Bangladesh: Climate-Resilient Infrastructure Assessment

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The following people have contributed to this project and report, by organisation. From Oxford: Alison Peard, Amelie Paszkowski, Daniel Adshead, Jim Hall, Raghav Pant, Sarah Gall, Mohammed Sarfaraz Gani Adnan, Tim Fowler and Tom Russell; from UNOPS: Ian Rector, Sandra Díaz, Syeedul Haque and Stefan Kohler; from CEGIS: A.M. M. Mostafa Ali, Champa Rani Saha, Md. Mostafizur Rahman, Md. Yachin Islam, Moshiur Rahman Rimu, Syed Arman Akib Rahman; from GCA: Danilo Cançado.

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EXECUTIVE SUMMARY

Bangladesh is widely acknowledged as being one of the world's most vulnerable countries to climate hazards. Its tropical location in the centre of the Bay of Bengal means that both acute climate hazards, such as widespread monsoonal fluvial flooding, strong cyclonic winds, and high storm surges, as well as chronic hazards such as sea-level rise and saline intrusion, continuously impact the access of services to local populations and their sustainable socio-economic development. Infrastructure systems underpin society; they comprise of interconnected networks of assets that provide basic services to society, enhancing socio-economic growth through transport connectivity, access to health and education, supply of water, and safety, and many other factors. Therefore, acute climate hazards can cause direct physical damage to infrastructure assets and directly or indirectly disrupt the provision of services. The repeated damages caused by climate hazards in Bangladesh limit the country's progress towards achieving the Sustainable Development Goals (SDGs), long-term climate resilience, and overall socio-economic growth.

Led by Bangladesh's Ministry of Environment, Forest and Climate Change (MOEFCC), this assessment brings together expertise via the Global Center on Adaptation (GCA) and the United Nations Office for Project Services (UNOPS), with technical analyses undertaken by the University of Oxford and the Center for Environmental and Geographic Information Services (CEGIS), and support from the Ministry of Infrastructure and Water Management of the Netherlands. The aim of this assessment is to quantify the impact of climate hazards on the provision of infrastructure services and the achievement of the country's development objectives under current and projected climate scenarios. This includes four key objectives:

1. Spatially assess the exposure of infrastructure assets and networks to different climate hazards and pinpoint hotspots of risk across Bangladesh.
2. Quantify the economic damages of different climate hazards on the transport, energy, water, and critical social infrastructure sectors in Bangladesh, understanding how these damages affect populations differently.
3. Identify how infrastructure service disruptions affect welfare at the household-level in the coastal area of Bangladesh.
4. Strategically assess how service disruptions on household welfare can impact on the country's progress towards the achievement of SDG targets.

The first part of this assessment analyses climate threats to Bangladesh's infrastructure and human welfare at the **asset level**, identifying hotspots of infrastructure asset exposure through the intersection of climate hazard data with geospatial mapping of assets and networks. Subsequently, global depth-damage curves are used to estimate direct tangible damage to different infrastructure assets.

The **transport sector** is highly exposed to climate hazards, with 95% of the road network (170,782 km), 93% of the railway network and 94% of railway stations (488 of the 519 stations), 100% of ports (32 ports), and 100% of airports (13 airports) exposed. Coastal flooding is the most impactful hazard on the transport sector. In 2050, considering a 50-year return period coastal flood event under RCP4.5, the total damage to the road network is estimated at €7.4 billion for that single year, which is 17.6% higher than the baseline year (estimated at €6.3 billion). This accounts for up to 1.8% of the national GDP in 2021 and affects 20.5% of the national population (~33 million people).

In the **energy sector**, 67% of power plants, 65% of electricity substations, 90% of electricity grid lines (24,152km), 13 gas fields (52%), and 4,462km of gas lines, are currently exposed to climatic hazards. A total direct economic damage of approximately €45 million is anticipated for the baseline scenario. Cyclonic winds have the greatest impact on the energy sector, and the electricity grid has the most population impacted by disruptions in the service it provides. Overall, the economic damage of cyclones to the electricity grid affects 145 million people in Bangladesh, making up 88% of the national population.

This study assessed three water treatment plants (WTPs) for the **water sector**, none of which are exposed to flooding during a 50-year event. One of the WTPs - Saidabad WTP (in Dhaka) - may, however, be exposed in the case of extreme flooding, under which economic damages caused by river flooding could reach approximately €2,000 in 2030 (RCP 4.5), and up to €10,000 (or a 400% increase) by 2080 (RCP 8.5).

The analysis also considers **critical social infrastructure** in Bangladesh, which is highly exposed to climatic hazards. Overall, 95% of healthcare facilities, 70% of cyclone shelters, 93% of market centres, and 95% of education facilities are exposed to climate hazards for the baseline year. The most impactful hazard is high cyclonic wind gusts; around 86% of Bangladesh's market centres, education facilities and healthcare facilities are within areas of potentially damaging wind gusts (>30m/s). Coastal flooding, including cyclonic storm surges, can generate direct economic damages of approximately €20 million for the baseline year, which increases by 24% (to €25.72 million) for the year 2050.

The second part of this assessment uses household-level data to provide a deeper understanding of the link between exposed assets, users, and development outcomes. Climate threats to Bangladesh's infrastructure, human welfare and development objectives are assessed through the lens of infrastructure services provided to **households.** Overall, 100% of the almost 9 million households in the coastal region of Bangladesh are impacted by some level of service disruption caused by climate hazards. Those caused by cyclones affect the greatest number of households, with over 77 million instances of households being affected by infrastructure disruption across all baseline (present day) 1-in-50-year probability hazards. For the energy, transport, and social infrastructure sectors, an average of 71%, 75%, and 72% of households are disrupted by cyclonic winds, respectively. For coastal flooding, which is closely related to cyclones, there are almost 40 million instances of households being affected by infrastructure disruption for the future 2050 (RCP4.5) 50-year coastal flood event, with 80% of these corresponding to rural household impacts. Under the baseline scenario, coastal flooding, river flooding, cyclones, and erosion disrupt on average 42%, 24%, 94%, and 47% of the coastal population, respectively, across all assets.

Finally, the assessment links asset exposure and socio-economic indicators from the household data to determine where SDG progress across selected indicators in SDGs 3, 4, 7, 8, 9, and 13 might be at risk. The greatest multi-hazard threat to SDG progress is seen in the Satkhira and Khulna districts.

Overall, the findings from this assessment can help target and prioritise adaptation investment options to enhance the resilience of infrastructure and livelihoods of vulnerable populations. In addition to the technical advances provided in this study through high-resolution, multi-hazard, and societal welfare assessments, analyses of the enabling environment, through continuous consultations with local stakeholders, have ensured that the technical work is relevant for the current policy and planning landscape in Bangladesh. In order for the process-based infrastructure modelling approach to be successful, it will have to be deemed as being 'useful' for the Government (relevant ministries or agencies), and it will have to be 'owned' by the Government and fully integrated into their existing systems and processes (with any necessary modifications if required). The enabling environment assessment was aimed at determining the level of impact in relation to these two questions.

Over the next two decades, Bangladesh is expected to experience an accelerated pace of change that will be rapid and transformational. It will have to cope with rapid transformational shifts in agriculture, trade and industry, in education and healthcare, in transportation and communication, and in the way the government conducts its business. Rapid growth will be balanced with an emphasis on equitable distribution of the benefits of growth for all, especially the poor and the vulnerable.

A number of policy drivers have been developed by the Government, including the Vision 2041, which seeks to eliminate extreme poverty and reach Upper Middle-Income Country (UMIC) status by 2031, and High-Income Country (HIC) status by 2041, with poverty approaching extinction. While early warning and preparedness throughout the country are proving successful, the losses to development gains, particularly in relation to infrastructure assets, are increasing and this may significantly undermine the mid to long-term strategy targets of the government.

This assessment is therefore timely. Entry-points within the Government's infrastructure planning processes and also within existing or planned development initiatives have been identified, together with recommendations for integrating this initiative through Government institutions. A number of risk identification and analysis tools and methodologies that complement the study have also been developed and/or identified, including the DRIP and DIA; however, these are individual tools and a more comprehensive policy, institutional and compliance framework, such as that being developed by the National Resilience Programme, is required to enable them to reach their full potential, in contributing more strategically to the achievement of risk-informed development and resilience outcomes.

The enabling environment study concludes that the strengthening of technical competency to use and practice the methodology for assessment and analysis purposes, will require specialised *"tailor-made"* training (CBT- Competency Based Training) programmes, targeting multiple levels. These must be institutionalised so that the capacities, and ongoing capacity development is sustained for the long-term.

1. INTRODUCTION

Bangladesh is situated in a global hotspot of natural hazards. More than 80% of Bangladesh consists of floodplain lands of the Ganges-Brahmaputra-Meghna river system (Brouwer et al., 2007), exposed to frequent and intense fluvial, pluvial and tidal flooding, cyclonic winds and associated storm surges, and widespread erosion (Adnan et al., 2019). Every year, 30-70% of Bangladesh is inundated with flood waters as a result of one, or a combination, of these flood sources (Islam et al., 2010; Rahman et al., 2015). Parts of the country, particularly the north-west, also experience droughts during the dry season (Shahid and Behrawan, 2008), whilst the southern coastal region, especially the south-west of Bangladesh, experiences significant saline intrusion (Payo et al., 2017).

Despite the country's highly exposed geographic location, it is one of the world's most densely populated regions. At present, there are over 165 million people living in Bangladesh, in an area of just under 150,000km^2 (average population density of 1,265 people per km^2). Approximately 20.5% of the current population live below the national poverty line of $1.90 per day, which has been steadily decreasing over recent decades (ADB, 2022). Given the densely populated floodplain and deltaic lands, the frequent and severe inundation, cyclonic wind damages, and flood-induced erosion can have dramatic impacts on the socio-economic growth of affected populations.

Infrastructure systems underpin society and play a critical role in ensuring social and economic prosperity. They consist of interconnected networks of assets, and provide electricity and water to households and businesses, they connect people and the economy through the accessibility of transport, and provide health, safety, education, and economic services to societies through critical social assets, such as education facilities, hospitals, and cyclone shelters. Thus, when climatic hazards, such as cyclones or widespread flooding take place, they can damage physical infrastructure assets and directly or indirectly disrupt much wider social and economic services, due to their networked nature. With climatic hazards taking place every year in Bangladesh, the repeated damages and disruptions can place a heavy burden on the country's economic growth, overall climate resilience, and its progress towards achieving the Sustainable Development Goals (SDGs).

Infrastructure resilience to climate hazards is therefore directly associated with Bangladesh's broader objectives to achieve sustainable development. In this assessment, climate threats to Bangladesh's development objectives are analysed, by quantifying their role in disrupting infrastructure service provision at a range of scales. Led by Bangladesh's Ministry of Environment, Forest and Climate Change (MOEFCC), this study brings together expertise via the Global Center on Adaptation (GCA) and the United Nations Office for Project Services (UNOPS), with technical analyses undertaken by the University of Oxford and the Center for Environmental and Geographic Information Services (CEGIS). The participatory nature of this study has ensured that the best available data and expert knowledge from in-country partners is incorporated, including a series of governmental ministries and agencies, and the academic community.

This project directly underpins key current policy documents within Bangladesh, including the 8th Five-Year Plan, the Mujib Climate Prosperity Plan, and the Bangladesh Delta Plan 2100, which all aim to ensure that rapid future development is climate resilient (see. Section 7.2 for further details). In this context the project has been developed across two linked activities:

A. Development of an infrastructure stress test to assess the impact of climate shocks and stresses on infrastructure assets and disruption to household access to services.

B. Enabling Environment Assessment: an assessment of the planning / development process in Bangladesh that aims to analyse the existing policies, plans and initiatives within Bangladesh to understand where the stress test process and analysis could fit, how it should be tailored, and how it can support the integration of climate risk and resilience into infrastructure planning policies and processes

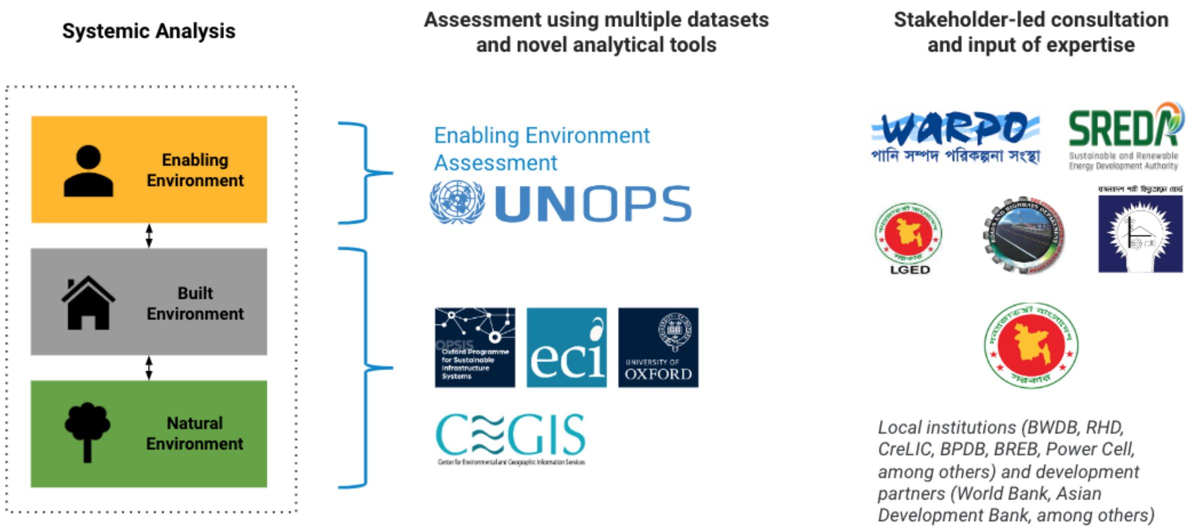


Figure 1: Stakeholder Mapping of the Assessment

2. STRESS TESTING BANGLADESH'S INFRASTRUCTURE RESILIENCE

This technical component of this assessment has four key objectives:

1. Spatially assess the exposure of infrastructure assets and networks to different climate hazards and pinpoint hotspots of risk across Bangladesh.
2. Quantify the economic damages of different climate hazards on the transport, energy, water, and critical social infrastructure sectors in Bangladesh, understanding how these damages affect populations differently.
3. Identify how infrastructure service disruptions affect welfare at the household-level in the coastal area of Bangladesh.
4. Strategically assess how service disruptions on household welfare can impact on the country's progress towards the achievement of SDG targets.

The overall approach to achieve these four objectives is illustrated in Figure 1. As evident in the four objectives and in Figure 1 below, the study is split into two spatial scales, the first (blue) section addresses objectives 1 and 2 at the national scale, whilst the second (grey) section addresses objectives 3 and 4 for coastal Bangladesh. Part one of the study assesses the exposure of Bangladesh's infrastructure to climate hazards by intersecting a range of different high-resolution spatial hazard datasets with infrastructure asset and network data for the energy, transport, water, and critical social infrastructure sectors. Using state-of-the-art geospatial analyses developed at the University of Oxford (detailed in Annex 1), key hotspot areas of infrastructure exposure to multiple hazards are assessed at the national scale.

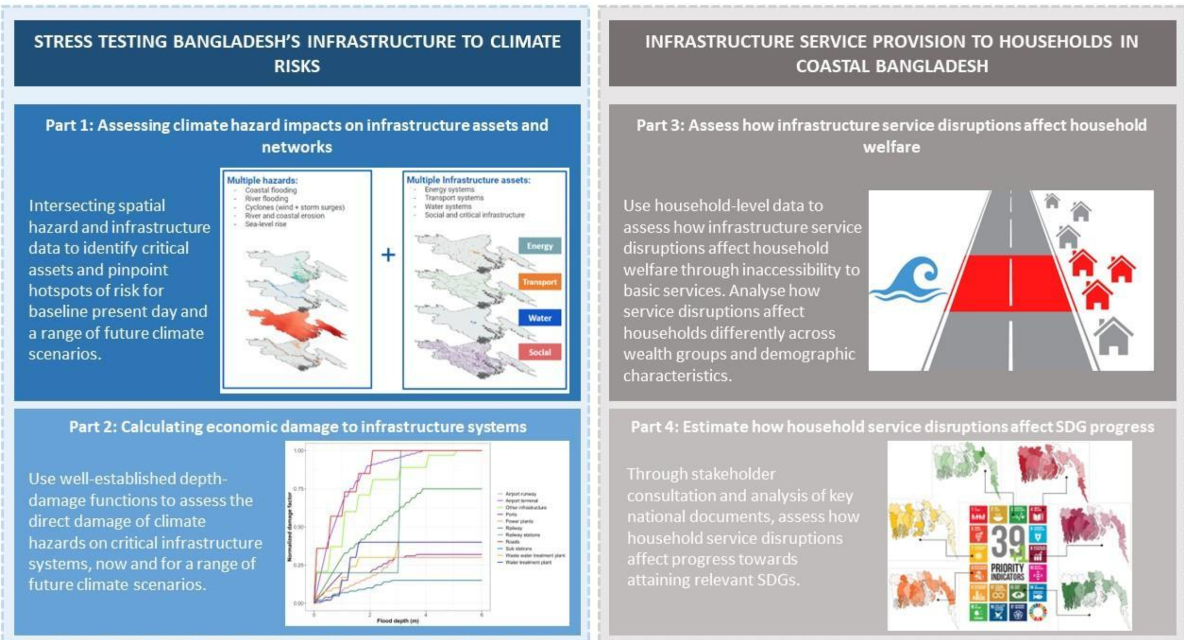


Figure 2: Overall methodology of the technical assessment

As part of this first section, the study also calculates economic damages that climate hazards can have on infrastructure assets and networks for the present day, as well as for a series of different climate scenarios for the future. High-level assessments of poverty and gender are combined with the economic damage assessment to understand whether there are wealth or gender biases in infrastructure exposure. It is the first time that a national-scale multi-hazard study is undertaken at such high-resolution in Bangladesh.

In the second section, the study focuses on the coastal region of Bangladesh (19 coastal districts) and assesses infrastructure service provision at the household scale. A new, exceptionally high-resolution synthetic household dataset from the World Bank (Rubinyi et al. *in press*)[1] is used to develop a spatial proxy of household welfare and infrastructure access in the coastal zone of Bangladesh. This enables a deeper understanding of potential inequalities in the implications of disaster impacts, as inspired by previous work on household resilience (Hallegatte et al., 2016; Verschuur et al., 2020), which can help target adaptation investment options for resilient infrastructure. In addition, household-level risk profiles developed as part of this study, showing whether households face single or multiple types of hazards, further underpin the prioritisation of future development interventions.

The final part of this study aligns the household-scale infrastructure access with SDG attainment, which can serve as a way to guide future adaptation investments to meet development objectives. In order to achieve this, priority SDG targets from national documents and stakeholder inputs are first identified, measurable indicators for relevant SDG targets are selected (e.g., access to energy, distance to health facilities, schools, etc.), and social dimensions that could further threaten SDG attainment (e.g., poverty) are considered. These are combined to develop comparative metrics of SDG performance across measurable indicators linked to the energy, transport, and social infrastructure sectors, for a range of climate hazard scenarios used in this study.

Overall, the technical advances in this assessment of high-resolution, multi-hazard, and societal welfare analyses (Figure 2), can support the spatial prioritisation of climate-resilient infrastructure investment. Moreover, analyses of the enabling environment, through continuous consultations with local stakeholders, have ensured that the technical work is relevant for the current policy and planning landscape in Bangladesh. Key entry points in the planning process have been identified together with ministries and agencies, safeguarding the longevity and sustainability of the work undertaken as part of this study.

To further support the longevity of the technical assessments undertaken as part of this study, close collaboration with local technical institutions ensured that there is local capacity to undertake the technical analysis independently. This also enables local institutions to incorporate more data into the analytical approach in the future, when more information will be made available, keeping the results relevant and up to date. Finally, the methodological

[1] **Disclaimer:** To protect identifying information, outputs of this assessment will be anonymised through aggregation - they will not be presented at high enough resolution so as to identify specific households.

approach is modular and transferable; the analyses can be tailored to a region, sector, hazard, or asset of interest.

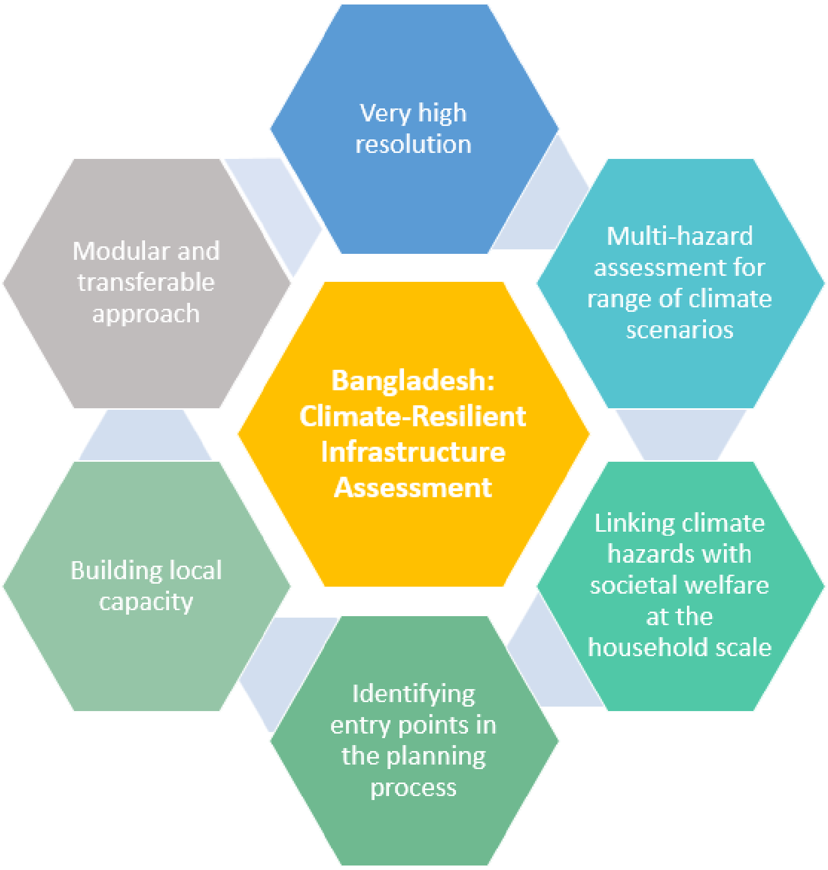


Figure 3: Added value of this study

3. ENABLING ENVIRONMENT: APPROACH AND METHODOLOGY

In order for the process-based infrastructure modelling approach to be successful, it will have to be 'useful' for the Government (relevant ministries or agencies) and it will have to be 'owned' by the Government and fully integrated into their existing systems and processes (with any necessary modifications if required).

Fundamental to any Technical Assistance Project are two key questions that have to be considered and addressed in the project architecture:

1. Who will use or benefit from the Assistance - does it address a need or problem that the Government needs to resolve?
2. What are the outputs from the project and who will be responsible for 'owning' them - ownership refers to the necessary resources to own, operate and maintain any tools or products created by the project such as GIS databases, analytical models/tools, etc. and will they be integrated into existing processes and systems.

The enabling environment assessment is thus aimed at answering these two questions. Further, the assessment will identify key entry-points within the Government of Bangladesh's infrastructure planning processes and provide recommendations of strategies to integrate this initiative through Government institutions.

3.1 Approach and Methodology of the Analyses

Many of the issues faced by infrastructure owners and developers are not really 'asset' problems but instead capacity problems related to the 'knowledge' and 'institutions' dimension of an infrastructure system. To this end, the objective of the assessment of (infrastructure) planning/development processes in Bangladesh will be to identify:

1. The different **planning documents** and instruments in Bangladesh (**Knowledge dimension**) related to infrastructure development
2. **Government structures**, roles and responsibilities (**Institution dimension**)
3. **Planning processes** and how the process based infrastructure modelling approach being developed can be integrated into the planning processes in Bangladesh. (**Knowledge** and **Institutions** dimensions)

The approach and methodology is a mixed modality of desktop study and analyses and key informant/stakeholder interviews.

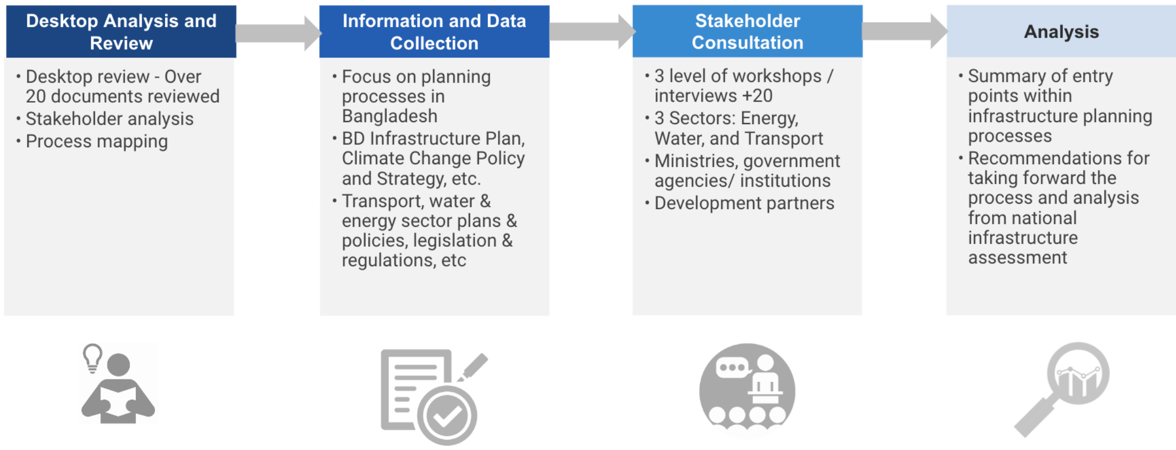


Figure 4: Enabling Environment Assessment Methodology

3.2 Desktop Analyses and Information and Data Collection (Phase 1)

The desktop analysis comprising a review of the planning instruments and documents in Bangladesh has been conducted. The analyses identified:

- The key development planning documents in Bangladesh
- The level these documents are aimed at - Timeframes, National, Regional, Local
- The 'core' planning documents and which are 'cross cutting' and how they relate.
- Which Ministries/Agencies are responsible for their creation, approval and implementation
- An overview/mapping scenario of the overall planning and implementation processes.

3.3 Stakeholder Consultation and Analysis (Phase 2)

The list of stakeholders to be consulted was developed in consultation with the project board and key advisors from the Government of Bangladesh. As a summary, the key stakeholders were:

- Senior Officials who have been or are currently involved in the Planning Processes in Bangladesh - both the development of strategic plans and their implementation
- The Centre for Geographical Information systems (CEGIS) who is a key government partner. CEGIS has played a role as advisor on GIS systems, access to data and integration into Government planning processes.
- The key ministries/agencies who are involved in the management of local level infrastructure related to energy, water and sanitation and transport. These include meetings with Water Resources Planning Organisation (WARPO), Bangladesh Water Development Board (BWDB),
- Local Government Engineering Division (LGED), Roads and Highway Department (RHD), Climate Resilient Local Infrastructure Centre (CreLIC), Bangladesh Power Development Board (BPDB), Rural Electrification Board (BREB), Power Cell,

Sustainable And Renewable Energy Development Authority (SREDA) and Planning Commission.

The stakeholder consultations sort to:

- Confirm the desktop analyses and verify any assumptions or gaps
- Obtain feedback on the proposed sustainability of the outcomes of the project, identifications of challenges in the planning processes and recommendations on how best to integrate the approach into the planning processes.

The findings of the assessment are captured in a report with identification of the key potential entry-points, risks/opportunities to integrate this process based infrastructure modelling approach into the planning processes in Bangladesh.

4. STRESS TESTING BANGLADESH'S INFRASTRUCTURE TO CLIMATE RISKS

Bangladesh has a monsoonal climate, with 90% of its annual rainfall (1700-2400mm) observed in the summer monsoon months (June until October) (Bhuiyan and Dutta, 2012). As a result, riverine flooding and associated erosion are widespread across the country. In addition, Bangladesh's low-lying deltaic characteristics (two-thirds of the country is below 5m above mean sea level) within the Bay of Bengal have resulted in high risks to annual tropical cyclones, which can have storm surges of up to 9m (Dasgupta et al., 2014; Whitehead et al., 2018).

The climate hazards considered as part of this study include coastal and riverine flooding and erosion, as well as cyclonic winds and their storm surges (see Figure 3). Although droughts and saline intrusion are significant hazards in Bangladesh, with drought mainly affecting the north-west of the country and saline intrusion affecting particularly the south-west, the data for these hazards did not have any future scenarios and lacked hydrological assessments to understand how they would impact infrastructure sectors in Bangladesh, especially the water sector. Moreover, the water sector data has been extremely limited (further discussed in Section 2.3 for the water sector); no water supply or borehole data was made available. As a result, these two hazards are excluded from further analyses undertaken as part of this assessment. The climate hazard datasets used, and the scenarios tested, are detailed in Box 1 below.

In this section, the exposure of the transport, energy, water, and critical social infrastructure sectors to different climate hazards is assessed, and the direct damages to the infrastructure assets and networks is estimated.

BOX 1: Climate hazard datasets used for the study

Riverine flooding

The global Aqueduct flood data (Winsemius et al., 2015) was used to understand future river flood risks across scenarios for the baseline year, 2010, 2030, 2050, and 2080, as well as for return periods 2, 10, 25, 50, and 100. All of these return period and future year combinations are available for Representative Concentration Pathways (RCPs) 4.5 (realistic) and 8.5 (extreme). The hazard data provides flood depths across Bangladesh at a resolution of 100m by 100m. It is important to note that it does not provide information on the time or duration of the hazard. For the purpose of this study, and after consultations with key in-country partners and stakeholders across government agencies, RCP 4.5 (realistic), the 50-year return period (the recommended extreme event for planning purposes), and the year 2050 is used throughout the report, and Annex 2 has further results for the following scenarios:

- Baseline year, return period 10
- Baseline year, return period 50
- RCP 4.5, return period 10, year 2030
- RCP 4.5, return period 50, year 2030

- RCP 4.5, return period 10, year 2050
- RCP 4.5, return period 50, year 2050 (the scenario used across the report)
- RCP 4.5, return period 10, year 2080
- RCP 4.5, return period 50, year 2080
- RCP 8.5, return period 10, year 2030
- RCP 8.5, return period 50, year 2030
- RCP 8.5, return period 10, year 2050
- RCP 8.5, return period 50, year 2050
- RCP 8.5, return period 10, year 2080
- RCP 8.5, return period 50, year 2080

Coastal flooding

Current and future coastal flooding scenarios are also taken from the global Aqueduct dataset (Winsemius et al., 2015). The coastal flood dataset from Aqueduct includes both tidal inundation as well as storm-surge induced coastal flooding. The same climate scenarios are available for coastal flooding as outlined for river flooding above, at the same resolution of 100m by 100m. Similarly, RCP 4.5, return-period 50, and the year 2050 is used throughout the report when assessing exposure or damages from coastal flood risks, but Annex 2 has further results for the same additional scenarios as outlined in the list above.

Cyclonic winds

In order to incorporate cyclonic wind damages into the study, the maximum wind gusts (in m/s) for different return-period events are re-simulated using the Steptoe (2021) data. This dataset is based on nine different ERA5 climate models of historical events and has a resolution over all of Bangladesh of a 4.4km grid. This dataset does not entail information about potential future cyclonic winds; thus, the exposure and economic damages from cyclonic winds is reported for the present day only. Although this dataset is only for the present day, it does provide maximum wind gusts for return periods 2, 10, 25, 50, and 100. For the purpose of this report, the 50-year event is reported, for consistency with the flood scenarios.

River and Coastal erosion

For river and coastal erosion, the DeepWaterMap model was used, which is a satellite-based model that measures channel and coastline changes over time (Jarriel et al., 2020). The resulting erosion map has a resolution of 30m by 30m and shows the cumulative area that has eroded over the last 35 years (1987-2022). This data layer does not entail information about potential future erosion; thus, the exposure and economic damages from riverbank and coastal erosion is reported for this 35-year period only.

Figure 3 illustrates the spatial extents of the four hazards considered. Coastal flooding is the most geographically extensive hazard, with 23.15% of Bangladesh's land area affected by a 50-year storm surge event, under the baseline (present-day) scenario, rising to 26.18% under a 2050 RCP4.5 scenario. This predominantly affects the Khulna, Barisal, and Chittagong divisions. Riverine flooding affects 19.22% of Bangladesh's land area under the baseline scenario and reaches 24.75% for the same scenario in 2050 (RCP4.5). Cyclonic wind gusts reach 70m/s, with the Barisal and Chittagong divisions suffering the highest expected gust speeds. Finally, approximately 10,800km^2 of land has been eroded in Bangladesh over the last 35 years, which has predominantly been evident in the river corridors of Bangladesh's major river systems (Paszkowski et al., *under review*).

These hazard layers are intersected with infrastructure assets across Bangladesh for the transport, energy, water, and social infrastructure sectors to assess the exposure of these assets to climate hazards, now and in the future. In order to estimate the direct damages that the above hazards have on infrastructure sectors, asset- and hazard-specific global depth-damage curves and cyclone fragility curves from the literature are used (see Annex 1 for all the curves used, as well as their sources). Depth-damage curves (also known as stage-damage functions) show the association between flood depth and economic damage of a variety of different infrastructure assets, and cyclone fragility curves estimate the potential damage to various infrastructure assets at various gust speeds. Both categories of damage functions used in this study exhibit fractional damage (hereafter referred to as the normalised damage factor) to assets when exposed to varying water depths (for flooding) and gust speeds (for cyclones). This factor is multiplied by the footprint area of the asset and the damage cost per unit area, which results in the total damage for a given structure.

The following sections provide the key findings of infrastructure systems exposed to different climate hazards in Bangladesh for the transport, energy, water, and social infrastructure sectors. In each of these sections, the relevant infrastructure, hazards, and depth-damage curves are first outlined. The main scenario reported throughout these sections is the RCP4.5, 50-year return period event for the year 2050, as this is most aligned with the planning landscape in Bangladesh. Results for additional scenarios are available in Annex 2.

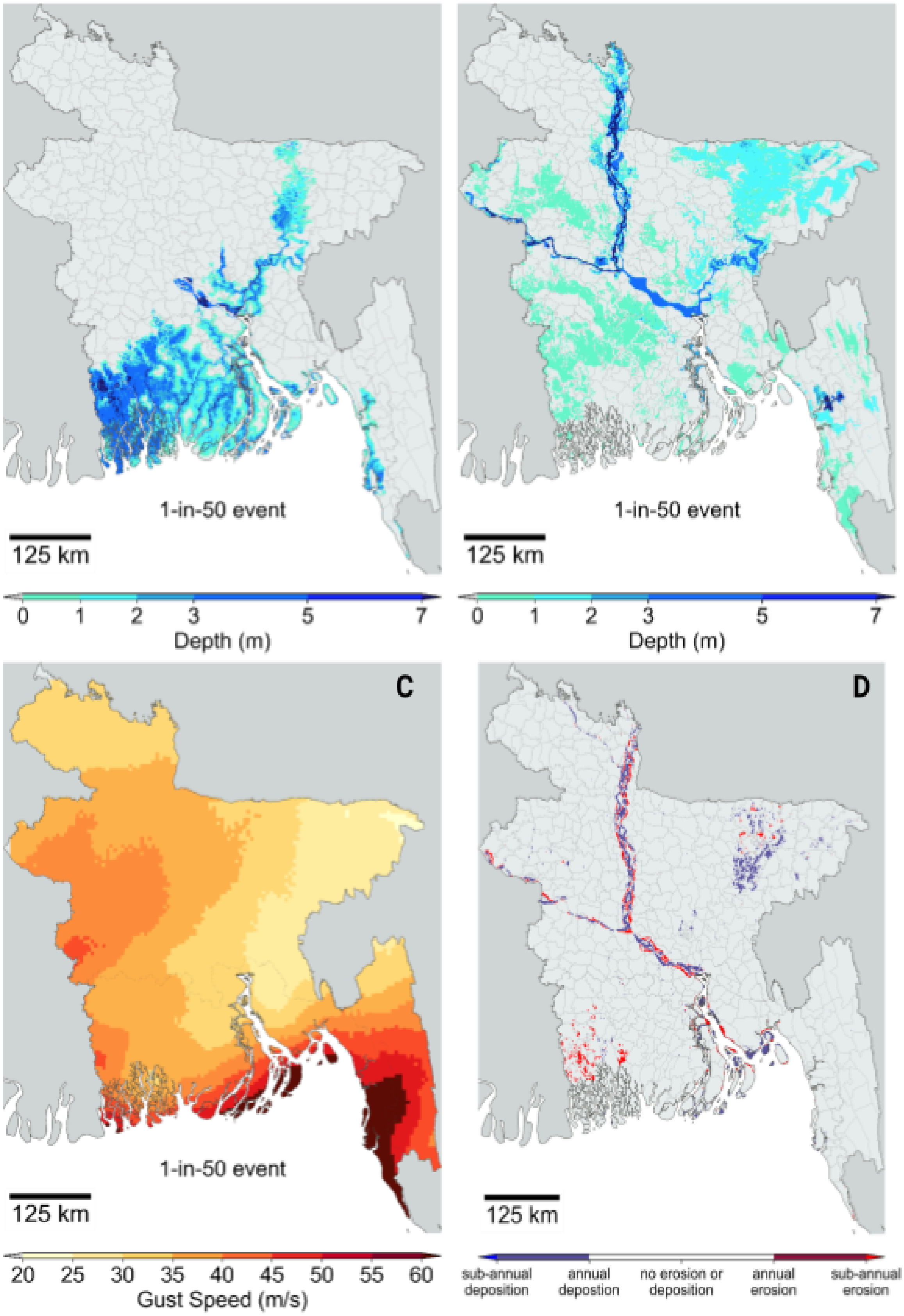


Figure 5: Hazard maps: (A) coastal flood depths for RCP 4.5, return period 50, year 2050; (B) riverine flood depths for RCP 4.5, return period 50, year 2050; (C) cyclone maximum gust speeds for the 50-year baseline event; and (D) cumulative erosion and deposition from 1987 to 2022

4.1 Climate Risks: Transport Sector

The transport sector is growing rapidly in Bangladesh, with evermore rural communities being connected via roads, impressive bridges being built across vast river systems, and ports and inland waterways being expanded for accelerated navigation and trade. The transport system is extremely interconnected with other sectors, and thus if there are disruptions in the transport system, impacts are typically felt much more widely than solely in the area of impact. For instance, disruptions in the road and railway system may affect households' ability to access healthcare, education, their livelihoods, or other basic services such as clean water or safe shelter. If ports or airports are disrupted, international trade of imported and exported goods can also have significant impacts on the national economy. Thus, the resilience of transport assets and networks in Bangladesh is absolutely crucial for its stable long-term socio-economic growth and development objectives.

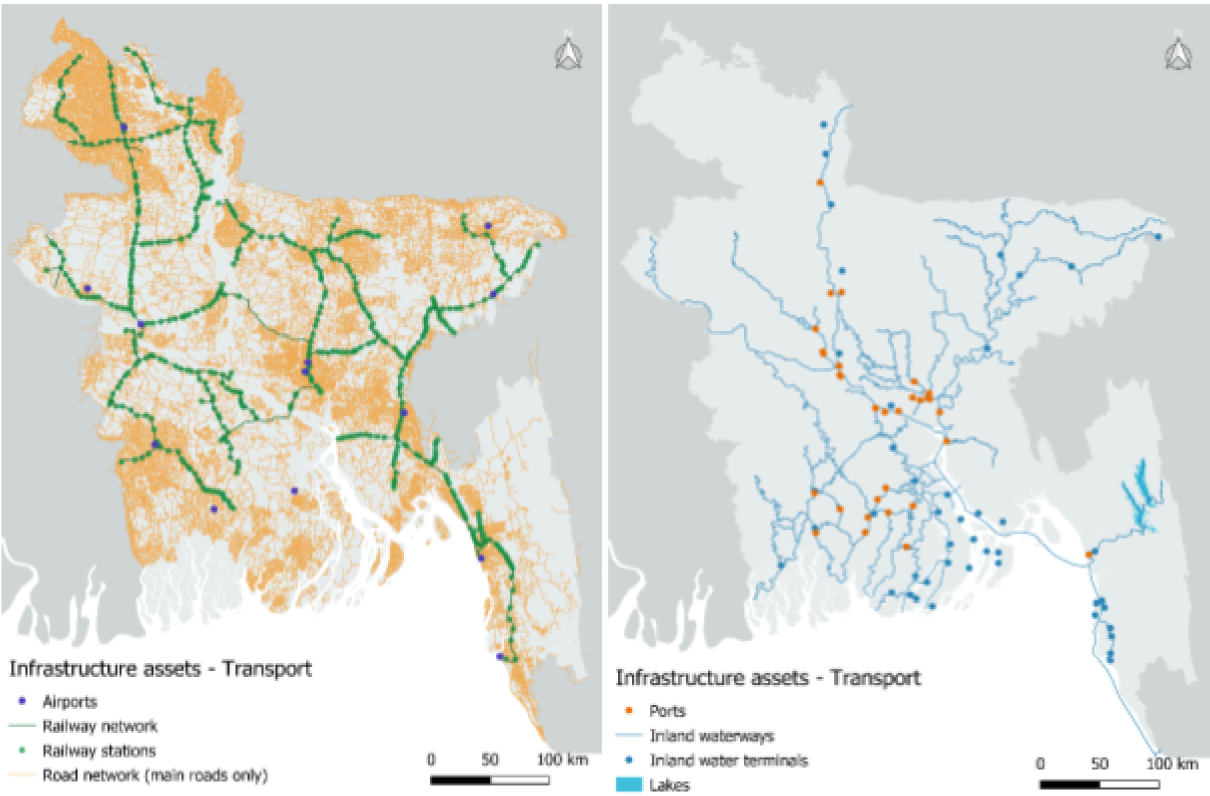


Figure 6: Geospatial data for transport sector infrastructure assets and networks

Transport infrastructure assets and networks considered as part of the climate risk assessment are illustrated in Figure 4 above, and consist of 173,809km of roads, 519 railway stations, 3,159km of railway lines, 13 airports, 32 ports, 6,056km of waterways, and 80 inland water terminals. Road datasets were provided by LGED and RHD, railway assets by Bangladesh Railway, ports, waterways and water terminals by WARPO and airport dataset was prepared by CEGIS. All these asset specific datasets were compiled, updated, processed and validated by CEGIS. The exposure of these assets to the four hazards of coastal flooding (including storm surges), riverine flooding, cyclonic winds, and coastal and riverbank erosion is assessed.

When intersecting flood, cyclone and erosion data with these transport assets, the analyses show that the transport sector, as a whole, is currently highly exposed to climate hazards (see Table 1 for summary of transport asset exposure to all hazards, and the Figure below for a spatial example of exposed transport assets and networks to coastal flooding).

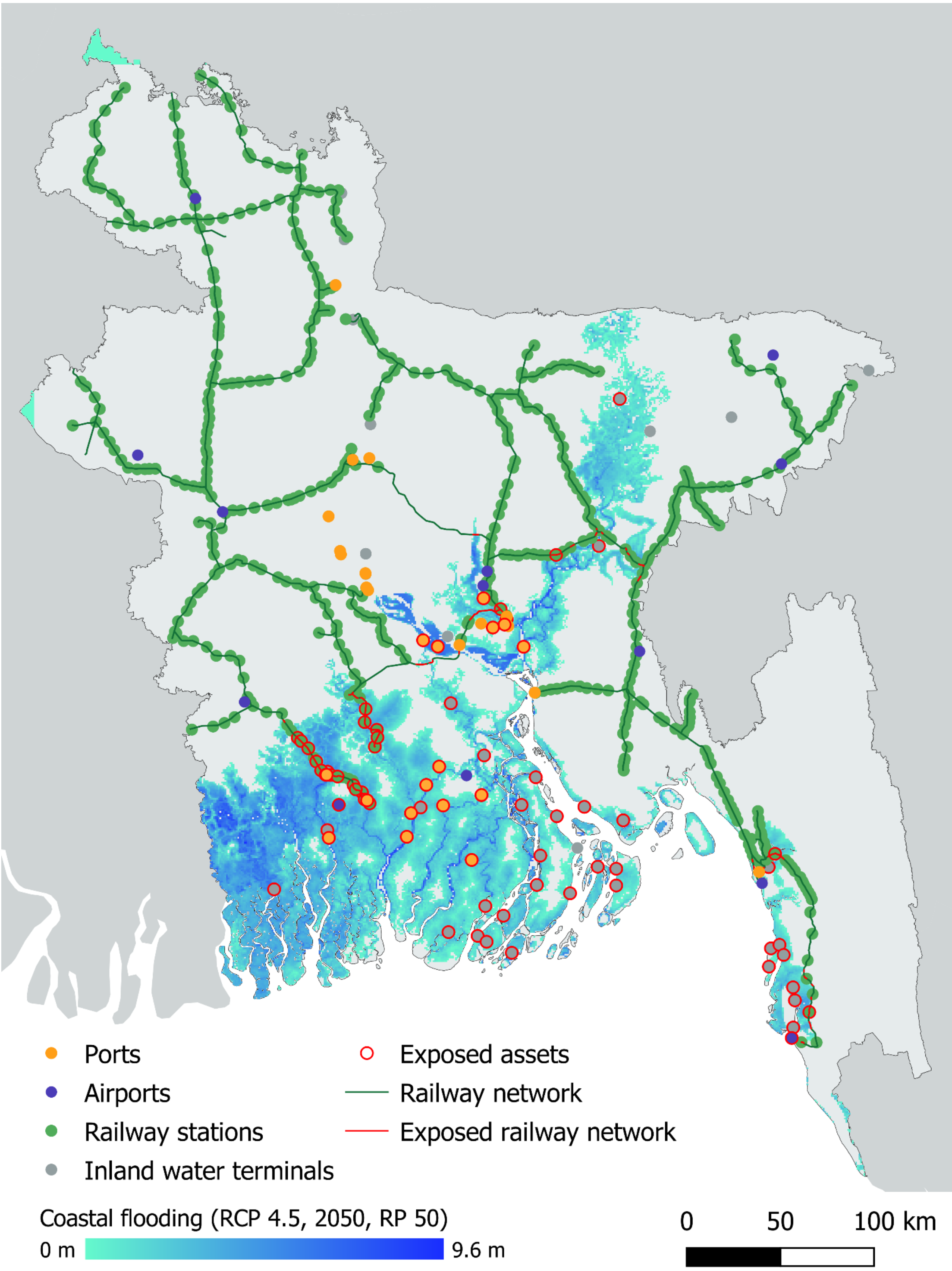


Figure 7: Example of exposed transport assets to coastal flooding. Note, the road network is excluded from this example map, as it covers the whole country and detracts attention from other assets.

The most impactful hazard on the transport sector is coastal flooding, which affects between 0.8% of (railway stations) and 23.75% (water terminals) of assets for the baseline year under a 2 year flood event, and between 9% (railway stations) and 70% (water terminals) of assets for a 2080 (RCP4.5) scenario under a 100 year flood event. If all hazards are considered[2] in unison, 95% of the road network (170,782 km), 93% of the railway network (2,933 km) and 488 of the 519 stations (94%), 100% of the 32 ports, and 100% of the 13 airports are exposed to climate hazards for the baseline year. The exposure of transport sector assets to coastal and riverine flooding also increases into the future, which can be seen in Table 1. Under a 2050 (RCP4.5) *coastal* flood scenario, 2.87% more of the road network is exposed, while 0.79%, 0.42%, and 3.1% more of railway lines, railway stations, and ports are exposed. Similarly, under a 2050 (RCP4.5) *riverine* flood scenario, 2.29% more of the road network is exposed, while 7.2%, 5%, 9.3%, and 7.5% more of railway lines, railway stations, ports, and water terminals are exposed.

Such widespread exposure to a range of different hazards in Bangladesh can cause large damages if severe hazards do occur, which result in significant economic costs. The analyses show a total economic damage of €12.3 billion (2.95% of GDP in 2021) for the baseline flood (riverine and coastal) scenario, which increases to €12.7 billion (3.05% of GDP in 2021) for the future 2050 50-year event (RCP4.5). It is important to note that the damages estimated for 2050 are for that respective year, not cumulative until then. The coastal flood hazard has the most significant economic impact on the transport sector, and the economic damage to the road network makes up the majority (51 - 58%) of that total damage value in the transport sector. The exposure and damage of all individual transport assets for a range of different scenarios of climate hazards are available in Annex 2, some of which are outlined in Table 1 below.

Table 1: Summary of the transport sector's exposure and estimated economic damage as a result of climate hazards

Hazard		**Transport Infrastructure**											
		Roads		**Railway lines**		**Railway stations**		**Airports**		**Ports**		**Inland water terminals**	
		% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)
Coastal	Present day	15.71	6259.80	4.55	2.80	4.05	0.11	15.38	0.16	46.88	0.19	61.25	2.03
	2050*	18.59	7362.46	5.35	3.68	4.43	0.18	15.38	0.16	50.00	0.21	62.50	2.18
Riverine	Present day	22.03	6016.12	19.26	6.69	20.23	0.55	15.38	0.05	43.75	0.16	32.50	0.85
	2050*	24.32	5352.26	26.47	5.42	25.24	0.46	15.38	0.04	53.13	0.14	40.00	0.70
Cyclones**	Present day	86.13	NA	84.38	NA	82.27	NA	76.92	NA	100.00	1.83	95.00	NA
Erosion***	Present day	39.71	NA	39.71	NA	56.26	NA	61.54	NA	31.25	NA	40.00	NA

* Scenario shown here is for RCP 4.5, and a return period of 1 in 50 years.
** Exposed to more than 30m/s of max wind gust
*** Exposed to erosion more than once per year

[2] Considered hazards for each asset type are chosen based on their relevance for the asset type. In the transport sector all four hazards are considered for railway lines, railway stations, ports and airports; flooding and erosion is considered for roads and inland water terminals; and erosion is considered for inland waterways

Given that the road network experiences the highest estimated damages, with the most significant damages caused by coastal flooding, the road network's exposure to the 50-year coastal flood event for RCP4.5, for the year 2050 is taken as an example to illustrate the spatial trends in exposure (Figure 5). For this future scenario, 15.71% of the road network is exposed to coastal flooding. The cumulative plots in Figure 5A illustrate the percentage of road infrastructure exposed across all flood depths for all climate scenarios, which show that less assets are exposed to high flood depths. For example, taking the reported scenario of RCP4.5, return period 50 and the year 2050, we follow the orange dot-dashed line in the top panel. If we are interested in the percentage of assets exposed to >1m of flooding, we follow the scenario line until the point where 1m is on the y-axis. In this case, approximately 15% of road assets are exposed to >1m of coastal flooding (as stated above). The point at which the scenario lines meet the x-axis is the percentage of assets exposed to any level of flooding. Some key upazilas where the road network is most exposed are Patuakhali Sadar, Shyamnagar, and Hatiya for coastal flooding (see zoomed-in map in Figure 6) and Dharampasha, Nageshwari, and Chatak for river flooding.

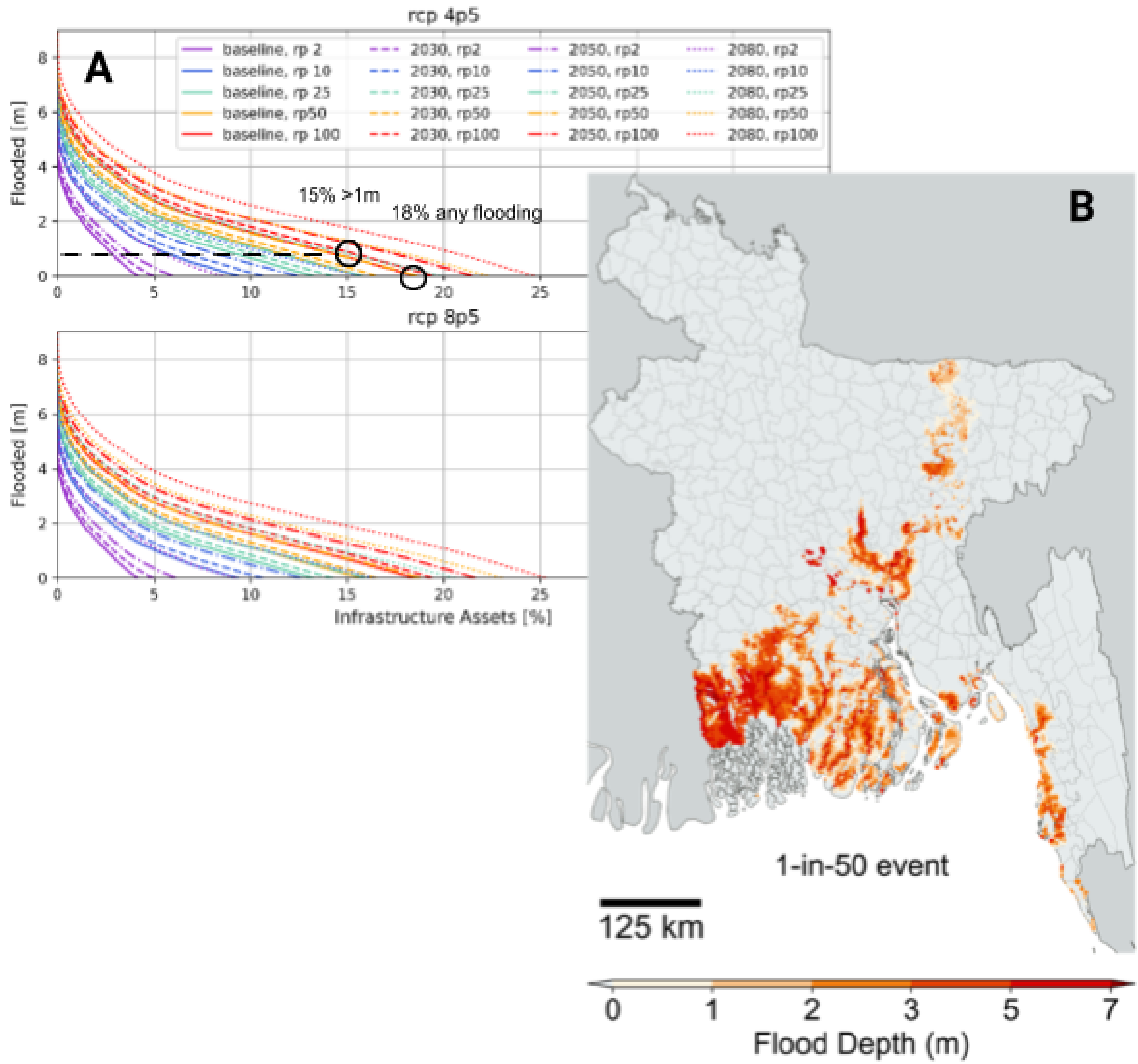


Figure 8: Exposure of the road network to coastal flooding at the national scale. (A) Cumulative road network exposed to coastal flooding at the national scale across all climate scenarios, and (B) Spatial distribution of exposure of road assets to coastal flooding for the 2050 RCP4.5 50-year event.

When focusing on the Patuakhali Sadar area (as shown in the zoomed-in map in Figure 6), the distribution of flood depth is more apparent. High flood depths of >2m don't only have significant impacts on the direct area affected[3], but can also create cascading impacts that spread much wider than the local area and can generate disruptions that may last a long time.

The direct economic damage of coastal flooding on the road network is calculated using the depth-damage curve for roads from Huizinga, et al. (2017). Figure 6 illustrates the severity and spatial distribution of economic damage to the road network across Bangladesh. Overall, for the 2050, 50-year return period coastal flood event (RCP4.5), the total damage to the road network is estimated at €7.4 billion, which is 17.6% higher than the baseline year (estimated at €6.3 billion). This makes up 1.8% of the national GDP in 2021. The upazila that experiences the greatest economic damage to the road network as a result of a 50-year coastal flood event is Patuakhali Sadar, in the south-central coastal region of Bangladesh. Here, up to 183.8 km of roads are exposed to coastal flooding, which can cause direct damages of €368.6 million across the upazila.

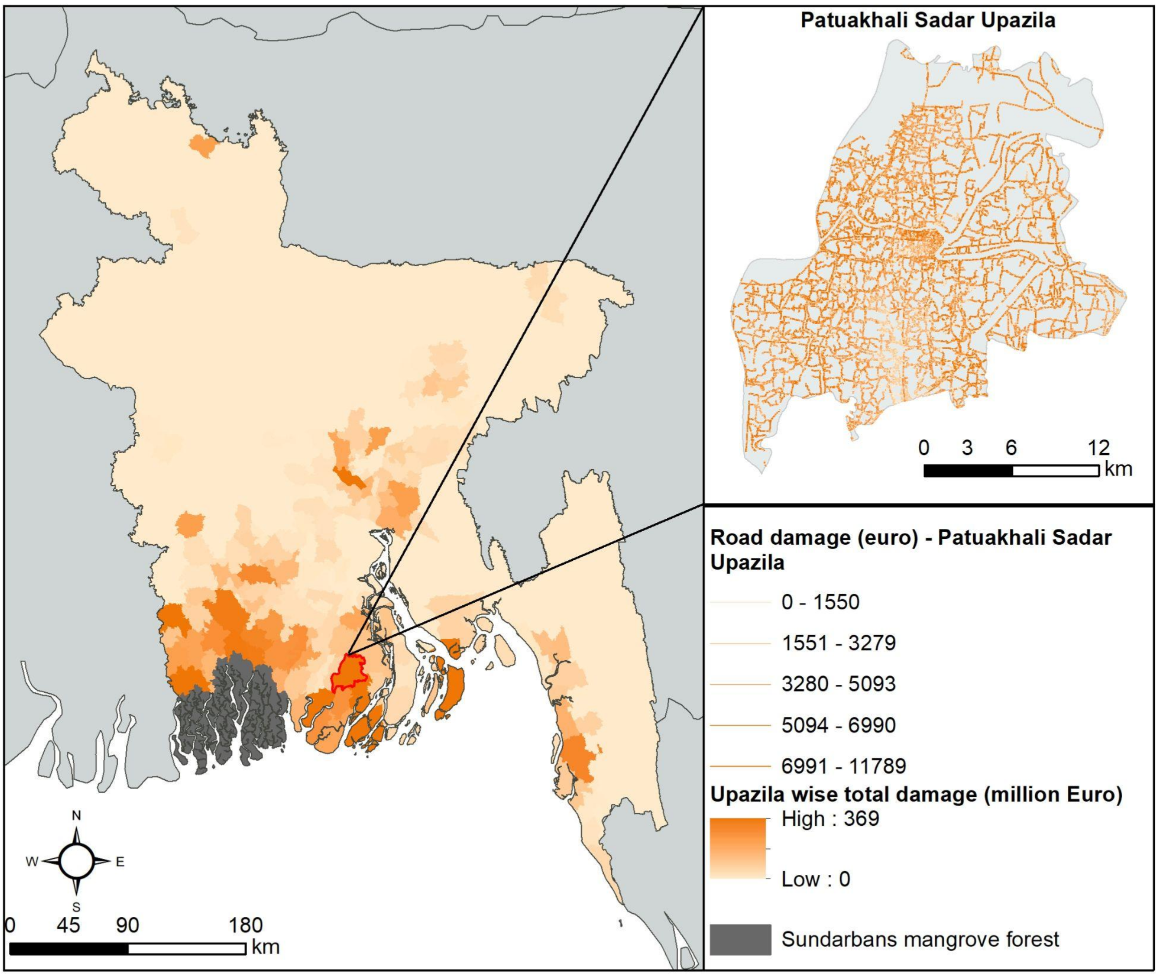


Figure 9: Upazila-wise total direct economic damage to the road network as a result of coastal flooding for the 50-year coastal flood event, for RCP 4.5, in the year 2050

[3] For flood depths of > 2.1m, 100% of a structure is likely to be damaged

By intersecting these damage findings with WorldPop population data (Tatem, 2017), we find that this overall economic damage of the road network to coastal flooding in Bangladesh affects 20.5% of the national population (~33 million people), of which 50.4% is female. Moreover, by using spatial poverty data developed by Steele et al. (2017), this study finds that the poorer portions of the population are most impacted by damages to the road network; the average wealth index (WI) of affected populations is -0.24[4]. Such road disruptions in poor, rural areas of Bangladesh can result in local populations not being able to access other basic services, such as healthcare and safe shelters, education being paused for extended periods of time, and livelihoods and sources of income being disrupted. This can slow or reverse many households' journeys on their progress out of poverty, which is a key nationwide ambition, that by 2041, the country will have no households below the national poverty line.

4.2 Climate Risks: Energy Sector

Bangladesh mostly relies on hydropower, natural gas, coal, and oil for its energy needs. The country's energy resources are currently still insufficient, with the Ministry of Power, Energy and Mineral Resources estimating that only 70% of the population had access to electricity in 2015 (Uddin et al., 2019). In this study, the energy sector analysis in Bangladesh consists of assets and networks that make up the national gas and electricity service.

The energy infrastructure in this assessment includes 106 power plants, 113 electricity substations, 6,150km of electricity grid lines, 25 gas fields, and 11,098km of gas lines (Figure 7). Electricity data was provided by Power Division and BPDB and gas related data were [provided by GTCL and Petro Bangla. All these asset specific datasets were compiled, updated, processed and validated by CEGIS.The exposure of these energy assets to the four hazards of coastal flooding (including storm surges), riverine flooding, cyclonic winds, and coastal and riverbank erosion is assessed.

[4] Steele et al. (2017) developed poverty maps for Bangladesh through the combination of remote sensing, mobile phone operator call detail records, and traditional survey-based data. The wealth index measures household welfare, which is based on asset ownership, dwelling characteristics and access to basic services. The wealth index values can be either positive or negative, for Bangladesh ranging between -1.17 and 2.19, with greater positive values indicating higher socio-economic status.

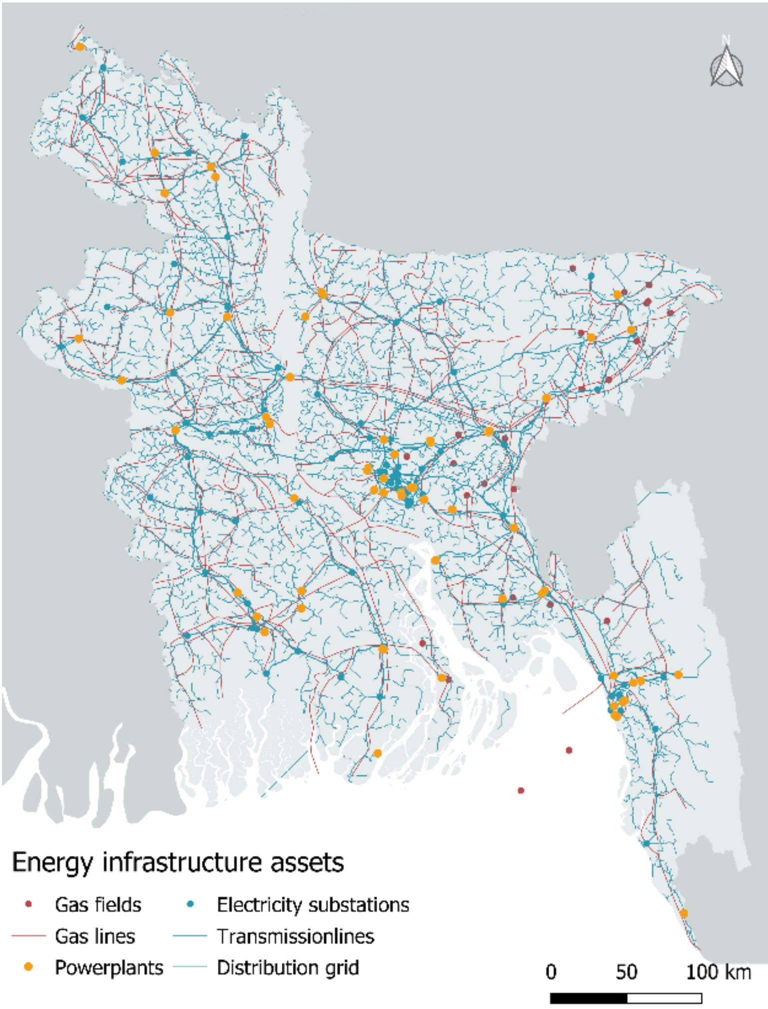


Figure 10: Geospatial data for energy sector infrastructure assets and networks

Considering all four hazards[5] for the baseline year, 67% of power plants (71 plants), as well as 65% of electricity substations (74 substations), 90% of electricity grid lines (24,152km), 52% of gas fields (13 gas fields), and 4,462km of gas lines, are currently exposed to climatic hazards. Under a future 2050 RCP4.5 scenario, asset exposure due to a 50 year hazard event increases by 4.71% for power plants, 4.42% for electricity substations, 2.1% for the electricity grid, 4% for gas fields, and 1.58% for gas lines for coastal flooding; and by 3.77% for power plants, 6.18% for electricity substations, 7.3% for the electricity grid, 16% for gas fields, and 7.03% for gas lines for riverine flooding. A more detailed overview of the exposure in the baseline year as well as for the year 2050 (RCP 4.5, 50-year return period) can be found in Table 2.

Table 2: Summary of the energy sector's exposure and estimated economic damage as a result of climate hazards

Hazard	Energy Infrastructure				
	Powerplants	Electricity substations	Electricity grid	Gas fields	Gas lines

[5] Considered hazards for each asset type are chosen based on their relevance for the asset type. In the energy sector flooding and erosion is considered for power plants, substations and gas fields; cyclones and erosion are considered for the electricity grid and only erosion is considered for gas lines

		% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)
Coastal	Present day	28.30	3.17	19.47	0.08	11.24	NA	4.00	0.03	12.09	1.41
	2050*	33.02	4.78	23.89	0.13	13.35	NA	8.00	0.07	13.67	2.01
Riverine	Present day	31.13	1.60	24.78	0.07	19.06	NA	4.00	0.03	21.99	1.45
	2050*	34.91	2.31	30.97	0.08	26.42	NA	20.00	0.04	29.02	1.97
Cyclones**	Present day	79.25	35.91	89.38	0.72	83.64	4.95	32.00	NA	83.93	NA
Erosion***	Present day	46.23	NA	54.87	NA	38.55	NA	52.00	NA	40.22	NA

* Scenario shown here is for RCP 4.5, and a return period of 1 in 50 years.
** Exposed to more than 30m/s of max wind gust
*** Exposed to erosion more than once per year

The direct economic damage that these climate hazards can cause on the energy sector is also illustrated in Table 2; a total economic damage of €44.47 million (0.01% of GDP in 2021) is anticipated for the baseline scenario. Cyclones have the greatest impact on the energy sector, both in terms of exposure and economic damage, and the impact of cyclones on the electricity grid impacts most people in Bangladesh (as shown in the figure below).

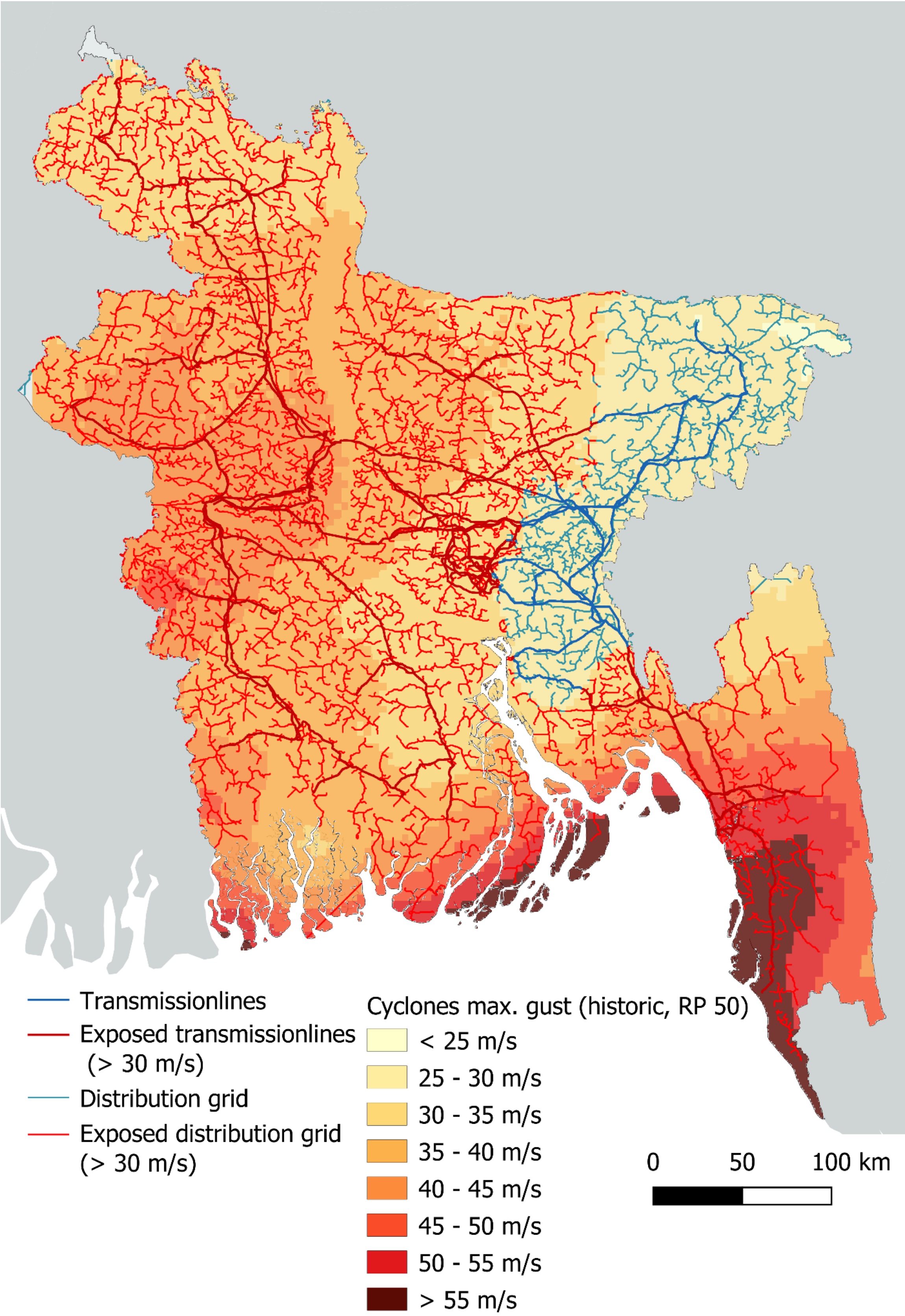
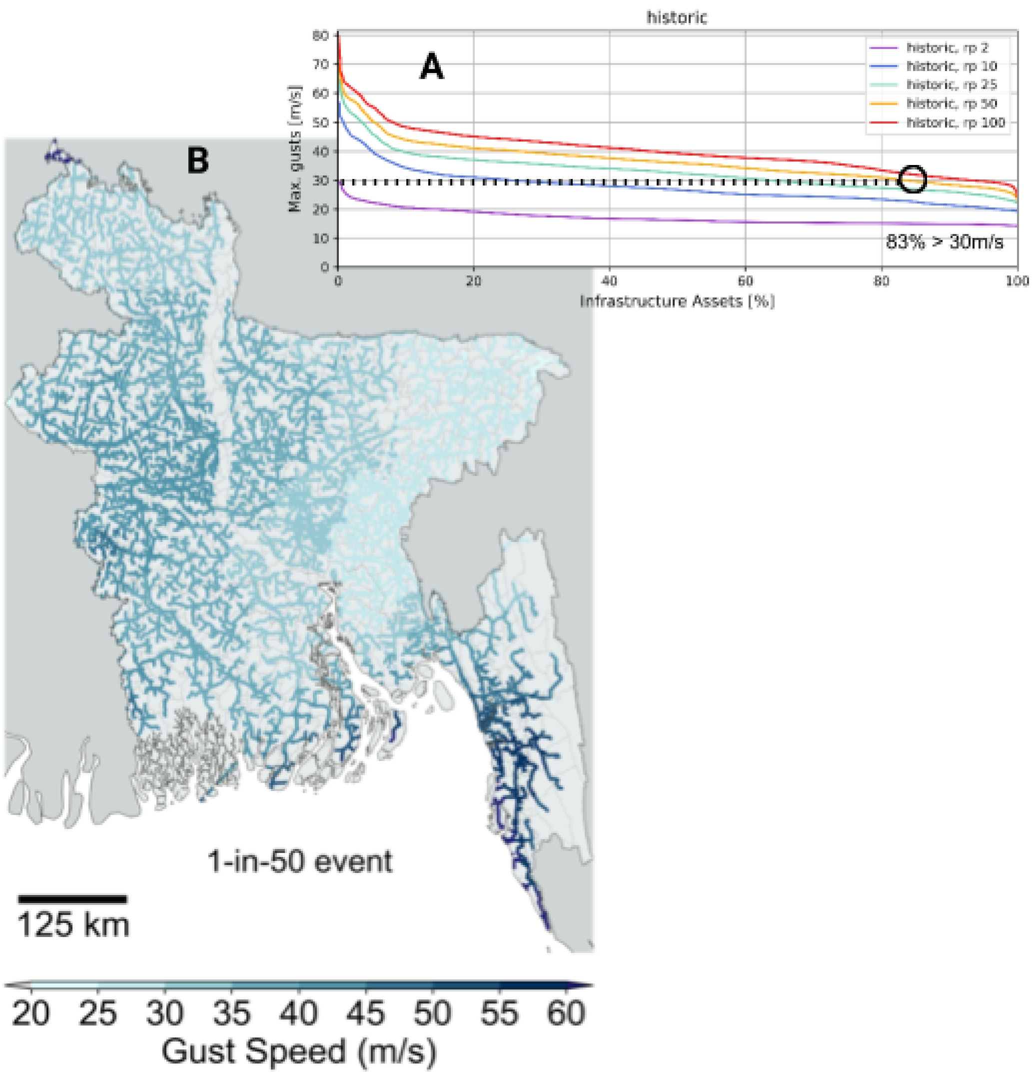


Figure 11: Example of exposed energy assets to cyclones.

The exposure and damage of all individual energy assets for a range of different scenarios of climate hazards are available in Annex 2, but given that cyclonic winds have the greatest impact on the energy sector, and the electricity grid has the most population impacted by disruptions in the service it provides, the exposure of the 6,150km electricity grid to cyclonic wind hazards for the 50-year maximum wind gust event is taken as an example (Figure 8). The cumulative plot in Figure 8A illustrates the percentage of the electricity grid exposed to varying degrees of cyclonic winds, as well as for all available return period events. Using this plot, we can see that for the threshold of damaging wind gusts of 30m/s, the percentage of the electricity grid that is exposed varies from around 23% for the 10-year event, to 90% for the 100-year event. The 30m/s threshold is based on the depth-damage curve from Miyamoto International (2019), detailed in Annex 1. The key areas where the electricity grid is most exposed to damaging wind gusts is Chakaria (see zoomed-in map in Figure 9). Parts of the electricity grid in this area are exposed to wind gusts reaching 64m/s. Such wind gusts can result in significant damage to the pylons and electricity transmission and distribution lines that distribute power across this region in Bangladesh[6]. For instance, Tropical Cyclone SIDR in 2007 caused damages to the power sector of US$13.4 million with wind gusts in excess of 70m/s (over 260km/h) (Shahid, 2012).



[6]For gust speed of more than 55 m/s, 75% of a structure are likely to be damaged

Figure 12: Exposure of the electricity grid to cyclonic winds at the national scale. (A) Cumulative plot of electricity grid exposed to cyclones at the national scale for all available return period events. Less of the electricity grid is exposed to extremely high wind gusts. (B) Spatial exposure of the electricity grid to cyclonic winds for the 50-year event.

With wind gusts exceeding 30 m/s, many energy infrastructure assets can be destroyed. This destruction can have significant direct damage costs, and can cause widespread disruptions due to the networked nature of the energy system. In order to calculate the direct economic damage of cyclonic winds on the electricity grid, the depth-damage curve from Miyamoto International (2019) is used. Figure 9 below illustrates the upazila-scale spatial distribution of economic damage to the electricity grid across Bangladesh for a 50-year cyclone event. Overall, the damage to the electricity grid as a result of this cyclonic event is estimated at €4.95 million, with the most significantly impacted upazilas located in the south-eastern region of Bangladesh (Figure 9). The extremely high wind gusts in the Chakaria upazila could damage up to 125km of upazila's electricity grids. The population in Chakaria that rely on this electricity network, and thus could be impacted by its damage, is 760,000 people.

Overall, the economic damage of cyclones to the electricity grid affects 145.1 million people in Bangladesh, making up 87.95% of the national population, of which 49.5% is female. This is a vast proportion of the national population. Given the Government's plan to achieve the SDGs, which includes providing clean and affordable energy and national electrification, this high exposure of the energy sector to climate hazards is particularly alarming. In addition, the average wealth index (WI) of the affected population is -0.25 (see footnote 4 for further detail). Overall, for the energy sector, disruption to the electricity grids affects the poorer portions of the population, whilst damage to substations predominantly impacts wealthier populations (WI=0.14). This is likely because of lower electricity coverage in rural areas compared to urban areas (Rahman et al., 2013), where the values of WI are relatively high.

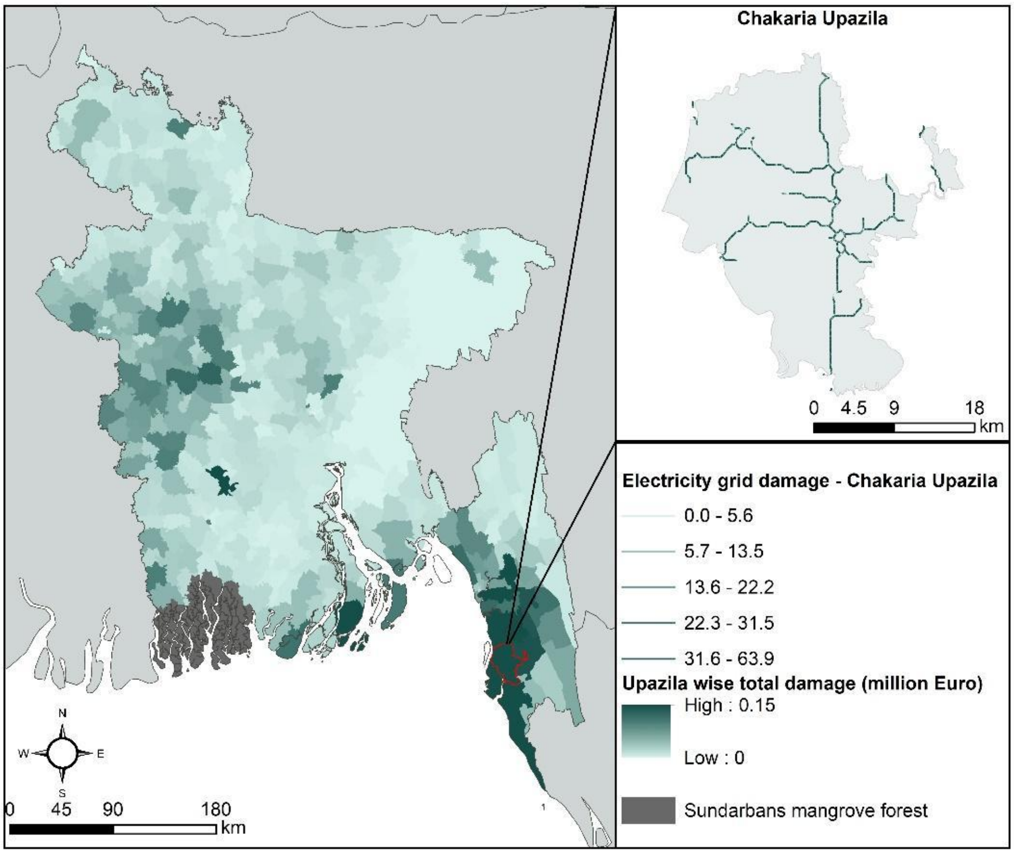


Figure 13: Upazila-wise total direct economic damage to the electricity grid as a result of a 50-year cyclonic wind event

4.3 Climate Risks: Water Sector

Climate-related hazards such as floods, cyclones, and droughts are predicted to have an impact on water infrastructure, over short and long timeframes, which might reduce the efficacy and quality of water supply. In Bangladesh, there is very limited data available on water infrastructure assets. The water infrastructure considered in this study includes three water treatment plants (WTPs), located in Dhaka (Saidabad and Chandni Ghat WTPs) and Sylhet (Kushighat WTP) (data for other WTPs was not made available). The only other datasets that were made available were the underground water supply network for Dhaka and national observation wells. Both of these datasets are not considered in this study, as they either are not affected by climate hazards (underground water supply network) or do not impact societies if affected (observation wells). Given this constrained number of water infrastructure assets, the analyses for the water sector were very limited; thus, further work is required, including data collection, to better understand water-sector climate risks. Riverine flooding is the only hazard that has been considered for this assessment, as it is the only climate hazard that affects the WTPs.

For the base year, none of the three WTPs experienced flooding, and Chandhi Ghat and Kushighat WTPs are not located in flood-prone areas for any of the flood scenarios. However, Saidabad WTP is expected to be flooded in the event of future extreme flooding (RP 100) in 2030 and 2050. In 2080, this WWTP can experience inundation during moderate (RP 25) and extreme (RP 100) events. Flood depths could range between 0.05m and 0.68m. Such exposure to flooding can result in direct economic damage. Table 3 exhibits Saidabad WWTP's exposure to riverine flooding in various future events and resultant economic damages. The total economic damage of €1,960 in 2030 (RCP 4.5) may increase to €9,798 (or a 400% increase) by 2080 (RCP 8.5). The other two WWTPs are not exposed to river flooding.

Table 3: Summary of the Saidabad WTP's exposure and estimated economic damage as a result of river flooding

Year	Return Period	RCP Scenario	Flood depth (m)	Damage in euro
2030	100	4.5	0.13	1,960
2050	100	4.5	0.16	1,960
2080	50	4.5	0.05	1,960
2080	100	4.5	0.23	1,960
2080	25	8.5	0.24	1,960
2080	50	8.5	0.47	3,919
2080	100	8.5	0.68	9,798

* Scenario shown here is for RCP 4.5 and RCP 8.5, and a return period of 1 in 25, 50 and 100 years

4.3 Climate Risks: Critical Social Infrastructure

Critical social infrastructure underpins the socio-economic functioning of societies. It is fundamental for the nation's progress towards sustainable development, for instance through the provision of education and healthcare. Access to critical social infrastructure is closely interlinked with the nearby transport network. The critical social infrastructure assets considered as part of the climate risk assessment are illustrated in Figure 10 below, and consist of 2,062 market centres, 3,086 healthcare facilities, 3,777 cyclone shelters, and 73,814 educational institutions. Location of market centres were provided by WARPO, healthcare facilities by Department of Health, cyclone shelters by LGED and educational facilities by BBS. The datasets were compiled, updated, processed and validated by CEGIS. Damage to these assets as a result of climate hazards can oftentimes result in a break in education, a disruption in access to required healthcare, and loss of livelihoods – and sometimes also lives – due to a lack of safe shelter. The four hazards of coastal flooding (including storm surges), riverine flooding, cyclonic winds, and coastal and riverbank erosion can all significantly impact social infrastructure, and thus are all considered in this assessment.

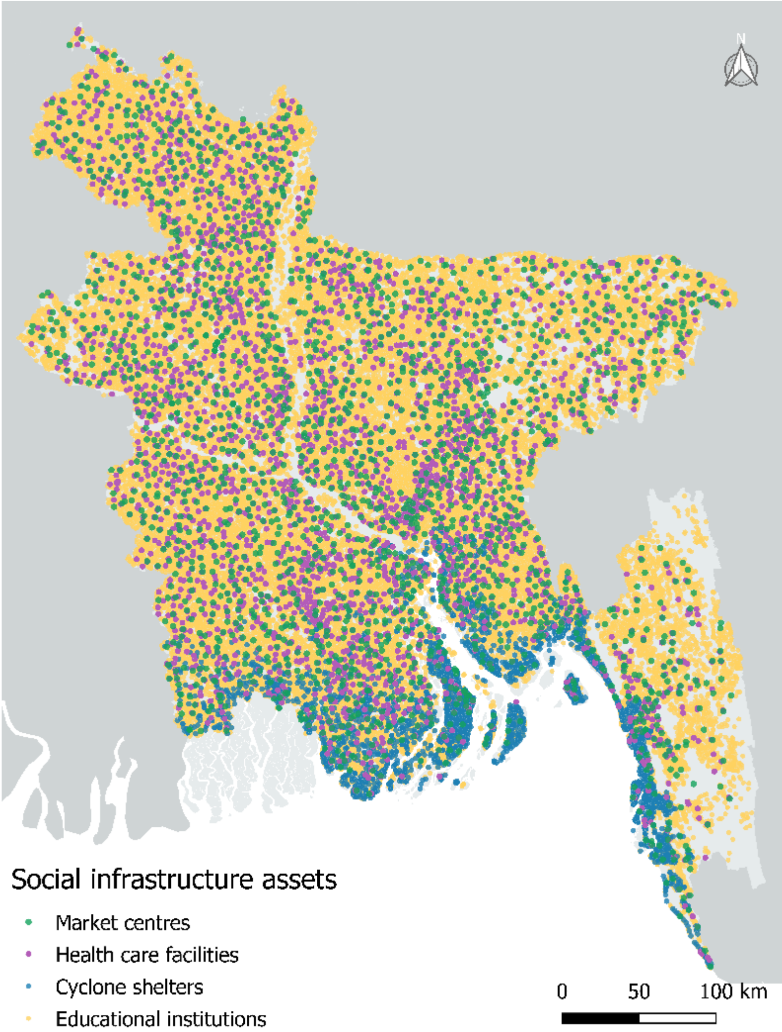


Figure 14: Geospatial data for water sector infrastructure assets and networks

Critical social infrastructure in Bangladesh is highly exposed to climatic hazards (Table 4). Overall, 95% of healthcare facilities (2,931), 70% of cyclone shelters (2,643), 93% of market centres (1,913), and 95% of education facilities (70,123) are exposed to all climate hazards combined for the baseline year. Under a 2050 RCP4.5 scenario, exposure to a 50 year *coastal* flood rises by 3.33% for healthcare facilities, 6.79% for cyclone shelters, 3.06% for market centres and 2.88% for education facilities. Under the same scenario, exposure to a 50 year *riverine* flood rises by 7.32% for healthcare facilities, 5.96% for cyclone shelters, 6.9% for market centres and 7.49% for education facilities.

The most impactful hazard is high cyclonic wind gusts; around 86% of Bangladesh's market centres, education facilities and healthcare facilities are within areas of potentially damaging wind gusts (>30m/s). Given that cyclone shelters provide safety to local populations within cyclone-prone areas, the high percentage of cyclone shelters exposed to cyclonic winds is expected.

The direct economic damages of the four climate hazards on the different critical social infrastructure is also illustrated in Table 4. For the baseline year, coastal flooding can cause approximately €20.71 million in damage, which increases by 24% (to €25.72 million) in 2050. For river flooding, the direct economic damage is estimated to be €13.18 million in 2050, which is projected to decrease in 2050 but then increase by 59% (to €20.90 million) in 2080.

Table 4: Summary of the critical social infrastructure sector's exposure and estimated economic damage as a result of climate hazards

Hazard		Critical Social Infrastructure							
		Health facilities		Cyclone shelters		Market centres		Education facilities	
		% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)
Coastal	Present day	14.65	0.34	51.79	0.67	13.61	15.55	14.64	4.15
	2050*	17.98	0.42	58.54	0.80	16.67	19.33	17.52	5.17
Riverine	Present day	17.24	0.18	15.78	NA	17.44	12.66	17.71	3.17
	2050*	24.56	0.15	21.74	NA	24.34	10.38	25.20	2.65
Cyclones**	Present day	85.81	NA	97.38	NA	84.69	NA	85.72	NA
Erosion***	Present day	56.06	NA	38.20	NA	53.30	NA	57.25	NA

* Scenario shown here is for RCP 4.5, and a return period of 1 in 50 years.
** Exposed to more than 30m/s of max wind gust
*** Exposed to erosion more than once per year

The exposure and damage of all individual energy assets for a variety of different scenarios of climate hazards are available in Annex 2; however, given that the greatest number of people are impacted by damages in education facilities as a result of riverine flooding, the exposure of the 73,814 education facilities in Bangladesh to river flooding for the 50-year event in 2050 is taken as an example here (Figure 11). For this future scenario, 25% of education facilities (18,603) are exposed to any level of river flooding, with 8% of education facilities (6,168) exposed to flooding exceeding 1m. When considering the extreme climate scenario of RCP8.5, exposure of education facilities to flooding exceeding 1m increases to 13% (as shown in the cumulative plot in Figure 11). As evident in the spatial distribution of exposure in Figure 11, the key areas where education institutions are most exposed to river flooding are the upazilas Rangunia, Nageshwari and Kotwali. In some of these most critically exposed areas, flood depths of >2m could likely lead to severe damages[7].

When focusing on the upazila Rangunia – as illustrated in the zoomed-in map in Figure 12 – the distribution of flood depths across the different education institutions is more apparent. In some education institutions flood depths in excess of 2.5m are anticipated in 2050, which could significantly damage or potentially destroy the entire school, resulting in long disruptions and delays in education for children and young adults. Given the Government has ambitious plans to ensure 100% completion rate of primary and junior secondary education by 2030, the resilience of education facilities to climate hazards must be enhanced.

[7] For flood depths of 2m, 75% of a structure are likely to be damaged

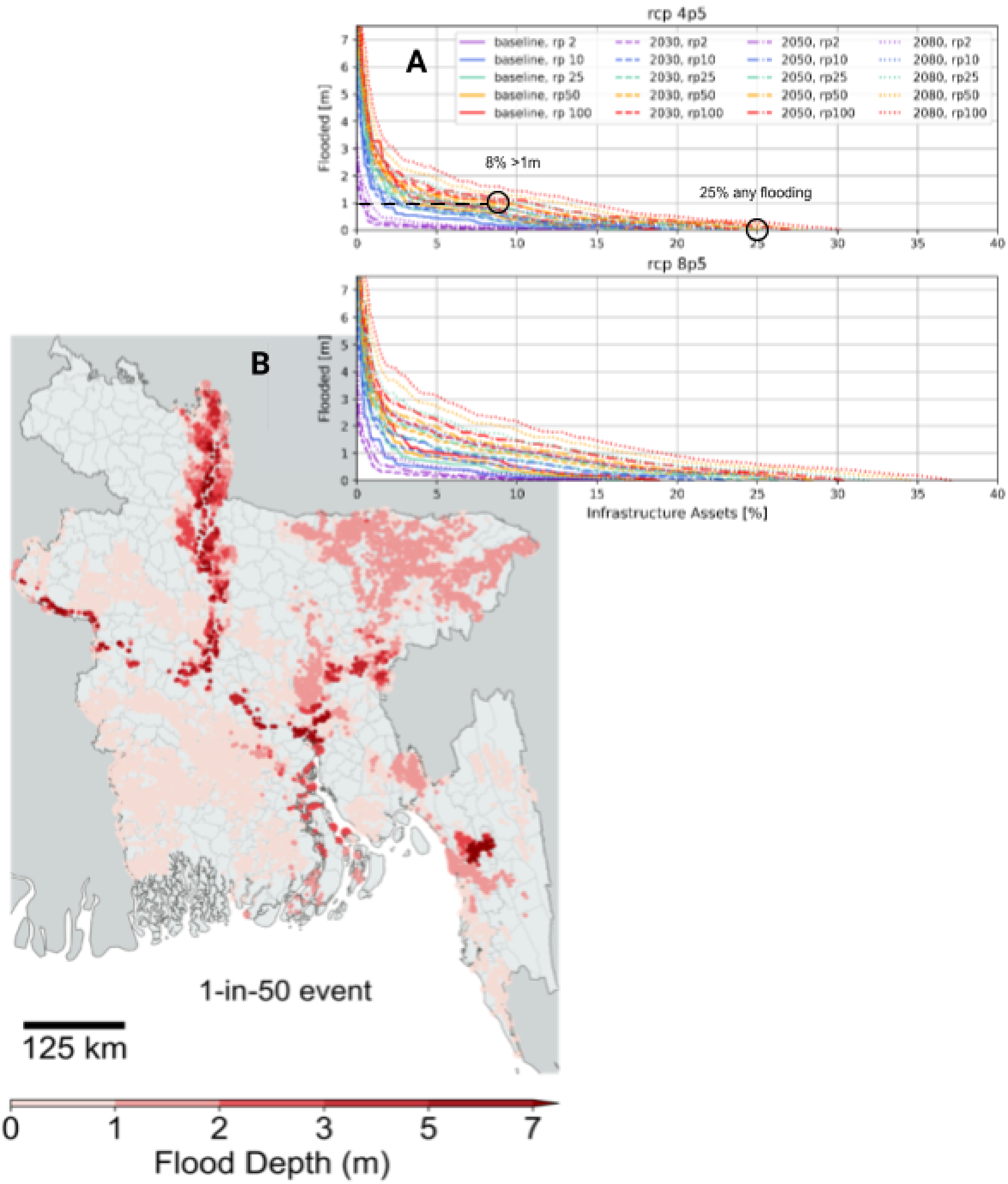


Figure 15: Exposure of education facilities to river flooding at the national scale. (A) Cumulative plot of education institutions exposed to river flooding at the national scale for all available climate scenarios. Less education facilities are exposed to high flood depths. (B) Spatial exposure of education facilities to river flooding for RCP4.5, a 50-year return period event, for the year 2050.

The direct economic damage of river flooding on education facilities is calculated using the depth-damage curve for education facilities from Huizinga, et al. (2017). Figure 12 below shows the spatial distribution, as well as the severity of economic damage to education institutions across Bangladesh as a result of river flooding for the 50-year event in 2050 (RCP4.5). Overall, the total damage to national education facilities is estimated at €2.65 million. This damage is likely to increase to €4.24 million in 2080. This is a significant increase in damage (60% higher than 2050) and does not represent a cumulative value. If such costs with respect to education facilities need to be absorbed at an annual scale, combined with additional (and more widespread) indirect disruptions, this will impact the nation's progress towards achieving SDG 4 (Quality Education) and will impede societal growth.

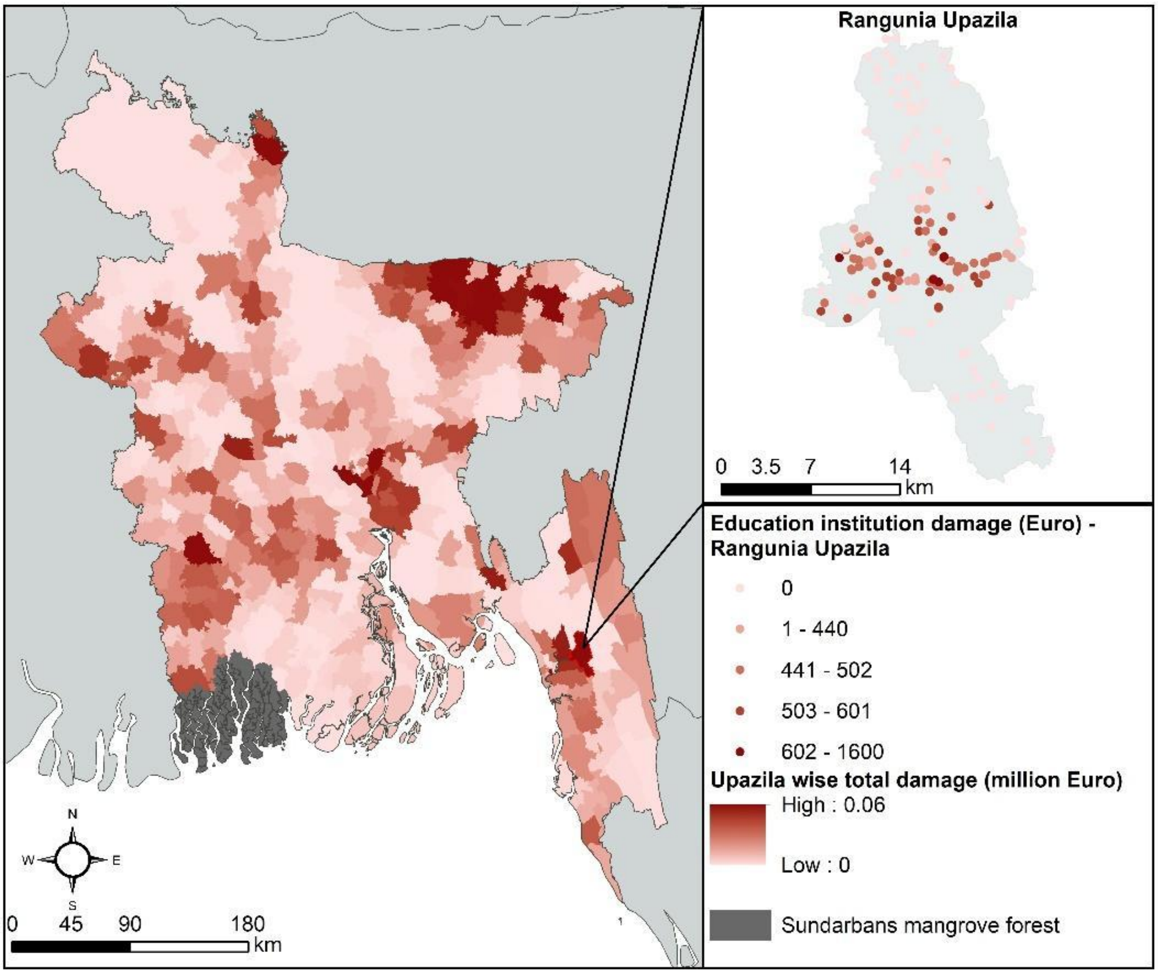


Figure 16: Upazila-wise total direct economic damage to Bangladesh's education facilities as a result of river flooding for the 50-year river flood event, for RCP 4.5, in the year 2050

The upazila that experiences the greatest total economic damage to its education institutions is the Rangunia upazila in the south-east of Bangladesh. Here, of the 162 institutions within the upazila, 80 experience economic damages of various degrees, with 20 located in areas where particularly high flood depths could be anticipated. Flood depths of this magnitude could also result in a series of other indirect impacts, such as nearby road damage, making education inaccessible for an extended period of time.

By intersecting this with population data (Tatem, 2017), the overall economic damage of river flooding on education facilities across Bangladesh affects 79.6% of the national population (~131.3 million people), of which 49.6% is female. The data also shows that these economic impacts to education facilities are predominantly affecting the poorest portions of the population, where the average wealth index across the 131.3 million people is -0.22 (see footnote 4 for further detail).

4.4 Summary of Climate Risks to Bangladesh's Infrastructure

When bringing all sectors and all hazards together, we can see, overall, where the hotspots are in terms of exposure and potential damages as a result of climate hazards.

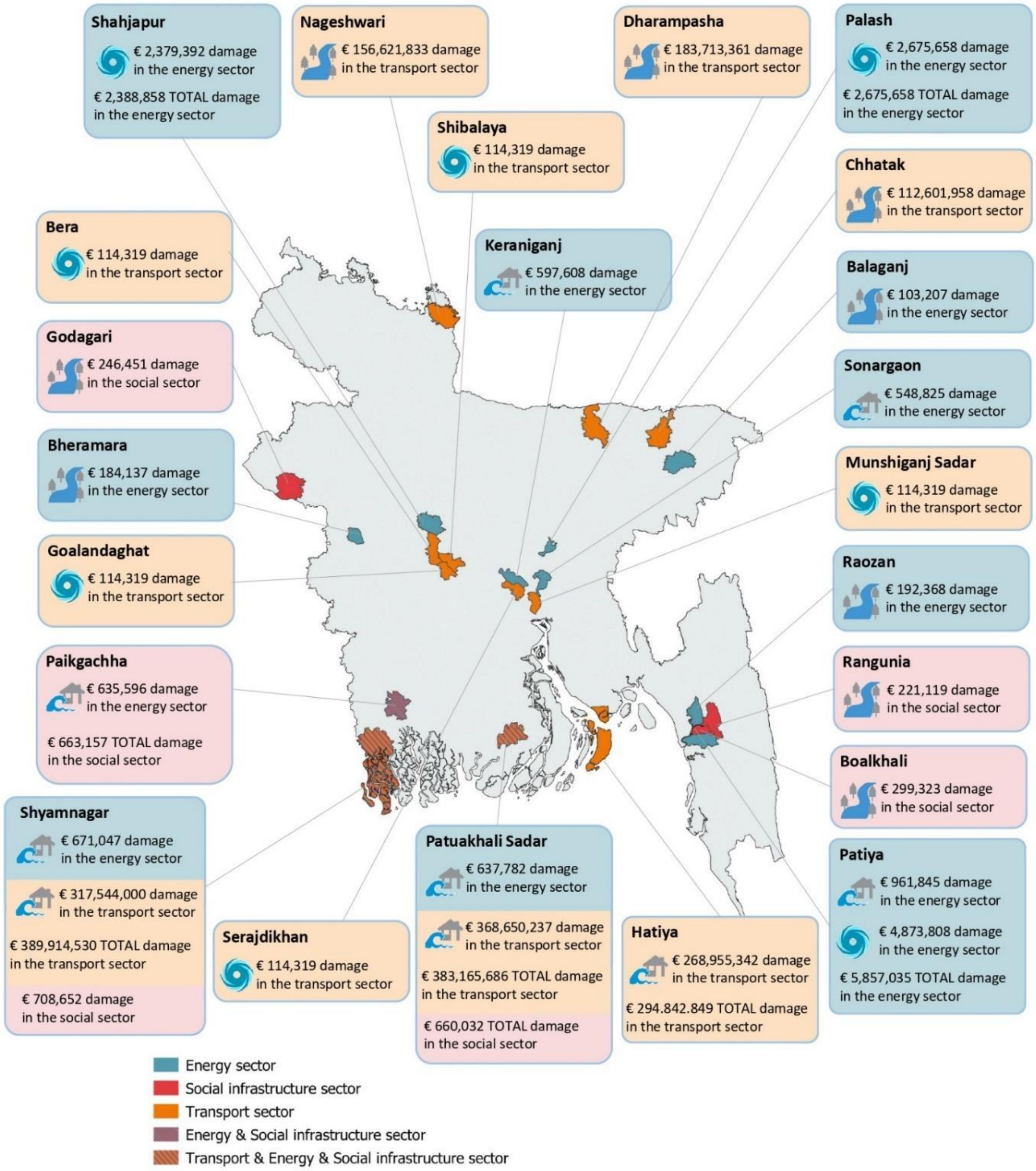


Figure 17: Summary map highlighting the key upazilas that experience the greatest exposure and direct economic damages to infrastructure assets

As evident from the summary map above, **Shyamnagar** and **Patuakhali Sadar** are the two upazilas where most impacts are felt across all infrastructure sectors from all hazards. In

Shyamnagar, transport assets and networks are expected to experience up to almost €400 million in damages as a result of climate hazards in 2050, of which the vast majority is caused by coastal flooding. In addition, critical social infrastructure could endure costs of over €700,000 as a result of climatic hazards, a similar figure evident in the energy sector. Similarly, in Patuakhali Sadar, the critical social infrastructure assets, as well as the energy sector assets and networks may experience damages of up to €660,000 each as a result of climate hazards, with the transport sector dominating the upazila-wide damage with an additional €383 million for the year 2050. It is important to note that the damage estimates are not cumulative; they represent the damage of solely the year 2050. Thus, climate hazards can have significant economic impacts on the transport, energy and social infrastructure sectors at the annual scale.

In addition to these two key upazila hotspots, there are also a number of other upazilas where significant exposure of assets and potential damages could be expected in 2050. Of note are Dharampasha (Sylhet region) and Nageshwari (northern Jamuna river region), where river flooding could lead to damages in the transport sector of up to €184 million and €156 million, respectively, and the Hatiya upazila (south central coast), where up to almost €300 million in economic damages could be anticipated in the transport sector, predominantly as a result of coastal flooding.

By combining this spatial understanding of where multiple climate hazards can generate risks to society via disruptions in access to basic services with other site-specific, localised knowledge, more targeted climate action can be implemented. This map alone, highlighting some key example areas of exposure and potential damages, should not be utilised as a prioritisation of assets or areas for climate adaptation.

5. INFRASTRUCTURE SERVICE PROVISION TO HOUSEHOLDS IN COASTAL BANGLADESH

The coastal region of Bangladesh is particularly exposed to climate hazards. Cyclonic storm surges affect the coast multiple times each year, with heights reaching 9m (Dasgupta et al., 2014). Considering 66% of Bangladesh is below 5m elevation (Dasgupta et al., 2014; Whitehead et al., 2018), coastal flooding can cause widespread disruption, damage, and destruction of infrastructure assets and the provision of services to people. In addition to such acute hazard events, background chronic hazards, such as natural and human-induced subsidence, are exacerbating the coastal risks to relative sea-level rise, salinisation, as well as the risk to storm surges and coastal erosion (Brown and Nicholls, 2015; Paszkowski et al., 2021). Climate change is expected to exacerbate the frequency and magnitude of these hazards in the coastal region of Bangladesh.

As a consequence of these interacting hazards, Bangladesh's Government has been focusing on the coastal region with a number of their coastal resilience investments and plans, including the Coastal Embankment Project (and it's subsequent Improvement Projects) (1968 onwards), the Gorai River Restoration Project (1998-2007), the Coastal Zone Development Programme, the Coastal Embankment Rehabilitation Project (1996-2002), and the Khulna-Jessore Drainage Improvement Project (1994-2002) (Paszkowski et al., 2021). At a strategic level, the Government has recently put together the Bangladesh Delta Plan 2100, which focuses on adapting to and mitigating future climate change to ensure a prosperous and resilient deltaic nation.

Given the complexity of natural and human interactions in the coastal region of Bangladesh, this section of the study assesses the impacts that infrastructure disruptions from climate hazards have on households for 19 districts (150 upazilas) in the coastal zone of Bangladesh. In order to achieve this, three key data categories are combined: (i) climate hazards; (ii) infrastructure assets; and (iii) household characteristics and welfare. The same climate hazards are used as in Section 2 of this report, namely, river flooding, coastal flooding, cyclones and erosion (see Box 1 for further detail). Figure 13 illustrates the infrastructure assets considered as part of this assessment, which span across the transport, energy, and critical social infrastructure sectors. The water sector is not included in this analysis because no data was made available for water infrastructure in the coastal region of Bangladesh.

The household-level population data was received from the World Bank (Rubinyi et al. *in press*). It is a spatially explicit synthetic household dataset for the coastal region of Bangladesh, including key household characteristics. One of the crucial attributes of the dataset is that it provides information on households' access to basic services. The Demographic Health Survey (DHS) Wealth Index (WI) is a previous household survey programme that has acknowledged that access to basic services forms an integral part of household wealth, particularly in developing countries, where wealth through income, expenditure, and consumption can be hard to measure. Thus, following such previous examples, the household-level information on access to basic services is used to develop a household-level wealth index for the coastal zone of Bangladesh. A separate wealth index is constructed for urban and rural households using a Principal Component Analysis (see Annex 1 for further detail).

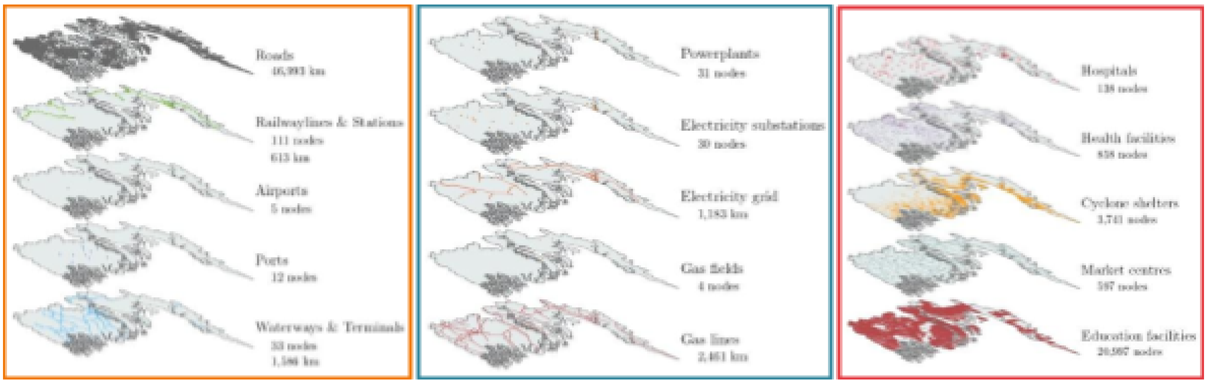


Figure 18: Infrastructure asset and network data for the coastal region of Bangladesh. Left box in orange illustrates the transport assets, teal box in the middle shows the energy assets and the red box on the right comprises critical social infrastructure assets

5.1 Household Access to Infrastructure Services

Overall, 100% of the almost 9 million households in the coastal region of Bangladesh are impacted by some service disruptions caused by climate hazards. Infrastructure service disruptions caused by cyclones affect the greatest number of households, with over 77 million instances of households being affected by infrastructure disruption across all baseline (present day) 1-in-50-year probability hazards. For the energy, transport, and social infrastructure sectors, an average of 71%, 75%, and 72% of households are disrupted by cyclonic winds, respectively. For coastal flooding, which is closely related to cyclones, there are almost 40 million instances of households being affected by infrastructure disruption for the future 2050 (RCP4.5) 50-year coastal flood event, with 80% of these corresponding to rural household impacts. Finally, under the baseline scenario, coastal flooding, river flooding, cyclones, and erosion disrupt on average 42%, 24%, 94%, and 47% of the coastal population, respectively, across all assets. Throughout the section, the term *cumulative number of households* is used when households are counted as many times as they have assets affected. For example, if a household experiences disruption to both its nearest railway station and education facility, it will be counted twice.

In rural parts of coastal Bangladesh, infrastructure service disruptions predominantly impact the poorest portions of the population. This is illustrated in Figure 14 below, which shows how service disruptions affect households cumulatively across wealth quintiles, and in rural versus urban environments. There is a natural skewness of the wealth index towards the poorer end of the wealth spectrum in rural areas, which may explain these results. Additionally, poorer rural populations are often more disproportionately impacted by climate hazards by living in higher-risk areas (Adnan et al., 2020; Brouwer et al., 2007; Hallegatte and Rozenberg, 2017; Winsemius et al., 2018). Contrastingly, in urban areas of coastal Bangladesh, the wealthiest portions of the population are most affected by infrastructure service provision. This is predominantly due to wealthier populations having access to more infrastructure services, and thus their cumulative disruption has a more significant impact, as well as the overall wealth index in urban Bangladesh being skewed towards the wealthier end of the spectrum.

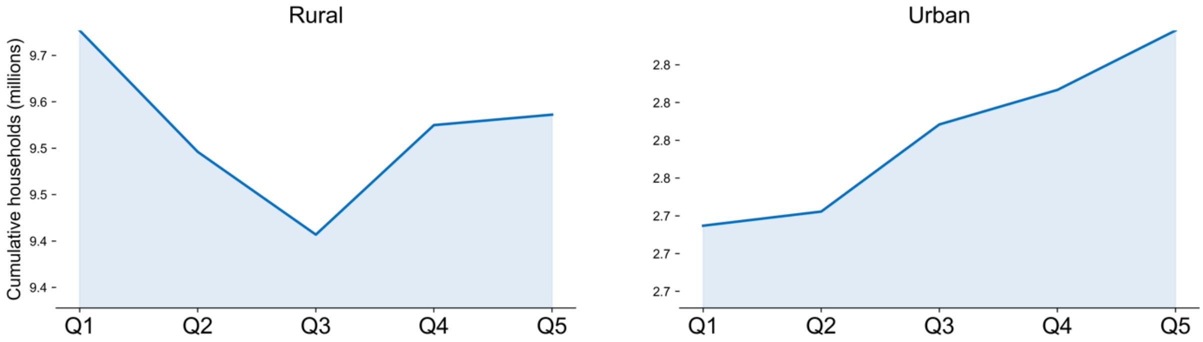


Figure 19: Cumulative number of households (in millions) affected by infrastructure disruption for rural and urban households

As mentioned previously, coastal Bangladesh experiences many hazards, which may coincide and have compounding impacts on coastal populations. In order to understand where such compound events may be most prominent, the number of hazards experienced per household in a given year in each upazila is assessed. Overall, 76% of coastal households are affected by more than one hazard, 37% by more than two hazards, and 6% by more than three hazards. The most common hazard combination is cyclones and coastal flooding, which is expected, as strong cyclonic winds are typically associated with high storm surges. As evident in Figure 15, the south-western coastal area of Bangladesh stands out as the area experiencing the greatest number of different hazards, with households in the Dighalia, Phultala, Gopalganj Sadar, Dumuria, and Shyamnagar upazilas experiencing infrastructure service disruptions from an average of 3.59, 3.58, 3.48, 3.33, and 3.3 different hazards, respectively.

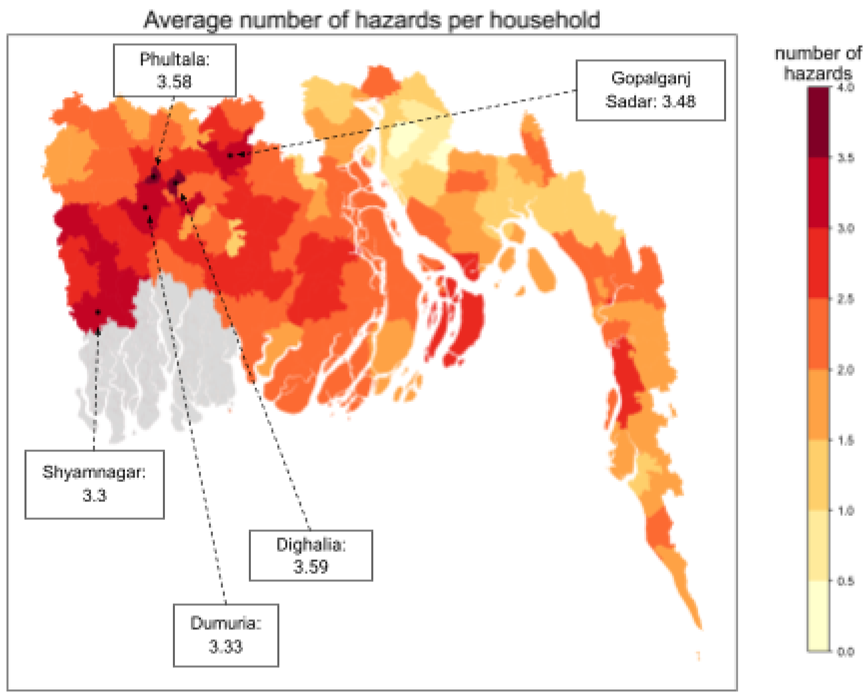


Figure 20: Spatial distribution of households affected by infrastructure service disruptions from a range of climate hazards, with five top most-affected upazilas and the corresponding average number of hazards each household is affected by.

Following on from the assessment of the sources of hazards that result in infrastructure service provision disruptions to households, spatial analyses are undertaken to further unpick how households are impacted differently at the infrastructure asset level (Figure 16).

For the **TRANSPORT** sector, 7,912,605 households in the coastal study area could be affected by disruptions in the nearby road network during a 1-in-50-year flood hazard, under the baseline (present day) scenario. Considering flooding in 2050 (RCP4.5), this increases to 7,923,813 households, or 97% of the 8,163,958 households in the coastal region. For railway stations and inland water terminals, 98% and 100% of households, respectively, experience disruption from a 1-in-50-year hazard under the baseline scenario. This disruption is largely driven by exposure to cyclone gusts which exceed 30m/s. Railway stations and inland water terminals are also exposed to erosion, affecting 44.53% and 21% of coastal households, respectively. Cumulatively, there are 18 million instances of households being exposed to disruptions to their nearest transport assets (roads, railway stations, or inland water terminals) due to any 1-in-50-year hazard, under the baseline scenario. Rural and urban households experience a similar level of disruption in the transport sector across all hazards. In urban areas, 42% of wealthiest households are exposed to road disruption by 1-in-50-year floods, compared to 48% of the poorest households. In rural areas, 52% of the poorest households are affected by road disruption due to floods, compared to 50% of the wealthiest households. The results for all hazard and asset combinations are included in Annex 2.

Taking the road network as an example for the rest of this section, we find that 2,718,761 rural households and 625,858 urban households are expected to be impacted in 2050 by disruptions in the road network as a result of a 1-in-50-year coastal flood event (RCP4.5). If the most extreme climate change scenario (RCP8.5) is considered, 25,0123 more rural households and 12,966 more urban households are impacted by the same event in 2050. Figure 16A shows the spatial distribution of the number of rural households impacted by disruptions in the road network as a result of river flooding, and has been categorised into the five determined wealth quintiles. It is evident across all wealth groups, that road disruptions have the greatest impact on households in the south-central and south-western upazilas of coastal Bangladesh. The maps in Figure 16A also show that wealth quintiles Q1 and Q2 have the greatest number of rural households impacted; for the whole coastal region, there are over 580,000 rural households affected by road disruptions in Q1, 70,000 more households than in the wealthiest quintile. The upazila with the greatest number of households affected by road disruptions is Galachipa (highlighted in the red box in Figure 16A, Q1). Here, over 75,000 rural households are impacted by road disruptions, of which 35% are in wealth quintile Q1, 28% in Q2, 18% in Q3, 13% in Q4 and 6% in Q5.

Therefore, in Galachipa, and in many other upazilas, disruptions in road services in rural parts of coastal Bangladesh impact the poorest portions of the population most significantly. In rural and remote parts of coastal Bangladesh, damages to the road network, on which vast numbers of populations rely, affect the mobility of households. Poorer populations may not be able to find other means of accessing basic services and continuing their livelihoods (e.g., by boat during flood season), which can have significant ramifications on household welfare, exacerbate poverty, and ultimately impair progress towards achieving household-level resilience.

For the **ENERGY** sector, all 8 million households in the coastal area are affected by potential disruptions to the nearest substation to at least one 50-year hazard event, under the baseline scenario. In all cases, assets are exposed to cyclone gusts exceeding 30m/s. In the electricity grid, 93% of households (7 million households) experience disruption to the nearest point on the electricity grid due to cyclone gusts, with 5 million rural households and 1.7 million urban households experiencing potential disruptions due to a 50 year cyclone. In urban centres, wealthier households experience more disruption; 99% of the wealthiest households experience disruption compared to 93% of the poorest households. In rural areas, poorer households are more exposed, with 95% of the poorest group experiencing disruption compared to 92% of the wealthiest households.

As highlighted in Section 4.2 of this report, the electricity grid (consisting of pylons and electricity transmission and distribution lines) is a key energy asset that is highly exposed to cyclones, and can have widespread ramifications due to its networked nature. Thus, the electricity grid is taken as an example to spatially assess how disruptions in this asset caused by cyclonic winds can affect the coastal population (Figure 16B) (see Annex 2 for results for all other hazard and energy asset combinations). In total, approximately 5.8 million rural households (71% of coastal households) and 1.7 million urban households (21% of coastal households) are affected by disruptions in the electricity grid for the 50-year cyclone event.

Figure 16B illustrates the spatial distribution of the number of rural households affected by electricity disruptions (via damages to the electricity grid) as a result of the 50-year cyclone event. These results are categorised across the five pre-determined wealth quintiles. In contrast to the impacts of road network disruptions, disruptions in the services provided by the electricity affect rural households equally across the coastal region; each wealth quintile makes up 20% of the total 6.3 million households impacted. The upazila with the greatest number of households affected by disruptions in the electricity grid is Sitakunda (highlighted in the red box in Figure 16B, Q1). Here, over 1 million rural households are affected overall, with the distribution across the wealth quintiles relatively even (Q1: 14%; Q2: 18%; Q3: 22%; Q4: 21%; and Q5:25%). Contrastingly, the Hatiya upazila (highlighted in the blue box in Figure 16B, Q1), contains the maximum number of households impacted within one wealth quintile, where over 43,000 households are affected by electricity grid disruptions within the lowest wealth quintile (Q1). This makes up 41% of the total 82,827 households affected in the upazila as a whole. In Hatiya, the wealthiest quintile only makes up 2.5% of the impacted households. This trend of poorer households being more exposed to electricity disruptions than wealthier households is true for 58 upazilas (28%) of the coastal region of Bangladesh. For 83 upazilas (54%) the opposite is true (the remaining 18% made up of unaffected upazilas). These findings suggest that, for rural coastal Bangladesh, disruptions in the electricity grid, due to damages to pylons or transmission or distribution lines, affect all types of households.

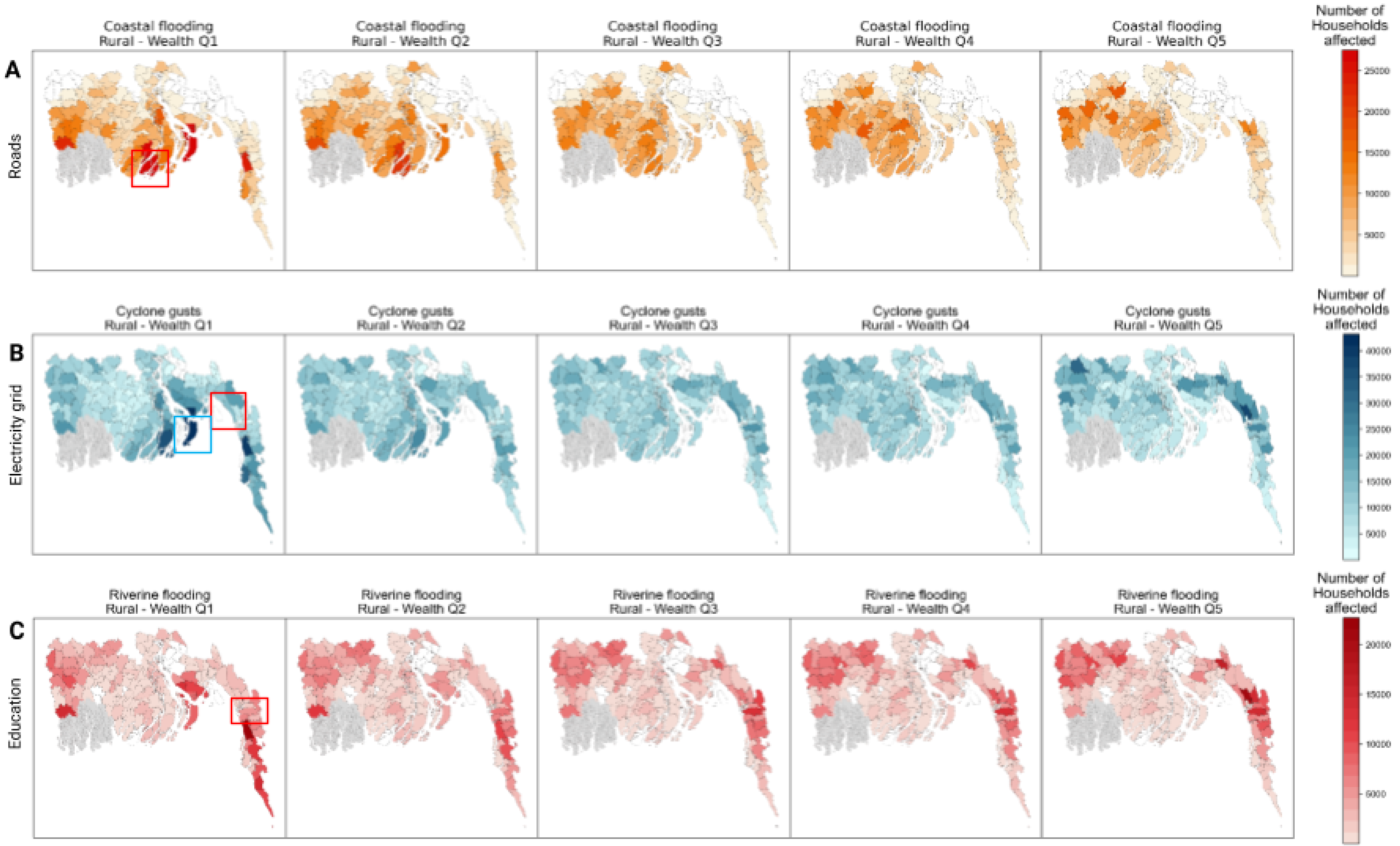


Figure 21: Examples of spatial distribution of number of rural households affected by disruptions in service provision across the five wealth quintiles for the three infrastructure sectors considered. (A) Example of road disruptions as a result of coastal flooding (transport example); (B) the number of households affected by disruptions in the electricity grid as a result of cyclones (energy example); and (C) the impact on households of disruptions in education services as a result of riverine flooding (social example). Note: wealth quintiles span from Q1 (poorest) to Q5 (wealthiest).

Finally, for the critical **SOCIAL** infrastructure sector, healthcare facilities, education institutions, cyclone shelters, and market centres, each have over 6 million households impacted by disrupted service from at least one 50-year hazard under the baseline scenario. Flooding alone affects between 3.8 and 4.8 million households under the baseline scenario, which increases to between 4.3 and 5.2 million for a 2050 RCP4.5 scenario. In both scenarios, cyclone shelters are the most exposed to flooding and healthcare facilities the least. For each asset, approximately 50% of all households in the coastal region are exposed to infrastructure disruption due to erosion, while over 90% of education facilities, growth centres are exposed to disruption due to cyclonic winds exceeding 30m/s.

Under baseline flooding scenarios, 51% of rural households (approximately 3 million) and 45% of urban households (approximately 80,000) are impacted by service disruption to education facilities. In both groups, the poorer wealth groups are more impacted with 40,000 more poor households affected than wealthy households in rural areas, and almost 30,000 more poor households affected than wealthy households in urban areas. As in Section 4, this section explores how river flood-induced disruptions to the 20,977 education facilities affect households differently in coastal Bangladesh (Figure 16C). As per the transport and energy descriptions above, Annex 2 provides the results for all other hazard and critical social infrastructure asset combinations. Overall, 1,344,215 rural households (21% of all coastal households) and 417,487 urban households (22%) are impacted by education disruptions as a result of river flooding.

Figure 16C shows the upazila-scale spatial distribution of the number of rural households impacted by education disruptions as a result of riverine flooding in the coastal region of Bangladesh, categorised into the five wealth quintiles. Similar to the findings for the electricity grid, disruptions in educational services affect rural households equally across the wealth quintiles in Bangladesh's coastal region; each wealth quintile makes up 20% of the total 1.8 million households impacted. The upazila that is most affected in terms of households impacted by educational disruptions caused by river flooding is Patiya, in the south-east (highlighted in the red box in Figure 16C, Q1). In this upazila, over 53,000 rural households are affected by service disruptions across the upazila's 515 education institutions. Most affected households are, in fact, in the wealthiest quintile (27%), with 24% in Q4, 25% in Q3, 15% in Q2, and only 9% in the lowest wealth quintile. This trend of wealthier households being more exposed to education disruptions than poorer households is true for 78 of the 153 coastal upazilas (51%, or 58% of the affected upazilas).

5.2 Summary of infrastructure service provision to households in coastal Bangladesh

To assess which upazilas are most at risk of disruption to multiple infrastructure services, Figure 17 shows, for four baseline 50-year hazard events (A-D), as well as across all four baseline hazards (E), the number of different asset types disrupted for each upazila. The colour scale shows the number of different assets across all sectors which are exposed to hazards, and the size of the marker represents the cumulative number of households dependent on the disrupted assets.

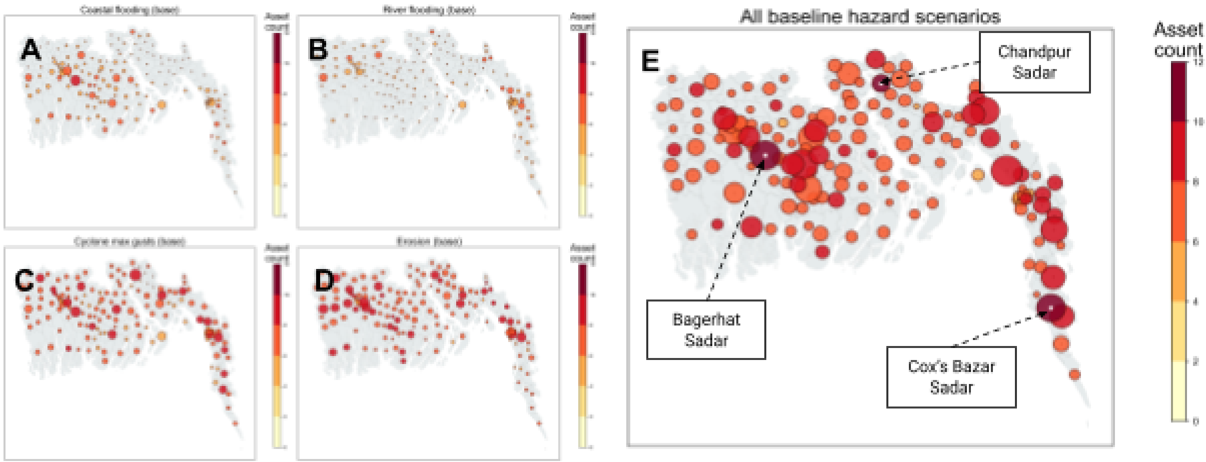


Figure 22: Number of assets and cumulative number of households affected by a 50 year hazard event for each of (A) coastal flooding, (B) riverine flooding, (C) cyclone maximum gusts, (D) erosion, and (E) across all hazards.

Across all baseline hazards, three upazilas experience disruption for all ten assets assessed (electricity substations, railway stations, inland water terminals, education facilities, market centres, health facilities, cyclone shelters, health facilities, the energy grid, gas lines, and roads). These are Bagerhat Sadar, for which over 4.5 million cumulative households experience disruption, Chandpur Sadar, for which over 4 million cumulative households experience disruption, and Cox's Bazar Sadar, for which over 1.5 million households experience disruption.

In the case of coastal flooding, Bagerhat Sadar is the worst-affected upazila, with disruption to eight different assets affecting over 1.9 million cumulative households. For riverine flooding, Patiya is the worst affected, experiencing disruption to seven different assets, affecting 915,085 cumulative households. Cyclone gusts disrupt nine different assets for Bagerhat Sadar, Chandpur Sadar, and Cox's Bazar Sadar, and erosion affects more than nine assets for five upazilas: Rupsa, Chandpur Sadar, Sitakunda, Feni Sadar, and Bagerhat Sadar.

The summary map below highlights key upazilas in the coastal region where high numbers of households are impacted by specific infrastructure service disruptions as a result of all climate hazards, and provides more information on results of specific asset and hazard combinations. As evident, disruptions in critical social infrastructure services have the most widespread and significant impacts on coastal households in Bangladesh. Of note, and in addition to the above-identified upazilas, are Hatiya and Banshkhali, where cyclones and coastal flooding affect both transport and social infrastructure service provision to households. Moreover, the tens of thousands of households highlighted within these two upazilas make up only the poorest portion of the upazila's population, emphasising that in these upazilas, poorest households are most severely impacted by service disruptions as a result of coastal hazards.

By combining such spatial understanding of hotspots of climate risks to society via disruptions in access to basic services with other site-specific, localised knowledge, more targeted climate action can be implemented. This map alone, highlighting some key example areas of exposure and households affected, should not be utilised as a prioritisation of assets or areas for climate adaptation.

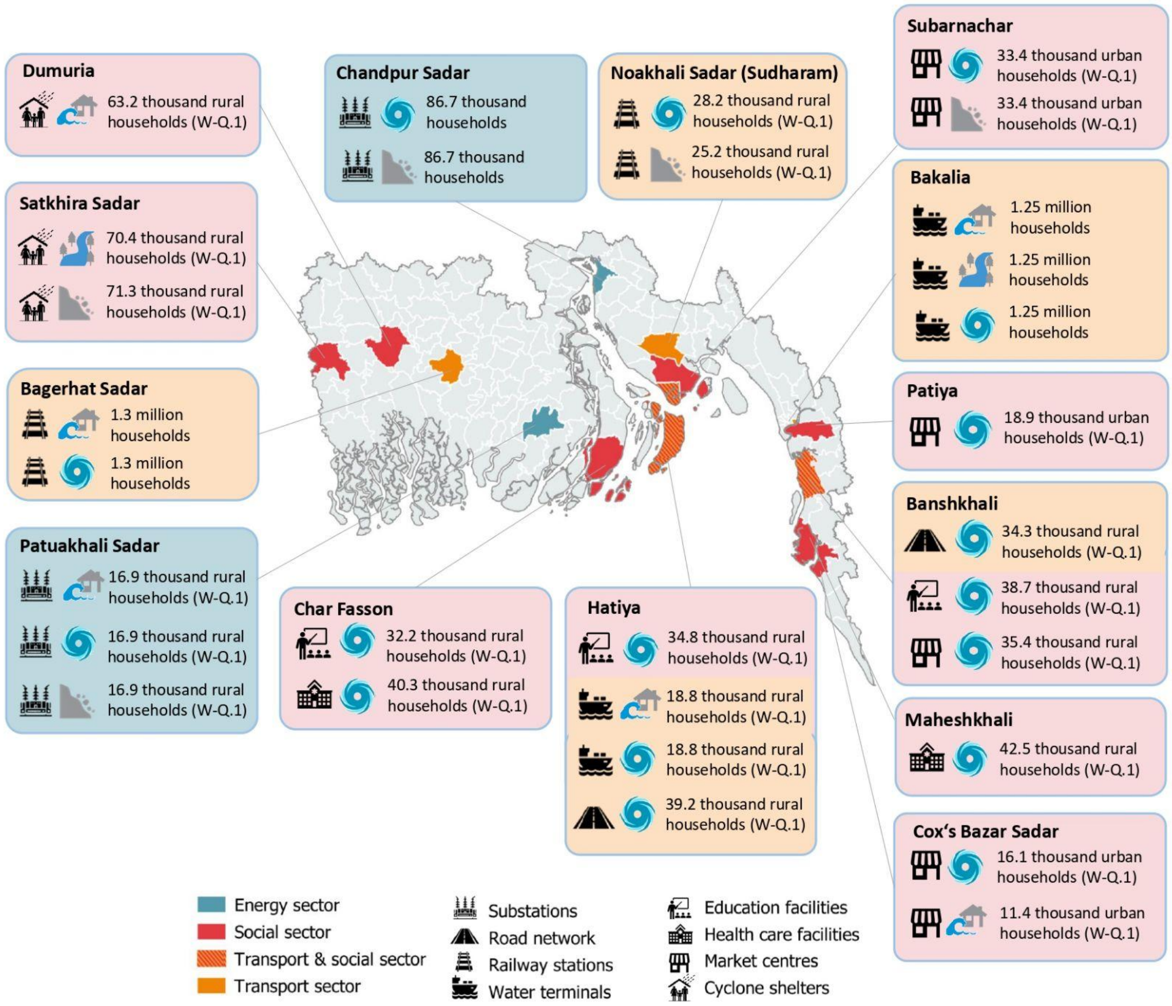


Figure 23: Summary map highlighting the key upazilas in the coastal region of Bangladesh where most households are impacted by service disruptions to a particular asset as a result of climate hazards

6. IMPACT OF SERVICE DISRUPTION ON THE ACHIEVEMENT OF THE SDGs

The household-level assessment has illustrated how different climate hazards can disrupt the services provided by infrastructure sectors, impacting households' access to basic services and overall wellbeing. The cumulative impact that such disruptions have on households affects Bangladesh's progress towards achieving national goals. In this section, the performance of selected SDG indicators, particularly across relevant and measurable indicators linked to energy, transport, and social infrastructure sectors is assessed, through the lens of service disruption as a result of climate hazards. The Government of Bangladesh has a framework in place to localise the SDGs, which highlights 39 priority indicators to measure progress towards key SDG targets, defined by the SDG Working Committee of the Prime Minister's Office and supported by all relevant government ministries. While some of these indicators are selected from existing global assessment frameworks and dashboards, others have been modified to account for the unique challenges experienced in the country (Figure 12). By assessing the current progress towards achieving a selection of these indicators, we can gain an understanding of how and where disruptions to infrastructure service provision play a crucial role in risking continued progress towards SDG achievement.

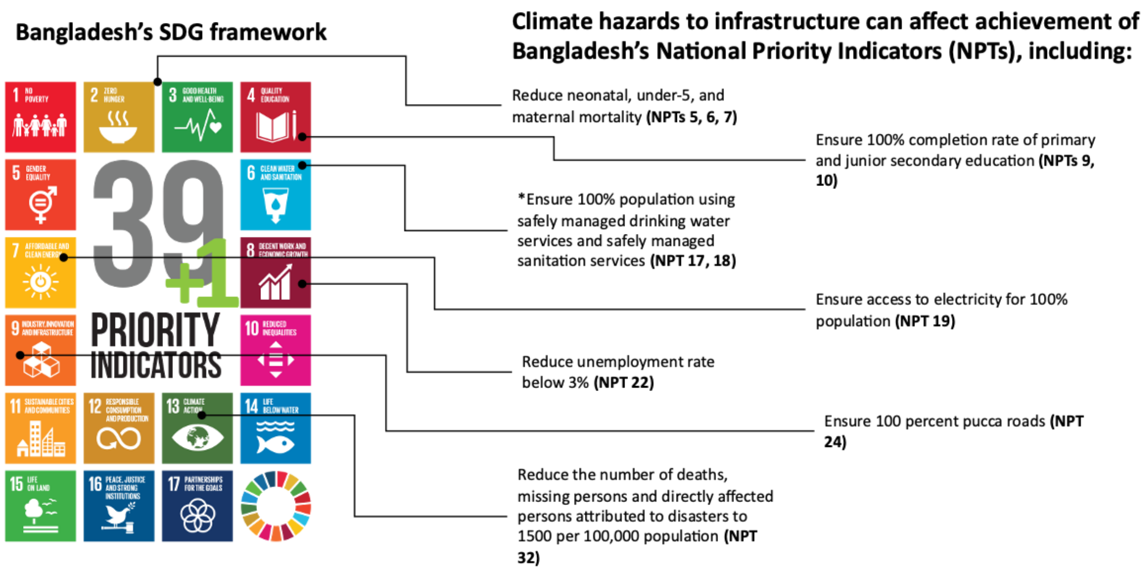


Figure 24: Seven SDGs have priority indicators that are directly linked to infrastructure service provision at risk to climate hazards

The coastal population's socio-economic characteristics, extracted from the household-level data addressed in the previous section, provides a spatial perspective of where the gaps in target achievement are largest. Intersecting these socio-economic characteristics with likely scenarios of climate hazard exposure (in this case, RCP 4.5, return period 50 for the year 2050 was used), gives us an understanding of where infrastructure is required to close these gaps. We connect infrastructure sectors or sub-sectors addressed in this study (e.g., substations, roads, education facilities, market centres, healthcare facilities, and cyclone shelters, amongst others) to the achievement of SDG indicators, assuming that their disruption may either halt or reverse progress. Given the lack of available water infrastructure data for the coastal region of Bangladesh, SDG6 could not be spatially assessed in relation to households. Thus, the progress towards achieving six relevant SDG targets is analysed, detailed in Table 6 below, which includes how the household-level data was used as a proxy.

Table 6: Relevant SDGs assessed, how their current SDG progress is measured using the household-level data, and how climate-induced disruptions to infrastructure services is used as proxy to estimate the impact on SDG progress

Relevant SDG & NPTs	Current SDG progress measured by district	Proxy of disruption to SDG progress
NPTs: 5, 6, 7	Households with health facility within 5km	Household disruption to nearest health facility (%)
NPTs: 9, 10	Completion rate of >5 years education reported by households	Household disruption to nearest education facility (%)
NPT: 19	Electricity access reported by households	Household disruption to nearest substation (%)
NPT: 22	>18 employment reported by households	Household disruption to nearest market centre (%)
NPT: 24	Household use of pucca roads (as share of total road use)*	Road network exposure (%)
NPT: 32	Households with shelter within 2km	Household disruption to nearest shelter (%)

* WB household data supplemented by road access data from BBS (2018) Report on Agriculture and Rural Statistics

The impact that the individual four climate hazards (coastal flooding, river flooding, cyclones and erosion) have on the progress of each SDG target is available in Annex 2, and a summary showing the average across the four hazards is illustrated in Figure 13. The results can be summarised as follows:

- **SDG 3 – Good health and wellbeing:** The Feni district, in the south-east of coastal Bangladesh, shows lower average household proximity to health facilities, combined with high exposure of these assets to multiple different climate hazards. In particular, cyclones, river flooding and associated erosion play important roles in affecting progress towards achieving this SDG. In the Feni district, up to 30% of progress towards achieving SDG3 is at risk. Other notable districts, where progress towards achieving SDG3 is also at risk include Noakhali and Cox's Bazar.
- **SDG 4 – Quality education:** The key districts that show lower overall household education outcomes, combined with high exposures of nearby education facilities to multiple climate hazards include Satkhira, Narail, and Bhola. Progress towards

achieving quality education in the Satkhira district in the south-west of Bangladesh is impacted by all four hazards, whilst in Narail, river flooding and its associated erosion have the most significant impact. In Bhola, cyclonic winds and severe coastal flooding affect progress towards achieving quality education most.

- **SDG 7 – Affordable and clean energy:** For energy access and electrification, Satkhira, Patuakhali, and Gopalganj districts have both low levels of household electrification and high potential disruptions to nearest substations from multiple hazards. Satkhira and Gopalganj's progress to electrification are impacted by all four hazards, whilst Patuakhali's progress is mostly impacted by cyclonic winds and their associated storm surges and erosion.
- **SDG 8 – Decent work and economic growth:** For employment, Khulna, Jhalokhati, and Narail districts report lower employment rates combined with interrupted access to markets, a key source of employment and income. The progress towards achieving SDG8 in Khulna and Narail is impacted by all hazards, and in Jhalokati, all hazards have significant impacts on progress except for river flooding.
- **SDG 9 – Industry, innovation and infrastructure:** For pucca road network development, the Narail, Pirojpur, and Khulna districts have low use of pucca roads combined with high degrees of road network exposure to multiple climate hazards. The progress towards achieving SDG 9 in each of these districts is due to a combination of all hazards.
- **SDG 13 – Climate action:** For the protection of people from climate shocks, households in Khulna, Satkhira, and Jhalokhati are furthest from shelters on average, which also simultaneously face high degrees of exposure to climatic hazards. The progress towards achieving SDG 13 in each of these districts is due to damage to shelters caused by all four climate hazards.

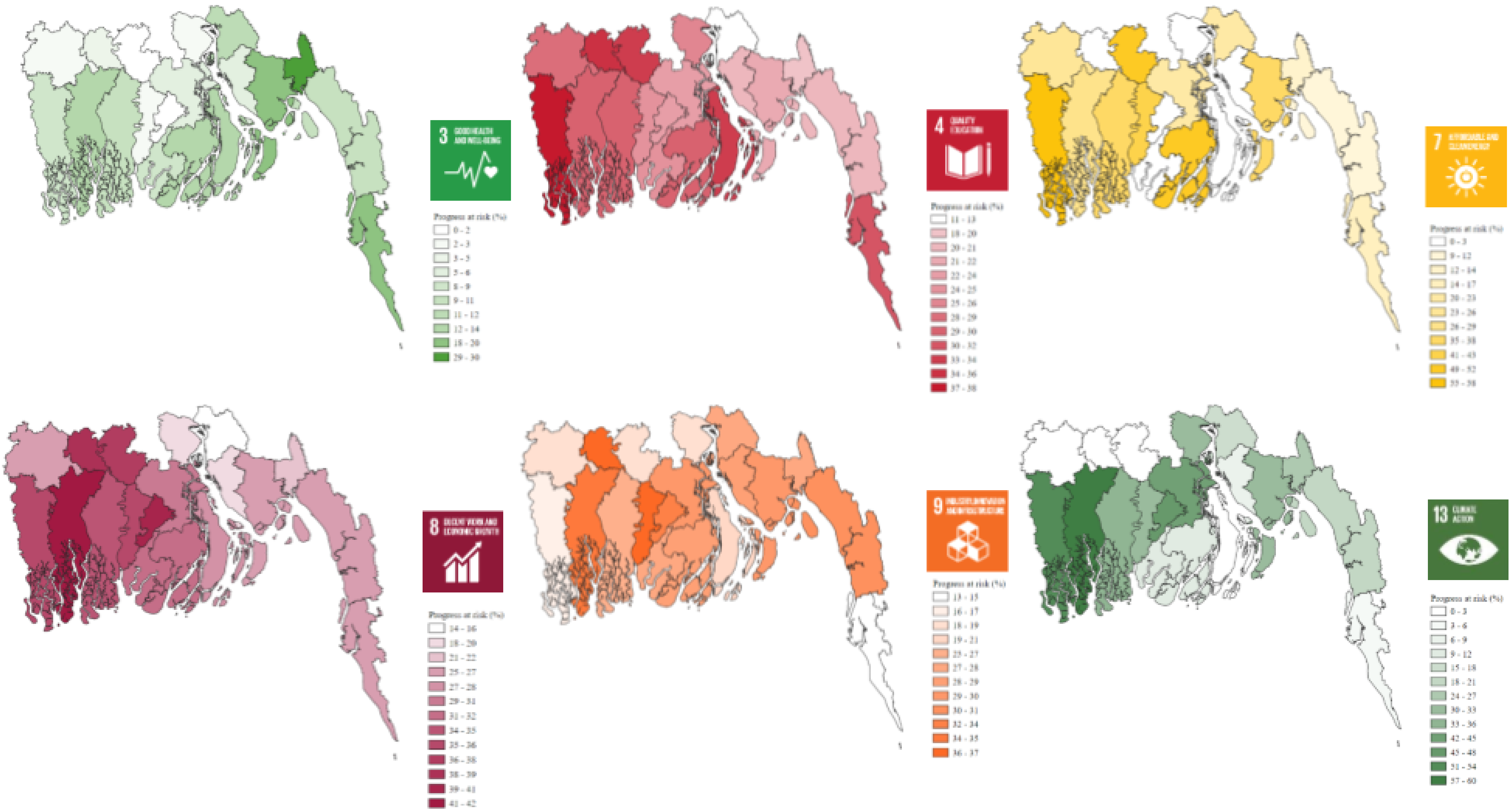


Figure 26: Summary of progress at risk for each of the six relevant SDG targets. Progress at risk refers to how climate hazards cause disruptions in infrastructure provision to households, affecting their overall progress for sustainable development.

When combining all the hazards and all the relevant SDG targets, Figure 14 illustrates the overall SDG progress at risk for each of the coastal districts, ranked. It is evident from this figure that the south-western coastal districts of Satkhira and Khulna are most likely to experience a halting or reversing of achieving infrastructure-related SDGs by 2050 due to the high exposure of key assets to different climate hazards, as well as low levels of current SDG progress. The figure also illustrates which SDGs are most affected for each district. In order to ensure localised progress toward full achievement of its national SDG agenda, the Government of Bangladesh should target its adaptation responses where climate threats to progress on priority indicators are most likely and impact the most vulnerable populations.

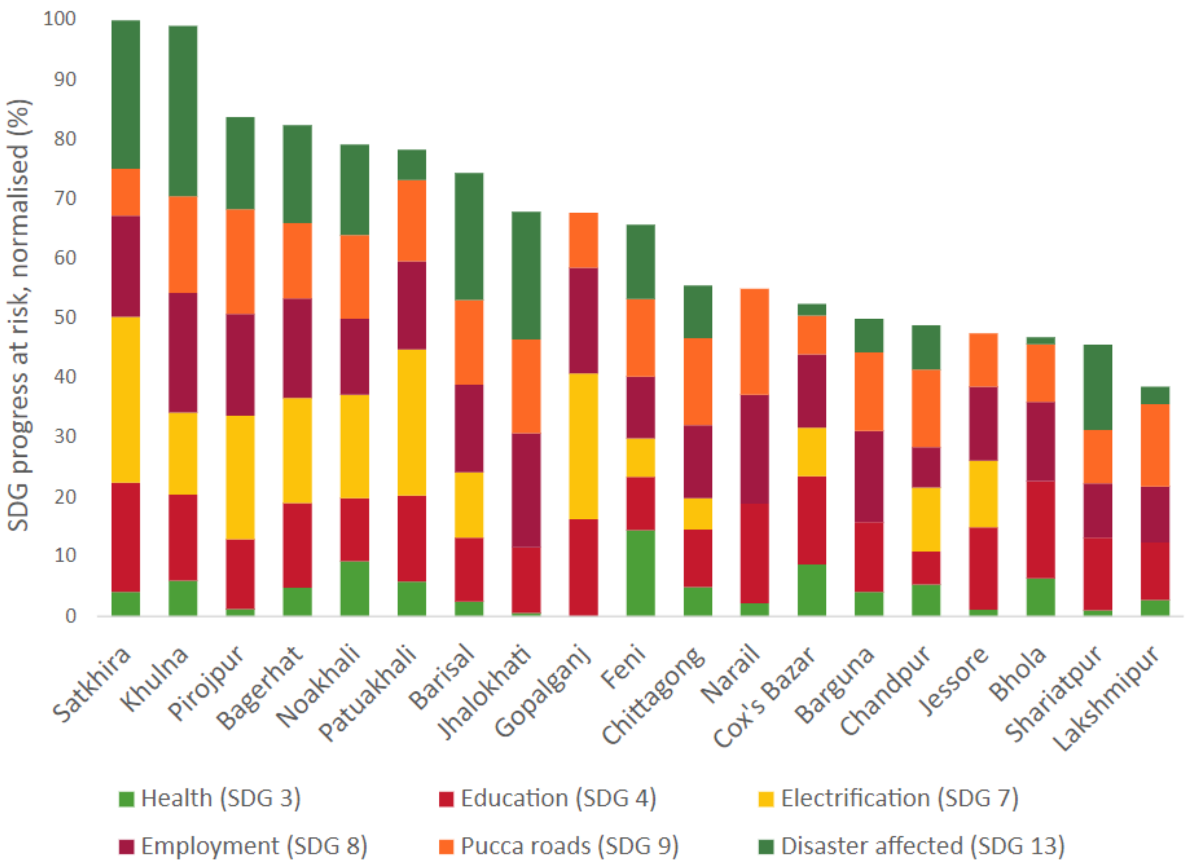


Figure 27: Ranked districts based on their cumulative SDG progress at risk from all climate hazards

7. SCALING UP CLIMATE-RESILIENT INFRASTRUCTURE IN BANGLADESH

7.1 Priority Infrastructure Adaptation Needs

Priority adaptation needs vary depending on the primary risks that prevail in a given geographical area. For example:

1. Coastal flooding has a major impact on the transport sector including roads and railway stations
2. The energy sector is vulnerable to cyclonic winds, which can impact the supply of power to 145 million people including the infrastructure assets that provide essential services.
3. Approximately 86% of social infrastructure (markets, schools and health centres) are significantly exposed to cyclonic winds.

Clearly, not all assets can be targeted for adaptation and or retrofitting at once. However, the planning for future and ongoing adaptation can commence. Adaptation measures for climate resilience in Bangladesh must take on a holistic multi sector, yet site-specific approach; the country's challenges are highly complex and intertwined, and therefore should be assessed across scales. Many scientific studies have highlighted that a mosaic of different adaptation measures are required in Bangladesh that strike a balance between (i) building elevation in order to sustain rising sea levels and increased flood risk (such as Tidal River Management); (ii) sustaining natural ecosystems and the services they provide through nature-based solutions, such as mangrove afforestation along the coastline to provide a buffer against cyclones; (iii) a level of controlled management of climate risks through hard engineering measures, such as river and channel embankments and coastal and riverine flood walls; (iv) localised individual household-scale measures that enhance resilience; and (v) land zoning that encourages out migration of high risk areas. Further multi-stakeholder and interdisciplinary research is required to identify which measures are most appropriate across which hazard-prone areas in Bangladesh. The assessment undertaken as part of this project supports this process by providing the first step in identifying which areas are most at risk, when assessing how climate hazards impact society through the provision of infrastructure services.

In this context, the LGED Asset Management and Decision Support System developed under the National Resilience Programme (NRP) can play a vital role in supporting the prioritisation of adaptation solutions, by enabling the various sectors to monitor the conditionality and functionality of these assets and then to programme retrospective resilience measures within annual operating budgets. Similarly, the AMS/DSS can be used to guide the decommissioning and replacement of assets, thus ensuring the sustainability of the services. This will require that assets identified within this study are uploaded into the AMS and that their conditionality be assessed against the prevailing risk context including those from non-climatic sources (i.e. built environment and earthquakes) and then frequently monitored.

7.2 Bangladesh priority areas of investment from key plans

Bangladesh has made significant progress in a range of sectors and aspires to emerge as a developed nation by 2041. Good achievement in attaining the MDG targets, crossing the lower income country level in 2015, reducing gender gap and increasing gender equality, impressive and well-recognized progress in economic, food production and infrastructure development, upcoming graduation from the LDC group in 2024 and upliftment into an upper income country by 2031.

Over the next two decades, Bangladesh will experience an accelerated pace of change that will be rapid and transformational. It will have to cope with rapid transformational shifts in agriculture, trade and industry, in education and healthcare, in transportation and communication, and in the way we work and conduct business. Rapid growth will be balanced with an emphasis on equitable distribution of the benefits of growth for all, especially the poor and the vulnerable.

The key policy drivers to achieve the change are:

1. Bangladesh Delta Plan (BDP) 2100

2. Vision 2041 seeks to eliminate extreme poverty and reach Upper Middle-Income Country (UMIC) status by 2031, and High-Income Country (HIC) status by 2041 with poverty approaching extinction.

3. Perspective Plan of Bangladesh 2021-2041' (PP2041). Fundamentally, the main focus of the PP2041 environmental management strategy is to integrate environment and climate change considerations in the growth strategy. Essentially, under PP2041, Bangladesh will adopt a green growth strategy. The specific strategies, policies and institutional reforms include: (a) Integrating Environmental Costs into the Macroeconomic Framework; (b) ***Implementing the Delta Plan to Build Resilience and Reduce Vulnerability to Climate Change***; (c) Reduce Air and Water Pollution; (d) Removal of fuel subsidies; (e) Adoption of green tax on fossil fuel consumption; (f) Taxation of emission from industrial units; and (g) Prevention of surface water pollution; (h) Geo-spatial data analysis for evidence based decision making

4. The 8th Five Year Plan. The government has launched the 8th Five Year Plan. This plan centres around six core themes, which are (i) rapid recovery from COVID-19; (ii) GDP growth acceleration, employment generation and rapid poverty reduction; (iii) **a broad-based strategy of inclusiveness;** (iv) ***a sustainable development pathway that is resilient to shocks and climate variability***; (v) improvement of critical institutions necessary to lead the economy to Upper Middle Income Country status by 2031; and (vi) attaining SDGs targets and mitigating the impact of LDC graduation.

In addition, the Bangladesh United Nations Sustainable Development Cooperation Framework (UNSDCF) Strategic Priority 3: Sustainable, Healthy and Resilient Environment is relevant; Sustainable Development Goals - 2030 Vision; the Sendai Framework for Disaster Risk Reduction (SFDRR), the Paris Climate Agreement, the 6th Session of the Commission of the Status of Women report detailing recommendations - "Achieving gender equality and the empowerment of all women and girls in the context of climate change, environmental and disaster risk reduction policies and programmes" are relevant global frameworks that Bangladesh is a signatory to.

For this study the intervention is limited and it is following the directives of the national policies listed above but for the purpose of this study we will be focussing on the concrete interventions and potential entry points that could absorb this outcomes - this will contribute to the objectives of the national plans

7.3 Integrating Adaptation into National Infrastructure Plans and Policies

Climate adaptation in the context of infrastructure follows an "all hazards" risk analysis process including non-climatic and built environment risks. The key is to be able to accurately determine the climate variability risk context and more specifically how this is changing existing risk associated with climatic hazards. Further, understanding what needs adaptation is required and in what sector is also important given that secondary risk impacts from one sector to another often go undetected. As such adaptation solutions are usually incorporated: 1) within the design process based on a Risk Informed Development process leading to resilience building - this includes cross sector and built environment risks; 2) as a consequence of the asset management process, where changes in risk contexts are observed and or the weaknesses in the conditionality of assets are identified and retrofitting or refurbishment is undertaken; and or 3) following a disaster where the failure analysis process has identified gaps in either the design, compliance or regulatory systems.

Importantly, adaptation must also apply to the systems that support the functioning of the infrastructure asset - energy, water, solid waste, ICT and access routes.

The processes for achieving "infrastructure adaptation" are highlighted in discussions around risk informed development and resilience broadly. Currently, the adaptation planning process follows the following steps and further discussions should be considered to integrate this into the broader risk informed and resilience planning frameworks which are underpinned by hazard and climate risk analysis:

- Prioritized NAP establishing an inter-institutional NAP coordination mechanism,
- enhancing climate variability data and use in planning,
- carrying out sectoral, regional and ecosystem-level climate vulnerability assessments, drafting a NAP, based on consultations,
- developing sectoral action plan and budgets,
- undertaking appraisals and costing of "adaptation" options with updating the Climate Fiscal Framework and
- establishing a monitoring framework for the NAP process

7.4 Description of the overall / line of sight planning processes in Bangladesh

The Government's Vision 2041 seeks to eliminate extreme poverty and reach Upper Middle-Income Country (UMIC) status by 2031, and High-Income Country (HIC) status by 2041 with poverty approaching extinction. To convert Vision 2041 into a development strategy, with policies and programmes, the government has launched 'Making Vision 2041 a

Reality: Perspective Plan of Bangladesh 2021-2041' (PP2041). The PP2041 builds on the successes of PP2021, while also drawing on the good practice experiences of current UMICs and HICs that have already travelled the development path that Bangladesh is endeavouring to travel.

Fundamentally, the main focus of the PP2041 environmental management strategy is to integrate environment and climate change considerations in the growth strategy. Essentially, under PP2041, Bangladesh will adopt a green growth strategy. The specific strategies, policies and institutional reforms include: (a) Integrating Environmental Costs into the Macroeconomic Framework; (b) *Implementing the Delta Plan to Build Resilience and Reduce Vulnerability to Climate Change*; (c) Reduce Air and Water Pollution; (d) Removal of fuel subsidies; (e) Adoption of green tax on fossil fuel consumption; (f) Taxation of emission from industrial units; and (g) Prevention of surface water pollution; (h) Geo-spatial data analysis for evidence based decision making

The government has launched the 8th Five Year Plan (FYP). This plan centres around six core themes, which are (i) rapid recovery from COVID-19; (ii) GDP growth acceleration, employment generation and rapid poverty reduction; (iii) a broad-based strategy of inclusiveness; (iv) *a sustainable development pathway that is resilient to shocks and climate variability*; (v) improvement of critical institutions necessary to lead the economy to Upper Middle Income Country status by 2031; and (vi) attaining SDGs targets and mitigating the impact of LDC graduation.

The vision contained within these plans is critical to focusing development efforts and priorities, however, Bangladesh remains a highly vulnerable country to the impacts of natural, climatic and human induced hazards or shocks and as such all development must be underpinned by a strong resilience foundation or development goals and ambitions will be severely undermined.

The Asian Development Bank (2016) estimated the economic loss from 2000 to 2013 was USD$10.7 billion, where floods caused USD$7.1 billion USD (66%), tropical cyclones USD$3.2 billion (30%), earthquakes USD$14 million (0.13%) and severe storms USD$374 million (3.5%). Such losses cannot be sustained if the ambitions of Vision 41 are to be realised.

7.5 Five Year Plan (FYP) Structure and Organisation

The FYP formulation process provides scope for integration at macro-level (National); it is divided into a four (4) step process:

Step 1: The General Economic Division (GED) of Bangladesh Planning Commission (PC) initiates the FYP formulation process with the evaluation of past plan performance, through measuring the progress against the previous FYP (Mid-term Evaluation). There are two parts associated with this process, namely (i) Macro Economic level, and (ii) Sector level.

- Technical background papers are prepared following each sector situational analysis and with prospective policies and strategies for next 5 years.

Note: Technical Background papers can give directives to the sector plans and strategies having the scope for integration (*Entry Points*).

Step 2: The Four Sector Divisions of Planning Commission (PC) initiate discussions with sector stakeholders (i.e. different MDAs) to establish what their plans are for the next 5 years. Following are the four relevant Sector Divisions of PC related to the UNOPS/GCA project:

a. Socio Economic Infrastructure (SEI) Division
b. Agriculture, Water Resources and Rural Institution (AWR&RI) Division
c. Industries and Energy (I&E) Division
d. Physical Infrastructure Division (PID)

Step 3: the GED analyses all inputs to ensure alignment with the Macro Economic Development Framework. It then reconciles the inputs with the resource availability in coordination with the three Divisions of the Ministry of Finance (MOF) - viz-a-viz., the Finance Division (FD), Internal Resources Division (IRD) & Economic Relations Division (ERD). In relation to foreign resources, the Programming Division (PD) of the PC will for the purpose of ADP, estimate the availability of resources for development projects and programs.

Step 4: According to the reconciliation against the resources mentioned at step 3, the GED calls back PC meetings and through iteration, aligns plans with the available resources.

FYP formulation cycle: Graphical representation

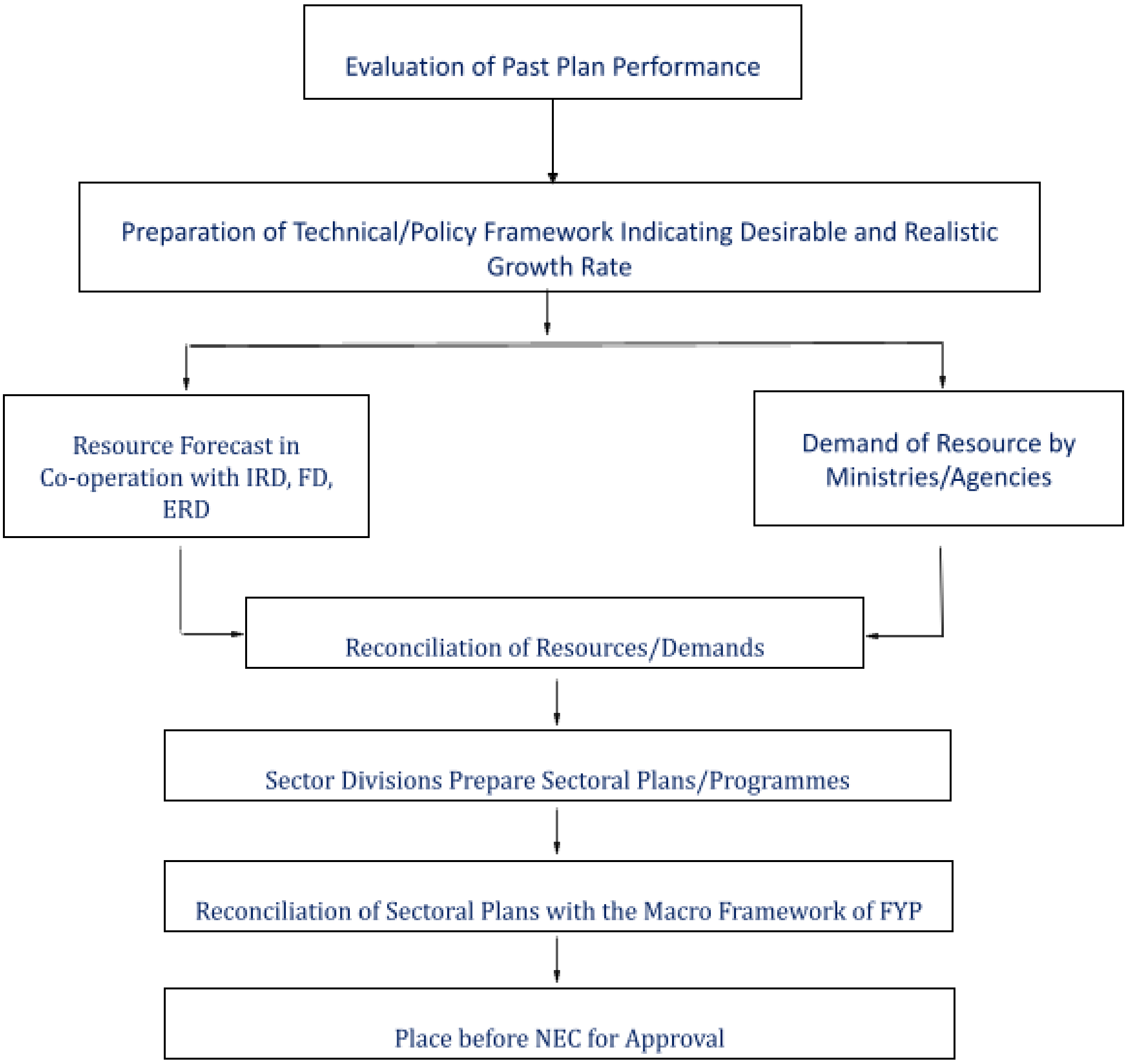


Figure 28: Graphical representation of the FYP formulation process

Description of Annual Development Programme more in detail and how it links with the development budget and the operation budgets

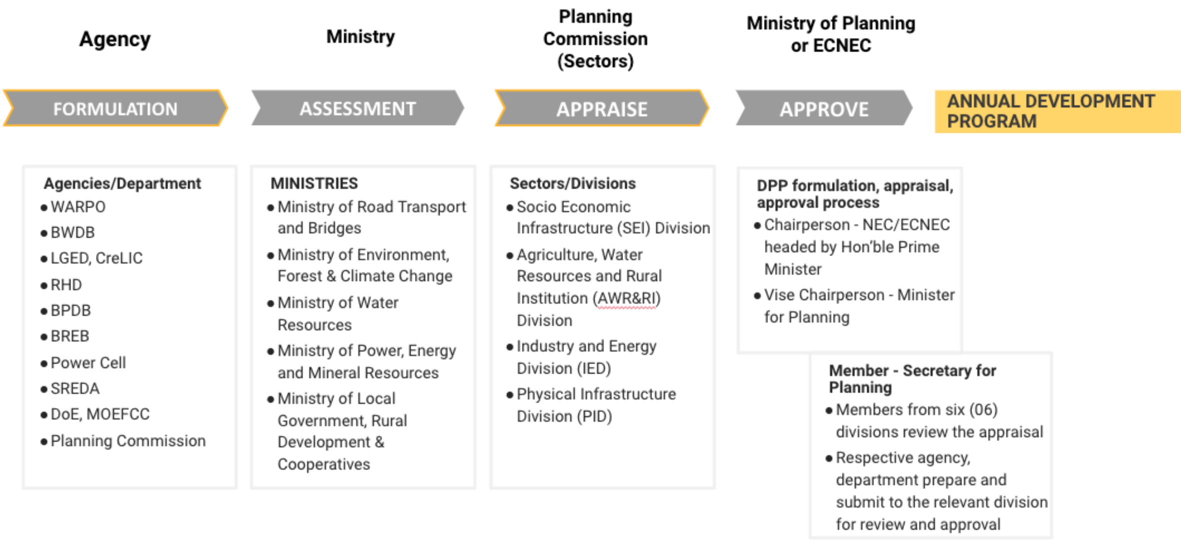


Figure 29: Annual Development Programme

7.6 Annual Development Programme and its linkage to Operational Budget

The Annual Development Programme (ADP) is the *'programming'* tool for translating development objectives of the Government outlined in the medium and longer term plans and visions through allocating resources to individual projects and programs (from the national budget source) implemented by different Ministries/Divisions and Agencies within a particular financial or budget year.

The national budget has a two-fold structure containing 'Development' and 'Operational' sections, which may possibly serve as the entry points for pro-active and retrospective resilience interventions.

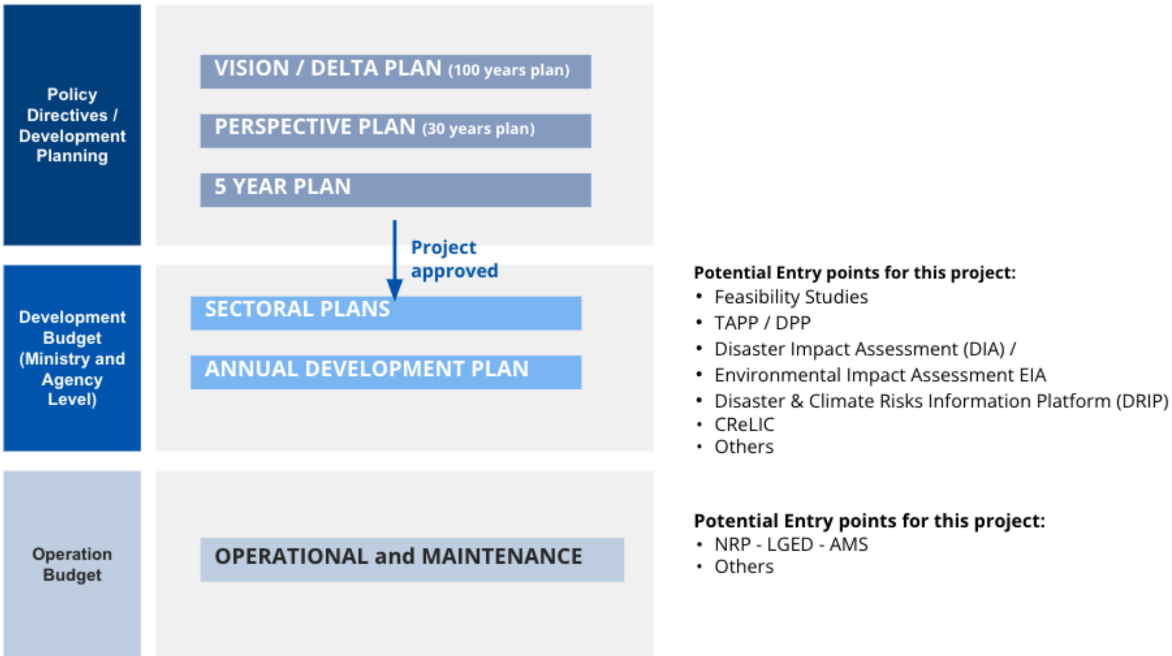


Figure 30: Line of Sight - planning process

An individual project or program serves as the *'building block'* for ADP, and therefore, any project/program can be chosen for *proactive resilience intervention* (e.g., during project formulation, appraisal & implementation) from the long list as an *Entry Point*.

While Operational part of the budget could be the source for an entry point of *retrospective resilience intervention* through Operation and Maintenance for the infrastructure assets (after handover of assets by the development projects).

7.7 Institutional Framework and Planning Process

Ministry of Finance (MOF): provides required resources through national budget (for both development & operational) thru following 3 separate Divisions for all kind of public expenditure:

- **FD (Finance Division)-** responsible for budget formulation, execution and coordination through the MTBF (Medium Term Budget Framework) process in consultation with PC and all MDAs.
- **ERD (Economic Relations Division)-** responsible for mobilizing foreign resources, mainly for the Development part (ADP) of the budget.
- **IRD (Internal Resources Division)-** responsible for providing domestic resources being collected by the **NBR (National Board of Revenue)** through taxes, levies, etc.

Ministry of Planning (MOP)

- **SID (Statistics & Informatics Division)-** provides official data & info collected through the BBS (Bangladesh Bureau of Statistics) for the planning purpose.
- **IMED (Implementation Monitoring & Evaluation Division)**- serves as the *watchdog* for monitoring implementation and impact evaluation of all public sector development projects and programs.

- **BIDS (Bangladesh Institute of Development Studies)-** serves as a public sector *think tank* through R&D and necessary advisory services (especially to PC/GED).
- **NAPD (National Academy for Planning & Development)-** provides capacity building activities including training for public sector officials. responsible for HRD activities

Line Ministries/Divisions & their technical Agencies (MDAs): are responsible for initiating development project proposals (through preparing DPPs in accordance to their mandates) in line with national and sectoral plans, strategies & objectives. Also, they are responsible for the primary assessment of project proposals before they are sent to the PC/MOP for approval, as well as implementation, supervision and progress monitoring of all development projects and programs under the purview of a Ministry or Division.

Planning Commission: as the central agency has a key role in achieving resilience.
It is entrusted with the task of planning for socio-economic development in Bangladesh, and has got following *3-fold* role:

- **Advisory role:** Advising GOB in matters of development goals and objectives, priorities, strategies and policy measures.
- **Executive role [provides integration scope for several Entry Points]:** Preparation of Plans (Delta, PP, FYP, etc.); processing of development project proposals (by MDAs), including appraisal function for final approval; and preparation of ADP (resource allocation to individual projects from *Development* part of the national budget).

- **Coordination role:** Coordination of a whole range of planning and development activities across the government.

Thus, the PC could serve as a *macro institutional platform* to be the *Entry Point* for risk informed/*proactive resilience intervention* through development projects and programs. The PC works through the following two high powered bodies, both chaired by the Prime Minister:

- **NEC (National Economic Council)**- is the highest body for consideration of development activities reflecting national development plans, policies and objectives, consisting of all Cabinet Members.
- **ECNEC (Executive Committee of the NEC)**- a selected *Committee* by the Chairperson from NEC that mainly considers and approves all Investment project proposals (DPPs), review of project implementation and other “day-to-day” functions at the national level in relation to development activities.

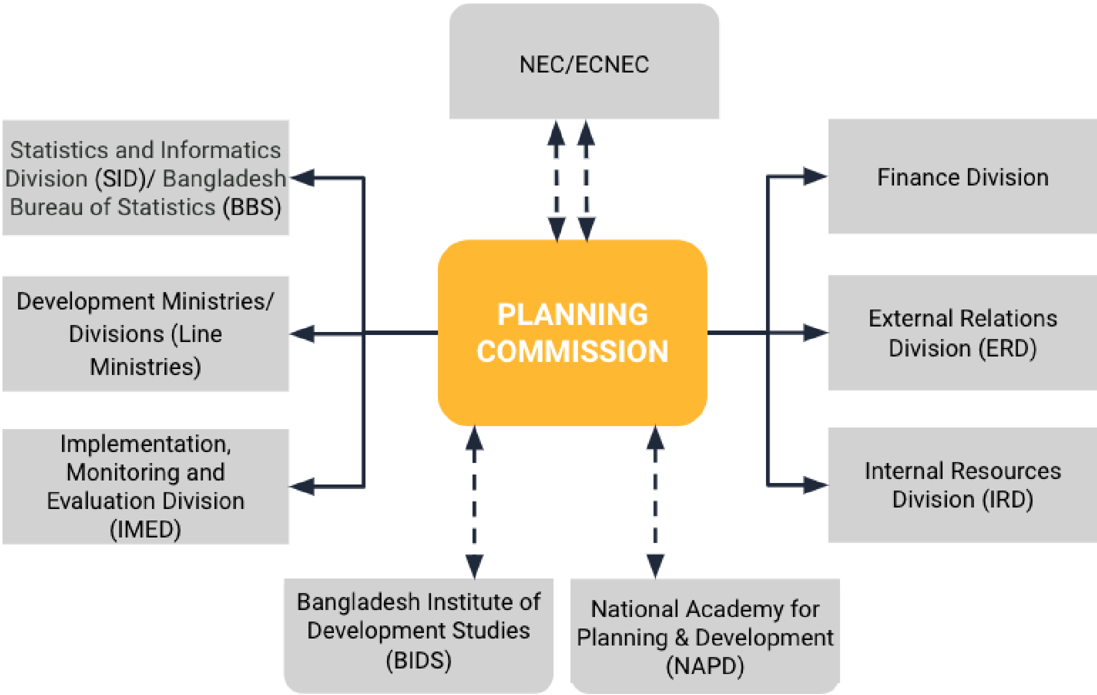


Figure 31: Planning Commission - Structure

8. INTEGRATING NATIONAL INFRASTRUCTURE PLANS AND POLICIES - ENTRY POINTS

Within this section there is an analysis of the suggested entry points for the outcome of this project in order to ensure the long term sustainability of the project outputs and its usability by the Government of Bangladesh to influence their development planning and investments. The analysis is based on the feedback provided by the Government Agencies consulted through the stakeholder analysis process.

Firstly, as a concept, resilience is not well understood nor consistently applied. It means different things to different professions and sectors but generally it implies that resilient infrastructure can withstand the impact of shocks with minimal damage so that the services that are delivered can be sustained. Resilience is also an outcome state that can be achieved but also maintained: 1) **proactively**, through decision support systems that underpin risk informed planning and design processes: 2) **retrospectively**, through asset management systems that monitor the condition and functionality of assets over time; and 3) **reactively**, through learning from the lessons from adversity (Failure Analysis) facilitating build-back-better solutions. The resilience streams fit within different stages at the infrastructure lifecycle stage and therefore will impact at different stages of the budget planning.

8.1 Feasibility Study

The following feasibility study sections are applied for all development projects as per the government circular (NEC/ECNEC Wing, 31.01.2021). The information from this study will be integrated within the existing risk information, methodologies and tool kits to ensure a more comprehensive database of assets is available, including within the AMS, as this is currently a major gap and if not addressed will undermine the decision support system capacity to guide infrastructure resilience building across government.

Section 4: Technical/technological and Engineering analysis Identify issues of hazard & climate risks (existing and future) in the proposed project location, and integrate relevant information into the technical design in order to address the impacts of hazards or other shocks. A summary of the proposed project shall be presented with the following headings:

(a) **Location:** description of the location of the project including a geographical illustration (map and/or geo-coordinates) with justification. Availability of land is a key aspect; evidence should be provided that the land is owned (or can be accessed) by the organisation which has the full title to use it or has to be (purchased or rented) through acquisition/requisition process. Identify the issue of “all hazard risks” (existing and future) in the proposed location including proposed site on hazard map.

(b) **Technical design:** description of the main components, technology adopted, design, standards and specifications. Key output indicators should be defined as the key physical quantities produced (e.g. metres, sq. metres, kilometres, numbers, man months, etc.) should be provided. If the project is to be implemented in high risk areas then hazard and climate variability risks information should be integrated in technical design and construction plans in order to address the impact of hazard on the project.

Section 5: Environmental sustainability, climate resilience and hazard risk analysis

Describe and specify effects/impacts of environmental/climate variability and hazard risk/impacts and possible actions/alternatives/counter measures to make the interventions resilient, incorporating the risk reduction costs.

5.1 Environmental, climate variability and hazard risk analysis

Provide baseline details on the project design context, hazard and risk analysis, including details on the management and institutional frameworks. Key issues related to these include:

Baseline Data - to establish the project context

a. What is to be built or established?
b. Where is it to be built or established?
c. What services will be delivered from the facility and to what standard?
d. What are the construction standards to be achieved?
e. What are the specifics about the operation of the asset (i.e. - will it operate 24/7)?
f. Who will be the primary and secondary target audiences to benefit from the services (demographics and gender)?

Hazard and Risk Information - what could undermine the resilience and sustainability of the asset and the services to be delivered?

a. What are the likely environmental shocks and climate variability impacts in the geographical area and their potential impacts?
b. What are the built environment risks in the vicinity of the project site and their potential impacts?

c. What is the hazard impact history of the geographical area?

Risk Analysis - measuring the risk and vulnerability impact on the project context:

a. What is the availability of utility services (energy, water, solid waste management, ICT and road access) as opposed to the needs of the project. A cost benefit analysis will be required if there is a resourcing gap and a decision as to injecting additional funds or reassessing the project context will be required.
b. Are the materials to meet the construction standards available and if not what is the cost of transportation to the project site? Will the construction standards as outlined in the project context require changing?
c. Are contractors with the right skills and experiences available to undertake the work?
d. In the case of service delivery - are qualified staff available to ensure that standards are met and maintained?
e. Does the implementation of the project compromise health and safety regulations?
g. Are there any settlement issues to be addressed? if yes, provide resettlement modality in brief.

Institutions and Management

a. Which agency is responsible for the oversight of design and construction of the project. Do they have the necessary skills and competencies to undertake this role?
b. Are policy and regulations in place and can the agency ensure compliance during construction and operation of the asset?
c. Does the agency have an asset management system to facilitate the operation and maintenance of the asset during its life cycle?
d. Does the agency have an asset decommissioning and replacement strategy?
e. Does the agency have, or has the agency established a professional development strategy to ensure the sustainability of staff skills and competencies?

8.1 National Resilience Programme Phase II

The proposed NRP phase (II) project in either its planned format or an abridged design represents the second series of actions dedicated to the advancement and consolidation of resilience building within and across the development and humanitarian sectors.

The aim is to ensure that government and donor investments in development are protected from the various shocks and stresses that frequently impact Bangladesh. In this context, the **key thematic** areas that underpin the project design and actions include Climate Change/Variability; Social Protection; Gender Responsiveness and Equality; Institutional Development; Humanitarian Actions and Cross Sector synergies.

That **communities will benefit** from having assets and systems that are more resilient and the essential services they deliver more sustainable, including within the: Health; Water; Education; Energy; Transport; Agriculture and Economic and Investment sectors. Broader benefits will be experienced as the project's focus moves beyond government, to include the Urban and selected private sectors.

Primary Entry Point: LGED Asset Management and Decision Support System

A key action to be continued through the proposed NRP (II) and led by the Local Government Engineering Department (LGED), is the further development and expansion across key government agencies, of the asset management and decision support system (AMS/DSS). This system provides the inputs for applying risk-informed design processes to improve the way in which infrastructure assets are prioritised, designed, implemented, managed, decommissioned and replaced across their entire lifecycle.

The key elements of the AMS/DSS are identified in the following holistic framework. The entry point for the study outputs is as an input to the Decision Support System. This compliments the inputs of the existing tools including the Disaster Impact Analysis (DIA) and Disaster and Climate Risk Information Platform (DRIP) and the LGED AMS.

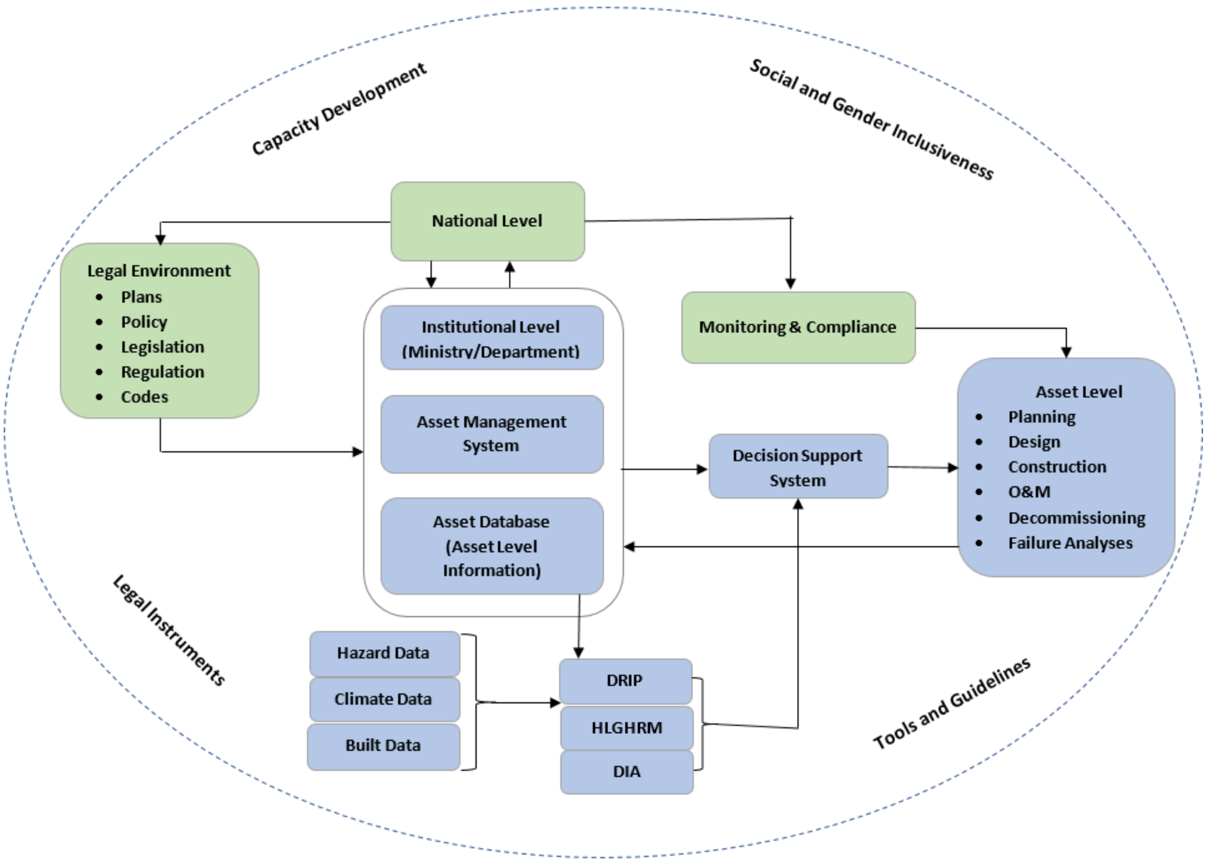


Figure 33: LGED Asset Management and Decision Support System Framework

Phase II of the NRP will further develop the expansion of the hazard and risk platforms (DRIP and DIA) to achieve a wider geographic coverage; the review of policy, legislation and other monitoring and compliance frameworks; the further populating of the AMS across sectors, including with information from this survey as this will facilitate a wider capacity to monitor infrastructure Assets; the institutionalisation of capacity building to strengthen and then maintain the skills to work within the system and apply risk information within development planning broadly; and also the mainstreaming of social and gender both in design and through the AMS process..

The institutional reform within LGED will trigger a paradigm shift by transforming business as usual development to a resilient and sustainable local infrastructure development all over Bangladesh.

8.2 Climate Resilient Local Infrastructure Centre (CReLIC)

CReLIC was established by the Local Government Engineering Department (LGED) under its Climate Resilient Infrastructure Mainstreaming Project (CRIMP), funded by- Green Climate Fund (GCF); the Government of Germany, through the German Development Bank (KfW) and the Government of Bangladesh (GoB), to mainstream climate resilience issues in designing and implementation of all infrastructures at local level.

It was envisioned as a center of excellence to address Climate Variability risks and impacts on infrastructure at the local level. The major role of CReLIC will be to complement the broader resilience building process, through creating awareness and improving the adaptive capacity of LGED, particularly in regard to the design and resilience of local level infrastructure.

8.3 Strengthening the Capacity of Local Institutions

Although critical infrastructure will be designed and constructed by central government agencies such as Public Works and LGED, other government agencies and local institutions will play a significant role in the operation and maintenance of the assets, in addition to supporting the conditionality assessment as part of the AMS process. This requires significant and sustained capacity development that can be driven by CReLIC, as part of their core business functions.

A capacity building strategy must be developed and institutionalised and include skill-sets associated with:

- Establishing a “proof of concept” so that the various methodologies are validated within the context of a strategic framework rather than as individual pieces of the framework.
- Undertaking policy interventions - the coordination of the upscaling across ministries will require a review and where necessary an amendment to policy, checklists and legal frameworks.
- Inclusion of the tools and methodology across the government system will require extensive capacity development supported by appropriate guidelines and directives - National Level Directives (planning + retrospective/maintenance phases)
- Direct support to government agencies and local institutions in installing and tailoring the broader RID methodologies and utilising the tools so they are consistent with the

different stages of the government project formulation, appraisal and implementation processes.

- The institutionalisation of capacity building at both individual & institutional levels to ensure the sustainability of capacities rather than as a once off activity.

ANNEX 1: DETAILED METHODOLOGY

Data collection and preprocessing:

- First, an overview of existing data and resources for geospatial vector data on infrastructure in the water, energy and transport sector, as well as other critical infrastructure services was done in collaboration with CEGIS. Some of the datasets, such as the road network data, are from open access platforms such as Open Street Map.

- Quality checks of the collected infrastructure data by CEGIS and Oxford and minor corrections of the data were carried-out.

- Limited water infrastructure data was made available. Global datasets, such as HydroWaste for wastewater treatment plants, were explored, but after quality checks done by Oxford and CEGIS, these were deemed inaccurate.

- Hazard data for coastal and river flooding was obtained from Aqueduct flood data (Winsemius et al., 2015), including scenarios for RCP 4.5 and 8.5, for the years 2030, 2050, and 2080, as well as for return periods 2, 10, 25, 50, and 100. The river flooding dataset includes the projections from five different models (NorESM1-M, GFDL_ESM2M, HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM) for the listed scenarios and one model (WATCH-model) for the baseline year.

- In order to incorporate cyclonic wind damages into the study, the maximum wind gusts (in m/s) for different return-period events were re-simulated using the Steptoe (2021) data. This dataset is based on nine different ERA5 climate models of historical events and has a resolution over all of Bangladesh of a 4.4km grid. Although this dataset is only for the present day, it does provide maximum wind gusts for return periods 2, 10, 25, 50, and 100.

- For river and coastal erosion, the DeepWaterMap model was used, which is a satellite-based model that measures channel and coastline changes over time (Jarriel et al., 2020). The resulting erosion map has a resolution of 30m by 30m and shows the cumulative area that has eroded over the last 35 years (1987-2022). This hazard map was extracted from Paszkowski et al. *under review*. This data layer does not entail information about potential future erosion.

- Other hazard maps were also considered. A drought hazard map and saline intrusion map were provided from CEGIS, but these were just one historic scenario and were spatially extremely coarse. Moreover, there were no models or more detailed pieces of information on how droughts and saline intrusion actually affect infrastructure assets, and given the water sector assets were so limited in this assessment, these hazards were excluded.

- All hazard maps were used in a raster format and resampled to the resolution of the aqueduct raster files to facilitate further analysis.

Exposure of Bangladesh's infrastructure to climate hazards:

- The infrastructure data is intersected with the hazard rasters using a Python library developed by Tom Russel at Oxford University (https://github.com/nismod/snail). The infrastructure points and networks are split along the raster grid and the associated hazard intensity is assigned to each asset or network segment.
- Subsequently the results are analysed and summarising statistics are calculated using Python. Maps and figures illustrating the results are produced in Python and QGIS.

Estimating direct damages to Bangladesh's infrastructure as a result of different climate hazards:

- The exposure assessed in the first step is used to estimate potential damages to the infrastructure assets. Expressing damage monetarily allows us to prioritise assets and areas for adaptation, but also allows us to compare different asset types in terms of the severity of damage.
- This is done by combining depth-damage curves and cyclone fragility curves with average asset costs and the footprint (area) of the exposed assets. The sector (or asset) specific damage curves represent the estimated share of an asset's value that would be destroyed when exposed to a certain level of hazard (such as metres of flooding). The potential consequential damage (in % of asset value) is multiplied with the asset cost per m² and the footprint area of the considered asset.
- Therefore, footprints (meaning the covered area) of all assets are needed. The data that was originally collected only included point and line data, so footprints had to be estimated using satellite images to measure the actual area an asset covers. Due to the high number of some of the asset types (such as education facilities) only a sample of assets per asset type was measured and an average value was assumed for the rest of the assets of the same type.
- For roads, the lengths of each road segment was multiplied by the mean width of different categories of roads to estimate the footprint area.
- For electricity grids and railway lines, normalised damage factors are multiplied by their respective lengths and the asset cost per unit area.
- Damage curves and average asset values/costs used as part of this assessment are shown on the next page, with their associated sources detailed.
- The damage curves, asset footprints, asset costs and asset exposure are combined, as described above, using R. The damages are estimated at the asset level. Then the calculated damages are summarised on an upazila level, as well as for the individual sectors. Bar charts are plotted in R as well, and maps are created in QGIS and ArcGIS.

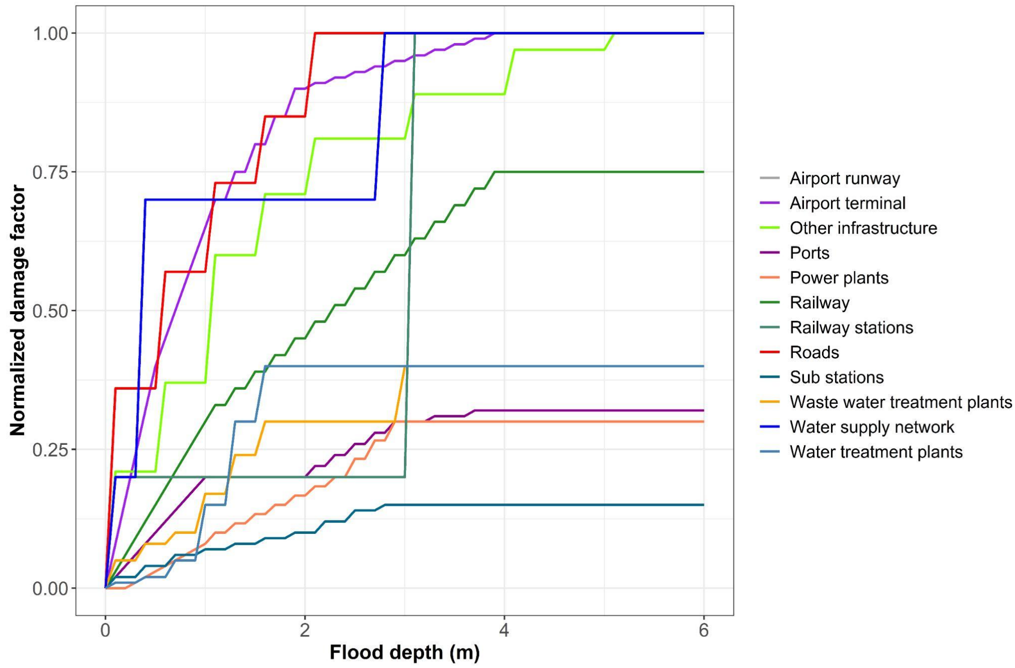


Figure: Flood damage curves (Sources: Huizinga, et al., 2017; Miyamoto International, 2019; FEMA, 2011; Kok et al., 2005; Snuverink et al., 1998)

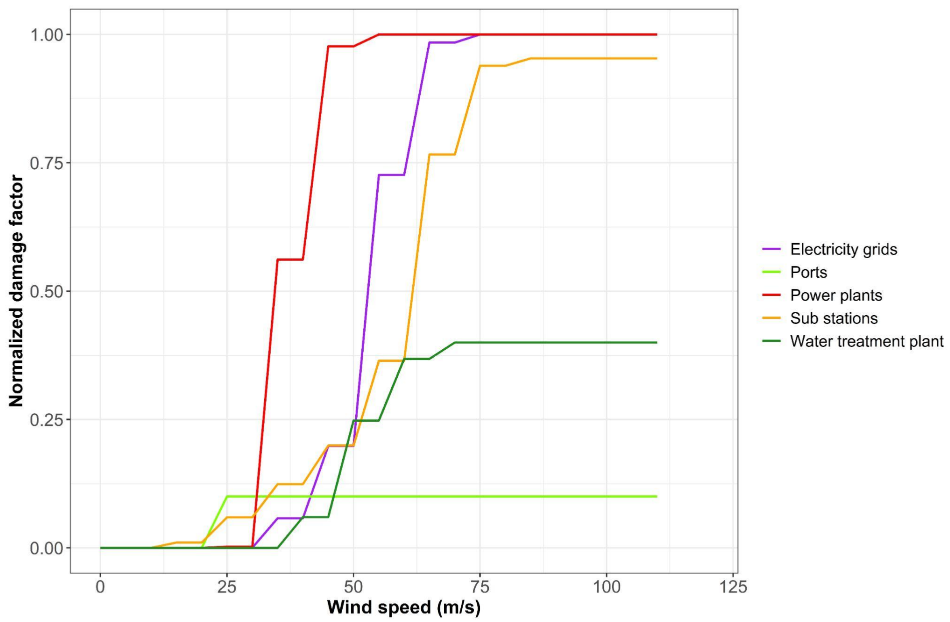
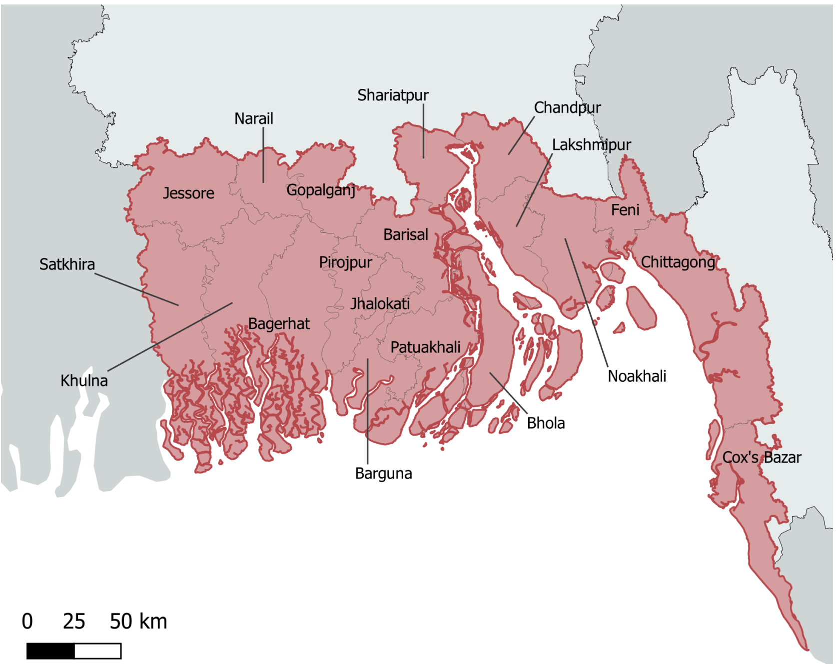


Figure: Cyclone fragility curves (Source: Miyamoto International, 2019)

Infrastructure service provision to households in coastal Bangladesh

- In order to assess the climate hazard effects on infrastructure service provision for households, a household survey dataset from the World Bank (Rubinyi et al., *in press*) was used. The household data includes information on household access to electricity, water, and sanitation, the housing type, as well as the fraction of household members that are literate, have a higher level education and are employed (see table below).



- At this point the household survey data is only available for 19 coastal districts, so this part of the study is limited to the coastal area, see map above.

- Using the information on each household (see table below) a wealth index was calculated doing a principal component analysis in R.

Variable	Inclusion in wealth index
Access to electricity	Yes = 1 No = 0
Water	Tap = 1 Otherwise = 0
Sanitation	Sanitary (with water seal) = 2 Sanitary (with no water seal) = 1 Otherwise = 0
Housing type	Pucca = 3 Semi-pucca = 2 Kutcha = 1 Otherwise = 0
Literacy	Fraction of members ≥18 years that are literate
Education	Fraction of members ≥18 years that have higher level education (>5 years)
Employment	Fraction of members ≥18 years that are employed

- Based on the calculated wealth index households are divided into wealth quintiles (Q1 representing the poorest quintile and Q5 the wealthiest). Additionally, the households in the survey were categorised as urban and rural households, so wealth quintiles were calculated for these two categories separately.

- In the next step, a nearest neighbour analysis was done in Python to identify the closest asset for each household across each wealth and rural/urban category. The nearest neighbour analysis is based purely on proximity of the assets to the households location. Only asset types where household proximity is relevant were considered (meaning that assets such as airports were not considered here). Assigning households to assets based on catchment areas or the distance along the road network was considered (i.e. network analysis), but the necessary data was not available and the quality of the road network data did not allow accurate routing results.

- Subsequently, the number of households an asset was assigned to was summed up for the wealth quintiles, as well as for overall numbers for all rural households, all urban households and the overall number of households. Thereby, households which wouldn't have access to a service, based on the information from the survey, were excluded for the corresponding asset categories (e.g., households that don't have access to electricity in their house would be excluded when summing up the number of households a substation was assigned to).
- The calculated numbers were summarised in Python and visualised in QGIS and Python.

Impact of service disruptions on the achievement of SDGs

- In this section of the analyses, the socio-economic characteristics are intersected with infrastructure assets and networks affected by climate hazards that are linked to the achievement of relevant SDG indicators to estimate the spatial distribution of SDG progress exposure to various climate hazards.
- Of the Government of Bangladesh's (GoB) 39 *priority SDG indicators (NPTs)*, identified by the *SDG Working Committee* of the Prime Minister's Office, nine indicators under six SDGs were selected, which are assigned to target levels signifying full achievement according to the GoB. These indicators were specifically chosen based on the likelihood of their progress being limited or reversed due to hazard exposure to the types of assets addressed in this study.
- A baseline level of progress was determined for each using responses from the household-level dataset, including socio-economic characteristics (e.g. employment, school completion), and access to services (e.g. reasonable proximity to health centres or shelter), with an average taken across each of the 19 districts of the coastal study zone.
- The share of potential household disruption to services for assets required to fully achieve these targets, calculated in the previous section, were used to estimate how much of the remaining progress could be put 'at risk' through exposure to coastal and river flooding, with return period 50, under a future trajectory of RCP 4.5, and historical cyclone and erosion exposure.
- In some cases, the link between hazard exposure and an SDG indicator could be directly quantified, e.g. exposure of a substation affecting *electrification access* of connected households. Where indicator disruption could not be directly quantified, an

indirect measure was used - for example, access to markets is considered key to measures of economic progress including rates of *employment*.

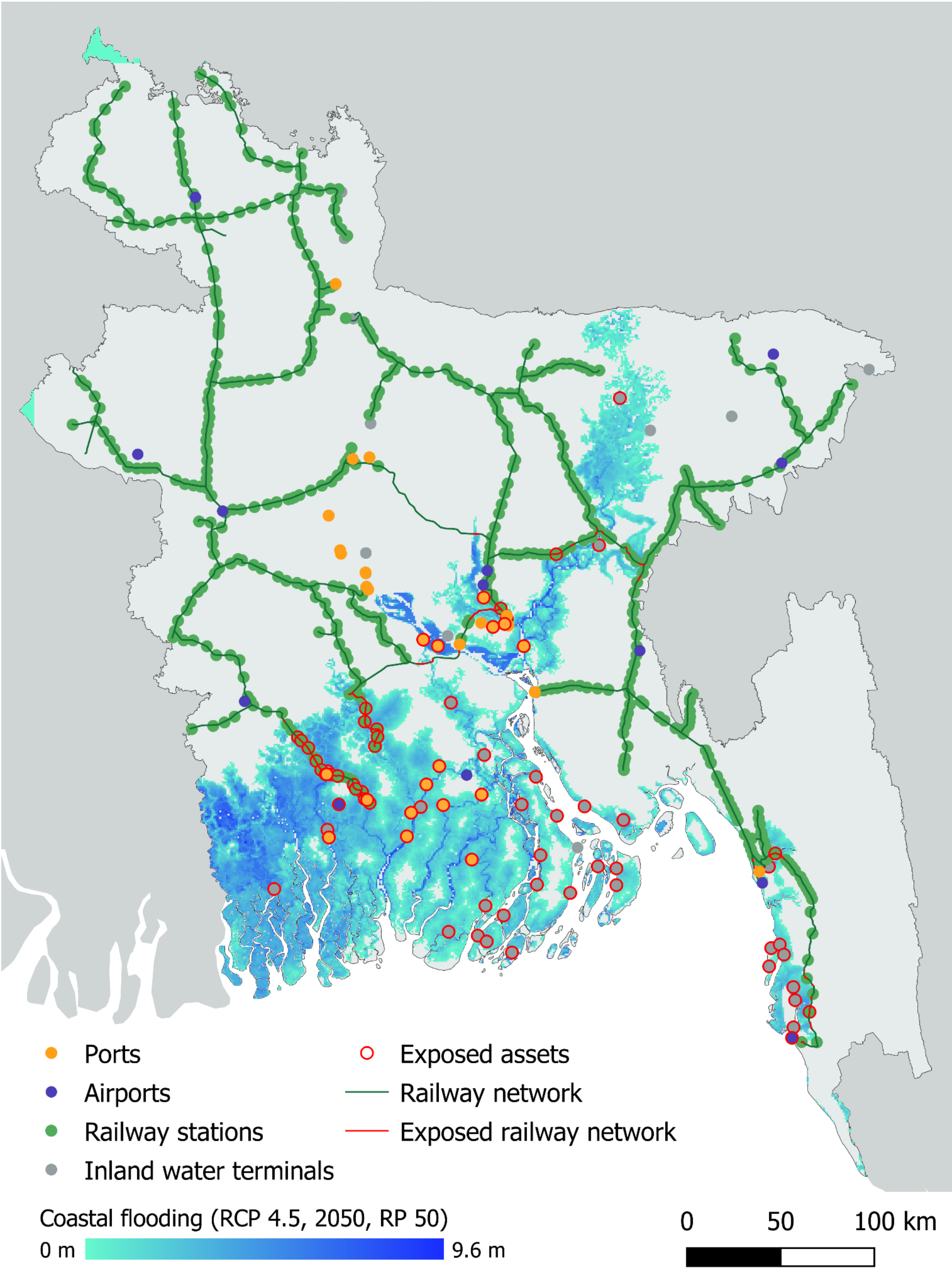
Required skills and competencies to take this work forward

- Experience with analysis of geospatial data
- Knowledge about available data and potential data sources
- Experience of geospatial analysis using ArcGIS or QGIS and Python
- Experience with data analysis in excel, Python, and R
- Experience with data visualisation in R or Python and map creation in QGIS/ArcGIS, Python or R

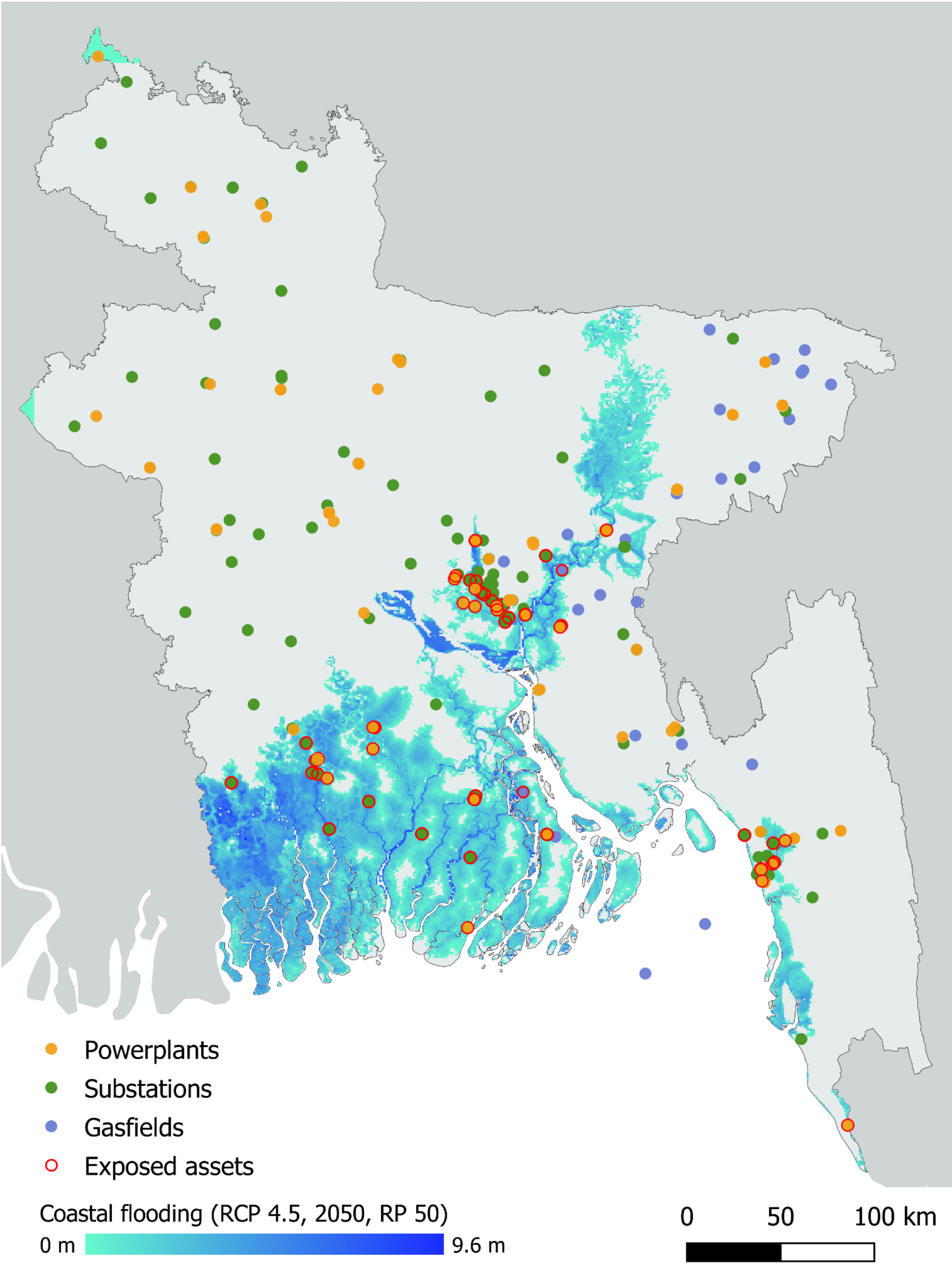
ANNEX 2: ADDITIONAL RESULTS AND ANALYSES

Sector-level maps showing infrastructure assets in hazard-prone areas:

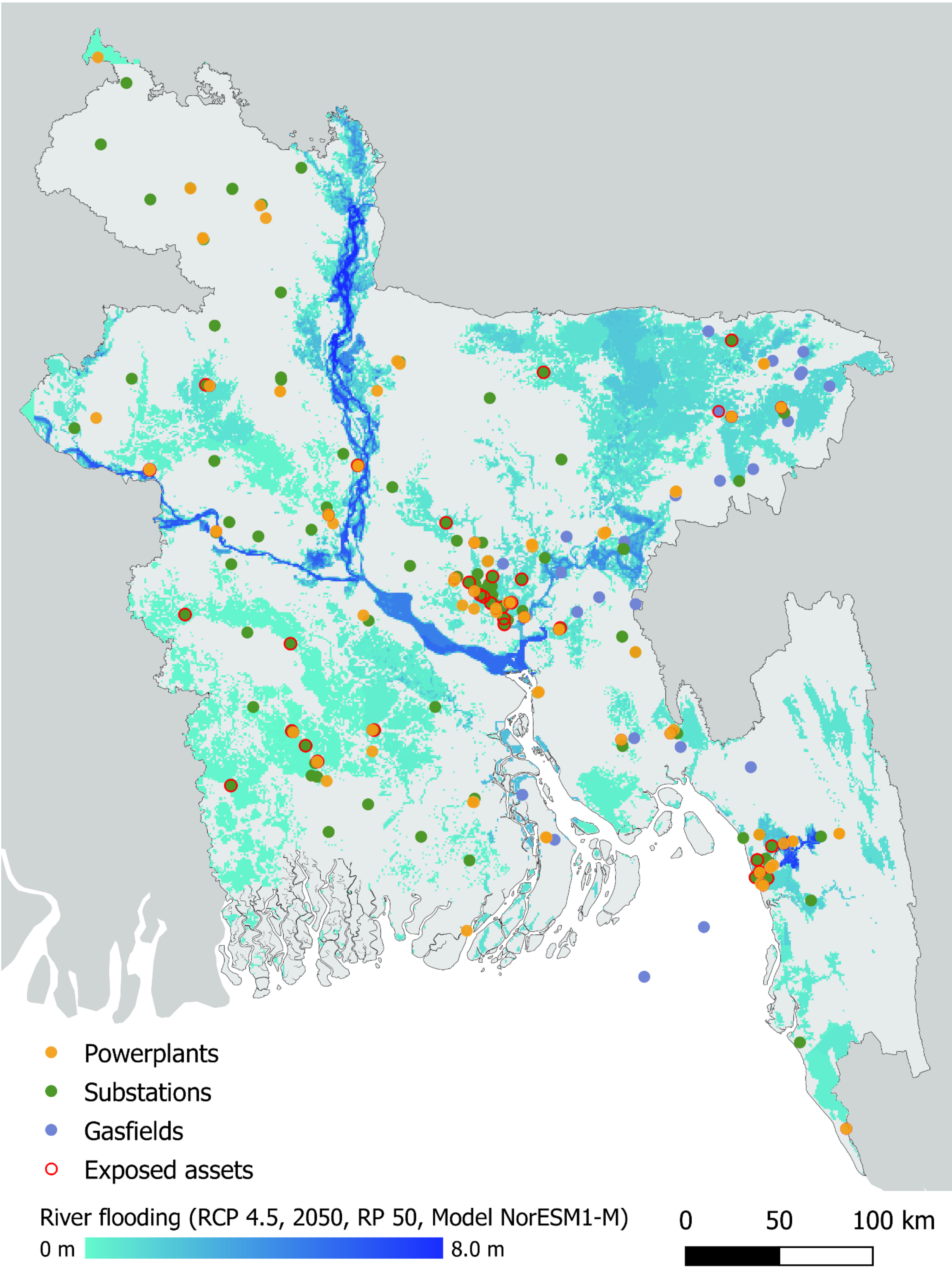
Transport infrastructure assets and networks exposed to coastal flooding



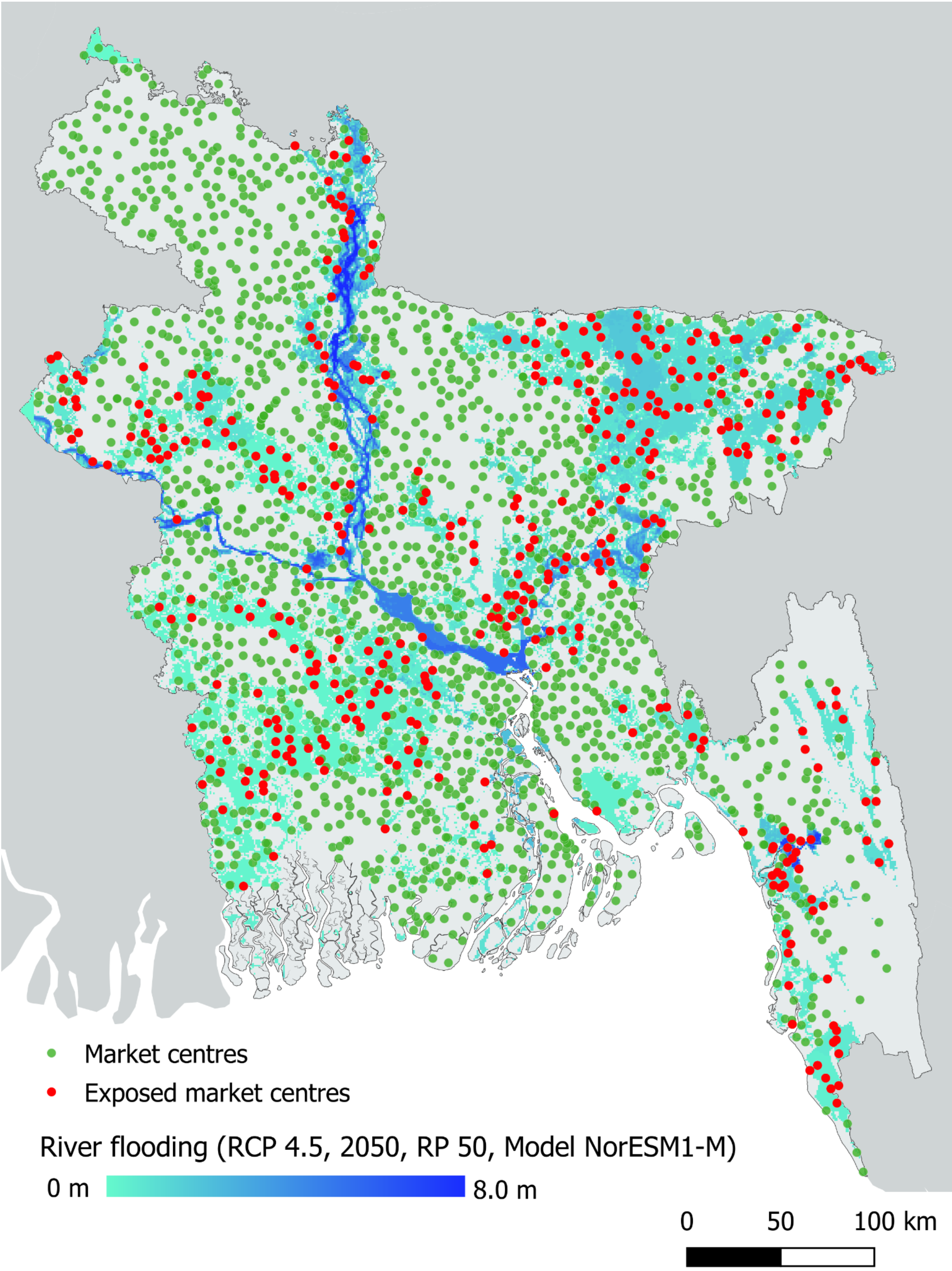
Energy infrastructure assets exposed to coastal flooding



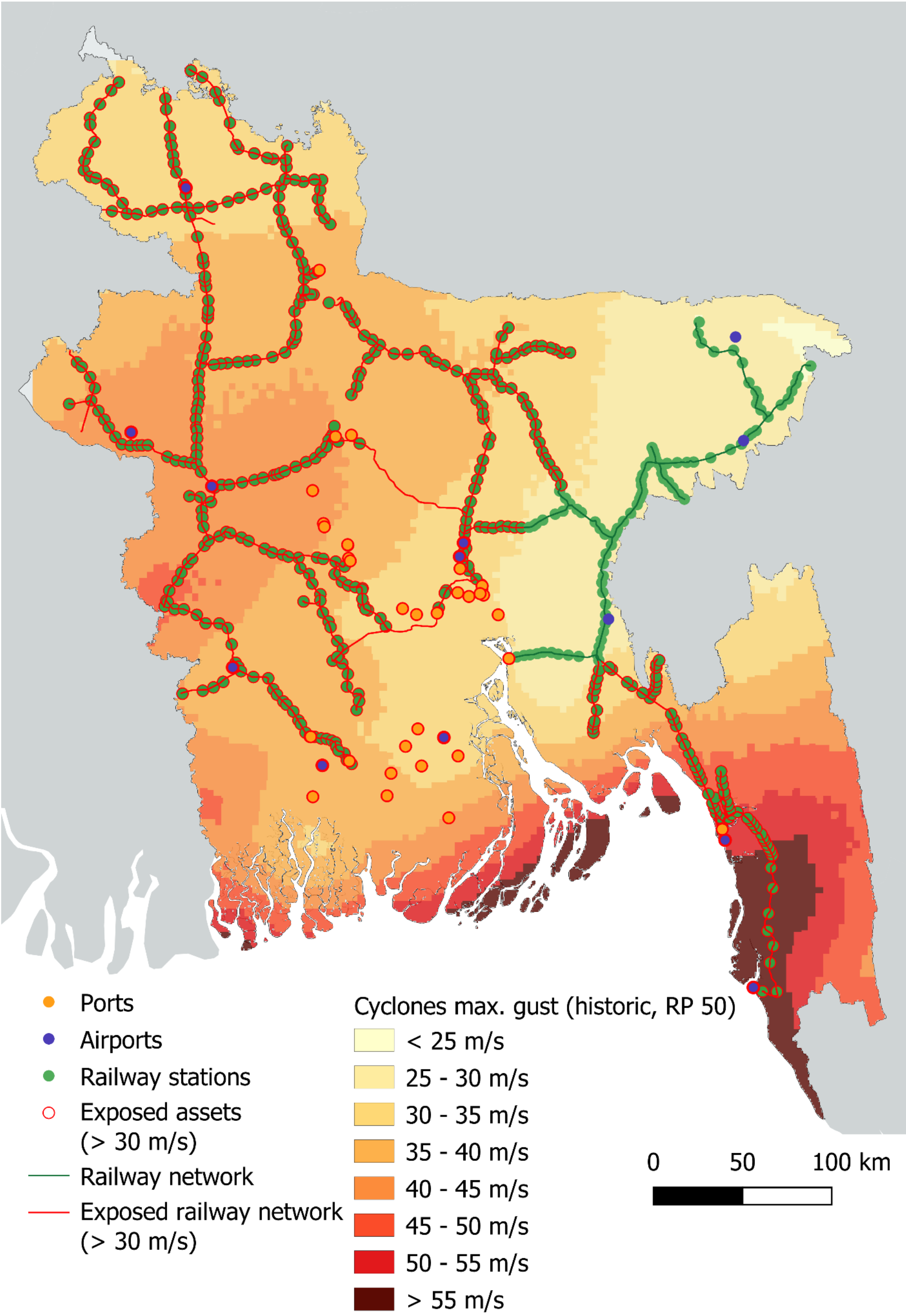
Energy infrastructure assets and networks exposed to river flooding



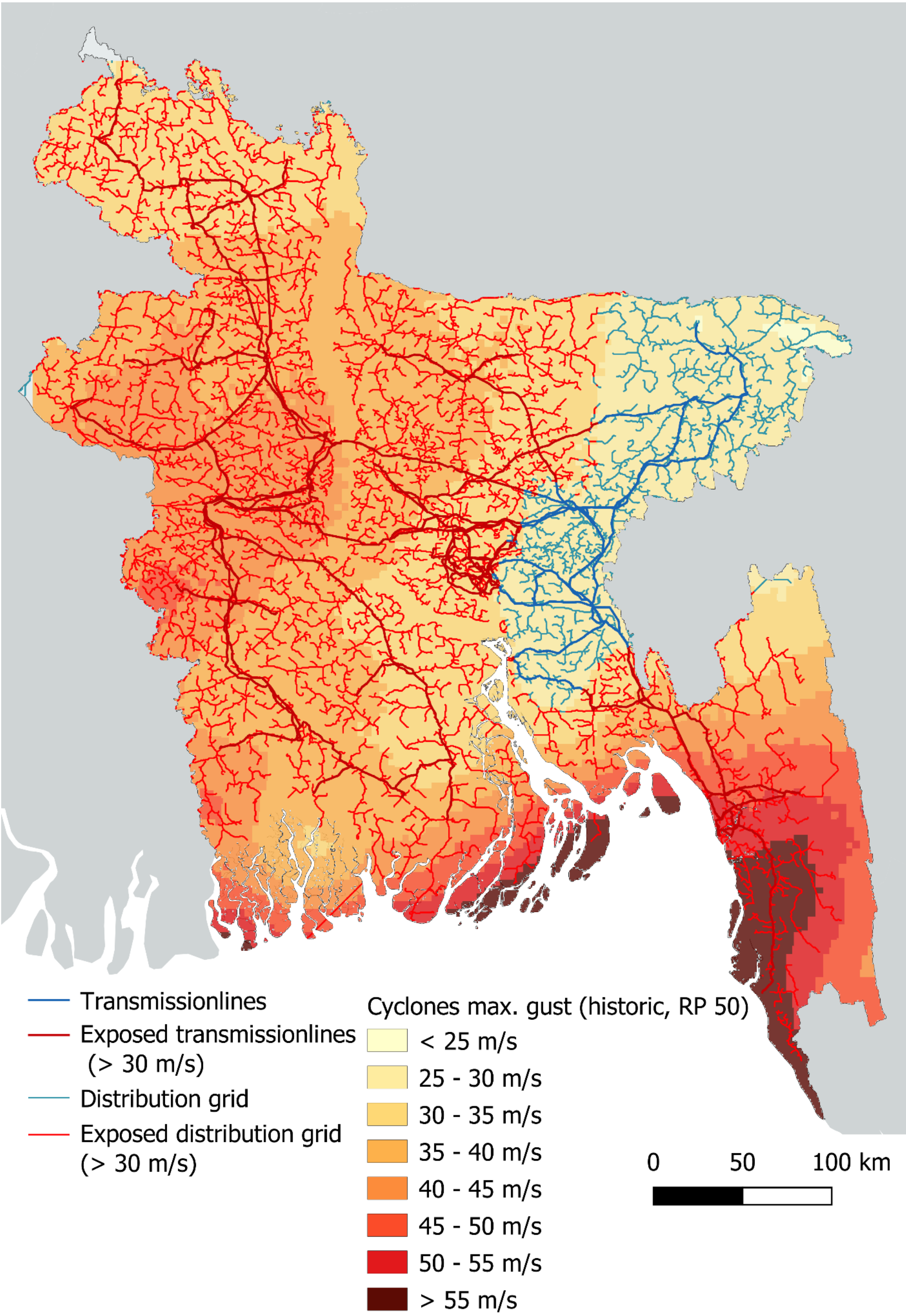
Social infrastructure assets exposed to river flooding - example: market centres



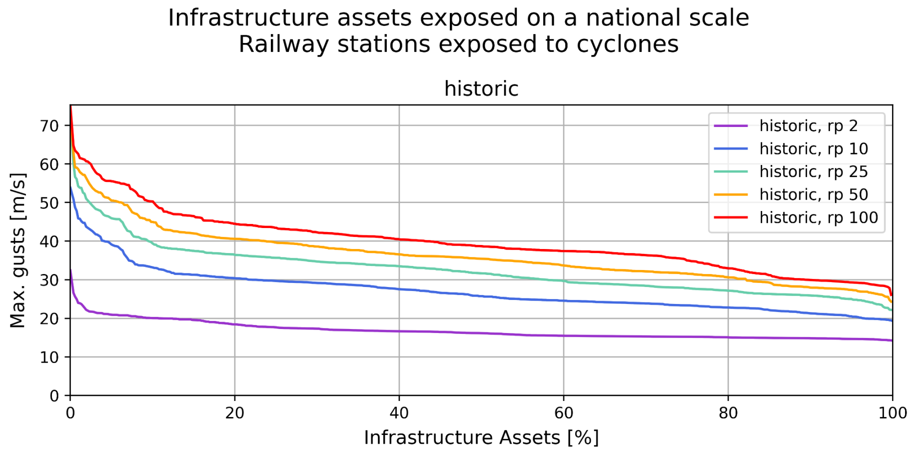
Transport infrastructure assets and networks exposed to cyclones

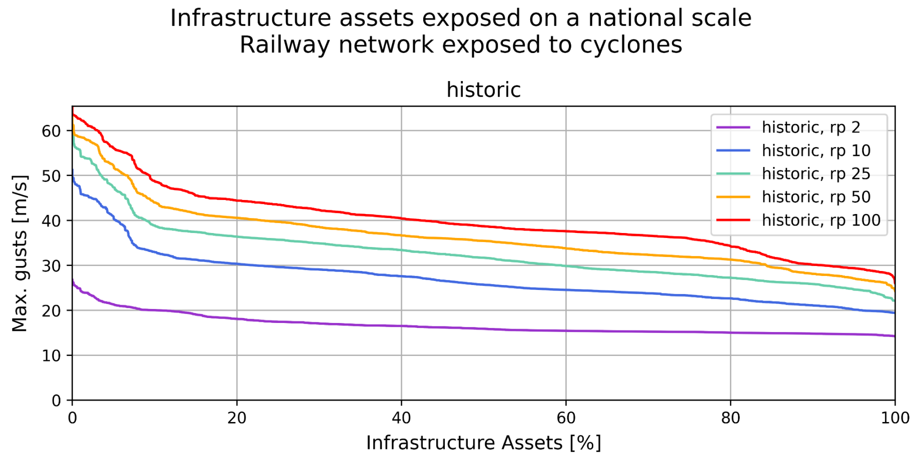


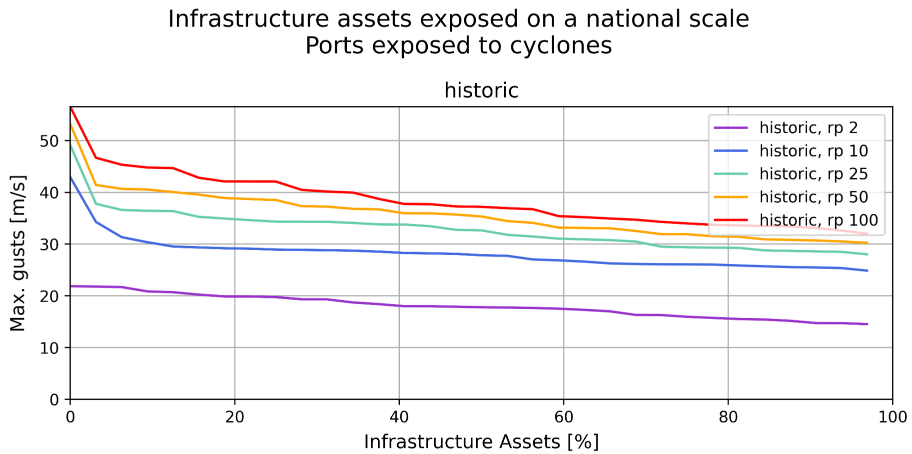
Energy infrastructure assets and networks exposed to cyclones

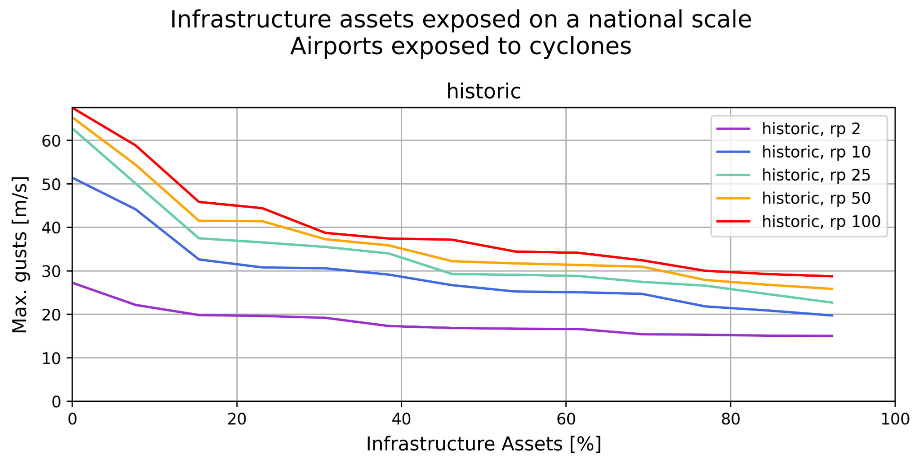


Transport assets exposure to cyclones

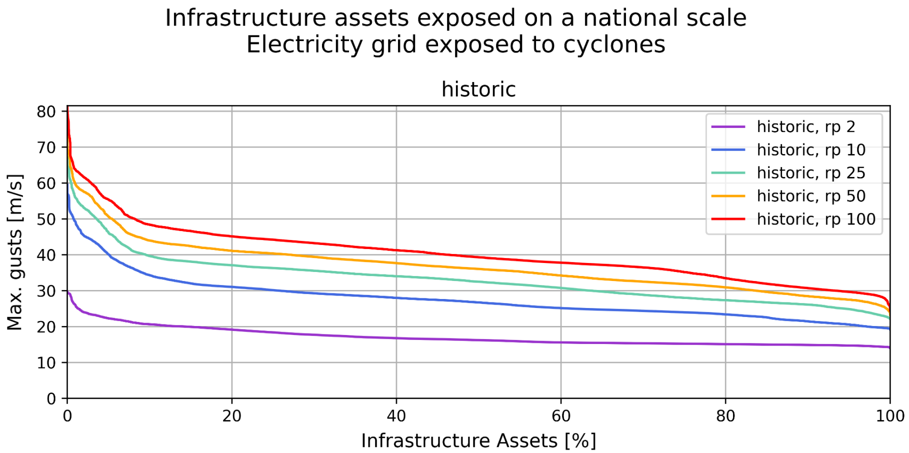


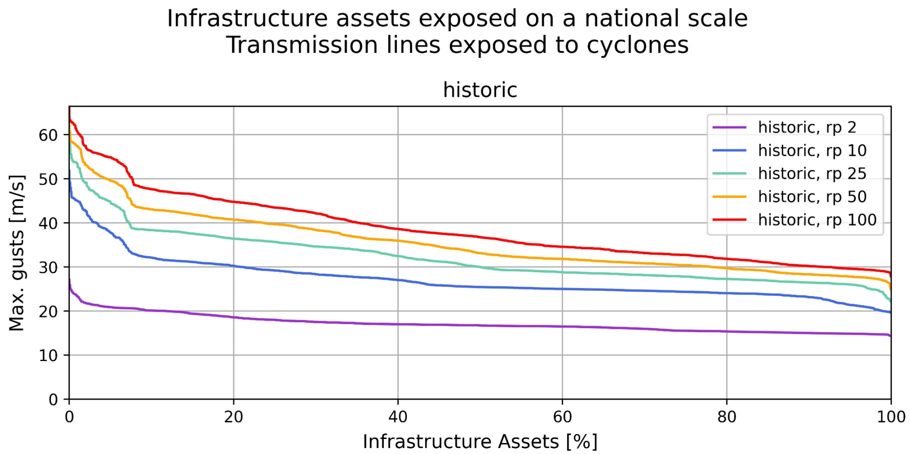




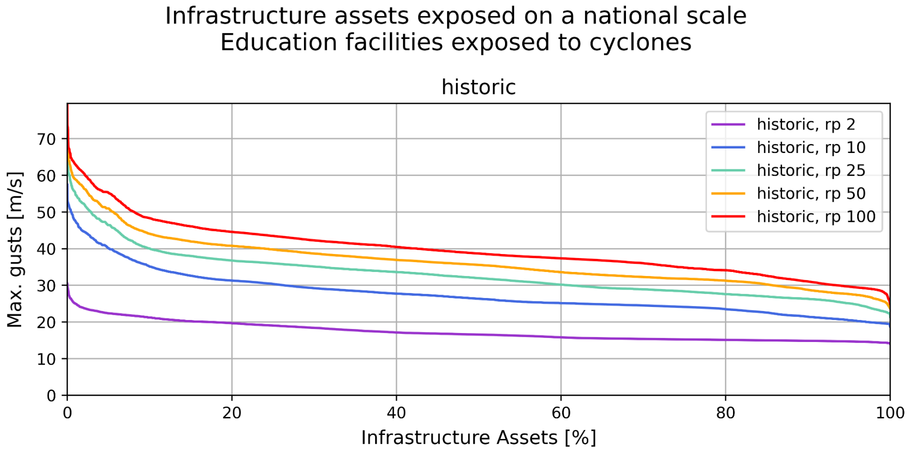


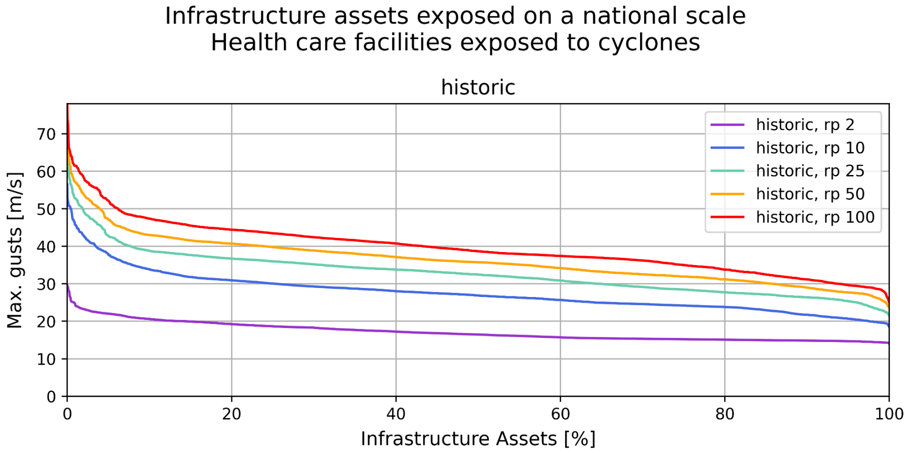
Energy assets exposure to cyclones

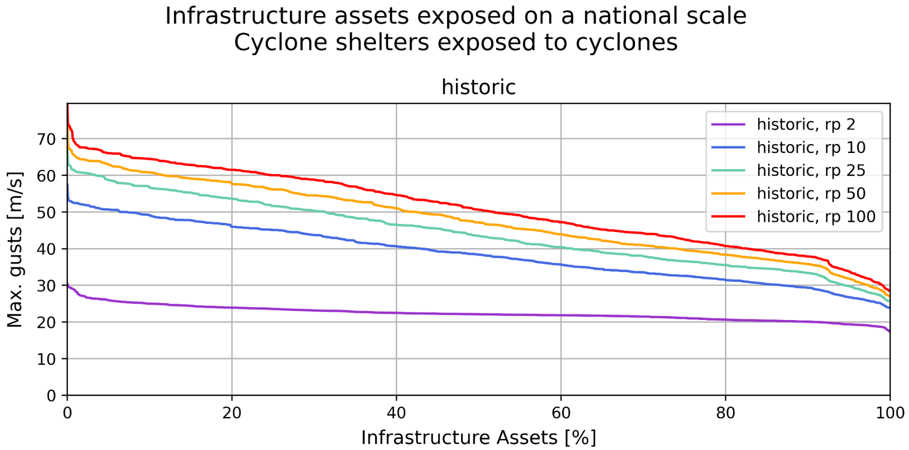




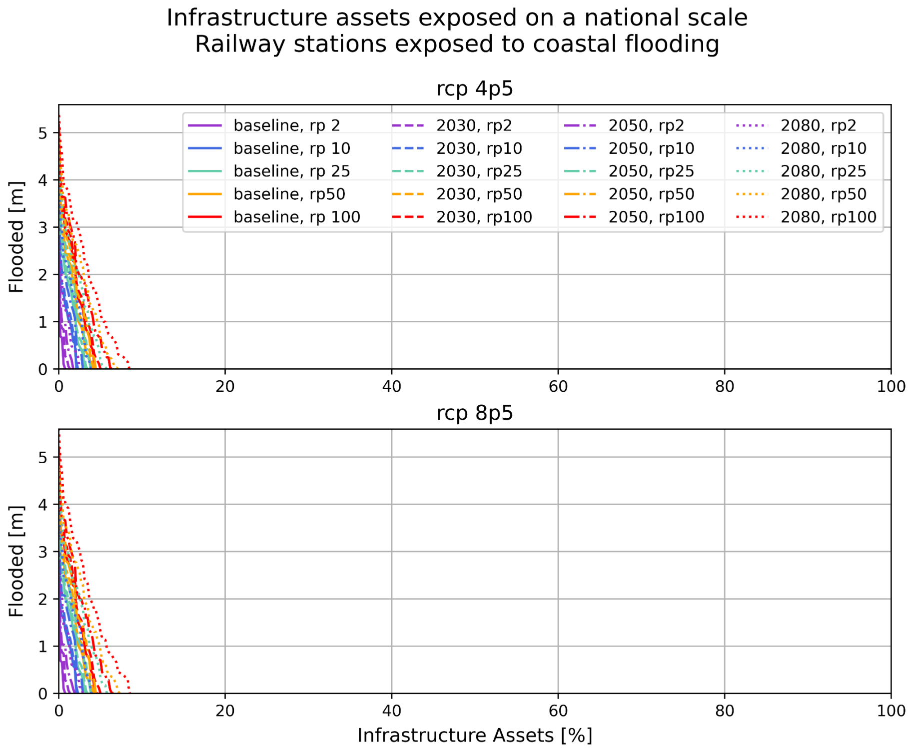
Social assets exposure to cyclones

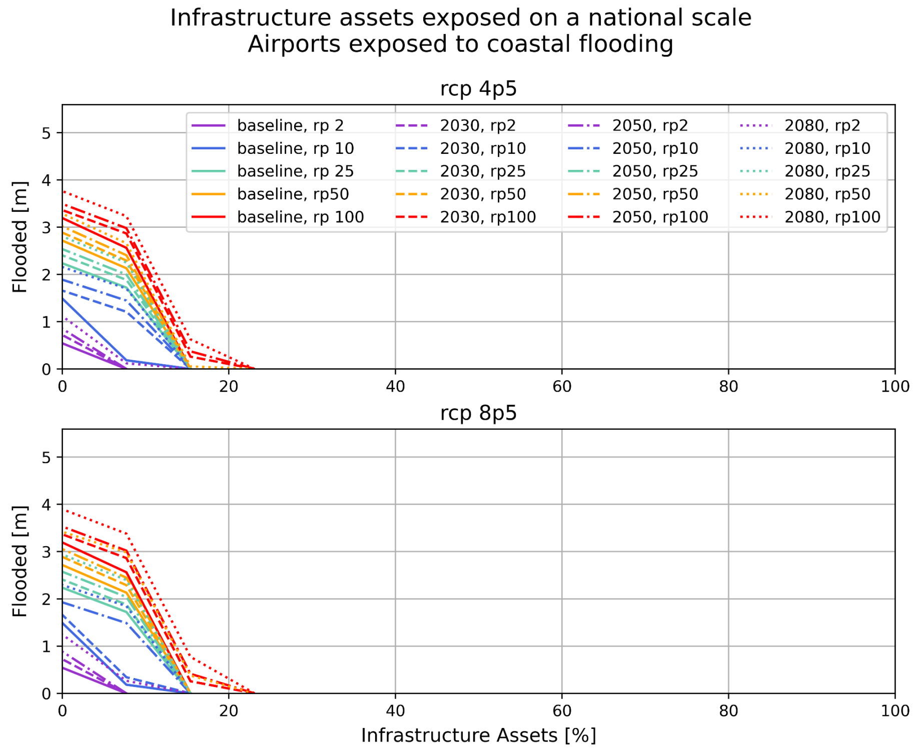


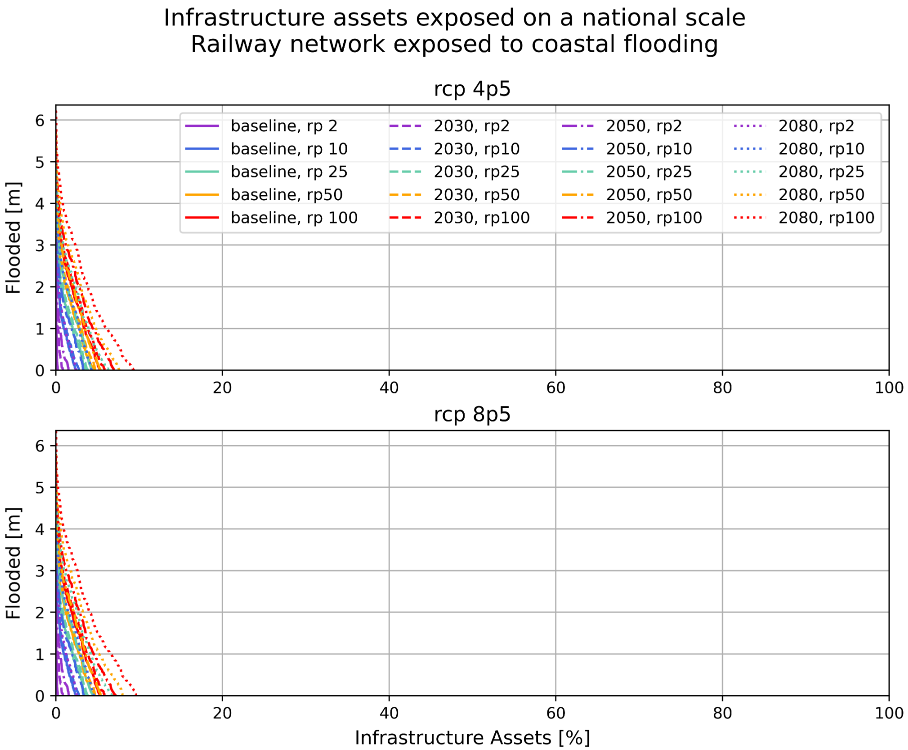


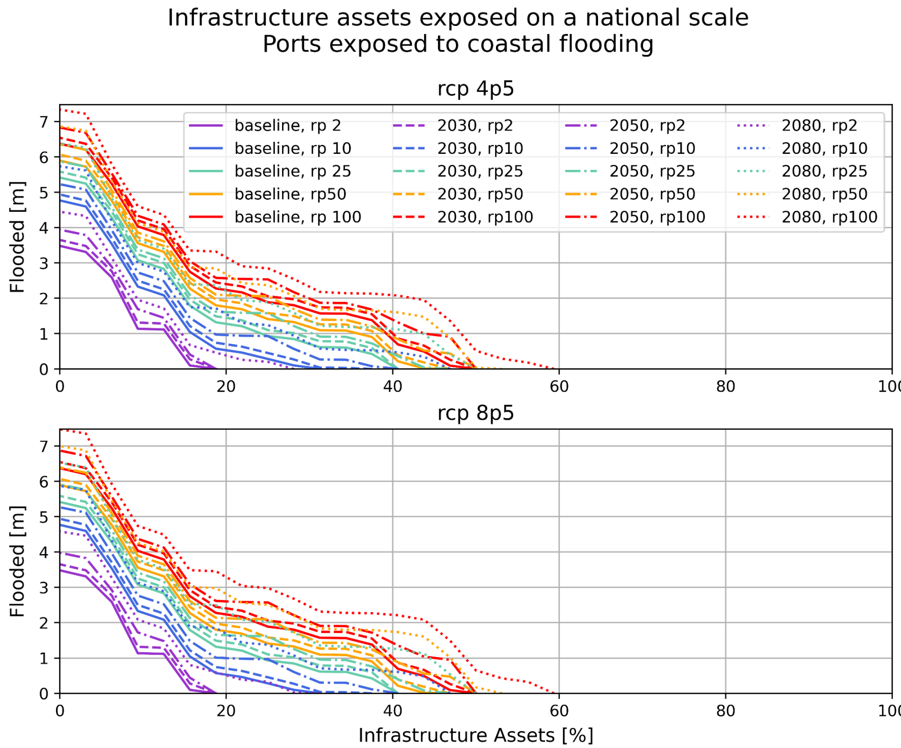


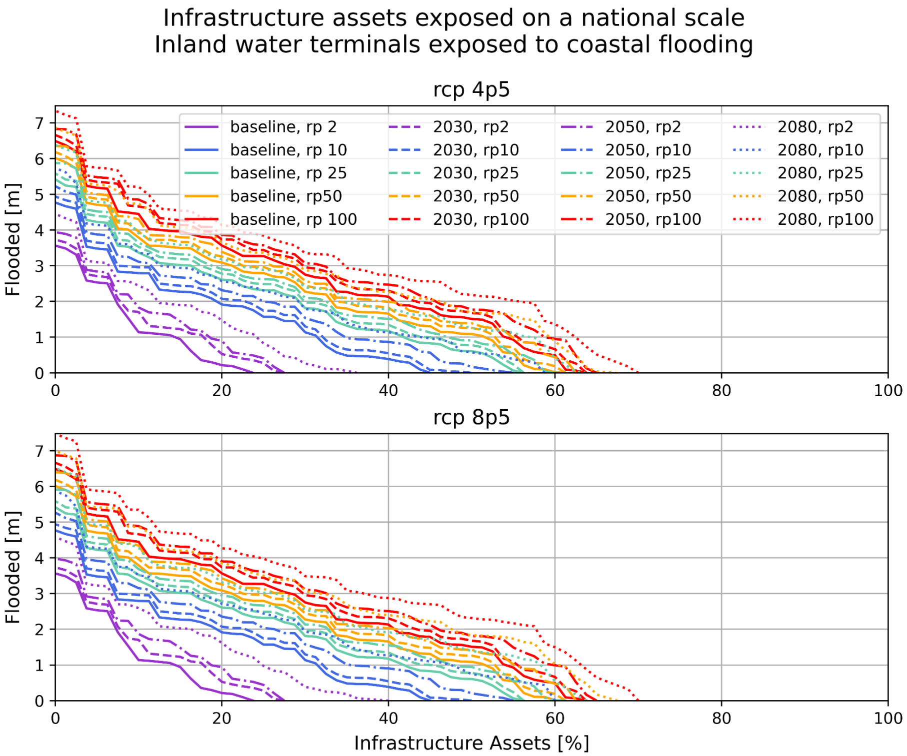
Transport assets exposure to coastal flooding

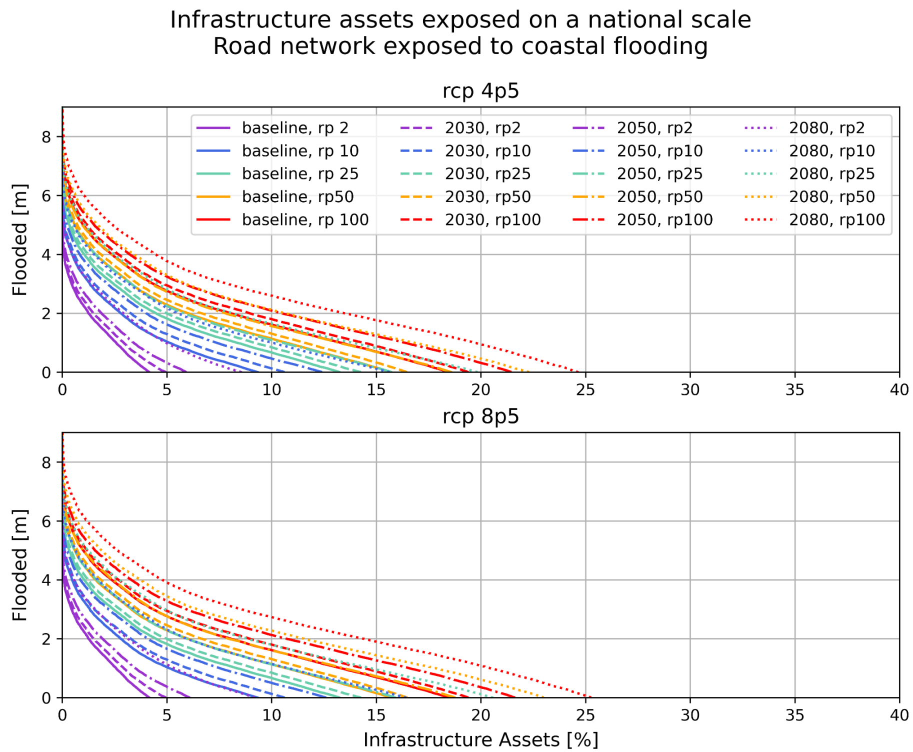




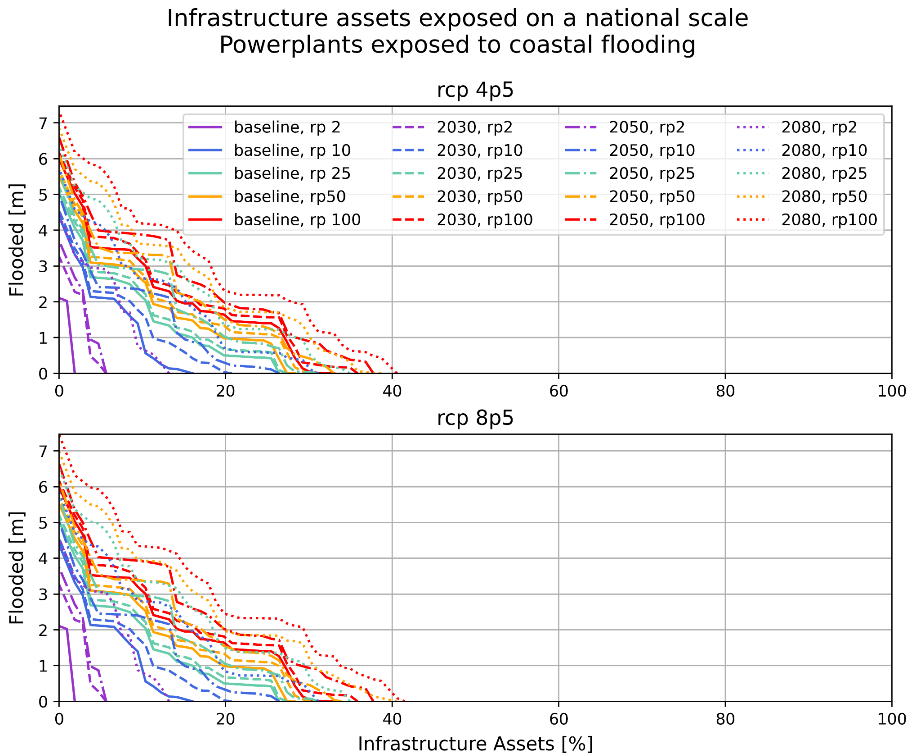

Infrastructure assets exposed on a national scale
Railway network exposed to coastal flooding
rcp 4p5
rcp 8p5
Flooded [m]
Infrastructure Assets [%]
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100

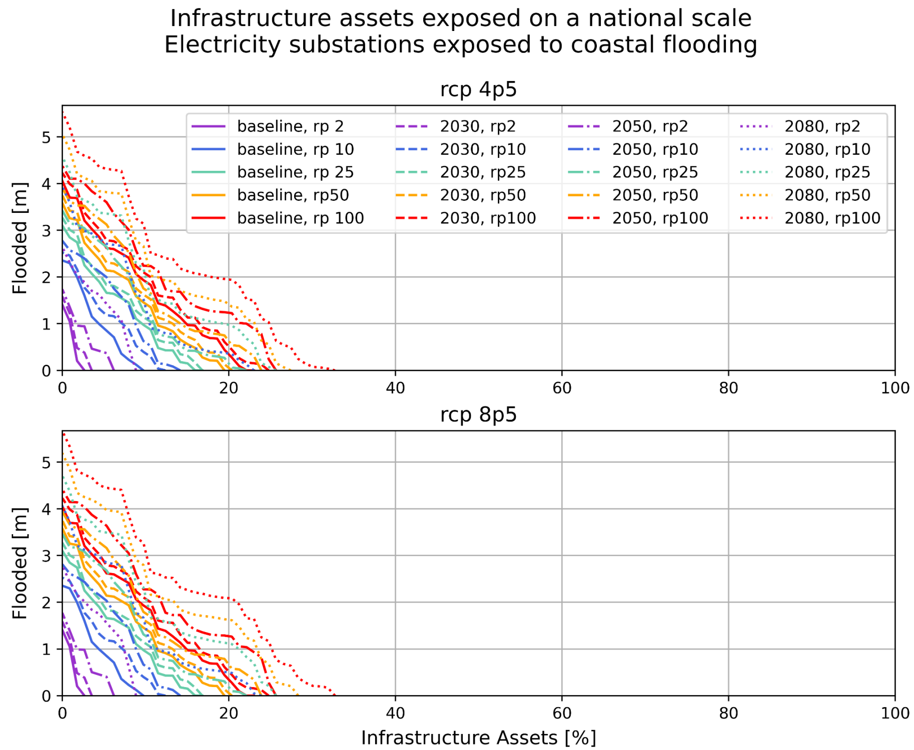

Infrastructure assets exposed on a national scale
Ports exposed to coastal flooding
rcp 4p5
rcp 8p5
Flooded [m]
Infrastructure Assets [%]
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100

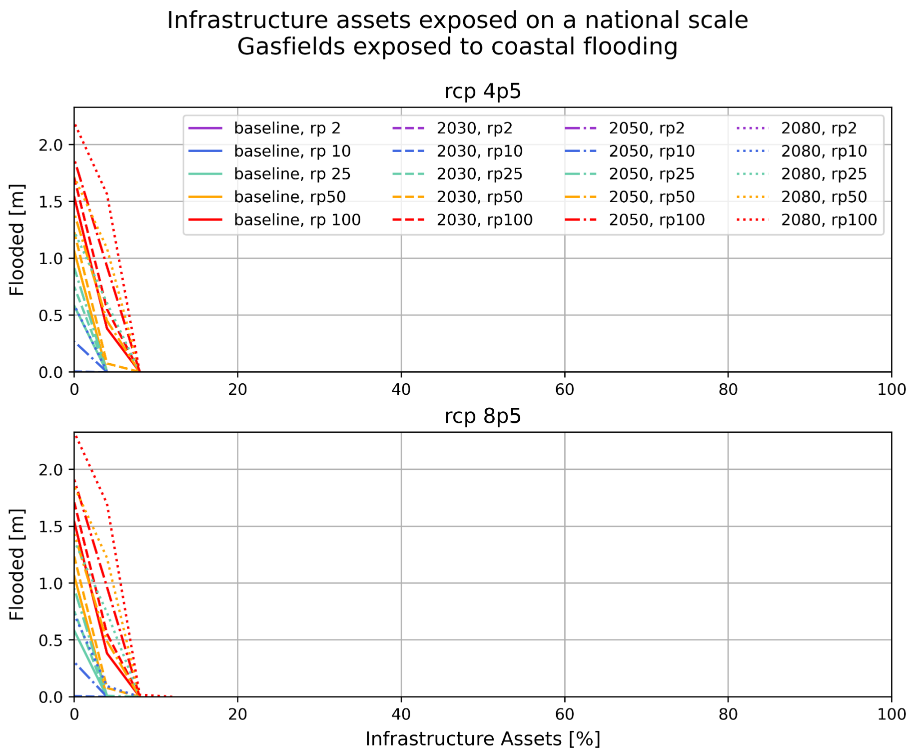

Infrastructure assets exposed on a national scale
Inland water terminals exposed to coastal flooding
rcp 4p5
rcp 8p5
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100
Flooded [m]
Infrastructure Assets [%]


Infrastructure assets exposed on a national scale
Road network exposed to coastal flooding
rcp 4p5
rcp 8p5
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100
Flooded [m]
Infrastructure Assets [%]

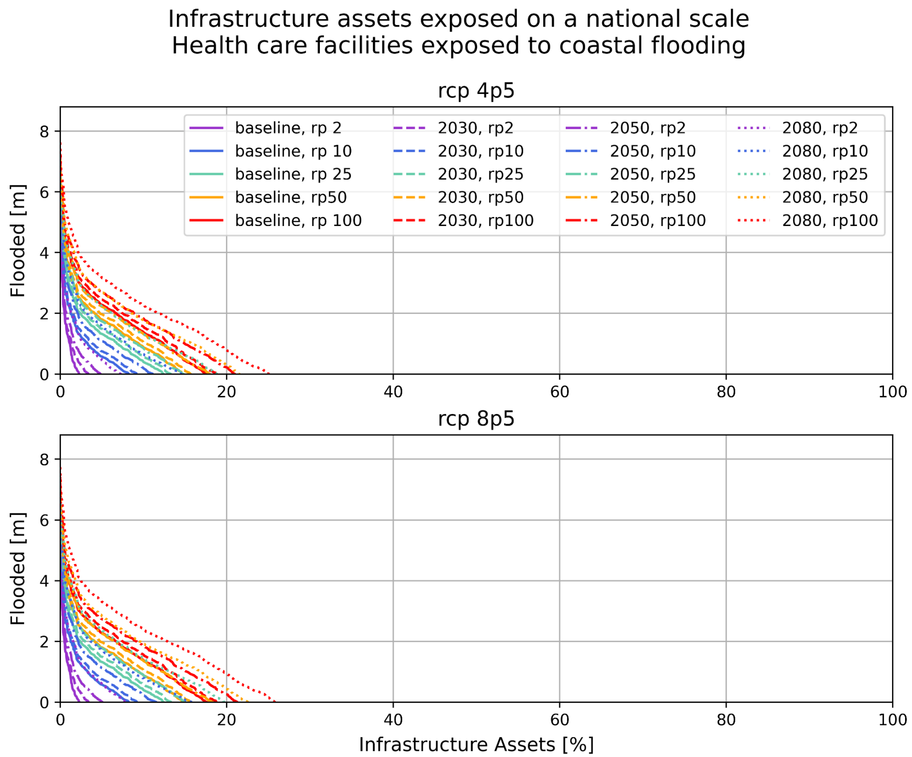
Energy assets exposure to coastal flooding

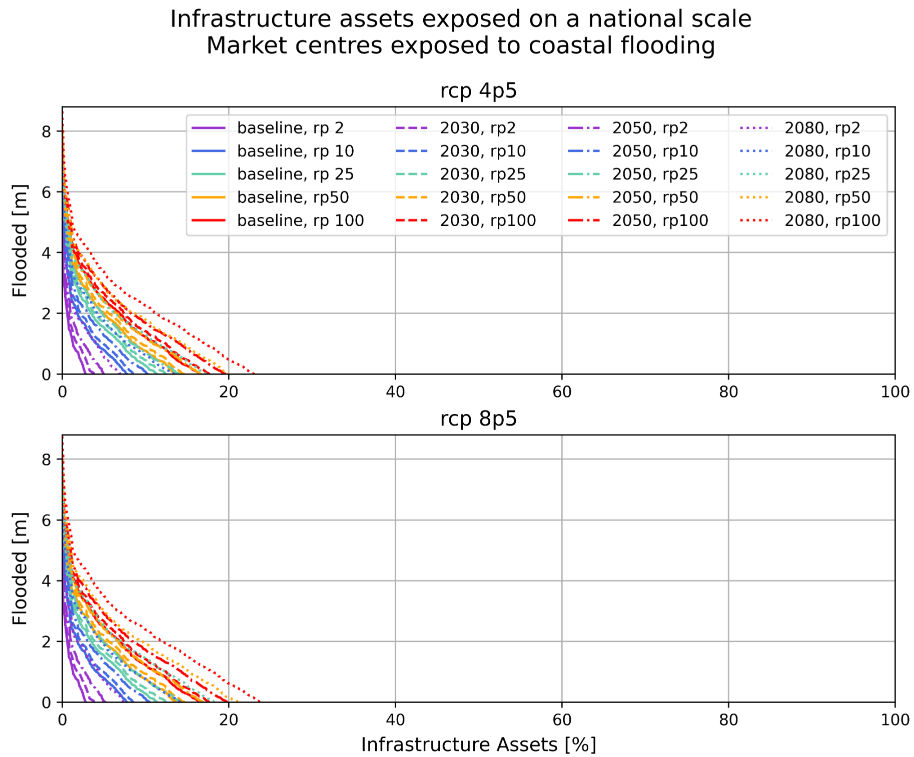


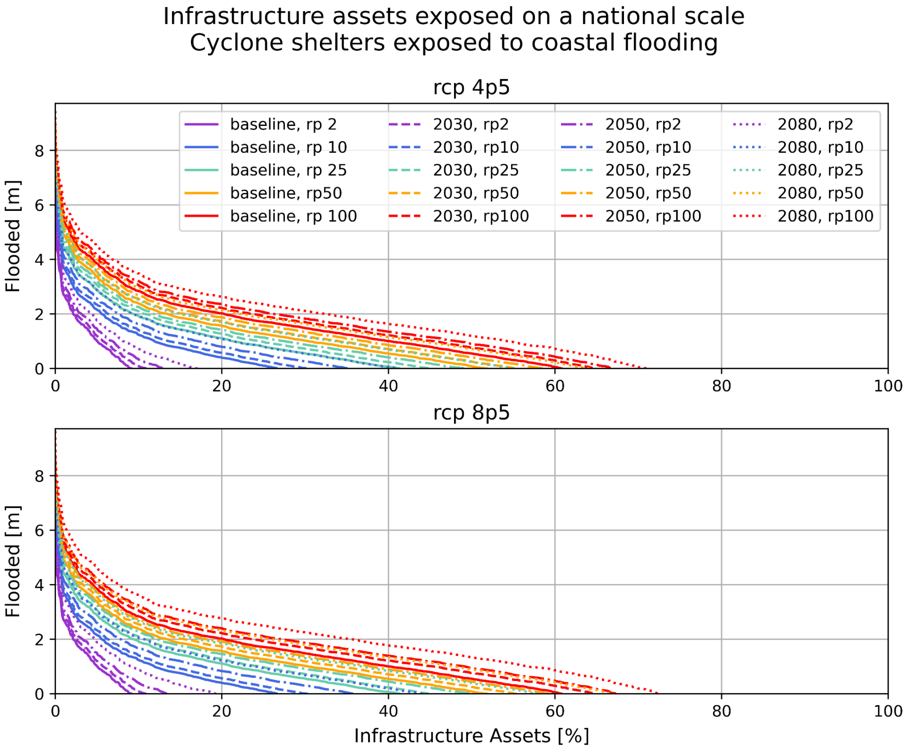


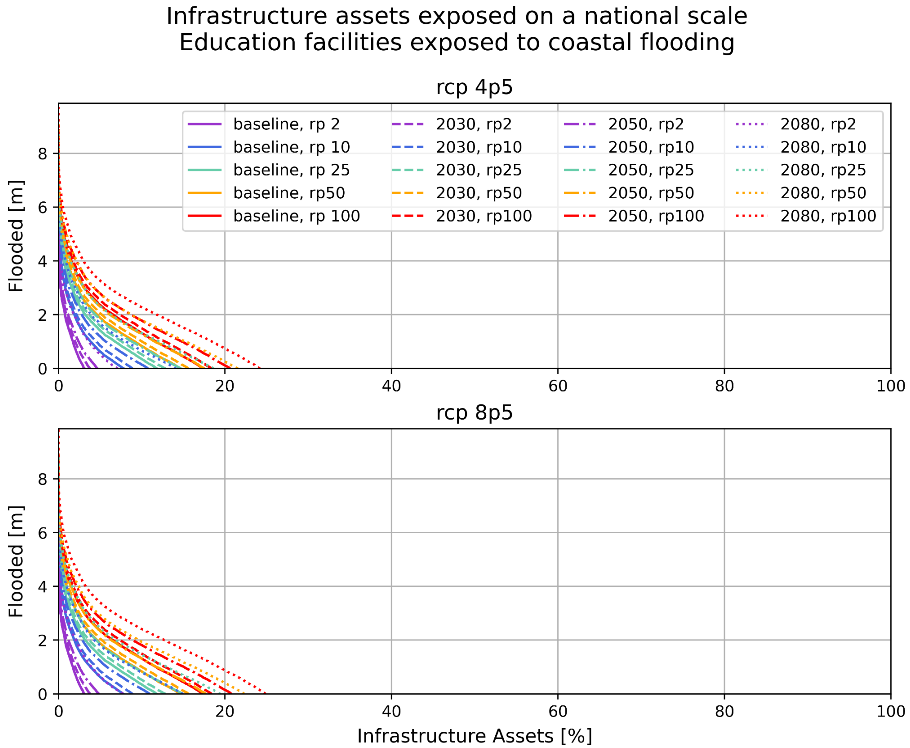

Infrastructure assets exposed on a national scale
Gasfields exposed to coastal flooding
rcp 4p5
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100
Flooded [m]
rcp 8p5
Flooded [m]
Infrastructure Assets [%]

Social assets exposure to coastal flooding

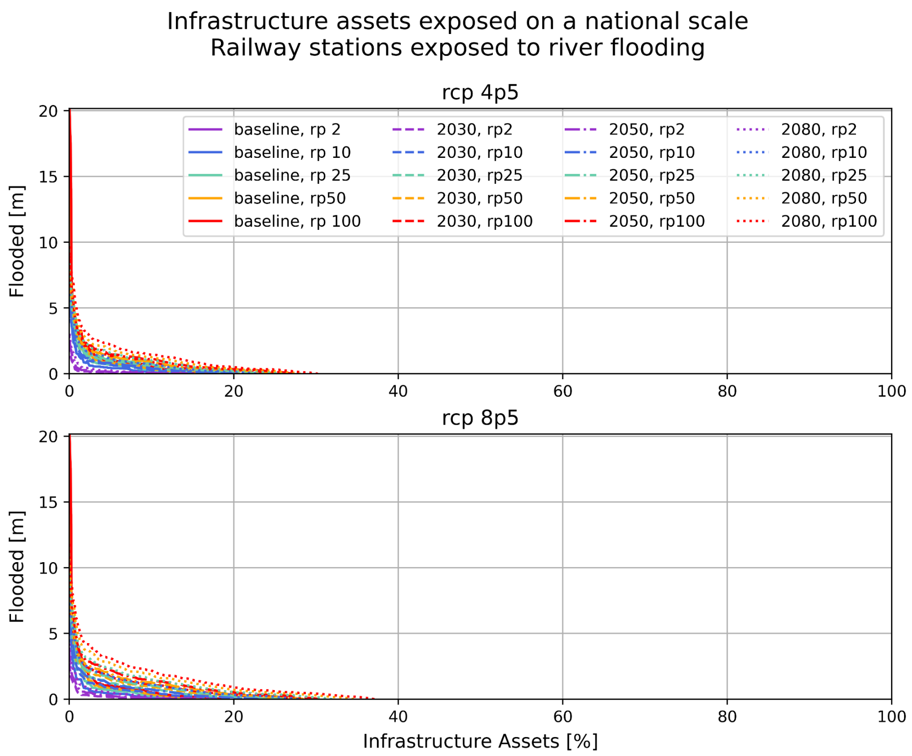


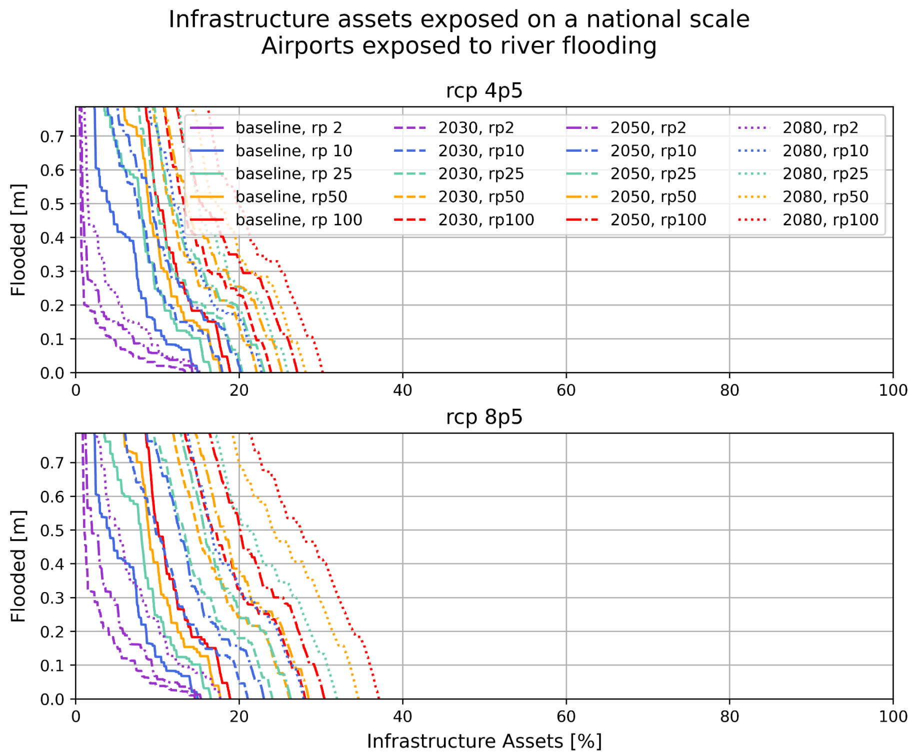


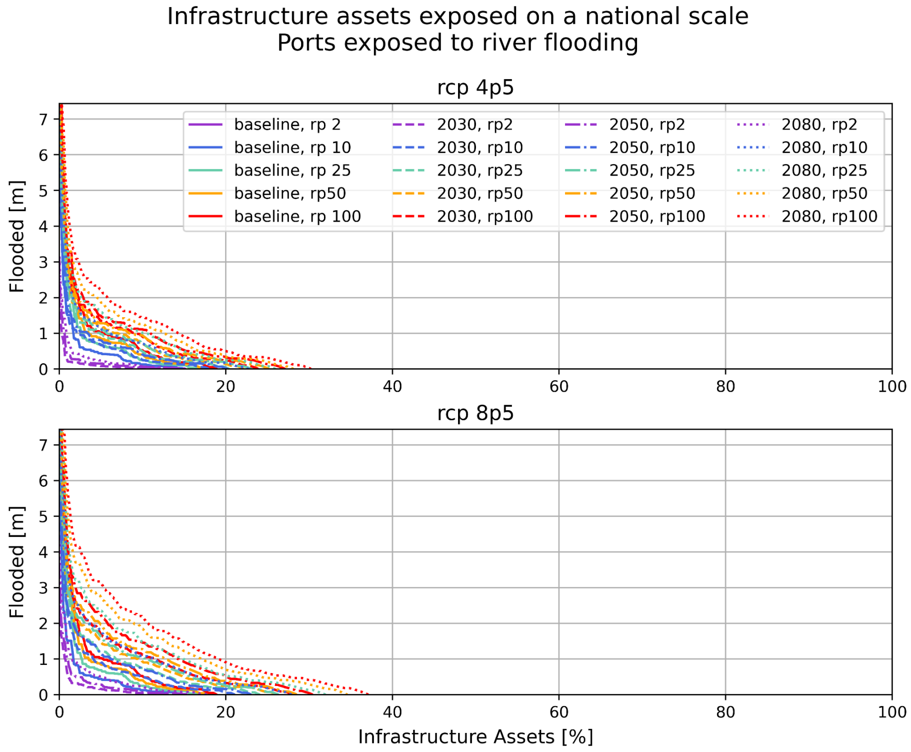

Infrastructure assets exposed on a national scale
Cyclone shelters exposed to coastal flooding
rcp 4p5
rcp 8p5
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100
Flooded [m]
Infrastructure Assets [%]


Infrastructure assets exposed on a national scale
Education facilities exposed to coastal flooding
rcp 4p5
rcp 8p5
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100
Flooded [m]
Infrastructure Assets [%]

Transport assets exposure to river flooding






Infrastructure assets exposed on a national scale
Ports exposed to river flooding
rcp 4p5
rcp 8p5
Flooded [m]
Infrastructure Assets [%]
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
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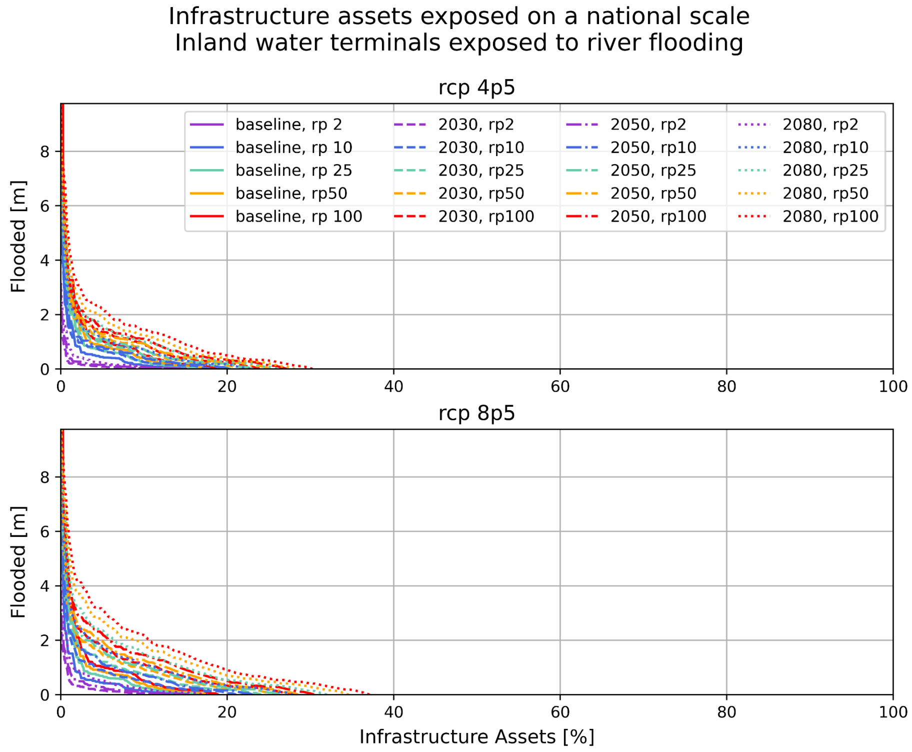
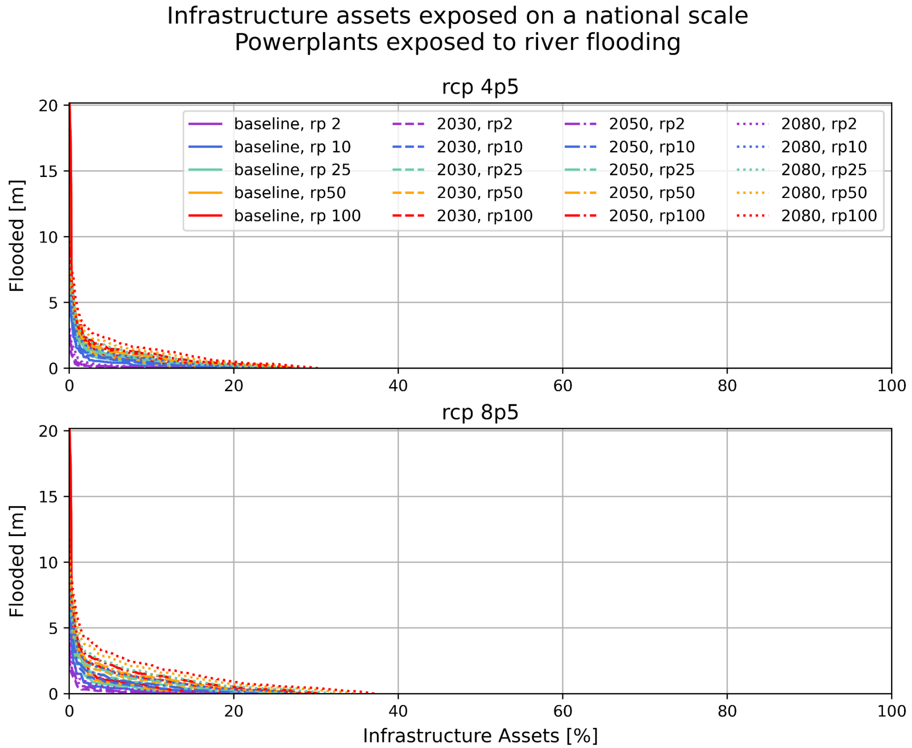
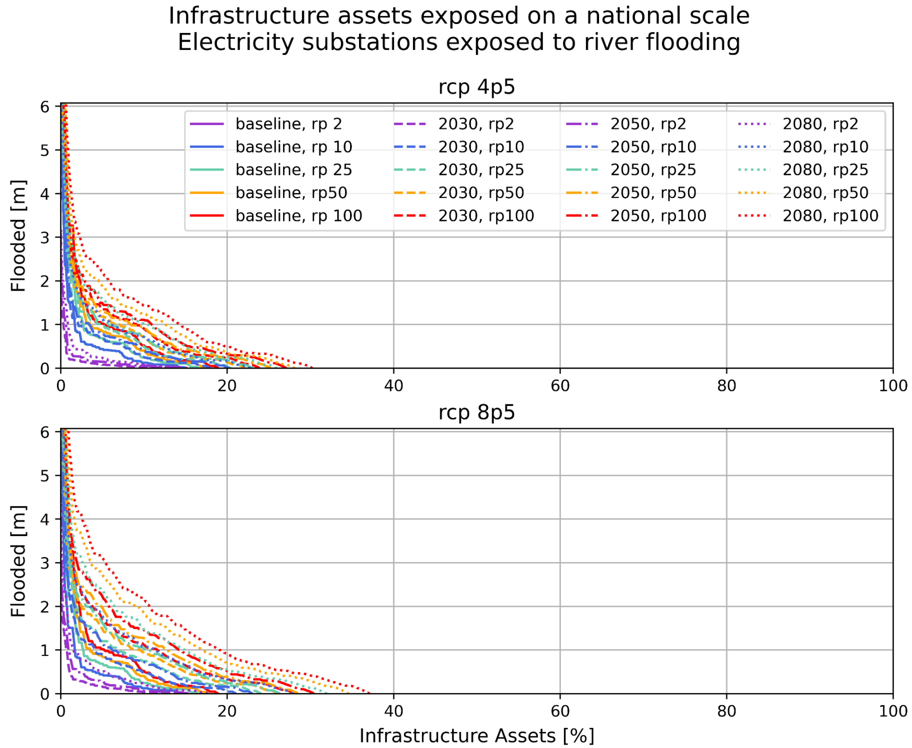
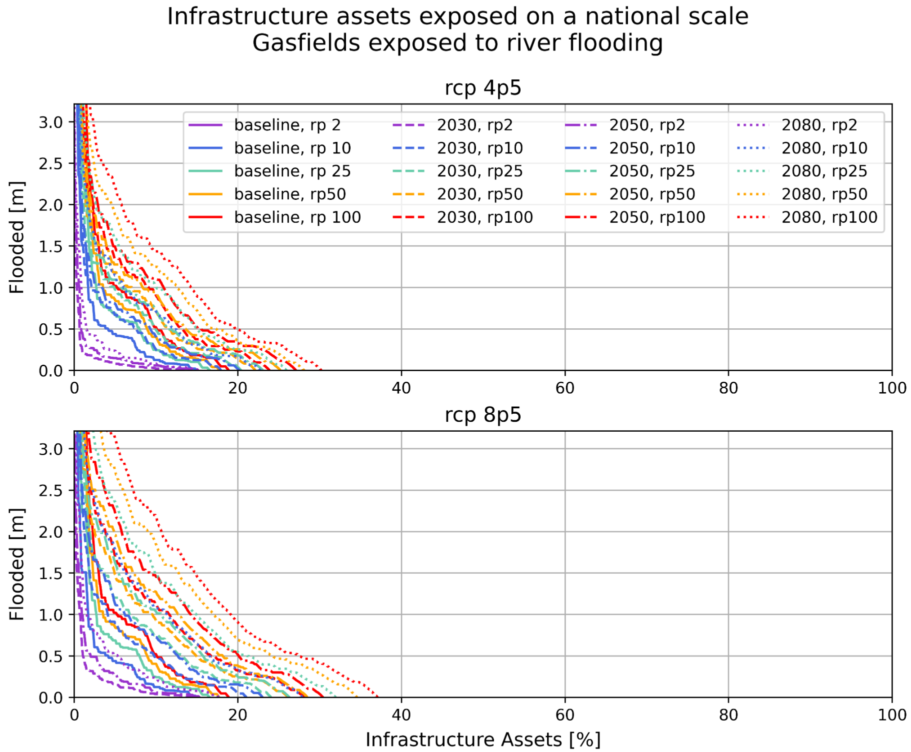
2080, rp50
2080, rp100


Infrastructure assets exposed on a national scale
Inland water terminals exposed to river flooding
rcp 4p5
rcp 8p5
Flooded [m]
Infrastructure Assets [%]
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100

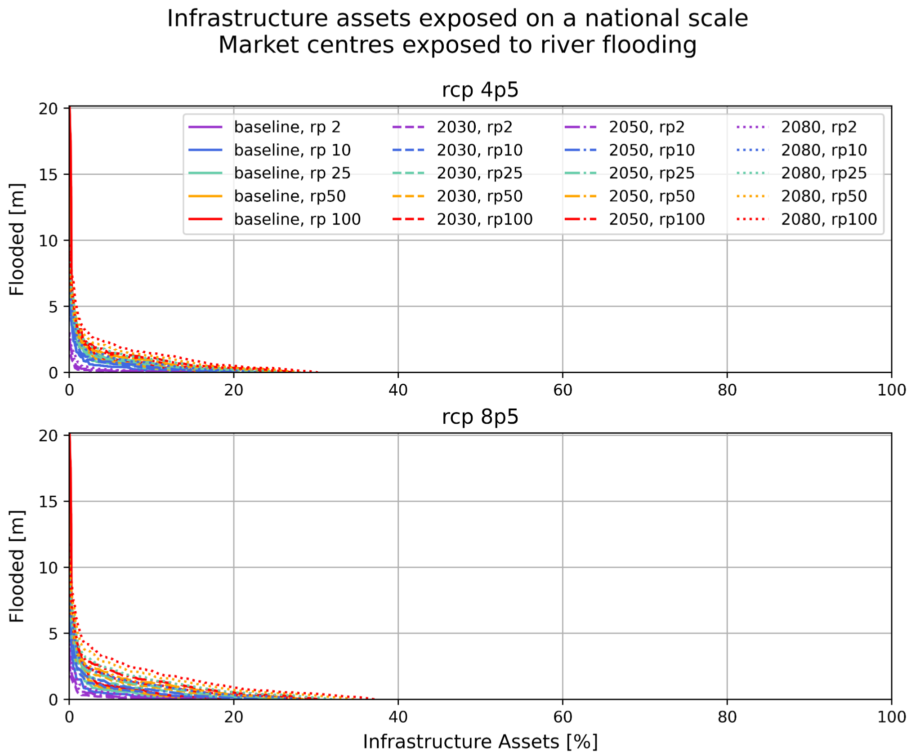
Energy assets exposure to river flooding

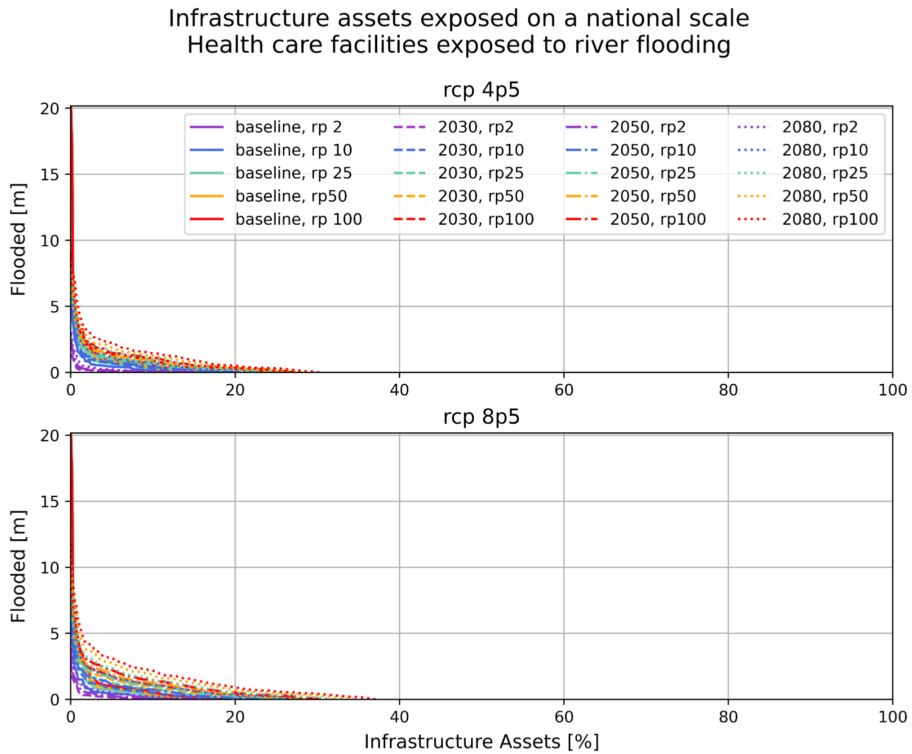


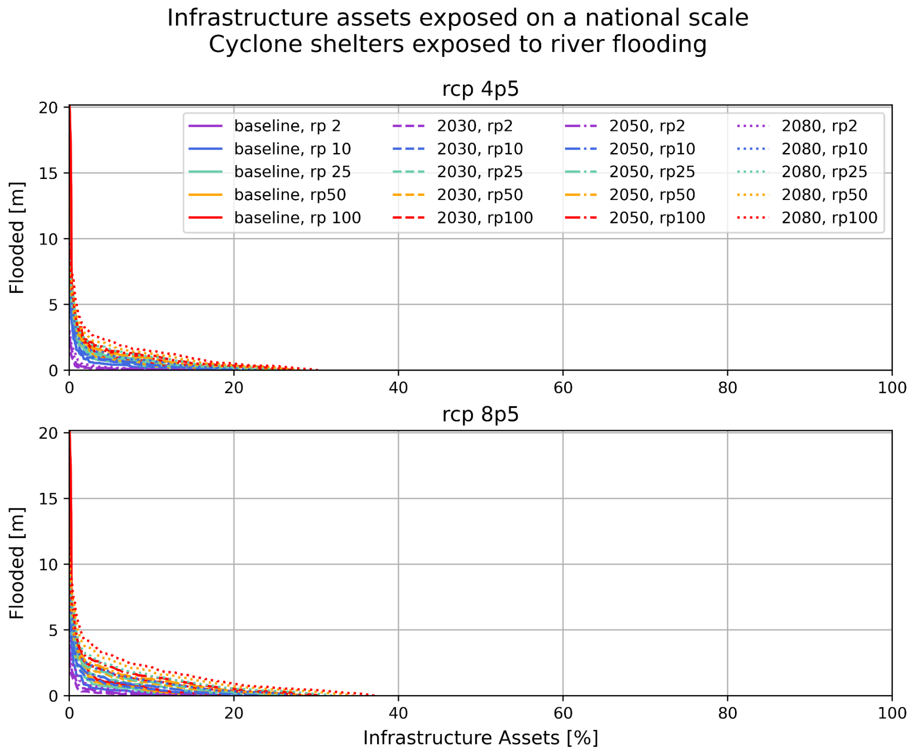


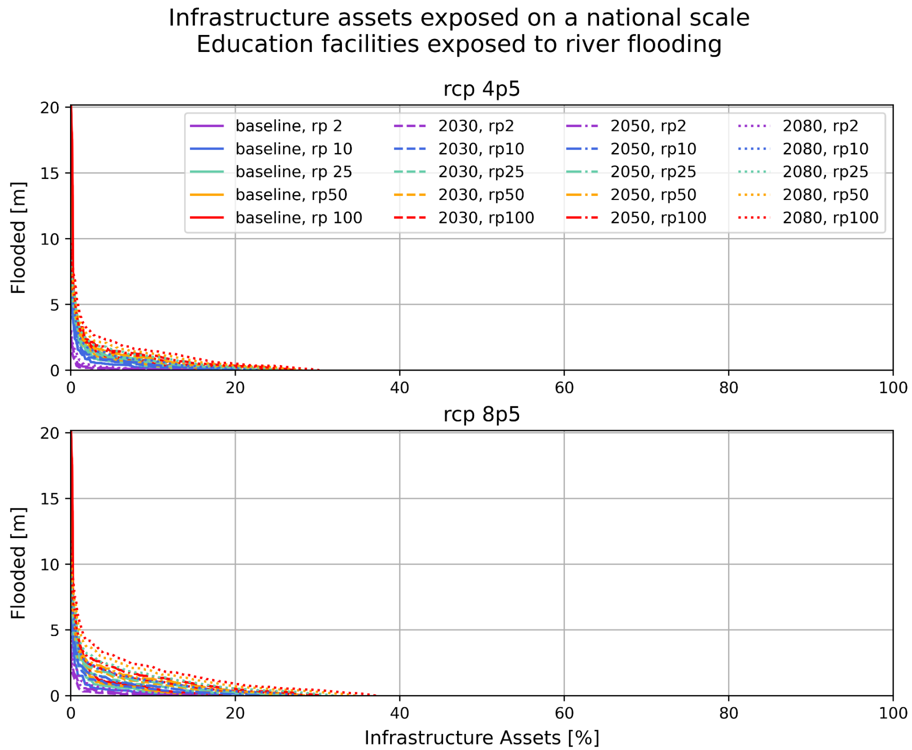

Infrastructure assets exposed on a national scale
Gasfields exposed to river flooding
rcp 4p5
rcp 8p5
Flooded [m]
Infrastructure Assets [%]
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100

Social assets exposure to river flooding

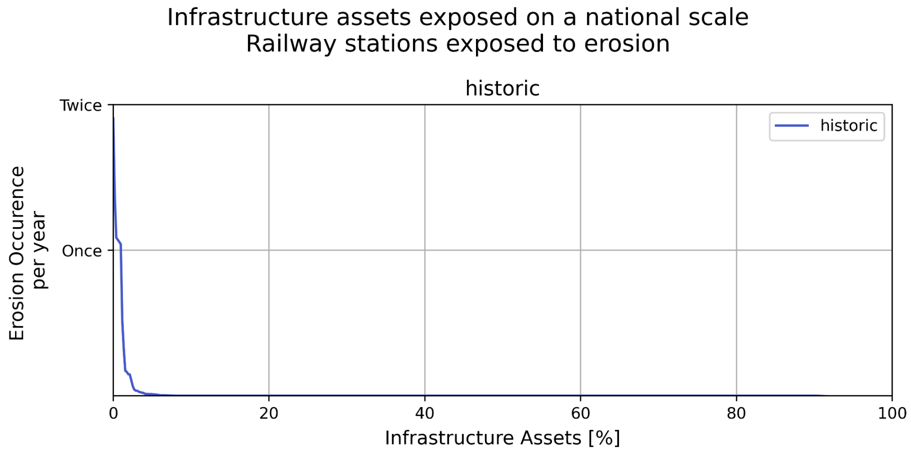


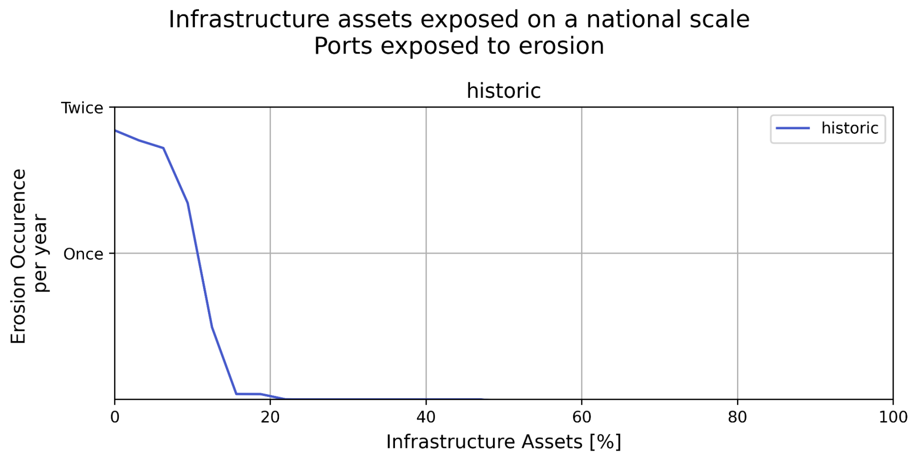


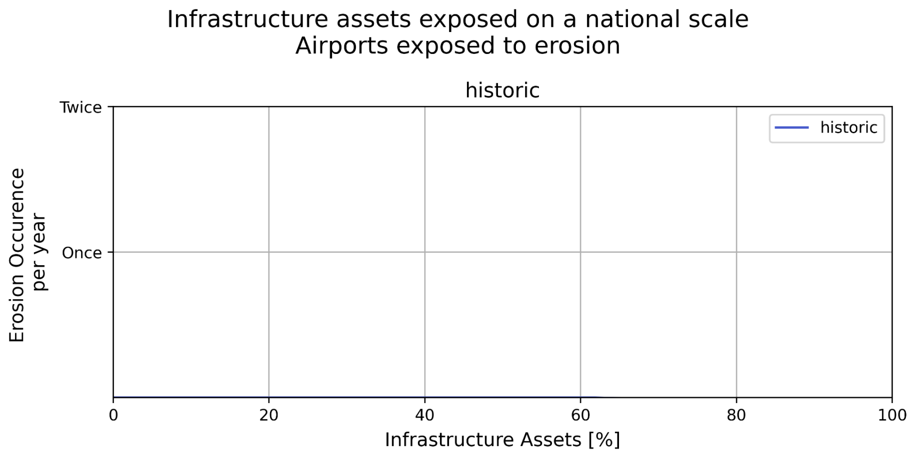

Infrastructure assets exposed on a national scale
Cyclone shelters exposed to river flooding
rcp 4p5
rcp 8p5
Flooded [m]
Infrastructure Assets [%]
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100

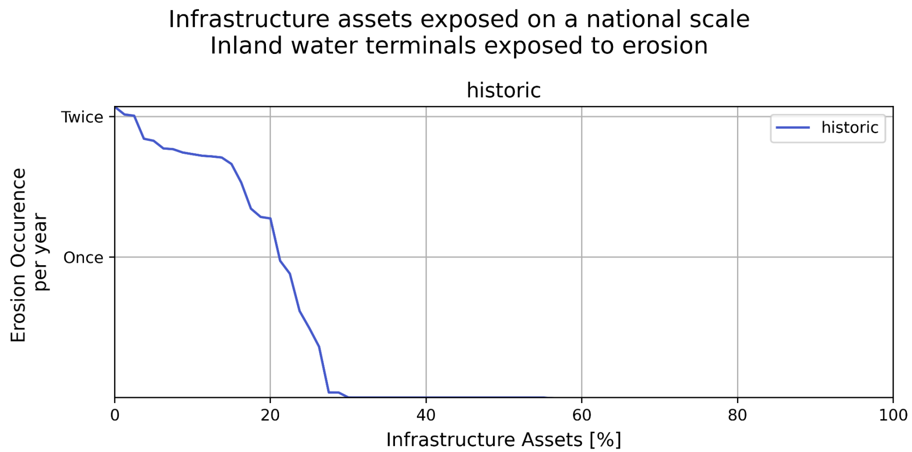

Infrastructure assets exposed on a national scale
Education facilities exposed to river flooding
rcp 4p5
rcp 8p5
Flooded [m]
Infrastructure Assets [%]
baseline, rp 2
baseline, rp 10
baseline, rp 25
baseline, rp50
baseline, rp 100
2030, rp2
2030, rp10
2030, rp25
2030, rp50
2030, rp100
2050, rp2
2050, rp10
2050, rp25
2050, rp50
2050, rp100
2080, rp2
2080, rp10
2080, rp25
2080, rp50
2080, rp100

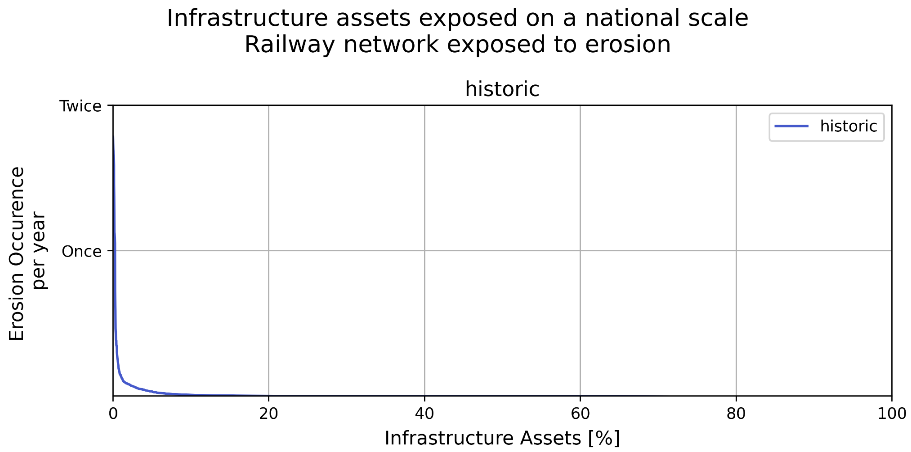
Transport assets exposure to erosion



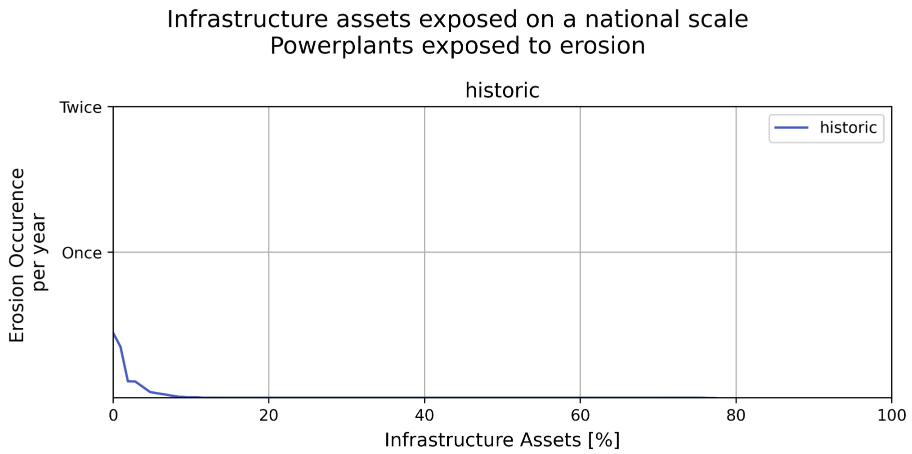


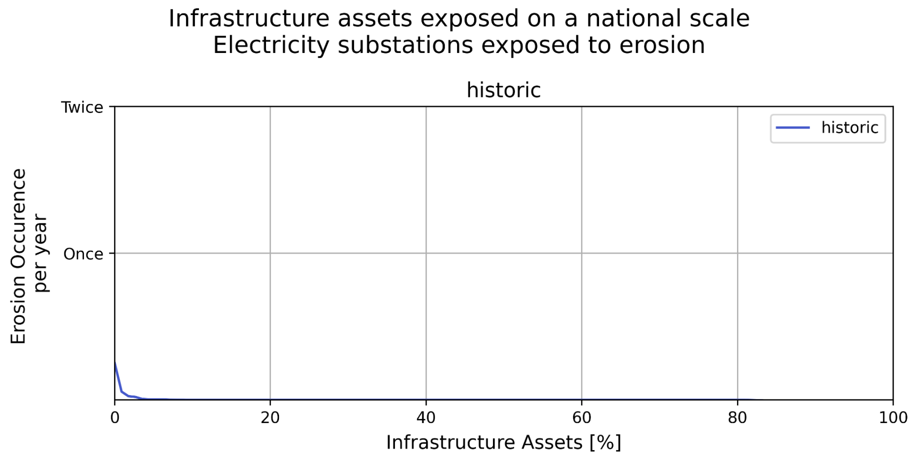


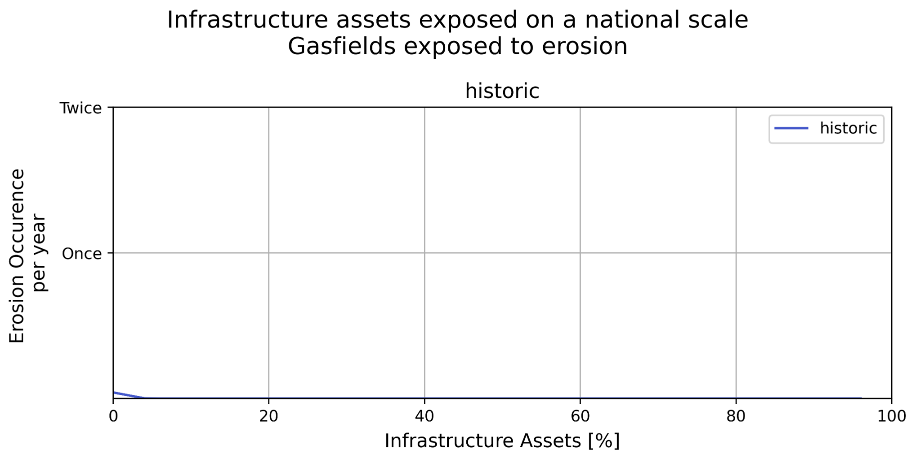


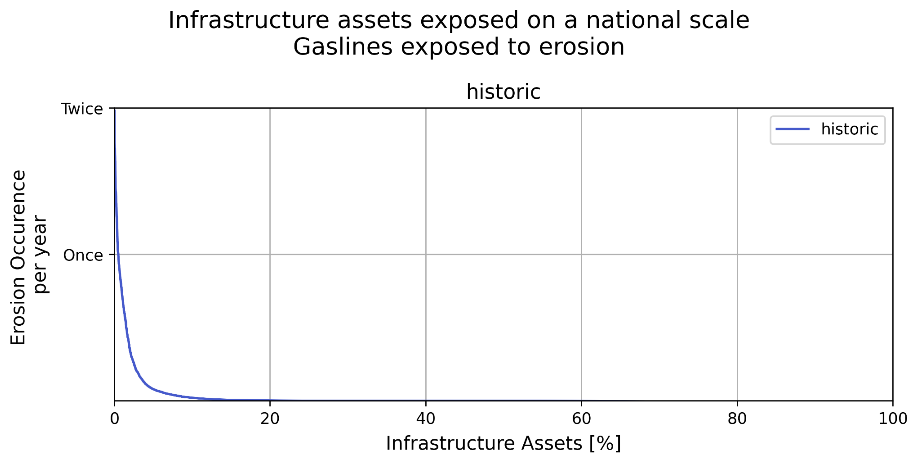

Infrastructure assets exposed on a national scale
Railway network exposed to erosion
historic
historic
Twice
Once
Erosion Occurence per year
0
20
40
60
80
100
Infrastructure Assets [%]

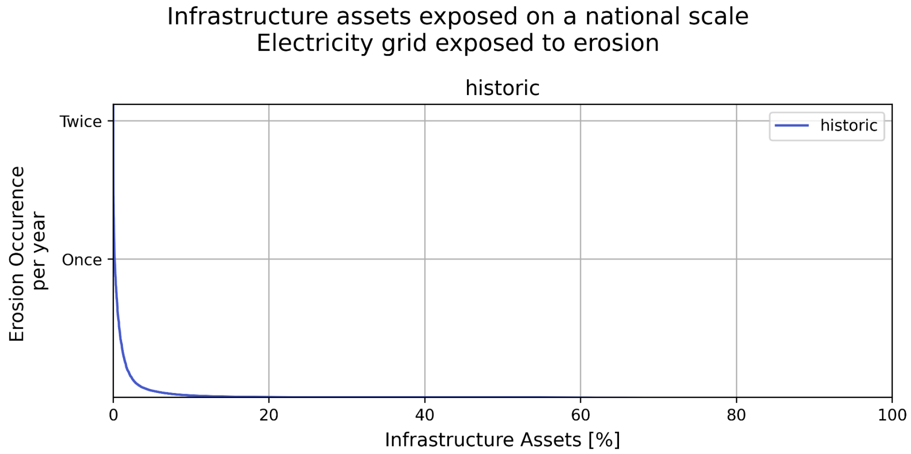
Energy assets exposure to erosion

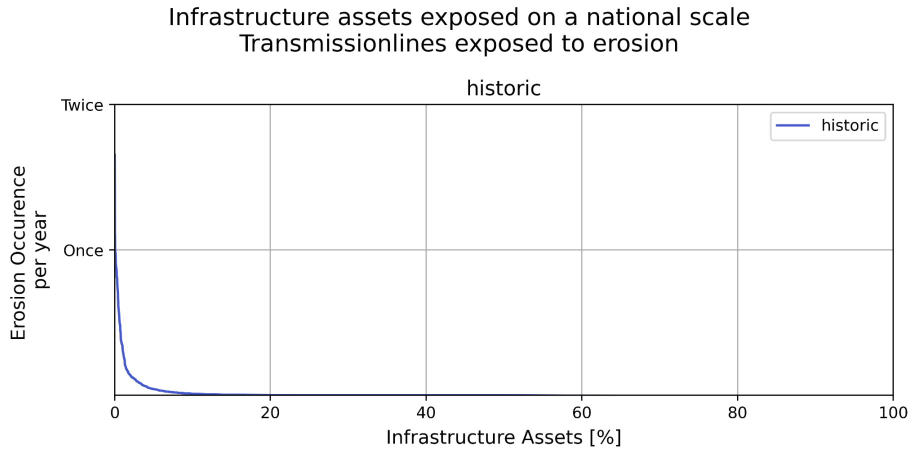




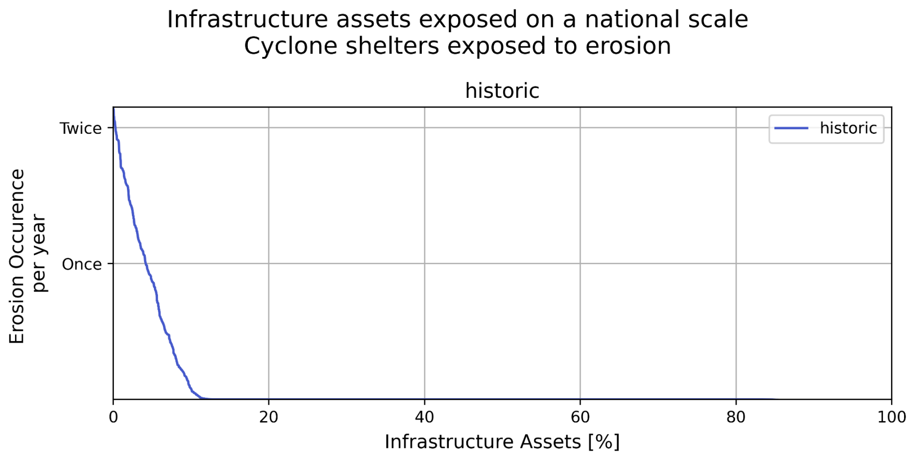


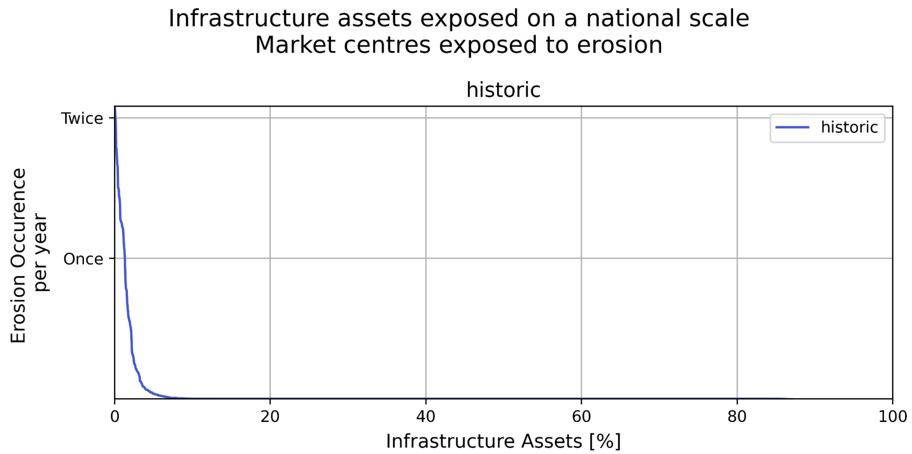


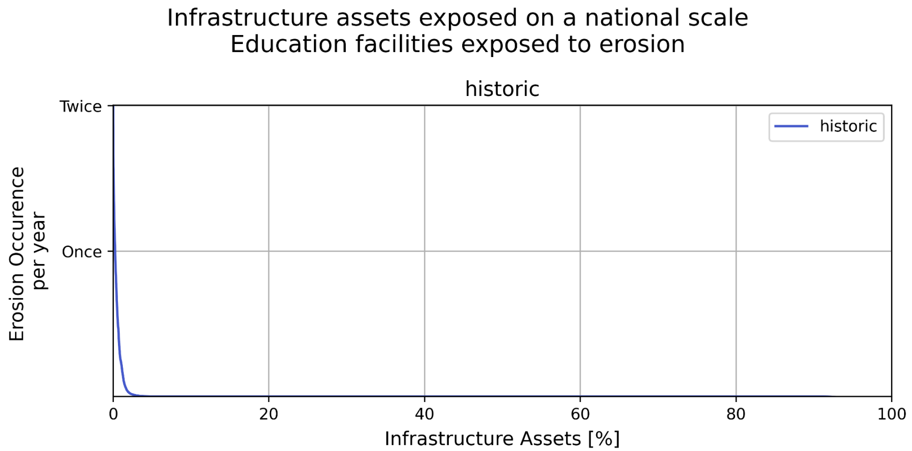

Infrastructure assets exposed on a national scale
Electricity grid exposed to erosion
historic
historic
Twice
Once
Erosion Occurence per year
0
20
40
60
80
100
Infrastructure Assets [%]

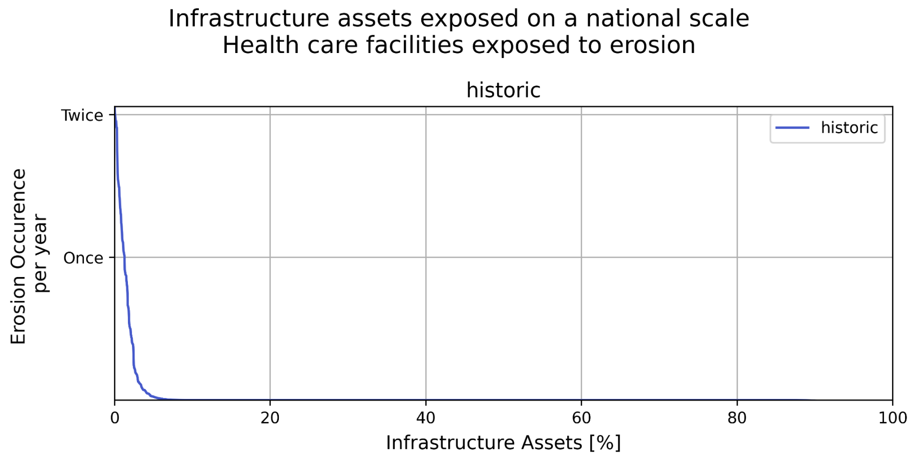

Infrastructure assets exposed on a national scale
Transmissionlines exposed to erosion
historic
historic
Twice
Once
Erosion Occurence per year
0
20
40
60
80
100
Infrastructure Assets [%]

Social assets exposure to erosion









Summary tables of exposure and damages to all assets from all hazards for a range of scenarios:

Hazard	Scenario	Transport Infrastructure												Total damage (million €)
		Roads		Railway lines		Railway stations		Airports		Ports		Inland water terminals		
		% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	
Coastal	**Baseline:** 10yr	9.34%	3370.13	2.47%	1.16	2.12%	0.06	15.38%	0.08	31.25%	0.11	45%	1.30	3372.84
	Baseline: 50yr	15.71%	6259.80	4.55%	2.80	4.05%	0.11	15.38%	0.16	46.88%	0.19	61.25%	2.03	6265.09
	RCP4.5: 10yr 2030	10.61%	3910.31	2.77%	1.35	2.31%	0.07	15.38%	0.14	37.50%	0.12	50%	1.42	3913.41
	RCP4.5 50yr 2030	16.47%	6664.71	4.68%	3.08	4.24%	0.15	15.38%	0.16	46.88%	0.19	61.25%	2.07	6670.36
	RCP4.5: 10yr 2050	12.41%	4654.25	3.31%	1.93	2.89%	0.08	15.38%	0.15	40.62%	0.15	55%	1.57	4658.13
	RCP4.5 50yr 2050	18.59%	7362.46	5.35%	3.68	4.43%	0.18	15.38%	0.16	50.00%	0.21	62.5%	2.18	7368.87
	RCP4.5: 10yr 2080	15.63%	6001.14	4.29%	2.85	3.85%	0.12	15.38%	0.15	46.88%	0.18	58.75%	1.82	6006.26
	RCP4.5 50yr 2080	22.30%	9066.72	7.59%	5.41	7.13%	0.28	23.08%	0.18	53.12%	0.24	67.5%	2.43	9075.26
	RCP8.5: 10yr 2030	10.63%	3913.14	2.77%	1.35	2.31%	0.07	15.38%	0.10	37.50%	0.12	50%	1.42	3916.2
	RCP8.5 50yr 2030	16.48%	6669.01	4.68%	3.08	4.24%	0.16	15.38%	0.16	46.88%	0.19	61.25%	2.06	6674.66

	RCP8.5: 10yr 2050	12.62%	4746.12	3.36%	1.96	2.89%	0.08	15.38%	0.15	40.62%	0.15	55%	1.60	4750.06
	RCP8.5 50yr 2050	18.77%	7456.05	5.43%	3.75	4.43%	0.18	15.38%	0.16	50.00%	0.21	62.5%	2.21	7462.56
	RCP8.5: 10yr 2080	16.43%	6379.12	4.65%	3.12	4.05%	0.14	15.38%	0.16	46.88%	0.19	60%	1.93	6384.66
	RCP8.5 50yr 2080	23.01%	9471.07	8.03%	5.86	7.32%	0.30	23.08%	0.24	53.12%	0.24	67.5%	2.48	9480.19
Riverine	**Baseline:** 10yr	19.14%	4399.65	15.35%	3.46	15.22%	0.41	15.38%	0.04	40.62%	0.11	30%	0.57	4404.24
	Baseline: 50yr	22.03%	6016.11	19.26%	6.69	20.23%	0.55	15.38%	0.05	43.75%	0.16	32.5%	0.85	6024.41
	RCP4.5: 10yr 2030	18.77%	4543.73	18.87%	3.55	18.50%	0.40	15.38%	0.03	43.75%	0.11	32.5%	0.60	4548.42
	RCP4.5 50yr 2030	21.78%	6015.04	23.44%	6.62	21.58%	0.49	15.38%	0.06	46.88%	0.16	36.25%	0.84	6023.21
	RCP4.5: 10yr 2050	20.56%	4069.18	21.23%	3.01	20.23%	0.37	15.38%	0.04	43.75%	0.10	35 %	0.55	4073.25
	RCP4.5 50yr 2050	24.31%	5352.26	26.47%	5.42	25.24%	0.46	15.38%	0.04	53.12%	0.14	40%	0.70	5359.02
	RCP4.5: 10yr 2080	21.89%	5562.25	24.25%	5.66	22.93%	0.47	15.38%	0.04	50.00%	0.15	37.5%	0.79	5569.36
	RCP4.5 50yr 2080	25.78%	7568.68	30.12%	9.78	28.90%	0.60	15.38%	0.07	56.25%	0.19	42.5%	1.07	7580.39
	RCP8.5: 10yr 2030	20.82%	4602.70	22.07%	3.51	21.19%	0.39	15.38%	0.03	46.88%	0.12	36.25%	0.61	4607.36

	RCP8.5 50yr 2030	24.28%	6058.68	27.36%	6.57	24.66%	0.49	15.38%	0.06	56.25%	0.15	41.25%	0.83	6066.78
	RCP8.5: 10yr 2050	22.05%	5897.37	24.54%	6.06	23.12%	0.49	15.38%	0.04	56.25%	0.15	41.25%	0.85	5904.96
	RCP8.5 50yr 2050	25.93%	7815.30	30.25%	10.00	28.52%	0.61	15.38%	0.07	59.38%	0.18	43.75%	1.04	7827.2
	RCP8.5: 10yr 2080	25.32%	6319.34	29.92%	7.24	28.71%	0.51	15.38%	0.06	59.38%	0.16	43.75%	0.90	6328.21
	RCP8.5 50yr 2080	30.13%	8618.39	35.92%	11.87	34.68%	0.67	23.08%	0.08	65.62%	0.21	47.5%	1.18	8632.4
Cyclones	**Baseline:** 10yr	30.43%	NA	22.25%	NA	22.16%	NA	38.46%	NA	12.50%	1.83	42.5%	NA	1.83
	Baseline: 50yr	86.13%	NA	84.38%	NA	82.27%	NA	76.92%	NA	100.00%	1.83	95%	NA	1.83
Erosion	Baseline	39.71%	NA	39.71%	NA	56.26%	NA	61.54%	NA	31.25%	NA	40%	NA	NA

Hazard	Scenario	Energy Infrastructure										Total damage (million €)
		Power Plants		Electricity substations		Electricity grid		Gas fields		Gas lines		
		% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	
Coastal	**Baseline:** 10yr	16.04%	1.46	9.73%	0.03	NA	NA	0.00%	0.00	7.75%	0.82	2.31
	Baseline: 50yr	28.30%	3.17	19.47%	0.08	NA	NA	4.00%	0.03	12.09%	1.41	4.69
	RCP4.5: 10yr 2030	20.75%	1.82	12.39%	0.04	NA	NA	4.00%	0.01	8.34%	0.89	2.76

	RCP4.5 50yr 2030	30.19%	3.44	20.35%	0.09	NA	NA	8.00%	0.04	12.59%	1.50	5.07
	RCP4.5: 10yr 2050	26.42%	2.38	14.16%	0.06	NA	NA	4.00%	0.01	9.74%	1.06	3.51
	RCP4.5 50yr 2050	33.02%	3.97	23.89%	0.11	NA	NA	8.00%	0.04	13.67%	1.67	5.79
	RCP4.5: 10yr 2080	31.13%	3.39	23.01%	0.09	NA	NA	4.00%	0.02	11.83%	1.33	4.83
	RCP4.5 50yr 2080	38.68%	4.78	27.43%	0.13	NA	NA	8.00%	0.07	16.11%	2.01	6.99
	RCP8.5: 10yr 2030	20.75%	1.82	12.39%	0.04	NA	NA	4.00%	0.01	8.33%	0.89	2.76
	RCP8.5 50yr 2030	30.19%	3.44	20.35%	0.09	NA	NA	8.00%	0.04	12.61%	1.50	5.07
	RCP8.5: 10yr 2050	26.42%	2.45	14.16%	0.06	NA	NA	4.00%	0.01	10.01%	1.09	3.61
	RCP8.5 50yr 2050	33.96%	4.00	23.89%	0.11	NA	NA	8.00%	0.04	13.74%	1.68	5.83
	RCP8.5: 10yr 2080	31.13%	3.61	23.89%	0.10	NA	NA	8.00%	0.03	12.44%	1.41	5.15
	RCP8.5 50yr 2080	40.57%	5.00	28.32%	0.14	NA	NA	8.00%	0.07	16.58%	2.09	7.3
Riverine	**Baseline:** 10yr	24.53%	0.70	23.01%	0.04	NA	NA	4.00%	0.02	19.25%	1.04	1.8
	Baseline: 50yr	31.13%	1.60	24.78%	0.07	NA	NA	4.00%	0.03	21.99%	1.45	3.15
	RCP4.5: 10yr 2030	29.25%	0.78	25.66%	0.04	NA	NA	4.00%	0.02	22.49%	1.08	1.92

	RCP4.5 50yr 2030	32.08%	1.47	29.20%	0.06	NA	NA	4.00%	0.02	26.43%	1.49	3.04
	RCP4.5: 10yr 2050	31.13%	0.64	27.43%	0.04	NA	NA	4.00%	0.02	24.49%	0.97	1.67
	RCP4.5 50yr 2050	34.91%	0.99	30.97%	0.05	NA	NA	20.00%	0.02	29.02%	1.31	2.37
	RCP4.5: 10yr 2080	31.13%	1.36	30.09%	0.06	NA	NA	12.00%	0.03	26.98%	1.38	2.83
	RCP4.5 50yr 2080	34.91%	2.31	33.63%	0.07	NA	NA	16.00%	0.04	31.93%	1.97	4.39
	RCP8.5: 10yr 2030	31.13%	0.82	28.32%	0.04	NA	NA	4.00%	0.02	25.38%	1.10	1.98
	RCP8.5 50yr 2030	36.79%	1.46	30.97%	0.06	NA	NA	16.00%	0.03	30.25%	1.45	3
	RCP8.5: 10yr 2050	31.13%	1.39	30.09%	0.05	NA	NA	8.00%	0.03	27.32%	1.46	2.93
	RCP8.5 50yr 2050	39.62%	2.16	32.74%	0.08	NA	NA	16.00%	0.04	32.26%	1.99	4.27
	RCP8.5: 10yr 2080	38.68%	1.69	32.74%	0.06	NA	NA	16.00%	0.03	31.68%	1.60	3.38
	RCP8.5 50yr 2080	44.34%	2.58	37.17%	0.08	NA	NA	20.00%	0.05	37.72%	2.22	4.93
Cyclone	**Baseline:** 10yr	24.53%	9.78	27.43%	0.38	25.67%	1.05	16.00%	NA	25.29%	NA	11.21
	Baseline: 50yr	79.25%	35.91	89.38%	0.72	83.64%	4.95	32.00%	NA	83.93%	NA	41.58
Erosion	Baseline	46.23%	NA	54.87%	NA	38.55%	NA	52.00%	NA	40.22%	NA	NA

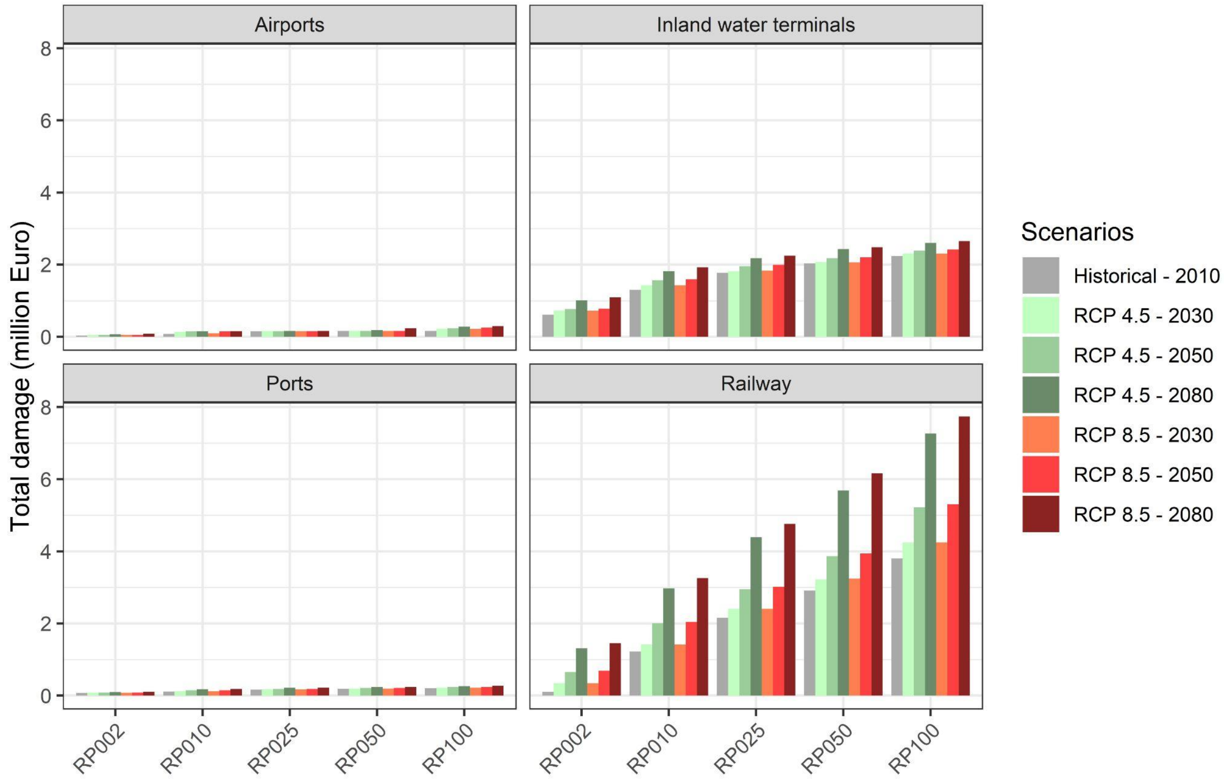
Hazard	Scenario	Social Infrastructure								Total damage (million €)
		Health facilities		Cyclone shelters		Market centres		Education facilities		
		% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	% assets exposed	Damage (million €)	
Coastal	**Baseline:** 10yr	8.23%	0.17	26.61%	0.30	7.77%	7.86	7.77%	1.92	10.25
	Baseline: 50yr	14.65%	0.34	51.79%	0.67	13.61%	15.55	14.64%	4.15	20.71
	RCP4.5: 10yr 2030	9.24%	0.19	30.18%	0.35	8.60%	8.93	8.88%	2.24	11.71
	RCP4.5 50yr 2030	15.75%	0.37	55.18%	0.74	14.67%	16.96	15.61%	4.51	22.58
	RCP4.5: 10yr 2050	11.21%	0.23	35.03%	0.42	10.25%	10.90	10.75%	2.77	14.32
	RCP4.5 50yr 2050	17.98%	0.42	58.54%	0.80	16.67%	19.33	17.52%	5.17	25.72
	RCP4.5: 10yr 2080	14.61%	0.30	40.80%	0.50	13.46%	14.37	14.12%	3.81	18.98
	RCP4.5 50yr 2080	21.61%	0.52	64.12%	0.92	20.07%	24.59	21.52%	6.69	32.72
	RCP8.5: 10yr 2030	9.30%	0.19	30.32%	0.35	8.55%	8.94	8.88%	2.24	11.72
	RCP8.5 50yr 2030	15.75%	0.37	55.36%	0.74	14.67%	16.96	15.64%	4.52	22.59
	RCP8.5: 10yr 2050	11.57%	0.24	35.77%	0.43	10.54%	11.20	10.98%	2.84	14.71
	RCP8.5	18.31%	0.43	59.31%	0.81	16.96%	19.71	17.72%	5.26	26.21

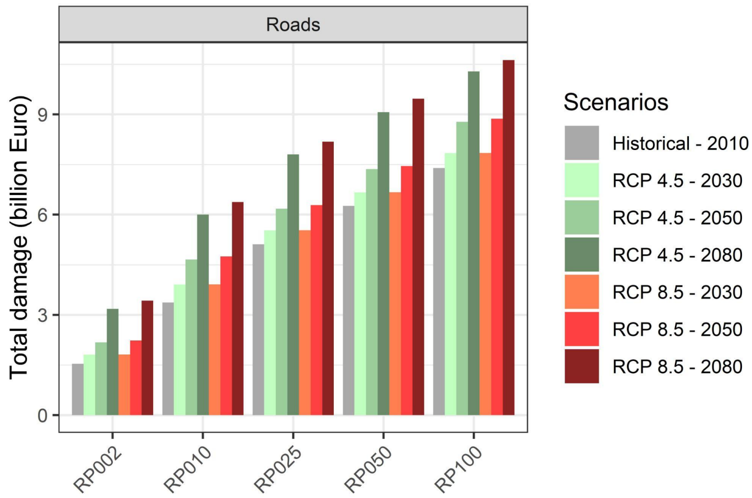
	50yr 2050									
	RCP8.5: 10yr 2080	15.81%	0.33	44.08%	0.55	14.14%	15.48	14.97%	4.12	20.48
	RCP8.5 50yr 2080	22.55%	0.55	66.53%	0.99	21.09%	26.09	22.32%	7.08	34.71
Riverine	**Baseline:** 10yr	14.71%	0.13	13.93%	NA	15.16%	8.61	14.92%	2.18	10.92
	Baseline: 50yr	17.24%	0.18	15.78%	NA	17.44%	12.66	17.71%	3.17	16.01
	RCP4.5: 10yr 2030	17.85%	0.12	15.36%	NA	17.35%	8.53	17.95%	2.15	10.8
	RCP4.5 50yr 2030	21.91%	0.18	18.06%	NA	21.77%	12.51	22.12%	3.16	15.85
	RCP4.5: 10yr 2050	20.29%	0.11	17.66%	NA	19.48%	7.28	20.21%	1.87	9.26
	RCP4.5 50yr 2050	24.56%	0.15	21.74%	NA	24.34%	10.38	25.20%	2.65	13.18
	RCP4.5: 10yr 2080	22.16%	0.15	16.84%	NA	22.59%	10.83	22.75%	2.79	13.77
	RCP4.5 50yr 2080	27.93%	0.22	20.65%	NA	27.55%	16.44	28.12%	4.24	20.9
	RCP8.5: 10yr 2030	20.67%	0.12	14.88%	NA	20.65%	8.40	21.03%	2.14	10.66
	RCP8.5 50yr 2030	25.37%	0.17	17.53%	NA	25.46%	12.01	26.16%	3.07	15.25
	RCP8.5: 10yr 2050	22.29%	0.16	16.28%	NA	22.50%	11.81	23.01%	2.97	14.94
	RCP8.5	29.13%	0.23	19.51%	NA	27.94%	17.05	28.48%	4.32	21.6

	50yr 2050									
	RCP8.5: 10yr 2080	27.90%	0.18	18.93%	NA	27.11%	12.85	27.88%	3.29	16.32
	RCP8.5 50yr 2080	36.03%	0.27	24.09%	NA	33.97%	19.48	34.60%	4.96	24.71
Cyclones	**Baseline:** 10yr	25.28%	NA	86.76%	NA	27.36%	NA	26.34%	NA	NA
	Baseline: 50yr	85.81%	NA	97.38%	NA	84.69%	NA	85.72%	NA	NA
Erosion	Baseline	56.06%	NA	38.20%	NA	53.30%	NA	57.25%	NA	NA

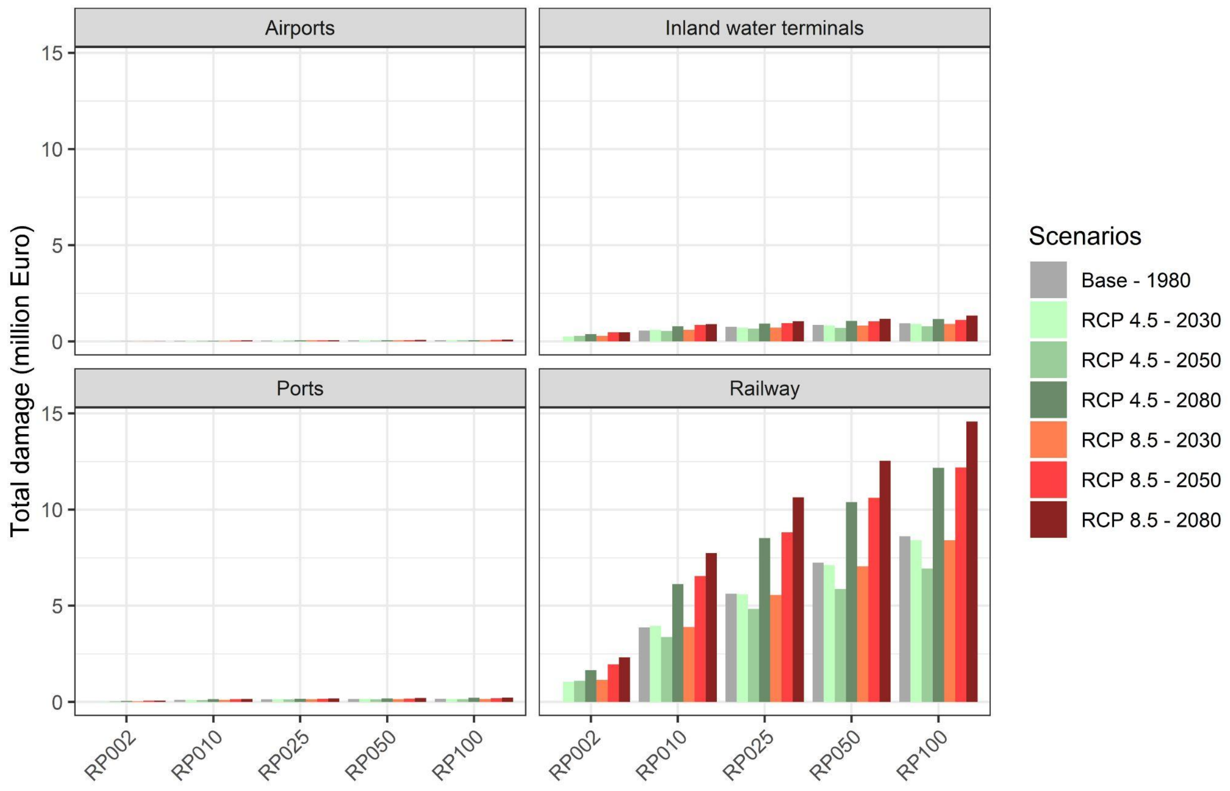
Bar graphs of damages to all assets from all hazards for a range of climate scenarios:

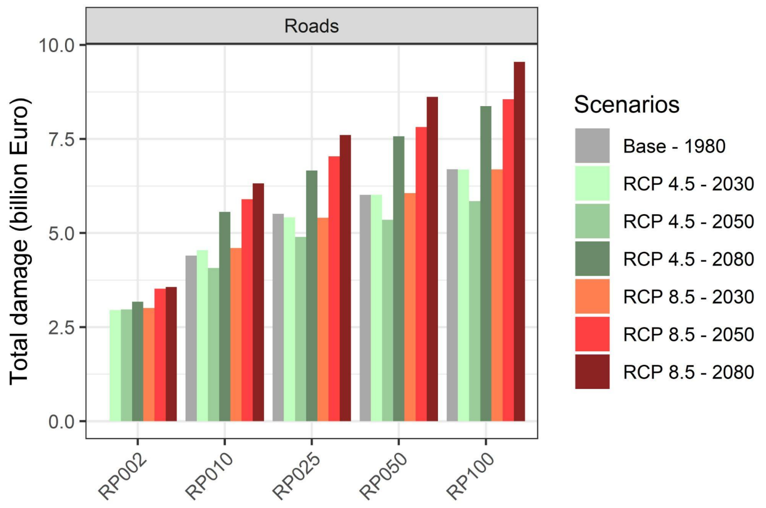
Transport sector damages caused by coastal flooding





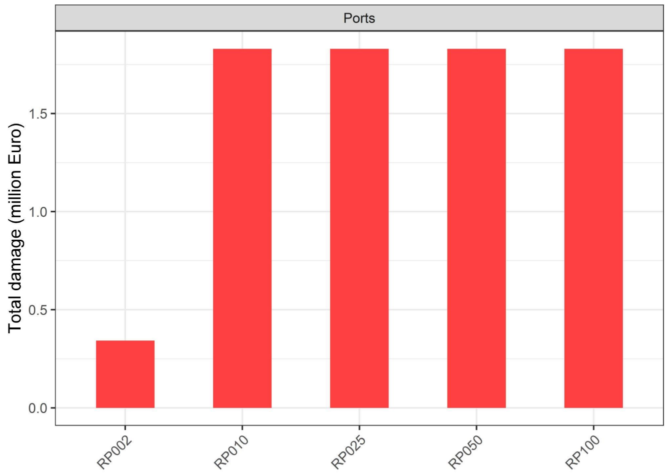
Transport sector damages caused by river flooding



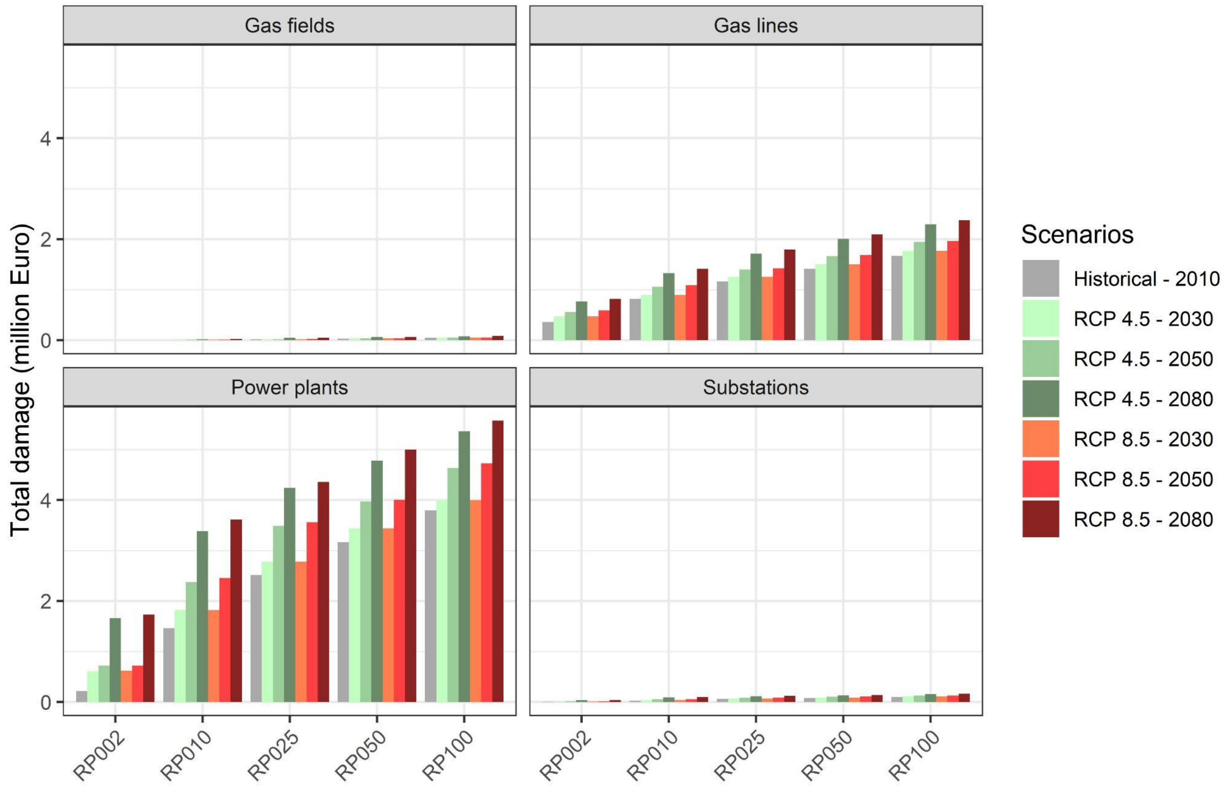


Transport sector damages caused by cyclones

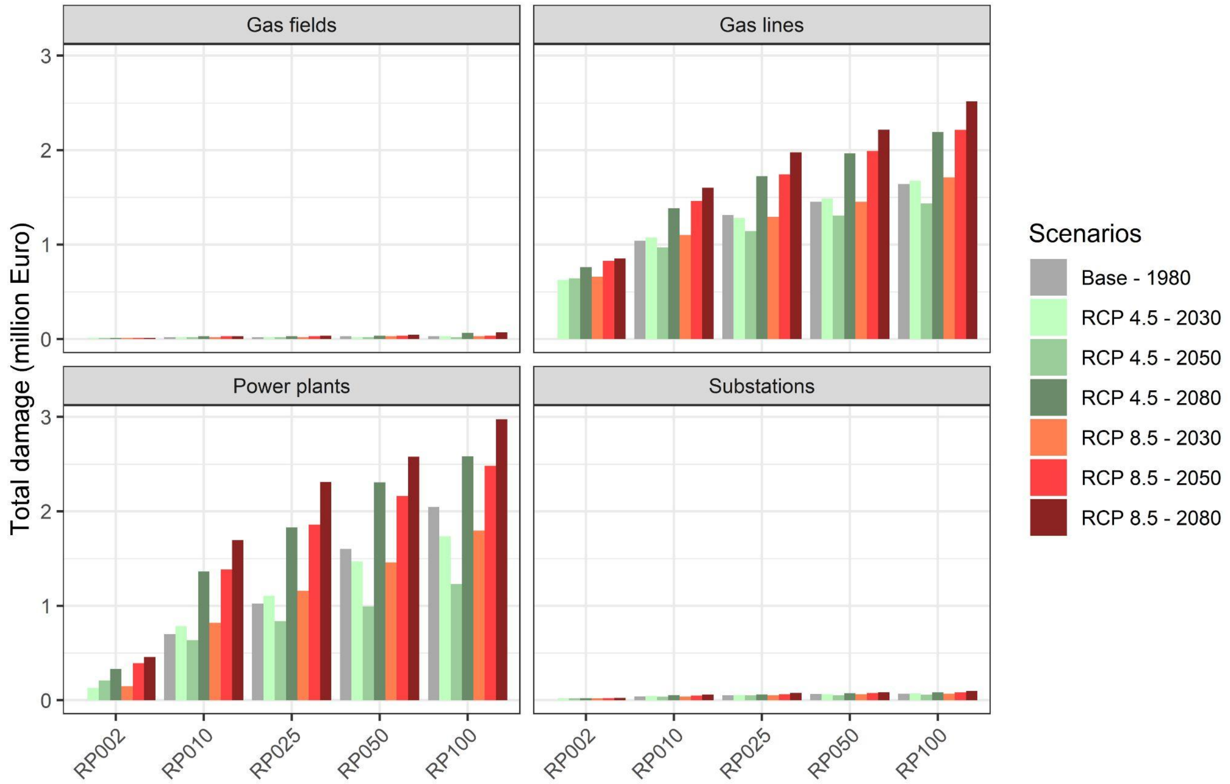
Note, there are no different climate scenarios for cyclones, only a range of return periods.



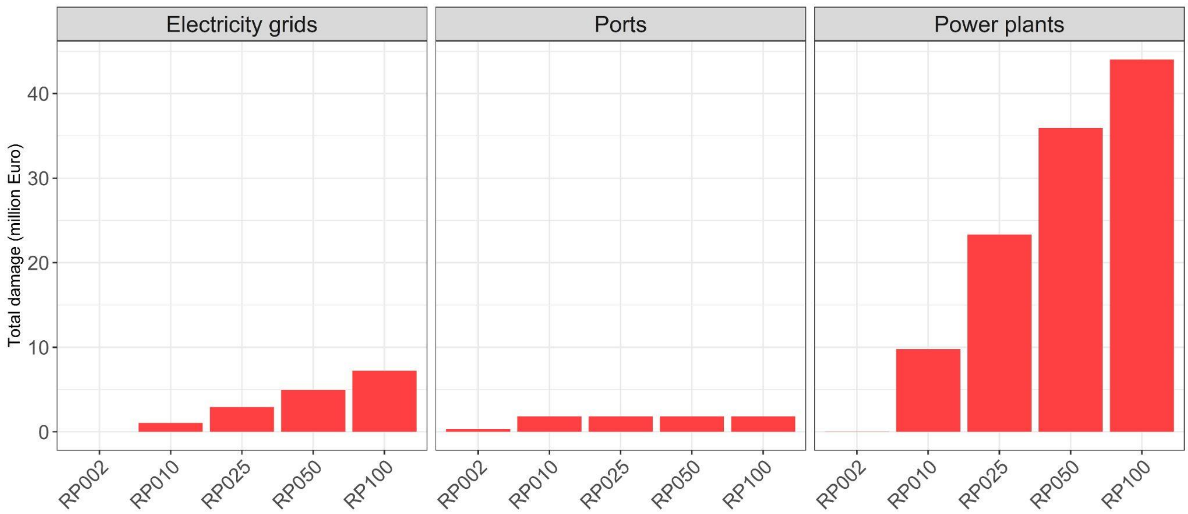
Energy sector damages caused by coastal flooding



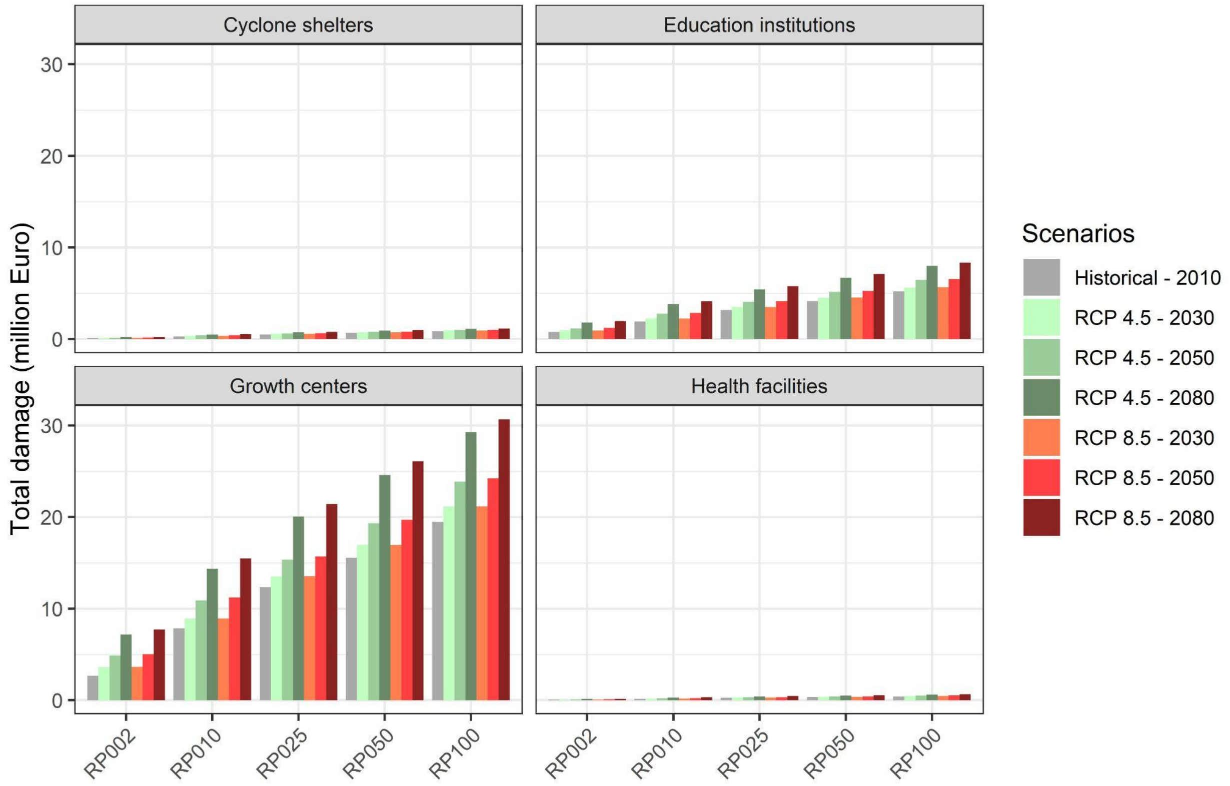
Energy sector damages caused by river flooding



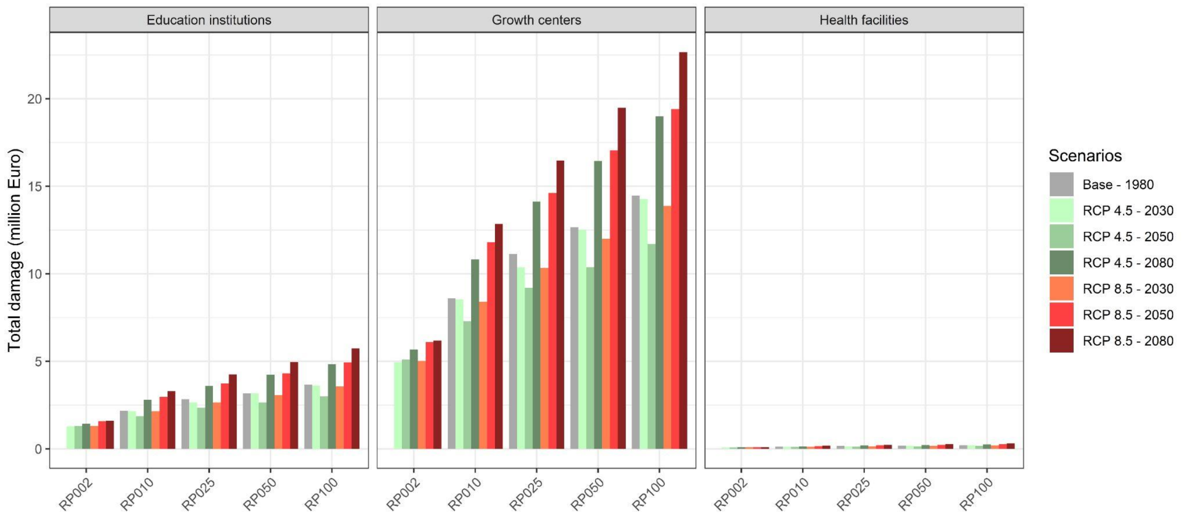
Energy sector damages caused by cyclones



Critical social infrastructure damages caused by coastal flooding



Critical social infrastructure damages caused by river flooding



Summary tables of percentage of female population exposed and overall average wealth index for all sector-specific assets

Hazard	Scenario	Transport Infrastructure									
		Roads		Railway lines		Railway stations		Ports		Inland water terminals	
		% population exposed (female)	Wealth index	% population exposed (female)	Wealth index	% population exposed (female)	Wealth index	% population exposed (female)	Wealth index	% population exposed (female)	Wealth index
Coastal	**Baseline:** 50yr	42.75 (49.43)	-0.185	11.40 (48.60)	0.291	2.99 (49.14)	0.268	2.62 (50.76)	-0.238	6.95 (50.61)	-0.373
	RCP4.5 50yr 2050	43.56 (49.39)	-0.177	11.40 (48.60)	0.291	2.99 (49.14)	0.268	4.57 (49.81)	-0.2	8.90 (50.16)	-0.353
	RCP8.5 50yr 2050	44.12 (49.34)	-0.168	11.40 (48.60)	0.291	2.99 (49.14)	0.268	4.57 (49.81)	-0.2	8.90 (50.16)	-0.353
Riverine	**Baseline:** 50yr	82.88 (49.64)	-0.217	34.50 (49.50)	-0.073	17.87 (49.92)	-0.076	5.12 (49.27)	-0.012	7.39 (49.73)	-0.149
	RCP4.5 50yr 2050	82.83 (49.65)	-0.212	32.28 (49.43)	-0.032	15.31 (49.82)	-0.097	5.01 (49.24)	0.04	7.08 (49.68)	-0.106
	RCP8.5 50yr 2050	84.95 (49.67)	-0.217	34.38 (49.51)	-0.055	18.03 (49.99)	-0.109	5.12 (49.27)	-0.012	7.62 (49.77)	-0.181
Cyclones	**Baseline:** 50yr	NA	NA	NA	NA	NA	NA	7.56 (49.76)	-0.145	NA	NA

Airports are excluded from the proximity analysis due to their impacts at the national scale

Hazard	Scenario	Energy Infrastructure					
		Electricity substations		Electricity grid		Gas lines	
		% population exposed (female)	Wealth index	% population exposed (female)	Wealth index	% population exposed (female)	Wealth index
Coastal	**Baseline:** 50yr	7.01 (47.97)	0.191	NA	NA	27.47 (49.42)	-0.179
	RCP4.5: 50yr 2050	9.87 (48.38)	0.175	NA	NA	29.41 (49.39)	-0.177
	RCP8.5 50yr 2050	9.87 (48.38)	0.175	NA	NA	29.41 (49.39)	-0.177
Riverine	**Baseline:** 50yr	10.81 (48.40)	0.327	NA	NA	61.30 (49.71)	-0.206
	RCP4.5: 50yr 2050	10.42 (48.35)	0.356	NA	NA	60.40 (49.69)	-0.192
	RCP8.5 50yr 2050	12.15 (48.17)	0.347	NA	NA	64.29 (49.76)	-0.203
Cyclones	**Baseline:** 50yr	31.73 (48.89)	0.135	87.95 (49.54)	-0.248	NA	NA

Power plants and gas fields are linked to the country's energy networks. Therefore, these two sectors were excluded from the proximity analysis in order to estimate population exposure.

Hazard	Scenario	Social Infrastructure							
		Health facilities		Cyclone shelters		Market centres		Education facilities	
		% population exposed (female)	Wealth index	% population exposed (female)	Wealth index	% population exposed (female)	Wealth index	% population exposed (female)	Wealth index
Coastal	**Baseline:** 50yr	23.31 (49.57)	-0.263	13.19 (50.37)	-0.344	22.44 (49.68)	-0.312	40.75 (49.40)	-0.187
	RCP4.5: 50yr 2050	26.44 (49.68)	-0.295	14.21 (50.42)	-0.337	26.11 (49.69)	-0.321	43.41 (49.41)	-0.195
	RCP8.5 50yr 2050	26.44 (49.68)	-0.295	14.34 (50.43)	-0.337	26.11 (49.69)	-0.321	43.98 (49.36)	-0.186
Riverine	**Baseline:** 50yr	46.39 (49.69)	-0.264	NA	NA	44.96 (49.67)	-0.258	79.46 (49.62)	-0.217
	RCP4.5: 50yr 2050	44.46 (49.65)	-0.257	NA	NA	42.71 (49.59)	-0.249	79.60 (49.62)	-0.216
	RCP8.5 50yr 2050	51.71 (49.83)	-0.276	NA	NA	49.79 (49.79)	-0.271	81.12 (49.64)	-0.219
Cyclones	**Baseline:** 50yr	NA	NA	NA	NA	NA	NA	NA	NA

Households impacted for each climate hazard and asset combination, across all wealth quintiles, for all available scenarios

Sector	Asset	Wealth	Coastal flooding						River flooding						Cyclones			Erosion		
			Rural		Urban		Total		Rural		Urban		Total		Rural	Urban	Total	Rural	Urban	Total
			Baseline	2050	Baseline	2050	Baseline	2050	Baseline	2050	Baseline	2050	Baseline	2050						
Transport	Roads	Q1	510968	575396	124463	143462	635431	718858	273289	347266	77865	97778	351154	445044	1226069	342228	1568297	575743	149553	725296
		Q2	528051	589442	123447	140232	651498	729674	252383	329754	78576	98307	330959	428061	1196132	341659	1537791	560887	147322	708209
		Q3	492749	547003	118955	133759	611704	680762	264739	344552	89848	107086	354587	451638	1164610	348436	1513046	538959	146285	685244
		Q4	517674	571313	117296	131202	634970	702515	275013	356900	95541	110317	370554	467217	1184995	351194	1536189	554669	140905	695574
		Q5	454024	503560	85342	93483	539366	597043	307235	382907	97980	104831	405215	487738	1175120	332435	1507555	536989	138588	675577
		Total	2503466	2786714	569503	642138	3072969	3428852	1372659	1761379	439810	518319	1812469	2279698	5946926	1715952	7662878	2767247	722653	3489900
	Railway stations	Q1	344184	346590	91990	92186	436174	438776	223988	240206	64301	71536	288289	311742	1192166	335779	1527945	561495	164538	726033

		Q2	421731	425134	111732	111936	533463	537070	232664	260106	70930	83564	303594	343670	1170156	336477	1506633	538250	168137	706387
		Q3	429868	433900	115293	115427	545161	549327	255105	293026	78058	94296	333163	387322	1145952	344395	1490347	510356	183706	694062
		Q4	474324	478703	117854	117962	592178	596665	265347	302484	83748	101540	349095	404024	1169122	350469	1519591	517984	201195	719179
		Q5	403541	408584	74398	74408	477939	482992	293444	329619	63758	84841	357202	414460	1165204	359572	1524776	517037	272628	789665
		Total	2073648	2092911	511267.	511919	2584915	2604830	1270548	1425441	360795	435777	1631343	1861218	5842600	1726692	7569292	2645122	990204	3635326
	Inland water terminals	Q1	1087100	1087100	296166	296166	1383266	1383266	449280	491876	142555	159808	591835	651684	1275202	362007	1637209	304160	73479	377639
		Q2	1103326	1103326	312156	312156	1415482	1415482	439033	493262	166915	189989	605948	683251	1272058	364502	1636560	300720	65037	365757
		Q3	1090682	1090682	326093	326093	1416775	1416775	481481	534157	195528	218421	677009	752578	1259619	365421	1625040	271483	62351	333834
		Q4	1118760	1118760	335903	335903	1454663	1454663	469816	522831	215800	239983	685616	762814	1272624	364049	1636673	291727	64063	355790
		Q5	1101570	1101570	352101	352101	1453671	1453671	531359	584751	297106	310591	828465	895342	1264451	364025	1628476	280192	33313	313505
		Total	5501438	5501438	1622419	1622419	7123857	7123857	2370969	2626877	1017904	1118792	3388873	3745669	6343954	1820004	8163958	1448282	298243	1746525
Energy	Electricity substations	Q1	599729	600671	147022	150164	746751	750835	230824	393667	65033	105934	295857	499601	1275202	362007	1637209	304160	73479	377639

		Q2	672034	673292	157387	163829	829421	837121	258456	386518	80584	112194	339040	498712	1272058	364502	1636560	300720	65037	365757
		Q3	646765	648318	153316	163970	800081	812288	276089	397270	104929	129099	381018	526369	1259619	365421	1625040	271483	62351	333834
		Q4	689512	691693	149783	166167	839295	857860	296253	413299	120313	137270	416566	550569	1272624	364049	1636673	291727	64063	355790
		Q5	613625	617462	115120	126029	728745	743491	312555	446676	156761	162319	469316	608995	1264451	364025	1628476	280192	33313	313505
		Total	3221665	3231436	722628	770159	3944293	4001595	1374177	2037430	527620	646816	1901797	2684246	6343954	1820004	8163958	1448282	298243	1746525
	Electricity grid	Q1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1235456	345689	1581145	541896	136297	678193
		Q2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1206999	347222	1554221	536739	134269	671008
		Q3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1177106	356475	1533581	523185	133588	656773
		Q4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1198543	362971	1561514	536811	130977	667788
		Q5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1188103	351305	1539408	520474	122224	642698
		Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6006207	1763662	7769869	2659105	657355	3316460
	Gas lines	Q1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1154750	334922	1489672	543249	146781	690030
		Q2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1142943	345041	1487984	542276	155205	697481
		Q3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1125652	365036	1490688	532997	168659	701656
		Q4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1153895	383003	1536898	554679	176584	731263
		Q5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1158122	417902	1576024	549011	233682	782693
		Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5735362	1845904	7581266	2722212	880911	3603123

Critical social	Health facilities	Q1	461628	510836	108167	123024	569795	633860	203978	253578	72440	90414	276418	343992	1213810	339175	1552985	537267	149812	687079
		Q2	480296	539619	110390	125987	590686	665606	188401	238696	94648	108732	283049	347428	1182379	337263	1519642	589612	162157	751769
		Q3	448361	506011	107512	121147	555873	627158	208780	258290	134225	145093	343005	403383	1151875	344492	1496367	609686	163589	773275
		Q4	468201	526156	107633	119253	575834	645409	220792	272112	175671	183924	396463	456036	1170546	350039	1520585	641197	162259	803456
		Q5	405186	456882	76136	81312	481322	538194	258750	304280	245348	248940	504098	553220	1161292	359398	1520690	636710	112781	749491
		Total	2263672	2539504	509838	570723	2773510	3110227	1080701	1326956	722332	777103	1803033	2104059	5879902	1730367	7610269	3014472	750598	3765070
	Cyclone shelters	Q1	555476	654776	142441	172517	697917	827293	317903	375781	96389	109363	414292	485144	NA	NA	NA	633616	181505	815121
		Q2	579932	676674	145465	172021	725397	848695	286253	339705	95988	106726	382241	446431	NA	NA	NA	658253	195849	854102
		Q3	545998	638592	143687	168763	689685	807355	304056	354855	109958	118099	414014	472954	NA	NA	NA	678487	203703	882190
		Q4	573823	675625	146001	168365	719824	843990	325078	374425	113960	119761	439038	494186	NA	NA	NA	709704	206968	916672
		Q5	517146	623301	103828	117023	620974	740324	374651	420539	117454	119449	492105	539988	NA	NA	NA	723374	191001	914375
		Total	2772375	3268968	681422	798689	3453797	4067657	1607941	1865305	533749	573398	2141690	2438703	NA	NA	NA	3403434	979026	4382460
	Market centres	Q1	445413	522701	131167	149403	576580	672104	203978	253578	72440	90414	276418	343992	343992	1197882	1533983	635818	169105	804923
		Q2	468359	533940	141702	156835	610061	690775	188401	238696	94648	108732	283049	347428	347428	1166616	1501767	638604	172777	811381
		Q3	438818	498675	148588	161598	587406	660273	208780	258290	134225	145093	343005	403383	403383	1135673	1478492	636595	169425	806020
		Q4	465158	525907	159712	169617	624870	695524	220792	272112	175671	183924	396463	456036	456036	1155191	1504161	669704	165946	835650
		Q5	409605	465677	158548	161343	568153	627020	258750	304280	245348	248940	504098	553220	553220	1143637	1502815	659812	107237	767049

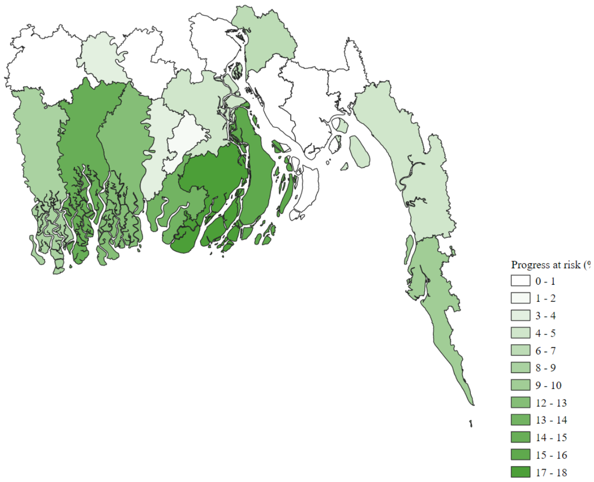
		Total	2227353	2546900	739717	798796	2967070	3345696	1080701	1326956	722332	777103	1803033	2104059	2104059	5798999	7521218	3240533	784490	4025023
	Education facilities	Q1	498689	574576	119788	139529	618477	714105	271954	342689	75400	93974	347354	436663	1203772	334568	1538340	612975	174484	787459
		Q2	516378	584171	118121	134503	634499	718674	247466	321048	74027	91750	321493	412798	1170727	331105	1501832	644904	187173	832077
		Q3	478637	536924	112039	126371	590676	663295	257119	332969	81909	97122	339028	430091	1139045	334630	1473675	659957	193015	852972
		Q4	501182	558496	108601	121467	609783	679963	264885	341592	84912	97302	349797	438894	1157917	334589	1492506	693681	190295	883976
		Q5	435535	488023	74651	81660	510186	569683	296293	367507	81778	87092	378071	454599	1148956	308791	1457747	697065	181320	878385
		Total	2430421	2742190	533200	603530	2963621	3345720	1337717	1705805	398026	467240	1735743	2173045	5820417	1643683	7464100	3308582	926287	4234869

**A subset of infrastructure assets was used for the households analysis, reflecting which households the nearest neighbours analysis made sense for.*

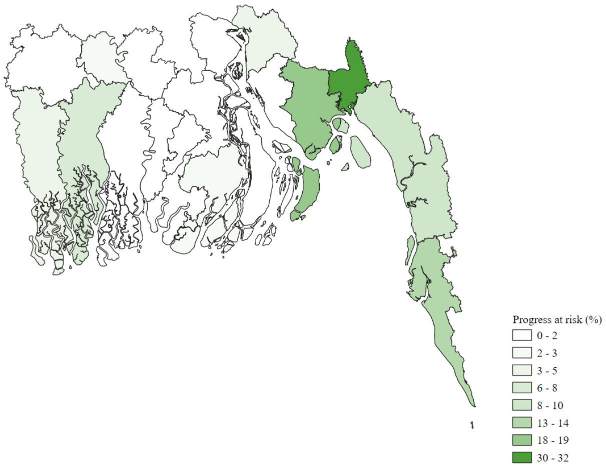
Hazard-specific maps on how SDG progress is at risk

SDG 3: Good health and wellbeing

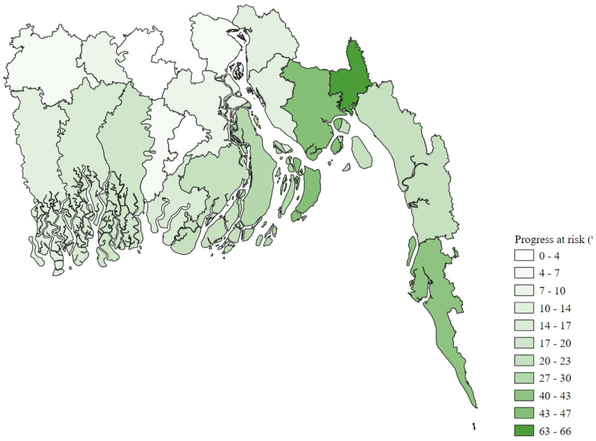
Coastal flooding



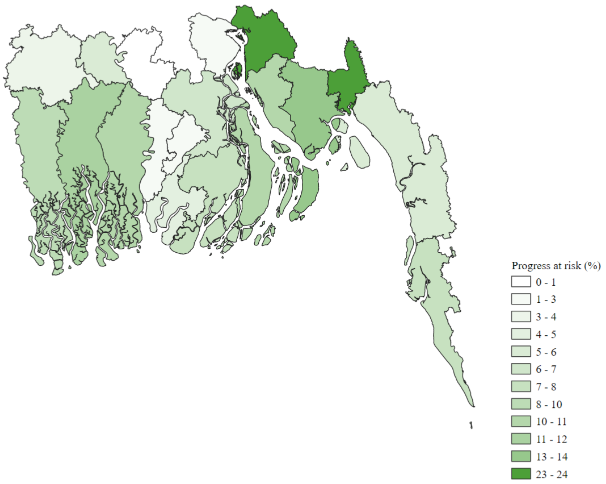
River flooding



Cyclones

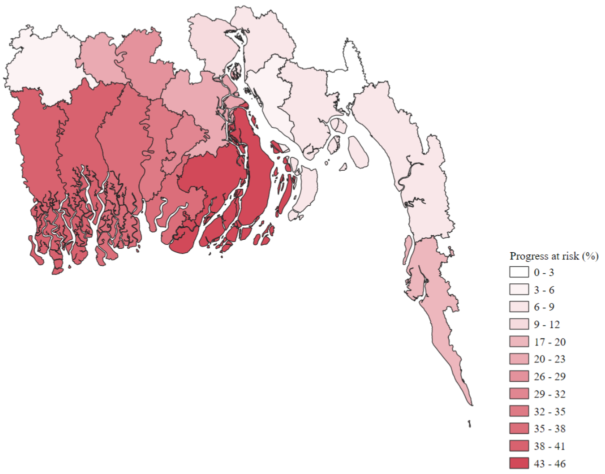


Erosion

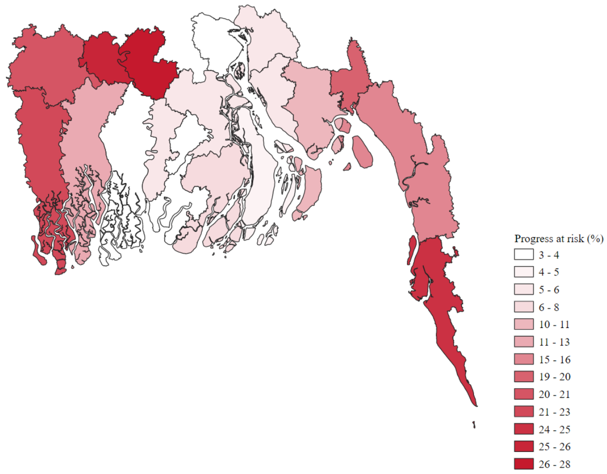


SDG 4: Quality Education

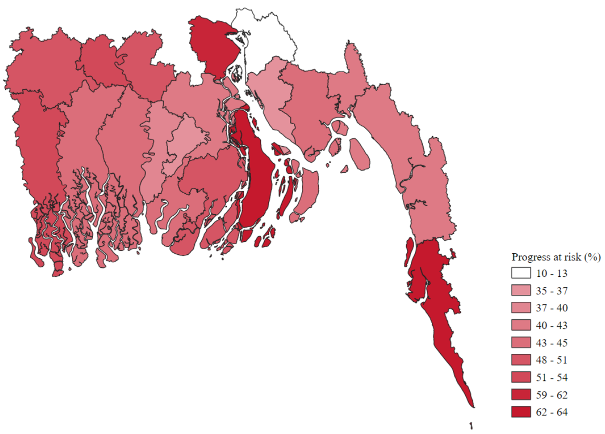
Coastal flooding



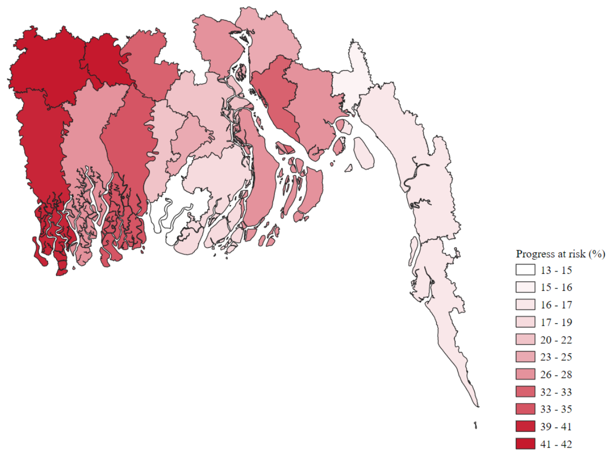
River flooding



Cyclones

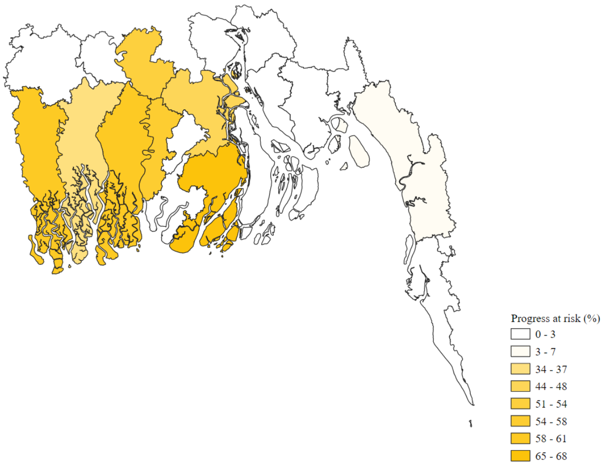


Erosion

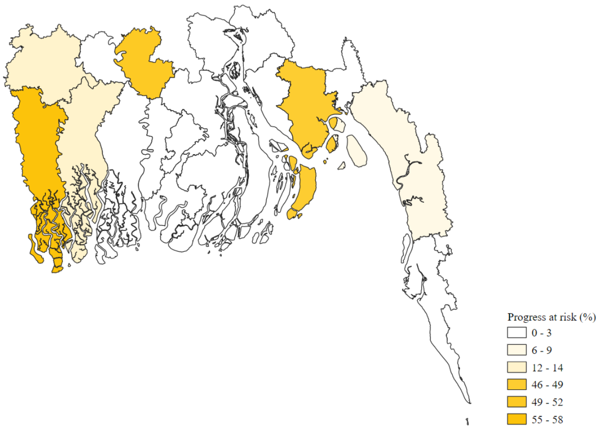


SDG 7: Affordable and clean energy

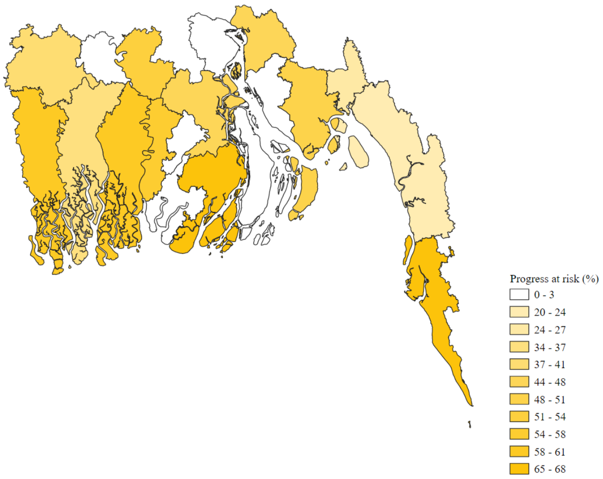
Coastal flooding



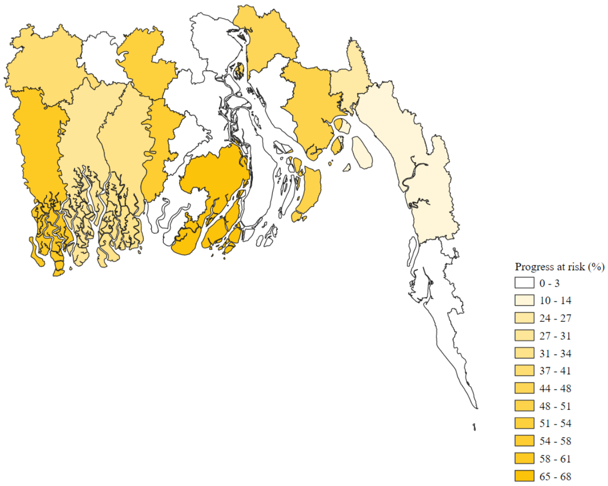
River flooding



Cyclones

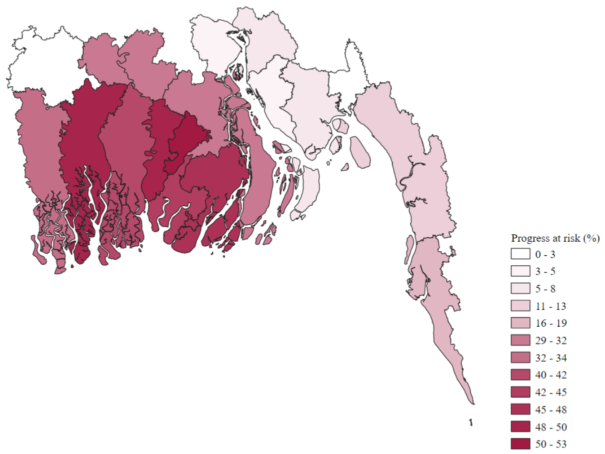


Erosion

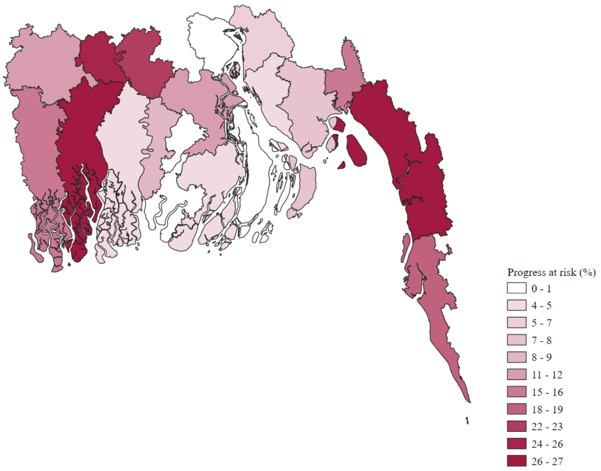


SDG 8: Decent work and economic growth

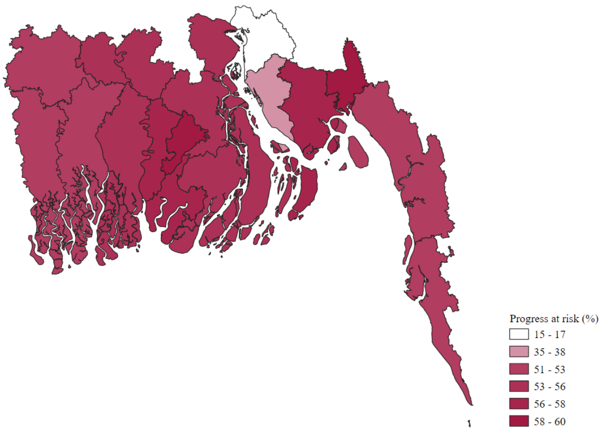
Coastal flooding



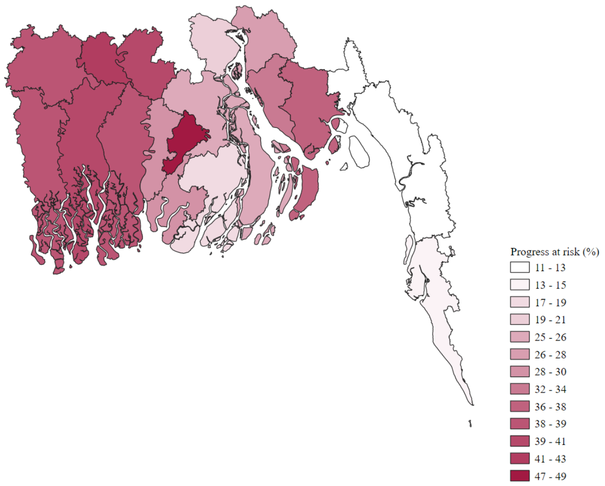
River flooding



Cyclones

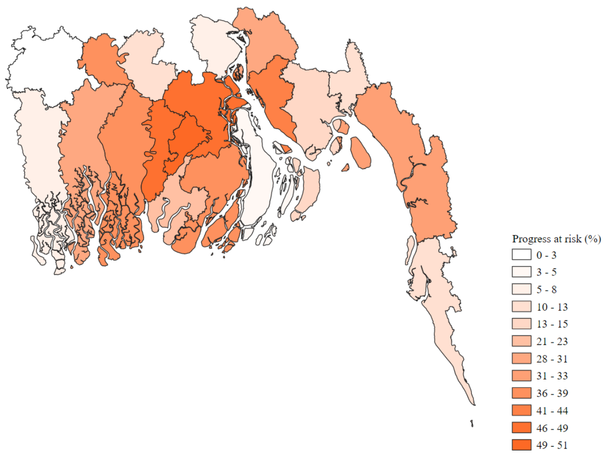


Erosion

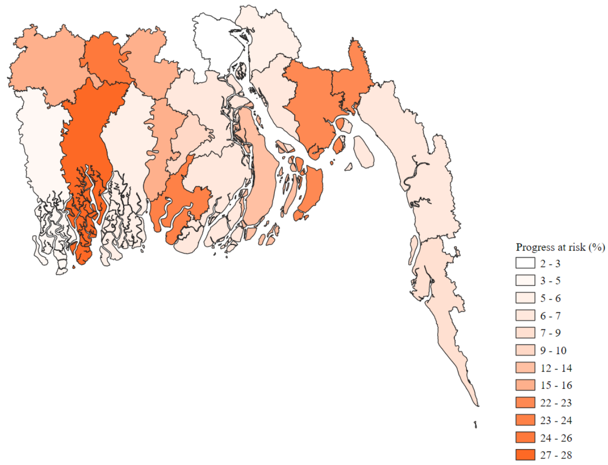


SDG 9: Industry, innovation and infrastructure

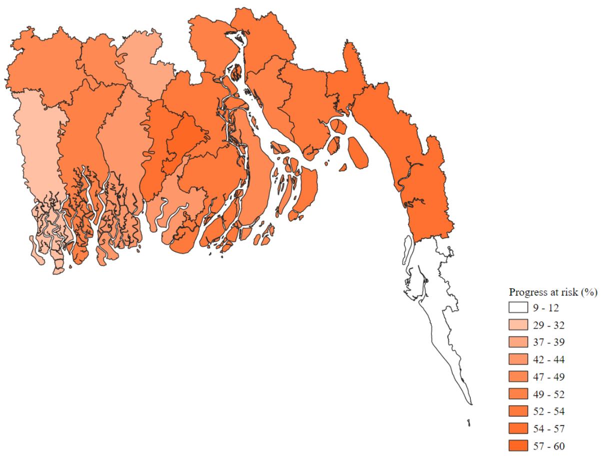
Coastal flooding



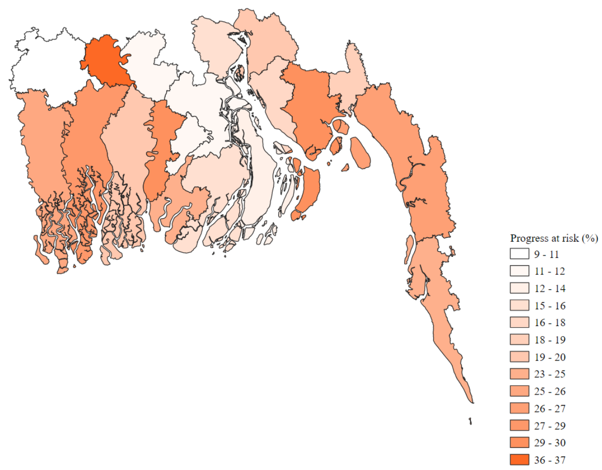
River flooding



Cyclones

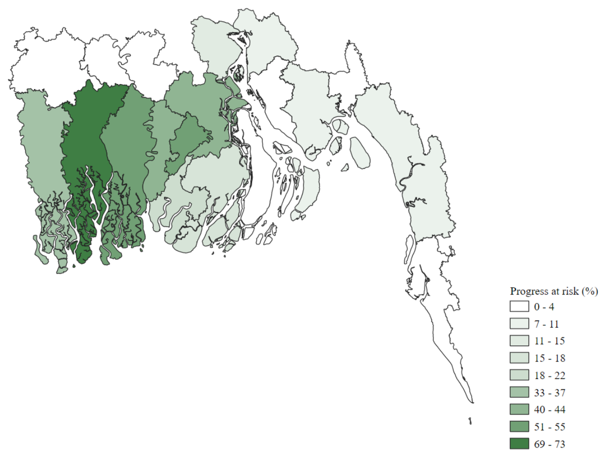


Erosion

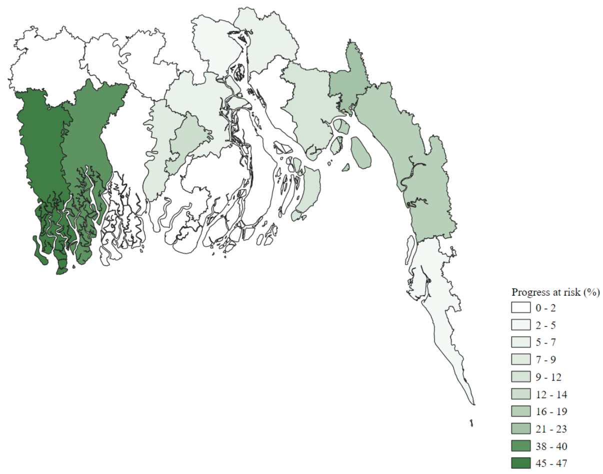


SDG 13: Climate action

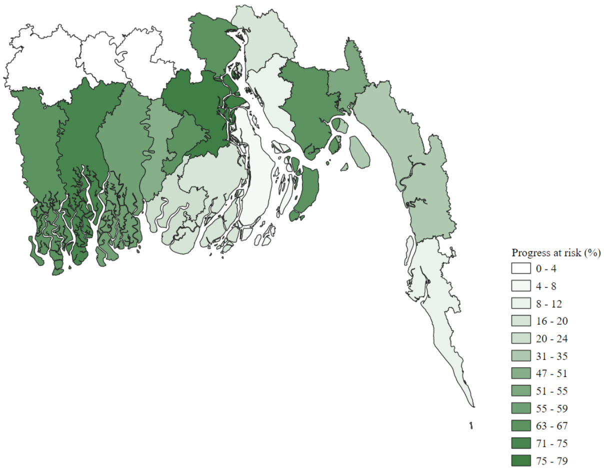
Coastal flooding



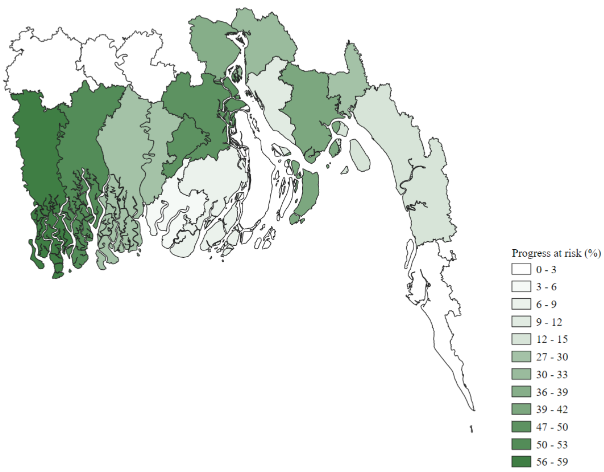
River flooding



Cyclones



Erosion



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