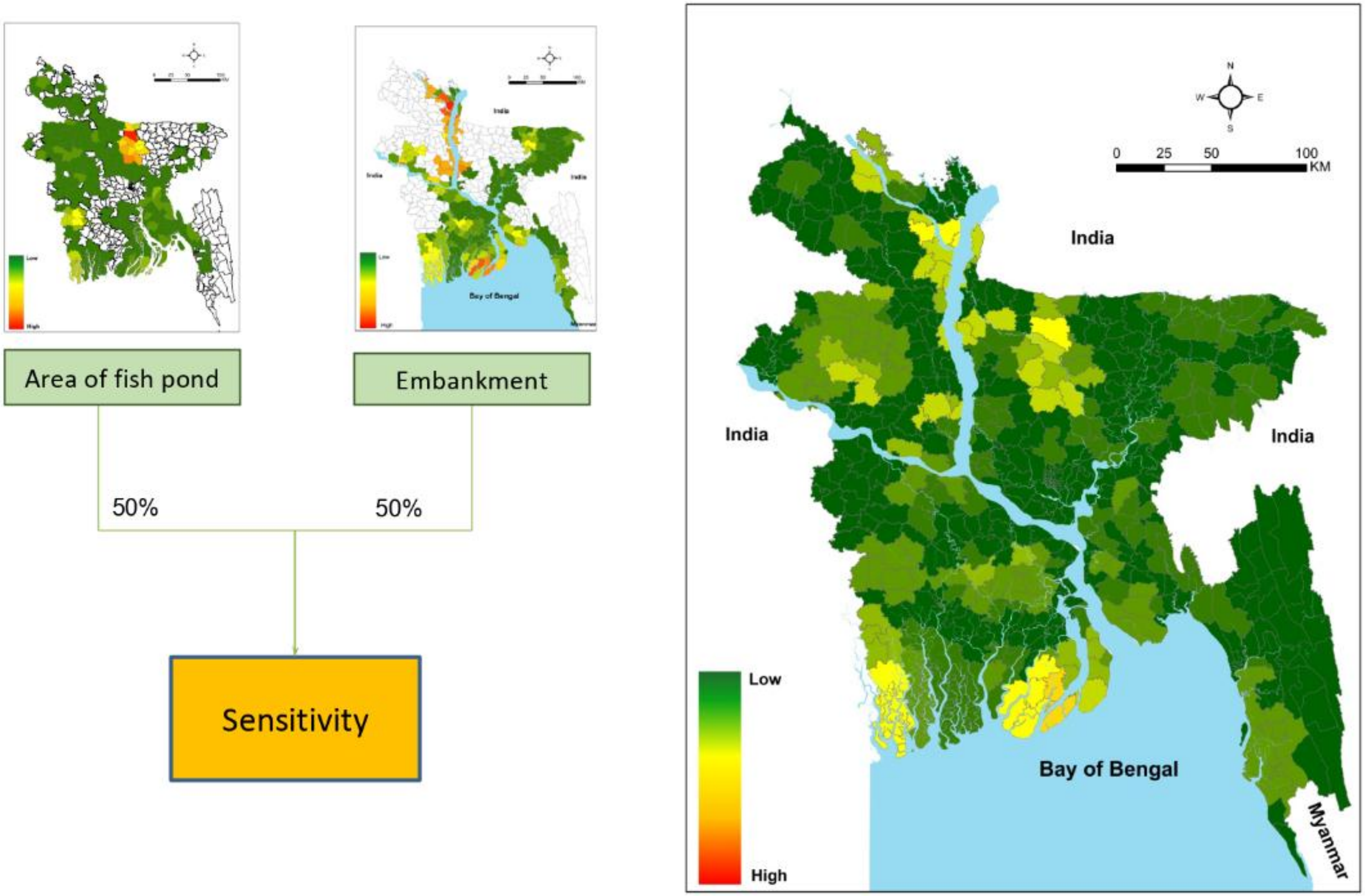


Figure G.2.3: Sensitivity of captured fish due to climate change

4. Potential Impact

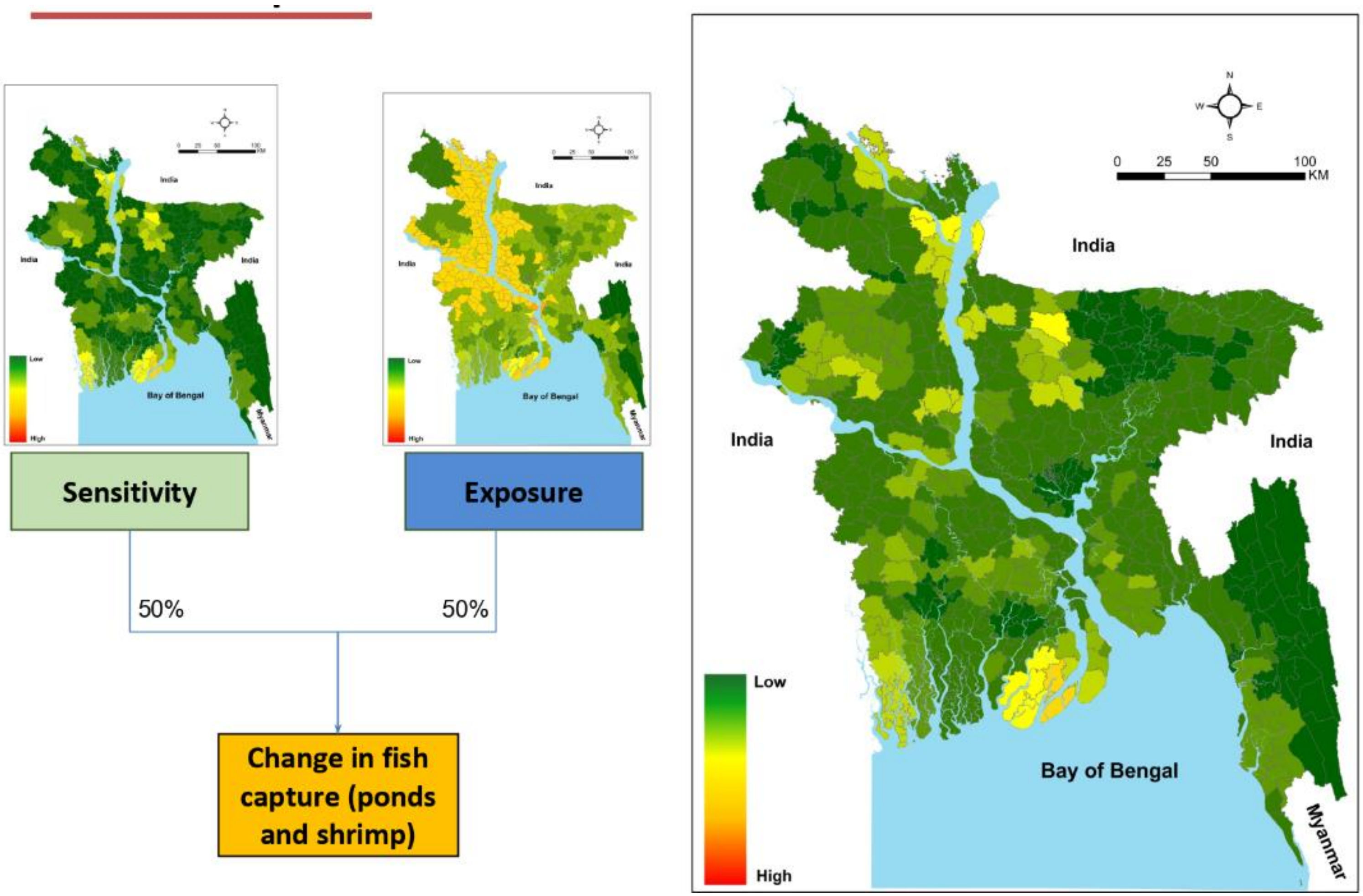


Figure G.2.4: Potential impact of captured fish due to climate change

5. Adaptive capacity

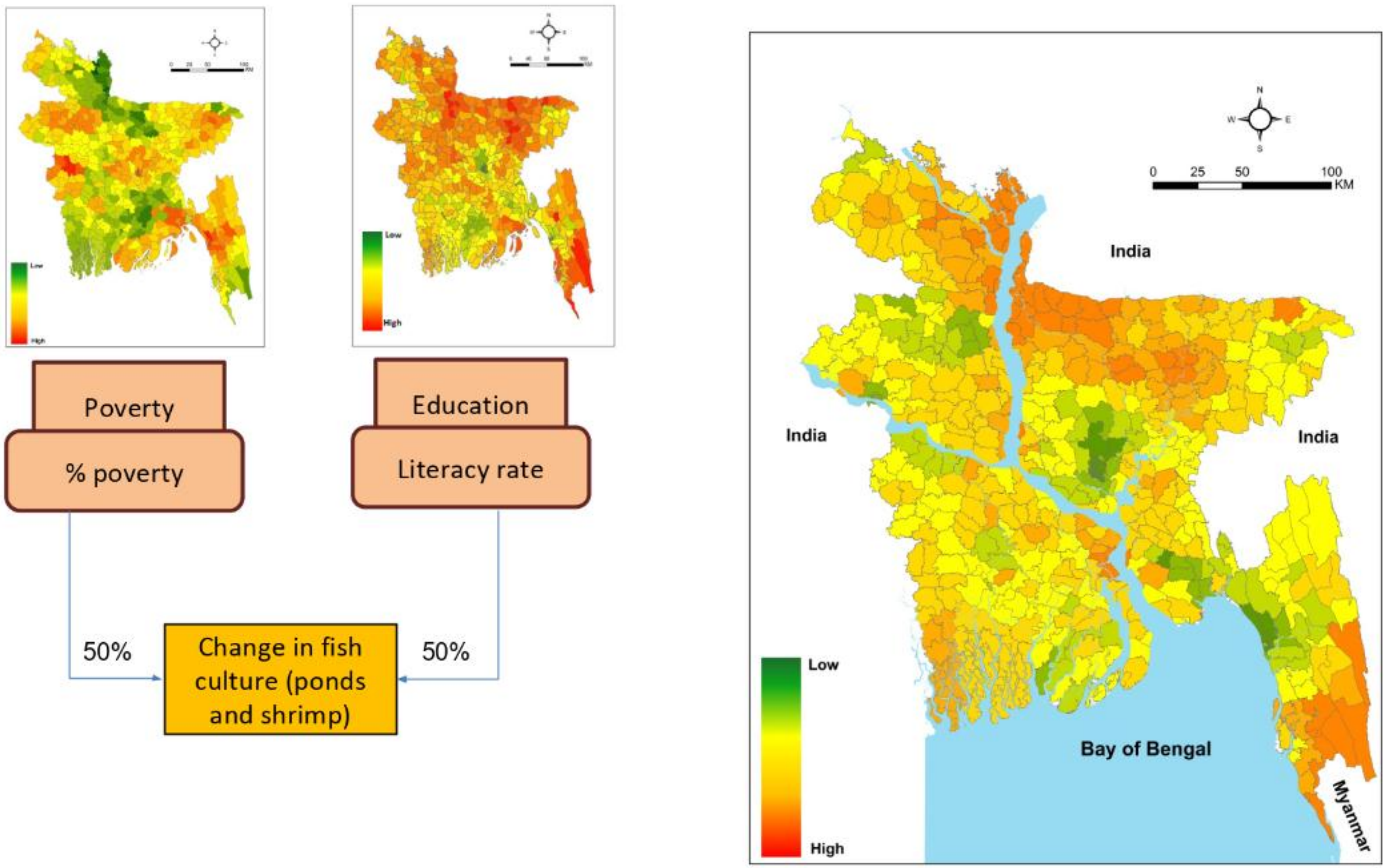


Figure G.2.5: Adaptive capacity of captured fish due to climate change

6. Vulnerability of captured fisheries

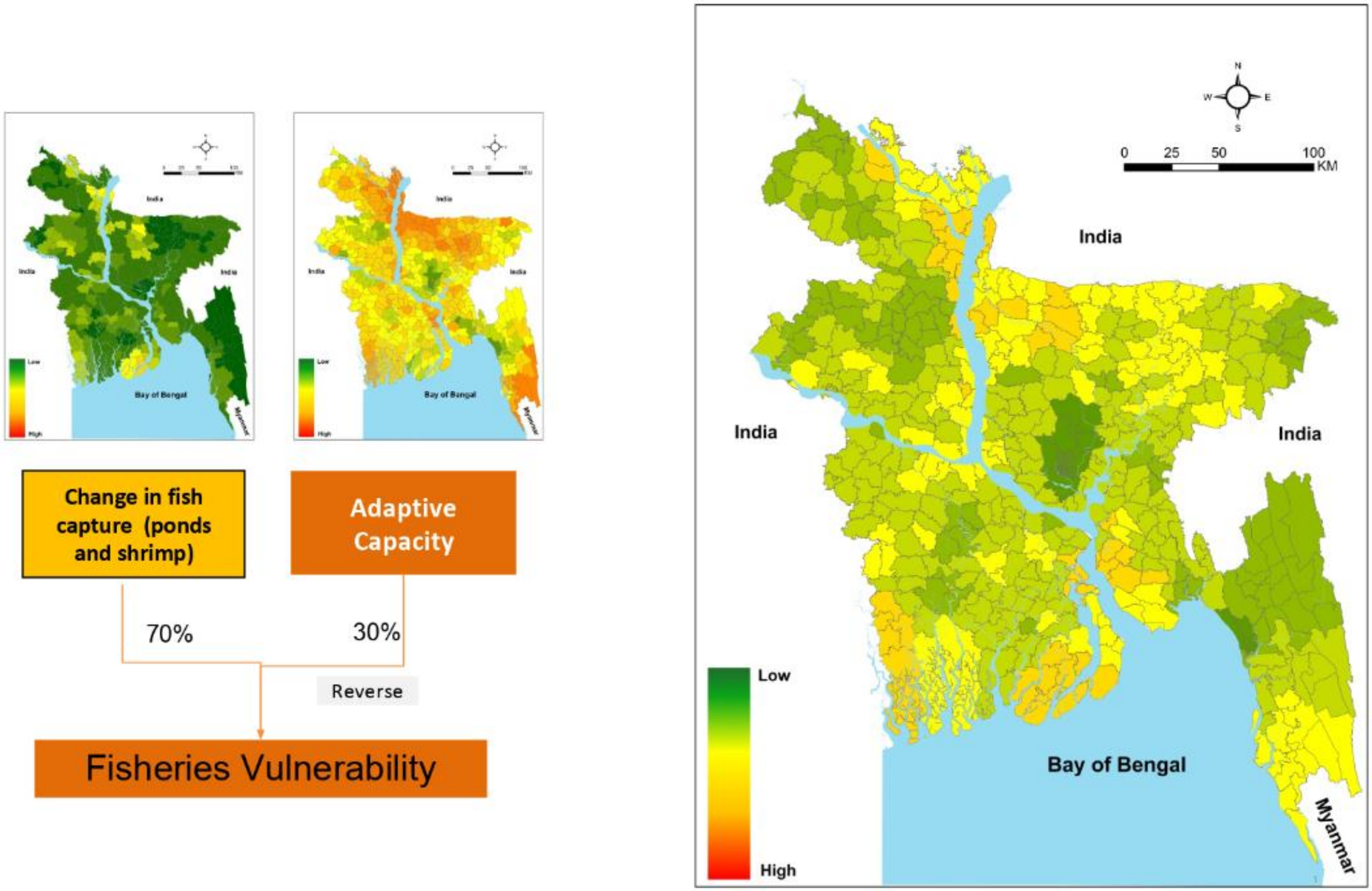


Figure G.2.6: Current vulnerability of captured fish due to climate change

H. Vulnerability of infrastructure due to climate change

H.1 Vulnerability of road infrastructure

1. Impact chain

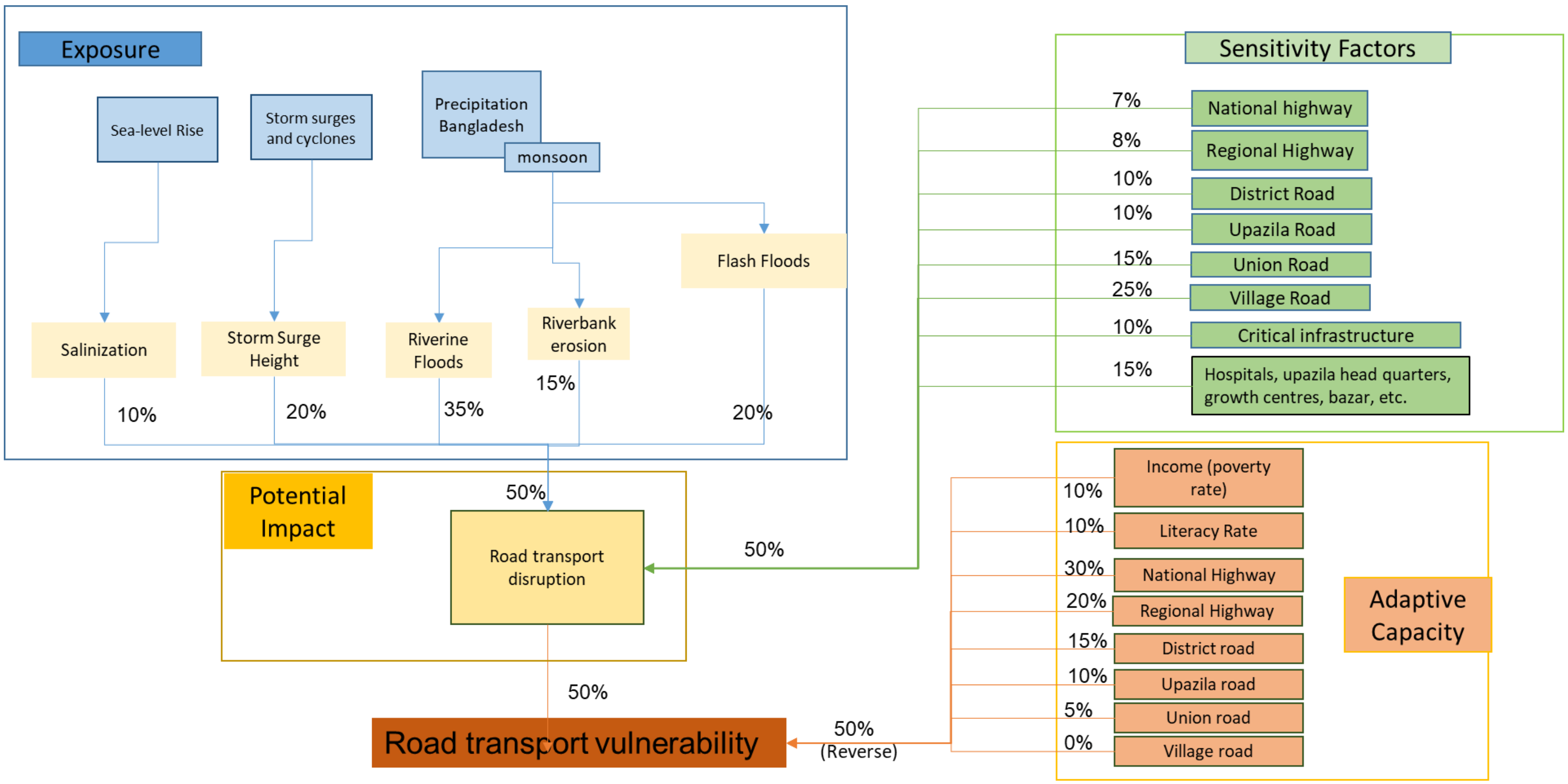


Figure H.1.1: Impact chain of vulnerability of road infrastructure

2. Exposure

[salinization] [storm surge height] [riverine floods] [flash floods] [river bank erosion]

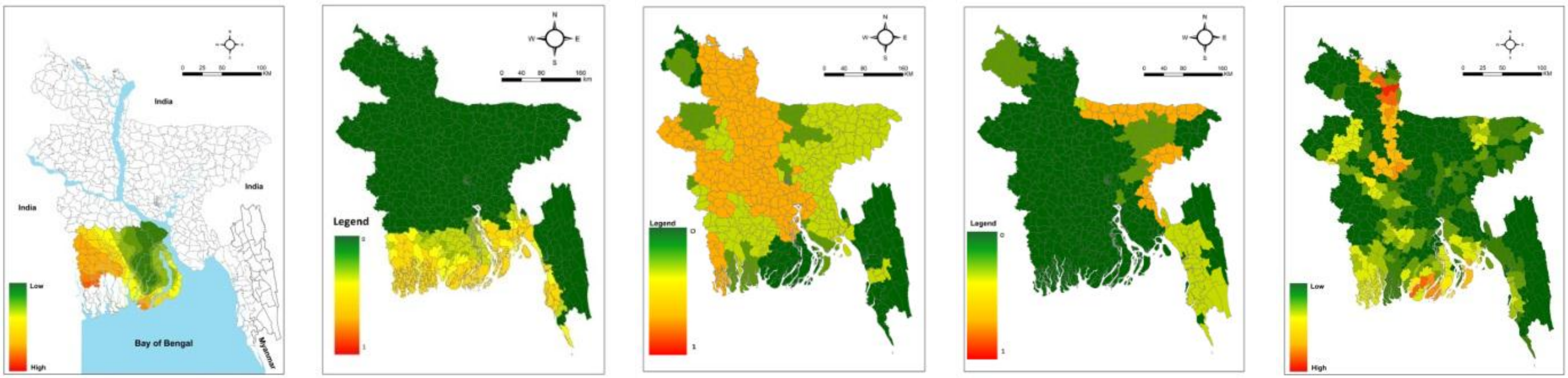
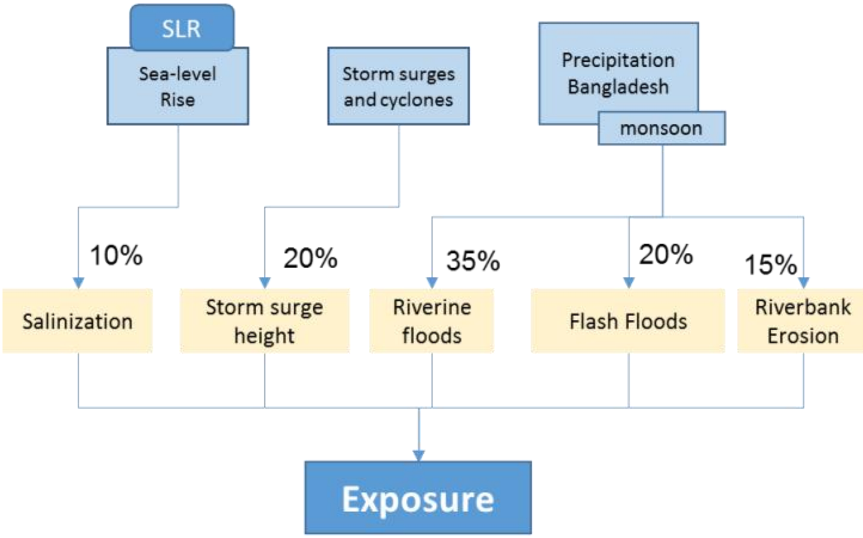


Figure H.1.2: Exposure of road infrastructure



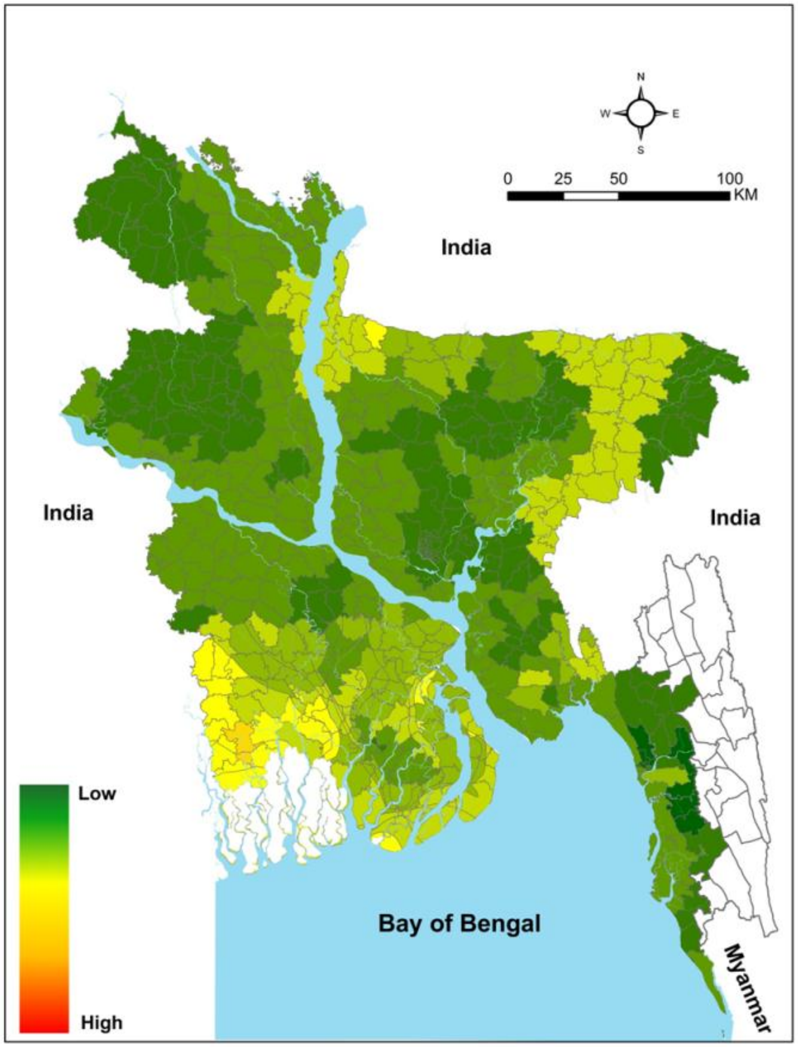
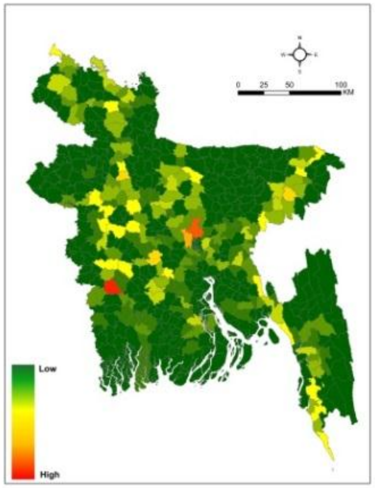


Figure H.1.3: Exposure of road infrastructure

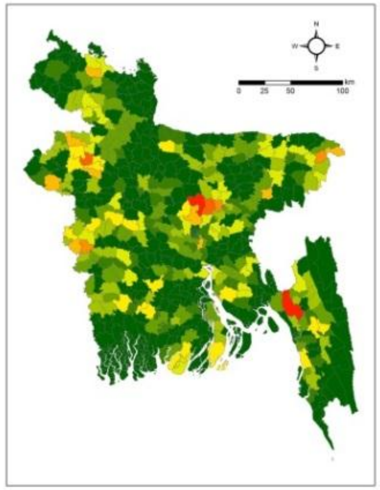
3. Sensitivity

[National highway]

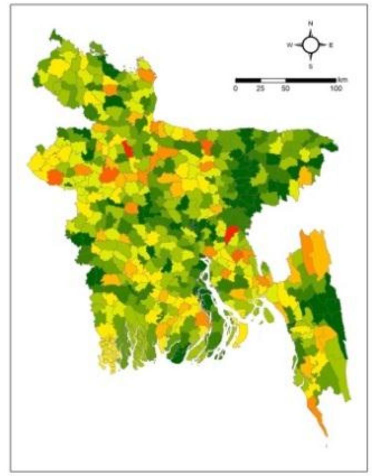


2

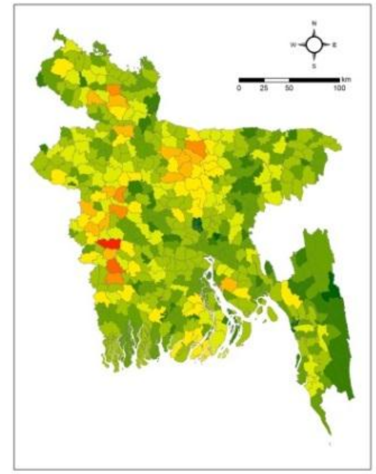
[Regional highway]



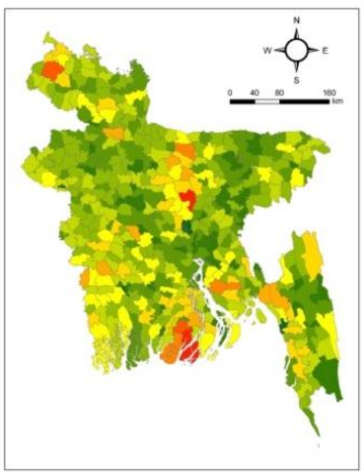
[District road]



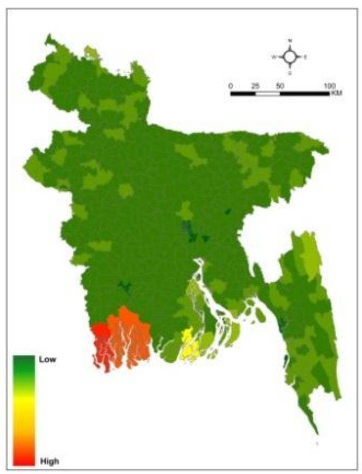
[Upazila road]



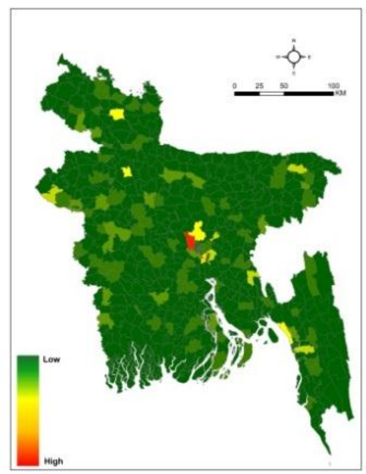
[Union road]



[Village road]



[critical infrastructure]



[]Hospitals, Upazila head quarters, growth centres, markets etc.]

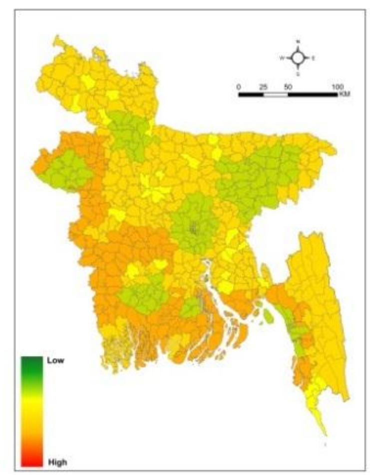


Figure H.1.4: Sensitivity of road infrastructure

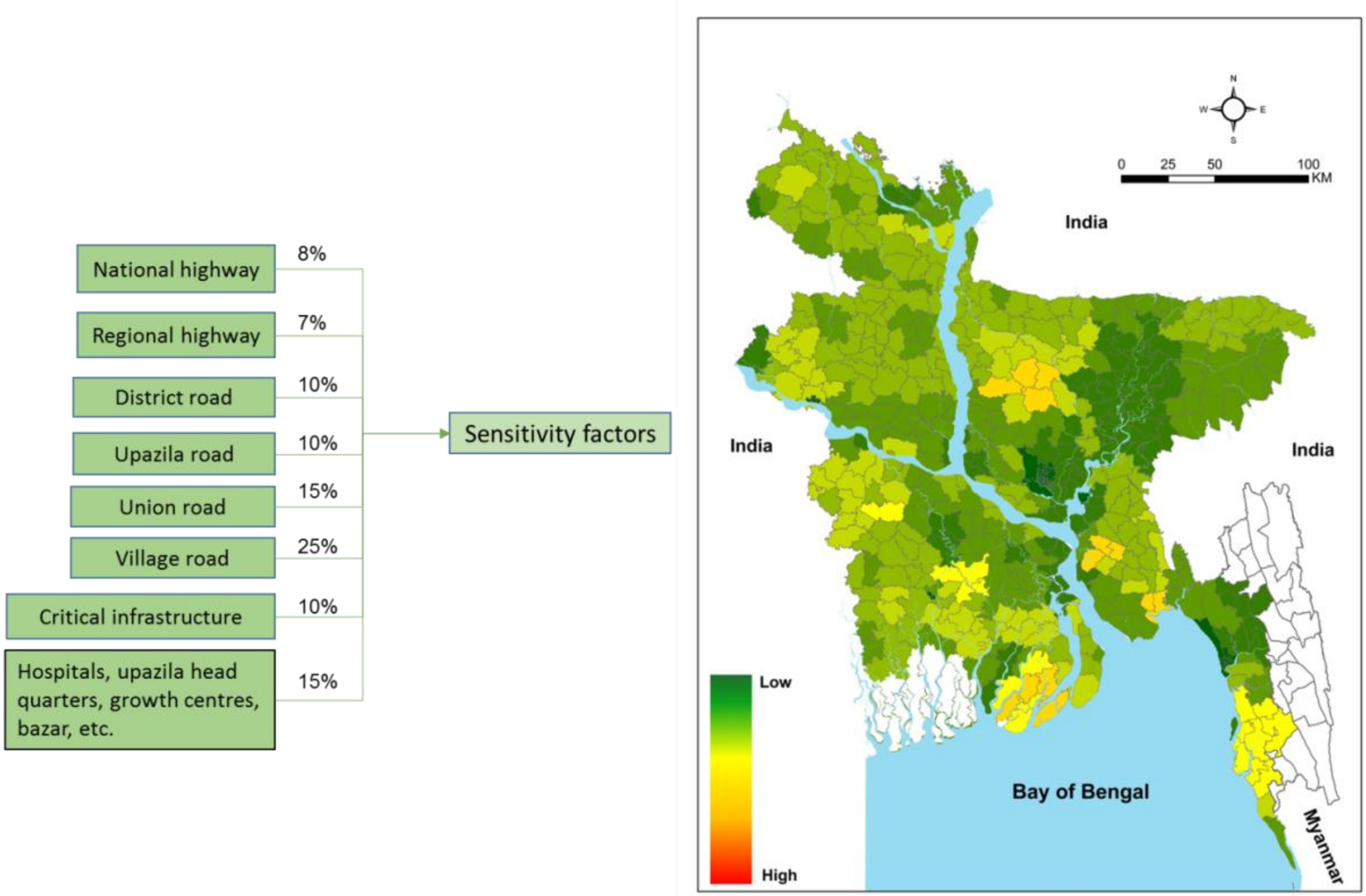
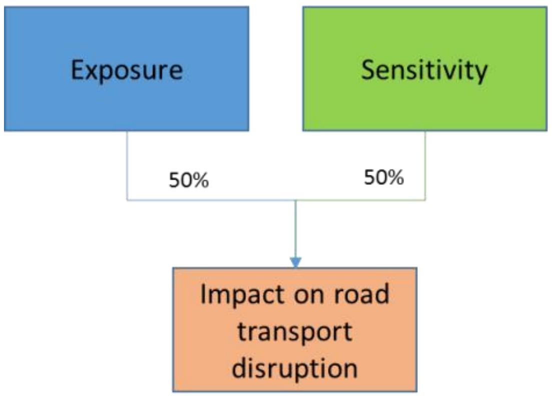


Figure H.1.5: Sensitivity of road infrastructure

4. Potential impact



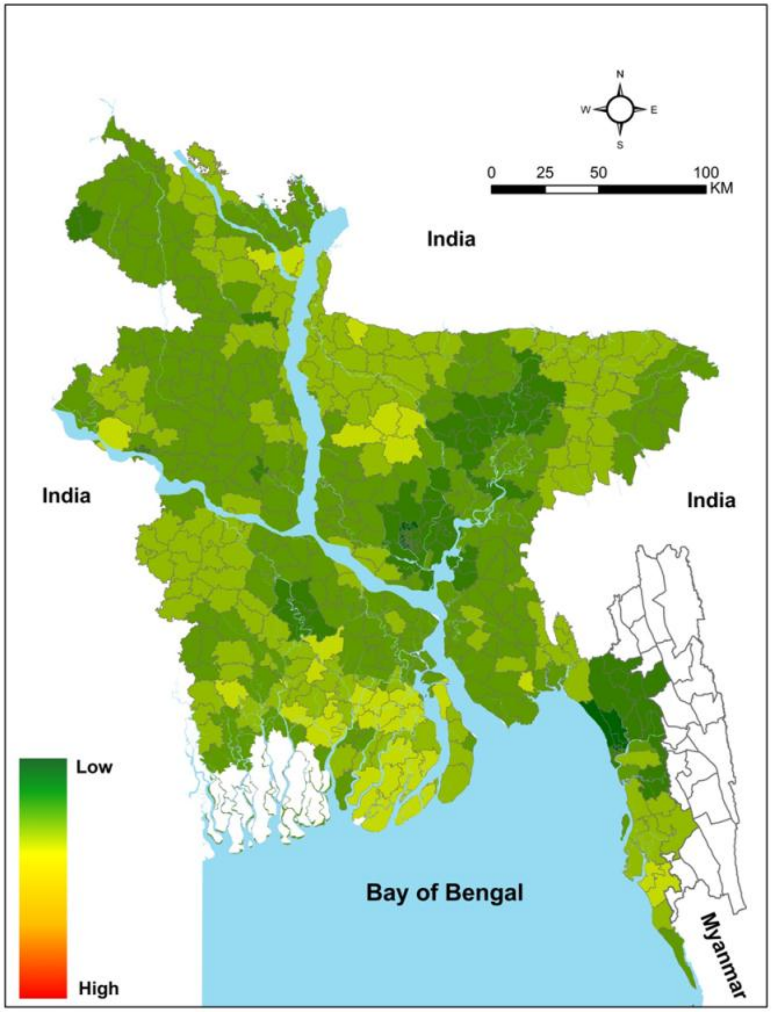


Figure H.1.6: Potential impact of road infrastructure

5. Adaptive capacity

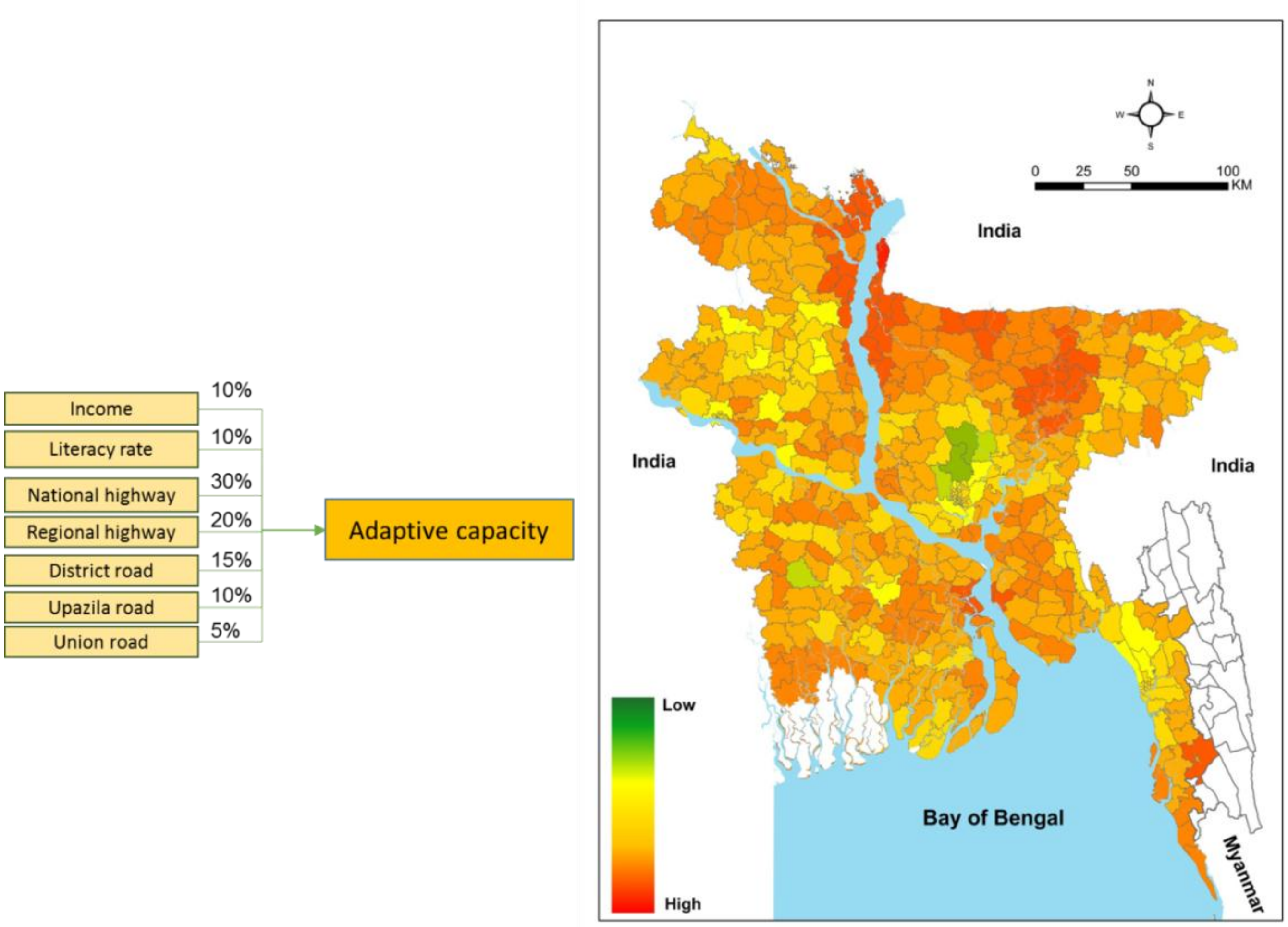
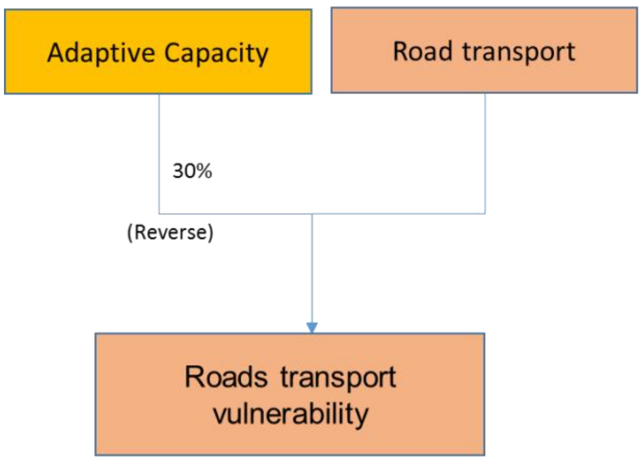


Figure H.1.7: Adaptive capacity to road transport vulnerability due to climate change

6. Current vulnerability of road infrastructure



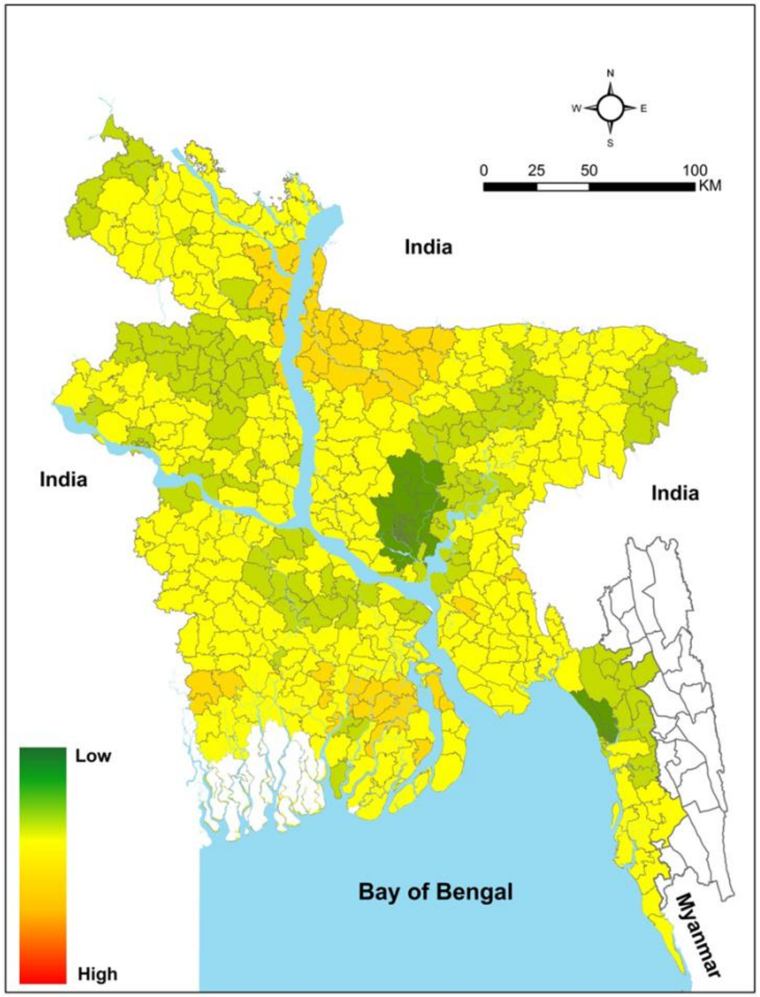


Figure H.1.8: Current road infrastructure vulnerability due to climate change

H.2 Vulnerability of rail infrastructure

1. Impact chain

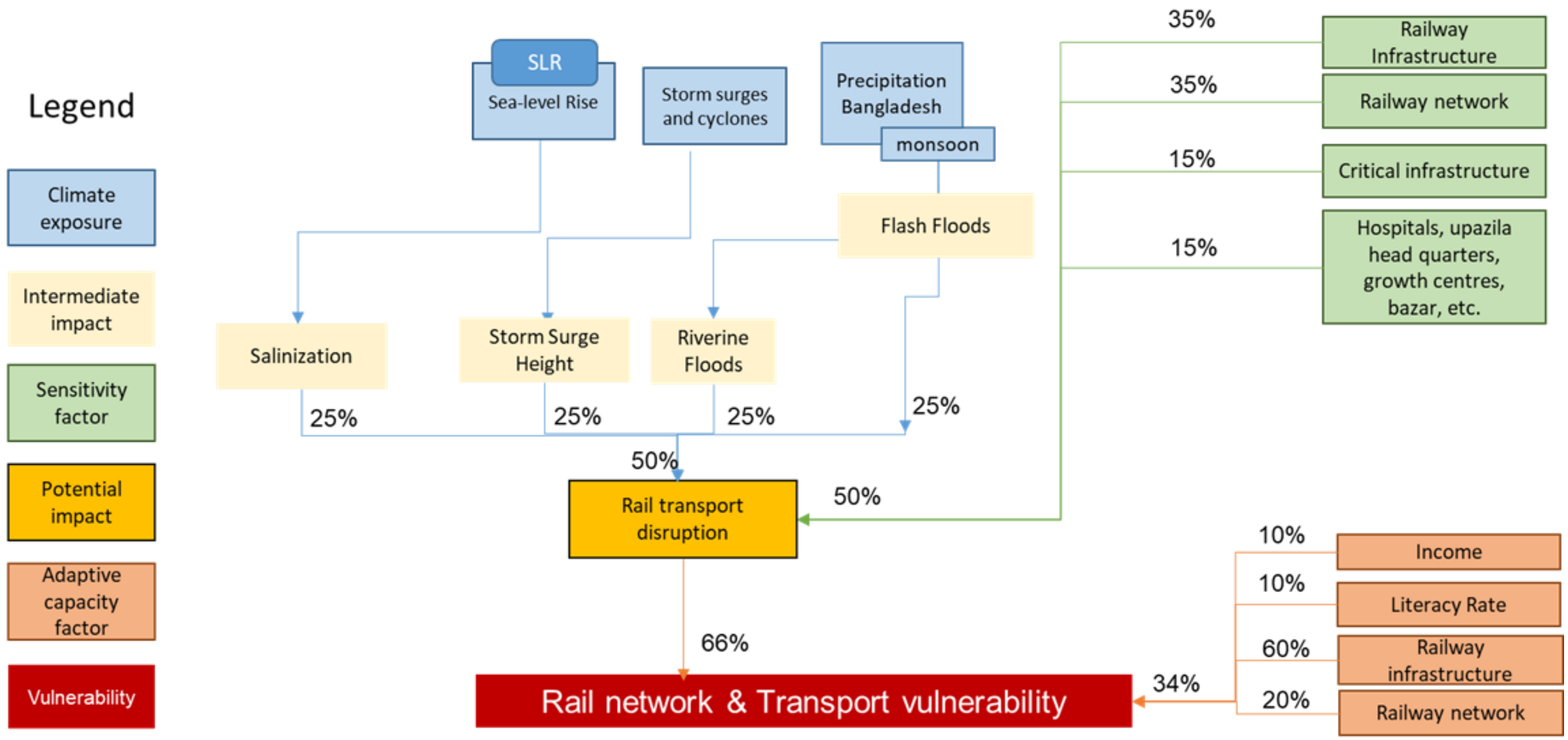


Figure H.2.1: Impact chain of vulnerability of rail infrastructure

2. Exposure

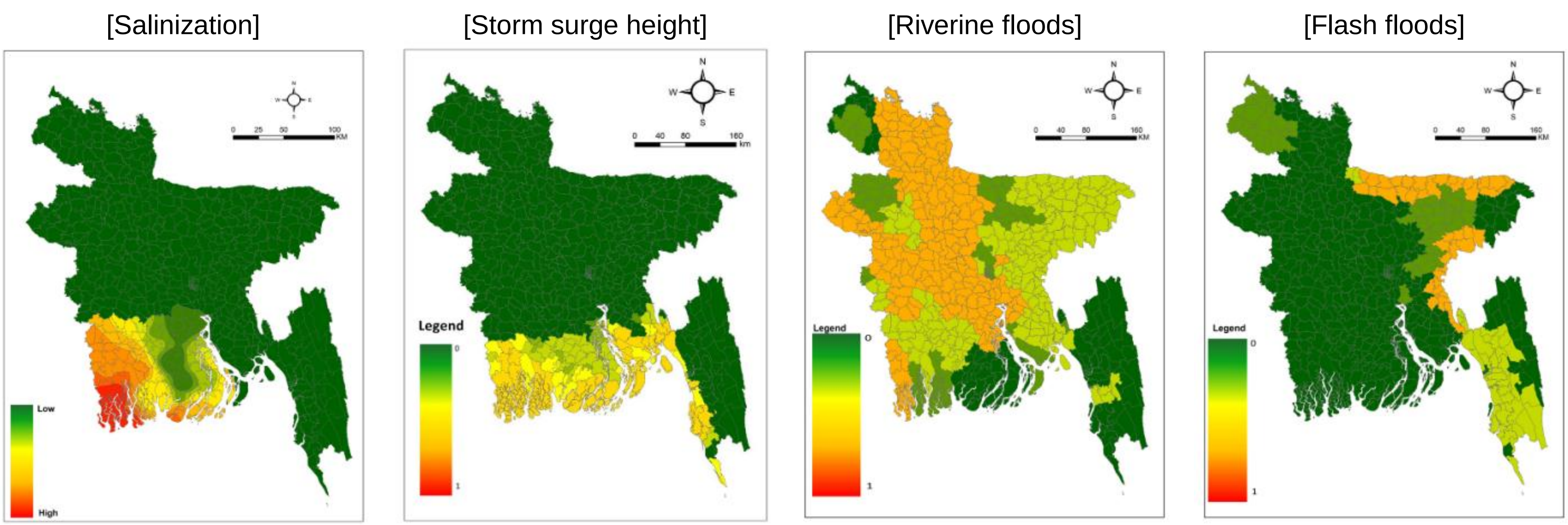


Figure H.2.2: Exposure of rail infrastructure

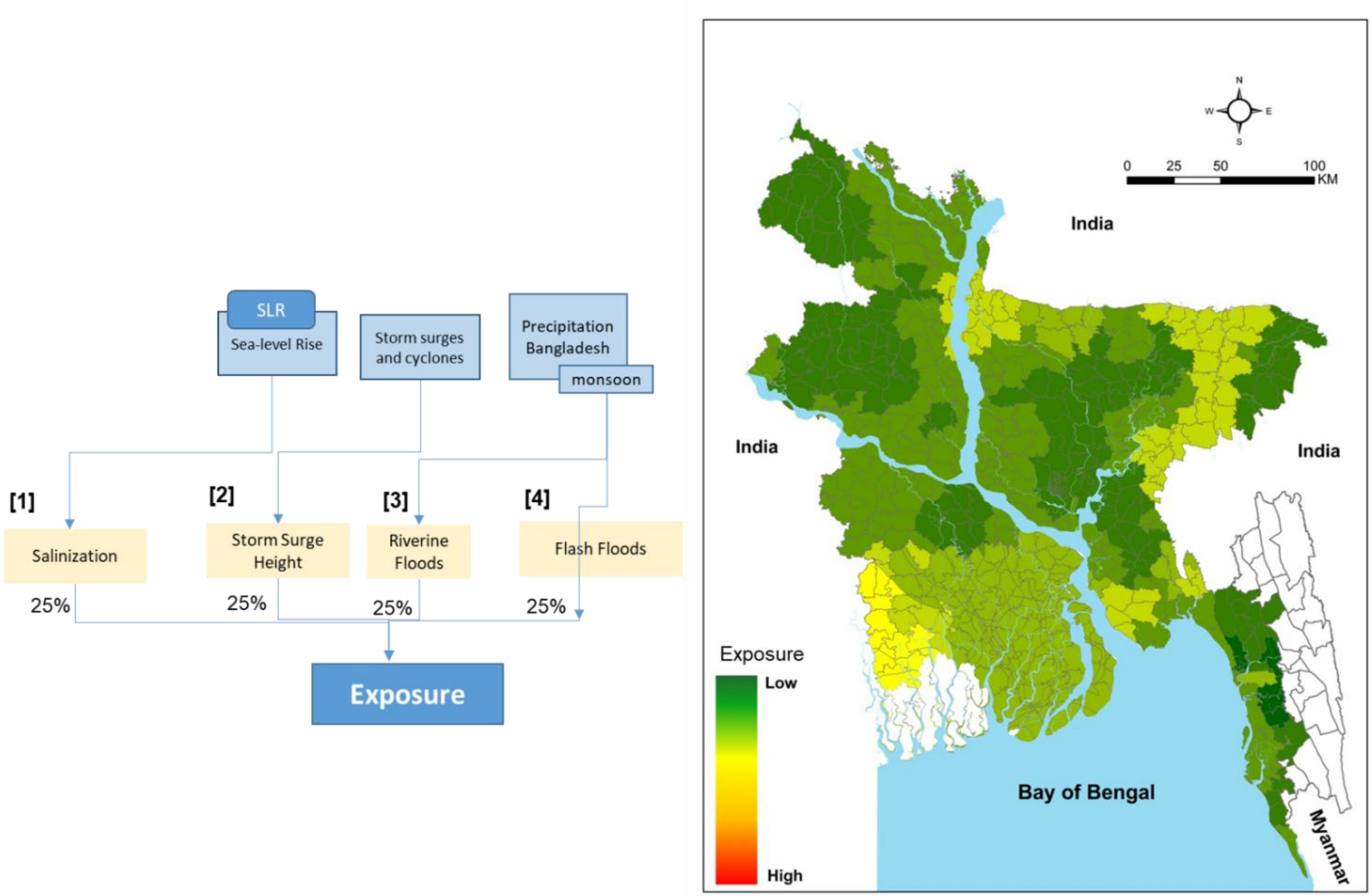


Figure H.2.3: Exposure of rail infrastructure

3. Sensitivity

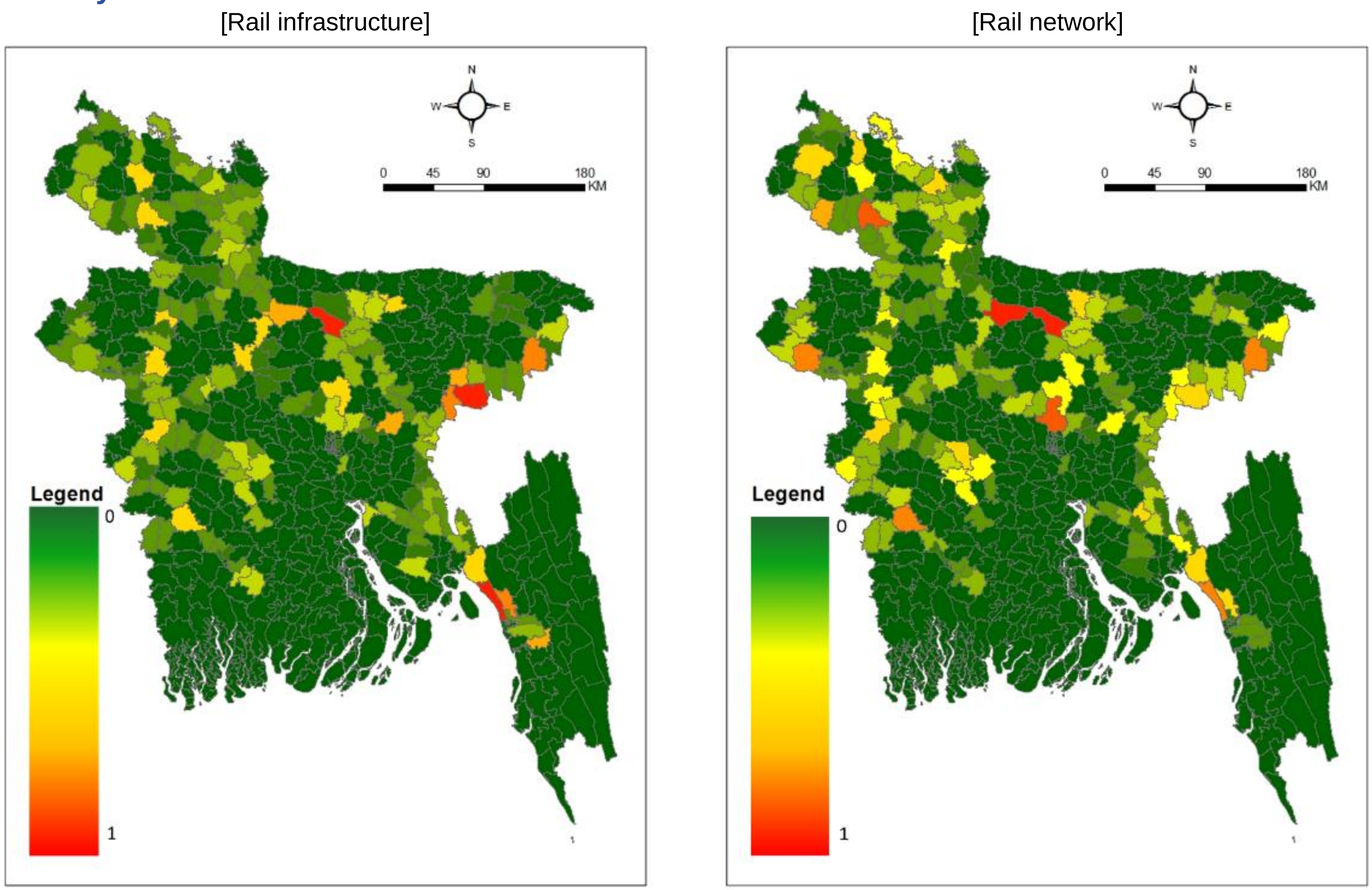


Figure H.2.4: Sensitivity of rail infrastructure

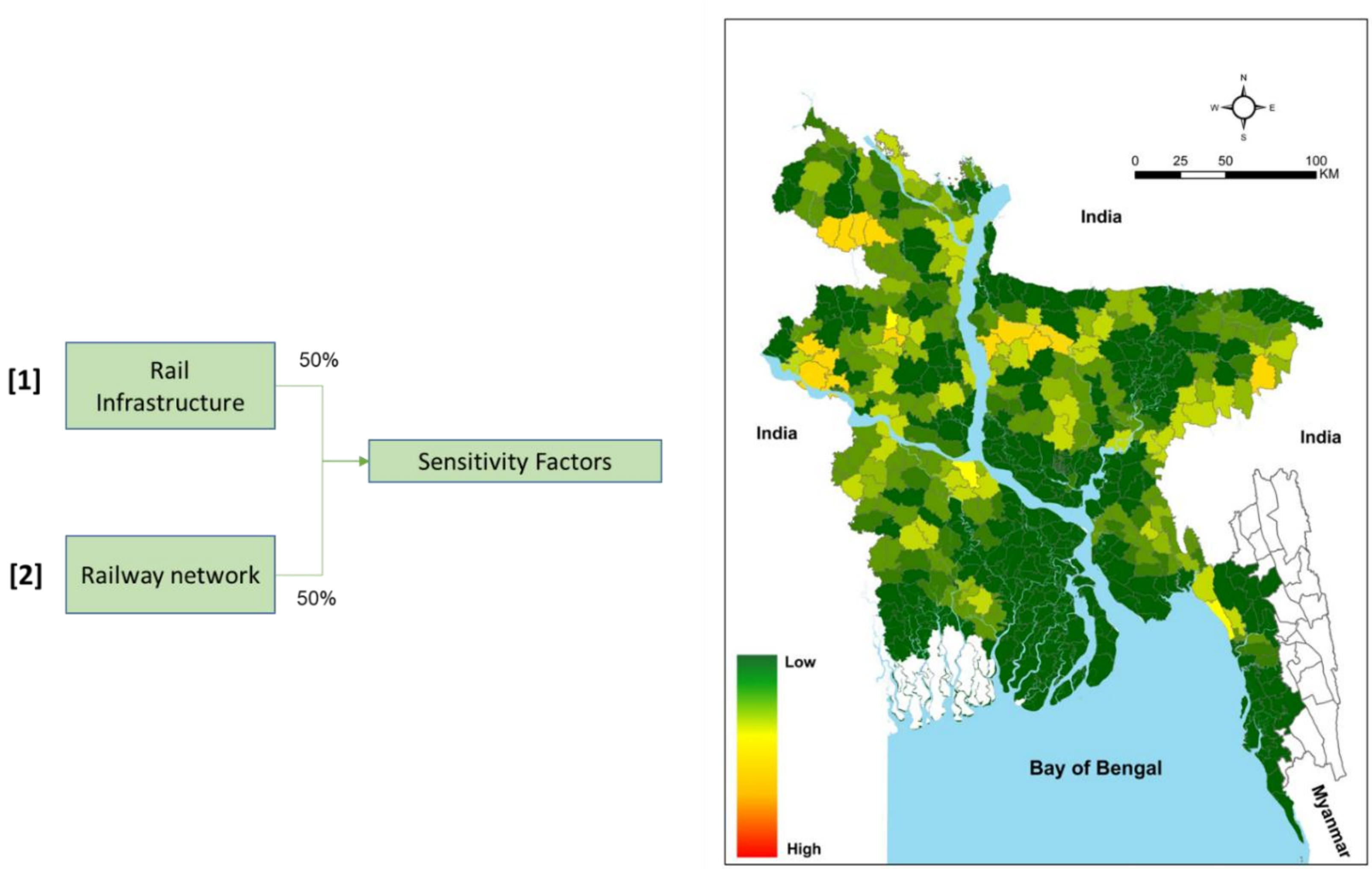
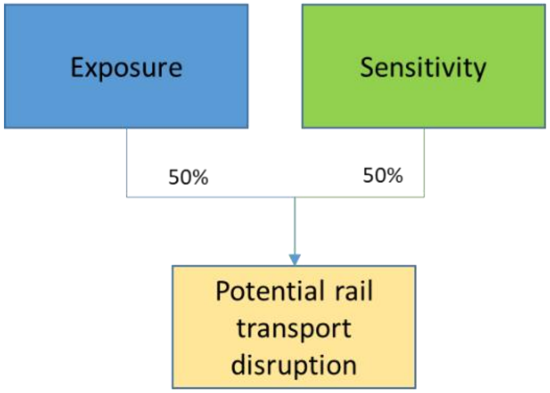


Figure H.2.5: Sensitivity of rail infrastructure

4. Potential impact



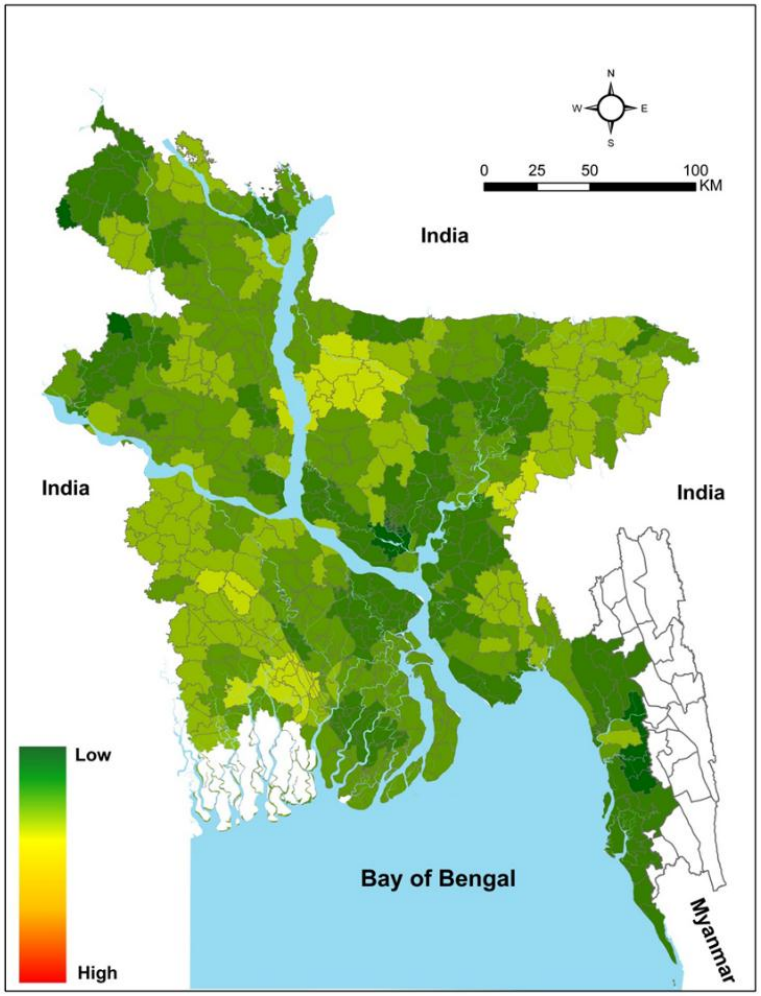
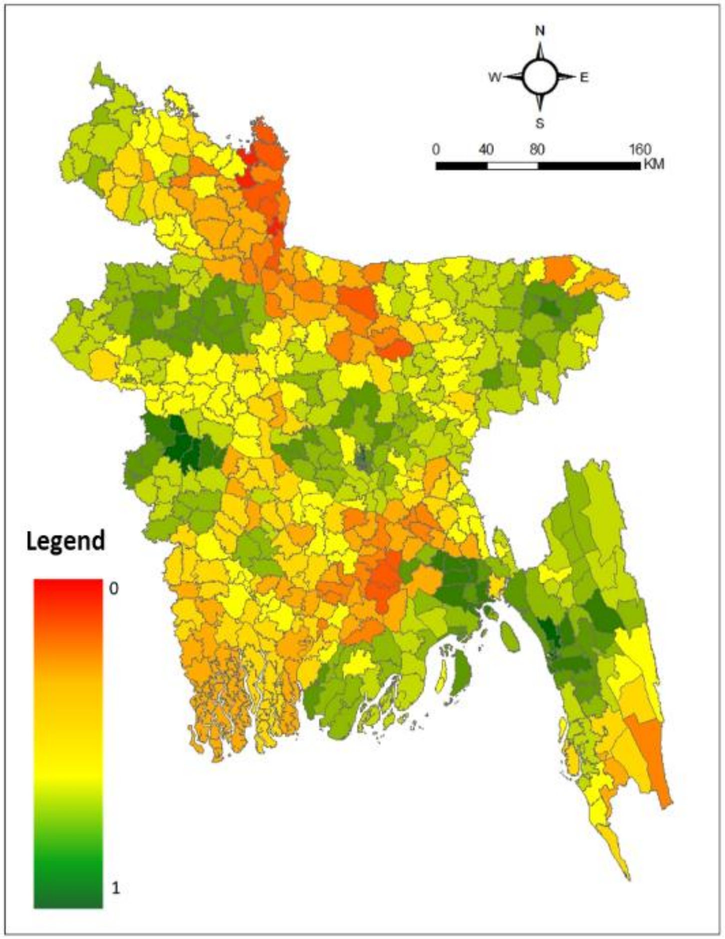


Figure H.2.6: Potential impact of rail infrastructure

5. Adaptive capacity

[Poverty]



[Literacy rate]

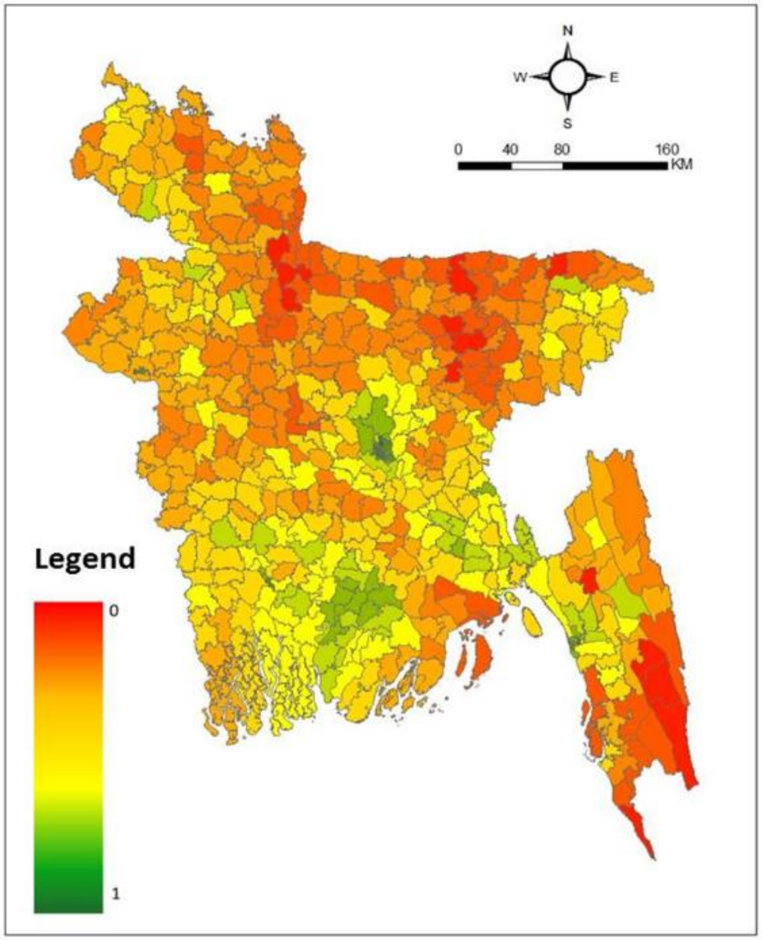
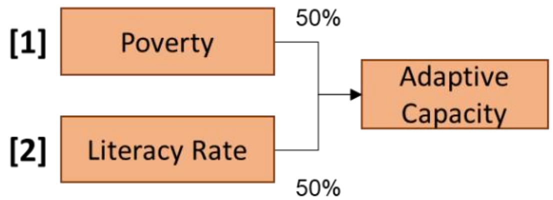


Figure H.2.7: Adaptive capacity of rail infrastructure



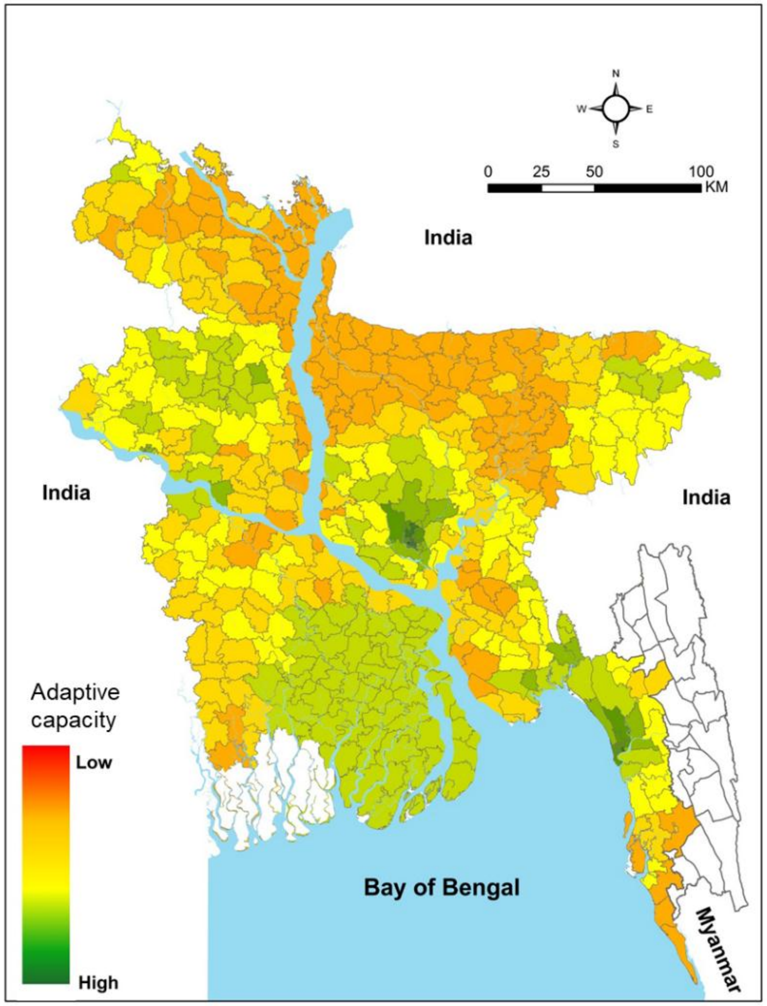
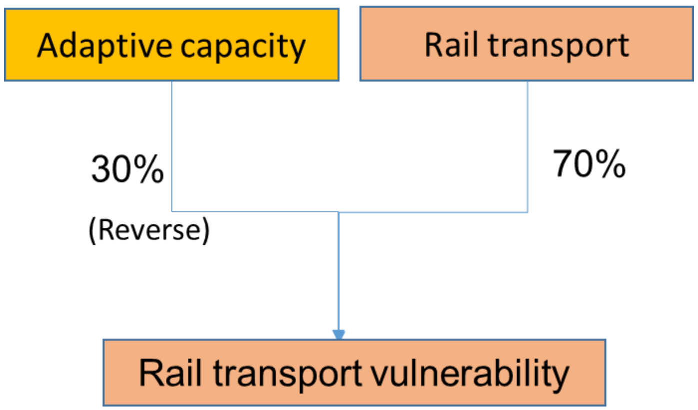


Figure H.2.8: Adaptive capacity of rail infrastructure

6. Current vulnerability of road infrastructure



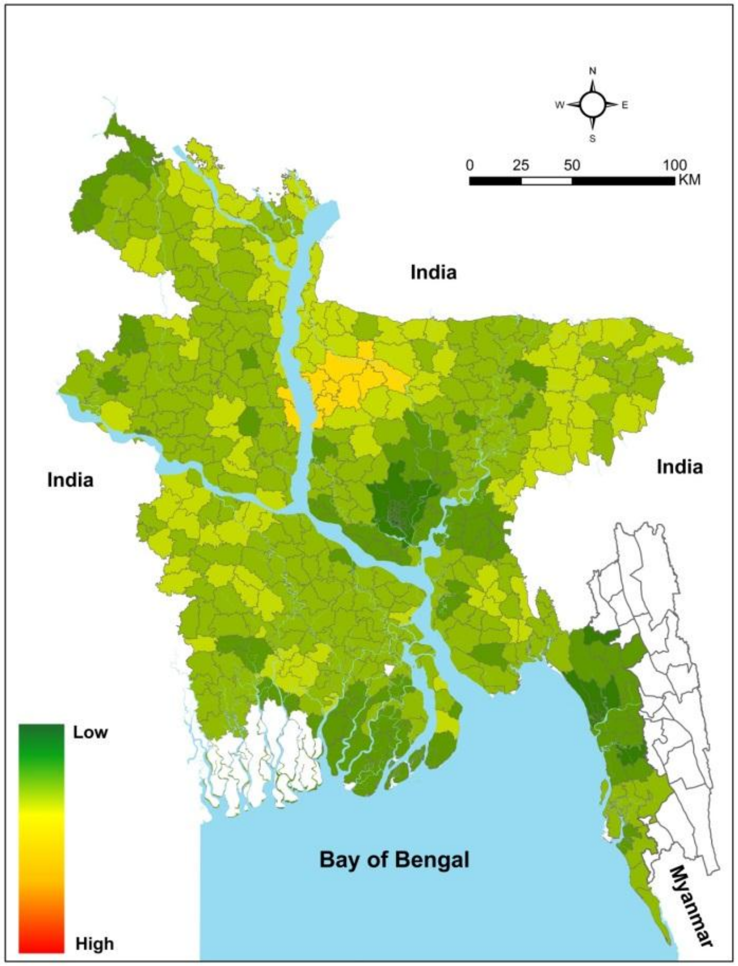


Figure H.2.8: Current vulnerability of rail infrastructure

I. Vulnerability of Mangrove forest

1. Impact chain

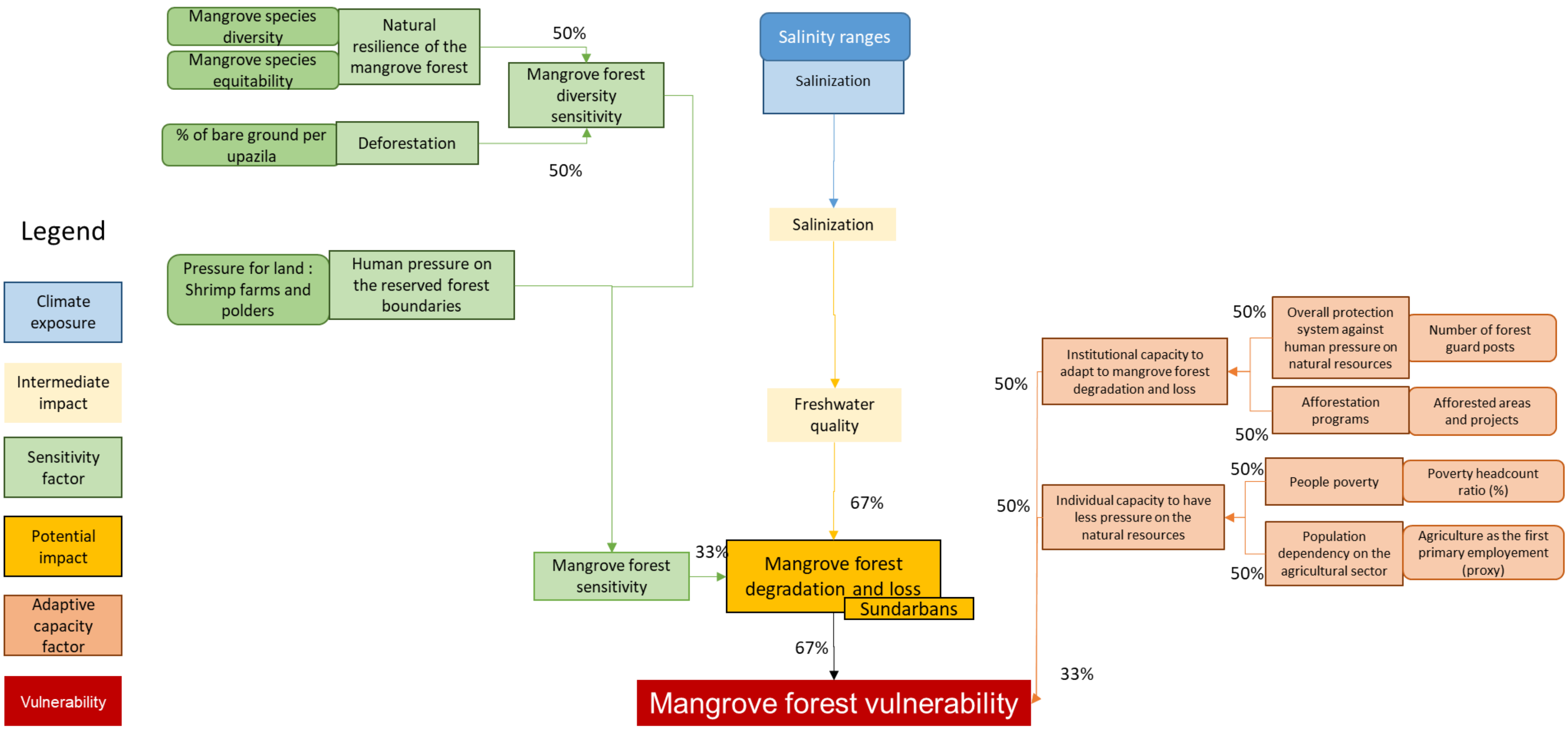


Figure I.1: Imapct chain of vulnerability of Mangrove forest

2. Exposure

[Salinity intrusion]

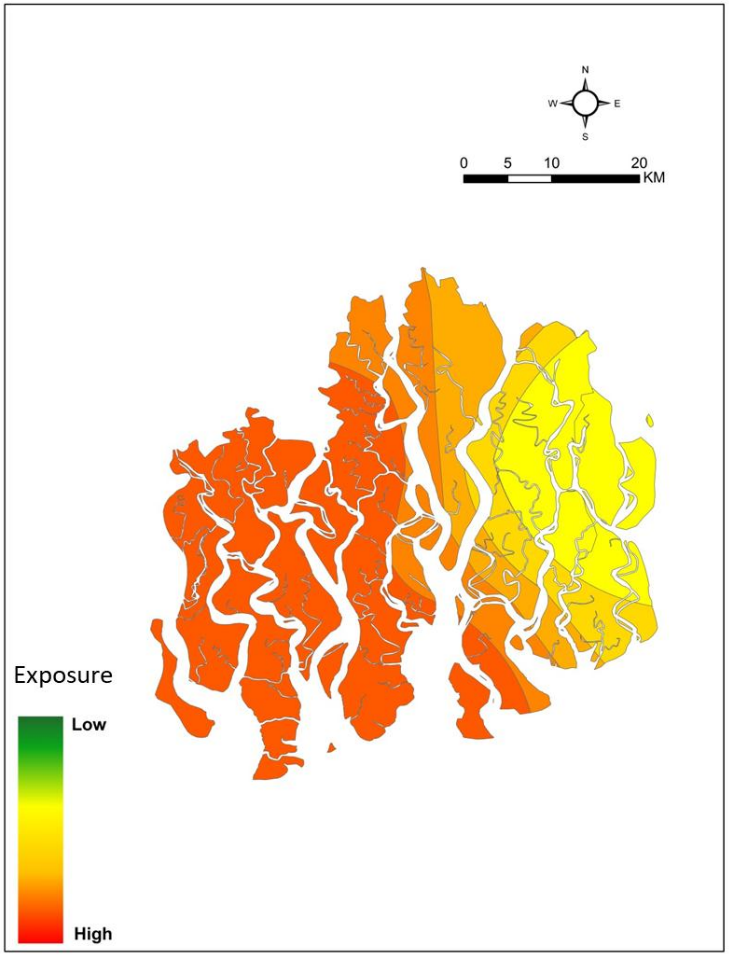
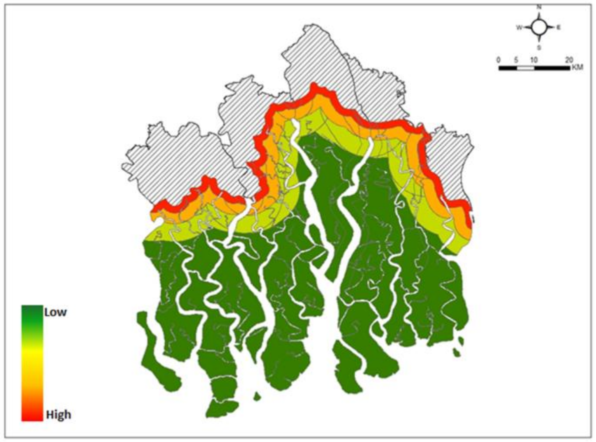


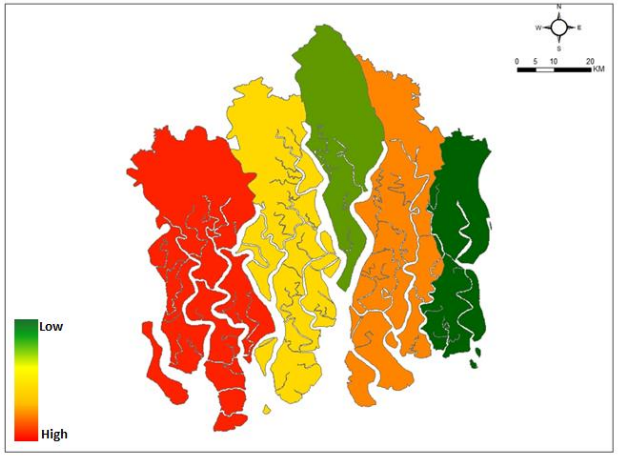
Figure I.2: Exposure of Mangrove forest

3. Sensitivity

[Human pressure]



[Deforestation]



[Species diversity]

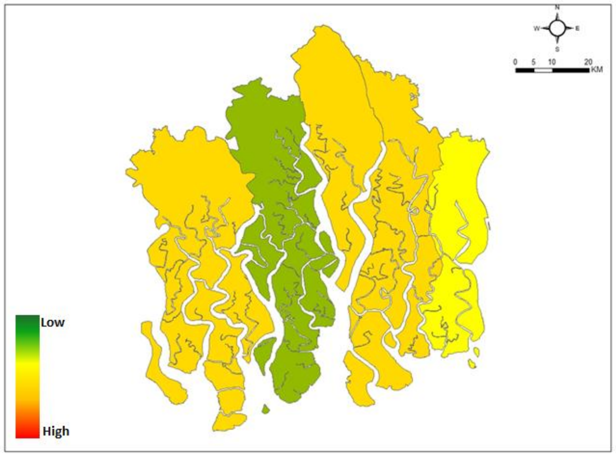


Figure I.3: Sensitivity of Mangrove forest

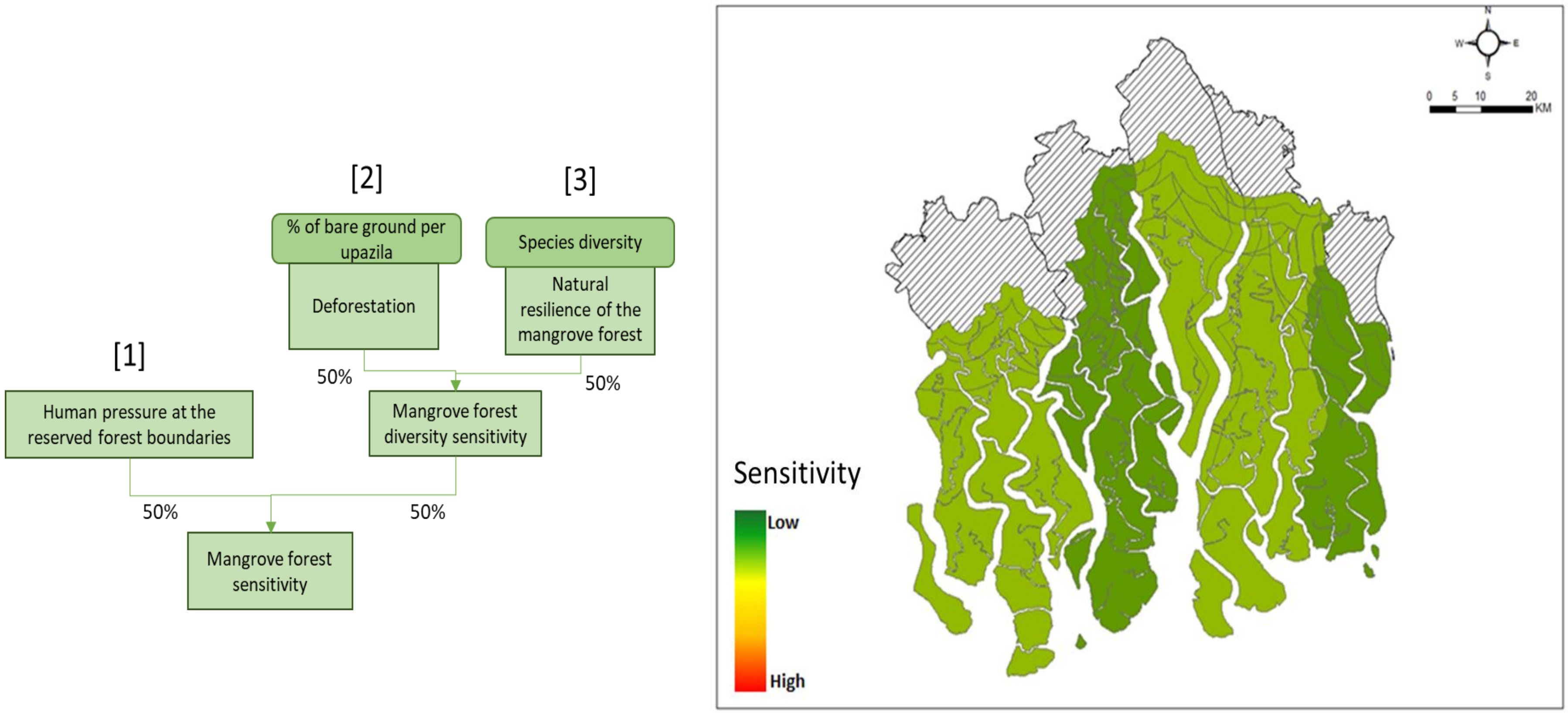


Figure I.4: Sensitivity of Mangrove forest

4. Potential impact

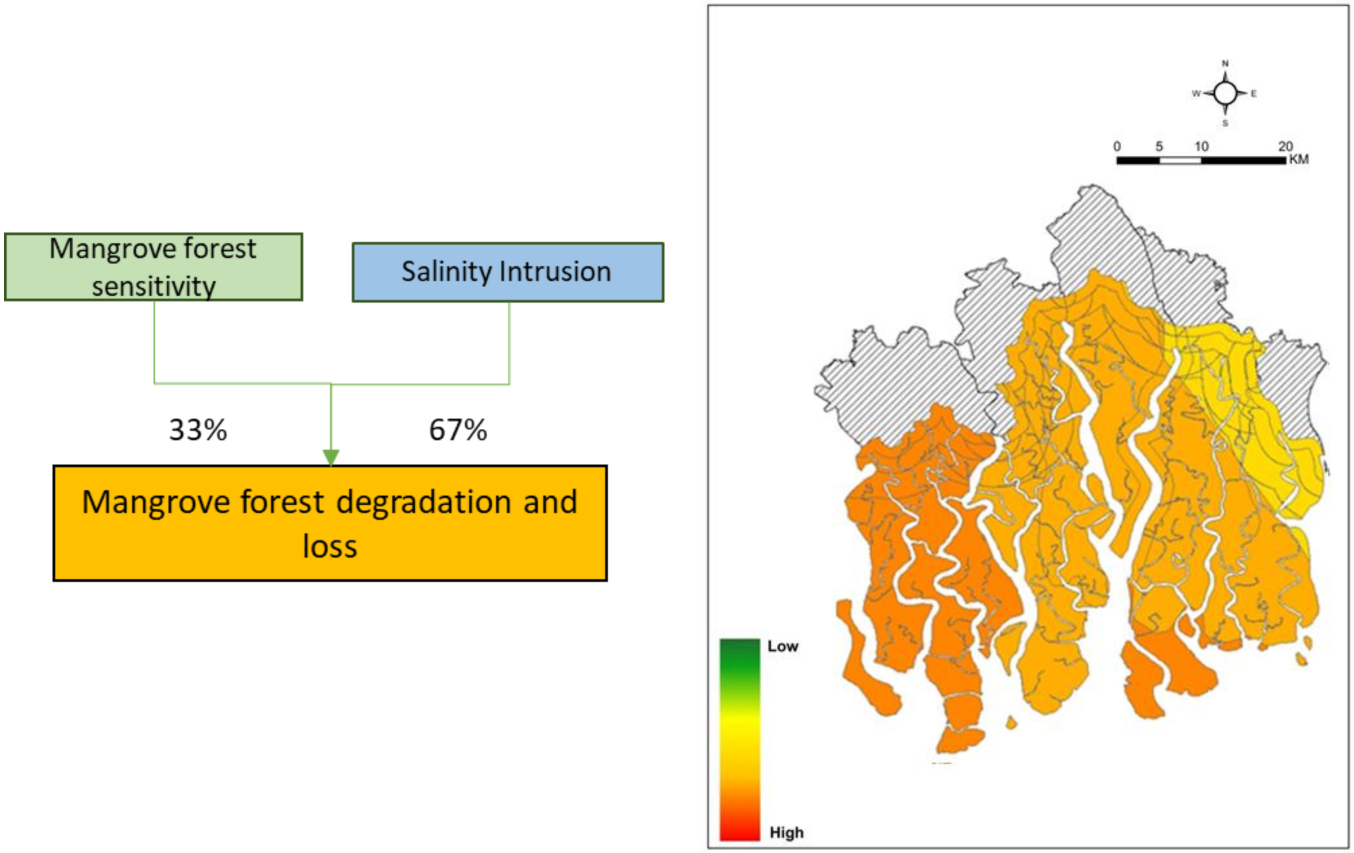


Figure I.5: Potential impact on Mangrove forest

5. Adaptive capacity

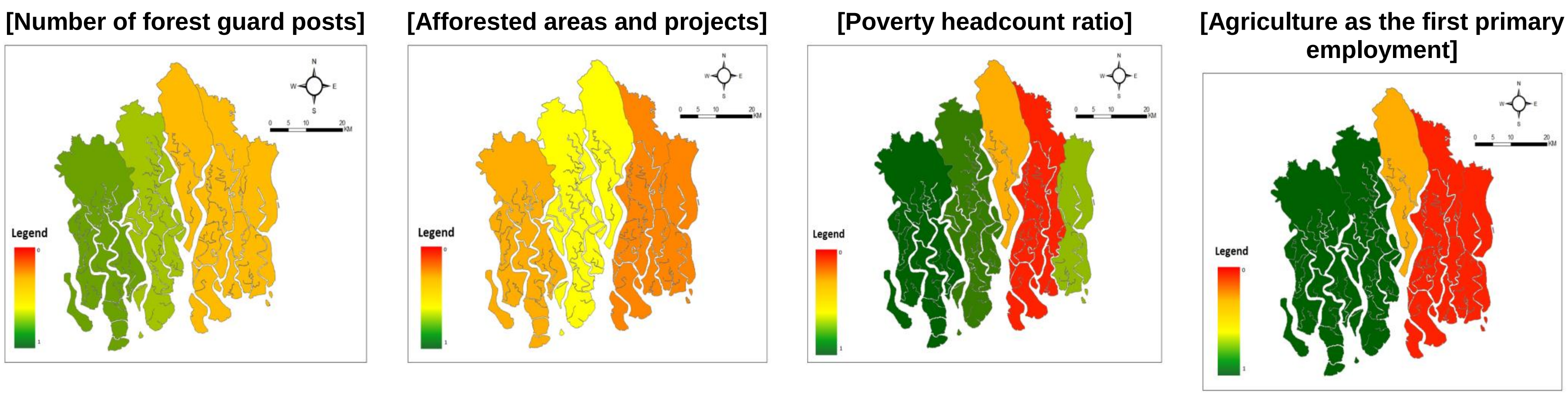
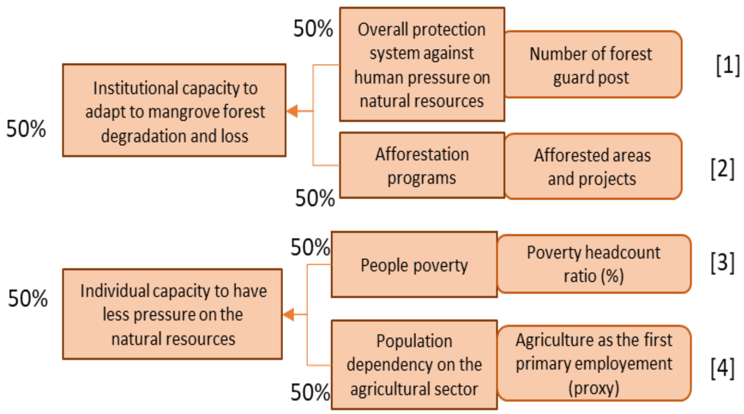


Figure I.6: Adaptive capacity to protect mangrove degradation and loss



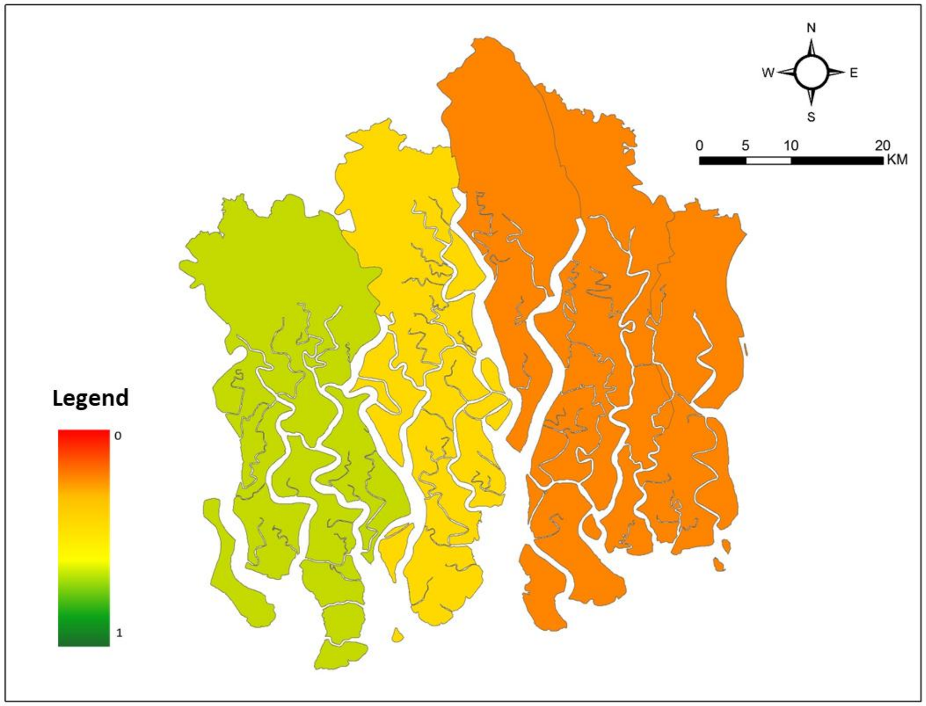


Figure I.7: Adaptive capacity to protect mangrove degradation and loss

6. Current and future vulnerability of mangrove fiorest

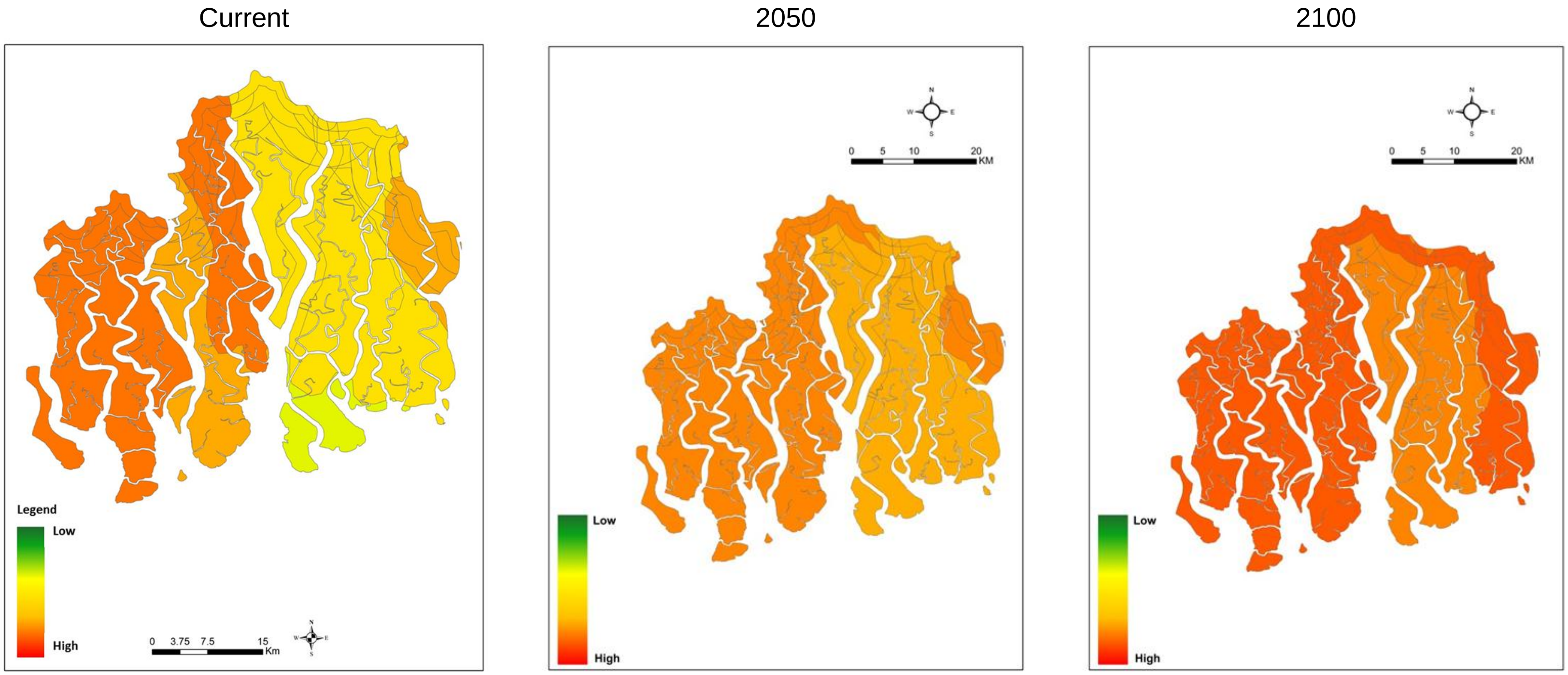


Figure I.8: Current and future vulnerability of Mangrove forest