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Green Development and Climate Adaptation for Urban and Rural Areas

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Green Development and Climate Adaptation for Urban and Rural areas

Climate Adaptation in a Changing World

CCICED Special Policy Study Report

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Executive Summary

The accumulating risks posed by climate change necessitate to urgently implement systematic climate adaptation measures. Climate change, combined with non-climate driven developments (such as demographic, economic, social, technological and land use developments) multiplies the risks for devastating impacts, in particular in cities and rural areas, river basins, deltas and coastal areas. Climate change increases the frequency and intensity of weather extremes, increasing occurrences of severe economic damage, casualties and community disruption. It challenges disaster management systems and reveals gaps in adaptive capacities. To learn lessons on how to improve climate resilience, a large number of experiences with climate related disasters, near disaster events and adaptation policies were studied. Information was collected through field visits in some typical regions in China and NW-Europe, combined with the findings of empirical studies and case studies retrieved from literature. The study places climate adaptation in the context of longer-term resilience; outlines a resilience assessment framework; and proposes priorities for improving climate resilience in urban as well as in rural areas.

Key Findings

1. **Extreme weather events** such as heat waves, typhoons, storms, peak-precipitation, flooding and drought **already exceed today's disaster management capacities** of regions and cities **('adaptation gap'**). The field visits in China, The Netherlands, Belgium and Germany confirmed this. Examples include severe disruption by multiple years of drought, extreme rainfall events (water bombs*)*, and extreme river discharges.
2. Climate adaptation and handling of long-term climate-related uncertainties is **an additional challenge for governments and societies.** The current sense of urgency of climate adaptation is not sufficient. Gaps in climate adaptation capacity, i.e. the capacity to systematically plan and carry out adaptation actions are ubiquitous. Based on case studies from the Chengdu-Chongqing urban agglomeration in the upper reaches of the Yangtze River, the Taihu Basin in the lower reaches, the Pearl River Delta, as well as the Rhine - Meuse - Scheldt River Delta in NW-Europe, the i**mportant gaps** in climate resilience included: i) insufficient capacity of urban and rural spatial patterns, structures and infrastructure to adapt to climate change; ii) inadequate regulations, procedures and standards to preventively address climate change and to build back better; iii) lacking cross-departmental coordination of urban disaster prevention infrastructure; under-utilization of the overall coordination function of the emergency management department; iv) low risk awareness and risk resistance of community residents; v) insufficient mechanisms of regional and interregional cooperation.
3. Conducting **climate resilience assessments** – also called climate resilience stress-tests **-** is crucial for identifying key challenges, adaptation gaps, and priorities. This SPS introduces **five critical capacities** for climate resilience, providing a constructive framework for assessing and improving the physical and institutional capacities to **reduce the climate adaptation gaps**. These capacities aim at i) adapting and improving the **disaster risk management** systems by improving *threshold capacity*, *coping capacity* and *recovery capacity* and ii) improve **adaptive and transformative capacity** in technologies, policy and decision-making to deal with the long-term future challenges. Ten enabling conditions are critical for strengthening these five capacities.

4. **Climate adaptation is not a stand-alone issue.** It requires integration in development strategies across many policy domains and across scales, from (inter)national to local. The findings support the need to **better tune sectoral and spatial policies** at all levels. **Integrated diagnostics and climate resilience stress-tests** should become the basis for improving policy coherence, stakeholder participation and measuring performance. The transition from a fragmented, reactive approach towards an integrated anticipating approach requires a huge effort from governments and societies. Reaching out to the local communities and other stakeholders and involving them in the planning and implementation of adaptation measures is essential to strengthening resilience.
5. **Climate adaptation offers comprehensive benefits**, not only by reducing the risks associated with extreme weather events but also by providing opportunities for green development. Successful examples are found in **combining grey and blue-green, nature-based solutions**. These adaptation measures maximize the multiple benefits, ecosystem services and economic return flows while minimizing the potential damage of extreme weather events. With proper incentives, implementing climate adaptation measures can drive technological innovation, attract investment in infrastructure improvement and strengthen urban resilience and ecological restoration.
6. Many practitioners emphasize that the design and implementation of policies to adapt to climate change should **consider the inequality and vulnerabilities of specific groups and regions**. This report highlights the connection with rural development and, specifically in China, the potential of the policy notion of *Common Prosperity*.
7. The **national government has a critical role** in helping to improve the disaster management and climate adaptation capacities on regional and local scale. While **local authorities lead** in their own urban and rural development, long-term **commitment and support** of the **national government** is of critical importance to accelerating and improving adaptation practices. They should help to develop and support long-term adaptive and transformative approaches in the decision-making process about future spatial social and economic developments and investments. **Priorities** include:

   i) strengthen the forecast and early warning capacities, establish a disaster response mechanism for local and regional/river basin coordination, and enhance awareness and disaster preparedness capabilities of urban and rural communities;

   ii) improve the resilience of disaster prevention facilities and critical infrastructure facilities to extreme weather disasters. Strengthen the adaptability, redundancy and backup of lifeline facilities;

   iii) carry out coherent assessments of climate resilience (stress-tests) on local, regional and national scale to identify the main climate risks, the short- and long-term adaptation capacity shortcomings and potential adaptation pathways;

   iv) change the mode of urban and rural spatial planning and construction. Strengthen the protection and spatial reservation of storage space for water, making ‘water and soil leading' in spatial planning and design;

   v) ensure the provision of independent knowledge based insights by introducing an institutional structure with structurally funded multidisciplinary research on climate change. This includes research on the impacts of climate change (at national, regional, and local levels) and an independent assessment and evaluative role with regards to current climate adaptation policies at all scales.
8. **Show how climate change is addressed in decisions** on urban and rural development and reconstruction plans. As urban spatial layout and infrastructure endures for centuries and is hard to

adapt, it is of critical importance to incorporate projected climate change in their planning and design. All authorities, from national to local level, ought to demonstrate how climate change is included in spatial plans. No-regret actions accelerating climate resilient development include re-assessing planned public and private investments and facilitating 'build back better' after a disaster. Change laws, regulations and insurance practices that hamper this.

9. **Financing of adaptation measures is challenging due to current financial structures**: accounting procedures, methods and regulations. Current incentives position adaptation measures as costs without accountable benefits. Consequently, business-as-usual developments and investments may lead to stranded assets in high-risk locations and may reduce the solution space for future generations. It is of critical importance to explore how new public and private financial spaces can be created to stimulate and support adaptation across sectors and scales. This aspect is lacking in CCICED's policy analyses.
10. The incorporation of climate adaptation in science, policy as well as in societal and economic practices is still in its infancy**. Further collaboration and exchange across countries, regions and cities** will be of critical importance in building *collective knowledge* and will support learning how to reduce disaster risks, increase adaptation resilience, and in create a solid financial and organizational foundations to support a transformative climate resilient development.

Main recommendations:

1. National, regional and local governments should urgently elevate the political and governance priority of climate adaptation, as climate risks are increasing, and disaster losses are huge.
2. The national government should build a systematic policy framework for short- and long-term action, from the central to the local level, across regions/basins and sectors, and with active participation of society, businesses and local communities.
3. The national government should establish and use a climate resilience assessment framework in order to identify gaps in climate resilience and to provide a solid foundation for urban and rural areas to assess, monitor and improve their adaptation policy and capacity.
4. The national government should pay attention to social equity and gender and enhance the climate adaptation capacity of less developed regions and vulnerable groups.
5. CCICED should continue to strengthen international knowledge exchange on climate adaptation policies and practices, as climate adaptation is still in its infancy regarding science, societal and economic integration and policy development.

Key words：

Climate adaptation, resilience, capacities, enabling conditions, case studies, lessons learned from disasters, stress-testing, equity, multi-scale, multi-government, multidisciplinary adaptation planning and design, immediate and future.

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Green Development and Climate Adaptation for Urban and Rural areas

Climate Adaptation in a Changing World

1. Introduction

Climate change is already here, now. The years 2014-2023 became the hottest decade on record, with more frequent and more severe extreme weather events, causing casualties, economic damage, social disruption, loss of biodiversity and reduced harvests all around the world [1]. Humanity and nature already suffer from floods, droughts and heatwaves to a degree never seen before. And the trend of global rising temperatures that is driving these changes will continue for the decades and centuries to come [2]. This trend will cause more adverse impacts, including sea level rise, shortages of water resources and water quality problems. While the reduction of greenhouse gas emissions – climate mitigation – is essential for reducing the future risk of climate-related disasters, it must be combined with immediate adaptation strategies to effectively manage the current and anticipated impacts on humans and nature [2].

While climate change is a global issue, adaptation needs are location-specific. Cities face increasing climate risks due to high concentrations of population and economic activity. The heavily urbanized and industrialized estuarine delta regions, such as the Yangtze River Delta, Pearl River Delta, and Rhine-Meuse-Scheldt River Delta, have in recent years experienced loss of life and property as a consequence of mega-rainstorms, mega-floods, extreme droughts, extreme heatwaves. The countryside is also facing a changing climate, affecting the rural population and the harvest yields they depend on. Cumulatively, reduced harvest creates the risks of regional - or even global - famine. Due to climate change, agricultural production practices must change, too.

Integrated river basin management is essential to effectively address the increasingly frequent floods and droughts. Water management in downstream areas must be balanced with water management upstream to prevent flooding after heavy rainfall as well as to ensure water supply in times of drought while maintaining and navigability of rivers through all seasons. In order to comprehensively address the problems posed by climate change, international, interregional and inter-organizational cooperation is needed to ensure the effectiveness and timeliness of adaptation measures. Moreover, measures must be taken with care for biodiversity, as loss of biodiversity puts pressure on human resilience, health and harvest yields. The social consequences of climate change are not to be underestimated. The most vulnerable groups in society – poor, elderly, women, children, undocumented residents - are the hardest hit by the impacts of climate change. Equity is important for climate resilience; equity between regions, countries and between generations. In many places of the world, the standard of living in rural areas is lower than in cities and access to education is more restricted. Consequently, the ability of the local population to invest in necessary adaptation measures is more limited.

The progressive nature of climate change, combined with already densely populated areas, increases the difficulty of action. At the same time, due to their social and economic strength and importance, densely populated urban and rural areas can become transformational centers for climate adaptation. Many initiatives and plans have already been launched in recent years around the world, such as the Delta Decision for Spatial Adaptation issued by the government of the Netherlands in 2015, the Sigmaplan in Flanders, Belgium, and the National Climate Change Adaptation Strategy 2035 jointly issued by 17 government departments in China in 2022, as well as pilot projects for the construction of ‘spongy’,climate-resilient cities throughout China. This is a good start for climate adaptation action. However, there are still problems such as insufficient early warning capacity for the multi-system risks brought by climate change, insufficient adaptive capacity of urban space and critical infrastructure, and insufficient systematic and cross-sectoral synergy of adaptation efforts.

This Special Policy Study (SPS) focuses on how to enhance climate resilience in urban and rural planning and construction. A key objective of the study is to provide an assessment framework for climate resilience that is appropriate for urban and rural planning and construction. It serves to identify gaps in urban and rural climate resilience, and to propose and prioritize interventions for climate adaptation. The study explores how different countries have responded to climate change and weather-related disasters, and what lessons can be learned from their responses and developments. Information was collected during field visits in China and Northwestern Europe – See annexes E and F - as well as through a wide network of experts that was consulted. The study focuses on the necessary capacities to build climate resilience around climate adaptation goals, as well as measures and approaches to strengthen these capacities.

The study identified the need for immediate climate adaptation action, the urgency of conducting urban climate resilience assessments, the urgency of fostering collaboration among stakeholders, including government and society, and the need to incorporate scientific knowledge on social equity and on long-term and short-term climate change into decision-making on climate adaptation. This is reported through the following structure.

Chapter 2 introduces a conceptual framework to systematically assess gaps in climate resilience. The framework identifies five capacities (threshold capacity, coping capacity, recovery capacity, adaptive capacity, and transformative capacity) and a set of enabling conditions that can be used to evaluate the climate resilience of a specific case area.

Chapter 3 provides illustrative cases of adaptation policies and practices for climate change. The chapter includes cases in different geographical locations, and identifies the impact of recent extreme weather events and the need for change towards the future.

Chapter 4 focuses on lessons learned from the response to extreme events worldwide. It illustrates that the need for adaptation is global. While effects can be devastating, the global character also creates the global possibility to learn from different nations and to incorporate good examples in future policy making.

Chapter 5 addresses equity aspects and addresses the need to take actions in a fair manner that empowers and protects the vulnerable.

Chapter 6 bundles the report's findings in terms of geography, time scale and institutional arrangements that impact the governance structure to handle climate change. In preparation for the study's recommendations, it presents insights in the relation between cities and regions as well as insights in balancing short-term and long-term action related to the five capacities and their enabling conditions.

Chapter 7 introduces a systematic way of climate stress-testing and adaptation planning, using the five capacities and their enabling conditions for creating climate resilience as an assessment framework to identify gaps and weaknesses in climate resilience, thus creating a solid basis for accelerating adaptation interventions planning and implementation.

Chapter 8 recommends both immediate actions to address climate change and the use of long-term perspectives as leading insights for action. It flags the need to collaborate between different layers of government and to minimize the boundless impacts of extreme weather events and to take action in a way that is fair, for the vulnerable, to nature, and for future generations.

2. Conceptual Assessment Framework for Climate Adaptation

In the context of heightened climate change risks and prevailing climate resilience gaps, an assessment framework is needed to systematically evaluate climate resilience and existing adaptation policies and practices in different countries and regions. This framework is also meant to analyse the lessons learned from climate disasters and narrow escapes. It is applicable at different spatial and temporal scales, from local district to river basin and from flash flood producing rainfall events to slowly increasing hazards from sea level rise or increasing drought risk. The assessment is to be based on an analysis of the local geographical situation, on lessons learned from disasters in the past and on a systematic analysis of the multiple climate risks, taking expected future social and physical geographic changes into consideration. The assessment results in actionable recommendations for the government, businesses and residents.

2.1 Climate resilience assessment methods

In recent years, in order to promote the effective implementation of climate adaptation measures and accelerate the transition, international organizations such as the United Nations, national governments such as USA and EU, 100Resilient Cities [3], academia and consultants launched a wide variety of tools to assess (a) the need for adaptation, (b) the benefits of climate adaptation measures and (c) the enabling conditions and tools to accelerate implementation . Some of these assessment frameworks support a qualitative evaluation of climate risks and adaptation opportunities, while other tools provide quantitative assessments; some come from a disaster risk reduction background, while other frameworks have their roots in the evaluation of sustainability. Without the intention of being complete, reference can be made to frameworks provided by IPCC [4], The Fifth U.S. National Climate Assessment [5], EU Adaptation Strategy [6], Leeuwen et al. [7], UNISDR [8], De Graaf-van Dinther and Ovink [9], UNDRR[10], The US White House [11] and Arcadis [12].

Rather than contributing to a further fragmentation, it was decided to use an assessment framework that can “host” elements from other frameworks, work with them all and help align these, tailored to phases of disasters, the geographical and political, cultural and policies context. The assessment framework allows for long term perspectives, as investments in infrastructure in general have a lifespan of decades to even centuries, while climate is changing, and future demands are unknown. The framework builds on an in-depth analysis of the physical, ecological, social and economic systems and their dynamics, locally and at river basin scale, as well as on an assessment of the climate vulnerability of the existing system, of trends in society that will have an influence on this vulnerability.

The framework is not only focussing on disaster risk reduction, for ‘sudden’ disasters like floods and droughts, but also on slow changes like sea level rise and the consequences of increasing average temperatures. It is helpful in identifying existing resilience gaps and potential policy pathways to enhance resilience, including short term adaptability as well as long term transformative changes and the enabling conditions needed for such fundamental changes in, for example, governance structure, financing, standards and legislation.

2.2 Five capacities and their enabling conditions for creating climate resilience

The various types of risks resulting from climate change are intensifying, and the frequency of extreme weather and related disaster events continues to increase in China and around the globe[2]. The objective of climate adaptation is therefore to build climate resilience capacity. Climate resilience capacity is needed to plan and implement interventions that minimize the risks brought by extreme weather events and sea level rise. These interventions, when nature-based and selected smartly, will also produce significant ecosystem services, economic and social benefits. Maximizing these positive effects while minimizing the risks is the core challenge of climate adaptation. In that sense, climate adaptation is more than mere disaster risk reduction.

To identify gaps in the existing climate resilience and to strengthen the resilience of urban and rural areas, five types of capacity are to be included in the assessment framework[9]: These are: threshold capacity, coping capacity, recovery capacity, adaptive capacity, and transformative capacity. There are also enabling conditions needed to effectively deploy each of these capacities.

2.2.1. Five capacities for climate resilience

A brief outline of the five capacities is given below. An extensive description of the capacities and their enabling conditions can be found in Annex A.

1. Threshold capacity

Refers to the ability to prevent any significant losses by maintaining a threshold to cope with serious limate events. This threshold is defined by the design load of the facilities. For example, in flood risk management, the threshold for rivers to cope with flood flows can be increased by constructing higher river embankments and increasing the flood discharge capacity of rivers. The determination of thresholds for disaster prevention requires the assessment of design standards for disaster prevention that take into account both historical disaster data and future-oriented trends in climate change, sea level rise and other changes.

2. Coping capacity

Refers to the ability of an urban or rural area to reduce disaster losses following a disaster caused by extreme weather. This includes, for example, the ability to reduce human and economic losses in the case of floods, or the ability to avoid water losses in the case of drought disasters. Factors influencing resilience include the presence or absence of measures to reduce disaster losses such as effective early warning systems, public awareness and education, and rational management mechanisms for disaster reduction and relief.

3. Recovery capacity

Recovery capacity is the capacity of urban and rural areas to recover from a disaster to a state consistent with, or better than, the state before the disaster (“Build Back Better”). The objective of this capacity is achieving rapid and effective disaster recovery and reconstruction. Influencing factors include inputs such as financial resources, technology, and specialized personnel. Depending on the spatial scale of the disaster's impact and its severity, recovery events range from weeks to decades.

4. Adaptive capacity

Adaptive capacity refers to the ability to cope with uncertainty about future climate change, as well as uncertainty about demographic, economic, technological and other developments. It is about improving the long-term adaptability of infrastructure to cope with known long-term and with yet unknown future conditions, maintaining an open and diverse design of climate adaptation measures.

5. Transformative capacity

This capacity refers to the ability of the current social, economic and governance system to transform and pro-actively change itself in the face of expected disaster risks, such as climate change impacts, by changing into a new system with different system characteristics. Transformative capacity is society’s capability to create an enabling environment that leverages adaptation.

2.2.2. Enabling conditions for five capacities

Enabling conditions are needed to be able to take action in strengthening the five capacities. If these conditions are insufficiently met, adaptation of existing infrastructure and practices will be hard, if not impossible. Enabling conditions needed for leveraging the five capacities include [13, 14, 15, 16]

- Sense of urgency: Informed public, businesses and decision makers on facts and figures in an appealing, clear and convincing narrative, driving their willingness to act.
- Systems approach beyond jurisdictions and, human-made borders, looking at the whole environmental/subsurface/water systems, economic dynamics and societal structures.
- Capacity development: Knowledge and skills of individuals, communities, and organizations to develop, implement and maintain resilience-creating interventions.
- Trusted knowledge, data and information: Independent research and open access, transparent data and information, shared with all stakeholders, feeding risk- and opportunity-informed decision making.
- Financing: Adequate, stable and coordinated funding to implement, operate and evaluate policies and interventions. Fair and just distribution of the financial burdens, risks and rewards.
- Citizens' engagement: Citizens' and NGOs' involvement in the definition, co-creation, implementation and assessment of interventions.
- Policy, legal & regulatory framework: Policies, legislation, regulations, planning strategies and standards spurring implementation and maintenance of interventions.
- Innovation: New methods, practices, and products to solve existing problems, and create new value. Creativity, research by design and best practices testing.
- Public-private system collaboration: Public-private cooperation and industrial symbiosis to develop and improve interventions. Early-stage public funding to create new markets.
- Equity and inclusion: Mechanisms to fairly allocate risks and benefits, protect the vulnerable and include silent, poor and powerless people.

2.2.3. Concluding remarks

As can be seen, the threshold, coping and recovery capacities are related to disaster risk reduction, enhanced by opportunities that will create added value in an area. The adaptive capacity refers to the ability to cope with uncertainty about future climate change and new social and economic conditions and requirements. And the transformative capacity relates to the human systems, the political and governance infrastructure and their power to steer the enabling conditions that result in systemic changes in spatial developments, economy and/or society.

3. Major Case Studies: Examples of Climate Adaptation Practices

Climate adaptation actions have been taken in many countries around the world, but mostly after suffering from climate disaster. Currently, countries are however increasingly aware of the progressive nature of climate change and the need for pro-active action. There is increasing awareness of the need to make the environment more resilient for weather extremes, rising sea level, salination, increasing average temperatures and related consequences.

Densely populated river basins and deltas are increasingly vulnerable to extreme weather events, such as the Chengdu-Chongqing region in the upper reaches of the Yangtze River in China, the Taihu Lake Basin, the Pearl River Estuary region, and the Rhine-Meuse-Scheldt urbanized deltas in North-western Europe, all of which have been challenged by severe extreme weather events in recent years. This chapter addresses these four case areas and provides an overview of their struggle with disasters, their adaptation efforts, the *adaptation policies put in place so far and the resilience gaps in their policies and practices when evaluating these from the perspective of the required five capacities and the enabling conditions for creating a climate resilient environment.*

A more extensive description of the cases and the analysis of their climate resilience gaps is available in Annex B.I and C.I, while Annex E and F provides a report of the findings collected during the work visits to the areas in June/July 2024.

3.1 Case 1: Climate adaptation in the Chengdu-Chongqing area

3.1.1. Trends in climate change

The Chengdu-Chongqing area is characterized by a humid subtropical monsoon climate and high-altitude plateau climate, with an average annual temperature ranging from 4 to 20.9°C and annual precipitation between 800 to 1200 mm. Over the past 50 years, the region has experienced a fluctuating upward trend in temperature, with an average increase rate of approximately 0.14°C per decade, while precipitation has shown a linear decrease, with a decline rate of about 17.5 mm per decade. The frequency of extreme weather events, such as heatwaves and heavy rainfall, has increased, particularly in the southwestern areas. The occurrence of rapid shifts between drought and flood has decreased, but their intensity has risen, highlighting the intensification of climate change effects.

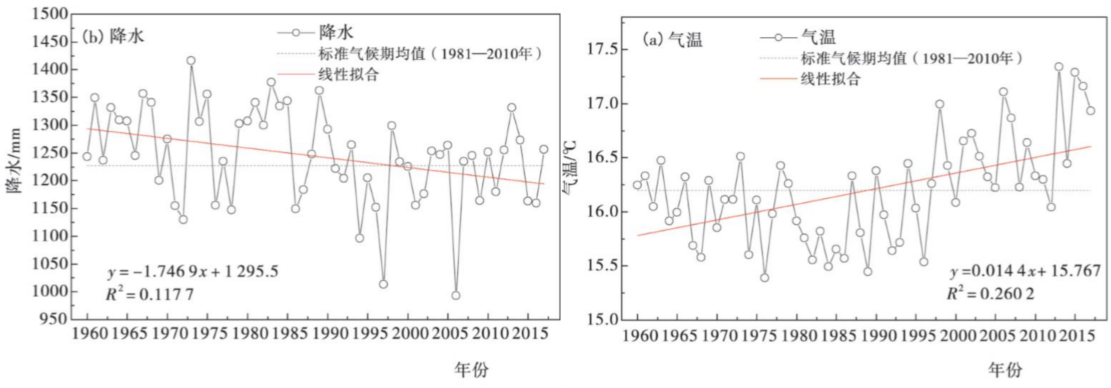

Figure 3.1. Statistics of precipitation(left) and temperature(right) trends in Chengdu-Chongqing area in 1960-2017.

3.1.2. Major disasters and issues arising from climate change

(1) Short-term heavy rainfall triggers flooding

Summer rainstorms are a frequent extreme weather event in Chengdu and Chongqing, exacerbated by global climate change and the urban "rain island effect." Recent years have seen an increase in extreme meteorological and hydrological events, particularly affecting the mountainous city of Chongqing at the confluence of two rivers. This has led to the dual threat of localized torrential floods and river flooding. For instance, in July-August 2020, prolonged and intense rainfall in the upper Yangtze River basin caused 32 rivers, including the Tuo, Jialing, and Qingyi, to exceed alert levels, resulting in a significant flooding in Chongqing. This disaster impacted 2.63 million people across 15 districts and counties, causing direct economic losses of 2.45 billion yuan.

(2) High temperatures and droughts trigger mountain fire disasters.

Chengdu-Chongqing area is rich in forest resources, subtropical broad-leaved evergreen forests, with the Chengdu-Chongqing area in recent years, high temperatures, drought and other extreme weather continues to appear, forest fires occur more frequently. Chongqing had 32 forest fires in 2022 ; Beibei, Banan, Fuling, Dazu, Tongliang, Kaizhou, Fengjie and 12 other districts and counties saw in August 17-August 26 concentrated outbreaks of hill fires. The time to extinguish a single mountain fire was as long as 1-5 days, and the total area of victimized forest area reached 22.62 square kilometers (3023.5 acres).

(3) High temperatures and droughts have triggered energy shortages.

The Chengdu-Chongqing region's energy structure relies heavily on hydropower, coal power, and natural gas, with hydropower comprising nearly 80% of Sichuan Province's total energy production. Seasonal climate variations significantly impact power generation, with a notable decrease in capacity during the dry season, leading to power shortages. Additionally, over 30% of Sichuan's annual power generation is exported to other provinces, exacerbating local supply tensions, especially during periods of extreme heat and drought. In the summer of 2022, Sichuan experienced prolonged extreme temperatures, reaching up to 44°C, coupled with severe drought. This led to a significant increase in cooling demands, with air conditioning accounting for up to 26% of the total power demand. Meanwhile, precipitation was 43% below the historical average, resulting in a drastic drop in hydropower generation by over 50%, from 900 million to 440 million kilowatt-hours, creating a critical power supply gap.

(4) High temperatures and droughts have triggered reductions in agricultural production.

By significant investment in agricultural technology and capital, the total grain output in the Chengdu-Chongqing area increased from 42.71 million tons in 2003 to 46.9 million tons in 2023. However, the impact of climate change has gradually weakened overall grain production, with extreme weather conditions, particularly drought, leading to periodic reductions in yield. Drought is now the primary cause of reduced grain production. The peak agricultural water use period from March to May does not align with the region's rainfall patterns, exacerbating water shortages. Additionally, extreme weather shortens the development cycle of pests and diseases, expanding their impact and severity. In 2022, persistent high temperatures and drought from June to October severely affected Sichuan Province, impacting 7.62 million people across 138 counties and damaging 522,000 hectares of crops. This led to direct economic losses of 4.8 billion yuan, marking the most severe agricultural impact in the past decade.

(5) High temperatures and heat waves threaten health and safety.

Extreme and prolonged high temperatures have become a significant issue in the Chengdu-Chongqing area, particularly in Chongqing, where summer heatwaves are increasingly frequent and intense. In the summer of 2022, Chongqing experienced a historic heatwave lasting 41 days. These conditions have led to higher demand for drinking water and electricity, while droughts, water shortages, and reduced power generation have made access to essential resources difficult, especially for vulnerable populations. Prolonged exposure to high temperatures can cause heatstroke, dehydration, and exacerbate cardiovascular, cerebrovascular, and respiratory diseases.

3.1.3. Overview of priority climate adaptation measures in place

(1) Promote disaster prevention and mitigation projects.

China has built a group of reservoirs in the upper reaches of the Yangtze River with the Three Gorges Reservoir at its core, with a total flood control capacity of about 38.7 billion cubic meters, effectively playing the role of stopping floods and cutting peaks and staggering peaks; it has continued to promote the construction of river embankments to enhance the ability to defend against floods The authorities have organized the excavation of fire protection zones and optimized the layout and design of infrastructure, and have upgraded the level of operation and management of the infrastructure.

(2) Strengthening climate monitoring and early warning.

For example, new ground meteorological monitoring stations have been built, and an integrated meteorological observation system consisting of ground meteorological observation stations and high-altitude meteorological observation stations has been established. The government has strengthened risk research and identification, organized geo-engineers and grid clerks to carry out flood and rain "triple checks", refined the granularity of heavy precipitation warnings, and enhanced climate change monitoring, early warning and risk management capabilities.

(3) Improving emergency response mechanisms.

These include the implementation of a daily dispatch system for disaster situations at the municipal level, the formulation of technical guidelines such as the Technical Measures for Responding to Grain and Oil Crop Production in Hot and Drought Weather, making full use of water-conserving facilities to increase the capacity for emergency irrigation, organizing late-autumn production to make up for the poor summer harvests, organizing drought-resistant agricultural service teams to go deep into the countryside, and strengthening the capacity for regional coordination and the mobilization of personnel and materials, among other things. During the "8-20" flood of 2020 (the largest incoming flood since the construction of the Three Gorges.), 251,000 people were evacuated and 132,700 people were relocated. During the high-temperature hill fires of August 2022 in Chongqing, the emergency response was activated in a timely manner, and three forest firefighting and rescue headquarters in Gansu, Sichuan, and Yunnan, with a total of over 1,500 people, were mobilized to provide rescue services.

(4) Enhancing the adaptive capacity of economic and social systems.

The Chengdu-Chongqing region has already carried out relevant power and energy projects to optimize the supply structure of power and energy and increase the regional power coordination and security capabilities. At the same time, new emergency water sources have been developed to provide emergency water supply for remote areas with serious water shortages, thereby enhancing the adaptability to climate change. In addition, the “Chongqing City Climate Change Adaptation Action Plan” and the “Sichuan Province Climate Change

Adaptation Action Plan" have been issued, proposing to promote the green development and transformation of the regional economy and society through climate adaptation.

3.1.4. Current gaps in climate adaptation

(1) Threshold capacity

The Chengdu-Chongqing region has insufficient capacity to deal with various climate disasters. The compliance rate of flood prevention and bank revetment projects in the central urban area of Chongqing for once-in-50-years flood events is less than 50%. In terms of forest fire response, the adaptability of forest structure is insufficient, with a lack of fire-resistant and drought-resistant tree species; the construction of firebreak systems needs to be improved. In response to crop failure caused by drought, the selection of crop varieties in some areas of the Chengdu-Chongqing region is not adapted to climate change, lacking resistance to diseases, pests, drought and flood. At the same time, due to the lack of systematic protection and restoration of the "pond-paddy field" system, partial destruction of ponds, paddies and canals has led to a decline in the regulation capacity for drought and flood events.

(2) Coping capacity

Firstly, the capacity for climate change risk prediction is not strong, and the capacity for precise identification, assessment and planning response to risks is relatively weak. The regional weather forecast model in the Chengdu-Chongqing area is not perfect, and the climate prediction model is rudimentary, which restricts the ability to warn about risks. For instance, during the rare major flood in Chongqing in August 2020, due to the late forecast information, there is not enough time to transfer materials in time, exacerbating the losses from the disaster. A climate disaster risk map system has not yet been established, and there is a lack of disaster-targeted real-time identification and control systems for disasters. In addition, it is impossible to accurately identify the spatial scope and affected intensity of the disaster-stricken region before and during the disaster, resulting in a hysteresis in planning and emergency plans.

Secondly, there is room for improvement in public awareness of disaster prevention and relief as well as climate change response. For instance, during the rare major flood in Chongqing in August 2020, some merchants at risk, due to an underestimation of the flood's severity and a mentality of luck, refused to evacuate, ultimately suffering from losses due to the disaster. In the rural areas of the Chengdu-Chongqing region, there are limited conditions for information dissemination, and the farming community finds it difficult to obtain the latest weather forecasts and scientific knowledge. For example, during periods of high temperatures and drought, some farmers consider the disaster to be a natural phenomenon that cannot be avoided, lacking proactivity and enthusiasm for response. In terms of flood disaster response, the flood responding pattern of "people retreat when water advances while people advance when water recedes" has not been effectively promoted. There is insufficient attention to highly vulnerable groups; during the high-temperature disasters from 2020 to 2022, government and health institution propaganda was mainly targeted at employers, focusing on high-temperature allowances, heat holidays and the protection of the rights and interests of the migrant worker group, lacking care for the elderly, children and other highly vulnerable groups.

Thirdly, the basic functions of urban lifeline systems such as power supply, water supply and drainage are still difficult to ensure. For example, forest fire prevention access roads are narrow and steep, making it difficult for large vehicles and machinery to reach the mountainous areas, resulting in untimely delivery of rescue supplies during mountain fires. The capacity of the main water supply pipeline network in the Chengdu-

Chongqing region is relatively small, which cannot supplement water sources for the vast rural areas. At the same time, mountainous rural areas lack alternative water sources, and a water resource allocation network that combines “large, medium, small and micro-scale” facilities has not been formed, leading to difficulties in drinking water supply for mountainous rural areas during heatwaves.

(3) Adaptive capacity

There is a deficiency in the adaptive capacity of key facilities, including flood control projects, ultra-high voltage direct current (UHVDC) projects, agricultural irrigation projects, urban cooling facilities, emergency drinking water projects and other aspects. For instance, the UHVDC project systems such as Gansu Electricity, Tibet Electricity and Xinjiang Electricity entering Sichuan have not yet been formed. The sewage facilities and pipeline network along the river have insufficient resistance to pressure, and the agricultural water conservancy projects and irrigation systems are not comprehensive enough.

The impact of climate on power supply is significant. Chongqing has limited potential for the development of its own energy resources, and the clean energy available for development and utilization is very limited. Sichuan's energy structure is relatively singular, with the main energy supply coming from hydropower, and power generation output is significantly affected by climate variability. In addition, the power production in the Chengdu-Chongqing region mainly focuses on export, accounting for about 30% of its total hydropower generation. Meanwhile, there is a lack of emergency energy security.

(4) Transformative capacity - the capacity to change

There is a lack of inter-departmental collaboration and smooth information sharing in the Chengdu-Chongqing region. The joint dispatching mechanism for water resources and energy across regions is yet to be improved. During droughts and floods, it is difficult to achieve overall dispatching and coordination in flood control, agricultural irrigation and other aspects. The regional linkage mechanisms for forest fire rescue and disaster relief need to be perfected. Besides, the public's understanding of and participation in climate change adaptation actions are relatively weak, and green and low-carbon mode of production and lifestyle have not yet been widely promoted.

3.2 Case 2: Climate adaptation in the Taihu Lake basin

3.2.1. Trends in climate change

In recent years, the Taihu Lake basin has experienced a significant increase in rainfall during the flood season, along with a rise in extreme weather events, leading to an elevated risk of low-probability natural disasters. Overall, annual precipitation has increased, with the area around Taihu Lake, the Pudong and Puxi districts, and the western part of the Hangzhou-Jiaxing-Huzhou region seeing the greatest increases. At the same time, there is a clear warming trend across the basin, with the impact of heatwaves in Shanghai intensifying, setting multiple high-temperature records in 2022.

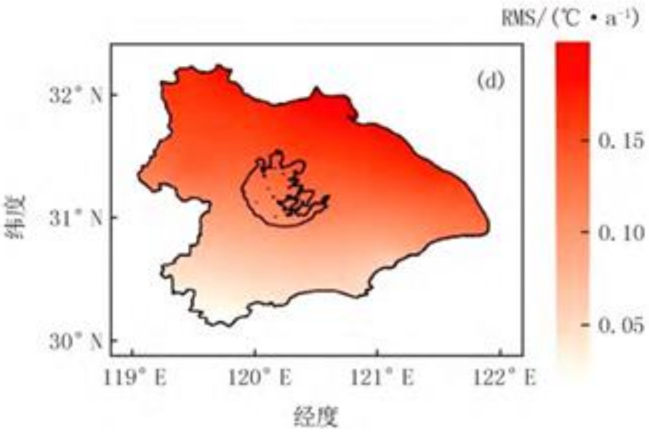

Figure 3.2. Spatial distribution of mean temperature increase in the Taihu Lake basin from 1990 to 2018

3.2.2. Major disasters and issues arising from climate change

(1) Frequency and intensity of extreme rainfall have increased significantly, and multiple events have shifted the focus of flood defense.

Strong convective rainstorms are prone to cause localized pluvial flooding in the city. Data from Shanghai between 2004 and 2015 show that thermal convective precipitation occurs on average every 11 days during summer under the influence of subtropical high pressure. For example, during the heavy rainstorm on July 21, 2023, central Shanghai, Qingpu District, and Northern Minhang District experienced six hours of continuous rainfall, with 71 stations recording over 100 mm of rain within two hours. The Minhang District saw a peak one-hour rainfall of 121.5 mm, surpassing the city's drainage capacity and resulting in severe waterlogging, with depths reaching up to 1.20 m in some areas and an average water depth of 0.23 m.

Typhoons are frequent, and "wind, storm, tide and flood" are the most serious disasters. Since 2010, Shanghai has experienced two major events where all four factors coincided: Typhoon "Fitow" in 2013 and Typhoon "In-Fa" in 2021. During Typhoon "In-Fa," the combination of high astronomical tides and upstream water from the Huangpu River pushed water levels at Mishidu Station to a record 4.79 m, exceeding previous highs by 0.20 m, and posing significant challenges to the Huangpu River embankment's safety.

(2) Increasing impact of the compound disaster chain of extreme heat wave and hydrological drought, such as flood season reversal and salty tide intrusion.

The persistent high temperature and low rainfall will easily lead to "flood season reverse dryness" in the basin. July-October 2022 precipitation in the Yangtze River Basin as a whole was over 40% less than in the same period of a normal year, and locally 80% less; local high temperature weather exceeded 40 days. Under the background of abnormal changes of drought and flood superimposed on global warming, extreme hydrological events of high temperature and low rainfall over a long period of time and "flood season reverse dryness" should be emphasized.

The intrusion of salty tide affects the safe and stable supply of raw water from the Yangtze River in Shanghai. During the incursion of salty tide in the Yangtze River Estuary, the salty water intrusion will cause the chloride concentration in the intake of the water supply system in the Yangtze River Estuary to exceed the standard, which will seriously affect the water quality of the drinking water. Monitoring data shows that in 2022, the intrusion of the salty tide in the Yangtze River Estuary has caused more than 27 consecutive days of intake stop at the three water intake points along the river in Shanghai , which has greatly restricted the city's water resources security.

(3) Shanghai and other coastal cities in the lower reaches of the Yangtze River are under increased threat from sea level rise

Continued high temperatures exacerbate the threat of sea level rise. Continued warming has further increased the rate of sea-level rise, intensifying the flood risk to coastal cities such as Shanghai, Hangzhou and Ningbo. According to the observation data of Wusong tide gauge station, the rate of rise during 1912-1960 was 0.92 mm/a, and has accelerated significantly from 1960 to the present, reaching 2.03 mm/a. It is expected that by 2050, the sea level will rise by 160 mm compared with that of 2020, and the existing flood control standard of 1 in 1000 years of the flood control wall of the Huangpu River will be lowered to 1 in 150 years, with the river and sea defenses facing a more severe test.

3.2.3. Overview of priority climate adaptation measures in place

(1) Taking the large polder as a unit, continuously expanding the scope of urban flood protection and defense standards.

Through the small dikes into large dikes, joint dikes and dikes, etc., the flood control standard of important cities in the basin basically reaches the standard of once in 50 years and above. As of 2020, a total of 3,195 dikes have been built in the basin, with a total flood-discharging power of 20,664 m^3/s. A single large dike has expanded from 10-20 square kilometers to 50-150 square kilometers nowadays, and its flood-discharging modulus has reached more than 3 $m^3/s/km^2$, which is 2.1 times higher than the average level of flood-discharging in the basin.

(2) Gradual expansion of urban ecological space and increased ability to adapt to high temperatures.

Under the global trend of carbon neutrality, the Taihu Lake Basin has increased green space in cities by expanding the area of green space and improving the green space coverage rate. Municipalities are actively carrying out green space expansion projects, both to effectively curb urban sprawl and to mitigate the urban heat island effect. In 2022, the greening rate of the built-up areas in the basin reached 41 per cent, an increase of 12 per cent compared with 2010, and exceeding the national average (39 per cent).

3.2.4. Current gaps in climate adaptation

(1) Threshold capacity

The local flood control and drainage facilities in response to catastrophes lack capacity. At present, Shanghai's flood control engineering system is basically perfect, but there is still 236.4 kilometers of the main drains (47.4% of the city) that has not yet reached the protection standard of once in 200 years; about 90 kilometers of the Huangpu River flood control wall is insufficiently high, only 72% of the peripheral sluice gates and 43% of the pumping stations meet the standards and of all rainwater drains in the center of the city only 19% meets the standard of once in 3-5 years. In 2021, during the “Hana” typhoon, the flood control wall was overtopped in some sections of the upper and middle sections of the Huangpu River, while in 2021, during the “fireworks” typhoon, the upper reaches of the local section of the flood control wall was overtopped; in the East part of the Pu Nan area flooding was serious, exposing that the regional flood control capacity is still insufficient.

Secondly, the reduction of natural detention spaces and the intensification/densification of infrastructure and constructions have exacerbated the risk of urban waterlogging. According to the analysis of land use changes, the area of constructed land increased by 56.0% and 40.3% respectively in the two stages of 2000-2010 and 2010-2020, while the second and third-level river channels, which play an important detaining role in urban drainage, sharply decreased by 19.9% and 38.3% respectively. This has led to an acceleration of confluence velocity and an overall reduction in the detention capacity of the basin; in addition, affected by the combination, consolidation and construction of polders, the flood regulation and storage capacity of the river network outside the polders is less than 20% of the total amount of once-in-100-years floods in the basin (16.3 billion m^3), and the operation and scheduling of the polder's pumping stations are difficult to give full play to the regulatory and storage effect within the polders, still taking the drainage needs of the towns themselves as the priority.

(2) Coping capacity

Firstly, there is room for improvement in the level of early warning and forecasts of sudden meteorological and extreme disasters. In 2020, the effective alarming time for sudden severe weather in Shanghai was advanced to 42 minutes, only 2 minutes longer than the national average. Taking July 21, 2021 as an example, the Shanghai Meteorological Center issued a blue rainstorm warning signal at 15:51, forecasting that most areas of the city would have short-term heavy rainfall of more than 35 mm per hour within 6 hours. At 16:02, a yellow rainstorm warning was issued. From 16:00 to 18:00, there were 71 stations with rainfall exceeding 100 mm actually, and some areas had already exceeded the red rainstorm warning standard. Moreover, as the interconnectivity and staggering of climate driven hazards continue to strengthen, their superposition increases the complexity of emergency handling. Although Shanghai currently has a relatively complete single disaster risk forecasting system, it is relatively insufficient in simulating and predicting interrelated disasters such as "four-in-one" events (namely the circumstances where typhoons, rainstorms, high tides and floods occur simultaneously).

Secondly, although the emergency plan system framework has been basically established, the linkage and precision are not high, and their comprehensive guidance role has not been fully exerted. Taking Shanghai as an example, the current comprehensive security plans are difficult to adapt to the urban operation status under extreme disaster scenarios; for instance, special plans for meteorological disasters, marine disasters, tourism emergencies and others were mostly formulated before 2015 and have not been timely adjusted according to emerging safety issues, advancements in disaster prevention and mitigation technologies and similar factors, thus the comprehensive guidelines for disaster response needs to be strengthened.

Thirdly, the leading role of planning related to resilience in disaster prevention to particular spaces such as high-risk regions and grassroots governance units is insufficient. The current comprehensive disaster prevention plan only considers the city-district-subdistrict (township) three-level disaster prevention zones, lacking detailed guidance in emergency energy redundancy design, emergency material distribution channels, the conversion of community space from peacetime to emergency use in the community level and other safety monitoring and controlling system. In addition, for areas with high risk and high vulnerability, less consideration is given to the spatial needs of the elderly and vulnerable groups in disaster response.

Fourthly, the safety and disaster prevention supporting facilities are insufficient at the community and grassroots levels, and the public's awareness of disaster prevention is not strong. Currently, there is less consideration for climate adaptation and the need for safe resilience in housing areas, and the supporting facilities for disaster prevention and reduction are insufficient. The construction of comprehensive and professional talent teams for disaster response at the grassroots level such as subdistricts and communities is relatively weak, and there is a significant difficulty in the practical operation of community emergency plans and a lack of experience in emergency plan drills. The organization of emergency publicity and education is "fragmented", and residents lack sufficient understanding of the risks they face, and do not pay enough attention to enhancing the disaster response capacities of individuals, families and communities.

(3) Adaptive capacity

Firstly, the flood prevention standards between upstream and downstream cities in the basin are inconsistent, making it difficult to manage intercity rainstorm and flood management in a coordinated manner. Currently, upstream cities such as Wuxi and Jiaxing have a flood prevention standard of once-in-300-years in their central urban areas, while Shanghai, part of the downstream area, has a standard of once-in-200-years for its central urban area, and the upstream suburban area of Shanghai's Huangpu River has a standard of once-in-100- years. As can be seen, there is a lack of coordinated flood prevention standards between upstream and downstream cities.

Secondly the impact of continuous high temperatures combined with rising sea levels poses risks to water supply safety. Affected by factors such as global climate warming and sea level rise, the risk of intake points encountering salt tides has increased; in addition, the water quality of the Huangpu River's upstream water sources is at risk due to factors such as heavy metal contamination in upstream water inflows and pollution from ships. Moreover, the current water sources of the Yangtze River and Huangpu River in Shanghai, as well as their raw water systems, are relatively independent and weakly interconnected, making it difficult to meet the challenge of timely allocation of water sources in case of a failure of a particular water source.

(4) Transformative capacity -the capacity to change

Firstly, there is insufficient understanding of the various new environmental changes brought about by climate change. In recent years, the geographical environment of the Taihu Lake basin has undergone significant changes, but the current understanding of the mechanisms behind the formation of extreme natural disasters and potential hidden dangers at the basin level is still insufficient. For example, affected by factors such as the reduction of upstream sediment and changes in tidal power, the Qingcaosha Reservoir in Shanghai faces the risk of embankment collapse, which seriously threatens the safety of urban water supply.

Secondly, the overall coordination function of the emergency management department has not been fully exerted. At present, some local emergency coordination organizations within the basin, such as the Emergency Committee and the Disaster Reduction Committee, have their executive offices set up in different departments, which makes it difficult to efficiently exert the coordination functions, including professional command, material allocation and force coordination. There is a need to further improve the multi-departmental coordination mechanism.

3.3 Case 3: Climate adaptation in the Pearl River Estuary region

3.3.1. Trends in climate change

Climate change in the Pearl River Delta (PRD) has led to an increase in both the frequency and intensity of heavy rainfall, with storm centers shifting toward highly urbanized areas. The occurrence and magnitude of extreme precipitation events have risen significantly. At the same time, sea level rise, in combination with storm surges, threatens low-lying coastal areas, particularly affecting regions such as the Tan River, the Pearl River estuary, and surrounding areas.

3.3.2. Major disasters and issues arising from climate change

(1) Extreme rainstorms

Climate warming has increased the frequency and intensity of extreme rainfall in urban areas, leading to an increase in the frequency and extent of flood disasters in urban areas. Heavy rainfall and flooding disasters not only causes direct losses in the flooded areas, but also indirect losses to surrounding areas and facilities due to knock-on effects. In many cases, indirect losses even exceed direct losses.

Take the "9.7" extreme rainstorm in Shenzhen in 2023 as an example. The city's average rainfall was 281.7 mm; the largest was observed in the Luohu, 466.2 mm. The city's 31 reservoirs exceeded the flood limit level. It triggered disasters such as extensive flooding, river overflow, flooding of underground space, landslides, etc. The city was flooded over 18 square kilometers, more than 220,000 people were evacuated, and 220 public building basements and 7 subway stations were inundated with water.

(2) Sea level rise

The disaster effect of sea level rise is related to the geological structure of the coastal zone system, land geomorphology, coastal types, coastal sediment dynamics, hydrodynamic and other conditions, which will strengthen the role of surges, tides and waves and will change ocean dynamics, exacerbate the occurrence of salty tide disasters in the estuarine coastal areas and prolong the duration of salty tides. Due to the higher water levels along the coast, the natural drainage capacity of the city decreases, and urban sewage discharge gets more difficult or is even backed up, increasing the difficulty of drainage, and aggravating flood disasters.

Take the case of sea level rise in the Pearl River Estuary as an example. According to data from the Hong Kong Observatory, the average rate of sea level rise in Victoria Harbour from 1954 to 2023 is 31 mm per decade. The China Sea Level Bulletin shows that in 2022, the coastal sea level in the Pearl River Estuary will reach its highest since 1980, 138 mm higher than normal (1993-2011), and also higher than the average coastal sea level in China (94 mm higher than normal). Taking Shenzhen Shekou as an example, assuming that the sea level rises by 1 meter in 2100, the return period of the highest tidal level of once in 100 years will be reduced to less than once in 10 years, and the highest tidal level of once in 50 years and once in 100 years will be 3 m and 3.3 m, respectively, which will threaten the safety of all coastal protection facilities.

(3) Saltwater upwelling and water crisis

Insufficient flow of freshwater rivers in years of climatic drought and seawater intrusion are the main reasons for the formation of salty tides in the estuaries of the Pearl River Delta. The rise in sea level, the indiscriminate mining of river sands and the reduction in the flow of water in the rivers due to the sharp increase in the use of water for production and domestic purposes are the driving factors for the further expansion of the intrusion of salty tides. When the salty tide extends upstream to the water intake of water supply plants, it will affect the normal public water supply, which is hazardous to human health, and will also affect the normal production of industrial enterprises. At present, the water supply sources of PRD cities are mainly river water intake, with water withdrawal accounting for more than 50% of the total water consumption; the storage capacity of local reservoirs and emergency back-up water sources are insufficient. The amount of externally transferred water is even more seriously insufficient, accounting for less than 10% of the total. Therefore, during the dry season, the intakes of water from the rivers are highly susceptible to the impact of the salty tides. On the other hand, due to the high concentration of population and economic activities, the total water demand of the cities in the Pearl River Delta is high, which puts enormous pressure on the existing water supply system.

Since the end of 2021, rainfall in the Pearl River Basin has been persistently low, and the Pearl River Basin has suffered the most severe drought in 60 years. The water inflow of major rivers is 30%-70% less, including the Dongjiang and Hanjiang rivers, which are 70% less. In 2022, around February 15, high tide levels coincided with the astronomical tidal wave. The tide difference was large, superimposed on the unfavorable Northeast wind conditions of grade 6 to grade 7. The salty tides intruded deeply into the estuarine areas of the Pearl River Delta, many times. According to the Marine Disaster Bulletin of the South China Sea Region, the intrusion distance of the salty tide in the Pearl River Estuary was more than 60 kilometers at the farthest. As a result, the water supply safety of some areas in Zhuhai, Zhongshan, Dongguan and Guangzhou were challenged.

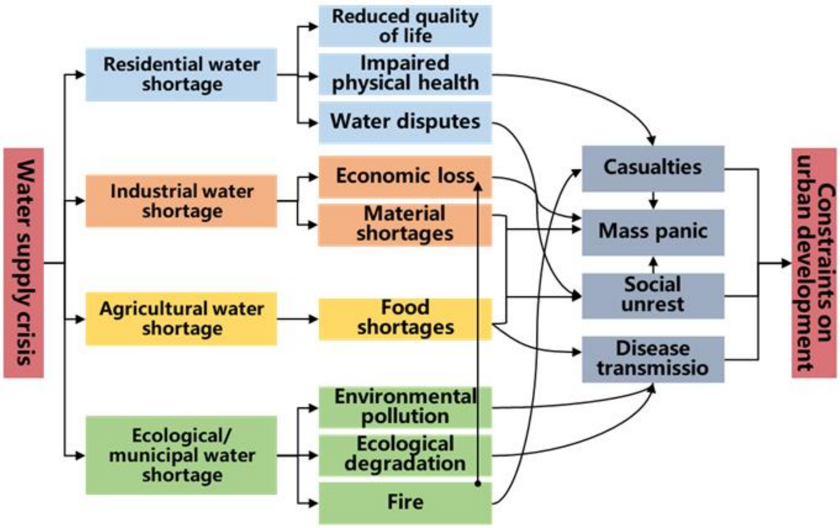

Figure 3.3. Schematic Dissemination of the Disaster Chain of Water Supply Crisis in the Pearl River Delta

3.3.3. Overview of priority climate adaptation measures in place

(1) Pearl River Basin Sectors Link Up to Cope with Salt Tide Intrusion Disasters

During the 2022 Pearl River Delta salty tide intrusion disaster, the Ministry of Water Resources instructed a basin-based unit to release water from a cluster of reservoirs in the Xijiang and Dongjiang river basins in order to replenish the downstream river part and suppress salty water intrusion. The Pearl River Water Resources Commission was commissioned to collaborate with the Fujian, Guangxi and Guangdong Water Resources Departments to implement water dispatching of the Northwestern River, the Dongjiang River and the Hanjiang River to focus on replenishing water to the downstream river section and suppressing salty water, so as to make the limited water resources play the greatest drought relief benefits.

(2) Guangdong, Hong Kong and Macao cooperate closely to carry out climate response and maritime emergency rescue.

In 2019, the Guangdong Provincial Government and Hong Kong set up the Hong Kong-Guangdong Co-operation Group on Environmental Protection and Climate Change, which is dedicated to improving regional air quality, protecting the water environment, forestry care, marine resources care and combating climate change in the Pearl River Estuary. In 2024, The Guangdong Provincial Government signed the "Framework Agreement on Guangdong-Hong Kong-Macao Co-operation in Emergency Management and Greater Bay Area Co-operation in Emergency Rescue Operations" with Hong Kong and Macao to strengthen the co-operation and exchanges among Guangdong, Hong Kong and Macao in emergency management and rescue.

(3) Hong Kong and Shenzhen Joint Social Forces to Address Climate Change - A Case Study of Mangrove Protection and Restoration

Learning from international experience and strengthening cooperation with Hong Kong, cities such as Shenzhen have begun to actively introduce NGO organizations to join in the protection and management of mangrove forests. For example, the Mangrove Foundation (MCF), which has developed in Shenzhen, is the first environmental protection foundation initiated by the private sector in China, and the only non-profit social organization in mainland China that operates and maintains mangrove nature reserves and mangrove parks. In 2020, the Shenzhen Municipal Government signed a Framework Agreement on the Cooperation for the Protection and Development of the Coastal Wetlands of Shenzhen Bay with the MCF, with the aim of creating a Shenzhen model for coastal wetland protection and global wetland conservation.

3.3.4. Current gaps in climate adaptation

(1) Threshold capacity

Firstly, the resilience of urban spatial structure is insufficient. The urban spatial form cannot adapt to extreme rainstorms, and the local overflow capacity of some flood discharge channels is insufficient, causing upstream water levels to rise and leading to local flooding; other urban constructions are located in low-lying areas, which are prone to regional flooding disasters.

Secondly, the disaster prevention capacities of urban vulnerable nodes such as underground spaces are not strong. For example, the Shenzhen subway system is designed to a once-in-100-years flood prevention standard, but the flood prevention standards of interconnected underground walkways, parking lots, shopping malls and other facilities are lower than that of the subway, becoming a weakness in waterlogging prevention. Cities in the Pearl River Delta such as Shenzhen and Guangzhou have large multi-functional underground transportation complexes like Gangxia North and Chunfeng Tunnel, which are deep, extensive and complex in business types, have many hidden risks, and pose great difficulty in escape and disaster relief.

(2) Coping capacity

Firstly, there is a shortage in the monitoring and early warning capacities for meteorological disasters. Although the overall monitoring and early warning capacities for meteorological disasters are leading, and a three-dimensional observation network with high spatial and temporal resolution has been established, there are still shortcomings in the early warning capacities for specific areas such as businesses and transportation facilities. A large number of infrastructures and businesses under high operational intensity have increasing hidden safety hazards, and the pressure for disaster prevention and control is increasing year by year. In case of encountering extreme weather such as heavy rain, collapses are prone to occur. At present, the detection of facility hidden dangers is mainly based on manual inspection, and the timeliness and comprehensiveness of traditional vulnerability assessment methods are insufficient while the application of more advanced detection methods is limited.

Secondly, there is a need to enhance the disaster prevention awareness among communities and residents. During the heavy rain event on September 7, 2023, many communities suffered from severe waterlogging and flooding of underground garages. The failure in organizing the transfer of vehicles in advance led to a large number of vehicles being submerged, resulting in property losses for residents. Although meteorological and emergency management departments had issued emergency early warning announcements through text messages, television and WeChat in advance, there were still instances where residents did not take timely shelter during the red alert period and businesses did not cease operations as required, leading to injuries.

(3) Recovery capacity

The disaster resilience of major infrastructures such as urban lifeline projects needs to be enhanced. During the heavy rain event on September 7, 2023, in Shenzhen, several communities suffered from water and electricity outage caused by water and power supply facilities flooded for the second time.The shortage of emergency drainage facilities led to the inability to quickly drain the floodwater, preventing the timely repair of water and power supply facilities, and making it difficult for residents to restore their lives and business production activities quickly, also resulting in economic losses.

The quantity and pumping capacity of drainage facilities allocated internally within tunderground spaces is insufficient in some cities. The reserve and inter-departmental dispatch mechanisms for flood control equipment like water pumps are not well-established, leading to an inability to quickly restore facilities like underground parking lots after they are flooded.

(4) Adaptive capacity

Firstly, the risk of annual storm surges and flood disasters in coastal cities is exacerbated by rising sea levels, leading to a decrease in the actual flood and storm surge disaster prevention capacities of cities. The tidal protection level of major infrastructures such as nuclear power plants does no longer meet the design level requirements on the long run. Under the long-term impact of rising sea levels, there is insufficient awareness of unconventional disasters that may occur in the future.

Secondly, there is an insufficient capacity to adapt to salt tide intrusion and coastal erosion, making coastal ecosystems more vulnerable to damage.

(5) Transformative capacity -the capacity to change

Further improvement to systematically address disaster prevention and inter-departmental collaboration is needed. The coordination of flood prevention within regions and river basins remains to be perfected. There are disparities in the management standards between upstream and downstream as well as left and right banks of cross-regional rivers in the Pearl River Delta. When basin-type floods occur, flood disasters are easily transmitted between the upper and lower reaches of the basin. The regional coordination mechanism of water resources in the Pearl River Delta needs to be improved. When urban water supply is insufficient due to the upward movement of salt tides, there are deficiencies in the river basin's water resource allocation mechanism.

3.4 Case 4: Climate adaptation in the Rhine-Meuse-Scheldt delta

The Rhine-Meuse-Scheldt (RMS) delta involves three countries, numerous regions, provinces, water authorities and hundreds of cities and municipalities. Each jurisdiction has its own government, legislation, regulations, practices and culture and is governed by European legislation and practices. Despite all the differences, climate adaptation remains a priority for them. The region is flat and low-lying, but densely populated, highly urbanized, industrialized and agriculturally intensive. This makes their vulnerability or damage sensitivity so high that climate hazards are economically and socially unacceptable. Extreme weather events and near misses have been on the rise over the past few decades, and exposure to extreme weather and sea-level rise will exacerbate the threats, making adaptation to climate change urgent.

The European Union, the European countries, regions, municipalities and water authorities developed laws and regulations to facilitate adaptation, and accumulated knowledge, experience and skills on adaptation measures and their effectiveness, implementation and maintenance needs. This resulted in , reservation of budgets, planning and implementation of (large and small) adaptation projects. These projects mainly concern rivers, alluvial deposits and coastal flood control, and to a minor extent drought and heat and the associated problems of water quality, salinization, navigability, land subsidence and wildfires.

Europe aims to make climate adaptation locally based, systemic and inclusive (EU Mission on Adaptation to Climate Change), focusing on 1) supporting regional and local governments in their local efforts to strengthen physical and social resilience; and 2) investing in strengthening the adaptive capacity of large river systems, lakes and coastal defences. The European countries seem to be concentrating on strengthening the threshold capacity in order to avoid damage from extreme events, less attention seems to be paid to the coping, recovery, adaptive and transformative capacities needed to create climate resilience.

1. Threshold capacity; damage prevention

Water detention capacity or sponge capacity is recognized as key to avoiding damage during periods of extreme rainfall, droughts and heat waves; on the one hand, it avoids peak discharges and floods, and on the other hand, it allows water resources to fulfill basic water demands. Significant funds have been invested in creating more retention capacity along the Rhine tributaries, the Meuse, the Scheldt and their tributaries to withstand flooding. Detention for drought is often linked to groundwater resource management and surface water salinity control, and is another target of national climate adaptation policies and investments, such as the Flanders Blue Deal and the Dutch Delta Freshwater Program. The spatial integration of detention measures is challenging as it requires significant demands on the land.

2. Coping capacity

Planning and design goals should include minimizing damage from extreme events that exceed the threshold or design capacity of the water system, such as the "water bomb of 2021[1]" and the extreme drought of 2018. Using such extreme events to stress-test the climate resilience of urban areas and regions, as the Netherlands has done, is an important first step towards risk dialog and adaptation. As seen in and around Essen Eschweiler, Germany, redistributing important critical infrastructure, vulnerable populations and functions to the safest places in the region proves difficult in practice due to existing urban structures, vested economic interests and competition for space. Smart buildings and infrastructure can help to reduce the risk of damage caused by extreme weather in both urban and rural areas. New building codes are being considered in Germany and the Netherlands but are not yet fully implemented. Effective early warning and contingency planning are equally important to minimize damage, as the July 2021 floods in the Ruhr and Ahr-Erft river basins in Germany sadly demonstrated.

[1] The "Water bomb" that hit large parts of Wallonia in Belgium and Northrhine-Westphalia and Rhineland-Palatinate in Germany on 13-15 July 2021 with locally over 250 mm of rainfall caused over 220 casualties, affected more than 120,000 private homes and caused about 38 billion Euro direct damage.

3. Recovery capacity

Throughout the RMS delta region, preparations for disaster recovery are limited. In some cases, such as in Flanders, the financing of recovery is partly covered by private insurance; usually, the national government has to cover the losses. And, as seen in Germany and Belgium, "rebuilding better" is not always allowed. The statute states that one must rebuild what was lost; changes are not allowed. Research in Germany has shown that socially disadvantaged groups are more vulnerable to the effects of extreme weather than highly educated, affluent and healthy social groups. Such inequalities should be taken into account in disaster recovery. Recovery organizations and psychosocial help for traumatized victims can be strengthened.

4. Adaptive capacity

Rigid, grey adaptation measures are robust and have a long service life. However, an excessively long lifespan may be counterproductive when new conditions and/or newly emerging social needs are taken into account. Research in the Netherlands has shown that most nature-based blue-green solutions are better able to adapt and/or form a new equilibrium with demands when local conditions change in the future. In order to minimize the damage caused by extreme events (i.e., resilience) while maximizing the benefits and ecosystem services provided by blue-green infrastructure, innovative and smart combinations of green and grey infrastructure (GGI) are currently being developed across Europe. Smart green roofs and urban water buffers in The Hague, the Netherlands, are good examples.

5. Transformative capacity -the capacity to change

As demonstrated by the Dutch Delta Program, the Blue Deal and Sigma projects in Flanders, the flood recovery activities in North Rhine-Westphalia and Rhineland-Palatinate, and the EU Climate Adaptation Missions, climate adaptation is a continuous and collaborative learning process that requires research into new solutions, pathways and methods. Research-Based Design (RBD) has proven to be a valuable approach to this complex challenge, creating innovative solutions that are flexible in the long term. Adaptation-targeted 'design research' in the Netherlands is based on scenario studies such as the Territorial Outlook 2023 and the Delta Scenario [17, 18], which show the future spatial developments that could result from potential decisions. This approach allows experts to co-develop plans in collaboration with local stakeholders. Local urban adaptation projects in the Netherlands have shown that co-development of plans can help to raise public awareness of issues and deepen understanding of the characteristics of interventions.

New planning and design principles are being introduced, e.g. the Dutch National Policy Brief "Water and Groundwater Sphere", which includes the principle that climate issues must not be shifted, neither spatially, to neighbouring areas, nor temporally to the next generation, nor from private land to public space. Currently, the public sees adaptation to climate change as a government responsibility. People and businesses are aware of climate change, but hardly of the need to prepare for more frequent and severe extreme weather events. There is still a lack of understanding and outreach about the prospects for existing actions. Sustained funding for adaptation measures is crucial. In contrast to the irregular funding of the Sigma program projects in Flanders, Belgium, the Dutch Delta Fund provides continuous financial support. Long-term budgets reserved for adaptation measures also provide continuity in promoting government-social capital partnerships, knowledge research and innovation.

It is widely recognised that the replacement of the existing, rapidly aging infrastructure provides interesting opportunities for adaptation. An implicit obligation to consider climate adaptation as an essential element in such urban renewal and rural redevelopment project is found in the EU flood directive and in the water assessment ("watertoets"), obligatory part of the environmental permitting system in the Netherlands and Belgium.

3.5 Concluding discussion

As can be seen from the cases of the four regions, the prevailing climate change challenges to cities include: 1) the increasing frequency and intensity of extreme weather, especially extreme precipitation, which exacerbates the risk of flooding in urban spaces; 2) risk amplification due to a combination of climate change effects such as sea level rise ánd extreme weather, combined with human actions such as the seaward development of settlements in coastal cities and their harbors; 3) heat waves, intensified by the urban heat island effect which intensifies health and even life hazards to citizens; 4) high temperatures and drought that trigger hill fire disasters and energy shortage crises; 5) extreme droughts, threatening the water supply for domestic and industrial use and for irrigation of urban green, as well as impacting the quality of local surface waters and the shipping transport of goods.

Despite the great differences among regions in terms of geographic conditions, climate, population, welfare, and political and administrative systems, these four regions have revealed very similar challenges and deficiencies in their ability to cope with the climate crisis. Often mentioned are the following issues, without indication of priority: 1) insufficient resilience of the spatial building patterns to adapt to climate change; 2) insufficient ability to strengthen climate resilience with blue and green nature-based solutions; 3) aged, outdated major and vital infrastructures, such as the urban lifeline facilities, not designed for future climate conditions; 4) insufficient public awareness of climate change impacts on the local and global scaleand their ability to assess their climate risks; 5) insufficient awareness among community residents and businesses of the many options available for risk-reducing interventions 6) regulations, protocols and standards for addressing climate change still need to be upgraded; 7) insufficient cross-sectoral synergies in urban disaster prevention; the overall coordination function of the emergency management department has not been brought into full play; 7) the quality of extreme weather forecasting and of early warning systems for sudden meteorological disasters needs to be upgraded; 8) mechanisms of (cross) regional cooperation needs to be improved, and inter-city, regional and river basin wide climate crisis response plans need to be coordinated and intertwined; 9) the climate risks faced by villages, small and medium-sized towns are intensifying because of a lack of expertise, financial resources and, consequently, a backlog in infrastructure construction.

To address these challenges, it is important to further understand location-specific climate vulnerabilities and to determine whether climate adaptation measures can meet the needs of local urban and rural development and improvements in the lives of the population. Capacity-building actions to strengthen the five capacities needed to address climate change in urban and rural areas – the threshold, coping, recovery, adaptive and transformative capacity - will not be homogenous and undifferentiated. There is an urgent need to develop **climate adaptation strategies** that **are locally adapted - and coherent at the regional scale**.

4. Lessons from disasters: how to deliver precaution, relief and rebuilding

Thus far, most adaptation actions were taken after suffering from a climate disaster. Consequently, climate-related disasters and their aftermath provide valuable lessons on how to prepare for, respond to and recover from disaster in a better way, hence for creating a more climate resilient environment. This chapter provides reflections on a global assortment of another 16 cases to learn from. The reflections on these cases are based on this report's assessment framework with five capacities and ten enabling conditions. From this multitude of cases, a selection with explicit lessons was made and summarized . This provides the CCICED's global coverage combined with extra detail for China. For presentation purposes, cases and findings are grouped according to three typical phases and terminology commonly used in disaster risk reduction:

Precaution and Preparedness (directly related to Threshold capacity and Adaptive capacity and their enabling conditions)

Relief – aid, compounding risks, vulnerabilities (directly related to Coping capacity and its enabling conditions)

Rebuilding – adaptation, resilience, innovation (directly related to Recovery capacity, Adaptive capacity and especially Transformative capacity, as well as their enabling conditions)

Figure 4.1 illustrates the relation between the capacities, the enabling conditions and the elements of disaster risk reduction; this also sketches the logical flow of the chapter.

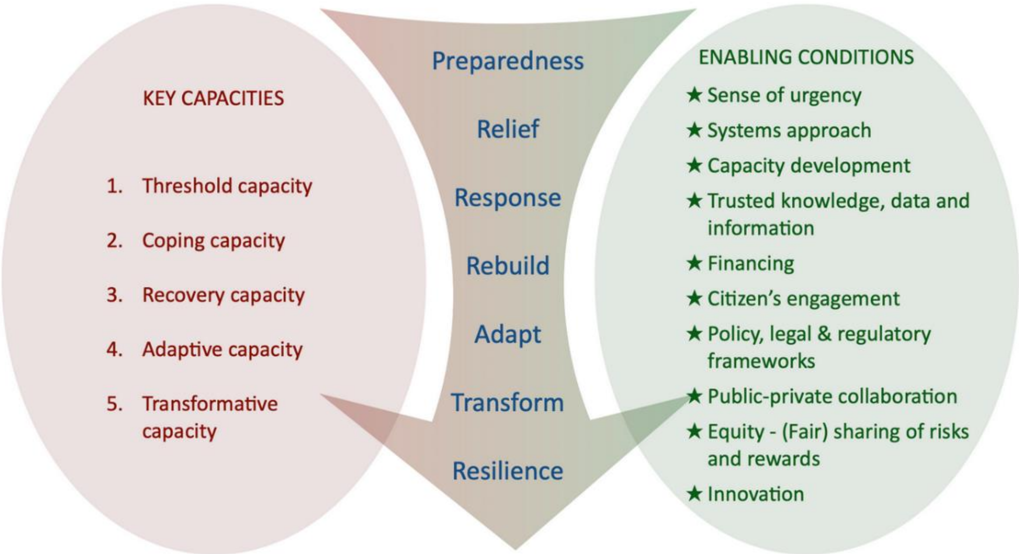

Figure 4.1. Phases of disaster risk reduction and its common terminology related to the five key capacities to develop climate resilience and their enabling conditions

For this chapter the four major cases portrayed in Chapter 3 have been considered, as well as sixteen other cases (all listed in Box 4.1). To demonstrate the global coverage of the cases, Figure 4.2 gives a map of the sites included in this analysis. Of these cases, eleven are summarized in this chapter itself. Details can be found in annex CII to this report. Each case has been analyzed, as far as applicable, in terms of weaknesses exposed and inspiration gained.

Box 4.1. Cases analyzed for this Special Policy Study

Major Cases (Chapter 3)
Case 1: Climate adaptation in the Chengdu-Chongqing area
Case 2: Climate adaptation in the Taihu Lake basin
Case 3: Climate adaptation in the Pearl River Estuary region
Case 4: Climate adaptation in the Rhine-Meuse-Scheldt Delta

Precaution & Preparedness
Case 5: The "July 20" extremely heavy rainstorm Disaster in Zhengzhou, Henan Province in 2021
Case 6: Early Warning For All(United Nations)
Case 7: Bangladesh – Early Warning Systems
Case 8: Singapore – Water Wise

Relief – aid, compounding risks, vulnerabilities
Case 9: Rare and catastrophic flood in Chongqing on August 20th, 2020
Case 10: California wildfires
Case 11: Repeated flooding in Nairobi
Case 12: Flooding and Rebuilding in the Aachen region 2022

Rebuilding – adaptation, resilience, innovation
Case 13: Extremely heavy rainstorm disaster in Beijing Tianjin Hebei in 2023
Case 14: New York – Hurricane Sandy Response
Case 15: Flanders – Post Floods, Preparedness / Resilient Waterland

Other cases
Case 16: High temperature and drought disasters in the Sichuan Chongqing region
Case 17: Mozambique – Partially Prepared
Case 18: Peru – Flood Resilience Task Force
Case 19: Water At The Heart Of Climate Action
Case 20: Water As Leverage -- Innovative Preparedness

More analyses of flooding-related cases: https://www.zurich.com/knowledge/topics/flood-resilience/zurichs-flood-resilience-program

World map of cases analyzed for this Special Policy Study

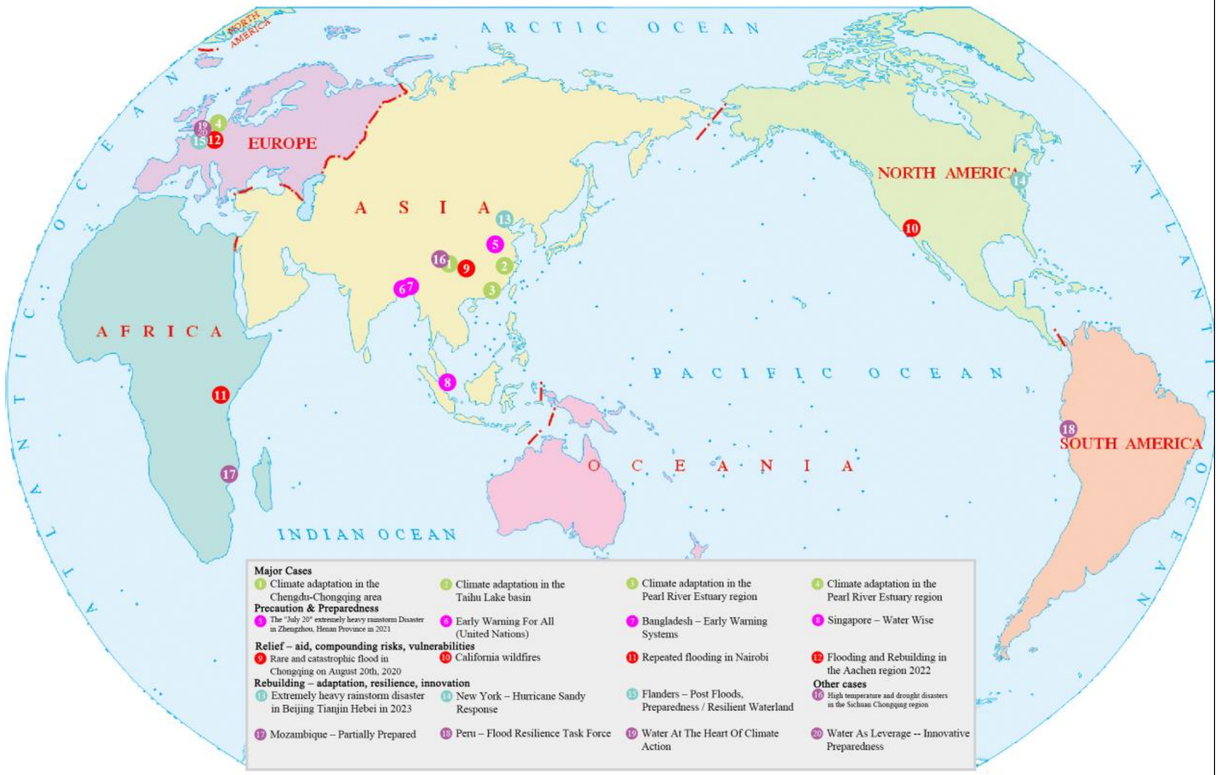

Figure 4.2 Global map illustrating the geographical spreading of the cases around the world.

4.1 Precaution & Preparedness

Enhanced early warning systems actively prepare societies for the impacts of disasters. These systems are cost-effective and reliable to enhance the coping capacity. Enhanced digital monitoring and systems of risk detection, developing and improving emergency response plans in collaboration with affected communities, and improvement of public risk awareness, can protect lives in case of natural disasters. Good early warning systems in a country (including governments ownership and public awareness) reduce disaster mortality by a factor eight compared to countries with limited coverage [19]. With disastrous events, 24 hours advance notice reduces damage by 30% [20]. Globally, people in Africa, South Asia, South and Central America, as well as on small island states, are suffering more than 15 times more from deadly hazards extreme events related to climate, weather, and water due to the lack of appropriate warning systems and disaster preparedness capabilities have caused [21].

4.1.1 Case 5: The "July 20, 2021" extremely heavy rainstorm disaster in Zhengzhou, Henan Province

From July 17 to 23, 2021, Henan Province experienced a rare extremely heavy rainstorm. The event led to serious floods, especially on July 20. Zhengzhou suffered heavy casualties and property losses. Insufficient preparedness in the prevention of, preparation for and response to flooding has been an important cause of the seriousness of these impacts. The problems included insufficient ability to issue timely and unambiguous warnings; attention to the extreme meteorological information was inadequate. In addition, the emergency response was late, and not soundly linked to the flood warnings. It was unclear who had to respond and how to respond. In contrast, the earliest city in the region to initiate emergency response, Denfeng City, did so 17 hours ahead of Zhengzhou City, and suffered the smallest number of deaths and missing persons among the four cities in the area. Furthermore, local media did not do a good job alerting the public, and the public's awareness of flood risk and their options to avoid danger was not strong. This is illustrated by the pattern of casualties: most of the people who died or went missing had continued their normal activities or had returned shortly after evacuation and then died.

4.1.2. Cases 6 and 7: Early Warnings For All and Bangladesh – Early Warning Systems

In March 2022, United Nations Secretary-General António Guterres [22] initiated the global Early Warnings for All Initiative, to ensure within five years universal protection from hazardous weather, water, or climate events through life-saving early warning systems. The need for early warning systems across the world only increases. Climate change exacerbate the impact of our disasters, as well as increases the vulnerability of our socio-economic and environmental systems. By now, over 30 countries including Bangladesh, Maldives, and Sudan have joined the Early Warnings for All program to carry out implementation work in disaster warning and preparedness, monitoring, and emergency response plans[21]. China, where a comprehensive meteorological observation system was established to strengthen the assessment of the impacts and risks of climate change, is still prone to significant losses in the face of major natural disasters due to inadequate preparedness, early warning and prevention.

WMO[2], UNDRR[3], ITU[4] and IFRC[5] with partners developed a people-centered Multi-Hazard Early Warning System (MHEWS), as an integrated information system for upcoming weather or climate events, while supporting institutions and communities in preparedness, relief and response actions. MHEWS is based on (i) Disaster risk knowledge; (ii) Detection, observation, monitoring, analysis, and forecasting; (iii) Warning dissemination and communication; (iv) Preparedness and response capabilities [21].

Bangladesh leapfrogged from a nation suffering from frequent and dramatic disasters to one being well-prepared, capable of moving millions of people out of harm's way, in the lead up to disasters. Thanks to Bangladesh's successful Cyclone Preparedness Program (CPP) – an early warning system where more than 76,000 volunteers, half of whom women, with the best available data on forecasting go around to even the most remote communities and guide everyone across the country to multifunctional shelter-infrastructure. This is an example of community-led mobilization at a scale unprecedented, anchored in national policy and legislation to ensure consistency, continuity and commitment [23].

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[2] WMO: World Meterological Organisation

[3] UNDRR: UN Office for Disaster Risk Reduction

[4] ITU: International Telecommunication Union

[5] IFRC: International Federation of Red Cross and Red Crescent Societies

4.1.3. Case 8: Singapore --- Water Wise

Singapore from its independence saw itself confronted with freshwater dependency and embarked on a bold water resilience approach. This laid the groundwork that married Singapore's freshwater security approach to its resilience strategy. Singapore's four National Taps refer to the four sources that Singapore relies on for its water supply [24]: 1) water from local catchments, 2) imported water, 3) high-grade reclaimed water (NEWater), and 4) desalinated water [25]. Singapore implemented a three-pronged water management system to meet the growing water demand: collect every drop of water; reuse water endlessly; and desalinate more seawater [26].

4.2 Relief – aid, compounding risks, vulnerabilities

Providing relief is a key component of disaster risk reduction, and therefore of the coping capacity. This includes actions taken directly before, during or immediately after a disaster to save lives, reduce health impacts, ensure public safety and meet the basic needs of people affected (UNDRR) [27]. Actions include the need to establish an emergency management system that can respond quickly, provide on-site assessments, conduct search and rescue, medical treatment and safe evacuation. Post-disaster provides a series of logistical challenges including providing temporary shelters, food, access to water, sanitation, medical and psychological support and repairing essential infrastructure including communications. These types of aid need to reach the areas most affected and the most impacted populations. Tailored responses are required for the most vulnerable populations including the poor, elderly, children, disabled and the injured. A timely response can halt secondary disasters such as the spread of diseases, after a flood event.

By way of contrast, a case for Nairobi, case 11 included here, is in which no positive actions or learning can be reported. In fact, it is a negative case of flooding that impacted informal settlements the most, because they were in riparian zones at risk from floods. This was followed by evictions with no recourses for these extremely vulnerable communities.

Effective relief requires strong government responses and capacity building support for communities and individuals to be able to respond appropriately in a post disaster context. Often, this requires institutional coordination across scales, for example, in the case of Chongqing, case 9 below, both at the local level and with national and international governments. There are also clear roles for civil protection, police and fire services including search and rescue, protecting people and property after a disaster. Civil society and the public have a strong role to play to provide reliable information, resources, mutual aid and to coordinate with local authorities for successful execution. Relief work will often last much longer than the initial days post-disaster and can support community resilience such as in the case of California, case 10 below, where the coping capacity and the recovery capacity became dovetailed.

4.2.1. Case 9: Rare and catastrophic flood in Chongqing on August 20th, 2020

On August 18-20, 2020, due to heavy rainfall upstream, the Yangtze River area in Chongqing suffered floods. Hundreds of thousands of people were affected over a wide area, including the main urban area of Chongqing, and direct economic loss was large. Subsequent measures taken to cope with disasters include a joint approach to dispatching excess water in the basin and ensuring ample retention capacity. This was reached through extensive departmental consultation and coordination *at basin-scale level*. In addition, emergency management and evacuation systems at various levels were linked: city, district, street, and community levels.

Over and above this, the prevention concept has shifted from engineering resistance to coexisting with floods. For example, this has been used in preparing flooding responses in the low-lying area of Ciqikou Ancient Town: personnel and property retreat when the flood comes; when the flood recedes, personnel and property return.

4.2.2. Case 10: California wildfires

The Rim Fire in California started on August 17, 2013 and burned over 1041 km^2, becoming the third largest wildfire in California history and one of the most severe fire events in terms of its rapid growth, intensity, size and smoke. It resulted in significant impacts to the local economy, threatened access to clean water, disrupted the lives of thousands of people, and damaged air quality. With funding from a federal program (National Disaster Resilience Competition, coming from Rebuild by Design), a combination of local, state and federal agencies collaborated to address unmet recovery needs and build long-term resilience. The program applied a systems approach to address forest recovery, economic recovery and community building. Two community resilience centers were built as evacuation centers for future disasters and during other times have been used as warming and cooling centers, charging stations for medical equipment during power outages, commercial kitchen for local small business product production, as local meetings facilities for community groups and nonprofits and for job training. This model is now being replicated across the state.

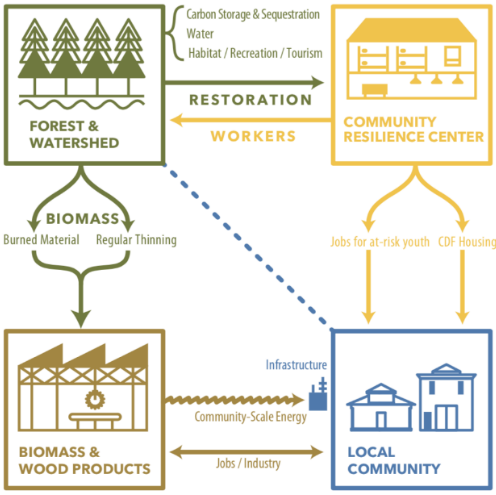

Figure 4.2. Community and Watershed Resilience Program, California [28]. The diagram shows the program's system-wide perspective considering forest recovery, economic recovery, and community building.

4.2.3. Case 11: Repeated flooding in Nairobi

In spring 2024, rains linked to El Nino 2023 triggered flash floods in Kenya that killed at least 228 people, left 72 people missing, and displaced more than 212,000 people. Over the period 1961 – 2018, Kenya recorded 21 major flood events, with most of the rainfall anomalies occurring in the more recent years. In the Nairobi area, the flooding events kept revealing critical weaknesses in urban planning, drainage systems, and emergency response mechanisms. The socio-economic losses from these events are staggering. In Nairobi, the floods have exacerbated the living conditions in informal settlements such as Kibera, Mukuru and Mathare Slums, where inadequate infrastructure and poor drainage systems leave residents exposed to the impacts of heavy rainfall.

This widespread destruction by the floods has revealed the urgent need for comprehensive flood management and mitigation strategies with government agencies, non-government agencies, and community groups working towards enhancing early warning systems, improving infrastructure and drainage systems, promoting sustainable land use practices, strengthening disaster preparedness and response, enhancing risk communication and public awareness as well as fostering cross-sectoral collaborations and partnerships. Significant gaps remain in policy formulation, implementation, and coordination among stakeholders. There is, therefore, a pressing need for a comprehensive, evidence-based policy framework that addresses the root causes of flooding, the consequences of extreme weather events and integrates sustainable solutions [29].

4.2.4. Case 12: Flooding and Rebuilding in the Aachen region 2022

The floods of mid-2021 caused widespread damage and loss of life in West Germany. The event had a probability of once in 400 years. It occurred in a moderately hilly area with small rivers. A multi-institution project is tasked with scientific monitoring of the reconstruction. Its recommendations point to an obvious need for smarter engineering, including a rethink of the region's many small bridges. The critical role of land use on hillsides and in narrow valleys is underlined once more, as is the need for good general access to risk information and for really fast warning in emergency situations; active preparedness and training at local level, even if these events are deemed to happen once in a lifetime. Rebuilding of individual houses and small businesses seems to have happened mostly in much the same location and type as they were, due to rigid insurance policy, thus perpetuating risk. Monitoring and support extend to mental impacts of the disaster and to the role of social networks at the scale of communities that live by the river and are formed by it.

4.3 Rebuilding – adaptation, resilience, innovation

Around the world, only learning by default and disaster seems to be common. Becoming faster in learning and pro-actively deploying that knowledge for preparedness, relief and rebuilding, innovative at scale and across the world is a big challenge. Climate preparedness offers a return on investment of five to ten times or more, accounting only for the losses prevented, and risks reduced. Considering the investment opportunities and added value – from better health, increased security, improved ecology, a decreasing gender gap and strengthened youth capacity – the benefits are numerous [30,31,32,33].

To sufficiently deal with disasters, both prevention and repairing are essential. All over the world, the impact shows vulnerability - human-made systems like cities built on hard structures are not fit for the future. Recent urban growth worldwide has largely been in the zones with largest flood risk [34]. Adequate capacity to hold the rains overflowing our storm water facilities is missing, parks or green roofs to mitigate heat island effects are lacking; sewage systems are not good enough to stand up to extreme events etc. This is devastating for climate resiliency, with disastrous impacts on marginalized communities and the biodiversity system, undermining food security and economy. It is doubtlessly important to learn to do better, to understand whether to mitigate or adapt, to prepare before responding and to invest in a sustainable future, leaving no one behind. Lessons learnt are however costly. Practice shows that it is time to change course now, with resilient and innovative actions, tackling social, economic, cultural and ecological challenges.

4.3.1. Case 13: Extremely heavy rainstorm disaster in Beijing Tianjin Hebei in 2023

After the Beijing Tianjin Hebei extremely heavy rainstorm disaster in 2023, the Chinese government acted along multiple lines. One line is planning guidance, led by the National Development and Reform Commission to organize the compilation of the "Plan for Enhancing Disaster Prevention and Reduction Capacity in North China Region with a Focus on Beijing Tianjin Hebei". Next to the reparation of damage, including the reconstruction of water detention facilities in river basins, strengthening the meteorological monitoring network in key areas, and improving urban drainage and flood prevention facilities. Other lines of government response in the same vein include increased investment and the issuing of more treasury bonds and an acceleration of projects, bringing facilities up to standard by 2024 and improving urban drainage capacity.

4.3.2. Case 14: New York – Hurricane Sandy Response

Hurricane Sandy battered the Northeast coast of the United States in 2012, wreaking havoc across the region. President Obama's Hurricane Sandy Rebuilding Taks Force's ambition was to use the recovery of Hurricane Sandy to leapfrog towards a state of resilience. It launched Rebuild by Design, part policy process, part rebuilding program, and part design competition, bringing together all levels of government, stakeholders and residents to innovatively design and develop new standards of regional resilience. Ten teams of architects, urbanists, engineers, scientists and activists engaged with communities and government agencies. In 2014, the federal government awarded US$ 930 million to state and local governments to implement the six winning designs. Rebuild by Design's key insights can inform innovative, comprehensive and inclusive development of vulnerable regions across the world [35, 36, 37, 38]. Rebuild by Design was scaled up nationally through the National Disaster Resilience Competition (see California, case10).

4.3.2. Case 15: Flanders – Post Floods, Preparedness / Resilient Waterland

After extreme flooding in July 2021 across the rivers Meuse and Demer, the Flemish Government appointed a multidisciplinary Expert Panel on flood protection. To protect Flanders and define the desired level of water safety, the Panel's advice 'Resilient Waterland' formulated a strategy with 10 coherent actions, almost precisely matching the enabling conditions identified in Chapter 2 and represented in Figure 4.1. These include: setting water security goals; water, soil and climate security as lead factors in spatial planning; four cross-sectoral regional programs; a knowledge and innovation program. The Expert Panel's advice was the start of a recalibrated systemic approach for water safety and water security in Flanders [39].

4.4. Summary of lessons and gaps

4.4.1. Zooming out before zooming in

Disasters expose the weakest elements of a city's resilience to extreme weather. Climate change is a risk multiplier, aggravating the problematic consequences resulting from such weaknesses. Urban and rural land-use planning is an essential process of people constantly adapting their environment to find and create better places to live and to work. In the context of accelerating climate change, this planning of spatial developments requires an overarching, long term perspective on all sorts of demographic, social, economic and technical developments, including scenarios for future extreme weather.

From a longer historical perspective, disasters have always accompanied urban development. Learning from disasters is not just about learning from one or two disasters, but also about learning from history. Therefore, it is necessary to review major disaster events in history and learn traditional wisdom. A great help in this is modern scenario analysis, enabling to assess the potential problems that cities may encounter in extreme situations, in order to determine the scope of impact, the vulnerability of various systems, and possible countermeasures. This must be done in a stress-test for all sorts of extreme weather events, including excessive rainfall, river floods, extreme droughts and heat, so that the impact on all sectors of society, economy and ecology can be evaluated. This way, the capacity of the lifeline systems can be evaluated, such as the capacity of the health care sector, and the flood resilience of its facilities

Cities are in open connection / in interaction with their rural environment, the region and the river basin that they are part of. And most extreme events tend to have their impact on a large regional scale, not at a very local scale. To evaluate the risks of cities for different extreme weather events, and the mutual influence between upstream and downstream areas, it is necessary to conduct climate resilience assessments at the local, regional and river basin scale. Joint consideration of the climate vulnerability at all spatial scales creates the possibility for high quality spatial development and a safe urban environment in a safe regional setting. And, as things will change over time and new insights will emerge, these resilience assessments need to be updated regularly.

4.4.2. Immediate lessons and injunctions

On this wider canvas, what can be learned from the selection of disasters discussed in this chapter, and the lessons learned, or not learned, there? Seven important overall lessons can be extracted.

1. Disasters create an **opportunity for exceptions to the existing rules and habits** and allow for creating exceptional processes, i.e. transformative capacity. Normal conditions often prevent progressive action, collaboration and unorthodox thinking, all needed to leapfrog for resilience; disasters create a window of opportunity to break with existing rules and arrangements.
2. For post-disater rebuilding/reconstruction it is essential not to replicate the past but to **'build back better'**, **strongly future-oriented**. The cases in this chapter include examples with an orientation towards a more resilient future, with innovative approaches and tools to explore the future and test ideas, thus strengthening the recovery and adaptive capacity.
3. Risk-informed planning and construction of infrastructure and services is key in addressing climate vulnerabilities. Thus, information on climate risks should be **mainstreamed into spatial planning** and construction of infrastructure and services, while strengthening local expertise. Tools are becoming available for this, as this report illustrates.
4. Learning requires pausing and thinking, after the event. This is often difficult, given the turbulence and agony caused by the disaster, and the public expectation of firm and immediate action. However, **understanding what went wrong**, in engineering and socio-cultural terms, is essential to build back better [40, 41].
5. Learning from disasters is costly and painful. This is especially so if the lessons remain limited to the very location where something went wrong. Learning from what happened elsewhere, and **joining forces** is of course much preferred. Important and inspiring opportunities exist in

connecting to peer networks, joining UN-initiatives and sharing lessons across innovative approaches, like Early Warnings for All (case 6) and Water as Leverage [42].

6. Cases also showed that **innovative technologies** at all levels of the information flow from monitoring to decision making (e.g. stress-testing, on-line monitoring network, early warning system, flood/drought risk assessment, water infrastructure regulation and digital twin technologies), are essential to adapt to risks caused by either climate change or other factors. The application of innovative technology can provide time, operationally and strategically.
7. All cases illuminate the importance of **governance and process**: strong institutions; political will and leadership, trust and ambition. Short-term agendas are a huge roadblock to adaptation planning. Climate resilience requires connection of national principles and resources to local specifics, opportunities and needs; broad engagement and equity, across all organizational boundaries and structures; and space for creativity and experimentation.

On balance, the litany of events, damages and personal losses recorded in the 20 cases analyzed reminds of an important saying by US President Obama: “We are the first generation to feel the effect of climate change and the last generation who can do something about it”. This quote is almost 20 years old, underlining the importance of mitigation and adaptation in one go [43]. By now, the governments of major countries around the world, such as China and the United States, have begun to pay more attention to climate adaptation, framing it as a national long-term challenge, especially in terms of innovation [44]. In January 2024, Chinese President Xi Jinping published an article proposing to enhance the ability to adapt to climate change and maintain the safety bottom line as essential elements for building ‘beautiful China’.

5. Equity and gender aspects; due consideration for vulnerable people and areas

There is ample evidence that socially and economically disadvantaged regions and populations are disproportionately affected by the adverse impacts of climate change, leading to further inequity (the `climate justice' agenda). As an essential component of the enabling conditions for the five capacities for climate resilience, focus on protecting social justice and gender equality[1] is therefore needed in climate adaptation planning, design and implementation.

5.1 Social inequities in climate change

A large body of evidence shows that socially and economically disadvantaged people suffer more from extreme weather events and by climate change impacts [45, 46]). Studies repeatedly found that economic resources and policy engagement are key drivers of the ability to cope with climate risks [47]. The ability to live climate-resilient lifestyles depends on socio-economic variables that determine people's ability to relocate to safer areas, secure assets, get access to amenities, services, and social protection. Existing poverty and severely deficient housing and basic services (such as water, sanitation, electricity) as seen in informal settlements, exacerbate people's vulnerability to climate change impacts and trap them further in poverty. With over 1.1 billion people globally living in slums or informal settlements and an additional 2 billion expected to live in such conditions by 2050 [48], providing low-carbon, climate resilient infrastructure and services is a critical requirement to minimize impacts on those most vulnerable.

5.1.1. Urban-rural and regional disparities

Worldwide urban-rural and regional disparities are evident and sharp disparities exist even between urban areas. Less developed areas face bigger challenges in coping with climate change Due to relatively poor infrastructure, limited economic resources and inadequate public services, rural and underdeveloped areas often lack sufficient capacity to cope with extreme weather events and climate disasters such as flooding, extreme heat, and landslides, as well as long-term impacts of climate change (e.g., sea-level rise, water resources availability and ecosystem degradation). Urban areas typically have better infrastructure, stronger economies and richer resources, which enables them to invest more effectively in climate adaptation measures, such as flood protection or refuge systems. However, rapidly growing urban areas in less developed and lower-income countries of Asia and sub-Saharan Africa face the triple challenge of lack of basic infrastructure and public services, growing populations, and increasing climate hazards like extreme heat and flooding. In addition, some regions experience an influx of climate migrants coming in search of economic opportunities due to droughts and other climate impacts in the rural areas they come from. It is not only the smaller cities that are growing the fastest, but also large cities in these regions that find themselves resource-constrained and unprepared to adapt.

At the same time, the vulnerability of rural and less developed areas to climate change involves demographic issues (young people moving to larger cities for career reasons). Rural areas usually have a higher proportion of elderly – and in the case of China also relatively more children and women –, groups that can be seen as more vulnerable. In addition, the degradation of agricultural land, such as soil salinization, and the instability of water supply sources threaten agricultural production and exacerbate the vulnerability of these areas. These problems affect livelihoods and pose a threat to food security and ecological balance.

5.1.3. Gender disparities: global background related to vulnerabilities

Research about gender disparities in *adaptation* to climate change is extremely limited [49]. But multifaceted data from around the world show that women are often more vulnerable to climate change and at times suffer disproportionately from the multiple impacts of climate change, including disaster casualties, displacement, gender-based violence, and violations of livelihoods and multiple rights. Moreover, considering that other vulnerable groups also face high vulnerability similar to women, this report focuses on vulnerable groups in a broader sense, including, for example, women, children, elderly and unrepresented groups. Such differences have to be factored into the design and implementation of adaptation policies.

For example, according to the United Nations Environment Program, 80% of those displaced by climate change worldwide are women [50]. In the face of climate change risks, the health of pregnant, poor, marginalized and rural young women is most affected. During the floods in Pakistan, nearly 700,000 pregnant women had no access to maternal health care, lacked food, security or basic medical care for themselves and their newborns, and experienced a sharp rise in spontaneous abortions [51].

The worldwide background to climate change vulnerability has been sketched by UNDP in terms of ‘low human development traps’ - referring mostly, but not exclusively, to the global South. In these situations, migration capacity and resources to respond to disasters tend to be distributed uneven between the sexes [52, 53]. Many poor women who live in remote areas have difficulty accessing adequate government financial support and services [54]. This has a significant impact on their ability to prevent and resist natural disasters, to recover or rebuild their homes, and to adapt to climate change and transform social development in the long term.

However, there is a significant lack of disaster and recovery statistics, or participation in resilience work, by gender or by different social identities. This lack of data is an important reason for the inability to identify and eliminate gender gaps.

Figure 5.1 Practical Action training community members in the ‘Brigadista for a Day’ event in 2018, Peru. (Photo: Giorgio Madueño).

5.2 Climate adaptation actions risk further widening social inequities

Several studies show that existing climate adaptation actions may hamper social equality [49, 55]. Climate adaptation actions are often seen as the responsibility of the government rather than the public interest of society.

This results in limited public participation in the decision-making and implementation processes. Adaptation action often does not consider the specific needs of the most vulnerable population groups. This includes women who face greater burdens from climate change in situations of poverty due to care-giving responsibilities [51] children, the elderly, those living in unserved informal settlements, and low-income outdoor workers working in construction, street vending, waste collection, and transport operations.

Especially rural areas and smaller cities, due to infrastructure shortcomings, and lack of government attention, struggle to obtain the necessary resources to address the challenges posed by climate change. For example, there is a lack of funds for the construction and maintenance of disaster prevention facilities, and inadequate and untimely relief when faced with disasters.

Overall, government bias in the formulation and implementation of climate adaptation policies is an important cause of increased social inequity. Unintended consequences of technocratic climate adaptation actions include social inequality, neglect of disadvantaged areas and groups, and irrational land use planning [56, 57]. The unbalanced distribution of resources not only exacerbates the gap between urban and rural development, but also weakens the ability of rural areas to the realization of an effective response to climate change – thus increasing the climate risks for urban areas as well. Smaller cities and urban areas face the greatest pressures of population growth and least capacity and resources for adaptation planning, the adaptation gap even between urban areas in the same country and between urban areas of less developed and more developed countries is very large [2].

5.3 Actionable improvements for social equity in climate adaptation

Social equity is the responsibility of all. Climate change adaptation policies should prevent further social inequities. In other words, in designing and implementing adaptation interventions ‘do no harm’ should be adhered to as a principle which is similar to the principle for the medical profession [58, 59] It is globally recognized in policy and academic circles that, when undertaking urban climate adaptation policy and planning, on the one hand the planning process must be inclusive and involve everyone; on the other hand, interventions should be steered towards equitable policy outcomes. There is a need to identify the beneficiaries and disadvantaged of adaptation policy decisions, and to assess how it affects vulnerable groups [60]

Climate adaptation in rural situations often have a larger-scale regional impact. Both the Sigma Plan in Flanders, but also the agricultural experiments in the peatlands of the Dutch Green Heart, as well as the ecological recovery plans for the open pit mines in Germany, have a direct impact on their rural environment as well as on the urban area of nearby urban conurbations (see also Annexes C.I and E). These plans show that urban and rural problems must be tackled in an integrated manner as peri-urban areas that span the space between rural and urban are critical for building resilience of cities and regions. A good example on how adaptation measures can benefit the vulnerable is the adaptation project in the city of The Hague, The Netherlands that created a green adaptation area in an area for low-income families that provided heat relief, water storage, and a green meeting place and playground (Annex E) An integrated approach to interventions in the physical and social system is indispensable. For example, preservation and restoration of green and blue spaces (parks, farmland, forests, lakes, rivers, and other water bodies) offers protection from flood and heat risks at a city and regional level, while enhancing livability, public health, and generating economic opportunities for citizens. Spatial and land use planning that is informed by climate risks can help prevent new development in risk-prone locations and keep citizens out of harm’s way.

Cases for ensuring social equity in climate adaptation:

In July 2022, researchers at CANUE Canada launched the Healthy Plan. City tool. The tool visualizes health-related attributes of urban environments with socio-demographic data from the Canadian Census, providing interactive maps that allow users to overlay different features of urban environments (e.g., heat islands and tree canopy cover) with the proportion of potentially vulnerable populations (i.e., seniors, children, indigenous / first nation people, low-income individuals, or individuals living alone) in Canadian communities. The tool allows policymakers, planners, and advocacy groups to identify which communities would benefit most from added features (e.g., new parks or more trees and vegetation) or where interventions should be prioritized (e.g., locating cooling centers during extreme heat events).

The "photovoltaic poverty alleviation" project implemented by China, through the construction of solar power generation facilities in impoverished areas, not only provides clean energy for residents, but also helps poor families to increase their income through the proceeds of power generation. In addition, through its "green finance" policy, China has provided financial support for climate adaptation projects in rural and less developed areas, ensuring that these areas have access to the necessary resources to meet the challenges posed by climate change, thereby achieving a more balanced and equitable enhancement of climate resilience across the country.

Shared definitions, as well as co-learning are crucial for successful results [61]. Openness in information provision and combining knowledge from local communities with that from technical social and economic experts, helps to quickly get important stakeholders on board to realize sustainable transitions. Hence, a recommendation on improving inclusivity and equity is to stimulate co-learning during the whole planning and implementation process via public participation aimed to co-create a shared vision for the future. This will increase support and effectiveness of policies.

5.4 Common Prosperity policy as a tool

In 2021, China's Fourteenth Five-Year Plan and Vision 2035 Outline released common prosperity (共同富裕) as the cornerstone of the national policy framework, aiming to enhance social equity and regional balance and to narrow the gap between urban and rural areas. Common prosperity as a policy is part of China's Ecological civilization paradigm [62]. It represents a strategic shift from a focus on (urban) growth and wealth accumulation to a more balanced and inclusive development model by improving rural infrastructure (public services, digital connectivity, etc.), and reducing economic disparities. This has direct impact on sustainable spatial development and climate adaptation.

There are currently still significant differences between urban and rural areas in their approach to flood risks and adaptation measures[63]. Urban areas are in terms of population density and economy extremely vulnerable to flooding and extreme heat but not always better protected against climate change impact. Much investment is needed in climate-resilient infrastructure to withstand the three types of climate risk – namely agricultural drought risk, urban waterlogging, and coastal storm surges – that China is most likely to face in the future [64] .

Urban adaptation measures even sometimes have big spatial impact on rural areas, a form of environmental injustice. It's easy to forget that problems in rural areas affect everyone in terms of food safety [65, 66]. So, to ensure the equity of its climate adaptation policies, governments need to focus on the requirements of social equity and on the development and promotion of common prosperity for the people's well-being, carefully designing climate adaptation and investment planning, rationally arranging the implementation of actions and the allocation of resources and encouraging the participation of residents and social organizations in climate adaptation actions.

6. Experiences show: Action, knowledge and investment required at multiple scales

This chapter discusses emerging insights for accelerating climate adaptation across different spatial scales and geographies (urban, rural, delta, mountainous, and hilly areas) and time horizons (long, medium, and short term), as derived from the case studies reported in the chapters 3 and 4, the discussion on equity and gender issues in chapter 5 and additional field and literature research. It highlights the vulnerabilities faced by each region, such as increased water supply challenges in urban areas due to extreme events and inadequate, aging infrastructure, drought-related issues in rural areas impacting water and electricity supply, salt-tide intrusion in coastal urban agglomerations, and flood and landslide risks in mountainous and hilly areas. Changes in the institutional geography and financing mechanisms are needed to strengthen the enabling conditions needed for the five capacities required to create resilience. Various adaptation means and lessons learnt are summarized, to create a basis for the Recommendations.

Pertinent insights that have emerged across the case analyses in this report, in the reviewed literature, and during the work visits in China and in North-Western Europe are extracted and discussed. Next to the five key capacities for assessing ability, capacity and potential for adaptation to climate change, the specifics of the local situation and the local conditions should be taken into account before formulating conclusions. Specifics include physical geography and hence specific risks, enabling/disabling conditions, as well as ‘institutional geography’, such as the relations between layers and pillars of government and the division of responsibilities between public authorities and private persons and organizations. Overall insights include:

- **A need to move fast**. This is in view of the existing adaptation gap in many situations, lead times to prepare interventions, and worrying climate projections. ‘Lead times are increasing and warning times are decreasing’[67].
- **A need to move beyond fragmented and reactive approaches**, which lead to restore the status quo or, at best, incremental changes -- while transformative change will likely be needed to strengthen this adaptive capacity.
- **A need to be location-specific and actionable knowledge**. National governments and, for some aspects, intergovernmental organization like the European Union and the United Nations, have to lead especially in setting ambition levels, expanding and spreading scientific understanding and creative design, and requiring assessment and mandating collaboration at scales that match the challenges.
- **Strong coordination among different governmental bodies is needed**. Land use planning, development planning, infrastructure construction, stormwater management, flood control, greenspace management and community governance are all sharing parts of the responsibilities of adaptation work, but coordination mechanisms to make synergies are often missing at various levels. Strong transformative capacity is required to achieve this coherence between different governmental bodies.
- **Multi-purpose adaptation goals** (for people, climate and biodiversity) promote alignments and facilitate trade-off for implementation. Issues of equity should be considered when defining the threshold, coping and recovery capacity and planning, designing and implementing adaptation measures, because individuals’ abilities to address climate change risks and to engage in adaptation vary.

Overall, this study illuminates promising and useful tools, approaches and networks to assess climate resilience at various levels of scale and support the planning of adaptation interventions. At the same time, weaknesses in knowledge are identified. For example, the economics and financing of adaptation to climate change seem under-emphasized in the current CCICED program of work.

6.1. Emerging insights related to spatial scale

6.1.1. Urban Area

This study on green development and climate adaptation focuses on urban areas. A broad range of case-specific vulnerabilities, adaptation gaps, lessons and inspiration were identified in the case studies. A persistent challenge remains moving beyond reactive responses to past events in specific locations and time-constrained circumstances. Improvement can be found in:

- Developing an ambitious and broadly supported mission-based approach [13]
- Learning from what went wrong, and went well, elsewhere – through peer learning networks such as C-40 Cities and The Nature Conservancy, common independent knowledge institutions such as Deltares, and the UN Early Warning for All.
- Complementing city-based assessments with assessment of national or regional approaches – facilitating local initiatives and developing long-haul climate resilience. Promising examples have been identified through the case studies and work visits and can be found in the Annexes of this report.

Specific insights include urban-expansion-increased water-related vulnerability:

- The increasing frequency of extreme events (storms, precipitation, river floods, high temperatures and droughts) poses a serious challenge to urban water management.
- Urban expansion and the rapid incorporation of peri-urban areas into city boundaries has resulted in more people living in metropolitan regions and mega-cities. . The mismatch between population growth and infrastructure adaptation has dramatically increased the vulnerability of urban drainage and water supply systems and healthcare in case of calamities.
- Traditional water detention and management structures have been dismantled to make way for construction in the process of urban expansion, further increasing flood hazards and the vulnerability of water supply capacity.

  Aging of the infrastructure and the need for maintenance, renovation and replacement in the light of the changing climate is a rapidly increasing challenge for the near future.

Lessons Learned: Developing and Implementing Integrated Planning for Urban Development

To cope with the negative impact of climate change, urban expansion and urban renewal should consider medium- and long-term climate change impact. In particular, the very long-term territorial spatial planning needs to be redesigned, to give more weight to climate adaptation. Measures or strategies adopted include:

- Protecting the underground space in cities (e.g., parking lots, basements, shopping malls, train stations, and tunnels) as well as using it as a potential resource to build a more flexible and sustainable water management system, which can not only store water during extreme rainfall events but also reduce the vulnerability of water supply in the city by harvesting rainwater. Considering the disaster-prone nature of underground spaces, reasonable planning and safety control of underground space should be strengthened. The subsurface space requires careful spatial planning because the ownership of underground space between administrations can be complex.

- Investigating the risk of nature-based solutions failing under extreme conditions through stress tests and considering the combination of nature-based, 'green' solutions with 'grey' engineering infrastructure. Combining nature-based, green solutions with traditional grey municipal engineering infrastructure forms a multi-level, 'green-grey' flood prevention and floodwater utilization system.
- Minimize the damage of rare but extreme events that overload the capacity of the drainage system. To achieve this, use solutions that maximize the day-to-day benefits and services for the residents and the ecosystem, so that people and ecosystem enjoy and benefit from these solutions every day.

One example of a planning support tool providing practitioners with suggestions for adaptation measures in various aspects such as flood control projects, water resource management, and ecological protection is the Climate Resilient City Tool (EN) / Xiangtan Adaptation Support Tool (CN). This system assists the user in the analysis of user-supplied data on rainfall, water level changes, soil types, and land use. It provided an effective tool for Xiangtan City to consider climate adaptation in urban expansion planning and can be tuned for other locations [68]. Another inspiring tool on the application of nature-based solutions in ClimateScan.

6.1.2. Rural Areas

Compared with the rural areas globally, rural areas in China face unique climate change challenges because of the population density in the villages, uneven water resource distribution, high agricultural dependency, weak infrastructure and urban-rural disparities. The climate-related challenges include health risks, agricultural production reduction and water and electricity cuts. Adaptation measures would not only protect rural areas, but also protect urban areas for flooding, water shortages and water quality issues. Issues for creating more climate resilient urban areas include:

- Water resource management is required to become more efficient through improving traditional facility and expansion of rainwater harvesting facilities (*good examples exist in Flanders, Belgium*).
- Drought requires more public awareness and participation. Many practitioners in Western Europe underlined the need for societal dialogue as the basis for adaptation to climate change, and, in turn, political mandate and information tools to support this dialogue.
- Social capital and community culture play vital roles in recovering from mental and social damages (*good examples in the Ruhr and Ahr-Erft basin, Germany*).
- Increasing the financial investment in rural areas to improve old infrastructure, agricultural production capacity, and water resource management, etc., to promote the fairness between rural areas and urban areas (*also see section 5.1.1.of this report*).

6.1.3 Delta regions

There is a widely recognized consensus that, particularly in delta regions, (i) adaptation needs to be accelerated, as these regions are particularly vulnerable to climate change, (ii) there is a significant gap in the integrated understanding and appreciation of deltas, specifically regarding their dynamic and complex behavior.

A system-based approach is crucial for managing these environments effectively, ensuring that solutions are both sustainable and resilient in the face of evolving climate conditions. Specific issues emerging from the cases include:

- Increasing salt-water intrusion in coastal urban agglomerations and agricultural lands: Coastal agglomerations and regions are facing increasing saltwater intrusion, requiring costly workarounds - for example, connecting to inlets from multiple rivers, or freshwater infiltration into the subsurface to create groundwater buffers - to guarantee service levels. While saltwater intrusion is an age-old phenomenon, its magnitude is increasing as it is one of the early manifestations of sea level rise for local water managers in coastal areas, resulting also in the need agricultural adaptation. Countermeasures to salt-water intrusion include potentially costly engineering such as managed aquifer recharge, cross-river connectivity and offshore freshwater lakes.
- Soil subsidence, other than in permafrost situations, always relates to ground water management (abstraction, phreatic groundwater level management in soft soil areas) and is a large complicating factor in flood risk management. It occurs in various megacities across the world, but also in peatland such as in the Rhine-Meuse delta. Subsidence, rain or river-based flooding risks, and sea level rise are all climate-related and add up to flood risk. Lasting solutions include groundwater regimes, combined with land use, for urban, agricultural, natural or other economic purposes.

6.1.4 Mountainous and Hilly Areas

Mountainous and hilly areas stand out as a separate category, due to the risks of flash flood and mudslide caused by extreme rainstorms. Flash floods and mudslides happen suddenly and are hard to predict, resulting in huge damages. In China, since 1949, more than 190,000 people have died by flash floods in mountainous areas. A recent example is the Sichuan Kangding flash flood and mudslide disaster: In the early morning of August 3, 2024, three villages in Kangding City, Sichuan Province, were hit by a short period of sudden and extreme rainfall, which triggered a flash flood disaster. The disaster resulted in the deaths of 12 people and 15 people missing.

Bridges and culverts in narrow valleys were found to considerably increase devastation during flooding and should be built back differently *(Case 12, Ruhr and Ahr-Erft basin, Germany)*. Although space for water detention is little, many decentral storage facilities can contribute to flood risk reduction. When considering reservoir construction in mountainous and hilly areas the risk of dam failure and residual flood risks should take into account. *(E.g. case 18, Peru Flood Resilience Task Force*.)

6.1.5 Integrated River Basin Management

Integrated river basin management considers the complete river basin to formulate collaborative management and development plans. Interdependencies at different levels are to be considered, such as basin level (upstream-midstream-downstream, left and right banks, mainstreams and river tributaries), urban-rural level (urban, rural and natural areas), as well as the administrative levels (cities/municipalities, provinces or countries). Coherence of the interventions at all spatial scales is essential for achieving the management goals and objectives set in the plan. The land use planning of riparian land and the floodplain plays a key-role in the management of floods, droughts and water quality issues. Both engineering and non-engineering measures of the basin management are essential for the coping capacity, i.e. to minimize the damage of extreme events. New tools and technologies for monitoring, early warning and real time control such as digital twin technology, big data and cloud computing are rapidly developing to this end.

For example, by strengthening cooperation among provinces and municipalities, the comprehensive management of the Yangtze River Basin protects different regions within the Yangtze Basin to against extreme events such as heavy rainfall, floods and droughts. The integrated operation of reservoirs plays a vital role in mitigating floods and droughts there. During the severe drought in 2022, the integrated operation of 51 reservoirs provided an additional8.3 billion m^3 water downstream. During the number 1 and 2 floods that happened in 2024, the reservoir groups in Yangtze River intercepted 233.5 billion m^3 water for mitigating the flood stress in the downstream part. In 2023, Hubei province published <Outline of Hubei Province's Integrated River Basin Management and Overall Development Plan>[69] , highlighting the integrated river basin management practices at province level.

6.2. Emerging insights related to time horizon, investment and finance

6.2.1 Strategies at Different Time Horizons

Effective adaptation to climate change requires adopting and pursuing different, but consistent strategies for distinct time scales (long-term for decades to more than a century, medium-term for months to years, and short-term for hours and days to months). Planning strategies are suitable for the medium to long term scale and contingency strategies for short-term scale. Major infrastructure and real estate developments need to be adjusted to climate change and need improvement of their threshold, coping and adaptive capacity for the long-term operation. Reviewing projects 'in the pipeline', though problematic, is recommended. The pain of revision must be weighed against the need to make up for time lost in adaptation.

- **A planning horizon of 2050 and an exploratory planning horizon to at least 2100** is recommended. As the expected lifetime of water management infrastructure such as flood defenses, drains and sewer systems will be in the same order of magnitude, these horizons are to be applied for planning and upgrading such infrastructural facilities. Long term climate impacts such as sea level rise, changing rainfall patterns and water resource changes will impact their performance on the long run. The facility should be prepared for handling these changes
  Societal systems, such as education require long-term planning too. Experiences, in Europe anyway, indicate that vocational training needs to keep up with the rapid developments in climate adaptation techniques. This does not only apply to engineering, but also to legal and communication aspects.
- **At the medium-term** (months to years) adapt measures and standards need timely to the challenges of climate change, as well as with developments in technology, economic development and societal demands.
- **At the short-term** (hours and days to months), improved early warning systems and contingency strategies such as establishing emergency response mechanisms, optimizing water resource dispatch systems and raising public awareness can be taken to improve adaptation capacity.
- **Keeping** the threshold, coping and recovery capacities **up to date** requires attention every 5-10

years. Climate resilience assessments and stress-tests are to be repeated to find new gaps in the resilience of areas, systems and populations.

6.2.2 Investment and Financing Strategies

A new perspective to the revenue stream of climate adaptation:

- The economics and financing of investments in adaptation to climate change differ significantly from the economics and financing of mitigation of climate change. The difference is in the revenue stream, or its absence. Adaptation to climate change can avoid enormous damage and painful losses. Blue-green and grey interventions can also generate multiple ecosystem services and societal benefits. However, they hardly ever generate direct a financial revenue stream and the cost-benefit balance tends to become positive only after several years.
- At project level, mixed public private financing approaches can sometimes be applied. Business models for leveraging adaptation funding in this way exist, and their accounting distinguishes between monetary cost and revenues, such as tax benefits from increased tourism, and non-monetary benefits, such as reduced risk of flooding. This, however, requires careful management of expectations, clear accounting of the various kinds of costs and benefits and clear legal agreements between the public and private partners in the project.

  For example, the China Three Gorges Corporation has participated in the ecological restoration and protection of the Yangtze River Basin through establishing an ecological compensation fund for environmental protection. Since 2013, the Three Gorges Group has carried out a series of efforts for rare fish habitat protection along the Yangtze River with the goal of "no net loss". It is conducive to maintaining aquatic biodiversity and improving the stability and resilience of the ecosystem for better adaptation to climate change. The group provides stable capital flow for ecological compensation projects with the help of diversified means such as green bonds and green financial products, promoting a double-win situation between ecology and economy. Meanwhile, it strengthens cooperation with the capital market, attracts more social capital to participate in green investment, and jointly promotes climate change response and the realization of sustainable development goals.
- Globally, there is an increasing focus on infrastructure investments to mitigate the economic impact of climate-related disasters and to support a sound recovery. However, there remains an overemphasis on grey infrastructure. This highlights an urgent need to demonstrate the economic viability of investing in sustainable Blue-Green Infrastructure (BGI) or, even better, the more extreme weather resilient Green-Grey Infrastructure (GGI), and to create an enabling environment for scaling up these initiatives. Infrastructure investments should not be limited to new projects and maintenance but should also include the upgrading and replacement of existing infrastructure to ensure resilience and sustainability in the face of future challenges.
- Adaptation could result in stranded infrastructural assets. This could be existing pieces of infrastructure that become obsolete or even new infrastructure with insufficient adaptive capacity. Adaptability to new, currently unknown climate conditions and other requirements is key to smart investments.
- The economics and financing of adaptation to climate change is not well covered in the current programme of work of CCICED and fall also somewhat outside the field of expertise of this SPS

in the current reporting cycle.

Overhaul of infrastructure and building stock:

- The coming years will see a surge in overhaul of buildings and infrastructure, urban renewal projects and, sometimes, spatial layout and land use adaptation. In China, the need to overhaul or replace buildings and infrastructure typically seems to come quicker than in Western countries, because of the presumed less robust construction. For buildings in China, 30 years of age is often quoted in this context and large parts of Chinese cities have now reached this age. Shenzhen, most of it 30-40 years young, is a striking example. This contributes to an enhanced adaptation potential and explains the relatively high rate of 'green transformation' in China.
- In many European countries, buildings and important infrastructure often date from shortly after the second world war. They, too, are now up for major maintenance, as well as review in the light of developments in technology, climate, energy-transition, demography and societal demands. This is yet another example of past developments in China having been compressed in time relative to elsewhere.
- The main opportunity, and a big challenge as well, is to use infrastructure overhaul wisely, considering its longevity and the expenditure involved. A useful strategic notion by the China-Europe Water Platform [70] reminds of the need to upgrade, or change, existing infrastructure and design and install new infrastructure and minimize the cost and maximize benefits, society-wide, across these two kinds of operation.

Current investment portfolios:

- The key challenge at present is to achieve an ambitious acceleration of adaptation to climate change within the current decade. Typically, good opportunities to improve climate resilience can be found in large-scale long-duration projects that are initiated for non-climate reasons. For example, industrial renewal in China; large-scale housing development and urban renewal everywhere, or infrastructure overhaul as mentioned before. It will be necessary to review all major investment programs considering climate change and required adaptation measures.
- Therefore, in many urban and peri-urban situations, it will be necessary to launch an adaptation acceleration program, typically covering 2025-2035. Such an acceleration program would identify specific climate risks - if this has not been done already - and assess performance on the five key capacities to adaptation as defined in this report and elsewhere. Creativity and pragmatism will be needed, as well as dedicated attention to the needs of vulnerable and non-represented groups to achieve equity and justice in climate resilience.

The financial industry and adaptation to climate change:

- Ill-orchestrated insurance practices like in Germany and The Netherlands can be a real impediment to building back better after disasters. In view of what went wrong and projected climate change, building back the same as was there before the disaster simply means building back worse (maladaptation). Recovery from a disaster provides an opportunity for improving resilience that ought to be seized, also by the insurance sector.
- At the level of general oversight of the financial industry and its portfolios of lending and

investment, national regulators are becoming more aware of climate risks, and are requesting lenders to assess and limit climate and biodiversity risks of their lending portfolios. Although this stepped-up oversight is by itself not generating adaptation capacities, it does add to a business climate that is increasingly conscious of risks posed by climate change to investments and makes investors aware of accountability on these aspects. The key organization on this is the Network of Central banks and Supervisors for Greening the Financial System NGFS. 139 regulators are members, including the People's bank of China [71].

6.3. Emerging insights related to institutional geography

6.3.1 Collaboration at National, Regional and Sectoral Levels

In adapting to unfolding climate change, ambitiously, effectively and fairly, a key challenge is to rise above fragmentation between departments in government, between government bodies, between government and private sector agendas and between world views. Collaboration across jurisdictions, relevant to adaptation to climate change, comes in many forms and shapes. The examples of the current SPS include: (i) a dedicated implementing body for work on Lake Taihu; (ii) regular collaboration between Guangdong province of mainland China, Hongkong and Macao; (iii) China's River Chief System; (iv) The European Commission with its water directives; (v) The International Commission for the Protection of the Rhine, with focus on coordinated monitoring and advice; (vi) Regional alliances like the Deltametropool as a joint hub for spatial planning and analysis by design, initiated and jointly maintained by four adjacent cities in the Amsterdam region. Varying widely in formal status and authority, all seem to have grown from working-level persistence and top-level mandate.

6.3.2 The business community; its struggle with adaptation

Businesses are essential elements of society and economy. Their struggle with the need to adapt to climate change is a peculiar problem. Not only their premises and facilities are threatened by extreme weather and by water resources availability. In many cases they depend on long supply chains and product distribution chains that are extremely vulnerable to extreme weather conditions. Investing in adaptation measures, stocks and alternative supply and distribution lines are ways to reduce the risks but require financial and other resources and does not produce cash-flow: it merely reduces the risk of disruptions of their production process.

Business owners consider climate adaptation to be a primary responsibility of the government, to be solved by public means on public land. They see the requirement "not to shift climate problems from private to public space" (see Anex C,I) as a burden, as it requires investments without revenues. Small enterprises are often missing the financial resources for implementing interventions, while large, listed companies feel the pressure of their shareholders to maximize short-term profits [72, 73].The insurance sector is struggling with the question how to limit its financial risks to a feasible level [74]. And public businesses such as most hospitals, public-transport organizations, institutes, universities, etc. depend on their public funders and beneficiaries to provide budget for planning and implementing interventions to strengthen their climate resilience. Evident is that nature-related financial and operational risks are to be included in the business' risk management and financial accounting system of each company in a transparent way. Central banks and national supervisors are working on rules and guidelines for this, in order to stimulate businesses to invest in climate resilience (see Annex E.) [75].

6.3.3 Knowledge Management

Because of the large funding involved, it is unavoidable that setting up and maintaining **scientific and advisory institutions** for adaptation to climate change is taken care of by national governments. Two critical conditions apply: stable funding, and a mandate to provide independent and unsolicited advice to governments and societal actors. Five tools, or approaches, are lauded in the cases analyzed and work visits made for this SPS. They are:

- Stress-testing: For understanding climate vulnerabilities (from being exposed to flooding, drought, heat and related consequences) in urban and regional situations stress-testing is available as a particular kind of tool. Core question is how, considering the five capacities, systems and organizations in a given area are capable of dealing with extreme scenarios. Stress-testing can be applied at various scales, such as a whole agglomeration, or plans for a transportation hub or a hospital campus. In the financial industry – where the term 'stress-test' originated - climate-related stress-testing seems to be accepted widely in Europe.

  For a useful and realistic result, stress-testing should also be applied to the area of the physical water system, the river basin, which normally is larger than a city, and comprise more than one jurisdiction. This may be complicated to organize but is important.

  Once applied to a whole region or even a small country, it is useful to make the results of stress-tests available to planners and the public at large. A good example is this on-line toolbox: www.klimaatadaptatienederland.nl, including tools like the Climate Impact Atlas and the Climate Damage Atlas. A related inspiring overview of implemented adaptation measures can be found at www.climatescan.nl. The online atlas provides users with a wealth of information related to climate change adaptation. The information includes the latest research, practical tools and guidance, as well as up-to-date events. Thus, the online atlas provides opportunities for different groups to learn and understand climate change adaptation and raise public awareness [76].
- Broad-based scenario approaches: There is much to be gained from applying the full width of modern scenario-based analysis. In particular, spatially differentiated scenarios for the key undercurrents in society (technology, demographics, industrial shifts) enable to adaptation strategies with an integrated view of a territory, with a long time horizon.
- Advances in strategically exploring and planning climate adaptation interventions. This is a complex challenge. Research by design and co-creative planning processes, involving experts from many disciplines and all direct stakeholders, are steppingstones to identifying crucial decisions to be made and creating widely accepted adaptation plans that add value to the livability of an area and the wellbeing of its residents.
- Advances in effective early warning: Effective early warning protects life from the impact of natural disasters. In March 2022, United Nations Secretary-General António Guterres initiated the global Early Warnings for All Initiative [10, 77]. Meanwhile, WMO, UNDRR, ITU and IFRC with partners developed a people-centered Multi-Hazard Early Warning System (MHEWS) [78].
- For river basins, digital twinning technology has emerged as an excellent tool in facilitating adaptation to climate change. Through mapping the real world to digital world, the digital system can reflect the full life-cycle process of the corresponding real watershed. During extreme events, based on the real-time monitoring, digital twin river basin systems enable managers to forecast

warnings, previews and preplans, make risk assessments and ex-ante evaluate operational decisions, thus strengthening the coping capacity.

Periodic assessment:

- Periodic, systematic and authoritative assessment of climate risks, resilience gaps and of adaptation capacities is essential to feed change, build alliances, engage citizens, check on equity and fairness, consider new information and technology. A climate change assessment system can systematically identify the climate risks and resilience gaps faced by cities and regions. The assessment results provide a solid scientific basis for the formulation of effective adaptation strategies and plans.

In the context of China, two concluding comments pertain:

- First, the city level. A city climate resilience assessment system is both necessary, as stated above, and opportune. An opportunity to establish a systematic climate resilience assessment system exists in the form of the "City Health Examination" system of the Ministry of Housing and Urban-Rural Development (MoHURD). Second, the national level. A robust, authoritative assessment of the national adaptation policy is essential as a base for national guidance and ambition, mandating collaboration between government bodies, motivating stable funding of adaptation programs and knowledge development, firm decisions in spatial planning, and dissemination of information. This level of assessment should address the strategic, long-haul issues including adaptation to slow but important changes such as sea level rise or adaptation of agricultural practices in view of heat and drought.

7. Operational Assessment Framework for Adaptation to Climate Change

The conceptual assessment framework presented in Chapter 2 was successfully applied in Chapters 3 and 4 to distill lessons from case studies and disasters and to produce new insights on the gaps and weaknesses in climate resilience, covering the physical as well as the institutional and governance aspects. Based on the experiences with the conceptual framework in the evaluation of the cases, this chapter proposes to establish a generalized operational *framework for climate resilience assessment. Comprehensive and consistent content and procedural steps are specified for the assessment of resilience gaps and adaptation strategies and pathways in urban and rural areas in different countries, regions and cities.*

7.1 Role of the operational assessment framework

Climate resilience assessment is the link between the recognition of the need for climate adaptation and the planning of adaptation actions. A generic operational assessment framework structures this step. A uniform approach of the assessment process and a comprehensive, consistent contents of the analysis results in robust adaptation plans for the local, regional and river basin scale. The application of such an operational framework allows for the identification of the main climate risks faced by urban and rural areas, and of the strengths and weaknesses in the five capacities and in the enabling conditions required for creating a climate resilient area. This analysis is input for adaptation planning, for setting goals and objectives, showing the effectiveness of proposed climate adaptation measures and for supporting the coherent identification of policy priorities for climate adaptation at the local, regional and river basin scale.

In the conceptual assessment framework, the five capacities and ten enabling conditions for resilience cover a wide range of potential weaknesses, including recovery capacity, long-term adaptability and the transformative capacity of society. Moreover, the approach recognizes the opportunities of climate adaptation, minimizing the potential damage of extreme events while maximizing the benefits and services provided by the proposed measures, taking a long-term perspective. This sheds new light on how to create a climate resilient environment and on potential bottlenecks in timely realizing the adaptation that is needed. Therefore, it is recommended to integrate these five capacities in the assessment framework, to position these in the assessment process and in its contents, creating a solid basis for an adaptation plan and its successful implementation in practice.

7.2 Contents and steps of the assessment

Climate resilience assessments need to be comprehensive, i.e., they need to integrate the impacts of climate change risks and adaptation measures on security, economy, society, environment and culture. Synthesizing relevant international climate resilience assessment and planning practices at different levels, such as global (IPCC), national (USA, Netherlands, EU), and region/city (New York, Tokyo, Flanders region of Belgium), four parts or steps are distinguished in the planning process. Considering the geographic and socio-economic characteristics of the area, these four parts should be carried out sequentially, in order to form a comprehensive adaptation plan. Moreover, these four steps are to be taken at the local, the regional and the river basin scale, in a consistent and coherent way, taking into account the differences in local characteristics between cities, regions and basins, in order to achieve a coherent set of adaptation measures over all the spatial scales.

7.2.1 Context and climate adaptation background assessment

The climate change trends and scenarios are to be studied and presented for all relevant spatial scales and major impacts faced by cities, regions and watersheds related to the project area. Also, the basic characteristics and development trends of the project area are to be mapped and analysed, such as topography, land use, population and socio-economic patterns and future development scenarios, infrastructure conditions, etc.

7.2.2 Climate Change Risk & Opportunity Assessment

Assess the climate change risks faced in cities, regions and river basins in terms of disaster hazards, exposure and vulnerability (terminology from IPCC, 2012[4]) by performing "climate stress tests" to study the impact of extreme climatic events. On this basis, the vulnerability of the community at the local, regional and river basin scale is identified, as well as the main challenges and weaknesses in the resilience of the physical and governance systems to cope with the risks. Also, an analysis is to be made of the synergetic opportunities that other developments provide to include climate resilience-strengthening interventions. For example, projects in the field of the energy transition, urban renewal, and technological innovation can be combined with adaptation interventions.

7.2.3 Assessment of a climate adaptation action plan

After this risk assessment, and to provide a starting point for the identification of resilience gaps and planning adaptation measures. These gaps can be studied from the perspective of the five capacities to creating resilience (threshold capacity, coping capacity, recovery capacity, adaptive capacity, and transformative capacity) and the weaknesses in the enabling conditions. Building on the outcomes of this analysis the planning of effective and fitting adaptation interventions can start. Design teams with experts from a wide variety of disciplines, including relevant stakeholders are best positioned to co-create balanced alternative solutions for the complex planning problem at hand. Potential adaptation alternatives are to be subjected to a feasibility and long-term effectiveness assessment. Equity in adaptation and public engagement are important aspects of drafting and deciding on the adaptation action plan.

This step results in a climate adaptation plan that is coherent with the adaptation strategy and plans at the other spatial scales. This local district plan should fit the city plan, the city plan should fit the regional plan and the regional plan should match with the river basin plan.

7.2.4 Performance evaluation of climate adaptation implementation

To be able to implement this plan the enabling conditions should be met. Often, this requires substantial efforts and funding. Progress monitoring and ex-post performance evaluation are standard elements of good governance; and provide input for a new cycle of climate adaptation planning. Repetition of this evaluation and planning cycle at least every decade seems recommendable, as new data continue to become available and new conditions and requirements will emerge over time.

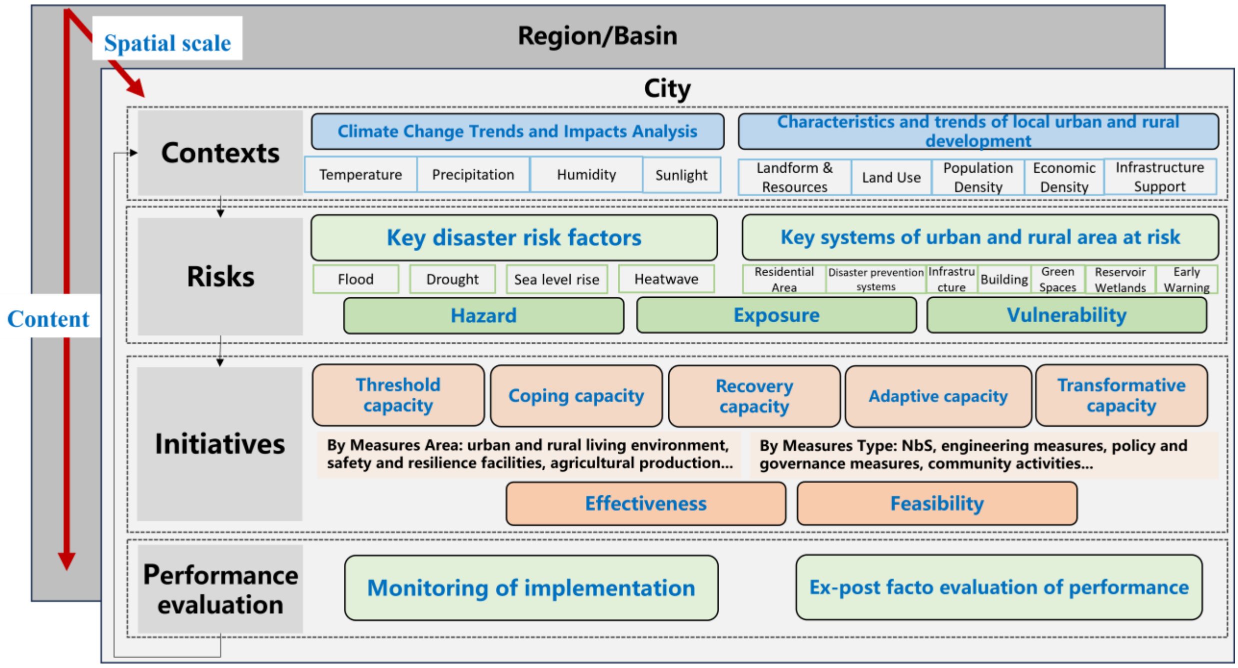

Figure 7.1 Proposed operational procedure to assess climate resilience and to plan adaptation interventions in urban and rural areas. Based on an analysis of the local situation, now and in the future, and on a systematic analysis to find the gaps in the five capacities required for a climate resilient environment, coherent adaptation plans can be made at the local, city, regional and the river basin scale. After implementation, monitoring and evaluations provide new insights for a new cycle of adaptation planning. The coherence of interventions at the various spatial scales – local to river basin – is arranged by connecting the planning cycles for the different scales.

7.3 Assessment challenges

7.3.1 Strengthen synergies to jointly conduct integrated assessments of climate resilience

Strengthening cross-regional and cross-sectoral synergies is needed to jointly conduct integrated assessments of climate resilience in urban and rural areas at local to river basin scale. Synergies and cooperation between different regions and government departments is required in climate resilience assessments. This includes defining a unified vision and goal for climate adaptation, integrating the risks and interests of different regions and sectors; establishing a unified framework and data and methodological basis for climate resilience assessment through information-sharing; and establishing synergistic mechanisms across regions and sectors, as well as between different levels of government and departments within cities, regions and ministries. It is necessary to shift from the sub-assessment of individual hazards and the "cost-benefit" evaluation of individual measures to a comprehensive, multi-objective decision-making based on integrated risk & opportunity management, taking decisions despite the many uncertainties for the long-term future.

7.3.2 Identify key risks of the project area, adaptive capacity of facilities and transformative capacity of organisations

Different regions and areas should carry out climate change risk assessments based on their geographical characteristics, focusing on identifying the key disaster risks and outstanding problems faced locally. Not only the risks induced by climate change are to be identified; also the adaptive capacity of key facilities and the transformative capacity of sectors and organizations is to be assessed. First, different regions and cities should carry out climate change risk assessments based on their geographical characteristics, focusing on identifying the key disaster risks and problems faced locally. Second, the adaptive capacity and the longevity of the existing infrastructural facilities in urban and rural systems is to be quantified in the light of the changing exposure to extreme conditions and the changing vulnerability of their function. Are assets going to be "stranded" because of their age and inadaptability? And how is the transformative capacity of the sectors and organizations that have to change and need to adopt new practices and business models? Are the enabling conditions sufficient to support these people in their transition towards their new future? A thorough stakeholder analysis and an analysis of the enabling conditions is an essential part of this assessment.

7.3.3 Analyse the correlation between different disaster risks; develop scenarios for adaptation

Climate adaptation planning should be based on different possible long-term scenarios of climate change and other social, economic and technological developments. Scenario analysis for adaptation measures should be carried out and adaptation pathways identified. To conduct a comprehensive assessment, it is necessary to consider the short-term extreme weather risks as well as the risks resulting from long-term climate change. Attention should be paid to the correlation and interactions between different hazards and the interactions between different facilities and with the physical, social, economic and ecological systems in the urban project areas and the river basin these are part of.

7.3.4 Differentiated assessments should be carried out based on spatial perspective

From the perspective of spatial geographic differences, a differentiated assessment should be carried out, taking into full consideration the great variability that exists between different regions in a river basin and between cities, city districts, villages and countryside, as well as the differences in climate adaptation capacity at the city level and at the community level. Priorities should be clarified for urban and rural settlements in different spatial regions, taking into account their characteristics, such as estuarine delta areas, densely populated small to medium-sized watersheds, and ecologically fragile areas in the upper reaches of watersheds.

7.3.5 Assess the implementation feasibility and performance of climate adaptation measures

The conclusions of scientific research, financial funding analysis and other factors should be synthesized to assess the feasibility of implementing, operating and maintaining specific adaptation measures. However, the current cost-benefit evaluation systems have difficulties in estimating the benefits of interventions, in particular the non-monetary and the long-term benefits. This is partly due to the lack of reliable data on the performance of these measures, as well as on the lack of mechanisms for creating a balanced and fair distribution of the costs and the benefits over the beneficiaries. Long-term monitoring and assessment of the social, economic and ecological effects of climate adaptation measures and policies will help to improve these economic and financial evaluation models.

7.3.6 Equity in adaptation and public participation in climate resilience assessments

Climate resilience assessments should strengthen attention to less developed regions and vulnerable groups and assess whether climate adaptation measures embody the principles of social equity and gender equality. To support this goal, public participation should be strengthened in climate resilience assessments and planning. The public, enterprises and other stakeholders should be encouraged to work together with government departments to carry out climate resilience assessments, plan and implement adaptation measures.

8. Policy Recommendations

The report concludes with a set of policy recommendations for the Chinese government as well as governments of other countries around the globe. Climate change is an urgent global issue, with very similar challenges for all governments and similar deficiencies in their ability to cope with the climate crisis. The need to accelerate the implementation of climate adaptation actions will benefit from implementing the following recommendations.

1. Climate risks are increasing and disaster losses are huge; action on adaptation is urgent.

Climate change is a risk multiplier; the effects of climate change will increase over the coming decades. Already today the disruption of communities and the economic damage due to climate change and intensifying weather extremes exceed scientific expectations, seriously threatening the safety of life and property in urban and rural areas. There is an urgent need to enhance climate resilience by raising climate adaptation to the level of the country's most important strategy, as in the case of climate mitigation and green low-carbon strategies.

1. National, regional and local governments should urgently elevate the political and governance priority of adaptation to climate change across all relevant ministries and departments, accelerate climate adaptation efforts in all policy domains, and enhance capacity-building in the five key dimensions of climate resilience (threshold capacity, coping capacity, recovery capacity, adaptive capacity, and transformative capacity) from national to local level.
2. Climate adaptation strategies should address both the challenges of increasing weather extremes and the slow-onset changes such as sea level rise, salinization, gradual warming, changing seasonal patterns of rainfall, water availability and ecological degradation. Urban and rural authorities and communities should be supported by the national, regional and water management / river basin authorities throughout the entire adaptation process, from planning, construction and operation to disaster relief and post-disaster reconstruction.

2. The national government should develop a systematic and comprehensive policy framework for short- and long-term action, from the central to the local level, across regions/basins and sectors, and with active participation of the society, businesses and local communities.

Climate change transcends institutional boundaries and requires a location specific and river basin wide approach that is integrated in allrelevant policies across sectors and scales. The approach should adhere to the action framework of national leadership, regional integration and synergy among multiple stakeholders, and establish a mechanism for coordinating adaptation actions across regions/basins and sectors. Priority actions are:

1. Develop and implement systematic and comprehensive climate adaptation programs and near-term action plans from national to local governments, building on the collective intelligence of all relevant governmental and non-governmental partners and stakeholders, based on the long-term goals for 2035, 2050, 2100 and beyond. Incorporate these into government development strategies at all levels and through all ministries and sectors.
2. Establish and commit to pro-active future oriented S.M.A.R.T. adaptation goals and targets across all policy domains, and establish a foundational system of regulations, administrative systems, financial and fiscal systems, policy systems and knowledge and data systems that effectively support climate adaptation strategies.

3. Create long-term stable adaptation funds as required by the long lead-time of adaptation strategies and implementation of measures, and coordinate government investment in different areas such as ecological restoration, disaster prevention and relief, and urban infrastructure construction and renewal.
4. Promote and support regional collaboration of climate adaptation strategies across administrative borders in key areas with high population and economic densities.
   For China, such key-areas are the Yangtze River Delta, the Guangdong-Hong Kong-Macao Greater Bay Area and the Chengdu-Chongqing region.

3. The national government should establish a climate resilience assessment framework and mechanism to identify gaps in climate resilience and priorities for climate adaptation in key areas and facilities which provides a solid foundation for urban and rural areas to monitor and improve their climate adaptation policy and implementation capacity

As the basis for climate adaptation policies and action plans, a localized framework for climate resilience assessment in urban and rural areas is required, taking into account natural resources and conditions, climate change characteristics and the level of socio-economic development and the potential interaction with other institutional policy programs and assessments.

In China, for instance, the "City Health Examination" could provide a policy and regulatory context for this.

1. Address the actual risks and problems in climate resilience assessments. Identify how resilient urban and rural communities are now and what are the resilience gaps. As shown in Chapter 7, priorities and implementation options for climate adaptation action can be identified by assessing the key climate risks, adaptation gaps in key areas and key facilities.
2. Evaluate existing laws, regulations, educational training programmes and funding mechanisms, based on climate adaptation requirements, and adjust these if needed.
3. Provide local and regional governments periodically with the latest insights from climate research, as well as the results of monitoring climate adaptation policies, at the national, regional, and local levels. Fund and mandate independent scientific and advisory institutions for this role.

4. The national government should pay attention to social equity issues in climate adaptation and should accelerate the enhancement of the climate adaptation capacity of less developed regions and vulnerable groups.

Social equity and gender research should be an important part of climate adaptation strategic policy, action and research. Particular attention should be paid to enhancing the climate resilience of underdeveloped regions, rural areas, small towns, and vulnerable groups and future generations. Priority actions are:

1. Raise the standards for disaster prevention infrastructure in vulnerable and underdeveloped areas as soon as possible, with increased financial investment to accelerate facility and capacity building.
2. Improve disaster relief services for vulnerable groups, such as disabled, children, elderly and low-income people.
3. Widely carry out publicity and popularization activities on climate adaptation, disaster prevention and adaptation solutions to enhance public understanding of and support for climate adaptation and improve public participation.

5. Strengthen international cooperation and conduct joint multidisciplinary research to lay an important scientific foundation for climate adaptation

Climate adaptation is still in its infancy as to science, societal and economic integration and policy development. Further international collaboration and exchange of experiences across countries, regions and cities is therefore of critical importance, focusing, amongst others, on basic theories and technical methods of climate change and climate adaptation, developing innovative, more effective green-grey adaptation measures and encouraging scientific research institutions and third-party organizations to participate in climate resilience assessment and research. For CCICED priorities are:

1. Strengthen sustained and in-depth international cooperation, to support learning from experiences around the globe and help to make leap-frog steps in climate adaptation policy development and practices.
2. Conduct integrated, long-term and task-oriented policy research across disciplines and policy areas; and develop highly adaptive climate adaptation measures to avoid maladaptation in response to the uncertainties in future developments.
3. Explore whether the economy and financing of climate adaptation, including the roles of businesses, should be a new topic for CCICED as there are still major gaps in this knowledge and experience hampering the implementation of climate adaptation.

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China Council for International Cooperation on Environment and Development (CCICED)

Green Development and Climate Adaptation for Urban and Rural areas

Climate Adaptation in a Changing World

Annexes to the

CCICED Special Policy Study Report

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November, 2024

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Annex A. Details of Assessment framework: Five capacities for creating climate resilience

Text on the five capacities adapted from two sources:

De Graaf-van Dinther R, Ovink H (2021) The five pillars of climate resilience. In: De Graaf-van Dinther R (eds) *Climate resilient urban areas; governance design and development in coastal delta cities*. Palgrave Macmillan, ISBN 978-3-030-57536-6, p 1-19, https://doi.org/10.1007/978-3-030-57537-3_1

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Text on the Enabling conditions is new

Resilience pillars

Increasingly, the concepts of resilience and vulnerability are associated with efforts to respond to, and prepare for, climate change. The concept of resilience emerged initially in ecology, where resilience was understood as the ability of ecological systems to persist in the face of disturbance and maintain functional system integrity (Holling 1973). In the last decades, the concept of resilience has been applied in a wide range of disciplines including economics, psychology, social sciences, natural hazards, and engineering (Bahadur et al. 2011). There are many different interpretations and definitions of both these concepts—vulnerability and resilience.

De Graaf et al. (2007) investigated literature definitions of vulnerability and resilience and derived from this a practical approach for the field of water management. This framework for resilience consists of four pillars: threshold capacity, coping capacity, recovery capacity, and adaptive capacity. For resilient water management, it is important to prepare and prevent damage resulting from environmental variation, to reduce damage during extreme weather events, to recover effectively after disasters, and to adapt to current and expected trends in the environment. More recently, a fifth component, transformative capacity, has been suggested (Ovink 2019). The impact of climate change can be so sizeable that adaptation is no longer sufficient (Kates et al. 2012). Instead, proactive transformation of the urban system becomes a necessity.

Olsson et al. (2010) defined the term, *transformative capacity*, as the capacity to transform socio-ecological systems' trajectories towards ecosystem stewardship. The practices and processes to build transformative capacity are "deeply participatory and co-creative" (Ziervogel et al. 2016, p. 7).

Transformative capacity, however, not only includes the social system (formal and informal), but is also about the physical system (De Graaf and Van der Brugge 2010). Through identifying and implementing catalysing interventions, enabling conditions are realized so that our physical systems can leapfrog towards a progressive state of resilience. These interventions are hotspots of the systems' vulnerability, and their capacity is to help leapfrogging towards resilience, among other things because of their capacity to be (easily) scaled up and replicated for progressive resilience impact. Transformative capacity is added as a fifth pillar to the framework

Five capacities

Climate resilience is defined in this framework as consisting of five capacities: threshold capacity, coping capacity, recovery capacity, adaptive capacity, and transformative capacity.

- Threshold capacity: the capability to prevent damage by constructing a threshold against environmental variation.
- Coping capacity: the capability of a neighbourhood, city, or country to deal with extreme weather conditions and reduce damage during such conditions.
- Recovery capacity: society’s capability to bounce back to a state equal to, or even better than, before the extreme event.
- Adaptive capacity: society’s capability to anticipate uncertain future developments.
- Transformative capacity: the capability to create an enabling environment, strengthen stakeholder capacities, and identify and implement catalysing interventions to transition proactively to a climate-resilient society.

Threshold capacity is a society’s ability to prepare and build up a threshold against extreme events in order to *prevent* damage. In flood risk management, examples include building river dikes and increasing flow capacity to set a threshold against high river flows. In addition to grey infrastructures, nature-based solutions are very well equipped with this threshold capacity. Nature-based solutions help to increase our resilience with multiple benefits— reducing heat islands, increasing the health and the quality of our social, environmental, and economic systems and places. The time horizon of threshold capacity originates in the past; a society’s past disaster experiences

are often the guiding principle determining the height of the threshold. Design standards for creating threshold capacity should however be future-oriented, taking climate change, sea level rise, and expected other long term developments into account.

Coping capacity is a society’s capacity to *reduce* damage if an extreme event exceeds the damage threshold, i.e. reducing flood impacts or reducing loss of the water supply during extreme drought. For flood management, a society’s coping capacity is determined by, amongst others, the availability of damage-reducing measures, early warning systems, a communication plan to create risk awareness among inhabitants, and a clear organisational structure and responsibility for disaster management. The time orientation is instantaneous, because in emergencies, only the here-and-now is important. The ability of a society to build, operate, and maintain coping capacity is determined by society’s social, institutional, technical, and economic abilities. Multiple actors such as firefighters, waterboards, municipalities, and other government agencies are involved. They all have to know what their role is and should have the skills, facilities and equipment to work under extreme/catastrophic conditions

Recovery capacity refers to a society’s capacity to *recover* to a state that is the same as, equivalent to, or better (“build back better”) than, before the emergency. The objective is to recover quickly and effectively after a disaster. The time horizon is instantaneous, right after the disaster, but will change gradually towards a focus on the future. Primarily, the country's economic capacity to finance the reconstruction – with public, private and bank/insurance sector means - primarily determines the recovery's success. It should be clear in advance who should be financing which part of the recovery. In addition, technical knowledge on how to 'build back better' and institutional capacity (i.e. manpower, skills, expertise) are also important. A society that is able to recover better (and fast) from impacts of hazards will be less vulnerable to these hazards. Recovery time may range from weeks to decades, depending on the spatial scale and disaster magnitude.

Adaptive capacity is a society's capacity to *anticipate uncertain and unknown future developments*. This includes more frequent and more extreme weather events due to climate change, but also unforeseen developments in demography, economy, technology etc. The time orientation of

adaptive capacity lies in the future. Although a system may be functioning well at present, social, economic and environmental developments, from both inside and outside the considered system, can put a system under strain in future and threaten its functioning. Developing adaptive capacity is a form of the precautionary principle. Without adaptive capacity, a society will try to recover from climate change impacts until it is no longer possible. Adaptive capacity is about the adaptability of our infrastructure on the long run. Preventing a technical lock-in pattern and securing diversity by keeping options open for future development contribute to adaptive capacity. New technologies and innovations will be developed in the future. Adaptive infrastructure means that innovative options can be incorporated adaptive water management systems.

Transformative capacity is a society's capacity to *transform* itself in face of expected catastrophic developments such as human-induced climate change impacts. The time orientation of transformative capacity lies in the future. The main difference is that adaptation is more associated with incremental change in the 'hardware' of the system, whereas transformation is regarded as transforming the current system, *transitioning* into a system with fundamentally different system characteristics. This transition towards climate resilient water management and urban systems involves changing multiple interlinked socio-technical systems such as energy, transportation, and land use planning, at different scales. For this purpose, climate resilience should be strategically linked to other societal objectives and urban dynamics. Innovation plays an important role in transformation processes, as they require new stakeholder roles, new spatial processes, new guidelines, new user practices, and new knowledge. Evaluating, improving, and learning from pilot projects to make them suitable for upscaling and mainstreaming to a larger scale are important components of transformative capacity. Stakeholder involvement and receptivity are key concepts for transformative change and thus a crucial component of transformative capacity. In addition to stakeholders' receptivity to such fundamental changes, an enabling context / environment should be present, developed, or strengthened to allow for transformative change. Components of such an enabling environment include social capital, trusted and reliable science, strategic funding, and market receptivity.

Enabling conditions

Enabling conditions are needed to be able to take action in order to close the gaps in and strengthen the five capacities. If these conditions are insufficiently met, adaptation of existing infrastructure and practices will be hard, if not impossible. Many different overviews of enabling conditions are found in the literature, each using their own structure and language. This makes it hard to define the 'perfect' overview. Moreover, the local political, social, physical and organizational conditions have an impact on each of these conditions, making it hard to complex to influence these factors.

The ten enabling conditions formulated in this report are a construct using various sources. UN-Water (2020) formulated an acceleration framework for Sustainable Development Goal 6, clean water and Sanitation, mentioning Capacity development, Innovation, Data and information, Financing and Governance as enabling conditions. In terms of ‘good governance” for a mission-oriented approach to the societal challenges Mazzucato (2019) formulates the need for citizens engagement, policy development, an appropriate legal & regulatory framework, public-private system collaboration, new markets co-creation and a fair sharing of risks and rewards. This is in line with the enabling conditions formulated by ARB already in (1997), who stated that for result-oriented policy development the appropriate policies had to be in place, as well as the regulatory and legal framework; moreover, the capacity (skills) of practitioners to implement the planned solutions and interventions and the capacity (skills) to maintain these solutions should be in place. And, last but not least, the organizational and financing structure has to be in place to guarantee that the policy can be implemented effectively.

Another perspective on enabling conditions was formulated by Brown and Clarke (2007). To make groups of champions successful in achieving transformative change they formulated eight enabling conditions: (1) the socio-political capital should be there in society, (2) bridging organizations are needed to bring parties together around the table, (3) trusted and reliable science is needed to provide a solid knowledge basis for the developments, (4) binding targets, once politically established, are drivers for change, (5) decision makers are to be held accountable for their decisions, now and in the past, (6) strategic funding points are required to support innovation, (7) demonstration projects and training/ human capacity development and (8) market should be – or be made - receptive for the new approach, technologies; there should be a business model for market parties.

All these insights in enabling conditions were summarized in the 10 conditions mentioned in Chapter 2 of this report. Many of these were recognized in the major cases and the lessons learned from disaster. But every situation is unique; it is impossible to say beforehand which conditions are strong or weak. The assessment of the five capacities can be used to find out which enabling conditions could be used to strengthen each of the five. This by building on a thorough analysis of the physical and socio-economic systems in place and a risk and vulnerability assessment using extreme weather events to stress-test the system, such as outlined in Chapter 7 of the report.

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Annex B: Details of Chinese case studies

Annex B consists of:

- B.I: Details of Chinese case studies
    1. Case 1: climate adaptation in the Chengdu-Chongqing region
    2. Case 2: climate adaptation in the Taihu Lake basin
    3. Case 3: climate adaptation in the Pearl River Estuary region
- B.II: Learning from Three Chinese Cases Related to Disasters

Annex B.I Three cases related to chapter 3, Major cases

1. Case 1: climate adaptation in the Chengdu-Chongqing region

1.1 Climate trends

Chengdu-Chongqing area belongs to the southwest monsoon and southeast monsoon influence range, the climate is humid, rainfall, the main climate type for the subtropical monsoon climate and plateau alpine climate, the average annual temperature is 4-20.9 °C, precipitation is 800-1200 mm. based on the research of the climate change in the last 50 years, the Chengdu-Chongqing area climate change trend has two main features.

Temperatures fluctuate upward overall, precipitation decreases linearly.

In terms of temperature, the average annual temperature in the Chengdu-Chongqing area shows a fluctuating upward trend, with an increase rate of about 0.14°C/10a, and in terms of rainfall, the rainfall in the Chengdu-Chongqing area shows a linear decrease trend, with a decrease rate of about -17.5 mm/10a. In terms of spatial distribution, the trend of the average annual temperature and annual precipitation changes in the Chengdu-Chongqing area shows a significant spatial heterogeneity, with a predominantly warming trend in various areas, and a significant warming trend mainly in the west, with a decreasing trend in the western part. In the spatial distribution, there is obvious spatial variability in both mean annual temperature and annual precipitation, in which warming is dominant everywhere, and the region with significant warming trend is mainly located in the west.

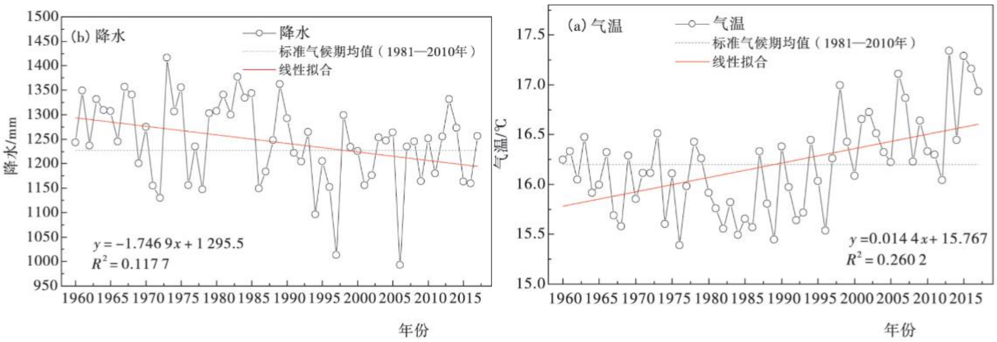
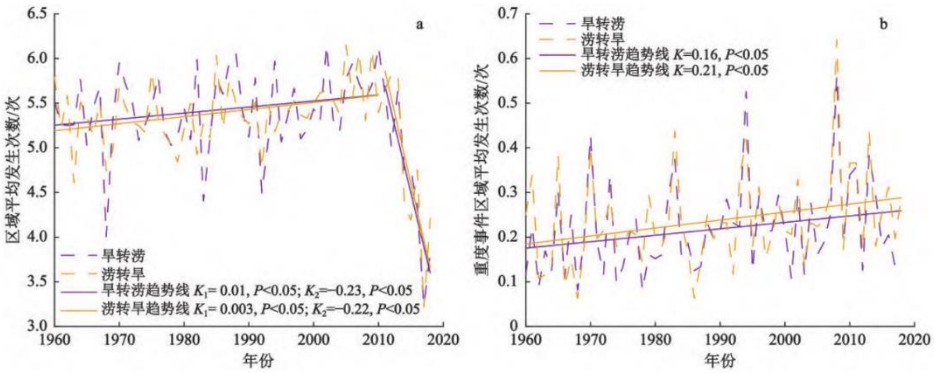


Figure 1 Statistical map of precipitation and temperature trends in Chengdu-Chongqing area in the past 50 years

Extreme weather is on the rise, with frequent occurrence of extreme weather events such as continuous high temperatures and short-term rainstorms in recent years

Extreme warm events have gradually increased, with significant growth in indicators such as the number of summer days, the number of hot night days, and the extreme high value of daily maximum temperature; the short-term extreme precipitation index and the number of days of heavy rainfall have shown an increasing trend, and the indicators of the short-term extreme precipitation index and the number of days of heavy rainfall such as the extreme precipitation and the maximum precipitation in a single day have shown an increasing trend as well. Meanwhile, according to relevant studies, the number of drought and flood emergencies in Southwest China showed an increasing trend from the 1960s to the beginning of the 21st century, and the number of occurrences in 2010-2018 generally decreased, but the intensity increased, showing the characteristics of extremity.



K_1、K_2 分别表示区域平均发生次数在 1960—2010 年、2011—2018 年的斜率，
K 表示重度旱涝急转事件在 1960—2018 年区域平均发生次数的斜率

Figure 2 Interannual trends in the regional average number of drought and flood emergencies in the Southwest, 1960-2018

1.2 Major disasters caused by climate change

Flooding caused by short-term rainstorms

Summer rainstorms are the most common extreme weather in Chengdu-Chongqing, posing a serious threat to people's lives and properties. Similar to the national trend, by global climate change and urban "rain island effect" and other factors compounding influence, Chengdu-Chongqing region in recent years tends to enhance extreme meteorological and hydrological events, especially with the "two rivers and four shores" typical of mountainous cities in Chongqing, built-up areas and infrastructure, more than the riverbanks Near the river, by the local heavy rainfall and flooding and the two rivers transit flood double threat, in recent years suffered a number of major floods and flooding disaster, intensity and frequency than previous years there is a significant increase in the defense situation is more severe, the task is more difficult. Such as July-August 2020, the upper reaches of the Yangtze River occurred on a wide range, long duration, high-intensity rainfall, Tuo River, Jialing River, Qingyi River and other 32 rivers exceeded the alert level, exceeded the guaranteed water level, Chongqing suffered a historically rare mega-flooding, resulting in the main urban areas of Chongqing, as well as Tongnan, Hechuan, and other 15 districts and counties, 263,200 people were affected by the disaster, with a direct economic loss of 2.45 billion yuan.

High temperatures and droughts cause hill fires

With the increasing global warming, the frequency and intensity of hill fires in the global outbreak is getting higher and higher. Chengdu-Chongqing area is rich in forest resources, high vegetation cover, subtropical broad-leaved evergreen forests, forest disturbance is more common, with the Chengdu-Chongqing area in recent years, high temperature, drought and other extreme weather continues to appear, forest fires show more frequent and frequent situation. Such as the summer of 2022, Chongqing Municipality suffered a long period of extreme high temperature and drought weather, from July 24 to August 29, 35 ℃ temperature above the duration of up to 37 days, the Department of 1961 since the same period of the longest, of which the highest temperature of 45 ℃ (Beibei District 8.18). Chongqing 2022 has 32 forest fires, Beibei, Banan, Fuling, Dazu, Tongliang, Kaizhou, Fengjie and other 12 districts and counties in August 17-August 26 concentrated outbreaks of hill fires. It took 1-5 days to extinguish a single hill fire, and the total area over fire reached 22.62 square kilometers (3023.5 acres of victimized forest area).

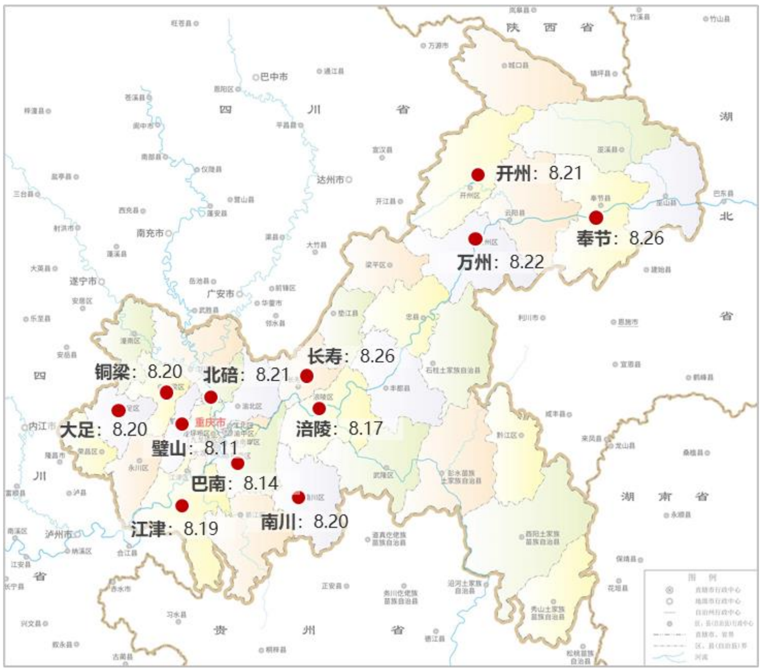


Fig. 3 Distribution of hot and dry hill fire events in Chongqing in summer 2022

High temperatures and drought trigger energy shortages

The energy structure of the Chengdu-Chongqing region is dominated by hydropower, coal power and natural gas, with hydropower accounting for nearly 80% of the total in Sichuan Province. The seasonal changes in power generation due to climate impacts are significant, and the decline in production capacity is obvious during the dry season, which leads to a shortage of power supply. At the same time, as a major province in the "West-East Power Transmission" project, more than 30% of Sichuan's annual power generation is exported to other provinces, which further leads to tensions in the local power supply, especially during specific periods of high temperatures and droughts when severe power shortages occur.20 In the summer of 2022, Sichuan suffered from prolonged periods of extreme high temperatures and droughts, with the highest temperatures reaching 44°C for a total of 41 days. days, with the highest temperature reaching 44°C. During this period, cooling loads such as air conditioning use increased significantly, accounting for up to 26% of the total load of the entire network, and the highest electricity consumption load of the whole society reached 59.888 million kilowatts, an increase of 1.3% year-on-year, which was a record high. At the same time, the province's precipitation during the drought was 43% less than the multi-year average, the least for the same period in history since 1961, hydropower generation from the same period of 900 million dry watt-hours fell off a cliff to 440 million kilowatt-hours (average daily drop of 2%), a drop of more than 50%, resulting in a serious power supply gap.

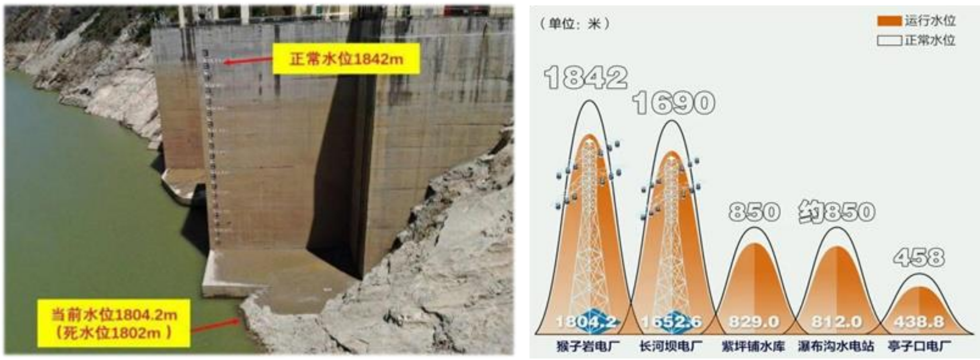


Fig. 4 Water level operation of Sichuan hydropower stations in summer 2022

High temperatures and drought triggered a reduction in agricultural production

Overall, thanks to the significant investment in agricultural capital and technology in Chengdu-Chongqing area in recent years, the overall food production by the degree of impact of climate change is gradually weakening, Chengdu-Chongqing area, the total food production from 42.71 million tons in 2003 to 46.9 million tons in 2023, but extreme weather conditions leading to a reduction in food production still occurs, and drought is the most important reason for the reduction in food production, due to the uneven spatial and temporal distribution of water resources in Chengdu-Chongqing area. Uneven spatial and temporal distribution of water resources, sustained hot and sunny high temperature and drought under the agricultural irrigation water is difficult to guarantee, crops around vulnerable to drought. On the one hand, March to May each year is the peak period of agricultural water use in Chengdu-Chongqing, but this time period does not coincide with the concentration of rainfall; on the other hand, extreme climatic events lead to a shorter period of pest development, prolonging the period of damage, and increase the fertility of pest populations, leading to an expansion of the scope of the damage, the degree of damage has increased.2022 Persistent high temperature drought resulted in drought disasters in Sichuan Province from June to October, causing a total of 20 crops, excluding Panzhihua, to suffer from drought damage, and the drought was not a major cause of food production. A total of 20 cities (prefectures) 138 counties (cities, districts) in addition to Panzhihua, 7,616,000 people were affected by the disaster, crop damage area of 522,000 hectares, direct economic losses of 4.8 billion yuan, the heaviest in the last 10 years.

Heat wave threatens health and safety

The frequent occurrence of high-temperature heat wave events has become an important issue that threatens human life and health. Affected by climate change, extreme and continuous high temperatures have become a significant climatic phenomenon in the Chengdu-Chongqing area, especially in Chongqing, where high-temperature heat waves occur frequently in summer, with more and more days of high-temperature heat waves and more and more intense intensity. Persistent high temperatures and high heat make the demand for drinking water and electricity rising, while the drought and water shortage, insufficient power generation, and high utility costs accompanying the heat waves have led to difficulties in accessing water for highly vulnerable populations, and the risk of disaster has further increased. At the same time, the intensity of the heat wave continues to rise, and continued exposure produces heatstroke and dehydration in light cases, and triggers cardiovascular and cerebrovascular diseases, respiratory diseases, and pyrexia in heavy cases.2022 In the summer, Chongqing Municipality was hit by a historic high-temperature heat wave. The high-temperature heat wave lasted 41 days. According to news reports, the Emergency Department of Chongqing Emergency Medical Center received 11 cases of pyrexia in less than half a month from July 1 to 14, including one death.

1.3 Gaps in adaptation to climate change in the urban and rural construction sector

Insufficient resilience in response to climate hazards.

In response to the flooding caused by heavy rainfall, Chengdu-Chongqing flood resistance is still mainly through the project flood prevention and flood control, difficult to meet the flood prevention and flood control standards in some of the flood risk areas are seriously affected, and the flood coexisted with the flood "water into the people retreat, the water retreats into the flood response mode; **in response to the high temperature brought about by the response to forest fires**, the forest stand In **response to forest fires caused by high temperatures**, the forest stand structure is not adaptable enough, the proportion of fire-resistant and drought-resistant forest species is insufficient, and the proportion of native plants and mixed forests is insufficient, and in addition, the construction of the mountain fire suppression system and the emergency response system needs to be upgraded, so that once a fire is easily caused by the prolonged spread of the fire, which makes it difficult to extinguish the fire. Energy, renewable energy is very limited, Sichuan energy structure is relatively single, hydropower in the production and use of electricity accounted for about 80%, power generation by the climate has a significant impact. In addition, the transmission of electricity is mainly sent out, hydropower sent out for five consecutive years more than 130 billion kilowatt-hours of electricity, accounting for about 30% of its own hydroelectric power generation, emergency energy security is insufficient; **in response to drought brought about by the reduction of agricultural production**, Chengdu-Chongqing part of the selection of crop varieties are not adapted to climate change, lack of resistance to pests and diseases, drought, floods and other capabilities, at the same time, Chengdu-Chongqing region widespread At the same time, the "weir-pond-flush-field" system widely found in the Chengdu-Chongqing area is able to cope with drought better, but due to the lack of systematic protection and restoration, the localized destruction of pond-field canals has led to a decline in the ability to regulate drought and flooding. **In response to the health and safety threats posed by high-temperature heat waves,** the Chengdu-Chongqing backbone of the water supply range is relatively small and cannot cover the vast majority of rural areas to replenish water sources, while the lack of backup water sources in mountainous rural areas, water supply pipeline networks between water sources are not connected, and villages and towns do not have enough awareness of storing and managing water and do not have a "large, medium-sized, small and micro" water resource allocation network, leading to a shortage of water storage in the city when responding to high-temperature heat waves. The lack of awareness of water storage and management in villages and towns, and the failure to form a "large, medium, small and micro" water allocation network have led to a situation in which the city's water storage capacity is balanced in response to high-temperature heatwaves, but rural areas in mountainous regions still have difficulty in accessing water, and have to rely on the construction of an emergency pipeline network and the manual delivery of water. Rural and urban areas have not been able to develop **a coordinated response** to **heat waves** due to insufficient public transportation services and the inability of highly vulnerable populations to afford to spend money on summer vacations during heat waves**.**

Inadequate adaptive capacity of critical infrastructure to cope with extreme weather.

Engineering water conservancy facilities construction and joint scheduling there is a short board, it is difficult to cope with droughts and floods, flood prevention and control, agricultural irrigation, drinking water in mountainous areas, water conservancy power generation and other scheduling of the overall coordination; **key facilities adaptive capacity is still insufficient**, including flood control projects, ultra-high-voltage direct current projects, irrigation projects, urban cooling facilities, emergency drinking water projects, etc., such as the central urban area of Chongqing, one in 50 years of flood control shore protection project Compliance rate of less than 50%, Nanbin Road and other local sections of the actual flood control capacity of only one in five years to one in 20 years, Long power into Sichuan, Tibetan power into Sichuan, Xinjiang power into the Sichuan ultra-high voltage direct current project system has not yet been formed, etc., along the river sewage facilities and pipeline network pressure-resistant capacity is insufficient, agricultural water conservancy projects and agricultural irrigation system is not perfect, etc.; **lifeline project security capacity is insufficient,** such as forest fire protection access narrow, steep slopes, such as the Beibei Jinyun mountain east wing slope reaches 60-70 degrees, large vehicles and machinery is difficult to go up the mountain, mountain fire during the rescue supplies mainly rely on motorcycle transportation from the mountain, resulting in part of the material delivery is not timely, to deal with flooding and high temperature drought when the power supply, water supply, water supply, drainage, gas, transportation, communications, and other urban lifeline system is still in the existence of the problem of the basic function of the difficult to guarantee.

The impacts of climate change have not yet been adequately taken into account in management mechanisms at the regional, municipal and community levels.

At the regional level, there are problems such as insufficient interdepartmental collaboration and poor information-sharing; the mechanism for cross-regional joint dispatching of water resources and energy has yet to be perfected, so as to safeguard the operating levels of hydropower stations and the amount of electricity produced during extreme droughts and the water used for irrigation in agricultural production; and the mechanism for regional linkage in forest and mountain fire rescue and disaster relief has yet to be established. **At the city level,** emergency plans at all levels need to be formulated and revised in a timely manner. Currently, the delineation of flood risk zones is imperfect, and there is a lack of distribution of urban flood risk zones in different scenarios; there is insufficient identification of hill fire hazards and vulnerabilities; it is not possible to formulate measures for emergency power distribution according to the level of power load in times of drought; and the investment in the research and development of drought-resistant crop varieties and technological innovations is relatively low, and there is a need to increase accumulation of relevant technologies. **At the community level,** there are still deficiencies in climate change publicity and education, resulting in insufficient awareness of and attention to climate change among residents, and insufficient intentional publicity and education on urban flood control and drainage, forest fire prevention, water and energy conservation; at the same time, there is insufficient attention paid to highly vulnerable populations, and there are no special health services such as hotlines and home visits for highly vulnerable populations such as elderly people and children living alone. In the long term, the urban and rural governance system for adaptation to climate change is not yet sound.

The climate change popularization and education system is imperfect, and society as a whole is weak in its knowledge of climate change and disasters.

Public awareness of disaster prevention and relief needs to be strengthened, for example, in August 2020, during the rare floods in Chongqing, the flood level was not high when the emergency response was initiated, and some of the threatened merchants along the river, such as Nanbin Road, refused to move due to insufficient knowledge of the intensity of the floods and the existence of a sense of chance, which ultimately resulted in losses due to the disaster. **The publicity and promotion capacity to cope with extreme climate needs to be improved**, and the accuracy of information popularization and promotion of the population is insufficient. The information dissemination conditions in the rural areas of Chengdu-Chongqing region are limited, and it is difficult for farmers' groups to access the latest information and scientific knowledge on climate change, for example, during the period of high-temperature drought, some farmers believe that disasters are natural phenomena that cannot be avoided, and they lack the initiative and initiative to cope with them, and during the period of high-temperature disasters in the period of 2020-2022 , government and health organizations publicity is mostly oriented to employers, focusing on high-temperature allowances, high-temperature leave, and protection of the rights and interests of migrant worker groups, but lacks care for highly vulnerable groups such as the elderly and children. **Public participation in addressing climate change is less enthusiastic, green and low-carbon production and living styles have not yet been promoted**, the awareness of participation by enterprises, institutions, social organizations and citizens is weak, and publicity and science popularization activities carried out at multiple holiday nodes such as World Meteorological Day, World Water Day and World Earth Day need to be strengthened.

Insufficient capacity to respond to climate change risk prediction, and weak capacity to accurately identify and assess risks and plan responses.

The monitoring and early-warning capability for extreme weather and climate events is not strong, and it has failed to effectively build a comprehensive survey and monitoring and evaluation system for meteorology, hydrology, deserts and other multi-factors and multi-circles, with an imperfect multi-factors, long-series and high-precision basic database, an unsound regional climate prediction model, and a rough climate prediction model, which affects the accuracy of the prediction and aggravates the disaster losses. For example, during the rare major flood in Chongqing in August 2020, some merchants in Nanbin Road and Maguikou received forecast information with insufficient timeliness and accuracy, which led to the transfer of materials too late and repeated transfers, aggravating the disaster losses. **The digital risk map or climate map system for climate disasters has not been established**, and there is a lack of real-time identification and prevention and control system for disasters, so the spatial scope of the disaster and the intensity of the impact cannot be accurately identified before and during the disaster, resulting in a lag in planning and emergency response plans. For example, in the planning and layout of urban disaster prevention and sheltering places, the coverage and accessibility of the facilities are not enough to consider, resulting in the response to the rare floods in Chongqing in 2020, there is a part of the flood risk area merchants, due to the lack of nearby easy to reach and reliable venues to transfer materials and aggravate the disaster losses. Another example is the ambiguous assessment of the areas affected by large-scale drought and the level of impacts during high-temperature disasters, which resulted in farmers being unable to take timely and effective countermeasures in the face of climatic disasters.

The layout and investment in science and technology are relatively small, and the research and development capacity of cutting-edge technologies to cope with climate change is insufficient.

The basic research system for climate change is relatively weak, the input of climate change innovation bodies needs to be upgraded, research on the impacts of ecosystems such as grassland ecology, mountain ecology, and alpine wetlands is weak, a synergistic system of climate change and ecological protection has yet to be constructed, the construction of climate change innovation bases and platforms is insufficient, and the construction of national key laboratories, national technological innovation centers, and laboratories needs to be upgraded. **New technologies and applicable scenarios to cope with climate disasters need to be upgraded**, new energy sources and related technologies are underutilized, diversified energy structure has not yet been formed, the utilization rate of new green energy sources such as wind energy, solar energy, nuclear energy and biomass energy is relatively low, the level of energy-saving energy storage for energy-consuming industries such as electric power, iron and steel, building materials and chemical industry is generally low, and the ability of pipeline network to resist risky supply is weak in the event of extreme weather such as torrential rain, high temperature, freezing and so on. The ability of water and fire, multi-energy complementation and peak pocketing needs to be strengthened. The application rate of the meteorological big data platform for agricultural development is low, the ability of agricultural refinement is poor, and the application rate of modern planting technology and management tools such as smart agriculture and green agriculture is low, which makes it difficult for food production to effectively respond to climatic disasters, and the popularity of the district photovoltaic building integration project is low, and the R&D capability of zero-carbon and low-carbon buildings or low-carbon and green transformation technology for buildings needs to be upgraded. **Scientific utilization of climate resources and value transformation R & D capability is insufficient**, Chengdu-Chongqing region, there are summer vacation, recreation, ice and snow and other ecological climate tourism resources, but has not yet constructed a refined tourism resources integration database, but also has not yet studied the relevant climate resources value accounting and transformation technology methods, in the "ecology + tourism + scientific research + economic" integrated development. The integrated development of "ecology + tourism + scientific research + economy" is yet to be explored.

2. Case 2: climate adaptation in the Taihu Lake basin

2.1 Climate trends

The trend of increased rainfall during the flood season is obvious, and the small probability risk of exceeding the standard due to extreme weather is increasing. The annual rainfall in the Taihu Lake basin is basically a continuous upward trend, in which the rainfall around the Taihu Lake area, Pudong Puxi District and Hangjiahu Lake area west of the greater increase; flood season rainfall accounted for 59% of the average annual rainfall, basically with the annual rainfall to maintain the same frequency of change; years of the maximum distribution of 1-day rainfall from the west to the east, from the north to the south of the trend of increasing rainfall, rainfall maximum value occurs in the eastern part of the Pudong Puxi District. In recent years, with the aggravation of climate change, Shanghai is facing a new situation of sea level rise, typhoons, high tide, strong convective weather, and increased intensity of rainstorms, etc. The maximum 1-day rainfall distribution over the years is increasing from the west to the east and from the north to the south.

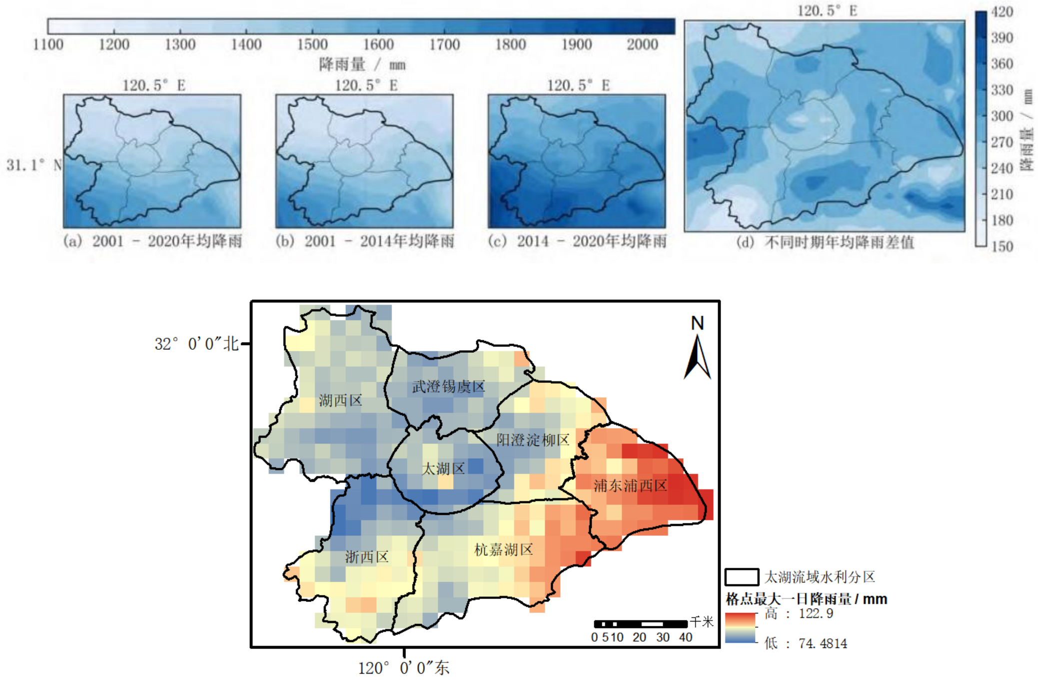


Fig. 5 Spatial distribution of annual average rainfall in Taihu Lake basin in different periods and the difference between them, and the distribution of the maximum 1-day rainfall over the years.

(Source of data: "Analysis of rainfall spatial and temporal characteristics and storm frequency in the Taihu Lake basin")

The basin warming trend is obvious, Shanghai by the increasing impact of high temperature heat wave. since 1990, the basin temperature fluctuation amplitude overall growth trend, the overall average temperature tendency rate of the Taihu Lake basin is about 0.29 ℃ / 10a, the basin from south to north is the fluctuation amplitude of the growth trend becomes larger. 2022, Shanghai, daily maximum temperature ⩾ 35 ℃ high temperature days amounted to 50 days, more than the normal number of days 29 days, ranking in history! The most in the same period; daily maximum temperature ⩾ 40 ℃ high temperature days amounted to 7 days, the most in the history of the record; October 3, 2022, Xujiahui daily maximum temperature of 36.0 ℃, is the first time in Shanghai in October, high temperature, the latest high temperature day in history.

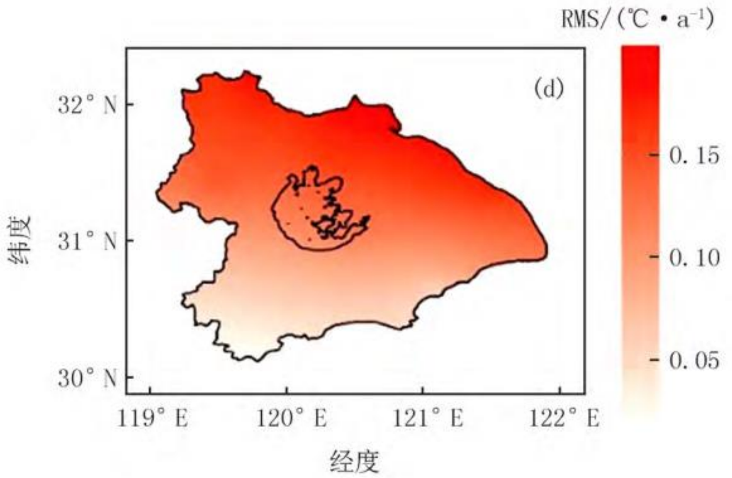


Fig. 6 Spatial distribution of changes in mean temperature fluctuations at various points in the Taihu Lake basin, 1990-2018
(Source of data: Characteristics of long-term changes in the amplitude of temperature fluctuations on multiple time scales in the Lake Tai Basin over the past 60 years)

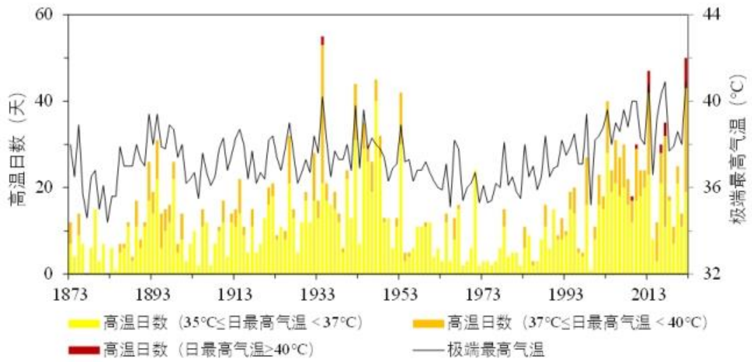


Fig. 7 Year-to-year changes in the number of high temperature days and extreme maximum temperature in Shanghai city area, 1873-2022
(Source: "Top 10 Weather and Climate Events in Shanghai in 2022")

2.2 Major disasters and problems caused by climate change

Frequency and intensity of extreme rainfall have increased significantly, and multiple events have shifted the focus of flood defenses

Short duration strong convective weather is prone to cause localized sea viewing in cities. According to the data statistics from 2004-2015, when under the control of the sub-high in summer, there are a total of 32 times of thermal convective precipitation processes, and on average, there will be 1d of thermal convective precipitation every 11d. It can be seen that short-term heavy precipitation weather is the primary disastrous weather brought by thermal convective weather. Taking the 7-21 heavy rain in Shanghai in 2023 as an example, the cloud system after the dissipation of the fourth typhoon "Terry" brought sufficient water vapor, which, together with the unstable weather at the edge of the sub-high, led to continuous precipitation in the central city, Qingpu District and the northern part of Minhang District for six hours (14:00-20:00), and the number of rainfall stations with more than 100mm in two hours reached 71. 71 stations. Single station maximum precipitation for Minhang District, the old North Zhai Road pumping station 170.0mm, the maximum 60-minute precipitation of 121.5mm, more than one in 100 years of hourly rainfall, far beyond the urban drainage standards, resulting in a number of urban waterlogging, under the interchanges of the deepest water is about 120cm, the largest waterlogging of the road is 0.3 ~ 0.57m, the average depth of waterlogging 0.23m.

Typhoons are frequent, and "wind, storm, tide and flood" are the most serious disasters. Over the years, the probability of wind, storms, tides and floods in Shanghai has been higher, with more winds, storms and tides, as well as storms, tides and floods. From 2010 to now, Shanghai wind (typhoon), rainstorms, high tide, regional flooding (flood) four head-on events have occurred a total of two times, for the 2013 "Fite", 2021 "fireworks". Typhoon "fireworks", for example, the typhoon period coincided with the astronomical tidal flooding, while the impact of the upstream water of the Huangpu River, the Mishidu station hit a record high of 4.79m (exceeding the highest level in history of 20cm), to the Huangpu River embankment facilities to bring great challenges to the operation of the safety of the facilities.

The impact of the compound disaster chain of high-temperature heatwave-hydrological drought brought about by flood season backsliding and salt-tide intrusion is gradually increasing

Persistent high temperature and low rainfall is likely to lead to the basin "flood season anti-drought". 2022, the Yangtze River Basin has a longer duration of extreme drought disaster, the phenomenon of "flood season anti-drought", July to October, the Yangtze River Basin precipitation as a whole compared to the same period of the year less than 40% or more, locally less than 80% of the historical period since 1961, the least. More than 40% of the overall precipitation in the Yangtze River Basin in July-October than the same period in normal years, local areas less than 80%, the least for the same period in history since 1961, the duration of hot weather more than 3 days, more than 40 days in local areas. Against the background of the pattern of change of drought and flood in the basin superimposed on global climate change, the high temperature and low rainfall in the Yangtze River and Taihu Lake basin over a long period of time and the extreme hydrological events of "flood season against dryness" should be given high priority.

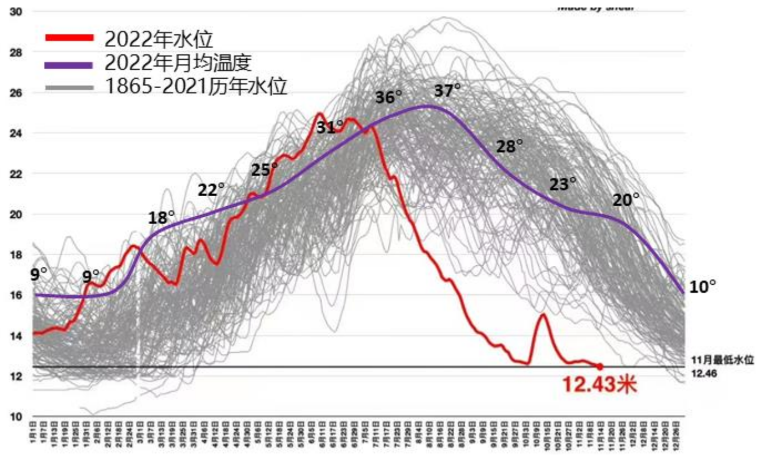


Fig. 8 Water level curve of the Wuhan section of the Yangtze River, 1865-2022

(Source of data: Adapted by the research group from "Analysis of change characteristics and causes of salt-tide intrusion in the Yangtze River Estuary")

Salt-tide intrusion affects the safe and stable supply of raw water from the Yangtze River in Shanghai. Although the Shanghai section of the Yangtze River has a large volume of water in transit to the sea and good water quality, when a salty tide invasion of the Yangtze River estuary occurs, the upstream salty water will cause the chlorine content at the intake of the water source of the Yangtze River estuary to exceed the standard, which will have a great impact on the water source of the Yangtze River estuary. According to the relevant monitoring data, the number of consecutive non-takeable days for the three water sources along the Yangtze River for the salty tide in the Yangtze River Estuary occurring after September 2022 exceeds 27 days, which seriously restricts the utilization of water resources in Shanghai.

Shanghai and other coastal cities in the lower reaches of the Yangtze River are under increased threat from sea level rise

Continued high temperatures exacerbate the threat of sea level rise. Continued warming has also further accelerated the rate of sea level rise, increasing the risk for coastal cities such as Shanghai, Hangzhou and Ningbo. According to the observation data of Wusong tide gauge station, the rise rate was 0.92mm/a during 1912-1960, and the sea level rise rate has accelerated significantly from 1960 to the present to reach 2.03mm/a. It is expected that by 2050, the sea level at Wusong station will rise by 160mm compared with 2020.According to the sea level rise prediction of "China Sea Level Bulletin," the In 2050, the existing flood control standard of Huangpu River flood control wall of 1 in 1000 years will be reduced to 1 in 150 years, and the river and sea defenses will face a severe test.

2.3 Current gaps in climate adaptation

Inadequate response to basic research: the level of early warning of sudden meteorological disasters and prediction of extreme disasters needs to be improved, and there is insufficient in-depth research on the fundamental principles behind climate change.

The warning time and accuracy of sudden meteorological disasters need to be improved. In 2020, the effective warning time of sudden strong weather in Shanghai is advanced to 42 minutes, which is lower than that of Suzhou City (45 minutes) at the basin level, and only 2 minutes higher than the national average, and the warning time and accuracy of warning for sudden, local, and highly disastrous disastrous disastrous weather need to be further improved. Taking July 21, 2021 as an example, the Shanghai Central Weather Station issued a blue rainstorm warning signal at 15:51, predicting that short-duration heavy precipitation of more than 35 mm for one hour would occur in most parts of the city within six hours, and updated it to a yellow rainstorm warning signal at 16:02, and the actual 16:00-18:00 rainfall stations with more than 100 mm reached 71 stations (accounting for about 18.3% of the total), and some areas have exceeded the red rainstorm warning standard.

Risk prediction for single disasters is relatively sound, but the simulation and prediction of extreme and correlated disasters is relatively inadequate. With the expanding scope of human production activities, the continuous advancement of urbanization, the continuous application of new technologies and other factors continuing to play a role, China has entered a high-risk period in which emergencies are prone to occur more often. In the case of emergencies associated, coupling is increasing, all kinds of emergencies risk of intertwining and superposition increased the complexity of emergency response, the current Shanghai city for a single line of disaster prediction is relatively perfect, but on the background of climate change, "four head" events, such as extreme disasters, coupled disaster simulation prediction is relatively insufficient, has not yet attracted sufficient attention. It has not yet attracted sufficient attention.

Insufficient understanding of the new environmental changes brought about by climate change. In recent years, the geographic environment of the basin has undergone major changes, including sea level rise, surface subsidence and other issues have brought long-term risks to cities in coastal areas, but the current basin level is not deep enough to understand the formation mechanism behind extreme natural disasters and potential risks. For example, by the completion of the Three Gorges, the upstream sand reduction, the complex tidal dynamics of the process of the long-term impact of the outside of the Qingcosa Reservoir, the outer beach of frequent changes in siltation, there is a risk of collapse of the embankment infrastructure, threatening the safety of the city's water supply.

Inadequate spatial response: natural storage space is insufficiently protected and a systematic spatial disaster response model has not yet been established

Natural storage space is reduced, and expansive construction exacerbates the risk of flooding. With the basin urbanization process continues to promote, 2000-2010, 2010-2020 two stages of construction land area increased by 56.0%, 40.3% (new construction land are located in the relatively low-lying areas), and bear the important storage function of the second and third level of the river were sharply reduced by 19.9%. 38.3%, resulting in a reduction in the catchment time and accelerated catchment speed, 38.3%, resulting in the convergence time shrinkage, convergence speed accelerated, the overall reduction of the basin storage capacity and uneven distribution of the increase and decrease; in addition, by the joint dike and dike and new dike influence, dike outside the river network flood storage capacity is less than the basin of the 100-year flood total of 16.3 billion m^3 of 20%, and dike operation scheduling did not give full play to dike within the storage space utility to prioritize to meet the towns and cities own drainage needs are mainly, showing a "The flood risk of the outer river is very big, the dike inside is peaceful and uneventful" phenomenon.

Resilience and disaster prevention-related planning does not provide sufficient guidance for specific spatial objects such as high-risk areas and grass-roots governance units. Existing comprehensive disaster prevention plans only take into account city-district-street (township) three-level disaster prevention zoning, and lack detailed guidelines for community-level emergency energy redundancy design, emergency material distribution channels, community space leveling and emergency conversion, and other safety prevention and control systems. In addition, construction control requirements are not further specified for high-risk and high-vulnerability areas, and insufficient consideration has been given to the spatial needs of the elderly and vulnerable groups in grass-roots governance units in disaster response.

Inadequate facilities response: insufficient emergency response capacity at water sources and engineering shortcomings in responding to excessive flood waters

The linkage between water sources is weak, and the impact of persistent high temperatures superimposed on rising sea levels has resulted in insufficient security of water supply. With the influence of global temperature rise, sea level rise, frequent occurrence of extreme weather and other factors, the water source reservoir intake encountered extreme salty tide risk has increased; by the upstream water part of the heavy metals and odor indicators exceeding the standard, flooding and drainage pollution and other impacts, water quality of Huangpu River upstream of the water source in Jinze facing multiple risks; and the current Shanghai Yangtze River, Huangpu River water source and its raw water system are relatively independent, each other At present, Shanghai's Yangtze River and Huangpu River water sources and their raw water systems are all relatively independent, with little correlation between them, so once a major problem occurs in one of the water sources, it is difficult for the other water sources to deploy water in a timely manner.

Local flood control and drainage facilities in response to catastrophes there are shortcomings. After years of construction, Shanghai flood control engineering system basically formed a thousand miles of ponds, thousands of miles of river embankments, regional flood control, urban drainage, "four lines of defense", but there are still 236.4 kilometers of the main ponds (accounting for the total length of the city's main ponds, 47.4%) has not yet reached the 200-year flood prevention standard, Huangpu River flood control wall safety is not enough height (About 90 kilometers of bank section) there are certain safety hazards, peripheral sluice gates and pumping station planning and implementation rate of only 72%, 43%, the center of the city, only 19.43% of the area to 3-5 years of drainage capacity and other issues. 2021 "fireworks" typhoon "small four head-to-head "During the period, the Huangpu River in the upper reaches of the local section of the flood control wall appeared over the waves and overflow, Pu Nan East part of the area flooding serious, exposing part of the regional flood control and flood control capacity there are still short boards.

Inadequate community response: community resilience-building has yet to reach a comprehensive consensus, and the breadth and depth of community co-construction has yet to be strengthened

Community safety and disaster prevention facilities are insufficient, and public awareness of disaster prevention is not strong. At present, cities have not yet implemented the requirements of climate adaptation and safety and resilience construction in community work and the construction of 15-minute living circles, and disaster prevention and mitigation facilities are not sufficiently equipped; the knowledge system, organization system and time schedule of emergency publicity and education are all "fragmented", and the publicity of the concept of resilient community construction is insufficient, and residents are still not fully aware of the risks and their potential impacts, and have not paid enough attention to improving the ability of individuals, families and communities to cope with disasters. The concept of resilient community construction is not sufficiently publicized, and residents are not fully aware of the risks they face and their potential impacts, and do not pay enough attention to improving the ability of individuals, families and communities to cope with disasters.

Capacity-building for grass-roots emergency management has been given insufficient attention and investment. Risk identification and analysis, assessment and control, monitoring and early-warning work requires a certain degree of specialization, and the comprehensive and specialized human resources required for large-scale emergencies are relatively weak. The investment of emergency resources does not adapt to the needs of the increasing task of emergency response, and the investment of local emergency management personnel is insufficient. At the same time, the lack of specialized personnel has led to problems such as the difficulty of practically operating community emergency plans and the lack of experience in rehearsing plans at the community level, and the ability to remove hazards safely needs to be strengthened.

Inadequate institutional response: a disaster prevention system for integrated watershed management has yet to be established, and urban emergency management mechanisms are inadequate

There is a lack of synergy in flood protection standards between upstream and downstream cities in the river basin, and it is difficult to coordinate rainwater management between cities. At present, the flood protection standard of the upstream city centers such as Wuxi and Jiaxing reaches one in 300 years, while the flood protection standard of the downstream city center of Shanghai is one in 200 years, and the flood protection standard of the upstream suburban section of the Huangpu River in Shanghai is one in 100 years, so there is a lack of synergy between upstream and downstream city flood protection standards.

The overall coordination function of the emergency management authorities has not been fully utilized. At present, the executive offices of some local emergency coordination bodies, such as emergency response committees and disaster reduction committees, are located in different departments. Due to the lack of a strong grip, some local emergency management departments have difficulty in efficiently playing the roles of professional command, material deployment and force coordination. The overall coordination function of the emergency management authorities has not been fully realized, and further reforms are still needed to enhance the "all-hazards, all-emergency" and multisectoral coordination mechanism.

The framework of the emergency preparedness system has basically been established, but there are certain deficiencies in the articulation and precision of the preparedness system, and the role of comprehensive guidance has not been given full play. In Shanghai, for example, the existing comprehensive protection plan is difficult to adapt to the city's operating conditions under extreme disaster scenarios; special emergency plans for the whole process of pre-disaster assessment, disaster response and post-disaster rescue are still insufficient, for example, meteorological disasters, marine disasters, tourism emergencies and other natural disasters, such as accidental disaster disposal plans for natural disasters, most of which were prepared before 2015, and have not yet been adjusted in a timely manner in accordance with the emerging security issues and technological advances in disaster prevention and mitigation, and the comprehensive guidance for disaster response has yet to be fully utilized. The plans have not yet been adjusted in a timely manner in the light of emerging security issues, technological advances in disaster prevention and mitigation, and other factors, and the comprehensive guidance for disaster response needs to be strengthened.

3. Case 3: climate adaptation in the Pearl River Estuary region

3.1 Climate trends

The PRD is located at the confluence of rivers and seas, where river networks are intertwined, in a hot, humid and rainy subtropical climate zone. Through rapid urbanization and large-scale land reclamation, the PRD region has formed a high-density urban contiguous area. In the context of global climate change, urban disasters and their impacts triggered by heavy rainfall and flooding, sea level rise, and water supply crises pose systemic challenges to the future urban safety and quality development of the PRD region.

Increased frequency and intensity of rainstorms

In the context of global climate change, extreme heavy rainfall events in cities at home and abroad have increased significantly and are characterized by short duration, high rainfall intensity and strong localization. Taking Shenzhen as an example, the number of times that the maximum 1h rainfall of typical rainfall in 1960-2020 exceeded one in 100 years amounted to 42 times, the number of times that the maximum 3h rainfall exceeded one in 100 years amounted to 10 times, and the number of times that the maximum 6h rainfall exceeded one in 100 years amounted to 2 times. The rainstorm center in the Pearl River Delta region shows a trend of shifting to highly urbanized areas, with extreme rainfall increasing by 44.3 mm per decade and extreme rainfall frequency increasing by 1.6 times per decade[6] .

Sea level rise

The southern part of the PRD is mostly an impact plain with low relief. With the intensification of global warming and the rapid development of the regional economy and coastal urbanization, sea level rise superimposed on storm surges is threatening the offshore vulnerable areas. The affected areas are mainly located in: the Tanjiang-Yamen waterway and its estuary (Jiangmen City), the Xijiang estuary (Zhuhai City), the Pearl River-Shiziyang coastline (Guangzhou City), the Hengmen waterway and the Hongqili waterway coastline (Zhongshan City), the west coast of Shenzhen and Shenzhen Bay, and the northern part of Daya Bay in Huizhou.

[6]HUANG Guoru, CHEN Yiying, YAO Zhijun. Spatial and temporal evolution of extreme rainfall in the Pearl River Delta region under the background of high urbanization[J]. Advances in Water Science, 2021, 32(02): 161-170.

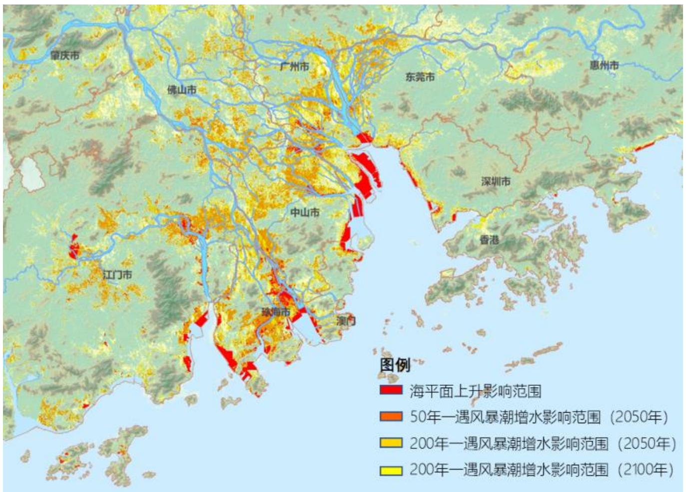


Figure 9 Schematic representation of high risk areas for sea level rise and storm surges

Inadequate water supply

Cities such as Guangzhou, Shenzhen and Dongguan are the major water users in the PRD region, and most of the water abstracted by these cities comes from rivers of the Pearl River system, such as the Dongjiang and Xijiang rivers. Entering the 21st century, affected by a number of factors such as a significant increase in water consumption, successive droughts and topographic evolution, the intensity of salty tides in the PRD has increased, and the salty boundary has significantly shifted upwards, which has a more and more pronounced impact on the water supply of the cities.

3.2 Major disasters and problems caused by climate change

Extreme storm disasters

Disaster-causing mechanisms and disaster chains. The disaster-causing factors for storm floods include all human factors that lead to the inability to discharge storm water in a timely manner, such as substandard urban flood control and drainage systems, irrationally constructed sewer locations, and inadequate management and maintenance of sewer entrances. Climate warming has increased the frequency and intensity of extreme rainfall in urban areas, changing the assumptions about the consistency of rainfall in the design of flood control and drainage facilities, leading to an increase in the frequency and extent of disasters in urban areas. Heavy rainfall and flooding disasters have a chain and mutability, chain refers to the lifeline system in the key points or surfaces due to flooding and damage, the formation of a chain reaction within the system or between the system, the scope of the impact of the disaster and the rapid expansion of the phenomenon of the disaster. Mutability refers to with the improvement of engineering facilities construction standards, standards within the flooding can be effectively suppressed, once beyond the defense capacity, the phenomenon of disaster losses and impact of a sharp rise. Due to the high dependence of towns and cities on lifeline systems, the scope of flooding impacts exceeds the scope of inundation, and indirect losses even exceed direct losses.

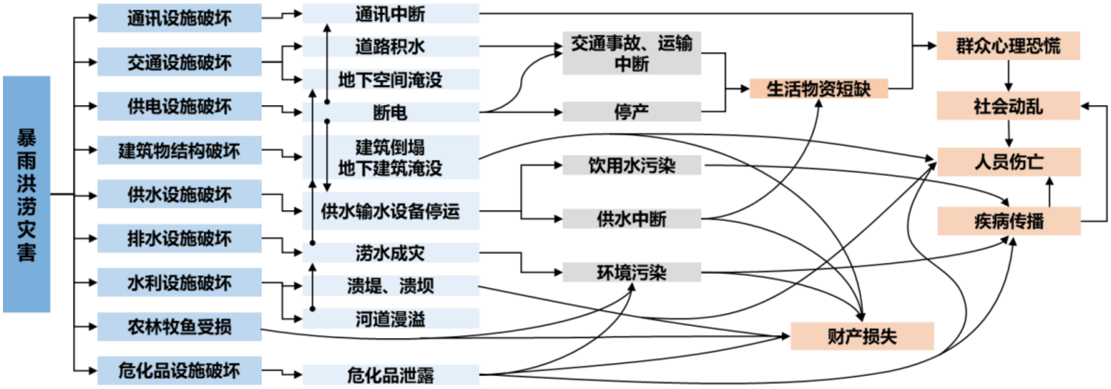


Fig. 10 Evolutionary structure of storm flooding network

Take the "9.7" extreme very heavy rainstorm in Shenzhen in 2023 as an example. By the Typhoon "anemone" residual circulation, monsoon and weak cold air together, Shenzhen "9.7" extreme heavy rainfall intensity super strong, long duration, heavy rainfall range super large. The city's average rainfall of 281.7 millimeters, the largest for the Luohu 466.2 millimeters, the maximum 2 hours, 3 hours, 6 hours, 12 hours, 24 hours, 48 hours, 72 hours of rainfall to break the Shenzhen City in 1952 since the meteorological records since the seven historical extreme. The city's 31 reservoirs exceeded the flood limit level. The rainstorm disaster triggered secondary and derivative disasters such as extensive urban flooding, overflowing rivers, flooding of underground spaces, landslides, and disruption of lifelines, with the city flooded over 18 square kilometers, more than 220,000 people transferred in an emergency, and 220 building basements and 7 subway stations flooded.

Sea level rise

The disaster effect of sea level rise is related to the geological structure of the coastal zone system, land geomorphology, coastal type, coastal siltation dynamics, hydrodynamic conditions, etc. Changes in regional ocean dynamics caused by sea level rise are mainly manifested in tides, waves, runoff and sediment, etc., and have become disaster-causing factors. Although sea level rise is a slow-onset marine disaster, Dan brings long-term potential risks to coastal areas such as the Pearl River Estuary through the superimposed transmission effect with other disasters. Land reclamation will reduce the tidal capacity of the Pearl River Delta, and the superposition of sea level rise, typhoons and astronomical tides will increase the destructiveness of storm surges and shorten the return period of extreme high tide levels. Sea level rise will strengthen the role of tides and waves and other ocean dynamics, exacerbate the occurrence of salty tide disasters in estuarine coastal areas, prolong the duration of salty tides, and at the same time strengthen the effect of sea water dragging the top of the coastal areas, so that the natural drainage capacity of the city will be reduced, and urban sewage will be difficult to discharge or even backed up, making it more difficult to drain floods and flood discharge, and aggravating the flooding disasters. Pearl River Estuary salty tide invasion of sea level rise is extremely sensitive, through numerical simulation found that, in the case of the upstream water unchanged, the salty tide upstream distance with the rise in sea level increased significantly[7] , sea level rises every 1 cm, Mordovia Gate channel salt water invasion average upward shift of 0.85 kilometers[8] . Sea level rise will also exacerbate coastal erosion and beach erosion, increasing the difficulty of repairing eroded coastal zones. The loss of coastal wetlands and mudflats caused by sea level rise will change the direction of ecological succession in coastal wetlands, affecting biodiversity and migratory birds.

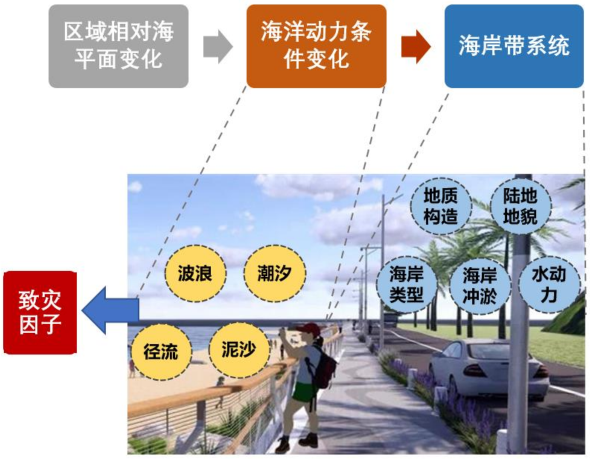


Figure 11 Sea level rise disaster effects

Take the sea level rise in the Pearl River Estuary as an example. According to data from the Hong Kong Observatory, the average rate of sea level rise in Victoria Harbour from 1954 to 2023 is 31 millimeters per decade. The China Sea Level Bulletin shows that in 2022, the coastal sea level in the Pearl River Estuary reached its highest since 1980, which is 138 millimeters higher than that of the normal year (1993-2011), and is also higher than the average coastal sea level in China (94 millimeters higher than that of the normal year). Sea level rise has led to a long-term potential risk of inundation in coastal areas, with inundation areas mainly distributed in coastal areas and areas on both sides of rivers entering the sea with low topography, and the inundation areas along the east coast of the Pearl River Estuary are mainly low-lying areas that have been reclaimed from the sea in recent years. In addition, land reclamation has shrunk the tidal capacity of the Pearl River Delta waters, and the sea level rise and the superposition of typhoons and astronomical tides have increased the destructiveness of storm surges and shortened the return period of extreme high tide levels. Taking Shekou in Shenzhen as an example, studies have shown that assuming a 1-meter rise in sea level in 2100, the return period of the highest tidal level for the 1-in-100-year event will be reduced to less than the 1-in-10-year event, and the highest tidal levels for the 1-in-50-year event and the 1-in-100-year event will be 3 meters and 3.3 meters respectively, threatening the safety of coastal engineering facilities[9] .

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[7] KONG Lan, CHEN Xiaohong, DU Jian, et al. Impact of sea level rise on the upwelling of salty tides based on mathematical model[J]. Journal of Natural Resources, 2010, 25(07):1097-1104.

[8] GUAN Shuai, LIN Yingyan, LIU Zufa. Numerical analysis of the impact of sea level rise on the upwelling of salty tides in the Mordor Gate waterway[J]. People's Pearl River, 2017, 38(08): 1-6.

[9] Li You, Wang Yanglin, Peng Jian et al. Ecological loss assessment of sea level rise - A case study of Shekou Peninsula, Shenzhen [J]. Progress in Geoscience, 2009, 28 (03): 417-423.

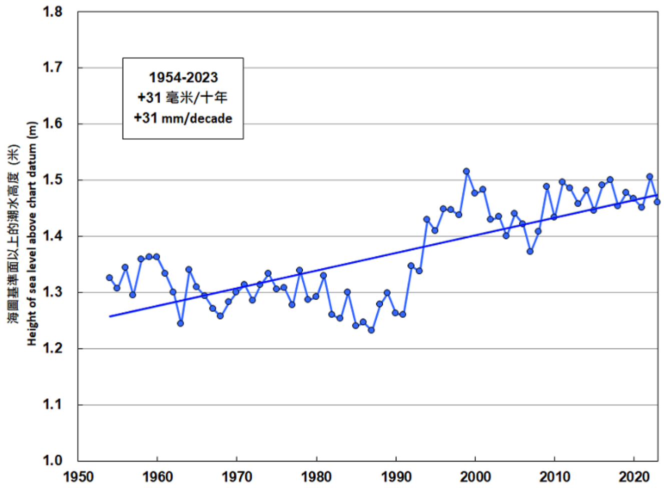

Figure 12 Mean Sea Level Height in Victoria Harbour, Hong Kong, 1954-2023 (Source: Hong Kong Observatory website)

Salt-tide upwelling and water crisis

Insufficient flow of freshwater rivers in years of climatic drought and seawater backflow are the main reasons for the formation of salty tides in the estuaries of the Pearl River Delta. The rise in sea level, the indiscriminate mining of river sands leading to a reduction in the gradient of river beds downstream of the rivers, and the reduction in the flow of water in the rivers due to the sharp increase in the use of water for production and domestic purposes are the objective factors for the further expansion of the upward range of salty tides[10] . When the salty tide extends upstream to the water intake of water plants, it will affect the normal supply of water resources, making tap water salty and bitter, with rising salt and chlorine content, which is hazardous to human health, and can also affect the normal production of industrial enterprises. At present, the water supply sources of PRD cities are mainly river water intake, with water withdrawal accounting for more than 50% of the total, the storage capacity of local reservoirs and emergency back-up water sources are insufficient, and the amount of externally transferred water is even more seriously insufficient, accounting for less than 10% of the total. Therefore, during the dry season, the runoff from the rivers decreases, and the intakes of the rivers are highly susceptible to the impact of the salty tides. On the other hand, due to the high concentration of population and economic activities, the total water demand of the cities in the Pearl River Delta is high, which puts enormous pressure on water supply. The eastern part of the PRD supports 68% of the resident population and 74% of the economy with 43% of its water resources. The water supply crisis will lead to a series of secondary disasters such as shortage of water for residents, industry, agriculture and ecological and municipal uses.

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[10] Qi Z; Bao Yun. Analysis of the trend of saltwater intrusion and its dynamics in the Pearl River Delta[J]. Journal of Guangdong Radio and Television University, 2009, 18(03): 43-47.

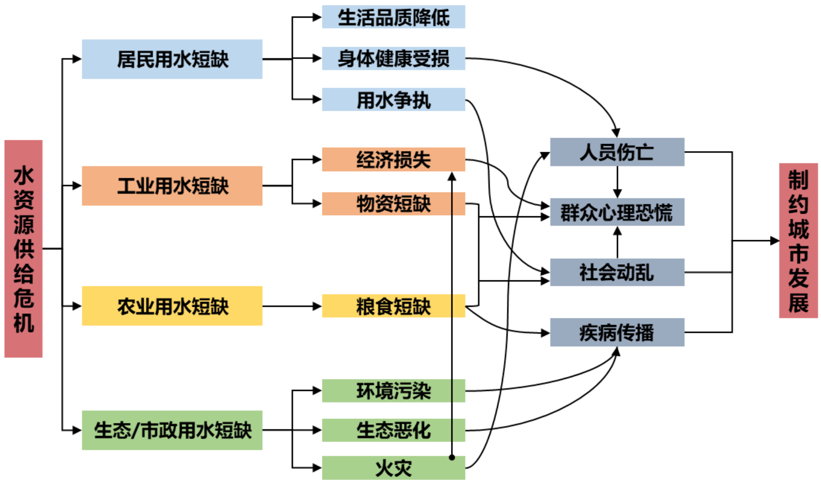

Figure 13 Schematic of disaster chain propagation for water supply crisis

Since the end of 2021, rainfall in the Pearl River Basin has been persistently low, and the Pearl River Basin has suffered the worst drought in 60 years. The water inflow of major rivers is 30%-70% less, including the Dongjiang and Hanjiang rivers, which are 70% less, and the backbone reservoirs have insufficient water storage. 2022 around February 15 coincided with the astronomical tidal wave, the tide level is high, the tide difference is large, superimposed on the unfavorable meteorological conditions of the northeast winds of grade 6 to grade 7, and the salty tidal wave upstream in the estuary area of the Pearl River Delta, the phenomenon of seawater backing up occurred many times. According to the Marine Disaster Bulletin of the South China Sea Region, the distance of the salty tide upstream in the Pearl River Estuary was more than 60 kilometers at the farthest. As a result, the water supply safety of some areas in Zhuhai, Zhongshan, Dongguan and Guangzhou of Guangdong Province has been challenged.

Figure 14 Extent of the upwelling of the salty tide

3.3 Current gaps in climate adaptation

Insufficient systemic and cross-sectoral synergies for disaster prevention

Insufficient regional and river basin flood control coordination and harmonization. Due to the differences in the economic level of the cities, there are gaps in the standards of river management upstream and downstream and along the left and right banks of the trans-regional rivers in the Pearl River Delta, and when there are river basin-type floods, the flood disasters are easily transmitted upstream and downstream of the river basins. The deployment of water resources in the river basin needs to be strengthened, and there is insufficient regional integration and coordination in the face of disasters such as droughts and upwelling of salty tides. There are problems with the construction of cross-sectoral facilities and the coordination mechanism. For example, the Shenzhen Metro system has a flood prevention standard of one in 100 years, but the underground pedestrian passageways, parking lots, shopping malls, etc. connected to it have a lower flood prevention standard than the Metro, which becomes a short board for preventing internal flooding. Pumps and other flood control equipment reserves and cross-departmental deployment mechanism is not perfect, resulting in underground parking lots and other facilities can not be restored in a timely manner after flooding. Responding to climate change and emergency disaster prevention work covers a wide range of areas with strong specialization in various fields, and the information grasped by the lead department for the work is not comprehensive, making it difficult to integrate and coordinate the work.

Shortcomings in monitoring and early warning capacity

Meteorological disaster monitoring and early warning capabilities are generally leading, and a three-dimensional observation network with high spatial and temporal resolution has been established and applied in urban disaster prevention and mitigation work, but there are shortcomings in the special early warning capabilities of transportation facilities and other facilities. After forty years of rapid urbanization in the Pearl River Delta, a large number of infrastructures have entered a period of high incidence of disease, with safety hazards gradually increasing under high operating intensity, and the pressure for prevention and control increasing year by year, and collapse accidents are prone to occur in extreme weather such as heavy rainfall. At present, the detection of hidden dangers of facilities is mainly based on manual inspection, the timeliness and comprehensiveness of traditional inspection methods are insufficient, and the application scope of advanced inspection means is limited.

Insufficiently resilient urban spatial patterns

Urban spatial patterns are unable to adapt to extreme rainstorms, and some flood-discharging rivers have insufficient local overflow capacity, resulting in poor drainage due to Yonggao's upstream water level; some urban constructions are located in low-lying areas and are prone to regional flooding; urban development has led to a higher proportion of impermeable surfaces, an increase in the volume of runoff and flood flow, and an early emergence of the peak flow; and the city is generally characterized by a high density of development and a high intensity of development, with a relatively small amount of space for storage. Underground space and other vulnerable nodes of the city do not have a strong disaster prevention capability; the number of pumping and drainage facilities configured within some underground spaces and their pumping and drainage capacities are insufficient, and the construction standards of the drainage networks of the surrounding municipal roads are on the low side. Some of the underground spaces are located in low-lying areas with high risk potential. Due to land resource constraints, there is a high demand for underground space in PRD cities, giving rise to multi-industry underground transportation super-complexes , such as Gangxia North, Chunfeng Tunnel, and the Headquarters Base section of Binhai Avenue, etc. These underground spaces are of great depth, wide range and complexity of industry, with many risks and hidden hazards, and difficulties in escape and disaster relief, as well as the current institutional mechanism of flood prevention is not yet perfect.

Inadequate infrastructure and blue-green defense facility capacity

The resilience of major infrastructures, such as urban lifeline projects, to be upgraded. During the 9.7 rainstorm, several neighborhoods in Shenzhen were cut off due to the flooding of secondary water supply and power supply facilities, and the shortage of emergency drainage facilities made it impossible to remove the water quickly after the disaster, and the water supply and power supply facilities could not be repaired in a timely manner, making it difficult for residents to return to normal and for enterprises to resume production activities, which resulted in economic losses. Coastal infrastructure is threatened by sea level rise, and is more vulnerable to storm surges and floods. For example, in July 2022, tropical cyclone "Siamba" affected the coasts of Guangdong and Guangxi, coinciding with the period of astronomical tides, and the increase in water over 50 cm along the western coast of Guangdong lasted more than 30 hours, and the sea level during the period of the impacts was 400 mm higher than normal, causing damage to many embankments. millimeters, causing damage to many dykes, aquaculture losses in many places, and direct economic losses of about 740 million yuan[11] . Rising sea level will lead to a decline in the actual standard of flood tide and wind protection in cities. Take Lingao Nuclear Power Station as an example, the station was designed according to the national unified specifications, the highest tidal level of the astronomical tide before the construction of the station and the historical data of typhoon water augmentation, and the design of tidal level was based on such data, which did not take into account the impacts of the change in sea level. Under the impacts of global warming and sea level rise, the design level of this station can no longer meet the requirement of the one-in-a-thousand-years design water level[12] . As regards water supply facilities, PRD cities are highly dependent on rivers for water intake. The quality of water at the intake is susceptible to the upward movement of salty tides, resulting in water plants having to be relocated upstream, and the amount of standby water resources is insufficient, making them susceptible to the impacts of dry weather and emergencies.

Lack of risk awareness among community members

Community and residents' awareness of disaster prevention needs to be enhanced, in the 9.7 rainstorm, a number of neighborhoods with serious waterlogging, underground garages were flooded, due to the failure to organize in advance to carry out the transfer of vehicles in the garage, a large number of vehicles were submerged, and the residents suffered damage to their property. Although the meteorological, emergency and other departments in advance by text message, television, microblogging and other ways to issue emergency warning announcement, but there are still residents in the red warning period did not take refuge in a timely manner, the enterprise did not follow the provisions of the work stoppage caused by injuries.

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[11] China Sea Level Bulletin 2022

[12] Wang L. Study on the change mechanism of sea level in the Pearl River Estuary and the risk of coastal inundation [D]. Tsinghua University, 2017.

Annex B.II Learning from Three Chinese Cases Related to Disasters

Case 5 Extremely heavy rainstorm Disaster in Zhengzhou, Henan Province in 2021

（1） Disaster situation

1. Characteristics of the disaster situation

From July 17 to 23, 2021, Henan Province encountered a rare extremely heavy rainstorm in history, which led to serious floods. In particular, on July 20, the intensity and scope of the extremely heavy rainstorm in Zhengzhou broke the historical records, causing heavy casualties and property losses. The main characteristics of rainfall and flood situation in Zhengzhou are as follows.

The rainstorm process has a long range, a wide range and a large amount, and the short duration rainfall is extremely strong. Zhengzhou covers an area of 7567 square kilometers, with a total of 5590 square kilometers receiving rainfall of over 400 millimeters and 2068 square kilometers receiving rainfall of over 600 millimeters from July 17th to 23rd. On July 20th, the Zhengzhou National Meteorological Station recorded a maximum daily rainfall of 624.1 millimeters, breaking the historical extreme and approaching the annual average rainfall in Zhengzhou (640.8 millimeters). The maximum hourly rainfall was 201.9 millimeters, surpassing the historical extreme of 198.5 millimeters in mainland China's meteorological observation records.

The floods in major rivers have significantly exceeded historical records, and there have been frequent and severe incidents of dangerous situations in embankments and reservoirs. Three major rivers in Zhengzhou, namely Jialu River, Shuanghui River, and Ying River, have all experienced floods exceeding the guaranteed water level, with the process flood volume exceeding the historical measured maximum value. A total of 418 dangerous situations have occurred in 124 rivers of different sizes in the city, and 84 out of 143 reservoirs have encountered varying degrees of danger, posing a threat to the safety of major infrastructure such as the downstream Zhengzhou urban area, the Beijing Guangzhou railway trunk line, and the South to North Water Diversion Project.

2. Disaster situation

Extreme heavy rainfall has caused multiple disasters such as severe urban waterlogging, river floods, and landslides. According to statistics, 380 people have died or gone missing in Zhengzhou due to the disaster, with a direct economic loss of 40.9 billion yuan, accounting for 34.1% of the province's total. Among them, due to the rainfall in the urban area far exceeding the drainage capacity, the main urban area was severely flooded on the 20th, and public facilities in residential areas were severely submerged. 129 people died or went missing in the main urban area due to the disaster, with drowning being the main cause.

The flooded area of the city is about 1777 square kilometers, accounting for about 34% of the administrative area. Among them, the main urban area has a water accumulation area of 328 square kilometers, accounting for about 32% of the total area of the main urban area. The maximum water depth on the road surface is nearly 2.6 meters. Among them, the North Tunnel of the Beijing Guangzhou Expressway experienced flooding and backflow, resulting in 6 deaths and 247 cars being submerged due to the closure of the tunnel and delayed traffic diversion.

3375 residential communities and public buildings in the city have been flooded, with over half (2067) of the communities' underground spaces and important public facilities submerged. According to calculations, the amount of water injected into various underground spaces reaches 30 million cubic meters, equivalent to the storage capacity of a medium-sized reservoir. Tens of thousands of parked vehicles in the underground parking lot are submerged. Among them, the 04502 train of Metro Line 5 encountered flooding and power outage while traveling to the up section from Beach Temple Station to Shakou Road Station, and was forced to stop. After evacuation and rescue, 953 people were safely evacuated and 14 people died; The ground floors of Building 1, Building 3, and Outpatient Building in the He Campus of Zhengzhou University First Affiliated Hospital were flooded, resulting in 7 deaths, dozens of surgeries in the hospital being interrupted, more than 600 people losing ICU equipment support, and tens of thousands of patients being forced to transfer.

Multiple water plants in the city have experienced water outages, and a large number of secondary water supply equipment have been flooded, affecting the water supply of 1864 residential areas. More than 6300 communication base stations in the city have been severely affected, with communication signals interrupted for hours to days. In addition, a large number of power supply equipment located in underground spaces were flooded, resulting in widespread power outages in the city.

（2） Exposed issues

1. There is a lack of overall consideration for drainage and flood prevention, and there are weak links in urban disaster prevention and reduction. One is that there is a deviation in the concept of urban construction, which greatly encroaches on the water system space of rivers and lakes, and the rainwater storage space continues to shrink. In 2018, the water area of Zhengzhou city decreased by about 28 square kilometers compared to 2009, with a reduction rate of about 10%; In addition, in urban planning and construction, there is not enough "white space to increase greenery", and the only blue-green space cannot play a regulating and storage role. For example, the Longfor Lake with an area of 5.6 square kilometers in Zhengdong New District cannot receive surrounding rainwater discharge and cannot play a regulating and storage role. The second problem is that the drainage channels are not smooth, and the urban river channels have a single way out for flood control and drainage, with a problem of "large upper and small lower" flood control and drainage standards. For example, floods in the urban area of Zhengzhou mainly flow into the Jialu River through the Qili River, but the flood discharge capacity of the upstream section of the Qili River is once every 50 years, while the downstream section is only once every 20 years. The upstream of the Jialu River is once every 100 years, and the downstream Zhongmu section is only once every 20 years. Thirdly, there is insufficient consideration for disaster prevention and reduction in key areas. The vertical design of some urban areas is unreasonable, and some underground spaces and facilities lack protection. In particular, drainage pump stations are located at low places and are prone to flooding and failure. Evacuation platforms in subway sections mainly consider fire and smoke prevention without considering flood prevention. Backup power sources for public facilities such as hospitals, water supply, and communication are mostly located underground, and once water enters, they lose their disaster preparedness function, posing a considerable degree of safety risk.

2. The emergency management system and capabilities are weak, and the linkage mechanism between early warning and response is not sound. One is the insufficient ability to issue early warnings, with problems such as confusion between severe weather forecasts and disaster warnings, and division of warning departments. The targeted, effective, and mandatory measures for disaster prevention and avoidance are insufficient, and there is a lack of a unified, authoritative, and efficient early warning mechanism; Secondly, the emergency response is seriously lagging behind, and the linkage mechanism between warning and response is not sound. It is unclear who will respond and how to respond. Zhengzhou only activated Level I response after issuing five consecutive red warnings, and the actual disaster has already occurred; The third issue is that the practicality of emergency plans is not strong. The emergency plans formulated are often triggered based on the occurrence of serious consequences, which often result in delayed activation, greatly reduced actual effectiveness, and lack of specific response measures.

3. The emergency response capabilities and knowledge of disaster prevention, avoidance, and self rescue

of cadres and the masses are seriously insufficient. One is the lack of experience in emergency response. Some management personnel are not familiar with disaster prevention, reduction, relief, and emergency management, and have not experienced major disasters such as floods and earthquakes, resulting in a serious lack of practical experience. Second, the publicity and warning were not in place. In the process of extremely heavy rainstorm response, the publicity and warning role of the media was not in place, and there were problems such as untimely and insufficient dissemination of disaster early warning information and weak warning effect. Third, the public awareness is not strong. The public lacks basic awareness of the hazards of the extremely heavy rainstorm, and the safety awareness and ability to prevent and avoid disasters are not strong. Most of the missing people who died in the disaster still do not take risk avoidance measures before they die, and even some of them return without authorization after transfer.

（3） Lessons and inspirations

1. Comprehensively promote the construction of resilient cities. The risk of extreme weather and climate events has intensified, and it is difficult to cope with disaster risk challenges through simple engineering measures. The 24-hour average rainfall in Zhengzhou urban area during this extreme rainfall is 1.6 to 2.5 times the flood control zoning planning and defense standards, far exceeding Zhengzhou's existing flood control capacity and planning flood control standards. At the same time, with the development of the economy and society, the disaster risks faced by cities are becoming increasingly complex and diverse. Transforming the development mode of cities and comprehensively promoting the construction of resilient cities is the only way for urban development. By promoting the shift from rigid engineering confrontation to coexistence, mitigation, and adaptation, continuously improving urban resilience is integrated into the entire process of urban planning, construction, and management, enhancing the ability of cities to withstand, adapt, and quickly recover from disaster risks.

2. Strengthen the integrated management of early warning and response. One is to refine the specific responsibilities, response mechanisms, and action measures of the commander and relevant departments and units, strengthen the integration of drills and daily inspections, issue warning information, and initiate response and implementation measures based on contingency plans and systems to ensure effective use at critical moments. The second is to establish and improve the mechanism for extreme weather and major risk assessment, quantify the standards for early warning and emergency response, standardize the release of forecast and early warning information, establish and improve the linkage mechanism between early warning and emergency response, and timely take the "three suspensions" (stopping gatherings, suspending classes, and closing businesses) mandatory measures in accordance with regulations. The third is to strengthen the review of the content of the contingency plan and the control of its connection, enhancing the overall, coordinated, and effective nature of the contingency plan system.

3. Improve the overall level of urban disaster prevention and reduction. One is to integrate extreme weather response and natural disaster prevention into major urban development plans, projects, and strategies, improve flood control and drainage standards, as well as disaster prevention and defense standards for public service facilities such as hospitals and subways, to achieve urban disaster prevention and mitigation capabilities that are compatible with economic and social development. The second is to strengthen the investigation and rectification of major risks and hidden dangers, accelerate the filling of the arrears of urban flood control and drainage facilities, strengthen the safety guarantee of major lifeline projects, classify and transform key facilities such as backup power supply, drainage pump stations, and high-value equipment located in underground spaces, revise relevant standards, strengthen safety protection measures such as closure, flood resistance, and relocation,

and ensure operational safety. The third is to strictly control illegal encroachment on river channels, enhance urban meteorological and hydrological monitoring and forecasting capabilities, implement "joint drainage and coordination" for floods, and prevent systemic risks. The fourth is to strengthen the construction of professional rescue forces, optimize the equipment for flood control and rescue, drainage and waterlogging, water search and rescue, especially in key areas and locations, equipped with special equipment such as maritime satellite phones, long-distance communication drones, emergency power generation vehicles, etc., to improve emergency support capabilities in extreme situations such as circuit breakers, power outages, and network disconnections.

4. Widely enhance the risk awareness and self rescue and mutual aid capabilities of the whole society. One is to fully utilize the role of various media, widely carry out disaster prevention, reduction, and relief publicity and education, and effectively enhance the public's awareness of risk prevention through simple and understandable interpretation of typical cases. The second is to start disaster prevention and safety education from basic education, highlight relevant content in the national education system, and promote the integration of disaster prevention, reduction, and relief knowledge into textbooks, schools, communities, and vocational training. The third is to expand diverse forms of practical exercises, establish disaster prevention and reduction education and training bases at all levels, science popularization experience venues, stimulate public interest, and enhance training effectiveness.

Case 13、 Extremely heavy rainstorm disaster in Beijing Tianjin Hebei in 2023

（1） Disaster situation

1. Characteristics of the disaster situation

Affected by multiple factors such as the residual circulation of Typhoon Dujuan and terrain, extreme heavy rainfall processes occurred in Beijing Tianjin Hebei and other areas from July 29 to August 1, 2023. Compared with the heavy rainfall processes in North China in 1996 (8.3-5), 2012 (7.21), 2016 (7.18-20), these processes exhibited characteristics such as long duration, large cumulative rainfall, and strong rainfall extremes.

Long duration. The heavy rainfall process in this region lasted for nearly 4 days, with a total rainfall duration of 83 hours in Beijing, far exceeding the 20 hours of "7.21" in 2012; Heavy to extremely heavy rainstorm occurred in Handan, Xingtai and Shijiazhuang of Hebei Province, Jinzhong of Shanxi Province, Hebi of Henan Province and the southwest of Beijing for two consecutive days.

Accumulated rainfall is high. The cumulative rainfall in the southwest of Beijing and the central and southwestern parts of Hebei Province is 350-600 millimeters, with some areas receiving 700-800 millimeters. The maximum cumulative rainfall reached 1003 millimeters (Lincheng County, Xingtai City, Hebei Province), exceeding the maximum rainfall of 861 millimeters when Typhoon Dujuan made landfall in Zhejiang Province; The rainfall area of over 100 millimeters reaches 170000 square kilometers.

The extreme nature of rainfall is strong. The average process rainfall in Beijing is 330.8 millimeters and the maximum rainfall is 879.4 millimeters, while the average process rainfall in Hebei Province is 153.2 millimeters and the maximum rainfall is 1003 millimeters, both exceeding the previous three heavy rainfall processes in North China; Among the national meteorological observation stations in Hebei Province and Beijing, 15 have exceeded historical extreme values in daily rainfall, and 26 have exceeded historical extreme values in 3-day cumulative rainfall.

2. Disaster situation

The continuous rainstorm has led to serious floods and disasters, as well as secondary disasters such as landslides, causing major property losses and casualties, especially in Mentougou District and Fangshan District of Beijing and Zhuozhou City of Hebei Province. According to incomplete official statistics, as follows:

About 310000 people were affected by the disaster in Mentougou District, Beijing, accounting for approximately 77% of the total population; 8418 collapsed houses and 26493 severely damaged ones; 37.39 kilometers of damaged municipal roads; 657.6 kilometers of the water supply network were damaged, and 5 water supply plants and stations were all damaged to varying degrees; 7 town level sewage treatment plants and 160 village level sewage treatment stations have been damaged or destroyed to varying degrees.

Over 60000 houses were damaged or collapsed in Fangshan District, Beijing; Damaged 10 county-level and above highways, 230 rural roads, 119 bridges, and 77 villages with broken roads; The South to North Water Diversion Project, Zhangfang Water Source, and Groundwater Source have all suffered varying degrees of damage; The water transmission and distribution pipelines, water supply production equipment, and security technology and physical defense systems of 19 water supply plants were damaged, and the water supply facilities in 218 villages in 17 townships were damaged to varying degrees; 19 sewage treatment plants in urban areas were damaged, and 900 kilometers of drainage pipelines were damaged and blocked to varying degrees.

116 counties (cities, districts) in Hebei Province were affected by the disaster, with 16 counties in Baoding, Langfang, Zhangjiakou, Hengshui, and Cangzhou being the key affected areas. A total of 3.896 million people were affected by the disaster in the province, with 40900 collapsed houses and 155500 severely damaged houses; 1150 damaged primary and secondary schools, kindergartens, and 1871 damaged medical institutions; The infrastructure such as transportation, electricity, communication, water conservancy, water supply and drainage, and municipal infrastructure in the disaster area have been severely damaged.

（2） Exposed issues

1. The flood control system in the basin is not sound: the northern branch of the Daqing River lacks regulating and storage reservoirs. The Daqing River basin is divided into two sub basins, the south and the north. The severely affected city of Zhuozhou is located in the northern sub basin of the Daqing River. According to the "Daqing River Flood Control Plan", among the six large reservoirs in the mountainous areas upstream of the Daqing River, there is only one Angezhuang Reservoir in the northern branch basin, which accounts for 9% of the total storage capacity of the six large reservoirs and has weak regulation and storage capacity; And the Angezhuang Reservoir only accommodates 476 square kilometers of the North Branch watershed area of 10151 square kilometers, accounting for only 4.7% of the total watershed area. This directly led to the flash floods rushing down and being difficult to store, exacerbating the flood disasters in the Zhuozhou area.

2. Inconsistent flood control standards in the basin: Upstream elevation increases downstream pressure. China's river flood control is designed in a cascade manner, with the flood control standards for mountain gullies, tributaries, and main streams gradually transitioning from a 5-year return period to a 20-200 year return period. In the past decade, cities around the world have vigorously promoted the comprehensive management of small and medium-sized river basins, increasing the flood discharge capacity to once every 20 years by widening small and medium-sized river channels. Although this upstream small and medium-sized river channel management method is beneficial for upstream flood control, it will lead to faster and larger water flow in downstream river channels. If the downstream flood control standards are not raised synchronously, it will cause greater damage to the downstream confluence.

3. Poor management of flood storage and detention areas in the basin: construction activities have not been effectively controlled. In the middle and lower reaches of the Daqing River Basin, there are national flood storage and detention areas such as Xiaoqing River Flood Diversion Area, Langouwa, Baiyangdian, Dongdan,

Wen'anwa, Jiakouwa, and Tuanbowa. Due to the low frequency of use of flood storage and detention areas, some cities and counties allow land transfer and construction activities within the flood storage and detention areas, resulting in significant disaster losses when the flood storage and detention areas are put into use.

4. Fragile urban lifeline engineering: improper site selection and insufficient backup. The water supply system of Zhuozhou City was severely damaged in the rainstorm flood. The raw water pipelines and urban water supply plants were damaged and polluted by the flood. The water supply in the urban area was cut off for more than half a month, exposing the planning and layout problems of urban water supply as a lifeline project. Firstly, the site selection is not scientific. The surface water supply plant in Zhuozhou City is located in the Xiaoqing River flood diversion area (storage and detention area). In order to obtain the construction permit, measures were taken to raise the ground by 3 meters and to design the project according to the 50 year return period standard. A flood impact assessment report was prepared and finally approved. Although this move complies with the flood control law, there are significant safety hazards in the site selection. In this disaster, the water plant was flooded to a depth of about two meters, causing the water supply equipment to be paralyzed. The second issue is the unreasonable layout of facilities and a single water source. There is only one water supply plant in the urban area of Zhuozhou, and the planned expansion phase II is still on the original site. The water plant can only be connected to the South to North Water Diversion pipeline and cannot switch to underground backup water sources, resulting in a fragile water supply pattern of "single water plant, single water source".

5. Insufficient urban emergency response capacity: Insufficient preparation of backup water sources. After the surface water plant in Zhuozhou stopped supplying water, the emergency response capability of urban water supply was insufficient. One issue is insufficient preparation for the activation of emergency and backup water sources. After the construction of a surface water plant in Zhuozhou City, most of the underground water source wells in the urban area were shut down due to a lack of thermal backup and operation maintenance. In emergency situations, the underground water source wells started slowly, the total amount was insufficient, and the water pressure was low. The second issue is the imperfect emergency response technology. Almost all backup water source wells have not been equipped with any treatment and disinfection processes, resulting in flooding and pollution of the pipeline network, serious exceeding of water microorganisms, and inability to achieve direct water supply after being put into use. Thirdly, the emergency organization mechanism for water supply is not sound. No dedicated emergency command center for water supply has been established, information transmission is not smooth, the problem of substandard water quality in the pipeline network has not been discovered in a timely manner, and a scientific disinfection and cleaning plan for the pipeline network has not been formulated.

（3） Lessons and inspirations

1. Establish a basin collaboration mechanism. Implement the water management concept of "water conservation priority, spatial balance, systematic governance, and dual pronged approach", deeply implement the river and lake chief system, adhere to the "one game" approach in the basin, and strengthen the unified planning, governance, scheduling, and management of the basin. Establish a sound watershed planning system, strengthen the role of planning constraints and guidance, and strengthen the responsibility for planning implementation. Coordinate water security, water resources, water environment, and water ecological governance, and strengthen the efficient coupling of multiple objectives. Improve the flood control engineering system in the basin, strengthen the safety construction and operation management of flood storage and detention areas, and enhance the overall defense capability. Strengthen the monitoring and forecasting of flood routing,

activate flood storage and detention areas according to flood dispatch plans, and improve multi scenario emergency plans.

2. Strengthen the departmental coordination mechanism. Each department should be based on their respective responsibilities, division of labor and cooperation, to achieve clear and interconnected responsibilities and rights throughout the entire space of "watershed province city urban area community community community community" and the entire cycle of "planning construction governance", with full coverage and no blind spots. Make good use of the experience of flood control and drought resistance command center coordination, explore new ideas for coordinated water management of water safety, water resources, water environment, and water ecology, and establish a new mechanism for normalized coordination among various departments to coordinate and promote the implementation of water related strategies such as modern water network, smart water conservancy, water ecological civilization construction, smart water management, sponge city, and black and odorous water treatment.

3. Adjust the flood control policy. In the context of normalized warm, humid, and rainy weather in the future Beijing Tianjin Hebei region, it is necessary to re-examine and optimize the overall policy of flood control in the region from a long-term and holistic perspective. We should move from "prevention first" to "coexistence with water", coordinate natural adaptation and artificial defense, coordinate flood control, drought resistance and water resource utilization, coordinate disaster prevention, reduction and emergency response, recovery, coordinate hardware facility construction and software mechanism construction, coordinate planning, construction and governance.

4. Optimize flood control and disaster reduction standards. Coordinate flood control and disaster reduction systems at both the watershed and urban levels, and systematically improve flood control standards. Taking into full consideration the new trends in rainfall patterns and patterns under global climate change, and following the principles of upstream downstream coordination and storage, detention, and discharge coordination, reasonable, systematic, and graded determination of flood control standards for rivers within the basin, scientific demonstration and determination of flood control projects and standards such as reservoirs, embankments, storage and detention areas, and diversion channels within the basin.

5. Improve the planning system. Clarify the division of labor among relevant planning departments and actively formulate corresponding responsibilities and rights for responding to flood disasters. One is to optimize the planning of the flood control system in the Beijing Tianjin Hebei region, formulate overall strategies for flood control under the new situation, and improve the overall layout of the flood control system. The second is to optimize national spatial planning at the provincial and municipal levels, delineate relevant control lines, and clarify usage control requirements. Thirdly, at the urban level, a special plan for urban water systems should be formulated to coordinate the layout and requirements of urban water systems and water related infrastructure construction, and optimize the relationship between urban and water resources; Develop a comprehensive disaster prevention construction plan, coordinate the spatial and facility layout of disaster prevention and reduction land, and propose a construction plan for the "Resilient Urban Lifeline System"; Develop urban designs that coexist with water at the community and neighborhood levels, combining comprehensive water management with urban design to meet people's needs for a better life while preventing natural disasters.

6. Strengthen the support of information platforms. One is to strengthen model simulation and prediction. Research and establish a runoff model and hydrodynamic model that are in line with the laws of watershed floods and urban drainage under global climate change, improve the accuracy of flood forecasting, advance the flood process in the digital flow field based on forecast data, and iteratively simulate the scheduling plan of the

watershed flood control and drainage system. The second is to build a comprehensive disaster prevention information platform. Taking into account the disaster prevention requirements of urban earthquake resistance, flood control, drainage, fire protection, etc., a comprehensive disaster prevention information platform will be constructed. Construct intelligent supporting facilities for "joint row and joint debugging", utilize information intelligence technology, and build a city safety monitoring system that integrates all time, all domain, and multi-dimensional data. Gradually forming an intelligent decision-making and response capability that combines human-machine interaction, achieving seamless switching of response processes, zero delay in command decision-making, and real-time monitoring and evaluation of situation progress. The third is to carry out the construction of the urban information model basic platform. Further coordinate various management information platforms such as urban comprehensive disaster prevention and smart water management, and carry out the construction of the City Information Model (CIM) basic platform. Promote data sharing and business collaboration among various industries and departments in the city, actively explore the multi-dimensional application of CIM basic platform in urban physical examination, urban safety, intelligent construction, smart transportation, smart municipal governance, smart landscaping, smart water management, smart community, urban comprehensive management and other fields.

Case 9、 Rare catastrophic flood disaster in Chongqing in 2020

（1） Disaster situation

1. Characteristics of disaster situation

In July and August 2020, large-scale, long-lasting, and high-intensity rainfall occurred in the upper reaches of the Yangtze River. Due to the convergence of multiple flows and the superposition of flood peaks, Chongqing suffered from a rare and catastrophic flood in history. From August 18th to 20th, the "5th Flood of 2020 on the Yangtze River" and the "2nd Flood of 2020 on the Jialing River" successively passed through the central urban area of Chongqing. The highest flood level since 1939 occurred at the Cuntan Station on the Yangtze River, exceeding the guaranteed water level by 8.12 meters. The maximum inflow of the Three Gorges Reservoir since its construction was 75000 cubic meters per second.

Rainfall has a wide spatial distribution. Rainfall covers six provinces, autonomous regions, and municipalities in the upper reaches of the Yangtze River, with an accumulated average rainfall of over 250 millimeters in an area of approximately 70000 square kilometers, mainly in the Jialing River and Mintuo River basins in Sichuan Province.

The duration of rainfall is long. From July to August, continuous rainfall in the upper reaches of the Yangtze River caused two numbered floods in the Jialing River and five numbered floods in the Yangtze River. The rainfall process lasted for seven days during the "8.20" flood disaster, and the heavy rainfall of rainstorm and above lasted for five days.

Floods gather in multiple streams. 32 rivers, including Tuojiang, Jialing, and Qingyi, have exceeded their warning and guarantee water levels. The Minjiang River has experienced historical floods, which have gradually spread downstream and converged in Chongqing.

Overlapping before and after the flood peak. The passage of the fourth peak of the Yangtze River is only 3 days after the formation of the fifth flood, and the passage of the first peak of the Jialing River is only 2 days after the formation of the second flood. The combined impact of the front and rear floods is significant.

2. Disaster situation

The flood has affected 263200 people in 15 districts and counties including Tongnan, Tongliang, Hechuan, Beibei, Yongchuan, Jiangjin, and the central urban area of the main city. 251000 people have been urgently evacuated, 132700 people have been urgently relocated, 3444 people need emergency living assistance, 23700 shops, 860 enterprises, institutions, and commercial markets have been submerged by the flood, 320 roads along the river, 148 bridges, 194 garages, 42000 parking spaces, 663 motor vehicles, 70 docks and stations, 84 Binjiang Park squares, and 4095 houses have been damaged. The affected area of crops is 8636 hectares (including 6958 hectares of farmland and orchards, and 1421 hectares of total harvest), with a direct economic loss of 2.45 billion yuan. But it did not cause any casualties.

（2） Exposed issues

1. The capacity of flood control facilities in some areas needs to be improved. Currently, there are no conditions for the construction of controlled flood regulation and storage projects in the Chongqing section of the Yangtze River and Jialing River main stream, as well as in the longer upstream sections. Due to factors such as urban construction land and landscape, according to the 50 year return period standard, the compliance rate of flood control and bank protection projects is only 48.2%. The actual flood control capacity in some areas is only once every 5 years to once every 20 years, and there are 10 weak flood control risk points such as Caiyuanba and Ciqikou. Urban flood control and drainage face great pressure.

2. The management of regional flood control needs to be strengthened. Currently, the 26 flood control and control water conservancy projects in the upper reaches of the Yangtze River have limited reserved flood control storage capacity for the Chongqing section, and the start-up conditions for joint operation of reservoir groups are relatively high. The contradiction between the high peak and large volume of passing floods and the insufficient discharge capacity of the central urban section of Chongqing is prominent.

3. The level of early warning and forecasting needs to be improved. During the flood disaster, some merchants on Nanbin Road, Ciqikou and other areas were unable to receive timely and accurate forecast information, resulting in delayed and repeated transfer of materials, exacerbating the losses caused by the disaster.

4. The disaster prevention capability of municipal and transportation infrastructure is relatively weak. According to statistics, 30.38% of the roads in the central urban area of Chongqing have a relatively high or very high risk of flood disasters. Many facilities such as distribution rooms, pressure regulating stations, and pump stations are located below the flood control and waterlogging design water level and cannot be relocated in the short term. During the double peak of the Yangtze River and Jialing River passing through Chongqing, important roads such as Nanbin Road and Changbin Road, known as the "Two Rivers and Four Banks", were affected by the disaster. Facilities such as drainage networks, pump stations, and sewage treatment plants were flooded, and the damage and siltation were severe.

5. The public's awareness of disaster prevention and relief needs to be enhanced. Due to the low peak water level during the emergency response, some merchants along the river, such as Nanbin Road, had insufficient understanding of the intensity of the flood and had a sense of luck. They believed that transferring materials would consume manpower and financial resources, and even some merchants refused to transfer, resulting in losses due to the disaster.

（3） Lessons and inspirations

1. At the regional level: firstly, strengthen the construction of monitoring and early warning capabilities, comprehensively integrate the monitoring and early warning perception network, enhance the interconnection and information sharing of meteorological, hydrological and other related monitoring and early warning systems, and improve the accuracy and timeliness of forecasting; The second is to strengthen the construction of

information dissemination capacity, standardize the dissemination of early warning information, strengthen emergency linkage of early warning, improve the pertinence of early warning information, and avoid "delayed" and "blind" response to flood disasters; The third is to strengthen the joint dispatch of floods in the basin, adhere to the overall situation and flood coordination, rely on the basin flood control engineering system to tap the potential of flood interception and peak shaving, and reduce the pressure of urban flood control and the losses caused by flood disasters.

2. At the urban level: firstly, carry out the delineation of flood risk areas, clarify the distribution of urban flood risk areas in different scenarios, strengthen hidden danger investigation and risk management; The second is to improve the emergency response system, formulate and timely revise emergency plans at all levels, enhance the pertinence of responding to extreme rainfall disasters, regularly conduct emergency drills, implement relevant work tasks, response procedures, and disposal measures; The third is to enhance the resilience of urban lifeline engineering, strengthen the construction of monitoring and early warning, risk perception, disaster prevention resilience and other capabilities of urban lifeline engineering, and improve the level of risk resistance. The fourth is to explore the flexible utilization mode of waterfront public spaces in cities along the Yangtze River, study the utilization mode of waterfront public spaces between different standard flood levels and normal water levels, assess the suitable functions of spaces at different elevations, optimize the layout of waterfront spaces, and explore the flexible utilization mode of waterfront public spaces with "graded defense, suitable rain and drought, water in and out, and water out and in".

3. At the community level: firstly, promote the construction of grassroots emergency response capabilities, enhance the independent combat and emergency response capabilities of townships (streets) and administrative villages (communities) in extreme situations such as power outages, power outages, and communication interruptions. The second is to enhance the emergency response capabilities of the entire population, develop emergency self rescue manuals for various types of emergencies, increase publicity and education on urban flood control and drainage knowledge, and improve public awareness of disaster prevention and avoidance, as well as self rescue and mutual assistance capabilities. The third is to improve the disaster insurance system, fully leverage the role of market mechanisms to promote flood insurance, improve the catastrophic compensation system, gradually form a multi-level disaster risk sharing mechanism, and reduce losses caused by flood disasters.

Annex C: Details of non-Chinese case studies

Annex C consists of:

- C.I: Case 4: Rhine-Meuse-Scheldt Delta
- C.II: Learning from disasters

Annex C.I Case 4: Rhine-Meuse-Scheldt Delta

The Rhine-Meuse-Scheldt Delta is a river delta ending in the Netherlands formed by the confluence of the Rhine, the Meuse and the Scheldt rivers. The delta covers more than 25 thousand square kilometre and is the largest delt in Europe [1]. The Rhine-Meuse-Scheldt Delta is densely populated and has a very important economic role within Europe, as the three rivers are major navigable waterways. The delta is the waterway entrance to Germany, and passes by major ports such as Rotterdam, Antwerp Vlissingen, Amsterdam (through the Amsterdam-Rhine canal) and Ghent (through the Ghent-Terneuzen canal). A map of the delta can be seen in Figure 1.

In the following sections, the expected climate trends will be described (Section 1) after which the risks caused by these trends will be discussed (Section 2). The climate adaptation approaches implemented in the Netherlands, Flanders and Germany will be elaborated on in Section 3. Finally in Section 4 and 5, the main observations are stated and a concluding discussion on climate adaptation in the Rhine-Meuse-Scheldt Delta is presented.

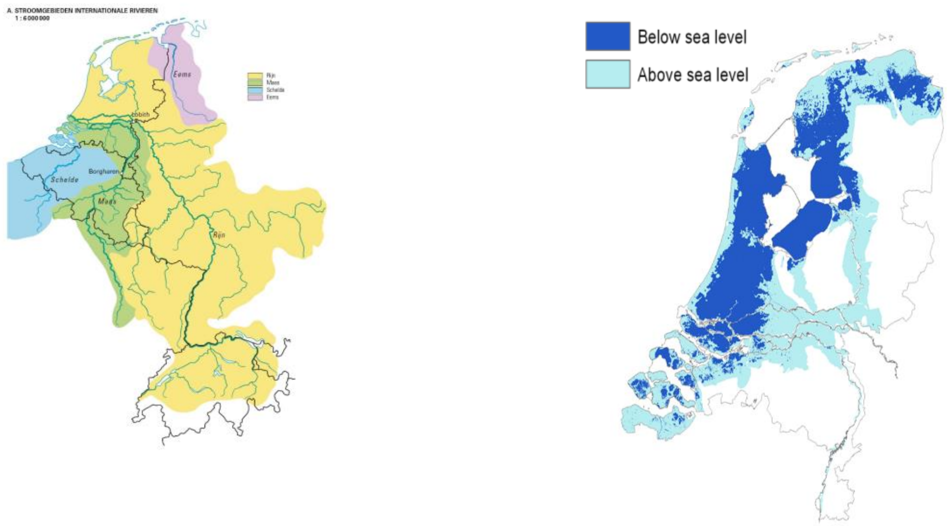

Figure 1: Map of the Rhine-Meuse-Scheldt river basins and delta (Rijn-Maas-Schelde) [2] and the Netherlands as delta country, partly below sea level.

1. Climate trends

The average temperature of the Earth has already risen by 1 degree in the past 130 years. If greenhouse gas emissions continue at the same rate, the Earth will become increasingly warmer, having major consequences for people, nature and the environment[3]. As a consequence of this global climate change, also the Rhine-Meuse-Scheldt Delta will be faced with increased extreme rainfall events, droughts and more low water in the rivers leading to reduced navigability. Sea level rise and salinization also pose a threat to freshwater availability in the delta [4].

In 2023, the KNMI, the Dutch national weather service, presented four new climate scenarios to quantify the potential changes in the Dutch climate up until 2100. The extent to which the climate will change depends on the amount of greenhouse gases that will still be emitted and the sensitivity of the climate system. A distinction is made between two emissions scenarios:

- **High emissions scenario** (indicated by the character 'H') in which emissions will increase sharply until 2080 and then level off. Global warming around 2100 is then estimated to be 4.9°C.
- **Low emissions scenario** (indicated by the character 'L') in which emissions are rapidly reduced and greenhouse gases are removed from the atmosphere, in line with the Paris Climate Agreement to limit global warming to well below 2°C. Global warming around 2100 will then be 1.7°C.

Regardless of the emission scenario, further warming means that summers will become drier and winters wetter. In the KNMI climate scenarios, two climatic variants per emission scenario are defined:

- **a 'wet' scenario** (indicated by the character 'n') in which the winters become much more wet and the summers slightly drier.
- **a 'dry' scenario** (indicated by the character 'd') in which the winters become slightly more wet and the summers considerably drier [5].

Extreme rainstorms

With warmer temperatures, the atmosphere is able to hold on to more water vapor, resulting in more precipitation that falls during a rain shower. Also, more water vapor in the atmosphere means that more condensation heat is released, allowing the air to rise and rain to fall more quickly. The KNMI predicts that the number of light summer shower will decrease in the future, while the number of extreme rainfall events will increase. Daily rainfall could increase over 30- 40 % in a once per 100 years storm, while hourly rainfall is expected to increase in the order of 15-45 % in a once per 100 years storm [5].

Drought and increased temperatures

According to the KNMI climate predictions, the risk of extreme droughts in the Rhine-Meuse-Scheldt Delta will increase. Drought is often quantified as the precipitation deficit, that is *the cumulative difference between precipitation and potential evaporation from April 1st untill September 30st*. In the high emissions scenario with a dry climate (‘Hd’), the average summer in the future will be about as dry as an extremely dry summer now, see Figure 2.

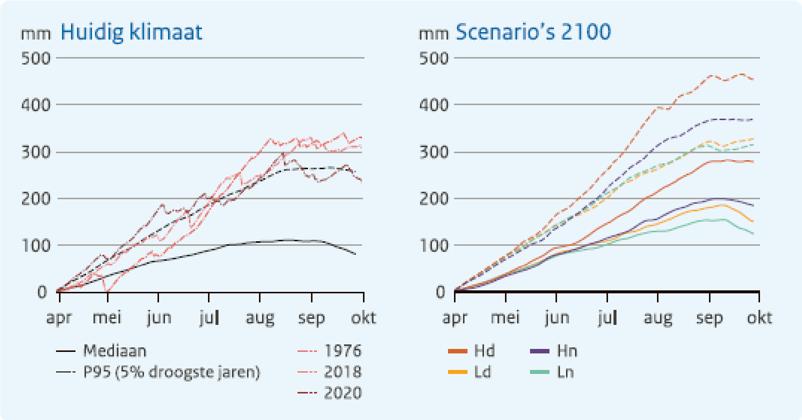

Figure 2: The average summer in 2100 will be about as dry as an extremely dry summer now. Cumulative precipitation deficit in De Bilt, the Netherlands, in the current climate (1991-2020) (left) and with the predicted 2100 scenarios (right). The dashed line indicates the 5% driest years [5].

In the high emission scenario with a dry climate ('Hd'), the precipitation deficit in the Rhine-Meuse-Scheldt Delta could even exceed 600mm once every 20 years, see Figure 3.

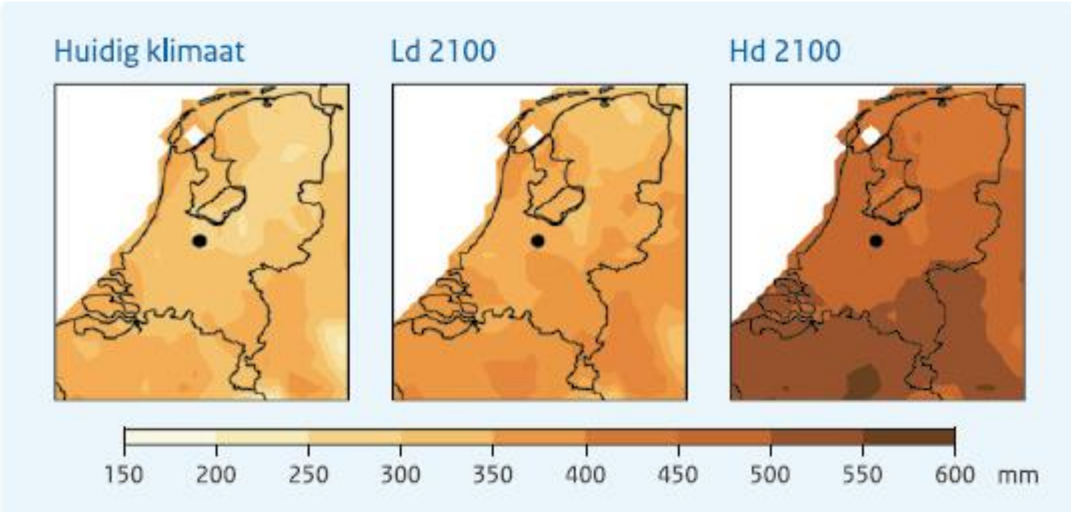

Figure 3: The expected precipitation deficit expected once per 20 years in the current climate (left) and in the two dry KNMI scenarios in 2100 (low emission in the middle, high emission on the right) [5].

Next to the precipitation deficit, the KNMI predicts an increase in average and extreme temperatures. For winters, there will be a significant decrease in the number of days having a maximum temperature below zero degrees (ice days).   For the high emission scenarios, the ice days in central Netherlands will decrease from six days per year (current climate) to less than one in 2100. In the low emission scenarios, the ice days are expected to decrease to four days per year.

Summers are expected to have more tropical nights, when the temperature does not fall under 20 degrees. The tropical nights in central Netherlands will increase from 0.3 per year (current climate) to 19 nights per year in 2100 in the high emission scenarios and to one night in the low emission scenarios. There will also be more hot summer days with a temperature of 25 degrees or higher. This will increase from 28 days per year (current climate) to 89 days per year in 2100 for the high emission scenarios or 40 days for the low emission scenarios. The increases will boost the use of air conditioners – and their energy demand. The increase in temperature will also affect the existing glaciers in Switzerland. Once these disappear, the flow regime of the Rhine River will change from a glacier-fed river to a rain-fed river, resulting in a substantial decrease of its discharge over summer and fall.

Sea level rise

Along the Dutch/Belgian coastline, and by the mouth of the delta, the sea level is expected to rise by about 26-73 cm by 2100 in the low emission scenario and by 59-124 cm in the high emission scenario [5]. But if the Antarctic ice sheet were to become unstable, the sea level rise could reach up to 2.5 m before 2100 in the high emission scenario.

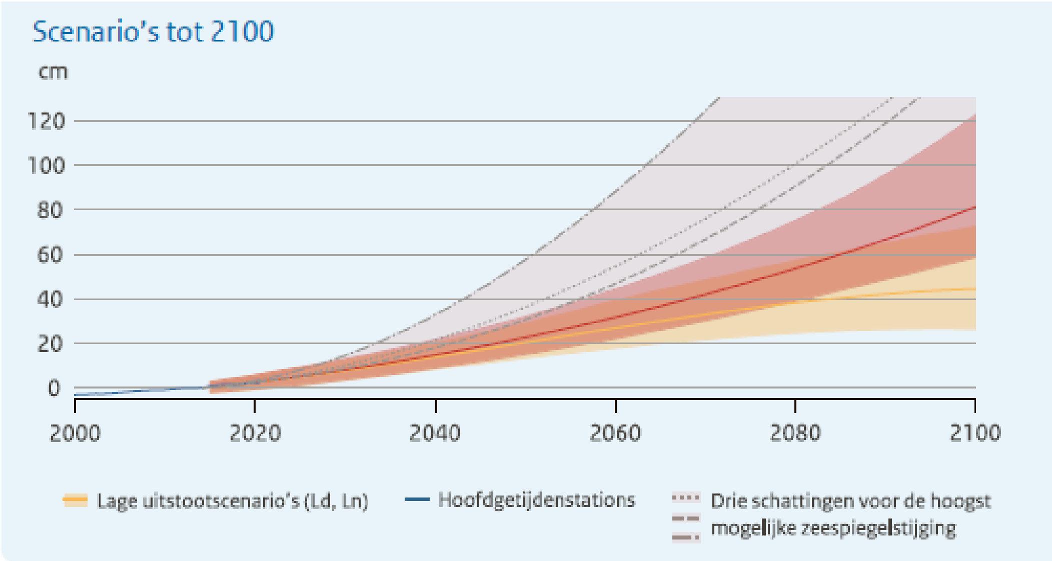

Figure 4: Sea level rise predictions for the Dutch coastline. The yellow band represents the sea level rise in the low emission scenario, the red band that of the high emission scenario. The pale bands represent the predictions of the highest possible sea level rise in case of an Antarctic ice sheet meltdown [5].

2 Major disaster risk caused by climate change

Extreme rainstorms

Rainstorms are expected to become more extreme. Consequently, the risk of pluvial and river flooding in the Rhine-Meuse-Scheldt Delta is increasing, with serious consequences. The "Water bomb" that hit large parts of Wallonia in Belgium and Northrhine-Westphalia and Rhineland-Palatinate in Germany on 13-15 July 2021with locally over 250 mm of rainfall caused over 220 casualties, affected more than 120,000 private homes and caused about 38 billion Euro direct damage. A lot of debris were transported with the flood wave resulting in fatalities, injuries, major damage to buildings, infrastructure and private property, erosion and sediment deposition [6].

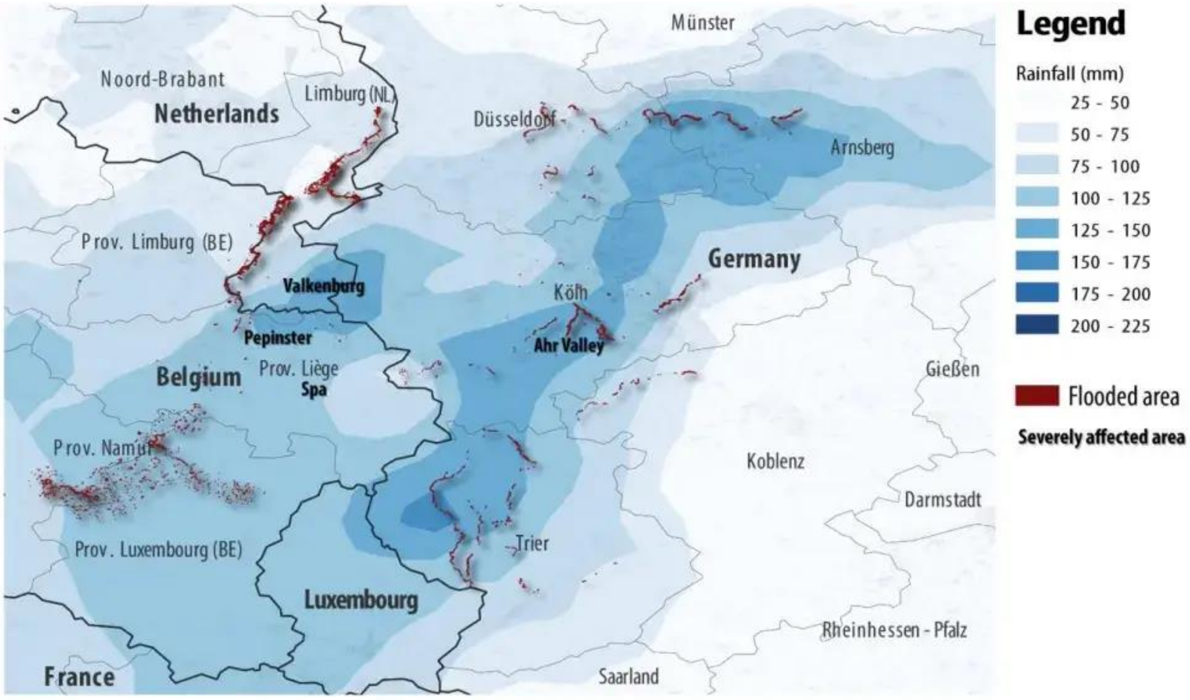

Figure 5: Precipitation quantities on the 14th and 15th of July during the "Water bomb" [7].

During such extreme rain events the ground becomes saturated with water, resulting in landslides, mud flows, flooded agricultural areas and damage to crops, buildings and infrastructure.

The July 2021 "waterbomb" disaster was a shock for water authorities in the Delta. What would have happened if this event had landed in their area? Many use the "waterbomb" event nowadays as part of their regional and local climate stress testing procedures, to investigate the impacts in case the water system becomes overloaded by such a dramatic event and study options for damage minimisation [8].

Drought and increased temperatures

The consequences of droughts and increased temperatures are multiple and depend partly on the landscape type. Droughts can lead to general water shortages, affecting agriculture, nature, shipping (reduced navigability) and drinking water supplies. In the soft clay and peat layers in the delta, droughts can exacerbate land subsidence, making the delta more vulnerable to sea level rise, and damaging foundations in urban areas [9]. The stability of levees is threatened by drought, as well as water quality and aquatic life. Salinisation of rivers and other surface waters is a common problem across the Delta.

2017 and 2018 were extremely dry years in Belgium and the Netherlands. During the 2018 heat wave, the Dutch national heat record was broken by more than 2 degrees on July 25, 2019 (40.7 degrees) [5] . The drought led to low river discharges and the other adverse effects described above and it became clear that the supply of freshwater could not always meet the demand [4]. Ecorys make an estimation on the damage caused by the 2018 drought in the Netherlands based on data analysis, literature study and conversations with stakeholders. They estimated the damage between 900 and 1,650 million Euros [10]

Persistent hot weather and heat waves lead to an increase in health complaints, sleep problems and premature death, especially among the elderly and chronically ill. Urban areas can be up to 5 degrees warmer than neighbouring rural areas [5]. This urban heat island effect can largely be attributed to the lower albedo and the reduction of evaporative cooling by urban green and blue areas. Heat can also lead to infrastructure damage like melting asphalt and moveable bridges getting stuck due to expansion [11]. Reduction of the heat stress problem requires water for evaporative cooling, potentially contributing to the water resources shortage, as periods of extreme drought and heat often coincide.

Sea level rise

The most evident risk of sea level rise is the water safety and flooding consequence. To protect the low-lying delta, the storm surge barriers such as the Maeslantkering, the Hartelkering and Oosterscheldekering, will have to be closed more frequently, see Figure 6. For example, the Oosterscheldekering is now closing about once per year, but by the end of this century, the barrier would need to be closed to up to 20 times a year in the high emission scenario [5], damaging to the vulnerable ecosystem in the Eastern Scheldt estuary. This not only leads to higher maintenance costs, but also to a reduction of the lifespan of these costly facilities.

Figure 6: Map with the Deltaworks in which the Eastern Scheldt storm surge barrier is highlight in red [12].

Sea level rise in combination with storm surge also increase the flood risk along the Westerscheldt and Scheldt River, threatening, amongst others, the large harbour facilities, industries and urban quays in Antwerp.

Water quality issues

Flooding, drought and heat all have a negative impact on water quality. As a result of heavy rainfall events, sediment loads can increase to dramatic levels while sewer, industrial and wastewater treatment plant overflows load the water with massive amounts of pollutants, not to forget chemicals from industrial sites and waste dumps being washed away. During droughts low flows cause higher concentrations of pollutants in both surface and groundwater. And heat causes higher water temperatures, stimulating the growth of algae, duckweed in meso- and hypertrophic surface waters. All these extreme conditions have a negative impact in the ecological system. Plants, fish and other biota suffer from these conditions; biodiversity is reduced, sometimes temporarily but permanently in other cases.

Furthermore, the combination of sea level rise with less fresh water over summer allows seawater to flow into the delta and mix with fresh river water, groundwater and ditch water. This saltwater intrusion puts stress on the drinking water resources, but also affects agriculture by harming crops [13]. For The Netherlands as the second-largest exporter of agricultural products in the world on a busy area of 41.543 km² with 17.5 million inhabitants managing these coastal threats is of eminent importance.

3 Current climate adaptation approach

Extreme weather-related disasters and narrow escapes over the past decades have triggered changes in policies and substantial investments in adaptation. The narrow escape from severe flooding in the Dutch delta in 1993 and 1995 triggered higher flood protection standards, the Room for the River investment program and, in 2007, the Dutch Delta Program including a Delta Act (legislation, now part of the Water Act), a Delta Commissioner at ministerial level, a permanent Delta Fund to implement a Delta Plan. Similarly, in Flanders, the original Sigma plan for the flood protection in the Scheldt River basin (1977) was updated in 2005 to include the new insights on climate change, seal level rise, nature conservation objectives and river management strategies. Recently, the “water bomb” that hit the Eastern part of Belgium and Rhineland-Palatinate and North Rhine-Westphalia in Germany has triggered new risk reduction policy development in these German states.

Likewise, the extremely dry summers of 2018, 2020 and 2022 triggered renewed awareness of the drought risks to society, including the vulnerability of public water supply, nature, industry, agriculture and urban environments [14] . Water quality problems, saltwater intrusion, limited navigability, limited availability of water for irrigation, land subsidence (peat oxidation), urban heat stress and building foundation problems caused billions of Euros damage, often slow and not immediately visible. Such droughts triggered the launch of the Blue Deal investment programme in Flanders in 2020 and put urgency on policy development and implementation of the Fresh Water component of the Dutch national Delta Programme.

Heat stress is becoming more and more recognized as a problem to public health. Heat waves like the one in 2003 have killed several 100.000 people in Europe. The heat problem is aggravated in urban areas due to the formation of urban heat islands. Water would help cool the city by evaporation but is often insufficiently available. Consequently, the urban water demand beyond water for the public and industry is increasing rapidly.

Netherlands

In the Netherlands, the responsibility for water management and climate adaptation policy at the national level rests with the Ministry of infrastructure and Water management, while its implementation for the main rivers and lakes as well as for coastal defence is with Rijkswaterstaat, the executing agency of this Ministry. Regional surface water management and domestic wastewater treatment is the task of the 21 Water Authorities, while the municipalities are responsible for the sewerage system. Groundwater management rest with the landowners, but groundwater extractions need permission from the province.

In cooperation with the regional, local and water authorities the Netherlands government is investing in programmes to make the Dutch delta climate resilient by 2050 and “*to make it the safest delta of the world*”. To accelerate climate adaptation in the Netherlands a National Adaptation Strategy (NAS) was launched in 2016 – to be updated in 2026. The NAS introduces strategies to accelerate ongoing climate adaptation initiatives across several domains including: Water, Agriculture, Nature & Environment, Human conditions & Culture and Living

& working. These strategies are more smart, more inclusive and move intensive. The priorities identified in the NAS are the formulation of adaptation targets, accessibility of knowledge and expertise on adaptation, stakeholder engagement, embedding adaptation policy in other domains and widening financing options for adaptation.

To operationalize this strategy, the Delta Programme covers three themes:

- Flood risk management, aimed at reducing the probability of flooding, e.g. by upgrading dikes, maintaining the coast with sand nourishment operations and giving rivers more room.
- Fresh water, to safeguard adequate supplies of fresh water, now and in the future.
- Spatial adaptation, (re)designing the country so that society can cope effectively with the impacts of climate change (heat, drought, problems with excess water and the consequences of flooding).

Each theme is now implementing its part; the plan will be evaluated and updated once every 6 years. Focus points for 2024 are to accelerate adaptation implementation, to make water and subsurface leading for spatial functions, to avoid shifting problems (not in place, not in time, and not from private to public land) and to seek synergies in addressing challenges between climate adaptation, the energy transition, and urban development and urban renewal programmes.

The Delta Programme on Flood risk management focusses on the implementation of the national Flood Protection Programme (*Hoogwaterbeschermingsprogramma*) and the Integrated River Management Programme, covering the Dutch coast, the large rivers, lakes and estuaries in the delta. Moreover, they are currently conducting a national research programme on Sea Level Rise. The programme is building up a multi-level water safety approach, including: 1. Prevention of flooding, 2. Spatial adaptation for minimizing the impact of flooding, 3. Improving crisis management and contingency planning, 4 Strengthening water awareness of the population, and 5. Climate resilient renewal of urban and rural areas [15].

As it is evident that more frequent and more extreme weather events will take place and that flooding and damage cannot always be prevented in those situations, strengthening public awareness of water risk and the need for water resilience, behavioural change and improved self-reliance is key. Different target groups (children, youth, elderly, businesses, etc.) will be addressed separately, in its own appropriate way. At national level, evacuation and contingency planning as well as operational rescue capacity and infrastructure are subject of ongoing evaluation and improvement.

The Delta Programme on Fresh water is aimed at making the Netherlands resilient to water shortages by 2050. This requires healthy and balanced water resources management, smart reservoir management, and a fair allocation of available resources to water-demanding functions and users. In periods of extreme droughts, a national priority list for water resources allocation is available and a national committee is overseeing its distribution. Salinity control in surface water is crucial for agriculture and water supply; salinity problems not only result from saltwater intrusion from the North Sea into the rivers but also results from saline upward seepage of groundwater in the polders below sea level. By changing the distribution of the river discharge over the various branches of the rivers in the delta, by allowing higher water and salinity levels in the rural peatlands and by increasing the retention capacity of lake IJsselmeer as well as the capacity to supply and flush the low western part of the country substantial improvements have been made and more are underway of in study.

To reduce saltwater intrusion in periods of low river flow, coastal sluice complexes in the Netherlands, like the IJmuiden sluice, are incorporating a salt dam (*zoutdam*). The salt dam has an opening at the bottom, allowing only the heavier saltwater that enters the fresh North Sea canal during the sluice opening, to be pumped back into the North Sea, see Figure 7.

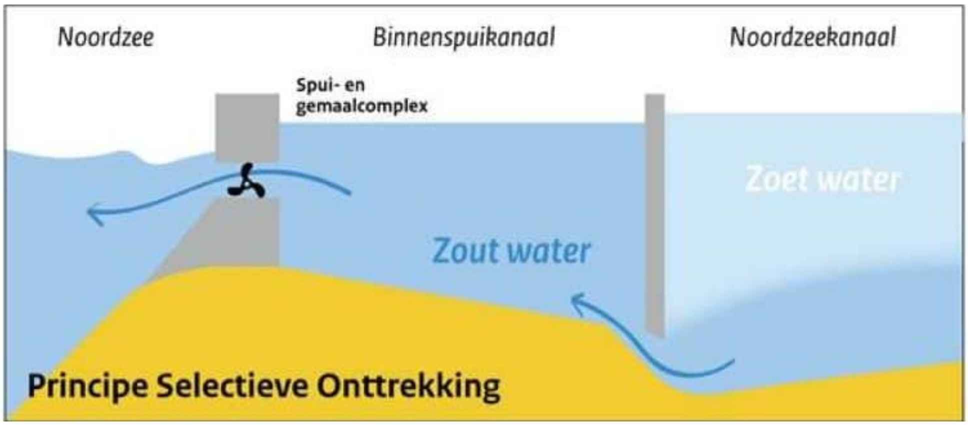

Figure 7: Diagram of the IJmuiden salt dam (right pillar). The salt dam blocks freshwater and ensures that only heavy saltwater that enters the North Sea Canal is pumped back into the North Sea [16].

Sustainable groundwater resources management is key in the central and eastern part of the country. Agriculture and drinking water supply companies use critical volumes, in particular in periods of drought. Sustainable use of the groundwater resources is under pressure. This frequently results in a ban on extracting groundwater for the irrigation of crops. As groundwater resources are available at a local or regional scale, the Dutch provinces and water authorities have a decisive role in their management. Studies have been made on how to strengthen the groundwater resources but implementation of corrective measures proved to be hard.

The Delta Programme on Spatial adaptation is supporting the provinces, cities, municipalities and water boards in the transition towards climate-resiliency of the urban and rural areas. The programme provides knowledge and tools – e.g. via the Climate Adaptation Knowledge Portal - by setting up regional networks, facilitating capacity building, design sessions, the dialogue with society and peer-to-peer knowledge exchange. A comprehensive approach is used, integrating climate adaptation with issues like the demand for extra houses, urban renewal, the energy transition, environmental and biodiversity challenges, future-proof agriculture, and social improvement. Water and Subsurface conditions are to be *leading* for the planning of land use, spatial development, urban and rural renewal. The Delta plan on Spatial Adaptation contains 7 steps towards climate resilience:

1. Stress test for flood risk, drought, and heat (45 regions / 342 municipalities).
2. Risk dialogue with stakeholders on ambitions and way forward.
3. Develop programme of measures.
4. Link with other major transitions (e.g. green energy, housing, agriculture, biodiversity).
5. Stimulate / facilitate realization (2021-2026 stimulus programme).
6. Regulate and secure planning & building standards.
7. Preparation for emergencies.

The extreme droughts of 2018, 2020 and 2022 and the 'water-bomb' that hit parts of Germany, Belgium and the Netherlands on 14-15 July 2021 have raised the awareness that spatial adaptation is urgently needed, that damage cannot always be avoided but should be minimized by improving spatial interventions and crisis management and that post-crisis recovery needs improvement [15].

Nature-based solutions – also called blue-green infrastructure – are preferred elements in the package of interventions. Such solutions are abundantly available for mitigating all climate risks, at scale from large interventions along the coast and along rivers to local interventions at the scale of a single house of backyard. See e.g. https://urbangreenbluegrids.com/ or https://www.ecoshape.org/en/ for examples. Their characteristics, performance and effectiveness of course depend on the local situation, the solution, its design, construction, and maintenance. Proof of the wide application of blue-green infrastructure in the Netherlands, and beyond, can be found at www.ClimateScan.nl ; this site provides a wealth of working examples – as well as, and equally important, examples of mistakes. To support governments and project developers, the Programme also launched a Climate Resilient City Tool for planning blue-green solutions and a toolbox on Green Climate Adaptive Built Environment, providing guidelines for climate resilient development.

Private flood insurance is non-existing in the Netherlands – except for some minor cases of water-logging due to extreme local rainfall. The damage of more destructive floods is covered by the national government. Private flood insurance companies are incapable of taking the financial risk of a massive flooding of a large part of the Netherlands. The government is currently investigating how to improve the cooperation with the insurance sector in fastening post disaster recovery, from stock-taking damages to fast and fair budget allocation to victims of flooding.

Long term scenarios have been developed and dynamic adaptation policy pathways studied in order to identify long-term trends, threats, developments and opportunities, to sketch potential adaptation pathways, to identify potential lock-ins, and to inform the dialogue on the crucial decisions related to flood and drought resilience. Socio-economic and spatial development scenarios for 2050 were developed by the Netherlands Environmental Assessment Agency [17] and Deltares produced the Delta Scenarios, which focus on the water challenges for 2050 and 2100 [18]. Existing approaches are effective for the century to come, but there is a limit to how much sea level rise and climate change can be handled in the traditional way, by increasing the level of dikes, by increasing the capacity of our lakes and groundwater as freshwater reservoirs and so on. The scenarios help to trigger the development of innovative, transformative solutions, in the physical as well as in the social and economic domain.

Several independent knowledge organisations were put in place by the national government to support policy development on climate adaptation, tool development, data and information support, and capacity building. These include Deltares, the Netherlands institute for applied research on water and subsurface, Wageningen Environmental Research, the institute for a sustainable green living environment, the Netherlands Environmental Assessment Agency, the national institute for strategic policy analysis in the fields of the environment, nature, and spatial planning, and the Climate Adaptation Services foundation who provides alignment, assurance and disclosure of spatial data and related knowledge tools in the public domain.

Flanders, Belgium

Flanders is the Northern, Dutch-speaking region of Belgium. Its Western boundary is the North Sea coast, while the River Meuse dominates the Eastern boundary – deviating here and there from its course. The largest part of the River Scheldt basin is located in Flanders, discharging in the Dutch Wester Scheldt estuary. Another essential waterway for Flanders is the Albert Canal, linking the river Meuse with the mouth of the river Scheldt and providing water and drainage capacity for the sandy grounds of the region. Coordination of the policy development on climate adaptation rests with the Flemish ministry of Justice & Enforcement, Environment, Energy and Tourism. The regional Climate Adaptation Plan for Flanders builds on the Belgian National Climate

Adaptation Plan 2017-2020. Strategies include the wide implementation of green-blue infrastructure, reduction of water consumption, making space for water detentions and drought prevention, recovery and resilient management of forests and nature, climate resilient public health policy and cooperation and coordination of adaptation related efforts. Sharing knowledge and good cooperation between the various levels of government is key to effective protection against and recovery from extreme weather events. Reference is made to the European Climate-ADAPT platform for sharing adaptation knowledge.

Water management and its climate adaptation policy in the Flanders region rests with the Flemish Ministry of Mobility and Public Works; implementation for the navigable waterways is the responsibility of De Vlaamse Waterweg nv, while this role is with the Flanders Environment Agency for all non-navigable waters. Wastewater treatment facilities are managed by Aquafin, an organization established by the Flemish government in 1990; by now, this organization also manages the sewerage systems in more than 100 municipalities. Groundwater management is regulated via the environmental permitting system of the region and executed by the Flanders Environment Agency. VITO is the independent research organization supporting policy development and practice with knowledge, advice and tools for climate adaptation practice. Lastly, the Flemish Hydraulics Laboratory (Waterloopkundig Laboratorium) is the research institute of the Ministry of Mobility and Public Works with a comparable role regarding flood protection.

The Flemish government has put large investment programs in place to make the region more climate resilient. The Sigmaplan to improve flood protection along the Scheldt River already started in 1976. The combination of high river discharges, spring tide and storm surge on the Westerscheldt estuary causes extreme fluvial flood risks in a large part of the river basin. Strengthening dikes and building 13 controlled flood areas (CFAs) in the river basin were mostly realized by 2015. Already in 2005, the plan was however updated to include new insights in river basin management - e.g. Room for the River - new sea level rise predictions and nature conservation objectives. The new plan includes 40 projects, including strengthening of 645 km of dikes and quays, creation of 2.500 ha of CFAs and 5.100 ha of riparian and tidal nature development by 2030.

The reconstruction of the historic quays in Antwerp are challenging. To protect the heritage and the quay-landscape, including its market halls, cranes, and cobblestones, innovative quay constructions were developed and are currently being constructed. This work is integrated into an urban upgrading and renewal project for the whole of the quay area.

A chain of controlled flood areas will be created along the Scheldt and its tributaries. New is the introduction of Controlled Reduced Tide in the operation of the CFA, a form of real time control in operating the detention basin. Operation of the network of CFAs is accompanied by an effective flood prediction and early warning system, based on intensive monitoring. Planning of these interventions is done in close cooperation with the local stakeholders. Riparian farmland is bought from the farmers, the spatial plan for the CFAs is made in consultation with the local population and the local farmers are invited to take a role in the maintenance of the area. Land use in the CFA is mostly natural wetland, with recreational co-use. To compensate the farmers for changing their business model and loss of income flanking measures are put in place. Public engagement is moreover roused by newsletters, visitor centres and guided tours - e.g. for bird watching on the mudflats and in the marshlands.

While the Sigmaplan is focused on flood protection the Flemish government also launched an investment programme on drought, called Blue Deal. Drought has serious consequences for agriculture, nature, industry and water supply; and climate change predictions show more and more extreme droughts and heat waves and higher seal levels, resulting in more salt water intrusion. A better and sustainable balance between water demand and water supply is needed. To achieve this, the Flemish government launched this 500+ M€ investment programme, aimed at Investing, stimulating and regulating drought resilience. The Blue Deal programme includes investments in own projects, support for local investments, investments in research and innovation and amending regulations. Blue-green, nature-based solutions and impact monitoring are important elements of the programme. The approach to achieve drought resilience is sketched in Table 1.

Table 1 Blue Deal's ways to improve the balance between water demand and water supply in order to improve drought resilience.

Approach the water system as a whole	
Water supply	**Water demand**
4. Increase water availability	5. Use water more efficiently
- Restore sponge function	- Use less water
- Create storage for alternative water sources	- Use water smarter
- Reduce leakage losses	- Reuse water
- Develop innovative technologies	- Develop innovative technologies

After the dramatic flooding by the water bomb in July 2021 a multidisciplinary expert panel on flood protection produced "Resilient Waterland", a substantiated advice on the strategy for water safety and availability. To achieve water security, four water sites were put forward: tidal rivers, watercourses, sponge landscapes and cities and villages. Ten coherent actions were formulated as well as an action plan to implement the new strategy. Decision making on the advice by the Flemish government is underway and the first concrete projects have been approved.

Implementation of the area-based projects and testing innovative measures in rural areas is realized through coalitions, collaborating under the title Water+Land+Schap. The coalitions unites 8 Flemish departments and agencies to come with joint investment plans, developed in cooperation with farmers and companies, inhabitants and landscape-managers in the area.

Coastal flood protection policy is documented in the 2011 Masterplan Coastal safety, meant to protect the coast till 2050 against storm surges and a once in 1000 year storm, taking into account 0.30 m of seal level rise. New insights on sea level rise resulted in the development of a new Coastal Vision, formulating a strategy to deal with a 3.00 m sea level rise. The preferred alternative, called "Seawards", includes heightening and widening of the dunes and dikes, shifting the coastline seaward by about 100 meters, meanwhile creating opportunities for nature, experiencing nature / recreation, sports and economy.

Ahr-Erft and Rur basin, Germany

In Germany, the responsibility for climate adaptation and water management at the federal level lies with the Ministry of Environment (BMUV), supported by institutes like the Federal Environmental Agency, Deutscher Wetterdienst and the Bundesanstalt fur Gewässerkunde. Until recently, the German Länder (regions or 'countries', united in the German federation) each had their own freedom and responsibility for the regional water management, flood forecasting, contingency planning, disaster relief and recovery, hence for climate adaptation. However, since June 1st 2024 the new federal Climate Adaptation Act is in force, setting a nationwide framework for all Länder to formulate a climate adaptation strategy, based on risk analysis and including measurable goals. From now on, climate adaptation is to be considered in any planning and decision making in a comprehensive way. This act was triggered by the catastrophic 2021 flooding events. In addition, the Ministry BMUV started regional dialogue sessions on climate adaptation in order to create stakeholder engagement in the transition towards an attractive climate resilient living environment. An information centre (Zentrum KlimaAnpassung - ZKA) was created to assist actors in climate adaptation planning with expertise and practice oriented advice.

The "water bomb" that hit Northrhine-Westphalia and Rhineland-Palatinate on13-15 July 2021caused over 180 casualties, affected 85,000 private homes – 17,000 people lost all their belongings – and caused over 30 billion Euro direct damage. Fortunately, the 24 dams in the Rur and Erft basin stood firm, despite their hydraulic overload. Their detention caused an estimated reduction of the peak discharge from approximately 1000 m^3/s to 354 m^3/s.

The flood and its recovery process was the subject of study of the Climate-Adaptation-Flooding- Resilience (KAHR)-project, funded by the German Ministry of education and Research. 13 German research institutes participated. The project focused on flood risk analysis and spatial risk management. The project produced 10 recommendations on the reconstruction and sustainability of flood-affected regions, as shown in Table 2.

Table 2 Recommendations of the KAHR-project on the reconstruction and sustainability of flood-affected regions; lessons learned from the June 2021 flooding.

Nr	Recommendation
1.	Rebuilding also provides an opportunity to initiate a strategic transformation process and strengthen disaster resilience.
2.	All potentials of flood modelling and risk analysis should be exploited for planning protection strategies, preparing, and warning affected people.
3.	Rivers need space. This does not only mean settlement retreat, but also adapted land uses. If space is not available, settlement areas, and commercial and industrial areas will be flooded.
4.	Bridges can significantly increase the risk of flooding during flood events. Bridges must be given greater consideration in future flood hazard assessments.
5.	Early warning of flood events needs to be strengthened.
6.	The signalling function of plans and planning must be strengthened. Heavy rainfall hazard and risk maps must be publicly available.
7.	Flood- and climate-resilient planning and building must be integrated at all levels of spatial planning, considering all facets of climate change impacts.
8.	Sustainable recovery succeeds when stakeholders establish forms of collaboration and work together inter-municipally. Funding should strengthen this collaboration.
9.	Intensive preparedness of emergency management and water resources management for infrequent flood and heavy rain events improves management of these events.
10.	New protection standards and protection goals for critical and sensitive Infrastructures need to be defined, and awareness of unavoidable residual risk needs to be raised.

Analysis showed that gradually, over the past centuries, the floodplain and riparian land was being urbanized and detention space was lost. Detention basins and other spaces for detention – large and small ones - are seen as the most important building blocks for creating stronger flood resilience. Options are currently being investigated, preferably in combination with options for land use changes and nature-based solutions for the ecological recovery of the water systems [6].

The KAHR-project includes an analysis of the social aspects of flood recovery and reconstruction. The social vulnerability of the population and the role of social capital in recovery was investigated. The flood event of 2021 had a traumatic impact on the local population. One year after the event 28 % of the interviewed residents showed signs of post-traumatic stress syndrome and were in need for support and treatment. The local social infrastructure (associations, clubs, social networks, social initiatives, schools, neighbour-contacts and -help) are extremely important for the way people deal with the catastrophic event and hence have an influence on the speed of recovery. This social capital, developed before the catastrophic event, proved to play a key role in the recovery capacity. Relocation [20], away from the flood-prone area, proved hard; about half of the interviewees indicated to be strongly rooted to place they are living. People renting a house turned out to be more willing to move. As expected, recovery was slower in socially weak and poor neighbourhoods; extra support and activities were needed to support recovery. Yet, the formal organization and administrative requirements of the recovery process resulted in social inequity, in particular regarding the accessibility of financial resources.

European Union

The European Union takes an active role in stimulating climate adaptation in a number of ways. The European directives such as the Water Framework Directive and the Flood directive set requirements for the European countries on their long-term protection against flooding, and for ecologically healthy and sustainable water resources management. In addition, the Union formulated an adaptation strategy to make the EU a climate-resilient society by 2050. As a first step, the European Environmental Agency produced a European Climate Risk Assessment . The EU Mission on Adaptation to Climate Change was started in September 2021; faster, smarter and more systemic adaptation are its objectives. The Mission is supporting *place-based, systemic and inclusive* adaptation by supporting the regions, bringing them together in a Community of Practice. 311 European regions, cities and local authorities have already signed the Mission Charter. 150 regions and communities were selected to become climate resilient already by 2030. 75 demonstration projects will be selected for developing enabling conditions and upscaling solutions that trigger transformations; 12 of these have already started.

4 Main observations

The approaches to climate adaptation in the three countries of the Rhine-Meuse-Scheldt delta – and even within the regions/Länder of these countries are sort of overlapping but have substantial differences. Despite the efforts of the European, national, regional and local governments, research organisations, private organizations and persons, substantial gaps and weaknesses in climate resilience are found in practice. A first inventory:

- Public awareness of the climate hazards is insufficient. This results in low preparedness of the population against floods, extreme drought, heatwaves and related problems with water resources availability, water quality and land subsidence. They trust and expect the government to solve the issues.
- Minimizing the damage of extreme events – events that exceed the design standards of facilities - is hardly recognized as a separate design requirement. Attention for extra protection of critical infrastructure and vulnerable people is increasing and the KAHR project also studied the role of

bridges and culverts in blocking discharges in these extreme conditions. But much more could be done, also in the private domain of homes and businesses.

- Public debate tends to focus on strengthening the threshold capacity by increasing the design standards; coping, recovery, adaptive and transformative capacity needed to create resilience is often neglected.
- Nature-based, blue-green solutions are promoted to strengthen climate resilience – for good reasons; these produce a multitude of ecosystem services and benefits. Many however fail if the design load is exceeded. By smart combinations of green and grey solutions the damage of extreme weather events can be minimized.
- Construction and maintenance of the blue-green infrastructure is new, and different from current practice. Experience and skills are limited. Capacity building and learning by doing – including learning from mistakes – requires open communication and is to be stimulated.
- Detention capacity is widely recognized as the way to reduce both flood and drought risk. The spatial integration of these detention measures requires a significant claim on land and is consequently hard to realize. Multifunctional use of such detention areas is to be stimulated.
- Climate adaptation has a social and economic impact. Businesses need new business-models to survive; and traditional jobs will be lost while other jobs are created. This social and economic dimension of adaptation is often insufficiently addressed. Stakeholder engagement in the planning of adaptation interventions is a step toward better understanding and wider public support.
- Socially weaker groups in society are more vulnerable to extreme weather than the higher educated, wealthier and healthier part of society. This inequity is to be considered in planning adaptation interventions as well as in disaster recovery.
- Monitoring climate and water – surface water and groundwater, quantity and quality - can still be improved; more important however is to make the data immediately available for other organizations and for the public.
- Financing adaptation is an issue. The beneficiaries of climate adaptation measures are for a large part different from the ones funding the interventions. And the gains are only evident on the long term. The tax system is not yet well-equipped to redistribute costs and benefits. And the insurance system stays away from funding adaptation, despite the risk reduction achieved by these interventions.
- Research by design is insufficiently used to find an attractive response to the known and unknown challenges now and in the future. The many aspects and uncertainties related to climate adaptation cannot be addressed as an optimization problem. What is 'the best solution' now is unlikely to be the best solution in 20, 50 or 100 years. This gives room for creativity and creative design.

5 Concluding discussion

Transformative capacity

The organization of climate adaptation in the Netherlands is organized differently from Flanders, Northrhine-Westphalia and Rhineland-Palatinate. The comprehensive approach via a separate Delta Programme – with a National Delta Fund, a Delta Act (now part of the water Act), A Delta Plan and a Delta Commissioner at ministerial level – creates long term continuity in efforts and investments. Moreover, the Netherlands national programme is strongly oriented towards strengthening the capacity of the local and regional authorities (municipalities, water authorities, provinces) to implement adaptation interventions. Tools, data, training and even supporting manpower are made available, Yet, also in the Netherlands, adaptation is, so far, often bound to interventions in the public domain; private homeowners, landowners and businesses are nudged mildly to take action on their private land. The principle that (climate) problems should not be shifted from private to public land was formulated only recently in the national policy brief "Water and Subsurface leading".

Public awareness of the risks of extreme weather and climate change has increased over the past decades, simply because of the many incidents and catastrophes. This awareness is however not yet translated into public action, as many people consider adaptation to be the task of the government and because many have no idea what they can do by themselves to contribute to solving the problem. Moreover, they would neither have the means nor the capacity to implement adaptation measures due to a lack of finances, time and/or other resources. Equity in adaptation capacity is a challenge.

Training practitioners will help reduce mistakes made during implementation and maintenance of blue-green adaptation solutions [21,22]. A lack of understanding of how the solution functions, education and skills training are important root causes of this problem. Involving construction and maintenance staff in the planning and design of facilities is another way to reduce failures.

The European ambition is to make climate adaptation place-based, systemic and inclusive. To prepare for climate disruptions, national adaptation programmes should focus on 1) supporting regional and local government with accelerating their efforts to strengthen the physical as well as the social resilience and 2) investments in strengthening the resilience of the larger river systems, lakes and coastal defences. Continuity in the funding of adaptation interventions is essential. Required funding streams can be derived from long-term perspectives on climate change, other societal and economic development and asset management of the existing, rapidly aging infrastructure. Multi-annual budget reservations for adaptation also provide continuity in public-private partnerships, knowledge development and innovation.

Threshold capacity

Detention (sponge) capacity is essential for damage avoidance in periods of extreme rainfall, drought and heat waves; on the one hand to avoid peak discharges and flooding, on the other to have water resources available for sustaining essential water demands. In flat areas like floodplains and deltas the gradient to make water flow is non-available. The only solution to excessive rainfall is local storage. In sloping areas, the flow velocity during extreme rainfall would become unacceptably fast, unless sufficient local detention capacity is installed.

The vulnerability (damage sensitivity) of urban and rural areas has become so high that damage due to flooding, water shortage, water quality problems, heat stress and related problems are economically very large and socially inacceptable. Increasing the design standards for protective facilities, to avoid damage by extreme weather up to a certain level, is a logical consequence.

Maintenance of facilities is crucial for their functioning, now, in times of crisis and on the long run. Their protective performances depend on the maintenance, as well as their provision of ecosystem services and other benefits. A professional maintenance organization and sufficient budget is required, both for grey and blue-green solutions. Innovative and private-public arrangements are sought to organise maintenance in the most efficient and effective way.

Coping capacity

Many things can be done to minimize the damage of extreme events that overload the threshold (design) capacity of the water system:

- Minimizing damage of extreme events like the “2021 waterbomb” and the 2018 drought should become a required element in designing and planning urban development and urban renewal projects as well as in rural and river reconstruction projects.
- Early warning systems can be improved, extending their lead time, improving their reliability and, above all, improving the communication with the population and emergency services. Contingency planning and the operational effectiveness of emergency services demonstrated weaknesses in the recent flood and drought events.
- Homeowners and businesses can take preventive actions to minimize the damage risk, both pro-actively and during the event. The people’s awareness of the risks of extreme weather is limited and so is their preparedness. Strengthening their self-reliance and self-sustainability by informing and training would be helpful.
- Critical infrastructure and vital facilities need extra protection. Their failure in operation is to be avoided ‘at any costs’. Extra protection is also needed for vulnerable people (children, elderly, handicapped, pregnant women, …) and for rare or dangerous species, e.g. in zoo’s). Saving pets is highly appreciated by the owners; likewise, saving livestock at farms is essential for farmers.
- Spatial planning, allocating the most vital and vulnerable functions to the safest places – or constructing safe spots for them **-** is an effective way to minimize the damage and thus create coping capacity.

Recovery capacity

Preparedness for recovery is limited. In Flanders and Germany many homeowners have some form of flood insurance via their private property or fire insurance contract; percentages range from 98 to as low as 50 %. In the Netherlands, damage of catastrophic flood events is covered by national government. Some private insurance contracts require to build back what was lost, not allowing for ‘building back better’. In all cases national government will make budget available for reconstruction – often with a substantial contribution from the European Union. Unlike for example in Japan [23], other aspects of recovery, such as recovery organization, seem to have limited attention. The benefits of fast recovery for the social-psychological condition of the traumatized population are not yet considered. And the importance of a fast restart of industrial production for the local, national and global economy is insufficiently realized so far.

Adaptive capacity

Scenario analysis shows us that the future is uncertain. Developments can go many ways, controlled and uncontrolled. Solutions to climate resilience are therefor to be flexible and adaptable toward that unknow future. Rigid, grey solutions can be robust and have a long lifetime. But too long a lifetime could be counterproductive in view of new conditions and/or new demands from society that will emerge by then. Most blue-green, nature-based solutions are better adaptable and/or develop a new equilibrium when local conditions change. The adaptive capacity of these solutions in combination with the many services and benefits they provide make them attractive, now and for the long run. However, this requires time, continuity, stable mandates and predictable financing.

Adaptive capacity also fits a 'research by design' approach to planning. Research by design is a valuable way to bring up new ideas in planning, allowing for co-creation of plans by the local population and other stakeholders. Co-creation helps create awareness of the problems and the features of the interventions.

Research, applied research, design and innovation are essential elements in stimulating the adaptive capacity. Together with academia, companies and the financial sector, governments should help develop, test and, if successful, mainstream new technological and social solutions. Organizing living labs and practical training facilities for constructors, builders, maintenance staff, practitioners and researchers is crucial for this. Independent knowledge institutes for applied technological and social research are playing a key role in developing innovating policies and practices, independently testing new solutions, developing scenarios for the public dialogue and decision makers, providing training and creating public awareness of both the problems and the potential solutions.

Climate adaptation is a continuous collaborative learning process in order to create collective intelligence, investigating new solutions, pathways and approaches. Learning from experiences elsewhere , from mistakes, narrow-escapes, disasters and recovery – see e.g. the sites of Climate-ADAPT and ClimateScan -is an obligation for all, so that we can adapt timely and sufficiently. This learning process however takes time, budget, energy and perseverance. Let's hope society is willing to provide this.

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Annex CII: Learning from disasters

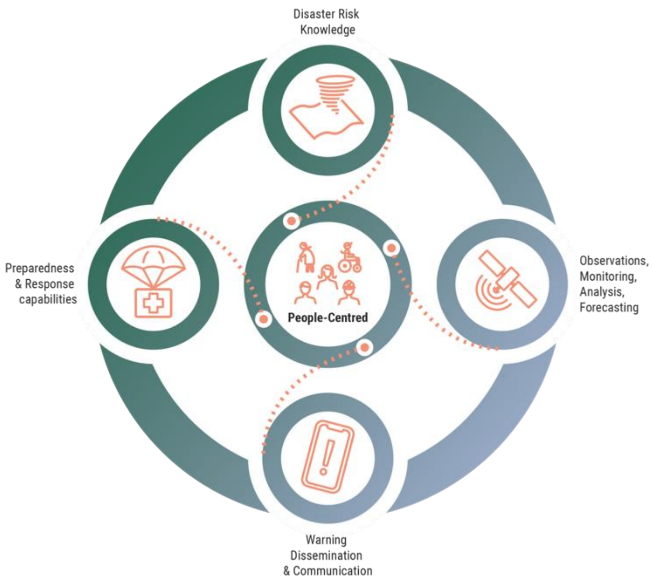
Details of non-Chinese case studies referred to in Chapter *Learning from Disasters*

Case 6: Early Warning For All

The Early Warnings for All initiative aims to ensure universal protection from hazardous weather, water, or climate events through life-saving early warning systems by the end of 2027, a call echoed by the United Nations Secretary-General António Guterres in 2022.

Today, one third of the world's people, mainly in least developed countries and small island developing states, are still not covered by early warning systems... This is unacceptable, particularly with climate impacts sure to get even worse. Early warnings and action save lives. To that end, today I announce the United Nations will spearhead new action to ensure every person on Earth is protected by early warning systems within five years. --- UN Secretary-General António Guterres on World Meteorological Day, 23 March 2022

With human-induced climate change leading to more extreme weather conditions, the need for early warning systems is more crucial than ever. Despite the urgent need, only half of the countries worldwide report having adequate multi-hazard early warning systems. A Multi-Hazard Early Warning System (MHEWS) is an integrated system which allows people to know that hazardous weather or climate events are on their way, and informs how governments, communities and individuals can act to minimize impacts. MHEWS should be people-centred to empower those threatened by hazards to act in sufficient time and in an appropriate manner, and must build on partnerships within and across relevant sectors.



Four pillars for delivery of end-to-end MHEWS

The initiative is built on four pillars to deliver effective and inclusive multi-hazard early warning systems, and is co-led by the World Meteorological Organization (WMO), the United Nations Office for Disaster Risk Reduction (UNDRR), the International Telecommunication Union (ITU) and the International Federation of Red Cross and Red Crescent Societies (IFRC) and other partners.

The delivery of Early Warnings for All requires scale up and coordinated investments and action across the four essential pillars of end to end, people-centred Multi-Hazard Early Warning Systems (MHEWS):

- Pillar 1: Disaster risk knowledge
- Pillar 2: Detection, observation, monitoring, analysis, and forecasting
- Pillar 3: Warning dissemination and communication
- Pillar 4: Preparedness and response capabilities

WMO leads the implementation of **Pillar 2: Detection, observation, monitoring, analysis, and forecasting**, with support from UN Development Programme (UNDP), UN Educational, Scientific and Cultural Organization (UNESCO) and UN Environment Programme (UNEP).

Pillar 2 is critical for societies to be better equipped to understand, prepare for, and respond to the evolving challenges of our changing climate: Early Warning Systems rely on worldwide sharing of data collected from the Earth's surface and space. This information is freely exchanged between countries and analyzed by highly advanced supercomputing modelling centres. These centres run numerical models which simulate how different parts of the Earth System (weather, hydrology, oceans, and cryosphere), interact with each other. From these simulations, predictions are made and then passed down from global to regional and national levels. This allows National Meteorological and Hydrological Services (NMHSs) to provide accurate forecasts to citizens. Without this coordinated effort facilitated by WMO, modern day weather and hydrology forecasts would not be possible.

Pillar 2 aims to address several challenges:

Only a third of WMO Members and Territories report having multi-hazard monitoring and forecasting system	**Half of the 30 countries** initially selected for Early Warnings for All coordinated assistance operate with basic monitoring and forecasting capacity, and close to a quarter with less-than-basic capacity	There are critical gaps in surface and upper air meteorological observations across Africa, parts of the Pacific and West of Latin America
Only 67% of WMO Members report having warning and alerting services available 24/7	**Only 56% of countries** report using hazard, exposure and vulnerability data in their forecasts, delimiting the progress on impact-based forecasting and warning	**Only 38% of Members** report having legal arrangements to enable MHEWS

In response to these, the Pillar 2 Implementation Plan is focused on delivering 5 outcomes:

Improving data quality and access:

It's essential to have more high-quality data available for checking and keeping an eye on major dangers. This data forms the backbone of services for weather, climate, and water. We need to make sure countries can get to and use this data to watch over their main risks.

These efforts start with setting up modern measurement networks (Global Basic Observing Network, Regional Basic Observing Network) and building the capacity of the NMHSs to maintain and upgrade them. Monitoring is not only done by in-situ measurement: crucial data also come from satellites (Coordination Group for Meteorological Satellites) and airplanes (Aircraft Meteorological Data Relay). Increasing the availability and usability of these data sets in all parts of the world is essential. Measurements by themselves are not enough - data needs to be collected and shared in real-time to feed the forecasting models, to be analyzed by the operational centers, and to inform decision-makers.

Sharing data worldwide:

Ensuring easy sharing and access to data globally is paramount, particularly when it comes to forecasting and issuing early warnings. Organizations tasked with collecting or generating data sets, creating forecast products, refining information, and offering storage services play a pivotal role in this effort. Our goal is to enable smooth data sharing across local, national, and global scales while keeping it cost-effective.

The WMO Information system (WIS) is the powerful mechanism that enables this international data exchange. We focus on improving real-time monitoring data exchange, ensuring this data is ingested into global and regional forecasting centers (WMO Integrated Processing and Prediction System). Additionally, we work on the seamless flow of digital predictions to the regional and national forecasting centers.

Enhancing forecasting capabilities:

Our focus is on refining the utilization of predictive tools for significant weather-associated challenges. The effort begins with establishing global and regional forecasting centers (WMO Integrated Processing and

Prediction System) producing state-of-the-art predictions and providing countries with high-level products tailored to meet their needs. Leveraging improved data, advanced computational power, and deepening insights into weather dynamics, our weather forecasting precision is enhancing. As we coordinate member capabilities, we prepare and distribute meteorological analyses and forecast products for all Members, ensuring the provision of consistent and harmonized services, which is essential for our future readiness.

The AI revolution allows us to add improved capabilities to the forecasters toolkit in the very short time range (nowcasting) and in the forecasts for the coming days and weeks.

Proactive measures for early action:

It's essential that our forecasts and alerts adhere to international standards. Strengthened by regional partnerships and bolstered by advanced tools and training, we're dedicated to enabling every nation to issue round-the-clock warnings. Our commitment isn't just about predicting severe weather events; we also emphasize the associated dangers. Such detailed insights equip communities to effectively brace themselves, safeguarding residences, infrastructure, and their environment.

Establishing robust leadership frameworks:

Robust governance is pivotal, which involves crafting appropriate policies, establishing efficient organizations, and ensuring collective participation to facilitate prompt warnings and actions. Such frameworks also foster platforms for knowledge exchange and discussions on current advancements and trends in disaster risk reduction.

The 193-Member Congress, which is the WMO's top decision-making body, has accorded that Early Warnings for All is the top overriding priority of the organization, as enshrined in the WMO Strategic Plan 2024–2027

Accordingly, key WMO activities are coordinated and consolidated under the Early Warnings for All umbrella including the work of the technical commissions and regional activities aligned to achieve the goal.

National Meteorological and Hydrological Services are the official and authoritative providers of early warnings for hydrometeorological hazards.

https://wmo.int/activities/early-warnings-all/wmo-and-early-warnings-all-initiative

Case 7: Bangladesh – Early Warning Systems

Early warning is a key element of disaster risk reduction. In recent decades, there have been major advancements in medium-range and seasonal forecasting. Babel et al. (2013) [1] developed an experimental medium-range (1–10 days) probabilistic flood-forecasting model for Bangladesh. This progress provides a great opportunity to improve flood warnings, and therefore, reduce vulnerability to disasters. This paper describes an integrated system on medium-range flood forecasts based on agricultural users' needs in order to reduce the farming community's flood impacts. For example, 1- to 10-day forecasts may provide farmers a range of decision options such as changing cropping patterns or planting times.

The methodology included risk and vulnerability assessments conducted through community consultation. The study involved developing a flood risk map and response options to flood risk probabilistic forecasts based on farmers' needs for early warning. Understanding the use of probabilistic forecasts is still very limited, and operational forecasters are often sceptical about the ability of forecast recipients to understand the ensembles prediction system.

This study showcases the ability to use probabilistic forecasts for operational decision-making purposes.

The forecast lead-time requirement, impacts, and management options for crops and livestock were identified through focus group discussions, informal interviews, and surveys. The results included flood risk mapping according to the vulnerability of the communities in the study area and the early warning impacts during and after the flood events.

https://www.sciencedirect.com/science/article/abs/pii/S2212420915300509

Case 8: Singapore – Water Wise

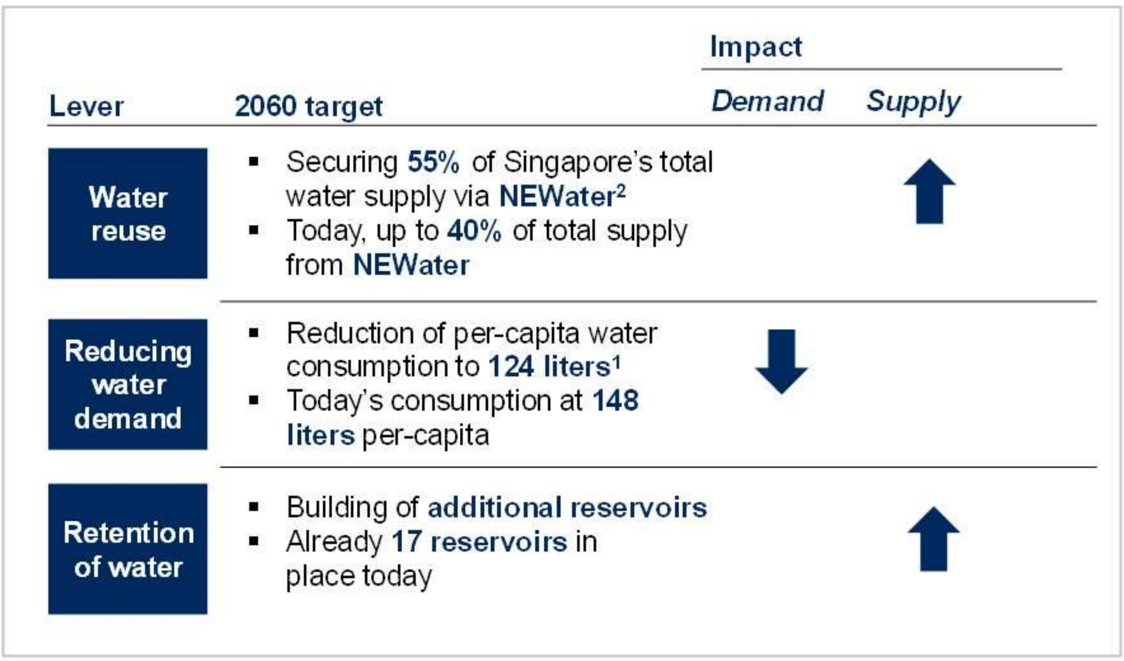
Singapore's circular water economy

In response, Singapore has been at the forefront of developing what is now called a circular water economy. While water becomes successively more polluted in a linear system, a circular water economy aims to reduce pollution to enhance future use. The circular water economy thus rests on maximizing water reuse. Additional pillars of the circular water economy are freshwater demand reduction, and increased rainwater retention.

Singapore has been at the forefront of developing what is now called a circular water economy

… from maximizing water reuse, to reducing freshwater demand, to increasing rainwater retention

Circular water economy – official targets formulated by Singapore



Lever	2060 target	Impact: Demand	Impact: Supply
Water reuse	▪ Securing **55%** of Singapore's total water supply via **NEWater**[2] ▪ Today, up to **40%** of total supply from **NEWater**		↑
Reducing water demand	▪ Reduction of per-capita water consumption to **124 liters**[1] ▪ Today's consumption at **148 liters** per-capita	↓	
Retention of water	▪ Building of **additional reservoirs** ▪ Already **17 reservoirs** in place today		↑

[1]*Target for 2030 is 140 litres; extrapolating the needed compound annual growth (CAGR); to reach this implies a target of 124 litres for 2060*

[2]*High grade reclaimed water*

Source: Adapted from ING – DiBa (2017); Public Utilities Board (PUB)(2017)

The Singaporean government has adopted ambitious plans to increase the rates of reused water. Reclaimed wastewater is recycled into NEWater. The five existing NEWater plants meet 40% of water demands today. Singapore aims to increase this share to 55% by 2060 by extending their production. NEWater is used for non-potable tasks, but during dry spells it also tops up existing freshwater reservoirs.

To reduce freshwater demand, water tariffs are currently being raised by 30% in two steps…

To reduce freshwater demand, water tariffs are currently being raised by 30% in two steps. The first raise took place in July 2017; the second will be in July 2018. The government regards it as an important and effective measure to reduce consumption. Indeed, after the raise in 2000 the per capita consumption in Singapore declined from 165 litres back then to 148 litres today. Furthermore, a mandatory labelling scheme promotes the use of water conserving fixtures and appliances in Singapore.

Finally, the government seeks to raise public awareness regarding water conservation practices through campaigns and public spaces that incorporate water bodies. Singapore hopes to reduce the per capita consumption to 124 litres by 2060.

…the government is also targeting an increase in harvested rainwater

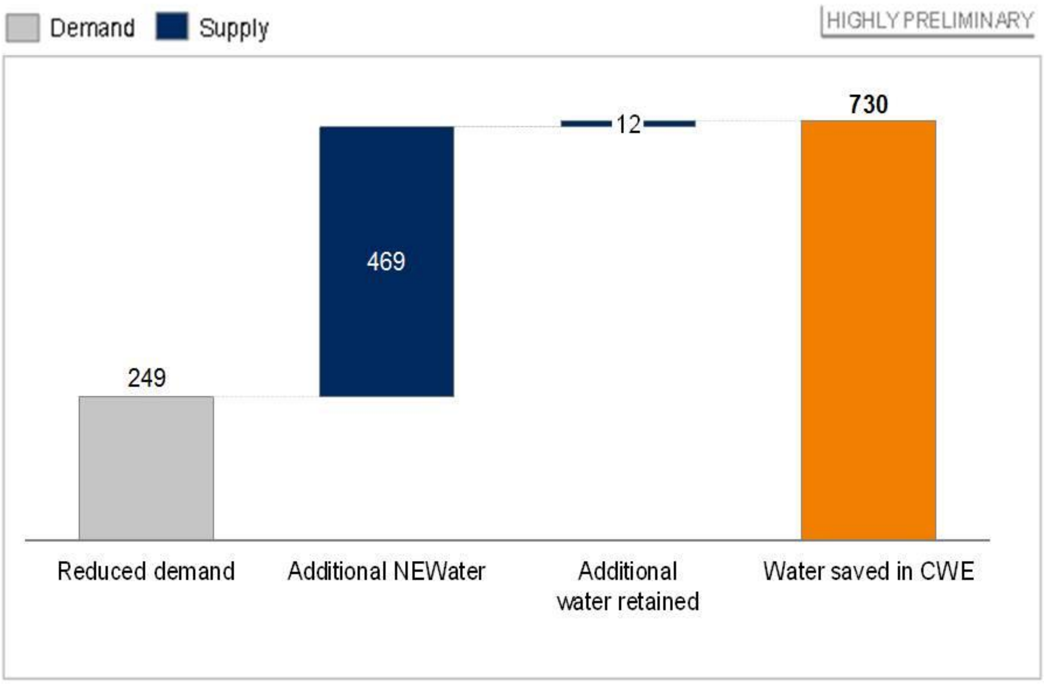
66% of Singapore's surface is already regarded a catchment area with the country overall featuring 17 catchment areas that harvest rainwater. Their share will increase by protecting previously unprotected water bodies to make them suitable for potable use. A separate underground sewerage system collects harvested urban storm water, ultimately suitable for large-scale consumption. The government targets a 15% share of harvested rainwater by 2060.

Our own tentative calculations quantify the impact of Singapore's circular water economy. By 2060, 730 million cubic metres of freshwater are saved compared to a business-as-usual scenario. However, implementing such a circular water economy is costly. The main cost drivers are NEWater processing and rainwater retention costs, with NEWater processing costing USD0.3 per cubic metre for instance. These costs are justified, though, considering that water scarcity can decrease GDP growth by up to 6 percentage points.

By 2060, 730mn m^3 of freshwater are saved compared to a business-as-usual scenario…

…costs of a circular water economy are justified as water scarcity can decrease GDP growth by 6 percentage points

Water saved via Singapore's envisaged circular water economy



[1]Compared to a business-as-usual model

Source: Authors' own calculations

https://chinawaterrisk.org/opinions/learning-from-singapores-circular-water-economy/

https://urbanresilience.medium.com/a-city-of-gardens-and-water-debf4eb5fe39

I took three main lessons from my short time in Singapore, lessons that can be applied to the US and just about any other place in the world.

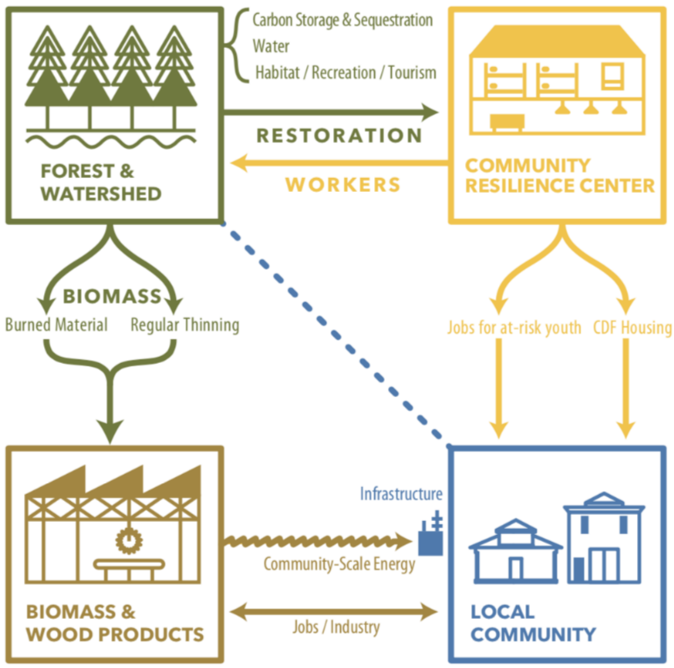
First is the importance of having a comprehensive water management strategy to build resilience in the face of a changing global climate and increasing resource demands. Global warming increases the frequency and severity of flooding and droughts, exacerbating Singapore's already significant water challenges. As early as 1972, just seven years into nationhood, Singapore had developed a far-sighted Water Master Plan to achieve water independence. Government leaders chose to value and manage all water — rainwater, wastewater, drinking water — through an integrated system. The holistic approach has paid off, and other cities would be well served by adopting it.

Second, integrating water resource management with other key public and private functions, such as housing, urban development, and parks, brings added benefits like increased property values and innovative, efficient use of scarce land. According to the Centre for Liveable Cities, "[d]ynamic urban governance is one key lesson … PUB understood the importance of working with other agencies and involved them accordingly to create visionary integrated landscapes."

Third, everyone wins when you incorporate water in the life of your city. Combine the need for storm water drainage with open space for recreation and wildlife habitat. Seize opportunities to restore or mimic natural hydrological processes to sustainably serve multiple water management functions. Engage citizens young and old through the magnetic attractiveness of water, creating opportunities to build social awareness of our linked fates in a climate-challenged world.

Case 10: California wildfires: Community and Watershed Resilience Program_

The Rim Fire in California started on August 17, 2013 and burned over 1,041 km^2, becoming the third largest wildfire in California history and one of the most severe fire events in terms of its rapid growth, intensity, size and smoke. It resulted in significant impacts to the local economy, threatened access to clean water, disrupted the lives of thousands of people, and damaged air quality. With funding from a federal program, a combination of local, state and federal agencies collaborated to address unmet recovery needs and build long-term resilience. The program applied a systems approach to address forest recovery, economic recovery and community building. Two community resilience centers were built as evacuation centers for future disasters and during other times have been used as warming and cooling centers, charging stations for medical equipment during power outages, commercial kitchen uses for local small business product production, local meetings for community groups and nonprofits and job training. This model is now being replicated across the state.



Three pillars of the Community and Watershed Resilience Program

Source: https://www.hcd.ca.gov/community-development/disaster-recovery-programs/ndrc/docs/ca_ndr_overview.pdf

Case 11: Repeated flooding in Nairobi

In recent years, Kenya has experienced major flood events roughly every two years on average affecting about 70,000 people per event (Arreyndip, & Kitengu 2024). Most flooding events occur during the long rains between March and May (MAM) or during the short rains between October and December (OND). In a period of 40 years from 1961 – 2018, Kenya is recorded to have experienced 21 major flood events with the most rainfall anomalies recorded in 1961, 1997-1998, 2006, 2012, and 2018. The 1997-1998 El Nino floods are estimated to have affected over half a million people and to have cost $870 million equivalent to 11% of the country's GDP leading to loss and damages across various sectors such as the Water systems, Roads, Communications, Buildings, Health systems, Agriculture among others (Kilavi et al., 2018). In 2024, the MAM long rains linked to El Nino 2023, triggered flash floods that killed at least 228 people, left 72 people missing, and displaced more than 212,000 people (Arreyndip & Kitengu, 2024). Additionally, over 9000 livestock were lost and at least 41,000 acres of farmland submerged (Acaps, 2024).

The long MAM rains in Nairobi led to flash floods that caused extensive damage and not only disrupted the lives and livelihoods of Nairobi's residents but also highlighted the city's vulnerability to climate-induced disasters (Rukanga, 2024). Historically, Nairobi has experienced several major flooding events, each revealing critical weaknesses in urban planning, drainage systems, and emergency response mechanisms. The floods have exacerbated the living conditions in informal settlements such as Kibera, Mukuru and Mathare Slums (Tom et al., 2022), where inadequate infrastructure and poor drainage systems leave residents particularly exposed to the impacts of heavy rainfall. The socio-economic losses from these events are staggering, with significant costs associated with damage to property, loss of agricultural productivity, health emergencies, and the disruption of essential services (Arreyndip & Kitengu, 2024).

This widespread destruction by the floods has revealed the urgent need for comprehensive flood management and mitigation strategies with government agencies, non-government agencies, and community groups working towards enhancing early warning systems, improving infrastructure and drainage systems, promoting sustainable land use practices, strengthening disaster preparedness and response, enhancing risk communication and public awareness as well as fostering cross-sectoral collaborations and partnerships. Despite these efforts, significant gaps remain in policy formulation, implementation, and coordination among stakeholders.

There is, therefore, a pressing need for a comprehensive, evidence-based policy framework that addresses the root causes of flooding, the consequences of extreme weather events and integrates sustainable solutions (Prince, 2024).

Case 12: Flooding and Rebuilding in the Aachen region 2022

The floods of mid-2021 caused widespread damage and loss of life in parts of Germany, notably Rhineland-Palatinate and North Rhine-Westphalia. The event was classified as having a once in 400 years probability and occurred in a moderately hilly area with small rivers. The KAHR project is tasked with scientific monitoring of the reconstruction, and formulating recommendations to guide it. Interesting observations on the event itself include: all 24 dams in the area performed as designed without damage; the many traditionally designed bridges in narrow valleys added significantly to the destruction; industrial protection systems that were designed to withstand once-in-500-year floods failed nevertheless; chemically contaminated mud posed a health hazard but was only flagged late, while inhabitants were already exposing themselves shoveling the mud.

The project put forward recommendations for the reconstruction. These point to, obviously, the need for smarter engineering in things like placing and designing bridges and location and placement of energy installations. The critical role of space on hillsides and in narrow valleys is underlined once more, as is the need for good general access to risk information and for really fast warning in emergency situations; active preparedness and training at local level, even if these events are deemed infrequent. Rebuilding of individual houses and small businesses seems to have happened mostly in much the same location and type as they were, due to narrow insurance policy.

The KAHR monitoring project is funded from the federal science budget and involves many organisations. Other than this, and related expert-level and academic knowledge exchange, the emphasis of learning from the disaster and addressing the risks seems to be at the level of a Land, not the German federal State. (The equivalent in China and many other countries would be a province.)

www.hochwasserkahr.de (in German)

Case 14: New York – Hurricane Sandy Response

After Hurricane Sandy impacted 13 states, costing more than $65 billion in damages and economic loss, President Obama’s Hurricane Sandy Rebuilding Task Force launched an innovative design competition, Rebuild by Design, that coupled innovation and global expertise with community insight to develop implementable solutions to the region's most complex needs. In partnership with U.S. Housing and Urban Development (HUD), Municipal Art Society, Regional Plan Association, NYU's Institute for Public Knowledge, The Van Alen Institute, and support from The Rockefeller Foundation and other philanthropic partners, the multi-stage competition guided participants through in-depth research, cross-sector, cross-professional collaboration, and iterative design. Participants collaborated with community and local government stakeholders to ensure each stage of the competition were based on the best knowledge and talent and final proposals would be realistic and replicable.

The **Rebuild by Design** Hurricane Sandy Design Competition changed the way the federal government responds to disaster and became the model now used in other regions to prepare communities for future uncertainties. Its success has also inspired other efforts. In 2014, President Obama launched the National Disaster Resilience Competition, which awarded $1 billion to 13 cities and states across the country to fund resilience-building projects. Internationally, The Rockefeller Foundation, in partnership with the USAID and The Swedish International Development Agency, developed the Global Partnership for Resilience based on the Rebuild by Design competition model and collaborative approach. The competition model's success also led to the formation of the Rebuild by Design organization, which is helping cities and communities around the globe become more resilient through collaborative research and design.

https://rebuildbydesign.org/hurricane-sandy-design-competition/

https://rebuildbydesign.org/digital-media/books/

https://www.nai010.com/en/product/too-big/

https://www.clc.gov.sg/docs/default-source/urban-solutions/urb-sol-iss-9-pdfs/essay-rebuild-by-design.pdf?sfvrsn=63c0e49c_2

Case 15: Flanders – Post Floods, Preparedness / Resilient Waterland

After flooding in Wallonia and along the Maas and Demer, the Flemish Government appointed a multidisciplinary expert panel on flood protection in October 2021. The panel provides substantiated advice to better protect Flanders against high water and to define the desired level of water safety. In the advice "Resilient Waterland" we formulate the strategy for water security in Flanders.

The impact of climate change translates into longer and more intense periods of precipitation and drought and in sea level rise. The water bomb of July 2021, with terrible consequences, unnecessary casualties and damage, was a water disaster that hit us, literally and figuratively, and also sounded an alarm bell for flood protection in Flanders. It exposed strengths and weaknesses and forced to face the facts: now is the time to act. The Flemish Government therefore appointed a multidisciplinary expert panel on October 22, 2021 to provide advice for future policy in Flanders.

Water security = Water safety + Water availability

With 'Resilient Waterland' we formulate, together with the other experts, an adapted strategy for water security in Flanders. The desired level of water safety can only be achieved in Flanders if the natural functioning of the water system in every upstream landscape and in every valley is rebuilt. If water is not given the space it needs, it will create that space itself, as became apparent last summer. This space for water must be available everywhere in Flanders, not just in the valleys. To achieve this, four water sites we put forward: tidal rivers, watercourses, sponge landscapes and cities and villages. This not only limits the damage caused by exceptional rainfall (water safety), but also focuses on replenishing water supplies to bridge periods of drought (water availability).

Flanders is taking control

In the advice Resilient Waterland, a strategy is formulated for water security in Flanders: ten coherent actions and an action plan to implement that strategy. An immediate call to government and society to get to work. It starts from existing successful and promising initiatives in Flanders. At the same time, it is pointed out that increasing water security and availability in the light of climate evolution is currently going too slowly. The realization must be accelerated, otherwise climate change will overtake us, with all its consequences.

The expert panel was also tasked with defining the desired level of water safety. Determining that level requires an integrated approach to the water system and a social debate is necessary. First and foremost, it is proposed defining task-setting goals in the field of water security (water safety and water availability) that can then be translated into concrete local action programs. The panel recommends investing heavily in Flemish management, in close consultation and collaboration with local and regional partners. To this end, it is putting forward a mandated Flemish Water Commissioner, who will put the importance of water first, over interests and partners. The directing role implements the water security goals and is best linked to a multi-year Flemish Water Security Fund, knowledge assurance and an innovation program. The panel also proposes to set up *Bekkenhuizen* that coordinate and strengthen implementation on the ground by local coalitions.

The panel calls for intervention in standards, rules and policies in order to ensure the maximum impact of the principles of retention, infiltration, buffering and delayed drainage in spatial development. What takes time must be accompanied by pilot projects, coalitions and innovative practices.

Water knows no boundaries

With this advice. The panel emphasizes the importance of international cooperation and calls for the Flemish approach to be placed on the European and world agenda. It calls for strengthened European cooperation for water security and water safety of our rivers and streams, cities and infrastructure, coasts and estuaries. The EU Adaptation Agenda, the Green Deal, the climate approach and international collaborations in the Scheldt and Meuse can be used for this

The panel also wants to focus on increased preparedness of people and infrastructure. Flanders must work on a culture of dealing with water. Citizens and companies must want to do their part and see it as their duty to retain water as much as possible.

The panel’s advice is not a conclusion, but a new beginning. The start of a recalibrated systemic approach for water safety and water security in Flanders. This is how Flanders is made a Resilient Waterland.

https://www.vmm.be/nieuws/archief/advies-weerbaar-waterland.pdf/view

The following areas will work with the advice of the expert panel:

- The upper reaches of the IJzer, where a solution is being sought for flooding in the villages along the IJzer (province of West Flanders).
- The area between Kortrijk and Roeselare, where 3 local area coalitions have united to prepare the urbanized area for the climate shocks in the Leie valley (province of West Flanders).
- The Gete region in Flemish Brabant, where work is being done to tackle erosion on the loam plateaus so that water and mud nuisance is avoided (South Hageland Regional Landscape and province of Flemish Brabant).
- The valley of the Herk and Mombeek in Limburg where the valley is designed with grasslands to store as much water as possible (Haspengouw and Voeren Regional Landscape).

Flemish Minister for the Environment Zuhal Demir gives the 'Resilient Water-Land-Scape' route the green light. In this process, 4 Water-Land-Scape areas will translate the 'Resilient Waterland' advice from the expert panel on high water protection into practice. For example, Flanders is working on the transition to a landscape system that first retains water as much as possible for infiltration, and only then reuses or drains the remaining water if this proves necessary. 5 million euros have been provided from the Flemish climate adaptation plan for the implementation of the Resilient Water-Land-Scape trajectory.

Case 17: Mozambique – Partially Prepared

Mozambique is one of the world's most vulnerable countries to climate-related hazards. But extreme weather events do not have to become disasters. A robust early warning system is critical to building resilience among communities and authorities to ensure that when the next weather hazard strikes, they are ready to receive and correctly interpret the warning messages and take immediate action to minimize its impact. The World Bank will continue to support the Government of Mozambique to strengthen its early warning system and the capacity of local communities to respond to future climate shocks.

https://www.worldbank.org/en/news/feature/2023/09/11/early-warning-system-saves-lives-in-afe-mozambique

https://www.anticipation-hub.org/experience/anticipatory-action-in-the-world/mozambique

Case 18: Peru – Flood Resilience Task Force

A part of the world where climate change is particularly consequential is the Andes. Peru's rugged coastal provinces on the Pacific Ocean constitute a prime example. Within Peru, this area accounts for only 10s per cent of the land area but is home to more than half of the population.

According to the Ministry of the Environment of Peru, 67 per cent of disasters in Peru are related to climatic phenomena. Climate-driven changes include glacier retreat and shifts in rainy season, causing shifts in agricultural cycles, as well as recurring landslides and floods. One important element for the region is El Niño, the warm water upwelling that every few years affects worldwide weather, with very heavy rainfall in these parts of Latin America. Climate projections have identified the risk that El Niño events may become more frequent.

In January 2017, coastal waters off Peru warmed suddenly and unexpectedly. Low lying coastal storms dropped intense rainfall at low elevation, causing flooding and devastating landslides. The flooding continued for nearly three months, affecting over 1.5 million people, causing hundreds of deaths, and damaging hundreds of thousands of homes – in some provinces, destroying one-third of dwellings. Agricultural land was ruined, roads blocked and other infrastructure damaged. South Colombia, too, was hit but the damage in Peru was especially severe.

Aside from national and international relief efforts, two elements of learning after the 2017 floods are noteworthy for this SPS.

First, under the auspices of the Zurich Flood Resilience Programme and others, a systematic analysis took place of what happened, what failed, and how recovery and rebuilding could use this painful opportunity to reduce risks, build back better and become more resilient. Key insights are the following.

1. "Greater coordination and communication is needed between all levels and sectors of government and between government and non-government entities." The analysis places this in the context of Peru being a young democracy.

2. “Social recovery is as critical to disaster risk reduction as infrastructure recovery”. The analysis refers to communities that have lost everything and where the social fabric is essential.

3. “Resettlement needs to be approached as a multi-faceted issue”. The analysis explains: “Resettlement is being framed as the solution to risk in areas deemed ‘unmitigable’. However, resettlement is far more complex than just relocating people from one area to another, and ‘unmitigable’ is not a black and white condition.“

4. “Protection infrastructure must be viewed in conjunction with its residual risk. Even with protective infrastructure, there is residual risk.” The analyis spells out implications in terms of awareness, early warning capacity, land use regulation, inspection and enforcement.

Source: Venkateswaran, K., MacClune, K. and Enriquez, M.F. (2017). Learning from El Niño Costero 2017: Opportunities for Building Resilience in Peru. ISET International and the Zurich Flood Resilience Alliance. http://floodresilience.net/resources/collection/perc

Second, Practical Action, in conjunction with the Zurich Flood Resilience Programme, embarked on a community-based comprehensive programme of flood resilience. In Peru, it focused on watershed vulnerable to landslides and floods. The decade-long programme gathers meaningful data from the communities most affected, in order to steer interventions. It raises awareness of disaster risk management, for example through ‘Bigadero for a Day’ This serves as a basis for more specialized training and events. The programme also sets up activities such as the basin-wide Participatory Rainfall Monitoring Network, coupled to the National Service of Meteorology and Hydrology, using manual rainfall gauges and a WhatsApp network. https://zcralliance.org/blogs/ten-years-alliance-peru/

Case 19: Water at the Heart of Climate Action

The **Water at the Heart of Climate Action** is an upcoming project for systematic change that aims to accelerate and scale up water action to mitigate the impacts of water related risks and increase the climate resilience of affected communities.

Timeline: August 2023- August 2028

Budget: 55 Million Euros in total

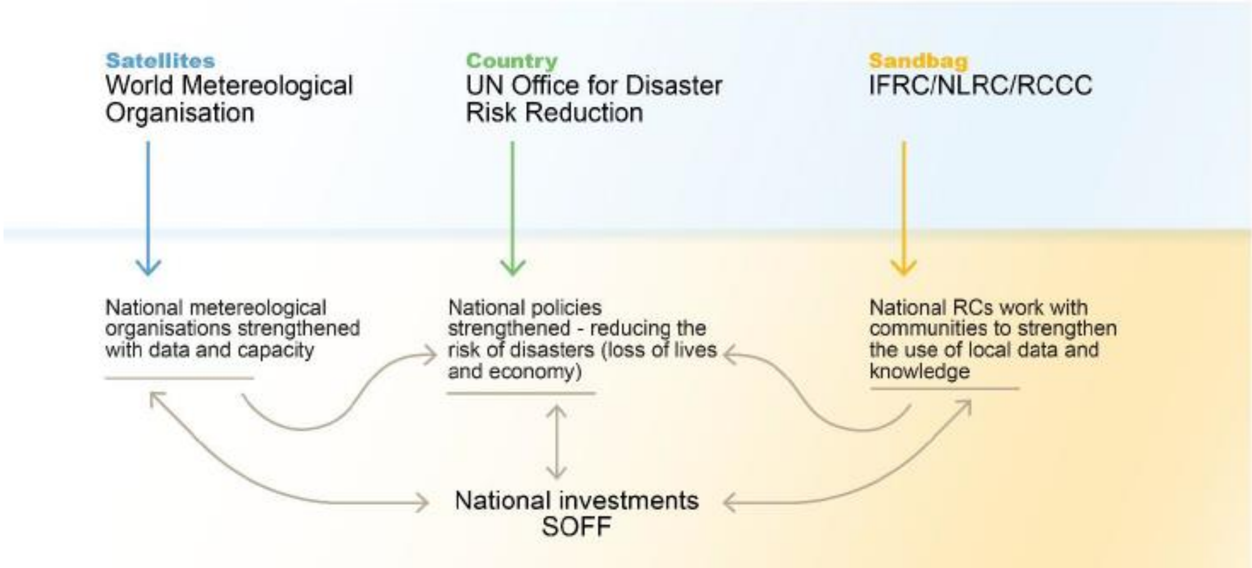
Donor: Ministry of Foreign Affairs (MoFA), Kingdom of Netherlands

This initiative of five years brings together three international organizations with a global mandate on the technical areas:

- International Federation of Red Cross and Red Crescent Societies (IFRC)
- United Nations Office for Disaster Risk Reduction (UNDRR)
- World Meteorological Organization (WMO)

These organizations are already working together under the umbrella of the Centre of Excellence for Climate and Disaster Resilience. They will be further strengthened by a dedicated UN multi-partner financing mechanism to fund weather and climate surface-based observations: the Systematic Observations Financing Facility (SOFF). These partners are uniquely positioned to deliver targeted results in local-level policy and products.

The partners involved in the initiative agreed to focus efforts on Africa, and, where possible, to select countries within the same river basin, as integrated water management and early warning early action approaches do not always follow political boundaries. They will deliver climate and hydrological products and services to support national and local disaster management actors. They share a common goal to ultimately reduce water risk and increase resilience in the most vulnerable communities. By unlocking barriers across the whole hydro-meteorological (Hydro-Met) value chain (referred to as "from satellites to sandbags"), this partnership will model a way of working that can ideally be scaled and replicated. The approach puts country teams in the lead and will be piloted in four countries around the Nile River Basin (Ethiopia, Sudan, South Sudan, Uganda).



This initiative contributes to the "Early Warnings for All Initiative" (EW4All) based on the UN Secretary General's challenge to provide early warnings for all by the end of 2027 and will be part of the commitments of the Netherlands Government for the Global Water Action Agenda presented the UN 2023 Water Conference.

https://www.floodmanagement.info/water-at-the-heart-of-climate-action/

Case 20: Water As Leverage -- Innovative Preparedness

Climate change-induced floods, droughts, pollution, starvation, diseases, and conflicts are fundamentally related to water. Coupled with rapid and unplanned urbanization, these issues threaten the resilience of life support mechanisms on earth. Cities worldwide face water-related challenges, growing population density, and urban expansion. Siloes between science, national and local governance, communities and financiers of urban infrastructure and housing development is causing a disconnect and is hampering sustainable urban development. Thereby often aggravating water and climate risks instead of mitigating them. But cities can become part of a solution when water is a lever and a unifying force for sustainable urban development.

The global Water as Leverage (WaL) initiative is based on this conviction. The programme facilitates resilient solutions by connecting long-term urban planning with short-term innovative transformations, ambitious climate adaptation plans with bankable projects, and water system knowledge with the construction of resilient cities. WaL integrates science and research, design, finance and implementation practices with inclusive urban partnerships.

The objective of the global Water as Leverage program is to accelerate climate change adaptation through innovative interventions developed in and with communities at risk, and with the partners that need to see through the implementation.

https://www.worldwateratlas.org/curated/water-as-leverage/
https://drive.google.com/file/d/1s9tNlk9VCLwtXakQ6-POKPlY4W6P112v/preview

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Annex D. Suggested further reading

English-language draft 20240904

This annex lists selected resources for the reader who wants to delve deeper in the subject of adaptation to climate change, in the context of urban and rural development. Long as well as short items are included. No comprehensiveness is pretended. Typically, these reports and websites were exchanged among team members for inspiration while planning and compiling the current report.

1	WMO: State of the Global Climate	https://wmo.int/publication-series/state-of-global-climate	The authoritative report on climate status and trends, also highlighting the impact of extreme weather.
2	IPCC Climate Change 2022: Impacts, Adaptation and Vulnerability	https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/	The Working Group II contribution to the Sixth Assessment Report assesses the impacts of climate change, looking at ecosystems, biodiversity, and human communities at global and regional levels. It also reviews vulnerabilities and the capacities and limits of the natural world and human societies to adapt to climate change.

3	IPCC Special report on Land Use	https://www.ipcc.ch/srccl/	Reports on A) People, land and climate in a warming world; B) Adaptation and mitigation response options; C) Enabling response options; and, D) Action in the near-term.
4	Future Water Challenges – bending the trend	https://www.pbl.nl/en/publications/policy-summary-of-the-geography-of-future-water-challenges-bending-the-trend 10 min shortread: https://themasites.pbl.nl/future-water-challenges/shortread/bending-the-trend/	Model-based assessment to 2070, exploring the effect of interventions worldwide. Distinguishes River basins; Cities; Deltas and Coasts; Drylands
5	Visualisation of Cascading Effects of Climate Change	https://www.scientificamerican.com/article/visualizing-climate-disasters-surprising-cascading-effects/	Short article visualizing the cascading effects of climate change, distinguishing secondary effects and short-term impacts.
6	The five pillars of climate resilience	De Graaf-van Dinther R, Ovink H (2021) The five pillars of climate resilience. In: De Graaf-van Dinther R (eds) Palgrave Macmillan, ISBN 978-3-030-57536-6, p 1-19, https://doi.org/10.1007/978-3-030-57537-3_1	The basis of the assessment framework employed in this report, applied to climate resilient urban areas; governance design and development in coastal delta cities.

7	China National Climate Adaptation Strategy 2035	June 2022, 54 pages, in Chinese only http://big5.www.gov.cn/gate/big5/www.gov.cn/zhengce/zhengceku/2022-06/14/5695555/files/9ce4e0a942ff4000a8a68b84b2fd791b.pdf	Jointly issued by 17 ministries and commissions. Specified the goal of building a climate-resilient society by 2035.
8	Notice on Deepening the Pilot Construction of Climate-Resilient Cities in China	August 2023, 7 pages, in Chinese only https://www.gov.cn/zhengce/zhengceku/202308/content_6900892.htm	Issued by 8 ministries and commissions. Aims to accelerate the Action Program for Urban Adaptation to Climate Change; identifies 10 priorities.
9	National Delta Programme, The Netherlands	https://english.deltaprogramma.nl/ https://english.deltaprogramma.nl/three-topics/spatial-adaptation	The Spatial Adaptation theme is directly related to the subject matter of SPS Adaptation.
10	Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change	https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082	
11	EU Climate Adaptation Mission	https://climate-adapt.eea.europa.eu/en/mission/	Sketches the use of EU research and development framework in support of location-specific interventions.

12	US White House: principles for adaptation to climate change	https://www.whitehouse.gov/wp-content/uploads/2024/07/Climate-Resilience-Game-Changers-Assessment.pdf	35-page policy guidance document, July 2024. Provides principles, sketches alliances, highlights connection with innovation.
13	Atlas of Accountability – rebuild by Design	https://rebuildbydesign.org/atlas-of-disaster/	
14	Mazzucato Mission Approach	Mazzucato M (2019) *Governing missions in the European Union*. Independent Expert Report. European Commission, DG for Research and Innovation, ISBN 978-92-76-08745-8, https://research-and-innovation.ec.europa.eu/knowledge-publications-tools-and-data/publications/all-publications/governing-missions-european-union_en	Next to the key capacities and enabling conditions identified in the assessment framework applied in this study, an ambitious, energetic, goal-driven movement is essential to move toward climate resililince.
15	Inclusive Adaptation Planning (C-40 and WRI)	https://www.c40knowledgehub.org/s/article/Inclusive-Climate-Action-Planning-Policy-Recommendations?language=en_US	17 possible interventions; policy recommendations
16	World Resources report Towards equitable Cities	https://publications.wri.org/transformations-equitable-sustainable-cities	
17	World Bank Toolbox for relief and reconstruction	https://www.worldbank.org/en/about/unit/brief/crisis-preparedness-and-response-toolkit	

18	Social Inclusion in Adaptation in Asia – What can we learn?	https://research.rug.nl/en/publications/social-inclusion-in-water-climate-adaptation-what-we-can-learn-fr	
19	Living with water: climate adaptation in the world's deltas	https://gca.org/reports/living-with-water-climate-adaptation-in-the-worlds-deltas/	
20	EU-funded research – RAMSES project	https://www.lse.ac.uk/cities/research/cities-environment-and-climate-change/RAMSES	RAMSES is a European research project which aims to deliver quantified evidence of the impacts of climate change and the costs and benefits of a wide range of adaptation measures, focusing on cities.
21	Adaptation Gap report 2023 (UNEP)	https://www.unep.org/resources/adaptation-gap-report-2023	Comprises a discussion of the finance gap
22	EU Guidance on river basin management in a changing climate	https://op.europa.eu/en/publication-detail/-/publication/0bdb11d0-4322-11ef-865a-01aa75ed71a1 https://climate-adapt.eea.europa.eu/en/news-archive/guidance-2018river-basin-management-in-a-changing-climate2019-adopted-by-eu-water-directors	This guidance aims to help water managers to integrate adapting to the inevitable impacts of climate change, such as the increase of intensity and frequency of intensive rainfall, prolonged droughts, and heat waves as well as slow-onset changes like

			warming, spread of invasive species and sea level rise, with special attention to nature-based solutions, cross-border/transboundary aspects, as well as the climate check of measures.

Annex E: SPS Europe work visit report

China Council for International Cooperation on Environment and Development

Special Policy Studies Work Visit Report

Trip in Europe (Netherlands – Belgium - Germany)

July 2024

Summary

The European work visit on Special Policy Study (SPS) focused on green urban development and climate adaptation was conducted from July 1 to July 9, 2024, encompassing visits to the Netherlands, Belgium, and Germany. This trip aimed to investigate diverse policy approaches, practical implementations, and innovative solutions addressing climate adaptation in different European regions. The delegation included experts from the China Academy of Urban Planning and Design (CAUPD), the Dutch Ministry of Infrastructure and Water Management (Ministry of I&WM), Deltares, and other relevant institutions and organizations.

From July 1 to July 9, the delegation conducted an in-depth visit to the Netherlands, Belgium, and Germany to explore and understand diverse climate adaptation strategies. Throughout the visit, the delegation engaged in 18 formal presentation sessions and conducted 9 site visits, gaining a comprehensive overview of regional climate adaptation approaches. In the Netherlands, they delved into urban climate adaptation projects, such as blue-green infrastructure initiatives and practical applications. The focus in Belgium was on flood risk management, including examining major projects like the Blue Deal and Sigmaplan, which are pivotal to Flanders's systematic water management. Another Belgium segment involved a detailed evaluation of EU-level climate adaptation policies and their implementation across member countries. In Germany, the delegation expanded its knowledge about urban and peri-urban adaptation challenges around Aachen, including the KAHR research program and visiting areas impacted by the 2021 water bomb event. Returning to the Netherlands in Amsterdam, the focus shifted to financing mechanisms for climate adaptation.

The European work visit highlighted the urgent need for effective and integrated climate adaptation strategies, emphasizing the importance of stable funding mechanisms, strengthened regulatory frameworks, enhanced international collaboration, and the integration of innovative solutions with practical implementation. Key observations included the successful integrated climate adaptation strategies in the Netherlands, comprehensive flood management approaches in Belgium, and critical lessons from recent flood events in Germany. The insights gained can be considered as eight points, including the urgent need for adaptation strategies, essential capacities for urban climate resilience, strategic coordination at all levels, the importance of independent research institutions, integrating spatial development with adaptation, the role of innovation, possible actions for overcoming financial and regulatory challenges, and the importance of international cooperation. These insights discussed further and deeper in the main SPS report, are expected to guide future initiatives and contribute to the development of robust, resilient climate adaptation policies that can effectively address the evolving challenges posed by climate change.

1 Introduction

The European work visit about Special Policy Study (SPS) on green urban development and climate adaptation was conducted from July 1 to July 9, 2024. This visit aimed to explore various policy approaches, practical implementations, and innovative solutions related to climate adaptation across multiple European regions. The delegation, comprising experts and practitioners from the China Academy of Urban Planning and Design (CAUPD), the Dutch Ministry of Infrastructure and Water Management (Ministry of I&WM), Deltares, and other related organizations, visited locations of climate adaptation practices in the Netherlands, Belgium, and Germany. The visit facilitated a comprehensive knowledge exchange, provided deep insights into advanced climate adaptation strategies, and fostered international collaboration on addressing the multifaceted challenges posed by climate change.

From July 1 to July 9, the delegation undertook an extensive visit to the Netherlands, Belgium, and Germany, with a focus on exploring and understanding various climate adaptation strategies. Throughout this visit, the delegation participated in 18 formal presentation sessions and conducted 9 site visits, providing a comprehensive overview of regional approaches to climate resilience. In The Hague and Delft, the delegation engaged in discussions on urban climate adaptation projects, such as blue-green infrastructure initiatives, and observed practical applications firsthand. In Antwerp, the focus shifted to flood risk management, where the delegation examined significant projects like the Blue Deal and Sigmaplan, which are central to the region's water management strategies. In Aachen, the delegation explored the challenges associated with urban and peri-urban adaptation, including a view of the KAHR research program. This segment of the visit included visits to areas affected by the 2021 water bomb event, providing critical insights into the impact of extreme weather. In Brussels, the agenda included a comprehensive evaluation of EU-level climate resilience policies and their implementation across member countries. The visit concluded in Amsterdam, focusing on financing mechanisms for climate adaptation and reviewing actionable recommendations for governments.

The European work visit underscored the urgent need for effective and integrated climate adaptation strategies, highlighted by the significant casualties and damage resulting from recent extreme weather events across Western Europe. Key observations included the successful integration of innovative climate adaptation strategies in the Netherlands, comprehensive flood management approaches in Belgium, and critical lessons learned from recent flood events in Germany. The EU's strategic approach further emphasized the importance of aligning national and regional efforts with broader European goals.

Insights derived from the visit emphasized the necessity for stable funding mechanisms, strengthened regulatory frameworks, enhanced international collaboration, and the integration of innovative solutions with practical implementation strategies. The visit highlighted the need for a systemic approach integrating spatial development with adaptation strategies to address complex climate challenges and underscored the importance of strong commitment and strategic coordination at all levels. Furthermore, it identified the key roles of independent research institutions in providing evidence-based assessments, fostering innovation in technologies and policies, and facilitating international cooperation. These elements are essential for developing resilient urban adaptation and transforming climate challenges into opportunities for sustainable development and improved water resource management. The insights gained from this visit are expected to guide future initiatives and contribute to the development of robust, resilient climate adaptation policies capable of effectively addressing the evolving challenges posed by climate change.

2 Detailed Itinerary

The work visit, commencing on July 1, in The Hague, involved a comprehensive exploration of climate adaptation strategies across multiple European countries, culminating on July 9, in Amsterdam. The delegation engaged in a series of presentations, discussions, and site visits in the Netherlands, Belgium, and Germany, focusing on innovative policies and practical implementations of climate adaptation. Highlights included the urban climate adaptation projects, policies and approaches in the Netherlands, Belgium's systemic flood management projects like the Blue Deal and Sigmaplan, and Germany's KAHR research program on flood resilience. The visit also delved into European Union climate resilience policies in Brussels, emphasizing the EU's strategic support for regional adaptation efforts. Concluding in Amsterdam, the delegation assessed investment and financing mechanisms for climate adaptation, examining public finance strategies and the financial sector's role in managing climate risks. The visit provided valuable insights and formulated actionable recommendations for future climate adaptation initiatives.

2.1 July 1-2: The Hague

The commencement of the work visit was marked by the arrival of international participants in The Hague on the afternoon of July 1. Participants were accommodated at the Babylon Hotel and had the opportunity to settle in. An informal dinner with local participants facilitated initial introductions and laid the groundwork for the forthcoming sessions and site visits. The initial briefing provided an overview of the agenda and objectives, allowing participants to prepare for the intensive program ahead.

The primary focus of the second day was on climate adaptation policies and initiatives in the Netherlands. The core question addressed was how to effectively organize decision-making in the Delta, considering the wide range of temporal and spatial scales that require simultaneous attention. Through a series of discussions and presentations, participants explored various strategies and initiatives designed to address this complex challenge. The day’s agenda emphasized understanding the emerging policy approaches to climate adaptation in the Netherlands, highlighting innovative methods and frameworks being implemented to enhance resilience against climate-related impacts.

The morning session commenced with welcome and introductory remarks by Ben Geurts and Jan Hendrik Dronkers from the Ministry of I&WM. This set the stage for a series of insightful presentations. Frans van de Ven from Deltares introduced the three-point sponge policy approach and the Blue-Green-Grey Infrastructure for resilience. His presentation provided a novel perspective on the urban flood challenge, emphasizing the importance of integrating natural and engineered solutions to enhance urban resilience. He also introduced the concept of the five capacities (threshold, coping, recovery, adaptive, and transformative) and three domains (from day-to-day events to extreme rainstorms) in urban water resilience. Jasmin Schous from the Ministry of I&WM discussed ongoing collaborative efforts between the Ministry and China, underscoring the significance of international cooperation in addressing climate challenges. This collaboration spans bilateral agreements (memoranda of understanding and implementation plans), European-level engagements (China Europe Water Platform), and international frameworks (such as the UN Water Conference and China Council).

Figure 1 Ben Geurts and the CAUPD delegation

Anne-Marie Hitipeuw, also from the Ministry of I&WM, elaborated on the Delta Program on spatial adaptation. She detailed approaches for integrating climate adaptation into spatial planning processes, including the seven steps outlined in the Delta Plan on spatial planning. She also reflected on the conclusions and messages from the 2021 water bomb event, emphasizing the need for multilayer safety, increased water awareness, and addressing new challenges in climate resilience. The session concluded with insights from Marko Hekkert of the Netherlands Environmental Assessment Agency (PBL), who provided an overview of Dutch delta scenarios and the spatial outlook for the Netherlands. He discussed four conceptual delta scenarios — "Global Corporations," "Volatile World," "Green State," and "Regional Roots" — which consider future economic and societal developments in the context of sustainable development. These scenarios serve as a basis for integrated urban and rural development planning in the future.

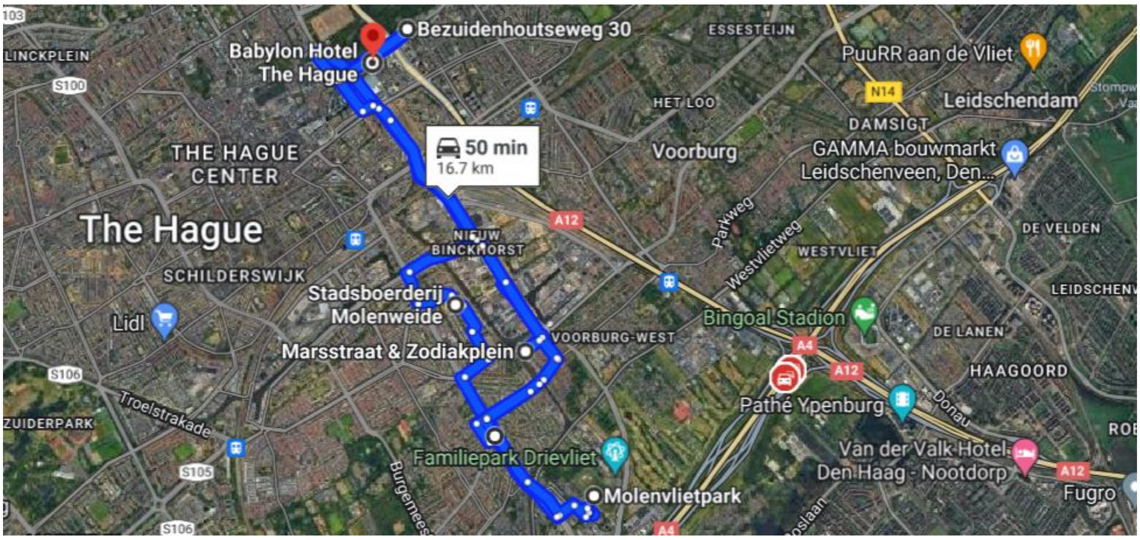


Figure 2 Route map of field visit in The Hague, on July 2

Figure 3 Visit at urban water buffer at City Farm Molenweide

During lunchtime, the delegation visited the PBL office. In the afternoon, participants engaged in a field visit to explore three climate adaptation projects in The Hague city. The first project visited was Farm Molenweide and its urban water buffer, designed in collaboration with the local community. This farm serves as a community park addressing urban heat and stormwater issues, while the urban water buffer is designed to sustainably harvest rainwater within urban neighborhoods. The second project was the water retention area at Molenvlietpark, which functions as a multifunctional space for water management, sightseeing, and recreation. This area comprises two connected polders with an outlet to the main canal, where a gate is used to control the water level in the polders and regulate the water volume extracted from the canals. The final project visited was the roof garden at Binck Island, which exemplifies green infrastructure solutions in urban building environments. The roof garden serves as a private open space for the local neighborhoods and is maintained by the community. The field visits were guided by experts Wiebke Klemm, Arthur Hagen, and Sander Westerhout, who provided detailed introductions, explanations, and insights into these practical implementations of climate adaptation.

2.2 July 3: Delft and Zegveld

On the third day, the delegation delved into the Dutch perspective and practices on climate adaptation, exploring various land use categories and spatial scales to understand the challenges and thought processes involved in climate adaptation. This provided a comprehensive view of Dutch strategies and innovations in addressing climate challenges across different geographical contexts.

During the morning session, Tjitte Nauta, the regional manager for Asia and Oceania at Deltares, welcomed the participants. Following this introduction, Nanco Dolman presented an in-depth overview of the challenges posed by climate change and urbanization, leading to the development of spatial adaptation and planning for climate resilience in the Netherlands, known as the Delta Plan. The session highlighted Rotterdam's transition into a water-sensitive and resilient delta city as a case study within the Delta Plan. Floris Boogaard then elaborated on blue-green infrastructure solutions in the Netherlands, aimed at enhancing climate resilience. His presentation covered aspects such as the history, current situation, design, maintenance, financing, and citizen participation in these infrastructure projects. He also introduced Climatescan, an open-source database website intended as a reference for climate-resilient urban design. Renske de Winter discussed the scenarios of the Dutch delta, which serve as important references for the adaptive cycles of the Delta Program and related research. Her presentation delved into the details of the four main scenarios with different socioeconomic developments, climate change, and emission reduction. She further showed the water-related consequences of the scenarios, insights gained, and the next steps for scenario research. This comprehensive overview concluded the morning's presentations on delta scenarios research, providing the delegation with valuable insights into the Dutch approach to climate adaptation.

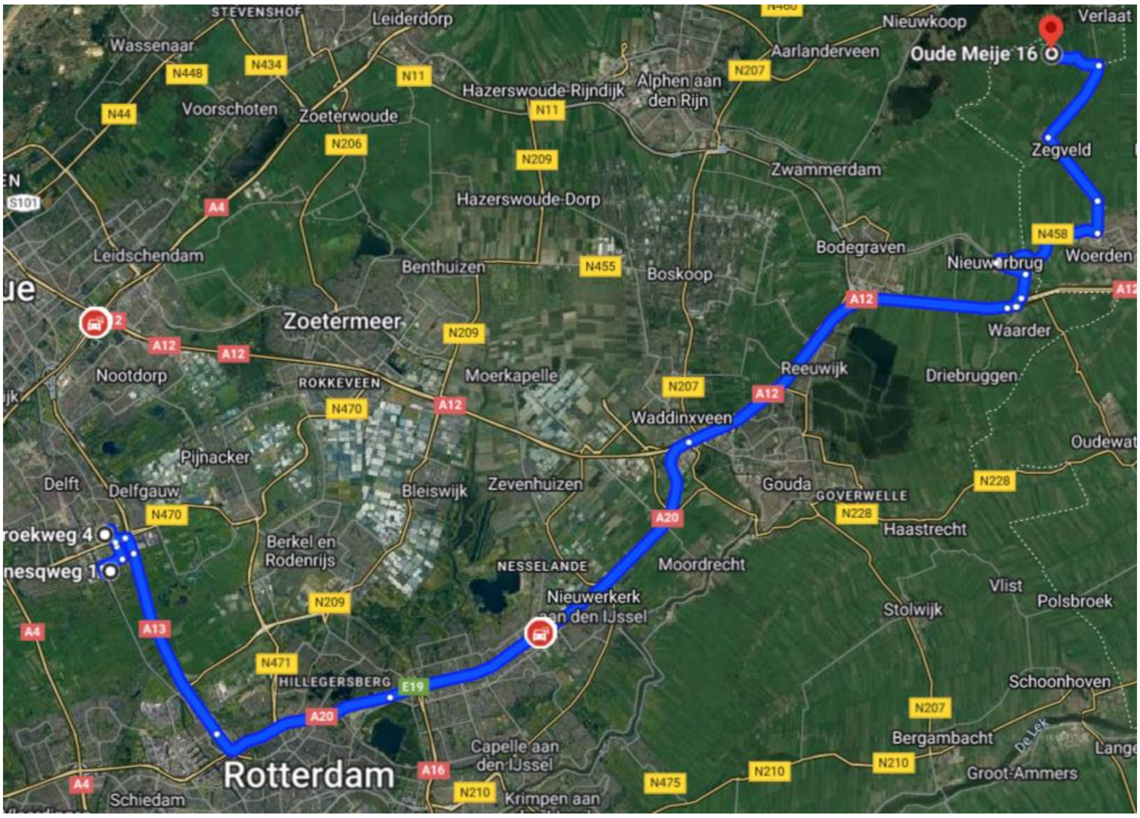


Figure 4 Route map of field visit in Delft and Zegveld, on July 3

In the afternoon, the delegation visited the TU Delft Green Village. This innovative site is designed to test and showcase research-based innovations under realistic conditions over several years, allowing for practical feedback and learning during the experimental phase. Lindsey Schwidder provided a detailed briefing on the cutting-edge research being conducted in the village. Many of the technologies being evaluated are related to climate adaptation, the built environment, and sustainability in water and energy. Examples include smart thermostatic houses, artificial green spaces, mobile green initiatives, green parking plots, and green energy projects (solar energy and hydrogen energy storage).

Following the visit to the Green Village, the delegation proceeded to the Dutch Peatland Meadow Innovation Center. Here, Tim Selders discussed the challenges and innovative approaches to peatland management in the Netherlands, focusing on issues including soil subsidence, groundwater management, and greenhouse gas emissions in rural areas. The delegation participated in a guided tour of the peatland, gaining first-hand experience of its unique characteristics and observing various innovative agricultural projects. These projects included the cultivation of new commercial plants adapted to the specific conditions of peatlands, demonstrating practical applications of sustainable peatland management practices.

Figure 5 Visit at Dutch Peatland Meadow Innovation Center

2.3 July 4: Antwerp and Ham

On July 4, the delegation focused on policy approaches to climate adaptation at the local and regional levels in Flanders, Belgium, specifically addressing issues related to flooding and water resources. The central theme of the day was learning from past failures and understanding the significant costs associated with inadequate adaptation measures.

During the morning session, several informative presentations highlighted the systemic approach to water availability in Flanders. Niels van Steenbergen discussed flood risk policy and practices in the region. He emphasized the devastating impact of the mid-July 2021 flood, often referred to as the “water bomb,” which caused significant losses. The concept of a resilient Waterland emerged from the lessons learned, underscoring the importance of cooperation, creating space for water, and setting water quantity targets in planning and design. Barbara Vael introduced the comprehensive Blue Deal project, which aims to establish a more resilient and climate-robust water system in Flanders. The core idea of the Blue Deal is to approach the water system holistically, leading to systematic changes to address the region's stress in water resources. The project has already positively impacted ecology, nature, drainage, water storage, and water reuse.

Edward Van Keer presented the Sigmaplan, an engineering project focused on flood protection and climate resilience in the Scheldt River basin. Initiated in 1977 following severe storm flooding in 1953 and 1976, and updated in 2005, the Sigmaplan involves a detailed water resources allocation strategy for the Albert Canal during flood and dry seasons. It takes into account both flood and drought mitigation, and incorporates climate adaptation measures such as controlled flood zones. It incorporates climate adaptation measures such as controlled flood areas. The current phase of the plan emphasizes “room for the river,” “working with nature,” and stakeholder management, combining controlled flood areas with the elevation and reinforcement of dikes and quay walls. These discussions and presentations provided the delegation with critical insights into the comprehensive and integrated strategies required to manage flood risks and water resources effectively, illustrating the importance of learning from past experiences to enhance future climate resilience.

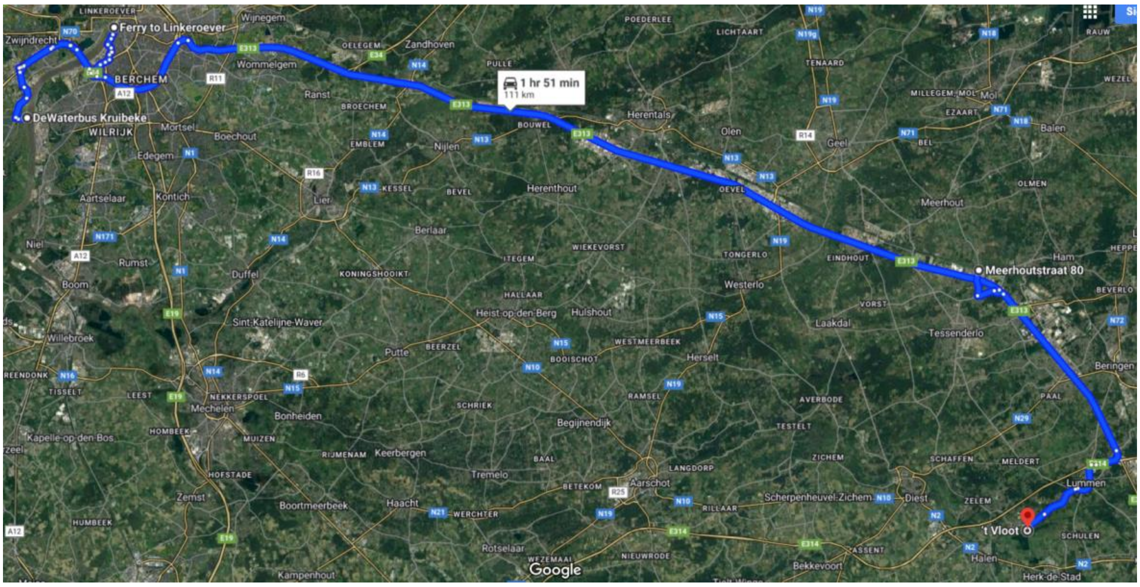


Figure 6 Route map of field visit in Antwerp and Ham, on July 4

Figure 7 Visit at flood control area of Sigmaplan

In the afternoon, the delegation embarked on a site visit to the Sigmaplan flood control area, where they explored the overflow dike, ring dike, and floodgates under the guidance of Niels Van Steenbergen and Jan Mangelschots. This hands-on experience was followed by a presentation at the Kustvisie (Coast Vision) Hydraulic Laboratory in Ham by Deschamps and Van Keer. The presentation covered a hydropower station that integrates low-flow water management (addressing water supply shortages) with hydropower generation. The delegation then visited the introduced hydropower station, observing its operations and contributions to regional water management. Continuing the exploration, the delegation visited the Schulensmeer retention basin and its pumping station. Here, Rik Scholiers introduced the retention basin's functions and led the group on a 1.3 km walk, offering further insights into local water retention and flood management strategies. These site visits provided the delegation with practical examples of how Flanders implements comprehensive water management solutions, combining flood control, water supply management, and hydropower generation to enhance regional climate resilience.

2.4 July 5: Aachen

On July 5, the delegation focused on climate adaptation challenges and opportunities in peri-urban and urban areas with smaller tributary rivers in Aachen, Germany. The discussions and site visits aimed to understand the connection between climate change adaptation (in both short- and long-term) and urban development and safety in areas upstream from the delta.

In the morning, the session began with an introduction to climate adaptation practices in Germany. Stefanie Wolf from the Institute of Engineering and Water Resources Management at RWTH Aachen University provided an overview of the activities and results from the KAHR (Climate, Adaptation, Flooding, Resilience) research program, funded by the Federal Ministry of Education and Research. She shared lessons learned from the water bomb event in 2021, which caused significant damage and casualties in Germany. Despite the devastation in the area, 24 affected dams remained operational and protected downstream regions. The German Ministry initiated the KAHR project to advance flood research through interdisciplinary flood risk analyses and spatial risk management. Drawing from the 2021 flood, KAHR formulated 10 scientific recommendations for reconstructing and sustaining flood-affected regions. These recommendations encompass flood resilience, flood risk analysis, water and land management, infrastructure protection, public awareness, and early warning systems.

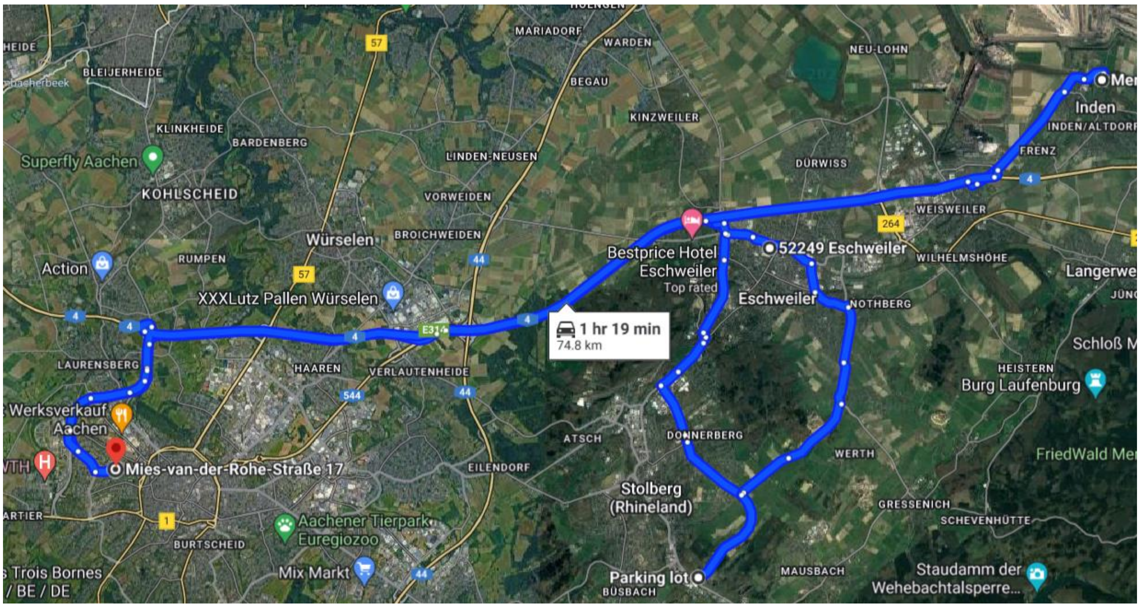


Figure 8 Route map of field visit in Aachen, on July 5

Following this, Li Xiaojiang from CAUPD introduced the focus and foundation of the year's SPS research. The goal was to establish a framework for examining urban and rural climate adaptation capabilities, referencing international experiences. Utilizing this framework, three empirical case studies were conducted in the Taihu Lake Basin, the Chengdu-Chongqing region, and the Pearl River Delta, each facing distinct climate adaptation challenges. Based on these case studies, seven recommendations were drafted for the Chinese national government on climate adaptation. These recommendations include accelerating systemic climate adaptation implementation, building evaluation and coordination mechanisms, incorporating community resilience and equity, and emphasizing the importance of continued research on climate adaptation.

Figure 9 Sight of the open pit mine Inden

In the afternoon, the delegation had several site visits to locations affected by climate adaptation measures and challenges. In Stolberg, they examined a factory impacted by the Vicht River during the water bomb event. This visit provided insights into the vulnerabilities and resilience measures of industrial facilities in flood-prone areas. The delegation then travelled to Eschweiler to observe the channelized Inde River and a nearby hospital that was flooded during the flood hazard. It highlighted the challenges of managing urban water systems and the importance of effective flood prevention and emergency response strategies in protecting critical infrastructure. The day concluded with a visit to the open pit mine Inden. Discussions here focused on the role of anthropogenically altered landscapes during flood events, including the potential for utilizing old open pit mines for water retention. This visit underscored the need for innovative approaches to land use and flood management in the context of climate adaptation.

2.5 July 6-7: Brussels

On July 6, the delegation's visit centered on exploring innovative climate resilience policies at the European Union level. The sessions aimed to understand how climate adaptation is being stimulated by the European Commission.

During the morning session, there were informative presentations on the European Union's programs and activities related to adaptation. Dr Philippe Tulkens provided an overview of the EU Mission on adaptation to climate change, detailing the mission's objectives and the collaborative efforts involved in enhancing climate resilience across member countries. This was followed by Prisca Haemers, who introduced the initiatives by the EU Commission, highlighting the EU's strategic approach to climate resilience. The objectives of the EU adaptation strategy are to be smarter, more systemic, and faster, while also stepping up international actions. The EU's mission aims to support at least 150 European regions and communities to become climate resilient by 2030. The EU supports vision and implementation by assisting in the development of climate adaptation plans, creating innovative pathways, and establishing enabling conditions for effective execution. This mission is shown as a localized-systemic-inclusive pyramid, with 311 regions, cities, and local authorities as charter signatories from 29 countries, representing about 40% of the EU population. The mission focuses on projects with objectives such as climate risk assessment, adaptation pathways, and testing and demonstrating adaptation solutions. So far, there are 32 projects with 840 participants, involving a total EU financial contribution of 337.7 million euros.

Figure 10 Presentation on the EU Mission on Adaptation to Climate Change

In the afternoon and the next morning, the delegation engaged in internal discussions focused on drafting recommendations. The participants evaluated the lessons learned from their visit, identified key insights, and deliberated on any necessary changes or additions to their perspectives. During the discussion, participants brainstormed recommendations for national governments, specified potential topics for the upcoming years, and outlined the next steps to further climate adaptation awareness and initiatives.

2.6 July 8-9: Amsterdam

On July 8, the delegation's research in Amsterdam focused on assessing investment and financing mechanisms in climate adaptation, intending to explore how adaptation measures can attract third-party private investment, climate adaptation-related risks in existing investment portfolios and actions that central banks can take, and potential stranded asset costs that may be caused by climate adaptation.

The morning session began with an overview of financing climate adaptation in China provided by CAUPD participants. Mark de Bel from Deltares discussed strategies for using public finance to support climate adaptation, emphasizing revenue generation, attracting external funding, and externalizing adaptation costs. Case studies from Sophia Beach, Batumi, and Texel were shared to illustrate successful implementations of these strategies, emphasizing benefits like improved flood protection, increased tourism, and ecological enhancements. The key difficulty is that adaptation to climate change, by itself, does not generate a cash flow. Thus, the successful projects shown, all mixed adaptation purposes with other objectives in one way or another.

Key lessons included the importance of co-benefits and aligning investments with public and private sector goals to maximize funding opportunities and resilience outcomes.

Marc Reinke from the Central Bank of The Netherlands (DNB) then presented on assessing exposure to climate and biodiversity risks, drawing on experiences from central banks and the network of greening financial services. The DNB prioritizes sustainability, integrating climate and nature-related risks into its supervisory tasks and using stress tests to understand the potential impact of climate events. Additionally, DNB is a member of the Network for Greening the Financial System (NGFS), which aims to promote green and low-carbon investments and enhance the global response to the Paris Agreement goals.

Figure 11 Presentation on climate and biodiversity financial risks

John Ganzi from the Climate Change Management Institute concluded the session with insights on the connection between climate adaptation and stranded assets, focusing on the significant costs of phasing out hydrocarbons. He stressed the importance of managing these assets as part of climate adaptation strategies. Solutions to the potential problems included international political cooperation, changes in accounting rules (allowing faster depreciation of fossil-energy assets), anticipating tipping points, and fostering leadership to support the transition to sustainable assets. Applying these insights to the domain of adaptation would require some professional interpretation.

In the afternoon, the delegation participated in a wrap-up session, evaluating the work visit, discussing insights gained and lessons learned, and planning the next steps for future engagements. This session was crucial for consolidating the knowledge acquired and setting the direction for upcoming climate adaptation initiatives.

On July 9, the final day of the visit, the local participants dedicated their time to a work session on the SPS report. They supplemented and improved the findings and recommendations from the visit. All the participants then departed from Amsterdam, bringing the work visit to a conclusion.

3 Insights from the visit

Summary of critical findings

a) Recent extreme weather events in the Netherlands, Flanders, and Aachen have caused significant casualties and extensive damage. The urgent need for serious attitudes, effective adaptation strategies and actions is clear to mitigate risks from intense precipitation, flooding, and droughts.

b) Urban climate resilience requires five capacities involving threshold, coping, recovery, adaptive, and transformative. Repatriating the shortcomings of these capacities has a strong effort to enhance urban climate resilience.

c) Effective adaptation requires strong commitment and strategic coordination at all levels and entities including EU, countries, cities, communities, and research institutions. Robust national frameworks and oversight ensure that regional and local adaptation efforts align with broader national goals.

d) Independent research institutions and committees provide critical assessments and information, supporting evidence-based policies and continuous improvement in adaptation strategies. Typically, this requires resource commitments at a national scale.

e) A systemic approach, integrating spatial development with adaptation strategies, and measures to protect against floods and droughts with measures to assure sufficient availability of water, is essential for utilizing the impact of planning, addressing the complex challenges of climate change and enhancing overall resilience.

f) Innovation in technologies, strategies, and policies is the key to climate adaptation. The challenges of climate adaptation are opportunities, in the meantime, to improve the new agricultural economy, sustainable energy, systematic water resources management, and innovative spatial planning.

g) Key challenges to effective adaptation include unstable financial conditions, short-sighted policies, lack of concrete targets, conservative regulations, and restrictive insurance policies. Conversely, effective adaptation in a resilient context requires stable funding, continued policy support, improved regulatory frameworks and international cooperation to overcome financial hurdles and support consistent progress.

h) Transnational and international cooperations, sharing the experience from successes and failures in climate adaptation, are meaningful for all the participants (e.g. EU and China). International platforms and projects like CCICED, the UN Water Conference, and the World Water Forum play critical roles in making the world more climate-adaptive.

3.1 The Hague and Delft, the Netherlands

Responding and Preparing to Extreme Weather Events

The severe flooding in Flanders and Western Germany in mid-2021 served as a wake-up call for the region. This event followed a Dutch proverb: “A ship on the beach is a beacon at sea,” highlighting the urgency of being prepared for extreme weather. The Netherlands experienced less damage compared to its neighbours and no casualties, although model exercises soon after indicated that if this water bomb event—a stalled precipitation system—had hit 50 or 100 km further into the Rhine-Meuse delta, severe damage and loss of life would have been inevitable. The flooding underscored that the primary threat lies with smaller river systems rather than the well-protected main rivers, and such events are expected to occur more frequently. While prevention is not always feasible, preparation is crucial. This event has spurred efforts to use model-based approaches to quantitatively and location-specifically inform urban developers and water managers about flooding risks from extreme rainfall, making water bomb event simulations a standard in stress tests. The main policy framework remains the Delta Program, which features a long-term strategy with a six-year update cycle, cabinet-level anchoring, and stable funding. Drought and heat are included in current policy, though somehow underemphasized relative to flooding, compared to policy in neighbouring Flanders.

Current Climate Challenges and Policy Framework

Weather extremes beyond scientific expectations are already occurring in the Netherlands, such as extreme heat and droughts from 2018 to 2020, severe flooding from the extreme water bomb event in 2021, and 2023 being the wettest and warmest year since 1900. These events have heightened public awareness of climate change. With the rising awareness, the National Delta Program and stable Delta Fund (both since 2010), and the National Adaptation Strategy (since 2016) are set in place to develop and implement coherent adaptation strategies and capacities from the national to the local level. These initiatives focus on safety against flooding, water availability and droughts, extreme precipitation, spatial adaptation, and heat waves, with the overall goal of making the Netherlands climate-resilient by 2050.

The Role of Government and Coordination

The Ministry of Infrastructure and Water Management coordinates these efforts, with all ministries responsible for their respective domains working together in the Directors Board of the National Climate Adaptation Strategy (DO-NAS). The DO-NAS ensures close interaction among the ministries, the Delta Program, the provinces, water boards, and municipalities, all of which are represented at a national level. Through both the Delta Program and National Adaptation Strategy, close interaction with regional and local authorities, as well as with societal organizations, is fostered. National safety targets for flooding are legally anchored, anticipating climate change. However, for other challenges such as heat, drought, water availability, and heavy precipitation, specific goals are yet to be set. A new national policy initiative, “Water and Soil Steering,” aims to guide spatial development based on an ecosystem approach. Although national spatial policy was abandoned early in the century, the need to reinstate it in the face of climate change is widely acknowledged, representing a major transformation challenge.

Contributions from Research Institutions

Independent research institutions like KNMI (Royal Netherlands Meteorological Institute), Deltares, and PBL provide the government and society with crucial information about climate change and related challenges. These institutions work closely together, offering insights into climate impacts (KNMI), water-related challenges and potential solutions (Deltares), and national assessments (PBL). They contribute to integrated outlooks and adaptation pathways, supporting informed decision-making and effective policy implementation.

3.2 Flanders, Belgium

Responding to the 2021 Flooding and Addressing Water Challenges

The mid-2021 flooding in Belgium, particularly in Flanders, resulted in severe damage and casualties. This event led to the formulation of a comprehensive policy response known as "Resilient Waterland," paying systemic attention to water availability in Flanders. This policy encompasses specific strategies for managing tidal rivers, watercourses, sponge landscapes, towns, and villages while distinguishing between pluvial (rainfall), fluvial (river), and coastal flooding risks. Municipal rainwater and drought plans are integral to this response, recognizing that climate change exacerbates pre-existing risks, particularly in a water-intensive economy. Notably, regulations and permits pertain to both plots and buildings. The overarching notion of water security involves setting targets for flood protection as well as measures to address drought. The challenge of accommodating these measures in a densely populated country remains significant.

The Flemish policy response is implemented through three coordinated programs that address the escalating risks associated with climate change. Some of these programs predate 2021 and are rooted in the Flemish Integral Water Policy of 2003, which coordinates efforts across government entities. The three detailed programs are the Sigmaplan (focusing on the Scheldt River), the Blue Deal (emphasizing water resource management), and the low flow water management program (including concerns for water used in shipping). These programs adopt a systemic approach and a philosophy of multilevel safety, similar to the Dutch Delta Program. They involve extensive efforts to secure retention opportunities along the Scheldt River, although political support fluctuates, and budgets are unstable, often requiring annual approval. The work on water retention capitalizes on arising opportunities rather than following a quantitative steering approach. These comprehensive efforts by Flanders aim to enhance resilience against flooding and drought, ensuring water security amid growing climate challenges.

Enhancing Flood Protection through the Sigmaplan

In Antwerp, the ongoing Flemish Sigmaplan aims to enhance long-term protection against flooding and sea-level rise from the Scheldt estuary. The program employs a stepwise approach that combines technical and spatial measures, including strengthening approximately 645 km of quays and walls to withstand a 90 cm increasing extreme water level, accounting for a future 60 cm sea-level rise. Additionally, the program develops 2,500 ha of retention areas and 5,100 ha of nature areas to manage an extra 30 cm water level extreme. These measures are integrated with urban quality improvements and nature development, combining flood protection with enhanced urban and natural environments. However, the implementation faces hurdles such as unstable budgets (to be secured annually in the political arena) and objections from organizations and citizens (even in the implementation phase), which can delay progress.

Learning from the 2021 Water Bomb Event

Following the devastating water bomb event in 2021, a special committee was established to evaluate and draw lessons to improve safety. The 2024 report provided fundamental advice based on a systemic approach, addressing river basin management, maximum retention within the system, and nature-based solutions. It also highlighted the importance of addressing water availability and drought through an integrated approach. Major actions recommended include special emergency and intervention plans for flooding, checks on new developments and investments, river widening and restoration, increased regional water retention, mandatory municipal rain and drought plans, and setting targets for flooding and drought in river basin strategy plans.

Addressing Water Availability and Drought

In response to five consecutive years of drought since 2017, the Flemish Blue Deal defines 70 actions based on a systemic approach and structural stakeholder participation. The Blue Deal involves an investment of approximately 500 million euros, sourced from EU Corona Recovery Funds. It aims to implement systemic changes to improve sponge functioning and storage capacity, reduce leakages in water supply systems, and utilize innovative technologies. The initiative, termed “Water and Landscape 2.0,” includes re-meandering 88 km of rivers, creating 6,400 ha of new wetlands, removing 113 ha of hardened surface, constructing 500 additional weirs to conserve water, adapting water management on 115,000 ha of agricultural land, creating 4~8 million m^3 of rainwater storage, and adapting regulations for houses and water reuse.

3.3 Aachen, Germany

Lesson Learned from the 2021 Flood

In mid-2021, severe floods caused widespread damage and loss of life in Rhineland-Palatinate and North Rhine-Westphalia. This event, classified as a once-in-400-years probability, occurred in a moderately hilly area with small rivers. The KAHR project had the scientific monitoring of the reconstruction process and formulating recommendations to guide it. Despite the immense destruction, all 24 dams in the affected area performed as designed, without damage, and considerably reduced downstream flows. However, there are also many failures. Traditionally designed bridges significantly exacerbate flood damage in narrow valleys. Industrial protection systems, although designed to withstand once-in-500-year floods, failed. The chemically contaminated mud, which was late identified and flagged, had already posed health hazards to inhabitants who already engaged in cleanup efforts.

The KAHR Project

The KAHR project is funded by the Federal Science Budget and involves multiple organizations. However, beyond this and related expert-level knowledge exchange, most learning and risk management efforts are conducted at the state level (equal to province in China and many other countries), rather than the federal level. A special independent committee, led by two professors, was established to evaluate the disaster.

The committee made ten recommendations, highlighting improvements in early warning systems, creating more space for water (not only by settlement retreat but also by adapted land use), improving information provision by hazard and risk maps, signalling risky new developments, better bridge designs, stakeholder participation, inter-municipal collaboration, and financial support. In detail, these include smarter engineering in the placement and design of bridges and energy installations, re-evaluating the use of space on hillsides and in narrow valleys, and improving access to risk information and emergency preparedness. The need for faster emergency warnings and active local preparedness and training was emphasized, even if these events are deemed infrequent. Reconstruction of individual houses and small businesses has mostly occurred in the same locations and types as before, due to limited insurance policies not providing funds for improvements.

Details from the 2021 Flood in Aachen

The extreme precipitation event was a once-in-400-year accumulated to 100 mm, locally even up to 200 mm (about 25% of annual rainfall). The flood resulted in over 180 casualties and affected 85,000 households and 10,000 companies. It destroyed 103 bridges. The total damage is approximately 30 billion euros. The 24 dams successfully retained the extreme water flow, significantly reducing downstream flow. Only 24 houses could be removed from the floodplain area, and no additional budget was available from insurance companies for improvements. Furthermore, there are no regulations to steer spatial development.

3.4 Brussels: EU Adaptation Strategy

The EU Adaptation Strategy aims to support countries in achieving climate resilience through several key initiatives. Firstly, it ensures comprehensive information provision by making resources such as the European Climate Risk Assessment Reports (EUCRA), the European Environment Agency (EEA) progress reports and outlook reports available to all citizens and regions across Europe. Secondly, the EU supports vision and implementation by assisting in the development of climate adaptation plans, creating innovative pathways, and establishing enabling conditions for effective execution. Lastly, it focuses on upscaling solutions through the implementation of 75 demonstration projects designed to transform climate adaptation practices. This EU Adaptation Mission is funded and operated by the Directorate-General for Research and Innovation (DG RTD) of the EU Commission. Fundamental principles of the strategy include a place-based approach, systemic thinking, and inclusivity. The Mission Charter Signatories, comprising 311 regions and 29 countries, represent about 40% of the EU population.

3.5 Amsterdam: Climate Adaptation and Financial Sector

The presentations and discussions emphasized the need for effective revenue generation, attracting external funding, and managing adaptation costs. Generally, adaptation investment has much less revenue and higher risk compared to normal investment. It makes the private sector are not willing to invest in adaptation. Therefore, to attract more investment, it is crucial to find ways to generate revenue and reduce the risk of adaptation. In principle, pure adaptation to climate change can avoid enormous costs, but generates no cash flow. Thus, adaptation costs can be seen as "defensive outlays," to be borne by governments. Alternatively, mixed approaches can be applied, depending on the project. A business model with a corresponding clear accounting scheme was explained for leveraging adaptation funding. It identifies three complementary options: (i) generating non-adaptation revenues for the public sector, such as tax benefits; (ii) attracting other funding, corresponding with a variety of societal goals; (iii) externalizing adaptation cost, including the cost of maintenance, to benefitting other parties. Successful case studies demonstrated a combination of important non-cash and cash benefits, such as enhanced flood protection, ecological improvements, and increased tourism and local tax revenue, underlining the importance of aligning investments with public and private sector goals in order to effectively finance adaptation.

On a separate note, central banks are increasingly integrating climate and biodiversity risks into their supervisory frameworks, using stress tests to assess potential impacts on current or projected investment portfolios, while promoting green investments aligned with global climate goals. The central banks also try to be the public backup to lower the risk of private investors in adaptation.

On yet another note, managing stranded assets given climate-related changes in the coming decades involves significant costs (write-offs). Numbers and examples were presented related to the value chain of extracting, producing, distributing, and using fossil energy carriers. In that sector, write-offs are unimaginably large. As losses in a company's annual reporting, these write-offs are mostly virtual and only appear because of accounting rules related to assets on the books. However, these virtual losses do steer executive behaviour. A common-sense way out would be to change internationally agreed rules for accounting and reporting, specifically requiring that, because of the energy transition, fossil-related assets and unexploited reserves are discounted with a short horizon. After all, who knows what place these assets will have in the world after 2035? Addressing these challenges requires international cooperation, revisions to accounting rules, and strong leadership to facilitate the transition to sustainable practices. Adaptation to climate change will of course see instances of stranded assets – such as wrong infrastructure, or urban expansion in the wrong location, or water-intensive industry where there will be insufficient water. Numbers and types of assets may be different from the energy sector, and slightly more distributed in terms of impacted sectors.

Annex F. SPS China work visit report

1 Introduction

From June 12 to 21, 2024, the research group went to China to conduct academic exchanges and professional research on the theme of green development and climate adaptation in urban and rural construction. The purpose of this trip was to explore the policy approaches, innovative solutions and practical implementation related to climate adaptation in China, and to discuss and promote the research progress of the topic.

The team conducted field research on representative cases of climate adaptation practices in Shenzhen, Dongguan, and Shanghai, China. The visit facilitated comprehensive research exchanges between the Chinese and foreign teams, provided on-the-ground insights into China's climate adaptation strategies, and promoted international cooperation to address the multifaceted challenges of climate change.

Throughout the visit, the team participated in 3 internal working sessions, conducted field research in 9 locations, and gained a comprehensive understanding of climate resilience approaches in various regions. In Shenzhen, the team held 2 internal working sessions and visited the Futian Mangrove Nature Reserve, Shenzhen Bay Coastal Recreation Belt, Dasha River Ecological Corridor, etc., to understand how to protect urban ecological space and biodiversity while carrying out urban construction with high intensity, and how to comprehensively utilize the ecological space to play the function of residents' recreational operation. In Dongguan, the group visited Dongguan Eco-Park, Songshan Lake and other case areas to understand how to consider economic benefits and ecological benefits in the implementation of urban renewal projects, and how to carry out eco-infrastructure construction in the city's industrial parks to cope with climate change and improve the ecological environment. In Shanghai, the research group held an internal working session and visited a number of case locations in Shanghai, including the Yangtze River Delta Eco-Green Integrated Development Demonstration Zone, Wusong Cannonball Bay National Wetland Park, and Yangpu District Riverside Climate Adaptive Embankment Construction and Waterfront Space. Through the research, the team learned about climate adaptation exploration in different areas of cities and villages in terms of ecological environment management, eco-agriculture development, infrastructure construction, and public space shaping.

Through this trip, the team, on the one hand, understood the climate risks faced by different regions in China and the urgency of carrying out climate adaptation actions, and also learned about the specific projects and experiences of climate adaptation carried out by various regions in China in recent years in conjunction with special policies on urban regeneration, rural revitalization, sponge cities, and ecological protection and restoration. On the other hand, the research group shared the progress of empirical research on the three cases in China, namely the Pearl River Delta, Jialing River, and Taihu Lake, through several working sessions, and discussed the existing contents of the SPS report and the next modifications chapter by chapter, which laid a good foundation for the next step of preparing the report on the subject and forming policy recommendations.

2 Detailed Itinerary

The team arrived in China in the evening of June 12th to start the working visit, and returned to Europe on June 21st from Shanghai. The team conducted a series of seminars, field studies and discussions in the Pearl River Delta, Shanghai and Wuhan, focusing on innovative climate adaptation implementation projects in Chinese cities and surrounding regions in the areas of urban renewal, rural revitalization, sponge cities and ecological space protection, as well as discussing the progress of the research.

2.1 June 13: Briefing Meeting and Shenzhen Field trip

The team arrived in Shenzhen in the evening of June 12th and started the official visit activities on June 13.

On June 12, the team held an internal working meeting in Shenzhen. The case studies of the Pearl River Delta region (PRD) and Chengdu-Chongqing region were presented by the teams from the China Academy of Urban Planning and Design (CAUPD) Shenzhen Branch and Western Branch respectively. Introduction of the major natural disasters brought by climate change to cities in the Pearl River Delta region and Chengdu-Chongqing regions, and the adaptive countermeasures.

Dr. Wang Chengkun from the Shenzhen Branch of the CAUPD introduced the PRD case study results, including regional characteristics, major disasters, gap analysis, and policy recommendations:

In terms of regional characteristics, the Pearl River is the second largest river in China in terms of runoff, and the total area of the Pearl River Basin is about 453,700 square kilometers. The PRD is located at the mouth of the lower reaches of the Pearl River, with a long river network and a long coastline. The PRD is the largest urban contiguous body in Asia and one of the most densely populated regions in the world, experiencing rapid urbanization, large-scale land reclamation and shoreline artificialization. The Bay Area concentrates 49% of the PRD's population, 65% of its economic output and a large amount of its infrastructure, but is therefore vulnerable to disasters. In terms of major disasters, the PRD is mainly facing extreme heavy rainfall disasters, sea level rise, upwelling of salty tides and water resources crisis. Extreme heavy rainfall events have been frequent in recent years, leading to extensive urban flooding and infrastructure damage. As the PRD is low-lying and the cities are developing towards the sea, sea level rise superimposed on storm surges poses a serious threat to low elevation areas, and the upwelling of salty tides affects water intake from rivers during the dry season, making the water resources crisis more and more serious. In terms of gap analysis, the PRD suffers from insufficient systematic and cross-sectoral synergy in disaster prevention and mitigation, shortcomings in monitoring and early warning capabilities, insufficient resilience in urban spatial patterns, weak capacity of infrastructure and blue-green defense facilities, as well as insufficient awareness of risk among community residents. Finally, in terms of policy recommendations, in order to enhance the disaster prevention and mitigation capabilities of the PRD region, it is recommended to strengthen regional synergy, enhance spatial resilience, optimize early warning capabilities and sectoral linkages, unify flood prevention standards, improve emergency evacuation systems, enhance the defensive capabilities of underground spaces and urban lifeline projects, and enhance community awareness of disaster prevention and emergency rescue capabilities. Meanwhile, through the construction of urban catastrophe scenarios, emergency spatial resource reserves and long-term strategies to cope with sea level rise, we will formulate systematic response plans and strengthen top-level design and cooperation among Guangdong, Hong Kong and Macao, so as to realize sustainable development and effective management of disaster risks in the region.

Ms. Yu Miao's Jialing River Basin case analysis mainly includes four parts: regional overview, main disasters caused by climate change, differences in climate adaptation, and policy recommendations:

In terms of regional overview, Chengdu-Chongqing is located on the second geographic ladder in China, the transition between the Tibetan Plateau in the Yangtze River Basin and the middle and lower reaches of the Yangtze River, with the mountainous areas around the basin of high ecological importance, and the central plains and hills of the region being the main agricultural production areas, as well as densely populated and urbanized areas. Disasters caused by climate change in the Chengdu-Chongqing region include floods, hill fires, energy shortages, reduced agricultural yields, and health hazards. Rising temperature fluctuations, reduced precipitation, and increased extreme weather events have led to flooding, waterlogging, and hill fires, which pose a serious threat to life and property, damage urban infrastructure, and affect agricultural production and the health of residents. Flooding poses inundation and waterlogging risks, and despite measures such as flood scheduling and meteorological warnings, it still exposes problems such as insufficient capacity of flood control facilities and the need to strengthen flood scheduling management. Mountain fire disasters destroy forest vegetation and infrastructure, reflecting the inadequacy of fire prevention monitoring systems and rescue forces while taking measures such as fire prevention early warning and infrastructure construction. The problem of energy shortage is particularly prominent under the extreme heat and drought in 2022, with a surge in electricity demand but a sharp drop in hydropower production, leading to a power gap and huge economic losses. This exposes the problems of a single energy structure in the Chengdu-Chongqing region, insufficient water resource deployment capacity, and insufficient interconnection and mutual aid with the power grids of other provinces. Agricultural production reduction was mainly manifested by insufficient irrigation water, aggravation of pests and diseases, and despite measures such as agro-meteorological early warning and drought response, the problems of engineered water shortage, damage to small and micro-irrigation networks, and insufficient agricultural smartness were still revealed. In terms of health hazards, extreme weather has led to increased incidence of pyrexia and drinking water difficulties, especially in rural areas, where water infrastructure is weak, disaster preparedness is inadequate, and planning and protection mechanisms are not sound, so there is an urgent need to strengthen response measures. These problems require the Chengdu-Chongqing region to upgrade its infrastructure construction and emergency management capacity. In addition, the differences in climate adaptation in the Chengdu-Chongqing region include prevention, resilience, recovery, proactive adaptation and change capacity all need to be strengthened. In terms of preventive capacity, the level of meteorological and hydrological forecasting and risk prediction capacity needs to be improved, the digital risk map system for climate hazards has not yet been established, and the conditions for emergency response and the preparation of plans need to be further optimized. With regard to resilience, the adaptive capacity of key infrastructure to deal with extreme weather is insufficient, and the emergency rescue system and capacity need to be strengthened. In terms of resilience, due to complex terrain conditions and insufficient financial support policies, recovery and reconstruction have become more difficult, and the role of communities and public participation need to be enhanced. In terms of proactive adaptive capacity, the resilience to cope with climate disasters is insufficient. In terms of transformative capacity, the popularization of science and education system, scientific and technological support system, and urban and rural governance system for adaptation to climate change are not yet perfect. In terms of policy recommendations, in order to enhance the region's climate adaptation capacity, it is recommended to strengthen the construction of engineered water conservancy facilities, cross-regional sectoral collaboration and information sharing, urban climate risk prediction and planning capacity, the adaptive capacity of key infrastructures, as well as the capacity of science popularization education and emergency services at the community level, in order to better respond to the challenges posed by climate change.

On the afternoon of June 13, the research group conducted a field trip in Shenzhen. The group first visited Shenzhen Futian National Nature Reserve and the adjacent OCT National Wetland Park to examine the connectivity between urban and natural ecosystems and the conservation of biodiversity within the metropolis. To understand how Shenzhen protects the mangrove forests in the metropolis, which in turn serves as an urban green island in the high density construction area. Afterwards the group went to Dameisha Seaside Stacks to investigate. This is the most beautiful hiking coastline in the eastern part of Shenzhen, known as the first long "seaside jade belt" around the world. Also, the group learned about the experience of coexistence of security and public space in typical coastal areas of Shenzhen.

2.2 June 14: Dongguan Field Trip

The team conducted a field study in Dongguan, focusing on sponge city construction, water control projects and road network layout adapted to the natural terrain in Dongguan Eco-Park and Songshan Lake. The study tour aimed to gain an in-depth understanding of how Dongguan weighs economic interests against social and ecological benefits in the process of urban renewal, and examined the construction of ecological infrastructures in the urban industrial parks in terms of combating climate change and improving the ecological environment. In addition, the group examined climate adaptation measures in high-density urban areas in Shenzhen.

2.3 June 15: Working Meeting in Shenzhen

On June 15, the group discussed the existing research content of each chapter of the report in two half days.

Among them, Mr. Lin Chenhui, Vice President of the Shenzhen Branch, conducted case studies mainly from six parts, inluding regional overview, climate change analysis, analysis of changes in adaptive capacity, major disasters and problems caused by climate change, differences in climate adaptation, and policy recommendations:

The Taihu Lake basin is located in the core location of the Yangtze River Delta and is dominated by butterfly-shaped depressions. Cultivated land has decreased by 20.5% and construction land has increased by 19.2% in the past 40 years. It is densely populated with dikes, and the water surface rate of rivers and lakes is 15%, which is higher than the average level of the Yangtze River Delta region. It is one of the regions with the most dynamic national economy, the highest degree of openness, and the strongest innovation capacity, and its GDP accounts for 10% of the country's. Extreme rainfall and persistent high temperatures have increased in the Taihu Lake Basin, especially in the eastern part of the region, where short-term strong convective weather can easily lead to flooding, and frequent typhoons have aggravated the disasters of "wind, storms, tidal waves and floods". The warming trend centered on Shanghai is significant, and the threat of sea level rise is increasing, exposing the basin to heavy rainfall and flooding, high temperatures and heat waves, as well as the risk of coastal cities. Climate change has led to the Taihu Lake Basin facing heavy rainfall and flooding, high temperature and heat waves, and coastal cities under the increased threat of sea level rise. The flood prevention and drainage system in the Taihu Lake basin needs to be optimized, lacks basin-wide storage and stagnation space, and relies mainly on the over-storage of Taihu Lake and the flood discharge of backbone rivers, which is more difficult. The coverage of dike area is high, and it is overly dependent on strong drainage. High temperatures have caused cities in the lower reaches of the basin to be invaded by salty tides, and water supply security is threatened. There are shortcomings in climate adaptation, involving basic research, space, facilities, communities and mechanisms. The warning time and accuracy of sudden meteorological disasters need to be improved, and there is a relative lack of simulation and prediction of extreme and correlated disasters. Natural storage space has been reduced, expansive construction has exacerbated the risk of waterlogging, and resilience and disaster prevention-related planning has not provided sufficient guidance for specific spatial objects such as high-risk areas and vulnerable populations. Weak linkage between water sources, persistent high temperatures superimposed on the impact of sea level rise, insufficient security of water supply, and shortcomings in local flood prevention and drainage facilities in response to catastrophes. Insufficient community safety and disaster prevention facilities, low public awareness of disaster prevention, and insufficient attention and investment in grassroots emergency management capacity building. There is a lack of synergy in flood prevention standards between cities upstream and downstream of the basin, and it is difficult to coordinate rain and flood management between cities. The coordination function of the emergency management department has not been fully utilized, and there is a certain degree of inadequacy in the articulation and precision of the planning system, and the role of the comprehensive guidance has not been fully utilized, and other problems. In order to enhance the climate adaptation capacity of the Taihu Lake Basin, it is recommended to strengthen basic research and the prediction and simulation of extreme disasters, improve the spatial layout of resilience, protect the natural storage space, and build a "centralized + distributed" urban spatial structure. It is also recommended to make up for the shortcomings of disaster prevention facilities, improve flood response capacity, improve the interconnected raw water system, enhance community emergency response capacity, strengthen the construction of community disaster prevention facilities, optimize the setting of shelters, and strengthen disaster prevention education and drills. It is recommended to establish a coordinated dispatch mechanism between the region and the river basin, and to enhance the coordination capacity of the emergency response departments.

Henk shared a number of relevant research examples, centered on the research theme of the "Learning from Disasters" chapter of the project report. He began by sharing research evidence on the increasing risk of all types of disasters due to climate change globally, as well as OECD and World Bank projections of economic losses due to climate change over the next 2050. Urban areas are particularly at risk of losses. Countries around the world therefore need to invest more in climate adaptation. Secondly, he proposed to promote transformational change in climate resilience, in particular by strengthening the role of research, planning and design. Finally, using the case of Hurricane Sandy in New York in 2012, he presented the Designing to Rebuild program in the region's post-disaster reconstruction, which combined innovation and global expertise with community insights to develop implementable solutions to the region's most complex needs. The project involved more than 180 organizations and hundreds of participants. The project's proposed sponge city construction has increased water storage capacity throughout New York many times over. The case also mentions the difficulties faced during the post-disaster reconstruction process., including ①There are obvious differences in the vulnerability of different communities to disasters due to economic reasons, such as the Long Island area and the surrounding regions. ② How to make the reconstruction work more systematic, in this regard, the then U.S. President Barack Obama allocated 60 million U.S. dollars to set up a post-disaster reconstruction team, organizing more than 20 organizations to help the U.S. government design how to carry out reconstruction. ③ In the post-disaster reconstruction, many residents are suffering from intense mental trauma and stress after being victimized, so it is necessary to carry out full public participation, listen to and address the demands of the residents as an important part of the reconstruction plan for habitation.

Finally, the panelists focused on the policy recommendations of the report. The initial consensus that emerged included the following key points:

(1) Climate risks need to be identified and quantified for each city, region, jurisdiction, and major

ecosystem, and potential interventions to reduce risk need to be demonstrated. Consider interactions with other scale levels-for example, cities within river basins. Consider that critical infrastructure, vulnerable populations, and vulnerable ecosystems will be more vulnerable.

(2) It is needed to implemented and evaluated stress tests for each city, region, and jurisdiction. Use long-term extreme climate change scenarios for these tests, including exceeding current infrastructure and public service design standards.

(3) Plan and implement adaptation measures in a way that minimizes damage from extreme weather events while maximizing the benefits and services provided by the intervention. Green-gray and blue-green infrastructure solutions have been shown to provide numerous social, economic, and ecosystem services while providing protection against floods, droughts, heat waves, and related disasters.

(4) Five key capacities for effective adaptation to climate change should be regularly assessed and ambitiously improved: building long-term resilience; the capacity to raise thresholds for the emergence of problems; the capacity to respond to problems immediately, including rescue resilience, and to take full advantage of future opportunities for adaptation to climate change (to rebuild better); preparedness based on the most up-to-date and forward-looking information; and the capacity to innovate transformationally, if necessary, to steer regional development on a new trajectory.

(5) Maintaining and improving these capacities now and in the coming decades will need to be tailored to the specifics of each city, region, jurisdiction, and major ecosystem. In particular, the capacity for innovation transformation requires a range of enabling conditions, including clearly mandated collaboration, broad participation, appropriately supported knowledge and creativity, and a coherent investment agenda.

2.4 June 18-19: Working Meeting in Shanghai and Field Trip

The group arrived in Shanghai from Wuhan on the evening of June 18 and started the working visit in Shanghai on June 19.

In the morning of June 19, the group went to the Shanghai Branch of the CAUPD and held an internal working seminar.

In the afternoon, the group went to the Yangtze River Delta Eco-green Integrated Development Demonstration Zone for research. The site was Yuandang Slow Walking Bridge and Cenbu Village, mainly to understand the ecological and environmental management of the Taihu Lake Basin, upstream and downstream water safety cooperation and rural revitalization projects.

2.5 June 20: Field Trip in Shanghai

On June 20, the research group conducted a field study in Shanghai along the river and coastal areas, including Wusong Cannonball Bay Wetland Park and Yangpu Riverside, focusing on the Yangtze River estuary migratory wetlands, climate-adapted embankment construction and waterfront space renewal projects. In the morning, the group visited the Wetland Park in Wusong Cannon Taiwan Wetland Park, Yangtze River Estuary Science and Technology Museum and riverside wooden in order to understand the formation and change of the Yangtze River estuary, the history of water conservancy development in Wusong River estuary, and to feel the charm of migratory birds wetland. In the afternoon, the group went to investigate the climate-adapted embankment construction and waterfront space renewal project of Yangpu Riverside, and researched four demonstration sites implementing the concepts of eco-green development and sponge city construction on Yangpu Riverside, including Yangshupu Power Plant Relic, Soap Dream Space, Green Mound (including the surrounding rain gardens, invisible embankments, locks, etc.), and Yangshupu Water Plant, to experience the vitality of the open space of Yangpu Riverside in the field.

3 Introduction to the research case areas

3.1 Futian Mangrove Nature Reserve

Shenzhen Futian Mangrove Nature Reserve was officially established in 1984 and designated as a national nature reserve in 1988, with a total area of 367.64 hectares, it is the smallest national nature reserve in China and the only national nature reserve located in the core area of the city. The investigation and investigation of the science exhibition hall of Futian Mangrove Ecological Park and the construction of the park itself, and a comprehensive understanding of the living habits of local mangroves, migratory birds and many organisms in Shenzhen Bay, the spatial evolution and changes of Shenzhen Bay and the protection of plants in the process of urban space evolution, as well as the actions and contributions of social organizations in this process.

For example, MCF's Maritime Forest Restoration Project is working to restore mangrove wetlands around the world through exchanges and discussions with Southeast Asian countries with developed mangrove forests through ASEAN. As of 2022, Shenzhen Mangrove Fund has helped six cities (Shenzhen, Zhanjiang, Quanzhou, Beihai, Haikou, Danzhou) and regions (or eight protected areas) to manage and restore mangroves through the management of invasive alien plants and the replanting of native mangrove plants.

Under the guidance of the government, MCF has carried out the restoration of fish ponds in the Futian Mangrove Nature Reserve since 2016. By raising the fish pond and leveling it so that there are bare tidal flats for water birds to rest at high tide. When the tide is low, the pond does not dry up completely, ensuring that fish, shrimp and crabs can survive in the pond. Since this project provides accommodation for waterbirds, we jokingly call it "Migratory Bird Lodge/Hotel". After the first round of remediation, we found 92 black-faced spoonbills in the pond, which was 2.3% of the total at that time.

MCF's job is to maintain a delicate balance between urban development, human activity and environmental protection. By the end of 2022, more than 800 volunteers had participated in MCF's guided tours, citizen science popularization, ecological restoration, venue operation and other projects, serving more than 35,000 visitors. Through cooperation with governments and professionals, much progress has been made in biodiversity conservation.

3.2 Shenzhen Bay Coastal Leisure Belt

Shenzhen Bay is the closest bay to the urban area, and the Shenzhen Bay Coastal Leisure Belt serves as the boundary between the city and the sea, divided into east-west and north-south sections with a total length of about 16 kilometers. Since 2003, the Shenzhen Bay Coastal Leisure Belt has undergone nearly ten years of design and service to try to balance the sensitive and fragile ecological environment with the dream of coexistence of urban coastal places for citizens. Here, the needs of the natural system come first, and human activity areas are appropriately separated from the ecological sites with dense birds and mangroves (Futian Mangrove Nature Reserve) to reduce impact; even in areas of human activity, large natural tidal flats are retained for the growth of benthic flora and fauna and for birds to forage.

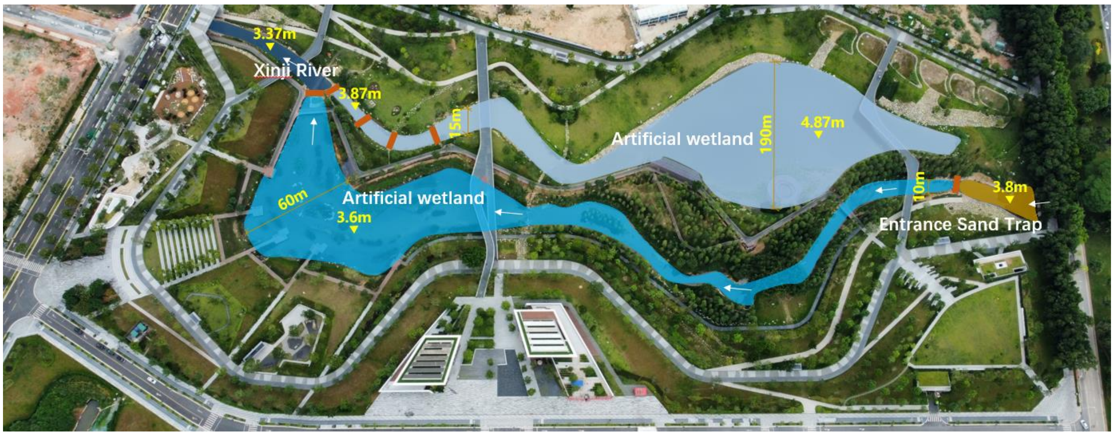

3.3 Shenzhen Dasha River Ecological Corridor

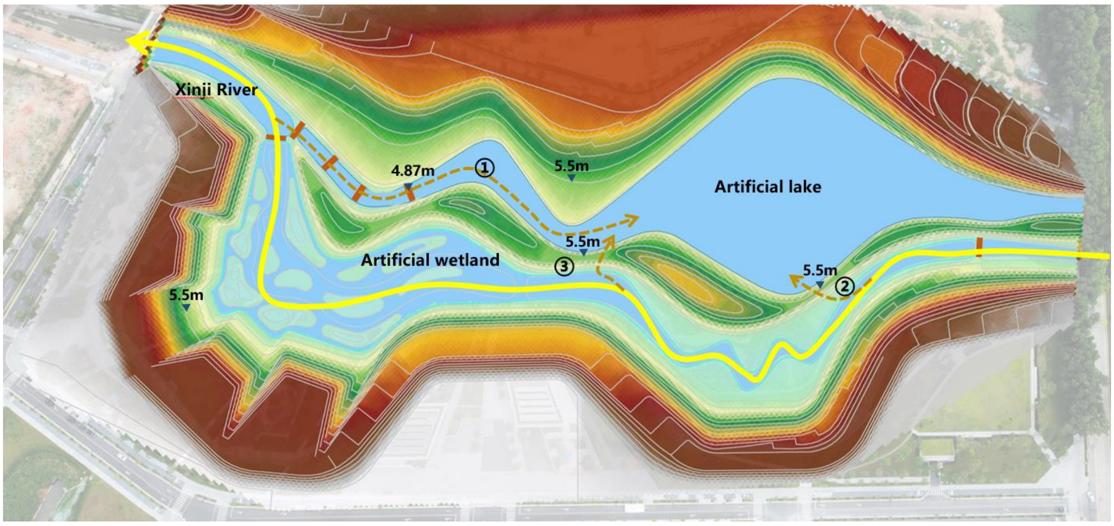
The Dasha River Ecological Corridor Greenway is 13.7 kilometers long, connecting the Shenzhen Bay Coastal Leisure Belt and the Shenzhen Talent Park at the estuary section, and stretches northward to the University Town, making it the largest waterfront slow traffic system in Shenzhen. Its uniqueness lies in its location; the right bank of the river is an important high-tech industrial cluster in Shenzhen, while the left bank represents the urban garden lifestyle of Shenzhen's Overseas Chinese Town. In addition, the Dasha River Ecological Corridor is an important part of Shenzhen's clustered spatial structure. At the beginning of urban construction, such a green corridor was planned to define the boundary of urban space growth, forming the city's green and wind corridors. After recent renovations, it has also become an important place for residents to relax and enjoy leisure time.



3.4 Center Park

Center Park is located between Dongguan Avenue and Hongtu Road, and is an ecological water-friendly park built on the basis of the Xinji River channel. It is positioned as the new living room of Dongguan city, covering an area of about 220,000 square meters, of which the first phase covers an area of about 120,000 square meters. It includes two relatively independent water systems, namely the artificial wetland (Xinji River channel) and the artificial lake water system. The area of the artificial wetland is about 1.01 hectares, and the area of the artificial lake is about 1.46 hectares. The artificial lake can accept its own rainwater and has an internal natural purification cycle; the artificial wetland (Xinji River channel) has a purification function, purifying the upstream base flow of the Xinji River (no clear flood discharge function). According to the river basin planning, the flood control design standard of the Xinji River is a 100-year return period design standard, and the flood discharge capacity of the park's water system meets the 100-year return period design flood (the flood peak flow at the Dongguan Avenue section is 155 m^3/s, and the water level of the park's water system does not exceed 7.20 meters during the flood discharge and storage. When the downstream water level exceeds 4.87 meters, the flood is blocked by the downstream and enters the artificial lake through path ①; when the water level of the artificial wetland ② and ③ exceeds 5.50 meters, the flood overflows from the artificial wetland into the artificial lake.

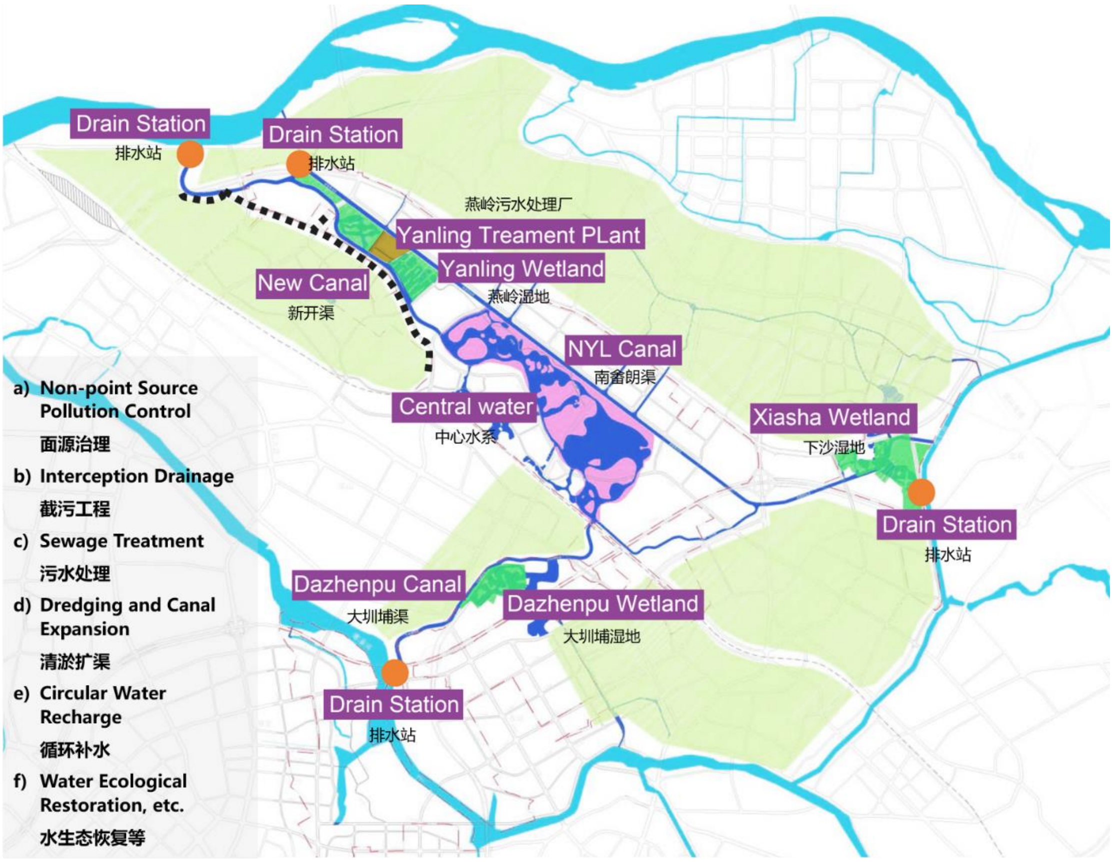




3.5 Dongguan Eco-park

Dongguan Eco-Park is a milestone in the urban development transformation and industrial upgrading of Dongguan, and it is also a practical example of sustainable development exploration in the Greater Bay Area. It adopts a pragmatic low-carbon ecological concept, and has implemented the path of ecological city construction with "water management as the forefront—ecological restoration—water management for urban development—reshaping production and life". Located on the edge of the six towns in the eastern part of Dongguan City, more than ten years ago, it was a typical example of the negative effects brought by the rapid urbanization of the Pearl River Delta, with garbage accumulation, sewage convergence, and frequent waterlogging disasters. After more than a decade of accompanying planning and design services, the water body is now clear, lakes are interdependent with islands, wetlands are charming, and it has become an environmentally friendly new type of industrial park, a gathering place for innovative enterprises in the Greater Bay Area, and a leisure travel destination favored by citizens.

Before the transformation and construction, the polluted water bodies in the area accounted for 55% of the park's area. Urban design started with the management of water environmental pollution, closely coordinated with the design of the water environmental system, and linked the reconstruction of the regional complex water ecological environment in the six towns. A series of environmental reconstruction measures such as pollution control, water management, restoration, and ecological regulation were adopted to achieve multiple goals such as "water safety, water landscape, water ecology, and water culture". A series of water environmental reconstruction projects were carried out within the basin (non-point source management, pollution interception projects, sewage treatment, dredging and channel expansion, cyclic water replenishment, and water ecological restoration), forming a "water ecological meridian" centered on the ecological park and connecting the surrounding six towns. After the implementation of the water management project, the water quality standard has been improved from the original poor Class V to Class IV, establishing a green water system centered on the ecological park, connecting the surrounding six towns, and comprehensively recycling rainwater and sewage.



3.6 Yuandang Slow Walking Bridge and Cenbu Village in the Shanghai-Yangtze Delta Demonstration Zone

Yuandang is a cross-border lake belonging to Shanghai and Suzhou, with a total surface area of 1,290 square kilometers, of which 9.93 square kilometers are within the territory of Wujiang District and 297 square kilometers within the territory of Qingpu District. At the same time, as an important storage body of water in the Taihu Lake basin, it is a key element in the flood control and drainage safety pattern of the two areas. Since the integrated ecological and green development of the Yangtze River Delta has been upgraded to a national strategy, the two regions have jointly carried out a number of water conservancy projects and water ecological environment improvement projects, which have greatly enhanced the flood control and drainage capacity of the lower Taihu Lake Basin, and improved the water ecological environment. Yuandang Slow Walking Bridge connects Shanghai and Suzhou across Yuandang Lake, with a total length of about 585.7 meters, of which the main bridge is about 485.8 meters long, in a curved design, like a colorful satin fluttering in the wind. The average width of the slow bridge is 6 meters, and the widest place reaches 16 meters. As the first large-scale landscape pedestrian bridge in the demonstration area, Yuandang Slow Walking Bridge not only connects Qingpu and Wujiang, but also buttresses the wetland landscapes on both sides of Yuandang Lake and the greenway around the lake, connecting the rich ecotourism resources and humanities resources in the surrounding area.

Cenbu Village is located in the Xicen area of Jinze Town, with rivers and harbors spreading across the village, and convenient land and water transportation. With the support of the government, Cenbu Village has begun to explore new paths of rural revitalization in the new era, and was awarded the title of the first batch of "Eco-Cultural Village" in 2009, and was successfully created as the fourth batch of rural revitalization demonstration villages in Shanghai in 2022.

Cenbu Village takes the ecological village as the entry point to create a "high-value" ecological livable village, and has completed the upgrading of 158 houses, improved infrastructure such as roads, bridges and piers, and laid out water purification landscape plants, ecological filter beds and fogging systems to enhance the ecological environment of the village, make the water upstream line more beautiful and unique, and make the hard-to-find traces of fireflies, which are hard to find, to increase significantly in density during the viewing period, to protect biodiversity, and to realize the ecological IP of Cenbu.

3.7 Wusong Fortress Taiwan National Wetland Park in Shanghai

Shanghai Wusong Fortress Taiwan National Wetland Park is located in Baoshan District, Shanghai, bordering on the Yangtze River in the east, relying on Fortress Hill in the west, ending at Tang Hou Road in the south, and ending at Bao Yang Road in the north, with a total area of 106.6 hectares, of which the original wetland area is 63.3 hectares, and the shoreline along the river is about 2,250 meters. Because the Qing Dynasty government had built a sailor's battery here, it was named "Cannon Taiwan" The original site of the park was the Yangtze River mudflat wetland, and since the 1960s, the land area of the park was formed by backfilling the waste steel slag one after another. 2005, the local government planned to build a wetland park here to improve the ecological environment of the region. After years of construction, the first phase of the park was completed and opened in May 2007, and the second phase was completed and opened in October 2011.

(1) Node I: Pit Park

Part of the Cannonball Bay Wetland Park is a slag pit left over from the industrial past, and sustainable design has allowed this "scar" caused by man-made interference to form a unique landscape - Mining Pit Park. In the face of this "big pit", some people have also considered filling the pit into flat land, but another design solution has gained more recognition for the local conditions, with clever design to tell the story of "steel slag".

Thus, the "pit garden" is not deliberately "digging" and become, but in the original "pit" on the basis of sculpture, the formation of a bonsai type of green ecological gardens, condensed the park's The park's "past life and present life". What's more special is that the water of the creek in the pit park and the slag with minerals at the bottom of the creek are combined, making the creek water appear blue-green. Slag paved paths, gurgling blue stream water restore the park's past; rich flowers, plants and trees, dancing colorful butterflies tell the park's today.

(2) Node II: Yangtze River Estuary Science and Technology Museum

Shanghai Yangtze River Estuary Science and Technology Museum is the first professional exhibition hall with the theme of estuary science and technology in China, with a total floor area of 7707 square meters, which is a thematic science and technology museum integrating estuary natural science, scientific research, popularization of science and humanities. The museum, which looks like a leaping fish, has four regular exhibition halls and one temporary exhibition hall, including the Prologue, Resources and Environment, Science and Technology, Application, Humanities and History, with a total of 51 exhibits, focusing on the nature, ecology, science and technology, and history of the Yangtze River estuary, and comprehensively displaying the relevant knowledge of the world's major estuaries.

(3) Node III: Riverside Wetland

The meandering riverside wooden walkway brings people close to the wetland, and is also the best viewpoint for looking at the Yangtze River. The vibrant wetland is rich in aquatic plants and small animals, attracting many waterfowl to roost and forage here, and is also the best stop for migratory birds traveling from south to north. There are mainly three kinds of plants in the wetlands along the river: cassis, reeds and wild wild wild rice. Common small animals in summer include the toothless mantis phalarope crab, red cheliped mantis phalarope crab, and Tan's mud crab, which live under the rocks along the river. According to bird surveys and birdwatchers' records in the past ten years, there are 144 species of birds in 14 orders and 39 families in Wusong Cannonball Taiwan Wetland Park, including 47 species of water birds and 97 species of land birds. Among them, there are 10 species of national second-grade protected birds. The park has also recorded the black-billed gull, which is classified as a vulnerable species by the World Conservation Union (IUCN), and the lesser taiping, a near-threatened species. From November to March every year, a large number of migratory birds roost and stay in the park. Common migratory birds include silver gulls and mottled-billed ducks, which can reach several hundred at times, and the number of birds is usually highest in February every year.

3.8 Yangpu Riverfront Climate Adaptive Embankment Construction and Waterfront Space Renewal Project

Yangpu riverfront is located in the east end of the Huangpu River shoreline, known as the Shanghai waterfront "east gate", its 15.5 kilometers of riverfront shoreline is the longest of the five districts along the Huangpu River. Yangpu riverfront shipbuilding, textile, public utilities and other industries have been prosperous and active, known as "the cradle of modern industry" is one of the origins of China's industrial civilization for a hundred years. Hundred years of industrial development, for Yangpu Riverfront left "the world's largest remaining industrial zone along the river".

In the Shanghai Urban Master Plan, it is proposed to build "an excellent global city, highlighting the core function of the central activity zone as a global city". As an important part of the Central Activity Zone, Yangpu Riverside (within the inner ring) will transform the closed production-oriented shoreline into an open and shared living shoreline, strive to build a hundred years of industrial civilization display base, post-industrial science education base, fully implement the requirements of the sponge city construction, and continue to improve the quality of Yangpu Riverside public space.

(1) Node I: Yangshupu Power Plant Relic Park

The remodeling process fully respects the natural state of the original site, and by preserving the original geomorphology, a low-lying wetland is formed that can collect rainwater. At the same time, the new plantings are mainly native herbaceous plants and water-resistant trees, forming a landscape environment with natural wildlife and industrial characteristics. In addition, a low-carbon café was built on top of the power plant's water purification pond. These innovative initiatives not only realize the reuse of industrial heritage, but also demonstrate the green and low-carbon concept of Yangpu Riverfront in practice.

(2) Node II: Green Mound

Green Hills was originally a tobacco company mechanic's warehouse, formerly known as the Jardine Cold Storage built in 1920. During the renovation process, the volume of the tobacco warehouse was cut down, crossing the road and intersecting the pedestrian and vehicular traffic. Through technical measures such as vertical greening on the roof, the building itself becomes part of the waterfront landscape by forming a "sky garden" with staggered terraces. The renovated Green Mound is positioned as an urban riverfront complex integrating municipal infrastructure, public green space and public supporting services, with a base area of 1.37hm² and a building surface of 17,500m².

The featured hydraulic and hydro-ecological landscaping around Green Mound includes an invisible embankment for the high piling dock, rain gardens and wetland design. In particular, the landscape architects worked with the hydraulic engineers to transform the original single flood wall into a two-stage system. For the flood wall modification, the top of the first stage wall is at the same height as the ground level of the retained high pile jetty, creating a continuous activity space. The second stage wall was adopted to a one-in-a-millennium standard and positioned 20 to 30 meters back, completely hidden in the landscape mulch and planted terrain. The 6% grass slope facing the river provides a comfortable view of the beautiful city skyline of the Huangpu River. The new flood control system enriches the landscape topography in a resilient way while reducing the threat of typhoons and heavy rains. The sponge concept is implemented by adopting the strategy of limited intervention and low-impact development, and ecological restoration and remodeling is carried out on the basis of respecting the spatial foundation and native form of the original site. The larger area in the hinterland behind the flood control wall was originally a low-lying waterlogged area with aquatic plants, preserving the original geomorphology and forming a low-lying wetland that can collect rainwater. When heavy rainfall can play a role in storing precipitation and slowing down the discharge of rainwater into the municipal network. In addition, through the installation of pumps and irrigation systems, the water collected in the wetland can also be used for watering the entire landscape site. The plants are mainly native herbaceous plants and water-resistant trees, and the landscape structure is equipped with light intervention steel structure, forming a landscape environment with native wildlife and industrial characteristics.