Sustainable Climate Change Adaptation: Insights and Reflections from the Field

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5

Sustainable Climate Change Adaptation: Insights and Reflections from the Field

5.1

Introduction

Despite the many extreme events occurring all over the globe and the media coverage reporting on climate change impacts in terms of droughts and flooding, progress toward properly addressing climate change is still slow (IPCC, 2022; UNEP, 2023; Pagnone et al., 2023, pp. 33-50; see also Sections 3.12 and 4.6). This can only partly be explained by deep uncertainty and the still incomplete understanding of the relationship between climate change causes and their outcomes. Challenges with understanding the where(s), when(s), and how(s) of incidents and emerging problems also make understanding and tackling current and future mitigation and adaptation needs a difficult task. Against this background, it has proven difficult in various socio-cultural contexts to unite actors around the decisions that need to be made on local and regional adaptation strategies and mitigation measures. And yet, while climate change mitigation agendas are still being debated, social and ecological systems already need to cope with very tangible losses and damages caused by climate change impacts—not to mention the need to prepare for future impacts (Hoegh-Guldberg et al., 2019; Puig, 2022; Seneviratne et al., 2021). Exploring climate adaptation strategies and assessing their opportunities and limitations has thus become an urgent task in the context of designing sustainability pathways (Gresse et al., 2023). Interfering with or acting in societal systems with their various social, cultural, spatial, temporal, and natural environments represents a challenging and even daunting task with its own opportunities and limitations. This results in the overarching research question for the current Outlook: "Under which conditions is sustainable climate change adaptation plausible?" This Chapter builds on the preceding chapters and provides empirical key insights into climate change adaptation.

Given the local and regional nature of climate change adaptation, this chapter empirically scrutinizes the contextual conditions that affect the plausibility of sustainably adapting to climate change in various geographical localities and regions. We use an inductive rationale that builds on an assessment of nine case studies, aiming to connect new research to recent developments with regard to climate impacts. Our investigation is interdisciplinary, grounded, and involves scientists from various disciplines such as anthropology, linguistics, geography, sociology, environmental economics, environmental law, urban planning, forestry science, soil science, agricultural science, climate science, biology, chemistry, physics, and coastal engineering. The case studies examine, analyze, and assess barriers to sustainable climate change adaptation across different regional contexts, providing empirical insights into the current state of the art of adaptation in urban, rural, and coastal settings.

The chapter is divided into the following sections and sub-sections: Section 5.1.1 provides a brief meta-review of documented climate change adaptation research around the world, depicting the emergence of climate change adaptation as a key topic and different disciplinary takes on this. It explains the emergence of climate change adaptation as a key topic; it also briefly considers what climate change adaptation actually represents, on which scales it takes place, what challenges are involved and what research gaps still exist. In Section 5.1.2, key concepts of climate change adaptation are presented and contextualized against the background of existing literature. Section 5.1.3 provides an outline of the methods used in the case study assessment. Section 5.2 then turns to the case studies as the empirical core of the chapter. Section 5.12 completes the chapter with a conclusion and an assessment of the plausibility of sustainable climate change adaptation.

The nine case studies aim to identify key contextual conditions for sustainably dealing with climate change impacts. They were selected to reflect the different realms of urban and densely populated areas, rural-agricultural areas, and coastal zones. Furthermore, it was important to reflect different continents and the northern and southern hemispheres in the broadest way possible (see Figure 5.1). Individual case studies were selected based on existing expertise in Hamburg, working contacts and cooperative relationships with scientists in the case study areas. Based on these criteria, the three urban areas of Hamburg, São Paulo, and Ho Chi Minh City were selected, as well as the three rural areas of northern Lower Saxony (Germany), Kunene (Namibia) and the Nepal Highlands and the three coastal areas of the German North Sea coast, the Taiwanese coast, and the island state of the Maldives.

Climate Change Adaptation: a Meta-Review of Current Research

The relevance of societal adaptation in responding to climate change was first formally acknowledged in the Rio Declaration developed in 1992 at the United Nations Conference on Environment and Development. In recent decades, climate change adaptation has repeatedly been raised in several reports of the Intergovernmental Panel on Climate Change (IPCC), for example in its 2001 report on Impacts, Adaptation and Vulnerability (Massey and Huitema, 2013). The 2018 report on the Impacts of Global Warming of 1.5° above Pre-Industrial Levels (IPCC, 2018) explicitly addresses the importance of public participation in climate change adaptation, while societal adaptation is also raised in the recent Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 'Climate Change 2022: Impacts, Adaptation and Vulnerability' (IPCC, 2022).

Looking back at the period from 1992 to today, it is clear that climate change adaptation has come to represent a central topic in the field of climate science, reflected in the vast number of publications addressing the subject. There has been exponential growth of publications on climate change adaptation over the past two decades (Callaghan et al., 2020; Haunschild et al., 2016; Nalau and Verrall, 2021), with a doubling occurring every five to six years between 1980 and 2014 (Haunschild et al., 2016). From 1978 to the mid-2020s, an average annual increase of 28.5% was observed in climate change adaptation publications; this rate had doubled by early 2022 (Nalau and Verrall, 2021). Looking at general publication trends from a disciplinary perspective, more than 60% of the literature is published in natural science journals that specifically address climate impacts and adaptation issues, while the social sciences and humanities concerned with the socio-cultural aspects of adaptation are lagging behind. Quantitatively speaking, within the past three IPCC assessment periods (2001-2018), adaptation may thus have become a fast-growing topic but the disciplinary perspective shows a persistent gap with respect to the social dimensions of climate change adaptation. It is interesting to note that climate change adaptation is the most widely addressed topic in relation to the baseline literature identified (Callaghan et al., 2020).

The bulk of academic publications deals with behavioral responses, followed by technical, infrastructural, and institutional responses (Nalau et al., 2021; Hunter et al., 2020). Adaptation planning is recognized globally and documented as undertaken by most nations (Berrang-Ford et al., 2021; UNEP, 2023), but this only refers to reported adaptation intention and planning and not necessarily to adaptation measures actually taking place (Berrang-Ford et al., 2021; Petzold et al., 2023a). All these different aspects are also mirrored in the number of scientific disciplines engaged in climate change adaptation research, ranging from the natural sciences (e.g., engineering, geophysics, climatology) to the social sciences (e.g., political science, sociology, economics, geography, anthropology) and humanities (e.g. philosophy, linguistics). Each discipline and its fields of research have developed their own theoretical, methodological, empirical, and sometimes interdisciplinary rationales for climate change adaptation. A point of convergence is the framing of climate change as a wicked or multifaceted problem (Hulme, 2009; 2021). Overall, work on climate change adaptation has often been devoted to conceptual issues, with empirically driven or even applied studies only starting to catch up during the past decade (Bouwer, 2022). On a grander level, however, there is still a lack of converging key concepts and practical application.

Contextualization: Key Concepts of Climate Change Adaptation

As shown above, climate change adaptation is a multidisciplinary concept that often lacks precise definition and conceptual consistency. It is for this reason that this chapter uses the globally agreed and guiding definition provided by the IPCC Sixth Assessment Report. Here, climate change adaptation in human systems is described as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities" (IPCC, 2022). This aspect is complemented by the inclusion of natural systems for which adaptation is described as "the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2022, p. 2898). Drawing on the definition established in the previous Outlook, we frame sustainable climate change adaptation "as the process of adjusting to actual or expected climate change and its impacts by minimizing trade-offs and exploiting synergies between climate action and other sustainable development goals" (Gresse et al., 2023, p. 65). In this vein, adapting to climate change in a sustainable manner means accounting for the broader range of societal goals and socio-ecological transformations involved in designing, planning, and implementing adaptation responses. Hence, a sustainable adaptation response has to necessarily address the various ranges of climate action while also fostering sustainability transformations, that is, multi-sectoral and system-wide shifts that foster human development while protecting and upholding the resilience of Earth's life-support systems (Gresse, 2022; Messner, 2015; Salomaa and Juhola, 2020). If adaptation measures are not properly tailored to the environment or situation at hand, the risk of misplaced or inappropriate adaptation increases. So-called maladaptation is defined as "an action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups" (Barnett and O'Neil, 2010, p. 211; see also IPCC, 2022; Barnett and O'Neil, 2013; Juhola et al., 2016; Magnan et al., 2016). Assessing maladaptive effects of adaptation action, however, is tricky as it requires ex-post analysis either after a longer period of time or following a disastrous event. As far as sustainable climate change adaptation is concerned, maladaptation can be observed at the local scale in the short term if adaptation measures lead to negative environmental or socio-economic impacts shortly after their implementation, making people and communities even more vulnerable to climate change (Schipper, 2020).

Conceptually, adaptation responses can be classified into three analytical categories: (1) coping, (2) incremental adaptation, and (3) transformative adaptation (Fedele et al., 2019). Within this conceptual landscape, coping strategies take the form of temporal, immediate, and reactive responses to climatic impacts on socio-ecological systems. Coping strategies do not aim at long term systemic change and can be constrained by limited technical and financial resources; they can also risk lock-ins in existing risk awareness and understanding (Kates et al., 2012; Perrings, 2006; Fedele et al., 2019, p. 118). Incremental adaptation, in turn, entails a stepwise approach along beaten paths, that is, "doing slightly more of what is already being done to deal with natural variation in climate and with extreme events" (Kates et al., 2012). Such an approach focuses on sectoral or context-specific adjustments resulting in a minor disturbance of systemic stability, which in the long run holds the danger of consolidating unsustainable systemic states (Adger and Jordan, 2009; Kates et al., 2012; Fedele et al., 2019; Wakefield, 2019). Finally, transformative adaptation intends to encourage fundamental changes in situations where incremental changes no longer suffice (Kates et al., 2012). It differs from the previous strategies by encompassing broader and deeper actions directed at the root causes of vulnerabilities while at the same time envisioning long-term systemic shifts. Characterized as a path departure, it combines ruptures that carve out spaces for interstitial and symbiotic approaches to change. Wright (2010, p. 298) points out that "both deliberate and unintended processes of social change are crucial for emancipatory transformation", which suggests that transformation is better conceived of as a continuous and messy process of change that cannot be controlled and managed within existing paradigms (Termeer et al., 2017). By enabling direct abrupt changes, or through the cumulative effects of indirect incremental adjustments, this type of strategy recognizes and addresses the need to fundamentally alter socio-ecological systems and human-environment relationships (Adger and Jordan, 2009; Adger et al., 2011; Kates et al., 2012; Fedele et al., 2019; Feola, 2015; O'Brien, 2012; IPCC, 2013).

Importantly, however, none of these three responses mean that the pathways adopted are necessarily sustainable. Nevertheless, coping and incremental adaptation have been more frequently related to unsustainable adaptation pathways, thus underlining the relevance of transformative adaptation strategies if progress is to be made toward sustainable climate adaptation.

Methodological Approach for the Assessment

The present chapter is designed as an empirical study grounded in case studies. It builds on frameworks, key concepts, and findings established in the two previous editions of the Outlook (Stammer et al., 2021; Engels et al., 2023). Methodologically, all case studies use inductive reasoning that draws on qualitative data collected by means of expert elicitation, literature reviews, document analysis, systematized interview studies, guided round table discussions, and on-site exploration of local and regional places. Unlike the social driver assessments (Sections 3.2 to 3.11), the case studies do not explore potential drivers of change and their respective enabling and constraining conditions. Rather, they focus on the plausibility of sustainable climate change adaptation by analyzing different types of adaptation responses and addressing the extent to which socio-ecological systems are able to adapt to climate change, that is, the context-specific limits of adaptation (Bouwer, 2022; Thomas et al., 2021; Berkhout and Dow, 2023). For this to be investigated among the overall group of the case studies, each author team was asked to fill out an initial questionnaire to organize, systematize and align their content. Invited experts from the case study regions then took an active part in organizing the comparative analysis and contributed to the writing process. This ensured content and empirical accuracy while at the same time widening the conceptual and empirical scope of each case study assessment.

Based on the agreed general framework, each team explored their case study's specific empirical evidence and then reflected on its findings at a more theoretical level. The expert elicitation among those involved in the case studies focused on an agreed-upon textual structuration to comparatively tackle the various dimensions of climate change adaptation in the different case studies. To ensure coherence with respect to the content of each case study, the following questions were chosen as a framework for orientation:

- What does climate change adaptation actually mean in the current case study?
- Who, where, how, and what is adapted to which specific features of climate change and impacts?
- Who initiates, structures, negotiates, and steers the adaptation process in what way?
- Who implements adaptation with whom under the existing framework conditions and takes decisions?
- And what are the resulting possible and plausible adaptation options, if any?

Delving into the rich empirical data provided by the case studies allows us to investigate which barriers and opportunities exist for sustainable climate change adaptation and which types of response are prevalent in dealing with climate change (i.e., the extent to which coping, incremental, or transformative adaptation is apparent in the cases investigated). In the case studies, we assess the context conditions affecting the plausibility of achieving sustainable climate change adaptation drawing on the definition and plausibility framework of previous assessments (Stammer et al., 2021; Engels et al., 2023).

This approach was collectively prepared during two moderated workshops in which 25 organizing and co-authors participated and where the scope and the conceptual procedures for the assessment were cooperatively developed, assessed by a steering group, and discussed among all authors. All empirical analyses for the case studies—including data acquisition—were carried out between 2019 and 2023. Content-based feedback to organizing authors of each case study secured consistency while the peer-review by external reviewers assisted in securing scientific quality and comprehensibility. In brief, the chapter develops nine empirical case studies from the three general categories of urban areas, rural areas, and coasts. The structuring logic was to start with a European perspective and then explore (sustainable) climate change adaptation issues in various non-European regions and places. Analytical emphasis was put on the context conditions of climate change adaptation in each region with the aim to explore convergences and divergences among them. Thematically, the case studies focus on local climate change impacts, the societal and governance framing of climate change adaptation endeavors and context-specific conditions for sustainable climate change adaptation. These aspects were then assessed more generally to consider limits and limitations of the various ways of doing climate change adaptation. So-called take-home messages summarize key lessons drawn from each case study.

5.2

Toward Plausible Sustainable Climate Change Adaptation in Urban, Rural, and Coastal Areas

The case studies demonstrate that climate change adaptation is a multifaceted, tricky, and wicked problem where social, political, and natural processes permeate each other. Such multifariousness obviously does not allow for one-size-fits-all solutions. Rather, it calls for a more contextualized perspective that investigates and considers the site-specific interconnections of climate change, climate change adaptation, people, place, politics, administration, law, and science. This represents a conceptual, methodological, empirical, and above all practical challenge for which more and better scientific knowledge is only of limited help. Other enablers, which are more fully explored in the case studies below, are needed. Taking these aspects into serious consideration would also help to overcome the problem that climate change adaptation has so far largely remained conceptual and is still waiting for place-based application. We synthesize and discuss the key findings of this chapter in Section 5.12.

Figure 5.1: Case study locations and climate change effects

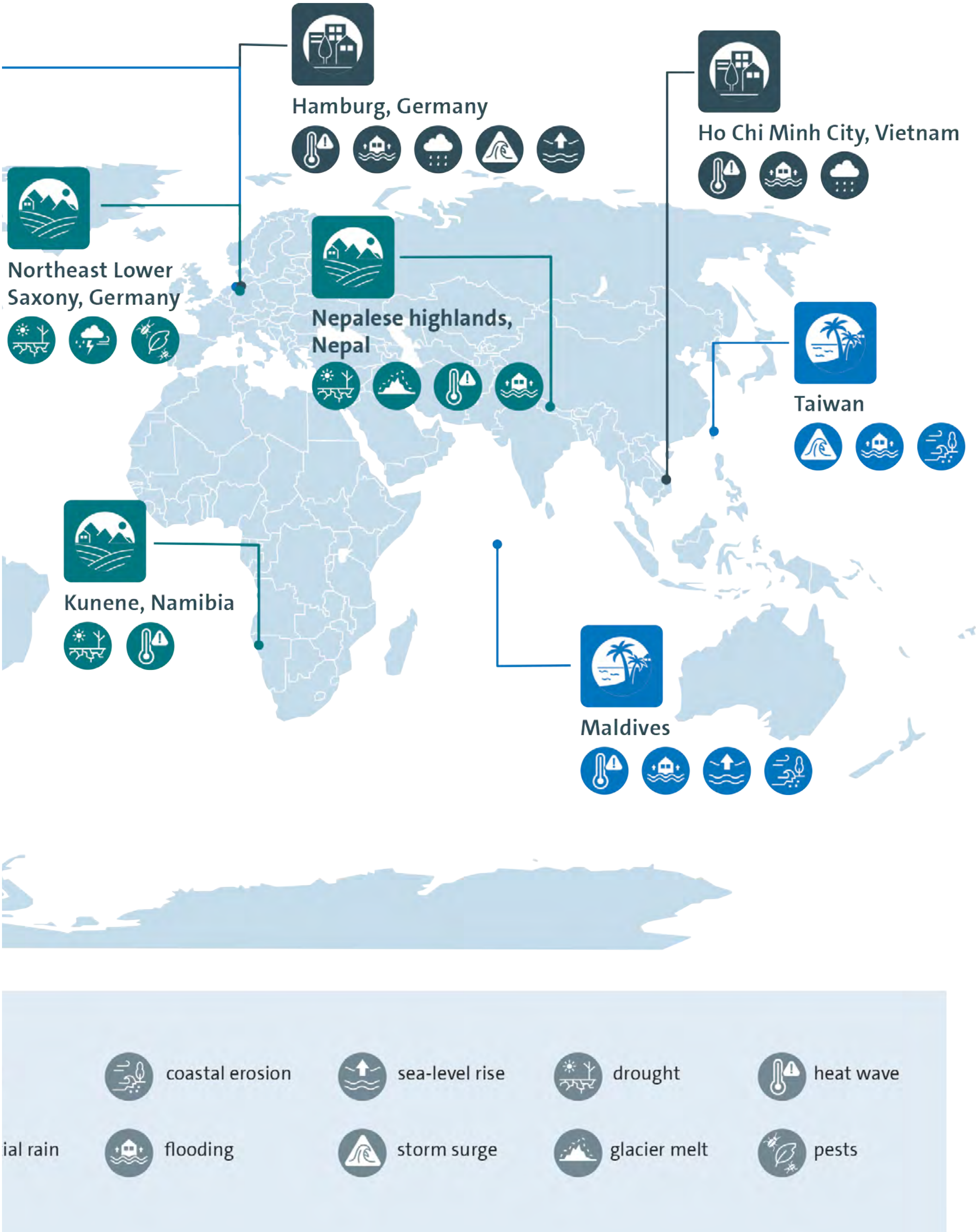
Hamburg, Germany
Ho Chi Minh City, Vietnam
Northeast Lower Saxony, Germany
Nepalese highlands, Nepal
Taiwan
Kunene, Namibia
Maldives
coastal erosion
sea-level rise
drought
heat wave
ial rain
flooding
storm surge
glacier melt
pests

TABLE 5.1

Case studies – Basic information

Region	Area size	Population	Topographical context / Climatic zone	
Hamburg (Germany)	755.3 km² [(1)]	1.9 Mio. [(2)]	**Topographical context:** coastal city and seaport in a transitional estuarine coastal zone, connection to the North Sea coast through the Elbe, Northern Germany **Climatic zone:** temperate, maritime climate, average temperature: 9.8°C, average annual precipitation: 720 mm	
São Paulo (Brazil)	1521 km² [(3)]	11.45 Mio. [(3)]	**Topographical context:** Brazilian southeast region, 760 m above sea level **Climatic zone:** humid subtropical climate, average temperature: 20.4°C, average annual precipitation: 1658,3 mm	
Ho Chi Minh City (Vietnam)	2095.4 km² [(4)]	>10 Mio.* (*pop. of the mega city exceeding administrative borders), according to Stat. Yearbook 2022 = 9.389 Mio inhabitants [(4)]	**Topographical context:** first mega city of Vietnam, northeastern edge of the Mekong Delta, large parts just 0.5 meters above sea level **Climatic zone:** tropical monsoon climate	
Northeast Lower Saxony (Germany)	47614 km² [(5)]	7.9 Mio. [(5)]	**Topographical context:** rural northeastern Germany, Lower Saxony, Wendland, low altitude, sandy soils, agricultural production: grains, maize, potatoes, sugar beets **Climatic zone:** temperate climate, transition between the Atlantic and continental climate zones, average annual precipitation: 550–750 mm	
Nepalese Highlands	122400 km² [(6)]	13.5 Mio. [(6)]	**Topographical context:** mountain region **Climatic zone:** (sub)temperate to tundra	
Kunene, Namibian Pastoralists	115239 km² [(7)]	86856 (census 2011) [(7)]	**Topographical context:** northwestern Namibia **Climatic zone:** (semi)arid, average annual precipitation: 100 – 300 mm, transformation to drier conditions	
North Frisia, German North Sea Coast	441 km of coastline and 5 islands [(8)]	169000 (2022) [(9)]	**Topographical context**: part of the Wadden Sea Region, which stretches from Den Helder in the Netherlands along the German coast up to Blåvands Hook in southern Denmark; low lying coastal region, tidal mudflats and marshlands **Climatic zone:** oceanic (moderate) climate, average temperature: 8.5–9°C [(5)], Average annual precipitation: 750 mm [(5)]	
Maldives	298 km² land area, 923322 km² total [(10)]	561631 (2022) [(10)]	**Topographical context:** indian Pacific, 1196 islands south of India, average land elevations ranging from 0.5 m to 2.3 m above sea-level **Climatic zone:** dry season with winter northeast monsoon and rainy season with summer southwest monsoon, average annual precipitation: 2,540–3,810 mm, temperatures rarely below 25°C	
Taiwan	36197 km² [(11)]	23.3 Mio. [(11)]	**Topographical context:** flat to gentle plains in the west, mostly forest-covered mountains in the eastern area, geologically very active area **Climatic zone:** subtropical, tropical climate on the south, monsoon climate, typhoons in summer, average annual precipitation: 2200–3800 mm	

Additional Sources: [(1)] Neumann, G. (2018). Hamburg- Location, Size and Population. Hamburg Marketing. https://marketing.hamburg.de/facts-and-figures.html (Last access: 11.03.2024), [(2)] Statistisches Bundesamt (2023). Städte (Alle Gemeinden mit Stadtrecht) nach Fläche, Bevölkerung und Bevölkerungsdichte am 31.12.2022. Available online: https://www.destatis.de/DE/Themen/Laender-Regionen/Regionales/Gemeindeverzeichnis/Administrativ/05-staedte.html. (Last access: 26.02.2024), [(3)] IBGE (2022). População. Instituto Brasileiro de Geografia e Estatística (IBGE). Available at: https://cidades.ibge.gov.br/brasil/sp/sao-paulo/panorama. (Last access: 06.03.2024), [(4)] General Statistics Office of Vietnam (2023). Statistical Yearbook of 2022. Statistical Publishing House, Hanoi. https://www.gso.gov.vn/wp-content/uploads/2023/06/Sach-Nien-giam-TK-2022-update-21.7_file-nen-Water.pdf (Last access: 21.02.2024), [(5)] Lower Saxony State Chancellery (2016). State Chancellery of Lower Saxony. Home of Diversity. Niedersachsen. Klar. https://www.niedersachsen.de/download/116564/Broschuere_Heimat_ (Last access: 23.11.2023), [(6)] Government of Nepal (2023). National Population and Housing Census 2021 (National Report). National Statistics Office, Kathmandu, Nepal, p. 614.

Political context	Climate change phenomena featured	Who adapts?
City, municipality, and Federal State in the Federal Republic of Germany, parliamentarian democracy	Heat waves, groundwater flooding, riverine flooding, coastal flooding, storm surges, pluvial flooding, torrential rain, coastal erosion, sea-level rise	Public bodies (politics, administration), business sector (e.g., Chamber of Commerce), housing industry (e.g., SAGA and cooperatives), citizens
City, capital of São Paulo federal state, Democratic Republic of Brazil	Torrential rain, inundation, flooding, landslides, droughts, heat waves	Local government, public administration (environment/climate-related secretariats), civil society, academia
Most populous city in the Socialist Republic of Vietnam, one-party state, authoritarian style	Heat waves, flooding, torrential rain	Public bodies (politics), households (micro-scale, such as elevated doorways)
Region in the Federal State of Lower Saxony in the Federal Republic of Germany, parliamentarian democracy	Drought, water shortage, decreased soil water availability, storm, damages in forests, pests: bark beetle infestations in forests	Farmers, forest owners, public bodies (politics on regional, national and EU level)
Region in the Federal Democratic Republic of Nepal, parliamentarian democracy	Droughts, glacier melt, flooding, heat waves	Indigenous people and local communities (IPLCs), households, local government
Region in the northwest of the Republic of Namibia, democracy	Droughts (impact on vegetation growth and livestock farming) leading to resource scarcity and food insecurity, heat waves	Pastoralists, local level households
Region in the Federal State of Schleswig-Holstein in the Federal Republic of Germany, parliamentarian democracy	Storms, storm surge, sea-level rise, coastal erosion	Inhabitants of the islands and the mainland; various interest groups (e.g., farmers, diking associations), local communities, parishes, nature conservation, and the relevant authorities
Republic of Maldives, presidential representative democratic republic	Heat waves, flooding, sea-level rise, coastal erosion	Maldivian government, Ministry of Environment, Climate Change and Technology
Difficult status: officially Republic of China (ROC) but considers itself a sovereign state with its own democratic system (government, military, and constitution); most countries recognize China rather than Taiwan diplomatically	Storm surge, flooding, coastal erosion	Taiwan Central Government, National Science and Technology Council (Disaster), Ministry of Transportation and Communications (Infrastructure), Ministry of Economic Affairs (Water Resources), Ministry of the Interior (Land Use and Coast), Ministry of Agriculture (Agricultural Production and Biodiversity), local governments

(7) Kumene Regional Council, Government of the Republic of Namibia (2015). Kumene Regional Development Profile 2015 – The ultimate frontier. Opuwo, https://kunenerc.gov.na/documents/53359/0/Dev_profile.pdf/e20fcb44-46e3-effa-6344-2189605e1c7f (Last access: 13.3.2024), (8) Schleswig-Holstein (2022). Kreise und kreisfreie Städte in Schleswig-Holstein https://www.schleswig-holstein.de/DE/landesportal/land-und-leute/kreise-kreisfreie-staedte/kreis-nordfriesland/kreis-nordfriesland_node.html (Last access: 31.01.2024). (9) Statistik Nord (2022). Bevölkerung insgesamt Nordfriesland. Tabelle aus Freier Datenauswahl für Schleswig-Holstein. Statistikamt Nord: Meine Region – Erzeugte Datentabelle aus der eigenen Zusammenstellung für Schleswig-Holstein (statistik-nord.de). (Last access: 11.03.2024), (10) Country economy (2022). Maldives GDP – Gross Domestic Product. https://countryeconomy.com/gdp/maldivas. (Last access: 11.03.2024), (11) Ministry of Foreign Affairs, Republic of China (Taiwan) (2024). Government Portal of the Republic of China (Taiwan), about Taiwan. https://www.taiwan.gov.tw/about.php (Last access: 20.02.2024)

5.3

Hamburg, Germany

Hamburg is the second largest city in Germany with 1.9 million inhabitants. The Free and Hanseatic City of Hamburg is one of Germany's 16 federal states, politically a city state, and a municipality. Hamburg has seven districts to which local tasks are assigned. These districts are further divided into 105 urban quarters (Statistisches Bundesamt, 2023). The Senate is the state government, consisting of the First Mayor, who leads the government, and the Senators, who oversee the ministries. Some public activities have been delegated to public corporations, such as water supply and waste water disposal, waste treatment, and port management. Hamburg's Metropolitan Area includes neighboring counties from the federal states of Lower Saxony, Mecklenburg-Vorpommern, and Schleswig-Holstein. This metropolitan region is home to about 5.4 million people (IKM, 2023).

Hamburg is a port city with one of the largest ports in Europe (Schubert, 2020). The city has a long tradition of trade and of political freedom from aristocratic and religious authority. Sovereignty of the Hamburg traders and citizens was granted in the 12th century and has resulted in multiple forms of self-organization and participation to manage the local community, for example a high degree of citizenship organization and of philanthropy. Hamburg has suffered severe disasters with strong impacts on the city's development and its preparedness for shocks (Paech, 2008), for example the Great fire in 1842, which destroyed about one third of the old town; a cholera epidemic in 1892 with more than 8500 deaths; and the North Sea flood of 1962 with massive destruction of buildings and technical infrastructure as well as 340 fatalities (von Storch et al., 2008). While most European river-port cities have undergone a major transition in recent decades towards a service-centered rather than an industry-oriented metropolis, Hamburg is one of the few river-port cities that have opted for port expansion (Grossmann, 2008). In recent years, Hamburg has been challenged by economic structural change questioning the role of the port and other sectors (e.g. the aircraft industry), and proposing more efforts for digitalization, services, and creative industries (Kulke, 2023).

Climate, climatic change, and society in Hamburg

Hamburg is located at the river Elbe, about 80 km south-east of the North Sea, with the biggest German harbor located in the core of the city. Besides the river Elbe there are a number of smaller rivers, for example the Alster, Bille, and Wandse, that feed into the Elbe. The city has a maritime climate with an average annual temperature of 9.8°C (DWD, 2021). The area average of the total annual precipitation for Hamburg is around 720 mm, with maximum rainfall during summer (around 220 mm) and minimum rainfall during spring (around 150 mm; see Meinke et al., 2014; 2018).

Hamburg's proximity to the North Sea distinguishes the city as a coastal city in a transitional riverine and estuarine coastal zone, posing distinct climate change-compounded risks (Glavovic et al., 2022). Climate-related threats stem from rising sea-levels and the associated rise in groundwater (i.e., groundwater flooding), severe storm surges causing coastal flooding, heavy and prolonged rainfall causing riverine flooding, and an increasing vulnerability to pluvial flooding due to increasing high-intensity rainfall events (Schlünzen et al., 2010; Schlünzen et al., 2018; Poschlod and Ludwig, 2021). In addition, these risks are exacerbated by the increasing sealing of urban surface areas as a result of growing construction activities.

The city of Hamburg is characterized by an urban heat island (UHI; urban-rural temperature difference in the surface near atmosphere), which, according to measurements (Bechtel et al., 2011, Wiesner et al., 2014), is up to 1.2°C on average (city center and HafenCity). The largest UHI values are found at night, with up to 2.7°C in the central district in summer compared to a rural measuring station (Wiesner et al., 2018). With climate change, the number of hot days and tropical nights in Hamburg is expected to increase, and summer heat waves will occur more frequently and probably last longer (DWD, 2021).

These physical hazards interact with non-climatic drivers of exposure and vulnerability. In Hamburg, social welfare, education, and age must be considered in order to identify particularly vulnerable population groups (von Szombathely et al., 2023). These groups are often disproportionately affected by negative environmental influences (EEA, 2019). In case of a water hazard, Hamburg-Wilhelmsburg, an Elbe island district characterized by numerous low-income residential areas, shows higher social vulnerability compared to neighborhoods in the north of the city, which are characterized by a predominantly high social status. The management of flood risk by the City of Hamburg has potentially huge implications for ensuring social, climate and environmental justice, and offers an opportunity to counteract unfair distribution effects (Driessen et al., 2018). However, the hazard at hand must also be taken into account when calculating exposure (Mason et al., 2020).

Overall, vulnerability, exposure, and the climate-related hazards mentioned generate a compound water-from-four-sides flood risk for Hamburg (Hanf et al., 2024, under review). In particular, the combination of heavy rainfall and storm surges in the greater Hamburg area can cause multi-hazard situations or so-called compound events (Zscheischler et al., 2018). For example, the storm series in February 2022 caused extreme wind gusts, storm surges, and heavy precipitation within a week, and led to long-duration high water levels of the Elbe river in conjunction with high river discharges in the Elbe tributaries (Mühr et al., 2022).

Awareness about climate change is quite high among the people of Hamburg. A long-term annual population study in Hamburg shows that the proportion of Hamburg residents who consider climate change to be a major or very major threat to the city ranges between 61% (2008) and 67% (2023). According to 56% of the respondents, the consequences of climate change are already being felt in Hamburg today, and the greatest threats to the city are attributed to storm surges by 63% of the respondents (2023). The assessment of being personally affected by a natural disaster in Hamburg increased from 2008 (46%) to 2023 (62%) (Ratter and Scheunpflug, 2023). This results in a high level of acceptance for adaptation measures within the society.

Climate change responses

Climate adaptation in Hamburg is part of a complex multi-level regulatory framework, including European law (e.g., Water Framework Directive), national law (e.g., Water Resources Act; Waterways Act), and Hamburg legislative competencies (e.g., Hamburg Water Act). Hamburg has enacted its first Climate Protection Act in 1997 (Hamburgisches Klimaschutzgesetz: HmbKliSchG), which was also the first Climate Protection Act in Germany. Comprehensive amendments were implemented in 2020. The Act was amended again in December 2023. Climate adaptation is not the focus of the Climate Protection Act. However, the Act contains some provisions that refer to it. The City and all its entities must take climate adaptation into account in all its plans, measures, and decisions (§1 HmbKliSchG). This applies particularly to plans and investments (§2 HmbKliSchG). Preventive flood protection as well as urban and landscape planning instruments are explicitly mentioned as adaptation measures (§5 HmbKliSchG). It is planned to set up a separate Climate Adaptation Act within the next few years. The legislative activities of the city must be seen in the context of national legislation. Germany adopted the first Climate Protection Act in 2019, with amendments made in 2021 following a groundbreaking decision of the Federal Constitutional Court that defined and underlined the constitutional significance of climate change mitigation and adaptation (BVerfG, 2021). In 2023, the federal government passed the Climate Adaptation Act (Bundes-Klimaanpassungsgesetz: KAnG), which will come into force in 2024. §10 of the Climate Adaptation Act requires the federal states to develop adaptation strategies that must be based on climate risk analyses. Furthermore, there is a general rule for taking climate adaptation into account when implementing federal law (§8 KAnG).

Mitigation and adaption efforts have a long history in Hamburg. In the early 1980s, a special office for environmental protection was created. When Hamburg signed the Charta of Aalborg in 1996 to promote sustainable development against the background of the Rio Declaration of 1992, responsibility for climate mitigation and adaptation was transferred to the Ministry of Environment, Climate, Energy and Agriculture (BUKEA: Behörde für Umwelt, Klima, Energie und Agrarwirtschaft). In 2007, the Convenant of Mayors was invited to the city, leading to the declaration of a comprehensive document concerned with climate protection. In 2011, Hamburg was appointed as the second European Environmental Capital because of best practices in various areas of environmental and climate policies. In 2015, the first Climate Plan was launched that brought together climate mitigation and adaptation. In 2019, this plan was revised with an expansive part on adaptation. In the next revision in 2023, a strategic change took place as climate change adaptation was separated from the Climate Plan. A separate climate adaptation strategy for Hamburg is currently being developed. Such an independent Climate Adaptation Plan is intended to emphasize the importance of the issue, although disconnected from climate mitigation. This strategic change correlated with a reorganization of the climate change issues in BUKEA. In 2021, climate adaptation was shifted from BUKEA's climate coordination office in the energy and climate department to a newly established adaptation management unit in BUKEA's water department.

In addition to the operational competency of BUKEA on environmental issues, climate issues have been organized in an integrative way in the Hamburg administration. The First Mayor is the head of a committee for climate and mobility, assembling the relevant ministries for decision-making. Below this level, numerous cross-sectoral steering and project groups deal with specific climate-related topics. Furthermore, in the fields of climate mitigation and adaptation, the Senate receives advice from a Scientific Advisory Board, and stakeholder activities contribute to the decision-making and implementation process, for example the Chamber of Commerce, the Chamber of Crafts, NGOs like Friends of the Earth (BUND), Nature and Biodiversity Conservation Union (NABU), or Future Council Hamburg.

In the academic field, Hamburg benefits from a strong branch of climate science within its universities. Regarding climate adaptation, the interdisciplinary KLIMZUG NORD research project generated diverse knowledge on the consequences of climate change for the city and developed strategies and measures for adaptation. In the context of the Cluster of Excellence CliSAP (2007-2018), the 'KlimaCampus' was initiated, bringing together universities, research institutes, the city administration, and federal administrations located in Hamburg to exchange and further develop knowledge on climate mitigation and adaptation. The current research Cluster of Excellence CLICCS (since 2019) builds on the CliSAP cluster's many years of climate research in Hamburg.

Hamburg is implementing a mix of adaptation measures to counter the multiple climate risks and increase resilience to water and heat stress in the long term. However, Hamburg is not giving all climate-related hazards equal attention. Storm surge protection is safely in the hands of the state and its institutions, which the population completely trusts in and relies on. Protection against other water-related hazards such as heavy rainfall events and related pluvial flooding, however, is mainly dependent on the actions of individuals (de Guttry and Ratter, 2022).

Against the backdrop of the traumatic storm surge in 1962, dike protection and traditional flood management (i.e., "hard" infrastructure) became the main strategies to prevent similar disasters. In fact, the storm surge and the subsequent flooding in 1962 marked a turning point in Hamburg and German coastal protection, which has since then been fundamentally overhauled. Today, storm surge protection in Hamburg includes dikes, flood protection walls and flood gates, flood barriers, sluices, private polders, base structures, escape routes, terps, public education, and improved warnings by the authorities and institutions involved (de Guttry and Ratter, 2022). Hamburg has a long history of citizen engagement for dike protection. Flood protection communities organize the coastline-dwellers that are exposed to storm surges to ensure that the dikes and other infrastructures are maintained (Fellmer, 2014). The city continuously adjusts the reference water levels and dike heights – also in consideration of the expected changes due to climate change (Müller and Gönnert, 2018).

However, in recent years, debates have promoted aspects such as "living with water", "water-sensible city", and "sponge city", which have put more emphasis on the integration of water issues into urban development. Together with the public enterprise in Hamburg that is in charge of water supply and wastewater disposal, the city launched the project Rain Infra Structure Adaptation (RISA, 2009-2015), which has created a solid theoretical basis for the implementation of sustainable adaptation of urban rainwater infrastructure (HW, 2023). In numerous pilot projects throughout the city (e.g., Germany's first rain playground, heavy rainwater-adapted school yards, and a sports pitch with underground storage elements for rainwater retention), new concepts were tested and implemented. In this context, green and blue infrastructure has gained more relevance, and the city has consequently set up programs to foster roof and facade greening. The RISA approach and urban greening strategies offer synergies with the heat and drought issues as secondary climate change-related stressors (HSE and BUE, 2015). As a co-benefit, urban greenery provides cooling for the city and its citizens. Green roofs were identified as one of the most promising adaptation measures by the Hamburg government (Bürgerschaft der FHH, 2014). In fact, Hamburg was the first major German city to launch a comprehensive green-roof strategy. The vision for Hamburg is to green at least 70% of new buildings and flat roofs under renovation (see Figure 5.2) in order to achieve cooling effects for densely built-up urban areas and to increase the rainwater retention capacity of the city (climate adaptation) while saving energy costs (climate mitigation).

With regard to urban development, the International Building Exhibition (IBA) 2013 focused on living with water and water-adapted buildings. The IBA took place in Hamburg-Wilhelmsburg, the core area of the 1962 flooding disaster. The exhibition presented models of how water can be integrated into new housing and how urban waterways can be used for housing. The new HafenCity district, the redevelopment of a former industrial harbor site which is claimed to be one of Europe's largest urban regeneration projects, was the first urban development outside the dike-line (Restemeyer et al., 2015). As of 2001, technical approaches were implemented that allow to live close to the water whilst still being able to react in time in the event of severe storm surges. HafenCity is an example of an urban development project in Hamburg that has attempted to replace the traditional flood management of "controlling and fighting water" with means of "adaptive flood risk governance", that is, adapting to the water through strategies such as space for the rivers and managed retreat to reduce the impact of flooding (Mees et al., 2014). There is a mix of innovative strategies: building on elevated plots with heights of +7.5 meters, elevating all infrastructures above street level to allow access during storm surges, and introducing built-in flood resistance such as flood doors and walls. Apart from these technical solutions, a clear division of responsibilities between public and private actors is an important innovation. This includes the formalization of private responsibility for flood preparation through the institutionalization of civic flood protection communities (HmbGVBl, 2002) among property owners and residents. These communities are responsible for flood prevention (financing of elevated building, flood gates, reserving the first floor for activities other than housing), timely alerting in the event of flooding, and operating mobile flood gates in case of storm surges (Mees et al., 2014).

Figure 5.2: Hamburg, Germany: Hamburg's vision of the implementation of the green roof strategy in the city center. The city of Hamburg is the first major German city to develop a comprehensive green roof strategy. The aim is to cover a total of 100 hectares in the city with green roofs. Photo: ©BUE, TH Treibhaus Landschaftsarchitektur, Luftbild Matthias Friedel.

Enabling and constraining factors

As a city-state, Hamburg has the option to pass its own laws. Within the national legislative framework, it has the power to legislate in the field of climate change. This gives the city the freedom to regulate climate adaptation according to its specific requirements. Simultaneously, it has access to federal legislative decision-making. As a federal state, Hamburg is represented in the German Federal Council, the second chamber of parliament at national level, and has the right to launch legislative initiatives.

The city's internal organization and the district structure can be seen as two-fold. On the one hand, the seven districts with their own councils serve as change agents for innovation in climate adaptation. There is some political competition between the districts' most practical solutions. On the other hand, due to the Hamburg Constitution the districts have only limited competencies and budgets that constrain their function as game changers.

Adaptation to storm surges (coastal flooding) and riverine flooding has a long tradition in the city of Hamburg. Thus, climate adaptation in the field of water exposure can build on knowledge, administrative capacity, and a cultural basis among decision-makers, stakeholders, and citizens. The pilot project RISA exemplifies this: It applied the administration's traditional competencies of water management to explore and establish a new strategic approach of water sensitive urban development with view of adapting to fluvial and pluvial floods (HSE and BUE, 2015). However, this long tradition in water or flood protection, which primarily involves making use of technical infrastructure (in particular dikes), has created a kind of path-dependency. Political strategies, administrative routines, and priorities and expectations of citizens have been locked-in on that technical, and expensive, path. This has constrained competing strategies that question the dike-strategy and are in favor of alternatives like "living with water" or "sponge city" (Zevenbergen et al., 2010; 2018). However, recent developments have shown that new approaches have been integrated into the city's adaptation strategy as a result of various impulses from within and outside the administration. For example, it can increase coping capacity if the city provides targeted subsidies for private homeowners who live in potential hazard areas (Mees et al., 2014).

Another innovation strategy can be found in special institutions such as International Building Exhibition Hamburg (IBA) and HafenCity

Hamburg (HCH). Although owned by the city, privately organized companies stand outside administrative routines, which facilitates exploring innovative solutions. Both used this freedom to establish water-sensitive building (IBA) and flood protection outside the dike line (HCH). Nevertheless, it seems to be a challenge to transfer knowledge of such specific structures into the planning and implementation routines of public administration. The reasons for this lack of mainstreaming may be competency, competition, or missing interlinkages to pass knowledge forward. In addition, institutional logics and the sector-oriented character of public agencies, including the problem of silo-budgeting, impede climate adaptation planning and its sustainable enhancement of urban resilience in Hamburg (Hanf et al., 2024, under review).

Further constraints to sustainable adaptation arise from land conflicts between housing and economic development on the one hand and climate adaptation, mainly the preservation of urban green, on the other hand. Due to high demand in the housing market, Hamburg has been pursuing an ambitious new building strategy for several years with the goal of approving 6000, and later even 10,000, housing units annually (BSW, 2021). This has put a high pressure on available land, and even protected green spaces have been mobilized for housing. Re-densification in existing housing stock from the 1950s and the 1960s seems appropriate from an urban design point of view at a first glance but can contradict water-sensitive development and further the loss of green space. Re-densification in already densely built neighborhoods has negative consequences with regard to heat exposure. In addition, re-densification, including the vertical extension of buildings, is associated with higher density urban living, which is increasingly criticized for its negative side effects on subjective well-being (Holden, 2019).

For the housing industry, the requirement for water-sensitive buildings poses the challenge of meeting affordable housing standards. The city's housing strategy has set the additional quantitative target of building at least 35% of apartments as social housing (BSW, 2021). Standards such as roof and facade greening or rainwater adaptation on the estate are often opposed as an additional burden, not only by the real estate industry but also by tenant associations who fear rising rents.

Take-home message

Hamburg is an example of a multi-level system that provides enabling and constraining factors for sustainable adaptation to climate change. Linkages between local, federal, and international responsibilities and activities must be considered crucial for successful adaptation policies. Furthermore, the nexus of adaptation and mitigation needs exploration to better use potential synergies and to avoid incompatibilities; for example, the densification of housing should be weighed against the goals of green infrastructure for water and heat adaptation. As compound events become more likely with climate change, a comprehensive and system-oriented risk assessment that considers the interactions and dynamics of various sectors of the urban system is a prerequisite for sustainable adaptation planning in Hamburg. With regard to adaptation governance, the role of different modes of governance and the instruments applied (formal, informal, networking, economic, etc.) are crucial for understanding and supporting local adaptation processes. In addition, the organizational side of local climate adaptation, for example through the interplay of classic administration and public enterprises, enriches and fosters adaptation strategies. This is important for breaking long-time path dependencies with path-breaking activities. Overall, the increasing implementation of sustainable water sensitive urban design through isolated RISA pilot projects, the exploration of co-benefits and synergies between climate adaptation and mitigation through Hamburg's green roof strategy, and the innovative strategies for adaptive flood risk governance characterized by attempts to shift from "government to governance" (Mees et al., 2014) in the HafenCity urban regeneration project are approaches with a transformative character. However, for the city of Hamburg to adapt to climate change in a sustainable way, greater attention must be given to issues of climate justice, synergies and co-benefits with other Sustainable Development Goals, and more participatory models of democracy in urban development.

5.4

São Paulo, Brazil

São Paulo is a culturally diverse, thriving megacity of historical prominence due to its economic power and regional leadership. It is often at the vanguard of social and technological developments in Brazil, a feat sometimes attributed to its industrious vocation, technical capacity, and cosmopolitan positioning. At the same time, São Paulo is a city with deeply rooted social inequalities. Economic and political interests are strongly intertwined and frequently overrule technical criteria in administrative decision-making processes (Back et al., 2022). These characteristics synthesize and explain some of the dynamics that have influenced the city's development in the past and continue to do so in the present day, especially with regard to climate change responses (Kohler et al., 2021; Schmidt et al., 2024). This case study addresses these processes and dynamics from a multidisciplinary perspective. It draws on a sociological analysis of historical events and recent empirical observations as well as on the expertise of climate adaptation experts from São Paulo. In terms of data, it builds on both new empirical research and existing literature.

Almost all (99.1%) of São Paulo's 11.45 million inhabitants live in urbanized areas that make up 60% of its 1521 km² territory (IBGE, 2022; SEADE, 2023a). The city constitutes the center of a global metropolis (São Paulo Metropolitan Region), which is composed of 39 municipalities with double the population of São Paulo and five times its territory (SEADE, 2023a). Single-handedly, São Paulo municipal's gross domestic product (GDP) represented 9.2% of Brazil's total GDP in 2021 (IBGE, 2023; SEADE, 2023b). Due to its population size and economic power, São Paulo is a global megacity of considerable influence in Latin American and international contexts.

São Paulo's wealth and influence originate from its past as an agrarian power based on coffee production and trade in the late 19th century. This status was maintained throughout the 20th century as the city transitioned into an industrial power by means of a condensed process of urbanization, industrialization, and expansion (Carlos, 2004; Francisconi, 2004). By the turn of the century, following a trend observed in other global cities, São Paulo transitioned into an economic power acting as a service and business hub: As of 2020, 83% of the city's GDP derives from the tertiary economy (SEADE, 2023b). Influenced by social processes that go back to the city's historical origins and more recent processes of accelerated industrialization and aggressive urban expansion, São Paulo's geographical space production engendered a territory with extreme levels of social inequalities, segregation, and environmental injustice (Dos Santos, 2011; Souza, 2004). Despite the city's high average human development index (0.805), this development is very unevenly distributed across its territory. A closer look at socio-economic data reveals considerable levels of inequality and segregation (PNUD, 2013; RNSP, 2022), which has important implications for climate change adaptation.

Climate, climatic change, and society in São Paulo

The city of São Paulo is located in the Brazilian southeast at 23°33′S 46°38′W at an approximate elevation of 760 m above sea level, 65 km away from the coastline (IBGE, 2010). The city has a humid subtropical climate. It is characterized by two pronounced seasons (dry winter from April to September and humid summer from October to March) with considerable daily temperature fluctuations that typically exceed the 9.7°C amplitude around the yearly average temperature of 20.4°C (IAG-USP, 2023; Rolim et al., 2007; Kottek et al., 2006). Monthly accumulated rainfall varies from a 62.8mm average during the dry winter to 214.6mm average during the wet summer, totaling a 1658.3mm yearly average (INMET, 2022).

São Paulo has historically faced important water-related challenges. The city is exposed to both floods and droughts in different seasons of the year. The water crisis experienced in São Paulo in 2014 demonstrated the importance of recognizing the political dimension of water security to develop effective strategies for climate change adaptation in any metropolitan region. In addition to the longstanding and continuous pollution of watershed regions and the inadequate management and planning of natural resources, the lack of transparency and limited opportunities for social involvement in water governance are significant factors that account for water insecurity (Jacobi et al., 2019). São Paulo has also experienced an increase in the number of days with heavy rainfall, which often leads to inundation, flooding, and landslides (Marengo et al., 2020). The stark contrast of socio-environmental living conditions ingrained in São Paulo's territory is clearly reflected in the differing levels of vulnerability to climate change impacts observed amongst its population (Roncancio and Nardocci, 2016). Extreme rainfalls frequently cause deaths in the São Paulo Macrometropolis region due to insufficient infrastructure and highly uneven risk exposure of the population (Travassos et al., 2020; see Figure 5.3).

Climate projections indicate that the state of São Paulo will have to deal with climate change in multiple ways. Projections considering the period between 2020 and 2050 were produced in 20 km resolution, using downscaling techniques through a regional model, under two different climate scenarios from four different climate models. The results were presented in terms of deviations of the future period (2020-2050) in relation to the historical period (1961-1990). All models used for both scenarios and their lower and upper limits point to a warming of the atmosphere. In the Representative Concentration Pathways (RCP) 4.5, the range of variation of the air temperature deviation, between the maximum and the minimum projected, lies between 0.5°C and 2.5°C. All models project a reduction in the duration of cold waves as well as an increase in the duration of heat waves. Regarding annual precipitation and related extreme events, there is no consensus of trend among the models (Armani et al., 2022). A trend of drier climate is also projected using indexes based on daily precipitation, which reaches annual rainfall reductions of more than 50 % in the state of Rio de Janeiro and between 40% and 45% in São Paulo and Santos (Lyra et al., 2018).

Climate change is expected to continue to aggravate environmental and urban problems and increase associated risks, especially for communities already living in vulnerable conditions (Nobre and Young, 2011; Di Giulio et al., 2018). The stronger warming projected by fine resolution simulations suggests more uncomfortable days and nights in the metropolitan area, high demand on cooling equipment, and consequently an increase in energy consumption. This scenario implies potential health risks for the poor and the elderly population (Lyra et al., 2018). In this context, the city must prepare to deal with changes in the distribution, intensity, and geographic frequency of risks related to climate events such as extreme and extended heat, extreme precipitation, which threaten to exceed its capacity to absorb losses and recover from climate-related impacts (PBMC, 2014; Nobre and Young, 2011). Already in 2023, the city faced an unprecedented heat wave with several negative consequences for human health (Valverde and Rosa, 2023).

Figure 5.3: São Paulo, Brazil: Torrential rainfall event within a short period of time on 5th March 2024 caused waves and led to the severe flooding under the Minhocão Viaduct in the city center of São Paulo, Brazil. Photo: Mathilde Missioneiro/FolhaPress.

Climate change responses

São Paulo's engagement with climate action agendas dates back to the mid-2000s. In an effort to foster cooperation between cities, local and regional governments on climate and urban governance, the city had joined several networks, including the United Cities and Local Governments (UCLG) in 2004, the global network Local Governments for Sustainability (ICLEI) as well as the C40 Cities in 2005, and, more recently, the Urban 20 (U20) in 2017 (for more details on how such transnational initiatives affect climate action, see Section 3.3). Since then, several climate action initiatives have been enabled or carried out in São Paulo and other Brazilian municipalities with technical and financial support obtained from these cooperation networks (Setzer et al., 2015). In São Paulo, examples of relevant initiatives include the elaboration of emissions inventories (D'Almeida Martis and Ferreira, 2011) and, more recently, the launch of São Paulo's Municipal Climate Action Plan 2020-2050 (Municipality of São Paulo, 2020a). Debates have been raised about the overall net effect of these external influences of global networks on local climate change adaptation (Setzer, 2009; Barbi and Macedo, 2019), but, regardless if positive or negative, São Paulo's role in constituting the cooperation networks is a testament to how the city's global reach and influence could be leveraged to promote climate change adaptation. The municipality of São Paulo promulgated its Climate Change Policy law in 2009, six months before the federal government and four months before the state government, becoming the first Brazilian city to have a specific law addressing climate change (Brazil, 2009; State of São Paulo, 2009; Municipality of São Paulo, 2009). This law committed São Paulo to the United Nations Framework Convention on Climate Change (UNFCCC) goals, with a focus on promoting climate change mitigation to secure food production and sustainable economic development (Municipality of São Paulo, 2009). In fact, the city established no measurable goal for adaptation and only one explicit goal for mitigation, which relates to greenhouse gas emissions, namely reducing emissions from the public transport sector by 10% each year from 2009 to 2018 (Municipality of São Paulo, 2009, ex.: art. 50). The law's climate change mitigation and adaptation directives and strategies have broad scopes and generic goals (Municipality of São Paulo, 2009, ex.: art. 12), and they depend on complementary legislation (Municipality of São Paulo, 2009, ex.: art. 14, 15 and 21). São Paulo's Climate Change Policy law also establishes either unspecified shared responsibilities between public administration, private initiative, and civil society for their implementation (Municipality of São Paulo, 2009, ex.: art 19 and 20) or ties climate action directives to economic gains (Municipality of São Paulo, 2009, ex.: art. 18, items III and IV). The law also consolidates the existence of the Municipal Committee on Climate Change and Eco-Economy, a collegiate organization founded with the aim of uniting several social agents to propose, stimulate, and supervise the implementation of the municipalitýs climate change-related laws, plans, programs, and actions (Di Giulio et al., 2018). However, this committee has only an advisory role, without direct means of interfering in the municipalitýs decision-making processes, which could limit its effectiveness.

Between 2010 and 2020, São Paulo steadily elaborated on its climate change mitigation agenda, mainly focusing on reducing transport and mobility related emissions. In 2018, the former municipal Climate Change Policy law (2009) was replaced by a new one, which has weakened the city's only measurable climate mitigation goal by postponing the emissions reductions deadline by two decades (Municipality of São Paulo, 2018). The adaptation agenda had a different, even more troubled trajectory (Di Giulio et al., 2018). In 2011, through a collaborative effort involving technical personnel from the Green and Environment Municipal Secretariat and non-state actors from the Municipal Committee on Climate Change and Eco-economy, the generic climate mitigation and adaptation strategies outlined in the city's Climate Change Policy were transformed into sector-specific proposals. These proposals were subsequently published as Directives for the Action Plan Towards Climate Change Mitigation and Adaptation in the city of São Paulo (Municipality of São Paulo, 2011). This document later served as a foundational stone for the expansion and improvement of the collaboration between technical branches of the municipality and non-state actors in the development of São Paulo's climate action plan, a two-year endeavor that began in 2018 out of a commitment established with the C40 Cities network and Local Governments for Sustainability (ICLEI). The initiative resulted in the launch of São Paulo's Municipal Climate Action Plan 2020-2050 (Municipality of São Paulo, 2020a). Although this remained the municipality's key action plan dedicated to both climate change mitigation and adaptation, other sectoral action plans that might benefit climate adaptation have been developed during the same period by the municipalitýs technical branches without taking adaptation needs into account. Examples range from the Municipal Atlantic Rainforest Plan to protect green areas (PMMA; see Municipality of São Paulo, 2017) to the Urban Mobility Plan (PlanMob; see Municipality of São Paulo, 2015), which the latter provides incentives for installing bike lanes, bicycle parking spots, roads with some priority for public transport, and exclusive bus lanes (Di Giulio et al., 2019). While the Municipal Atlantic Rainforest Plan may contribute to the reforestation and restoration of ecosystems that deliver multiple services which help to reduce climate change exposures and potentially delivers a set of economic, social, and environmental co-benefits that go beyond climate adaptation (e.g., reducing urban heat and flooding), the PlanMob helps to promote a low-carbon and a more inclusive and diversified transportation system.

São Paulo's Green and Environment Municipal Secretariat led or coordinated several technical studies that resulted in the publication of action plans mostly focused on biodiversity protection and the management of green areas (recovery, implementation, maintenance, protection, and conservation) or on overall and strategic improvement of urban greening. These include, besides the Municipal Atlantic Rainforest Plan, the Municipal Plan on Recovery and Conservation and Recovery of Environmental Services Providing Areas (PMSA; Municipality of São Paulo, 2020b), the Municipal Plan on Green Areas and Free Spaces (PLANPAVEL; see Municipality of São Paulo, 2022), and the Municipal Plan on Urban Arborization (PMAU; see Municipality of São Paulo, 2017; 2020b; 2022; 2020c). Although these initiatives might indicate important efforts that try to connect adaptation to sustainability, improving the well-being of human subjects and ecosystems, they are not directly tied to the climate adaptation discourse, indicating that there is still a local government hesitancy to use the term climate change and a resistance to accept and internalize climate issues in many local decisions (Di Giulio et al., 2017).

In 2010, São Paulo's Subprefecture Coordination Municipal Secretariat partnered with the Technological Research Institute (IPT) to update and extend the city's previous geological risk areas mapping, which dated back to 2005. Since 2018, this has continuously been updated by the Urban Safety Municipal Secretariat (Municipality of São Paulo, 2023). In 2011, the Earth System Science Centre of the Brazilian National Institute of Space Research (INPE), along with the Population Studies Center of the State University of Campinas, published the report Brazilian Megacities' Vulnerability to Climate Change: São Paulo's Metropolitan Region. The report indicates that around 20% of São Paulo's Metropolitan Region would be exposed to rain-related weather risks due to climate change by 2030 (Nobre and Young, 2011). In 2013, the Municipal Civil Defense Coordination started developing a yearly preventive action plan to reduce flooding during São Paulo's wet season, publicized as Summer Rain Prevention Plan (Morais, 2019).

While these developments indicate advancements in climate change adaptation initiatives in some fields of urban planning in the form of guidelines and intentions, most of the initiatives were strictly technical, carried out by technical branches of the municipality in cooperation with non-state actors, such as academics and civil society representatives, and supported by cooperation networks or foreign governments (Di Giulio et al., 2018; 2019). The difficulties arise in the process of implementation, when the initiatives are exposed to divergent political agendas, choices, and priorities. Considering that part of the technical branches of the municipality consist of politically appointed staff members, planning or implementation processes depend on the composition of the municipal government and are thus often exposed to discontinuity, instability, and also to lobbying by economic interest groups.

Throughout the past decades, changes in the municipality's elected officials often led to changes in appointed positions within the municipality's departments and secretariats, many of which bear decision-making or managerial responsibilities, thus compromising the continuity of planned actions. One of the major impacts observed was the Climate Change Executive Secretariat starting in June 2021, linked directly to the Mayor's office, with the aim of implementing the São Paulo's Municipal Climate Action Plan 2020-2050 (Municipality of São Paulo, 2020a). While predominantly composed of nominated positions, and thus more exposed to political interests, for the first two years this new Executive Secretariat took over most of the climate change-related responsibilities led by the Green and Environment Municipal Secretariat, a department composed predominantly by technical career professionals that had led several multi-secretariat initiatives with positive outcomes. However, upon the publication of the first PlanClima SP monitoring report in 2021 by the Climate Change Executive Secretariat, the effects of this change have not been clear, as the report does not provide much clarification on the progress achieved toward the attainment of the planned goals.

Another aspect that severely constrains sustainable climate change adaptation in São Paulo is the reliance of its Climate Change Policy on complementary sectoral legislation, such as the city's executive master plan, land use law, and building code (Municipality of São Paulo, 2014; 2016). While both pieces of legislation were revised in the years that followed the promulgation of the Climate Change Policy in 2009 in ways that included the consideration for climate change mitigation and adaptation amongst their directives and strategies, these inclusions are no more than general recommendations with no practical effect. Meanwhile, other aspects of both laws were revised and have fostered urban expansion and verticalization in ways that catered to the lobbies of private investors, real estate agents, and the construction industry, mostly based on grey infrastructure (i.e., carbon-intensive infrastructures based on traditional engineering approaches) with considerable negative effects to the quality of the urban environment and of climate change adaptation goals (Back et al., 2021; 2022). These alterations sparked the outcry of scholars and civil society actors such as environmentalists, neighborhood associations, and housing rights movements, resulting in a legal dispute that halted the law's approval and is still ongoing (Back et al., 2022).

Enabling and constraining factors

São Paulo is a megacity with the potential of playing a leading role in regional and global climate governance. However, the implementation of climate change adaptation measures is lagging far behind, despite the engagement of the city with different collaboration networks for climate action as well as the accumulated experiences in dealing with extreme weather events and climate-related risks and vulnerabilities and the support of civil society actors, scholars, and strong scientific institutions for ambitious climate action. Empirical studies point out that the perception that cities and individuals are at a greater risk of damage in the future is one of the main motivations for initiating adaptation planning and implementation at the local level (Ryan, 2015; Runhaar et al., 2018; Di Giulio et al., 2019). In the case of São Paulo, a recent empirical research project conducted by Rede Nossa São Paulo (2022) indicated that most of the interviewees who live in the city are very concerned about climate change and that 75% of them believe that climate change highly affects their quality of life. A recent assessment of cities' readiness to deal with climate change in the state of São Paulo concluded that the city of São Paulo has a comparatively high institutional adaptive capacity (Neder et al., 2021). However, there are key social dynamics inhibiting the design and implementation of adaptation strategies in São Paulo. In particular, unstable political dynamics at national, state, and local scales, high social inequalities, and the lack of political support for climate action and sustainability transformations constitute fundamental barriers for transformative strategies and sustainable climate change adaptation in the city and its metropolitan region. The observed adaptation measures implemented so far relate mostly to planning and networking, while the implementation and concrete action remain insufficient. This is mostly driven by political constraints and economic pressure as well as by lobbying efforts of powerful societal actors, in particular from the construction and real estate sectors (Calderon, 2022; Jacobi and Trani, 2019). Despite the existence of projects promoting the diffusion of knowledge on transformative pathways to urban sustainability and climate change adaptation (Moreira et al., 2022), the incremental changes that have been observed rather relate to climate change mitigation only (e.g., incentives for mobility shifts through the wide implementation of bus and bike lanes). Besides, in order to generate more sophisticated indicators than the crude, generalized ones currently used for the entire city, which neglect the high spatial and socio-economic disparities within the megacity, it is imperative to look closer at the significant inequalities among the 96 districts in São Paulo, to cross different layers of spatialized data, and to fuse socio-economic data with remote sensing and GIS data. Linking remote sensing and GIS data with city life at neighborhood and street scale, in the sense that the US National Research Council (1998) envisaged for a "people and pixels" perspective, would show a very different picture than the general official data currently offers as an average for the entire city (see also the discussion of the influence of grid size to simulate local precipitation extremes in Section 4.3).

By now, the city is mostly coping with extreme weather events and climate-related impacts rather than elaborating and implementing adaptation measures that could provide synergies between sustainability goals. These would include side-benefits such as improved housing and living conditions, supporting initiatives for review of regulations and technical standards for buildings and urban planning and design with a view to promoting resilient urban infrastructure, ensuring conveniently-located housing for low-income families living in situations of vulnerability. Hence, in light of the implementation gaps and political conflicts, sustainable climate change adaptation in São Paulo is currently not plausible. To become plausible, the very first step is the elaboration and implementation of a climate change adaptation plan that establishes clear actionable indicators, measurements, and responsibilities for their implementation as well as mechanisms for monitoring and evaluating established goals and targets. Moreover, land planning and the governance of water resources need to be integrated with land-use regulation, building codes, and transportation infrastructure plans, all of which requires a new level of coordination across sectors and policy levels.

Take-home message

São Paulo demonstrates a clear mismatch between the city's engagement with climate action initiatives at different scales of governance. At the global and regional scales, São Paulo plays a leading role in transnational initiatives for climate action, and the city is a pioneer in Brazil in terms of law-making and adaptation planning. However, when it comes to climate action at the local scale, there are remarkable implementation gaps, especially in terms of climate change adaptation. Engaging in transnational initiatives for climate action and establishing climate change policies, laws, and adaptation plans are crucial steps toward sustainable climate change adaptation. For São Paulo, overcoming persistent political conflicts, social inequalities, and other structural challenges at the local scale are key, inasmuch as they fundamentally hinder the implementation of climate change adaptation measures. The local government in power and its political agenda have a substantial influence on the implementation of climate adaptation measures (or lack thereof). In particular, the numerous political changes in the local administration in São Paulo, along with the lack of clarity with regard to responsibilities, results in an important mismatch of adaptive capacities and local climate vulnerabilities. There is an enormous need (but maybe also potential) for societal mobilization and the co-production of knowledge for sustainable climate change adaptation, drawing on the historical, accumulated experiences in dealing with extreme weather events and climate-related risks and vulnerabilities.

5.5

Ho Chi Minh City, Vietnam

Ho Chi Minh City, formerly Saigon, is Vietnam's biggest, most globalized city and the most important economic hub of this dynamically developing emerging country. Located on the northeastern edge of the Mekong Delta within a zone of tropical monsoon climate, the metropolis is the engine of social and economic change in the country and contributes about a quarter of Vietnam's GDP. Per capita income is about 1.5 times higher than the national average (GSO, 2023). Due to the economic boom, the spatial metropolitan growth has transgressed its administrative boundaries, so that an urban agglomeration with more than 10 million inhabitants has emerged. Ho Chi Minh City can thus be described as Vietnam's first megacity (Waibel, 2013).

The administration of Ho Chi Minh City struggles with the difficulties a megacity in an emerging country typically faces (Waibel, 2016). The planning authorities are overwhelmed by the high dynamics of population growth, for example. This is, among other things, related to the massive immigration from the other provinces. In the near future, Ho Chi Minh City is also expected to receive a huge influx of climate change refugees coming from the increasingly flood-prone adjacent Mekong Delta (Saunders, 2023). Like many other megacities in the region, the metropolis also suffers from massive environmental problems, such as rising air pollution, chiefly due a tremendous increase of car-related traffic. In addition, major infrastructure projects, be it sewer rehabilitation, bridge, airport, or subway construction, can usually only be carried out with the help of foreign investors such as the World Bank or the Japanese Development Bank (Waibel, 2019). This ongoing dependency on foreign donor organizations with specific (often parallel, but sometimes diverging) interests limits effective implementation – also in the case of municipal climate change adaptation (Waibel, 2016).

Climate, climatic change, and society in Ho Chi Minh City

Ho Chi Minh City is considered one of the 10 major cities in the world most affected by global climate change (ADB, 2010). First of all, this is simply due to its topography. Almost half of the city area is no more than 0.5 m above sea level (Waibel, 2019). Therefore, the city's main challenge is its vulnerability to urban flooding (Scheiber et al., 2023), particularly in the case of heavy rainfall in combination with high tidal events. A third of the metropolis is already now affected by regular flood events. The situation will get worse because the rate of extreme rainfall events is expected to increase in the future (An, 2021). It is predicted that by 2070, Ho Chi Minh City will have about 9.2 million people directly exposed to the impacts of climate change (such as floods, sea level rise, rain, storms, etc.), with estimated accumulated losses of about USD 650 billion (An, 2021).

However, the flooding within the settlement body of the metropolis is currently less directly attributable to global climate change than to deficits in urban planning: The growth of settlement areas in the course of urban spatial expansion in low-lying marshlands led to former wetlands being filled and transformed into new urban development areas such as Phu My Hung or Thu Thiem (Waibel, 2016) (see Figure 5.4). This resulted in an enormous loss of open and green spaces. With this area sealing, substantial retention areas got lost, leading to urban flooding in case of heavy rains that overload the inadequate drainage system.

Wide-spread land submersion is further aggravating the flooding issue: Like in other cities of the region such as Jakarta or Bangkok, the increasing building mass is pressing upon the soft alluvial sediments of the city surface, leading to land submersion of several centimeters per year in some areas, a process which is further exacerbated by groundwater extraction (Waibel, 2019). One means to fight land submersion and so to decrease the flooding risk at a building site would be the elevation of its land by sand. At this juncture, this is indeed a frequent adaptation practice. However, due to excessive sand extraction in the past and rising erosion, there is now a serious lack of sand (Anh, 2023). The lack of sand combined with rising sea levels also increases the issue of increasing salinization of the ground and the groundwater, threatening the water supply of the urban population.

Another serious problem is the increase of heat stress for the urban population. As a consequence of climate change, the heat will also last longer during the dry season. This particularly affects the densely populated and often informally built urban areas without green spaces. There, due to increasing surface sealing and the associated change in albedo, more solar radiation is converted into heat. Urban heat islands are forming, which are being intensified by the increasing use of energy-intensive air conditioning systems. Their growing use is also a consequence of changing demands of thermal comfort among the rapidly emerging urban middle class with increasingly resource-intensive lifestyles (Waibel, 2009). Heat stress seriously endangers the health of the most vulnerable urban populations (i.e., young and old people) (Katzschner and Burghardt, 2015), with thousands of heat deaths currently being reported in Ho Chi Minh City each year (Nguyen and Waibel, 2021).

As a result, it can be said that the increasing threats of global climate change intertwine with the effects of unsustainable urban development, all of which impose multiple serious problems onto policy makers.

Figure 5.4: Ho Chi Minh City, Vietnam: Aerial view of the highly vulnerable Thu Thiem new urban area opposite the Central Business District of Ho Chi Minh City, Vietnam. Photo: Michael Waibel.

Climate change responses

Following the national framework on environmental and climate change actions, especially the "National Climate Change Adaptation Plan (CCAP) for 2021-2030, vision to 2050" and the Vietnam Law of Planning No. 21. 2017.QH14 (promulgated in 2017), the municipal government issued its own "Climate Change Adaptation Plan 2021-2030 (CCAP-HCMC), vision to 2050" in 2021. The CCAP-HCMC is considered a joint umbrella for various actions dealing with climate change adaptation in the city. According to a leading representative of a local think tank, this plan will also guide the "Ho Chi Minh City Spatial Plan (Master Plan) to 2040, vision to 2060". This CCAP-HCMC will be integrated from 54 sectoral development plans, including economic, technical, and social infrastructure development plans as well as 23 territorial development plans (one each for the 23 administrative units of Ho Chi Minh City).

In this context, the municipal government has assigned the Department of Natural Resources and Environment (DoNRE) to assume prime responsibility and to coordinate with relevant departments and agencies in synthesizing information with a view of building and publishing updates on the progress of the CCAP-HCMC. DoNRE also holds the leading position of the so-called City Climate Change Steering Committee for implementing the Climate Change Adaptation Action Plan, a cross-departmental board that is regularly updating information to the public by means of a bulletin (HCMC Department of Planning and Architecture, 2016).

Specifically, the municipal government aims to strengthen resilience to reduce climate-related risks such as drought, heat, heavy rain, and sea level rise; and to improve natural disaster risk prevention, conservation biodiversity, food security, social security, healthy communities, and sustainable development (HCMC People Committee, 2021a).

Key sectors targeted in the CCAP-HCMC include urban planning, agriculture, energy, and, in the field of industry, commerce, construction, transportation, tourism, and land and water resources. The CCAP-HCMC defines key tasks and lists of potential initiatives for each sector including, for example, climate change impact evaluation, capacity building in the field of public management, public awareness raising, digitalization, etc. (HCMC People Committee, 2021b; Luu, 2023).

Enabling and constraining factors

The suggested measures for Ho Chi Minh City are mostly very ambitious, but it is not always clear where the funding to implement these plans could come from. Also, it can be criticized that there was a strong focus on expensive structural adaptation measures, such as the construction of the ring dike, of multiple flood gates, and of pumping stations instead of soft adaptation measures such as blue-green infrastructure solutions (ADB, 2010; C40 Cities Climate Leadership Group, 2016; Scheiber et al., 2023).

Another point to criticize is that there is a lack of specific and measurable targets even though the CCAP-HCMC contains specific goals, which are mostly of qualitative nature. It also contains no indicator system to monitor and evaluate the progress achieved. The role and responsibilities of the public sector, which should, among other things, lead efforts to achieve replication effects among urban citizens, for example in the field of green (public) buildings, is not clearly defined, either. Furthermore, the whole action program contains no specific gender component although women have been specifically identified as a highly vulnerable group (Hagedoorn et al., 2021; Hong and Downes, 2023).

Further challenges remain on questions such as:

- How to develop specific policies, legislation, and regulations that create favorable conditions for the implementation of adaptation projects and activities?
- How to increase the low general awareness among urban citizens about the municipal Climate Change Action Plan, which is regarded as a prerequisite for more civil engagement and for behavior change toward more sustainability?
- How to increase capacity with regards to the mainstreaming of climate change adaptive urban planning, the lack of which is a major reason for wide-spread gaps between plans and reality?

Past adaptation strategies have mainly focused on large projects with the aim to reduce hazard exposure, meaning that (too) much investments have gone into hard infrastructure such as dikes, sluice gates, and seawalls (ADB, 2010; UNRISD, 2019). In contrast, measures to promote blue-green infrastructure solutions making use of ecosystem-based services have only recently become part of the public planning discourse. As of now, there are only limited knowledge and skills in the field of nature-based solutions in Vietnam, especially when it comes to multi-sectoral planning (Lan et al., 2023).

Given the foreseeable lack of sand, which is needed for the construction of hard infrastructure, and the huge spatial dimensions of climate change affected areas within the whole megacity region, the implementation of blue-green infrastructure solutions is regarded as the most promising, resource-efficient, and cost-effective option of climate change adaptation.

A good-practice example of this is the recent construction of the Phu Xuan wetland park as a soft adaptation measure in the suburban district of Nha Be, characterized by many natural rivers and canals. The park was designed to preserve the existing 4600 m^2 water coconut tree area and even to extend it by approximately 3000 m^2. Besides its function to store rainwater temporarily, Phu Xuan Park provides attractive spaces for leisure activities. In this way the park is following the sponge-city concept. As a nature-based solution, it further serves as a demonstration project for soft climate change adaption in Ho Chi Minh City (HCMC Party Committee, 2022).

Evidently, the various challenges of climate change adaptation and sustainable urban development in Ho Chi Minh City require multiple measures from all levels of the government, but have to engage the private sector and urban citizens, too, if only to decrease the mismatches between state and non-state adaptation action (Garschagen et al., 2015).

It has become clear that climate change adaptation measures cannot be treated as separate from measures of sustainable urban development. While climate change adaptive capacity in urban planning needs to increase (Eckert and Waibel, 2009), it is also obvious that mainstreaming climate change adaptation into the local spatial planning systems can only be one component of adapting to climate change in a sustainable manner.

Successful sustainable climate change adaptation in Vietnam requires more crosscutting integrative transformative planning with less focus on expensive hard adaptation measures but more promotion of ecosystem based services. A very promising concrete countermeasure would be the creation of blue-green infrastructures, as shown in the good-practice example of Phu Xuan wetland park. Also, the potential of other decentralized rainwater detention solutions such as green roofs with multiple other sustainability benefits has not been fully exploited yet (Nguyen and Waibel, 2022).

In general, a shift in local planning culture, where it is more understood as a continuous multiple stakeholder dialogue and joint learning experience, is crucial. This would also support the (re-)gaining of trust of urban citizens and their local decision-makers as a precondition of a comprehensive transformation.

From the policy side, an increasingly integrated approach of regulations and decrees with (economic) incentives as well as the implementation of more participatory learning tools could foster the implementation of adaptation projects and signify a shift away from top-down-style authoritarian planning (Waibel, 2014; Schwede et al., 2016).

More such transformative adaptation approaches would involve a fundamental change going beyond technical solutions to reduce hazard exposure and address processes and structures that exacerbate vulnerabilities. In this way, transformative adaptation requires more process-orientated, co-constructive, and cooperative approaches as well as the development of inclusive people-led visions for the future (UNRISD, 2019). However, given the authoritarian political environment in Vietnam, its further implementation will remain a challenge.

From a governance perspective, the process of developing a municipal or urban district climate change adaptation plan could already become a transition-management instrument in itself. This could happen by communicating the progress of the action plan to the public in a transparent way during the whole process and by involving multiple stakeholders. Despite potentially being more time-consuming, such a procedure would surely increase civic engagement of the involved parties, support the development of action knowledge, potentially identify funding sources, and consequently increase the plausibility of much needed implementation on the ground.

Take-home message

Ho Chi Minh City is considered one of the world's most vulnerable cities to climate change impacts (Katzschner et al., 2016). Measures of sustainable climate change adaptation must go hand in hand with measures of sustainable urban development to tackle the multiple intertwined challenges. Successful sustainable climate change adaptation requires more crosscutting integrated planning as part of a wider process-orientated transformative adaptation process. A stronger involvement of the urban citizens, which goes beyond the mere raising of awareness, is regarded as essential to enhance private engagement and to close existing implementation gaps.

5.6

Rural Areas of Northeast Lower Saxony, Germany

This case study analyzes climate change adaptation in the rural northeast areas of Germany's federal state of Lower Saxony. Agricultural and forest enterprises are important economic sectors here and occupy about 50% and 25% of the area, respectively. More than half of the irrigated agricultural land in Germany is located in Lower Saxony, and two-thirds of it are located in the northeast region (Ostermann, 2019). Agricultural farms cultivate mostly grains, maize, potatoes, and sugar beets. Grassland use is generally limited to valley floodplains and lowland moorland sites, as well as dry hillsides. Without human intervention, oak and beech forests would dominate the landscape. Today, the region is predominantly characterized by managed forests in which the proportion of conifers was increased to facilitate renewable material production.

Climate, climatic change, and society in Lower Saxony

The region's temperate climate is located at the transition between the Atlantic and continental climate zones. Typical years receive between 550 mm and 750 mm of precipitation. Podzols, Cambisols, and occasionally Arenosols are formed on sandy substrates of different geological origin (Holocene and Pleistocene). The depressions and floodplains on Holocene sediment are dominated by Fluvisols, Gleysols, or bogs (Heger et al., 2021; Vásconez Navas et al., 2023a). The predominantly sandy soils have a low water capacity of less than 50 mm in the effective root zone (Schickhoff and Eschenbach, 2018). If plant-available water falls below 30–40% of the field capacity, plant growth is severely limited. This was evident during an unusually strong drought in 2018, which reduced crop yields in Northern Germany by 26% (BMEL, 2022) and caused financial losses to German farmers of EUR 770 million (BMEL, 2022). In forestry, severe storms during the springs of 2018 and 2022 combined with extreme drought and high summer temperatures in 2018–2020 and 2022 significantly damaged tree health. To date, 245 million solid cubic meters of calamity wood have been recorded for the period between 2018 and 2022. Over 20% of the spruce stock identified nationwide in the 2012 Federal Forest Inventory has accrued as unscheduled calamity wood. The forest area to be reforested is over 450,000 hectares in size (BMEL, 2023).

Climate projections for the region show temperature increases between 1°C (RCP 2.6) and 3.3°C

(RCP 8.5) by the end of the century compared to the 1978–2018 period. Under the RCP 8.5 projection, there will be more precipitation in fall, winter, and spring, but a decrease in summer precipitation. The associated increase in evapotranspiration can result in a net water deficit during the growing season from April to August (Valencia Cotera et al., 2022). Climate change, in particular the increase in drought during the summer months, is likely to reduce the vitality of trees and increase mortality. A reduced biomass growth also lowers carbon sequestration rates. Studies in hardwood floodplain forests of the river Elbe showed that soil organic carbon levels varied between 99 and 149 tonnes per hectar and that they are strongly controlled by the hydrologic situation of the floodplain (Heger et al., 2021). Sap flow measurements of oaks and elms in hardwood floodplain soils, which reflect a high spatial and temporal variability of water availability, revealed notable differences between tree species in reaction to drought (Vásconez Navas et al., 2023b). Disturbances due to drought are often the starting point for further damage, especially bark beetle infestation (Bayerisches Staatsministerium für Ernährung und Forsten, 2023; Senf et al., 2017; Senf et al., 2020). It was shown that future extreme events will negatively affect the resilience and survivability not only of spruce, but also of beech, oak, and pine, and consequently large-scale removals for these tree species can be expected as well (Martes et al., in print).

Figure 5.5: Lower Saxony, Germany: Irrigation of potato plants as a coping measure against drought conditions in Lower Saxony. Photo: Angela Riedel, LWK Niedersachsen.

Farming and forest enterprises in the northeastern region of Lower Saxony are severely influenced by policies and societal developments. Relevant policies include the EU's Common Agricultural Policy, environmental policies for nature and biodiversity preservation, fertilizer regulations, regulations to foster the transition to renewable energy, and the German National Climate Action Plan (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2016). While governmental subsidies are essential to sustain agricultural businesses, they pose severe restrictions on farming and require detailed business reports. In recent decades, increasingly tight restrictions have led to farmers' protests against fertilizer and wildlife regulations as well as other policies. Public debates have raised awareness of climate change and environmental impacts of agricultural and forest systems among a broader public in Germany (Feindt et al., 2019). Increased concerns about healthy food, animal welfare, and the environment stand in opposition to the efforts for financial profitability of production, income security, and affordable consumer prices (Dannenberg and Follmann, 2023). The continuing globalization and immense political influence of European (e.g., EU agricultural subsidies) and national policies (e.g., energy transition) have fundamentally changed the agricultural sector in Germany in recent decades (Dannenberg and Follmann, 2023).

Climate change responses

Adaptation to climate change includes short-term and long-term adjustments of different magnitudes, many of which are already being made by some farmers (Wiedergrün, 2022). Short-term measures help to cope with the acute impacts of droughts and other extreme events. For arable farms in this case study's region, acute coping measures against droughts consist of irrigation (see Figure 5.5) and adjustments of planting and harvesting dates. Mobile irrigation systems may be used on farms where other irrigation infrastructure is lacking. In dry years, farmers may skip the planting of a catch crop (Wiedergrün, 2022). Incremental adaptation options include improving soil fertility and water storage capacity, cultivation of better-suited crop varieties and crops, redesigned crop rotations, and investment in irrigation infrastructure (Valencia Cotera et al., 2022). Soybean, for example, is seen as a possible new crop for northern Germany under a warming climate regime. Soybeans combine drought tolerance, nitrogen fixation, and soil carbon improvements. Increased domestic cultivation of soybeans in Germany would also lower demands for imports from environmentally sensitive regions such as Brazil. So far, soybean yields in experimental trials in Lower Saxony are still too low to financially compete with wheat or corn (Schreuder and Visser, 2014). The decision on crop changes depends also on the possibilities to integrate a certain product—crop and livestock—into the entire production system (e.g., as fodder for own cattle) of the whole farm as well as on the technical equipment and manpower available (Wiedergrün, 2022).

Agricultural adaptation options also include transformative adaptations. These constitute fundamental changes to the farming system, such as the adoption of organic farming or precision agriculture, or the implementation of novel agro-environmental monitoring systems. The change from conventional to organic farming can improve agroecological impacts, food quality, and soil fertility, and, to some degree, resilience against unfavorable weather events (Gomiero et al., 2011; Lorenz and Lal, 2016; Lotter et al., 2003). These benefits need to compensate investment costs for new equipment, training efforts, and increased cost of plant control. Somewhat similarly, precision agriculture supports resource friendly land management but comes at high investment cost. Combining geographic information with machine sensors can optimize fertilizer applications, plant control measures, and reduce the environmental burden of nutrient emissions (Grunwald and Böhner, 2022; Wendland et al., 2023). Novel monitoring systems for agro-environmental services and disservices would employ state-of-the-art scientific simulation models to quantify detailed environmental impacts of farms (Schneider et al., 2019). Very high measurement costs of non-point source emissions could be avoided and replaced by model estimations. The accounting of environmental impacts would take place on a protected server, to which farmers could link their bookkeeping software. Participating farmers would benefit financially and through decision support but would have to disclose detailed land management data at farm level. Non-participating farmers would be subjected to a less favorable default accounting of environmental impacts. Such transformative adaptations are often linked to a generation change in farm leadership and the more progressive production philosophy of the new farm leader.

Future climate change makes it essential for forest enterprises to adapt to changing site conditions. Various adaptation options are being discussed. Nature conservation circles favor process conservation. This involves reducing human intervention to a minimum and relying on nature's self-healing capacity (Geyer et al., 2017). This approach can lead to forests entering a decay phase, which can lead to the entire forest ecosystem's collapse (Burschel and Huss, 2003; Otto, 1994). Examples of this can be found in the Harz National Park. Other approaches emphasize adaptive forest management. Here, silvicultural measures and the cultivation of climate-adapted tree species or provenances are recommended to adapt forests to changing environmental conditions (Högberg et al., 2023; Kauppi et al., 2022). Another issue concerns the role of forests as carbon sinks on the path to climate neutrality. Forests are a significant sink for atmospheric CO_2. The question of how to deal with the carbon pools of forests is discussed contradictorily. It is frequently advocated to refrain from wood utilization with the aim of preserving these carbon pools. The decisive factor here is the permanence of carbon storage. Another view on the matter highlights the carbon sequestration capacity rather than the level of carbon storage of forests. Nagel et al. (2023) studied beech stands that have not been managed for over 100 years. These stands have a similar total carbon pool as such stands that have not been managed for only 50 years, but they contain significantly larger amounts of deadwood and less living biomass. Better management of existing forests can improve forest growth and help mitigate climate change by increasing the forest carbon sequestration rates and by storing carbon in wood-based materials, substituting fossil carbon-based materials or other CO_2-emission-intensive materials. Martes and Köhl (2022) showed for the Metropolitan area of Hamburg that managing forests and harvesting timber actually leads to higher carbon offsets than the full conservation of timber.

Enabling and constraining factors

Ultimately, adaptation of agricultural and forest enterprises in the northeast of Lower Saxony is in the farmers' and foresters' own interest. Dialogues with land owners confirmed their genuine interest to maintain or improve soil fertility, keep forestry viable, and produce commodities in an environmentally friendly way (Jantke et al., 2020; Valencia Cotera et al., 2022; Wiedergrün, 2022). Interviews with farmers also revealed a general awareness of climate change, as manifested in changing precipitation patterns and increasing temperatures, leading to shorter and warmer winters and hotter summers. However, while many stakeholders acknowledged CO_2 as important determinant for climate change, they did not fully link droughts to climate change. Almost all farmers underlined the importance of soil organic matter for water and nutrient holding capacities, resilience to droughts, and crop yields. Land owners also emphasized that adaptation requires adequate resources, reliable decision support tools, and stable prospects to achieve economic viability. Livestock operations (cattle, pigs, horses) in Lower Saxony increasingly experience labor shortage, a situation that seems less problematic for machinery-intensive arable farms. Stronger competition for suitable farmland and increasing land use restrictions due to environmental policies reduce the scope of adaptation opportunities, especially for smaller enterprises. Forest systems, on the other hand, are particularly constrained by their long-time horizon and the uncertainty of future climate and environmental conditions. Adaptation to climate change requires various enabling conditions, such as the choice of tree species, shorter rotation periods, or preserving the canopy closure. All investments in a new land use technology or a new enterprise system require planning security for several decades. With frequently changing regulations, investment benefits will be uncertain and less attractive.

Agricultural stakeholders also expressed their views on governmental regulations and the public image of farmers within society. While financial subsidies are still vital for commercial survival, many farmers would prefer not to depend on them. Governmental regulations are often perceived as a threat for business rather than a support. Regulations change frequently and have become increasingly bureaucratic. The governmental aid offered after the 2018 drought was perceived as both too small and too slow. To make matters worse, these ineffective payments amplified an already negative public image of subsidy-dependent farmers. Farmers feel unfairly treated in the media, which, in their view, are overly critical of agricultural businesses for their alleged negative climate impacts, but hardly acknowledge the challenges of agricultural production in highly industrialized countries. Farmers also shared some frustration about the typical consumer who demands more environmentally friendly products but does not want to pay a higher price.

Take-home message

Climate change in northeastern Lower Saxony is likely to increase dry periods during the summer months. Storms may also intensify; however, there is less scientific agreement on the extent of this change. Efficient and effective adaptations to these impacts in agricultural and forestry systems imply changes beyond coping and incremental measures. However, in deciding adaptations, stakeholders must consider many business interests as well. Uncertainties and information deficits, lack of trust in policy, and a hard break with many business habits are currently major hurdles to transformative adaptation.

5.7

Rural Communities in Nepalese Highlands, Nepal

Nepal is highly exposed to climate change impacts such as glacial lake outbursts, droughts, floods, and landslides because of its geographical fragility and altitudinal variations from lowlands to high mountains. The combination of extreme orography, fragile ecosystems, impoverished socio-economic conditions, and limited adaptive capacity has rendered Nepal one of the most vulnerable countries to the impacts of climate change (Chaudhary and Aryal, 2009; Eckstein et al., 2021). The Germanwatch Long-Term Climate Risk Index 2021 identified the country as one of the 10 most affected countries by the impacts of extreme weather events over the past two decades (Eckstein et al., 2021). Nepal falls within the group of countries that are affected by extreme events on an ongoing basis. A World Bank report suggests that the extreme weather events are all projected to intensify over the 21st century (World Bank Group, 2021a).

This future risk exposure is amplified by elevation-dependent warming. Already in the recent past, observational records feature a widespread warming over Nepal, which is more pronounced over mountainous areas than in valleys and lowlands (Karki et al., 2020). Large-ensemble and high-resolution (~60 km) projections reveal abruptly increasing temperature signals over the upper reaches of the Hindukush-Karakoram-Himalaya ranges (Ishii and Mori, 2020), exceeding the respective global averages by far (Böhner and Hasson, 2023). This database on future climate change is used for policy decision-making and is designed for climate change risk assessments (Ishii and Mori, 2020). Accelerated warming rates over the world's highest and largest mountain system, often referred to as the Earth's Third Pole, suggest amplified future changes of highland-lowland interactions and resource flows, which are essential for the functioning of Nepal's social and economic systems. Although projections reveal almost no or only moderate changes in precipitation, the significant elevation-dependent warming and its impact on the cryosphere (permafrost degradation, glacier retreat) as well as deducible changes of hydrometeorological systems and runoff regimes in the Hindukush-Karakoram-Himalaya region may affect more than 200 million people (Schild, 2008; Schild and Sharma, 2011). The resulting need for robust, spatially explicit projections of climate change and environmental impacts, however, demands very high-resolution (i.e., convection permitting) model setups to account for Nepal's topographic complexity and heterogeneity (Böhner and Hasson, 2023; Karki et al., 2017), thus far only insufficiently represented by the few available and still coarse (~25 km) resolution climate projections of the CORDEX-CORE EXP-I initiative.

Global warming induced changes in the dynamics of regional climate change and variability and glacier retreat have extensive effects on regional hydrological cycles, ecosystem resilience, and communities' well-being. The changes affect the availability and delivery of the critical goods and services which the mountain ecosystems provide to its millions of inhabitants and billions living in the downstream areas. In general, poverty is higher in mountain regions, and people are often at a higher risk than the people living in lowlands. The Food and Agricultural Organization (FAO, 2015) draws attention to the estimation that one out of every two rural mountain people in developing countries is vulnerable to food insecurity. To sustain the mountain ecosystems and livelihoods in these (mostly downstream) regions, it is imperative to understand the drivers of change affecting mountain sustainability. The recognition of the substantial shift in climate and its impacts on mountain ecosystems and socio-economic settings is crucial for the timely development of effective policy responses to cope with the change (Qi-Bin and Ouya, 2020).

Climate, climatic change, and society in Nepalese highlands

Indigenous Peoples and local communities have an intuitive understanding of the local atmosphere over long periods ever since they started to feel and distinguish environmental changes. Data collected within CLICCS show how local people use their adaptation measures proactively against experienced impacts based on their individual perception of climate change gained from consistent engagement with surrounding environment, including daily weather patterns (Darjee et al., 2022). Local communities in the highlands of Nepal have keenly observed and experienced changes in the climate. They have experienced shifts in the growing seasons of agricultural crops such as rice, wheat, maize, lentils, and mustard. While the locals outrightly noticed the disappearance of the Himalayan Bulbul (Pycnonotus leucogenys) and the House Sparrow (Passer domesticus) in the middle hills, they observed an increase in their population in the high mountains. The locals claimed that the changes are caused by the rise in temperature.

The people perceived changes in rainfall patterns, including early onset and early cessation of the monsoon, and in rainfall distribution, with reduced duration of drizzling and increased instances of intense rainfall. They observed a decrease in the number of rainy days and an increase in prolonged dry episodes. They confirmed that such changes led to a reduction in water sources, including mountain spring water, wells, ponds, and lakes (Darjee et al., 2022). The local perception of climate change largely aligned with meteorological analyses of the past three decades (Darjee et al., 2022). The analyses estimated that the temperature has risen at a rate of 0.061°C and 0.063°C yr^{-1} in the mountains and mid-hills, respectively. In contrast, there has been a reduction in rainfall, with decreases by -9.7 mm and -3.6 mm yr^{-1} in the respective regions. Approximately 88% of the local respondents acknowledged the rise in temperature, while 74% of them noticed the decline in rainfall. Moreover, the locals observed reduction in snow cover, retreat of glaciers, as well as the enlargement and increased number of glacial lakes. They attributed these phenomena to the rising temperature. These findings suggest that Indigenous Peoples and local communities possess a strong awareness and understanding of climate change. Such cognition plays a pivotal role in driving their responses to the impacts induced by climate change.

Climate change responses

The participatory development of a Community Adaptation Plan of Action is a well-established practice across Nepal. Several Community Forest User Groups, a formally recognized organization type, have developed Community Adaptation Plan of Action in the mountain region along with their Community Forest Operational Plan. The Community Forest User Groups expressed that their experience with the development of the Community Forest Operational Plan has been supportive for the Community Adaptation Plan of Action development and its implementation. The Community Adaptation Plan of Action process involves collecting information and context analysis; stakeholder consultations; participatory evaluation of the likelihood of climate change impacts, vulnerability, and adaptive capacity; identifying, prioritizing, and operationalizing actions for the future; and making informed decisions for their livelihood options and risk reduction strategies. These are critical skills which underpin adaptive capacity and enable people to use their knowledge and experiences to manage the risks associated with a changing climate (CARE, 2015).

We found that a large number of households in the studied Community Forest User Groups in Nepalese highlands has implemented both proactive and reactive adaptation measures in response to local climate change impacts. However, they do not necessarily label them as adaptation but rather see them as survival strategies. We registered more than 50 proactive adaptation measures related to agricultural diversification (25%), shifting from agriculture to livestock (16%) or cash crop and agriculture-based small enterprises (10%), trade in agriculture products (8%), and disaster risk management (30%) (Darjee et al., 2023). Agricultural diversification measures include changing crops, changing varieties and cultivars of the cereal crops, switching to local varieties, kitchen garden, off-season vegetable cultivation, and changing seed varieties for two to three year rotation. Examples of the disaster risk management measures include partial drainage of glacial lakes (see Figure 5.6), tree planting in landslide prone areas, riverside bamboo plantation, drainage construction around the house, and livestock insurance. Community-based seed banks, a pro-poor hill leasehold forest and forage development program, and community learning centers are innovative examples of good practices.

Figure 5.6: Lake Tsho Rolpa, Nepal: Artificial outlet of the Tsho Rolpa lake to reduce the pressure on the moraine dam, Nepal. Photo: Udo Schickhoff.

Enabling and constraining factors

Rural communities of Nepal are aware of the changing climate and the increasing risks it poses. They proactively utilize their traditional and local knowledge to adapt to these changes. This local understanding serves as a valuable complement to the limited observational data and provides guidance to the design of appropriate adaptation measures tailored to the local circumstances.

The Climate Change Policy 2019 (GoN, 2019), the National Adaptation Program of Action (MoE, 2010), the Provincial Adaptation Program of Action (MoITFE, 2019), and the Local Adaptation Plans for Action (MoE, 2011) frameworks guide and support the development and implementation of adaptation actions at community levels in Nepal. These policies and frameworks share a common goal to reach the vulnerable communities. The National Adaptation Program of Action recognizes the significance of local community groups in its implementation and specifically emphasizes the importance of integrating local adaptation priorities for the most vulnerable communities through community-based adaptation. Moreover, the recognition of appropriate implementing entities (e.g., Community Forest User Groups) for the Community Adaptation Plan of Action enabled a broader acceptance of and eventually facilitated the desired outcomes outlined in the climate change policies and adaptation plans.

The local communities have demonstrated their ability to democratically elect their representatives and to make important decisions in community-based forest management since the 1990s. Community Forest User Groups have a prominent institutional setup for adaptation planning and have proactively implemented adaptation practices aligned with the Community Forest Operational Plan and climate change policies. Such an institutional memory of suitable practices have been instrumental for the preparation and implementation of Community Adaptation Plan of Action and Local Adaptation Plans for Action processes. The Community Adaptation Plan of Action process supports the narrative of "Adaptation is generally locally led" and ensures a bottom-up planning process.

Adaptation is an ongoing process and, therefore, the national adaptation goals and associated actions must be dynamic as well as linked to both capacity to adapt and the degree of impact risks. Moreover, the choice of metrics, indicators, and methodologies to develop adaptation plans at different levels needs immense knowledge. Community Forest User Groups have been developing the Community Adaptation Plan of Action using participatory tools and techniques. However, many methods do not offer conditions for exploiting innovative opportunities and assessing scenarios in the process (Khadka et al., 2018). Adequate and predictable financial and technological support, including support for capacity-building, are major constraints for the development, implementation, and adaptive management of the action plans at all levels.

Although Nepal's policies and practices show a commitment to involving local communities in climate change adaptation, there are significant gaps in policy coherence and in the localization of national policies. While the Provincial Adaptation Program of Action and Local Adaptation Plans for Action emphasize the role of local government institutions, the National Adaptation Program of Action focuses on existing community-level organizations.

The integration of community-based climate change adaptation in local development planning processes in order to deal with different ecosystem-based adaptation options along with the identification of climate change scenarios, impacts, trade-offs, synergies, and the sensitivity of management problems, is established policy in Nepal's high mountain areas (CARE, 2015). Lack of integration hinders the effective coordination and collaboration between community-level initiatives and local government efforts. Concerted efforts are needed to integrate adaptation planning and well-functioning institutions into the development planning processes of local governments, which also require the critical skills, and thus capacity development, to ensure that their activities and plans are resilient to climate change and support adaptation by communities.

In sum, one can say that global warming induced changes in the dynamics of regional climate change and variability and the consequences such as glacier retreat, snow melt, and prolonged draught have extensive effects on regional hydrological cycles, ecosystem's resilience, and the well-being of the mountain dwellers and downstream communities. Local communities possess a strong awareness and understanding of climate change and complement the scarce observational data. Both together play a pivotal role in driving the responses to climate change induced impacts. There is no monopoly on knowledge related to climate change, and local knowledge merits greater attention from science and policy.

The highlanders implemented more than 50 proactive adaptation measures that are no standalone measures but embedded within broader sectoral initiatives. Many of them combine adaptation and climate change mitigation and have the potential to contribute to Sustainable Development Goals (SDGs) by reducing food insecurity, enhancing food sovereignty, and increasing the extent of forest and agrobiodiversity.

The national government is highly visible within and influenced by UN climate governance (see also Section 3.2). The country has promulgated several climate-related policies and frameworks at national, provincial, and local or community levels. High-level policies to improve horizontal (between line ministries) and vertical (between adaptation plans implementation at the different levels) coordination, to better align decentralized government and community actions, eliminate institutional inertia, and break silos are crucial to achieve the adaptation goals. Stronger integration of community adaptation planning into development plans at all levels and the convergence of adaptation, disaster risk management, SDGs, and resilience-building priorities are important areas to be improved.

During the past decade, weather induced disasters in Pakistan, Myanmar, and Nepal, as well as the regularly occurring extreme events prove the urgency of scaling-up climate adaptation and resilience in Asian highlands. So far, adaptation efforts in affected countries have been mostly reactive and incremental, while transformative community-led climate change adaptation measures need increased and commensurate investments. However, the COVID-19 pandemic and reduced economic growth exposed the countries to severe debt vulnerabilities and limited fiscal space, which has sidelined the issue of climate change adaptation in the national agenda. Despite persistent efforts, grant-based financial arrangements have yet to materialize.

Take-home message

In Nepal, adaptation most often takes place on a small-scale community basis. The challenges are to measure, monitor, and communicate the adaptation efforts taken in such small-scale and remote geographical areas. This, in turn, limits the lessons that can be learned and shared. We are only beginning to grasp the extent of climate change impacts in the "third polar region", and significant uncertainty remains. The sustainable use of limited resources in highland countries and the enabling of climate benefits at the lowest possible cost is crucial for adjusted, plausible, and desirable adaptation measures.

5.8

Pastoralists in Kunene, Namibia

Namibia is one of the most sparsely populated countries in the world and home to about 2.6 million people. In 1990, Namibia gained independence from South Africa and has since established itself as a stable democratic nation. The country's economy is largely based on mining, agriculture, and tourism. Socio-economic inequalities in the upper-middle-income country remain, however, extremely high (Worldbank, 2023).

Climate, climatic change, and society in Kumene

Namibia is one of the driest countries in sub-Saharan Africa, and climate change has a significant impact on the region. Observed temperatures exceed global averages by about 7°C, mean precipitation levels decrease while heavy precipitation and pluvial flooding increase, and severe droughts occur more frequently, having increased by 220% between 1961 and 2016 (Engelbrecht et al., 2015; Yuan et al., 2018; Trisos et al., 2022). Projections indicate a high probability that this situation will exacerbate by a further rise in temperatures, increasing aridity due to reduced precipitation and soil moisture, and further increases in agricultural and environmental droughts (Ranasinghe et al., 2021). Extreme heat waves are projected to occur much more frequently in the near future (see also Section 4.5).

The projected expansion of arid regions puts pressure on the already vulnerable agricultural systems, affecting food security and the livelihoods of rural communities. About three quarters of Namibian households engage in smallholder agriculture. These farming households have limited or no access to mineral fertilizers or irrigation infrastructure. Namibia still suffers from substantial malnutrition and child mortality (von Grebmer et al., 2022), which will be exacerbated by climate change. Climate change adaptation is therefore crucial to enhance the resilience of rural communities.

Global stock-takes of actual climate change adaptation found that drought and precipitation variability are the most critical climate hazards in Africa against which adaptation measures are already being implemented. Individuals or households were identified as the key actors implementing appropriate measures, with rural areas being a focus of action (Berrang-Ford et al., 2021; Petzold et al., 2023a). Namibia's National Climate Change Policy established a legal framework to guide the development, implementation, surveillance, and assessment of climate change adaptation initiatives. Examples of adaptation objectives outlined in the policy encompass the promotion of climate-smart agricultural practices, diversification of the economy and livelihoods, implementation of smart irrigation and water management systems as well as the improvement of climate data, weather forecasting, and early warning systems (Ministry of Environment, Forestry and Tourism, 2021).

Climate change responses

The aim of this case study is to explore how pastoralists in the Kunene region of northwestern Namibia adapt to climate change (see Figure 5.7). The Kunene region is about 144,000 km^2 in size and, according to the latest census in 2016, has roughly 100,000 inhabitants. Due to the adverse climate conditions of the area, it has a very low population density of 0.68 people per km^2.

Figure 5.7: Kunene, Namibia: Pastoralist herding goats and sheep in Kunene, Namibia. Photo: Michael Schnegg.

Climatic context

Kunene is partly semi-arid and partly arid, with precipitation falling between 100 mm and 300 mm per year. In the past, the area had two rainy seasons, one in October and November and the second more extensive season between February and May. However, precipitation during the rainy seasons is patchy and uncertain. Some areas receive a considerable amount of precipitation while others receive much less (Schnegg and Bollig, 2016).

Both meteorologists and local communities agree that precipitation and its distribution have changed significantly over the past decades (Schnegg, 2021b). Firstly, the rainy season in October and November has become weaker and less reliable. The rain both starts later and ends earlier, making the rainy season much shorter than is used to be. This has consequences for vegetation growth. The vegetation growth period has become so fleeting that grasses essential to pastoralists' livelihood cannot be sown. This, in turn, negatively affects the following years' vegetation cover. Moreover, people observe that the intensity of droughts has increased.

Colonial context

The Kunene area is mostly inhabited by Otjiherero-, Khoekhoegowab-, and Oshivambo-speaking people. To understand the effects of climate change on their livelihoods, a look into colonial history is necessary. Namibia was occupied by the German Reich in the second half of the 19th century and became a German colony. To establish political power in the vast country, the most fertile parts were turned into commercial farmland on which German settlers, often former soldiers, were settled. With strong financial, political, and military support from the German state, they established a commercial cattle economy.

This had several important consequences. Indigenous Peoples were forced to live on marginal lands. Right from the start, however, it was clear that the carrying capacity of these marginal lands was not sufficient to maintain the population. This was a deliberate policy because it forced people to work for very low wages on the commercial farms or in the mines. Through doing so, a migratory regime was established, which is common for many parts of southern Africa. It also meant that stocking rates on the communal areas were so high that they became enormously vulnerable to droughts (Schnegg et al., 2013). Against the backdrop of these colonial and climatic conditions, it does not come as a surprise that Indigenous Peoples often say "there is no drought on the White man's land."

Economic context

Most people in the rural area of Kunene mainly rely on pastoralism for subsistence. Most of them own relatively few cattle, between five and 20, and some small stock, sheep, and goats. Animals are kept on the open communal pastures. They return to the community every evening because there are few open wells, and water is pumped from boreholes for human and animal consumption. In addition to livestock, a significant number of wildlife inhabit the area, including a quickly increasing elephant population (Schnegg and Breyer, 2022).

While many people maintain livestock, only some can live from it alone. Most often, households combine a variety of strategies as part of which some members work on commercial farms, in mines, or, increasingly, in town, while others maintain the household and animals. Moreover, children of those who work outside the rural communities tend to stay at their grandparent's house in the hinterlands. As people retire or lose jobs, they often return to their rural homes.

How climate change affects people

Further rising temperatures and increasing aridity are projected for the region. There are two major effects on Indigenous pastoralists. The first relates to the effect of changing patterns of precipitation on vegetation growth and livestock farming. Most significantly, the number of droughts and their intensity have drastically increased. During the last major drought that began in 2015, almost 70% of the livestock in the area died. This is a tremendous loss given that people often do not own any larger assets other than their livestock (Schnegg and Bollig, 2016). To put this amount into perspective, it helps to consider that a piece of cattle is worth about EUR 400, while a laborer makes about EUR 4 a day.

In addition, the changing patterns of precipitation have increased human-wildlife conflicts. The elephants in Kunene, whose numbers have increased significantly, typically stay in the dry river beds where they used to find sufficient food and water. With climate change, however, water levels in these ephemeral rivers have lowered so much that many trees close to the rivers have died, and it has become difficult for elephants to dig for water during the dry season. Because of this, they have to leave the rivers and come to the communities to seek water, often destroying water infrastructures (Schnegg and Kiaka, 2018).

Knowing climate change

Because weather changes have such a significant impact on people's livelihoods, they are salient in everyday talk. As something which is strange and not understood, people spend a great deal of time and effort to make them meaningful. These attempts are partly informed by scientific knowledge and partly by knowledge from Indigenous or religious registers (Schnegg, 2021a; Schnegg, 2021b). In this vein, it is commonly assumed in this area that weather change is caused in the region or in Namibia. People would also not say that weather changes have anything to do with the remote past; instead, they are associated with current wrongdoings in society. This is because in Namibia, as in most other parts of the world, the weather is part of an animated moral universe that encompasses humans, spirits, winds, and rains. All these entities have subjectivities, so when the rains fail to come and the weather is unforgiving, this is likely because people misbehaved (Schnegg et al., 2021).

Importantly, while these Indigenous and scientific ways of knowing are different, they also co-exist and even merge. In some situations, people draw on a particular understanding that is in part related to the way the weather and its changes are experienced in an embodied sense (Schnegg, 2021a; Schnegg, 2021b). While scientists and Indigenous communities thus observe similar tendencies of environmental change, they make these changes meaningful in different ways. This depends largely on their ways of *being-in-the-world* and of perceiving the world as scientists or pastoralists, connecting observations to different entities and for different ends, ultimately leading to different explanations of environmental change.

Adaptation at household and community levels

While people do feel the increasing threat of weather change, and many have lost significant amounts of their livestock, this is actually not considered entirely out of the ordinary. The collective memory retains other incidents of severe droughts. Animals dying and rotting in the fields are part of their narratives, tales, and—for the elders—past experiences. This explains why even during extreme weather change, people do not panic. What is more, many have survived drastic political and economic turnovers that they tend to classify as more severe than the current climate change. Also, many have developed a worldview in which natural events are perceived as simply befalling individuals, who have relatively little agency to influence them (Schnegg, 2023a; Schnegg, 2023b).

At the household level, there are few means to adapt to climate change within the pastoral economy. One option is migration, which is practiced to some extent but also increasingly leads to conflicts. On the one hand, the Namibian state has guaranteed its citizens the right to freedom of movement since independence in 1990; on the other hand, land is still issued by traditional authorities which are ethnically homogeneous and often hesitant to grant grazing rights to people who do not speak their language because they belong to a different ethnic group.

In addition to migration, diversification is a main strategy. However, we know of extremely few cases in which this has worked in the long run. This has to do with the fact that households have relatively little access to cash, and many economic strategies beyond pastoralism require some cash flow, when, for example, fodder needs to be bought or transported to the marketplace. Because clients often do not pay on time or at all, most of these activities fail. Where they work in commercial environments, it is mostly because there is cash and workers can be exploited to such a degree that production becomes profitable.

As a consequence, many of the organized attempts to diversify fail, which we have seen firsthand with communal gardens, fish farming, and comparable development efforts.

One of the problems with most of these efforts is that they require groups to do something jointly whilst people have little confidence in organizing economic activities beyond the household. In all cases that we were able to observe, this led to conflict and thus failure. Another contributing factor is that many of these development efforts are built on the idea that formal institutions, including committees, can govern them. This ignores the fact that in small, face-to-face communities, people interact in multiple roles, including kinship, which makes it often very difficult to apply formal rules and sanctions to, for example, elder kin, because such behavior would not only be considered rude, it would effectively cut someone off from long-term social and economic ties that are essential for survival (Schnegg, 2018).

Enabling and constraining factors

In rural areas of Namibia such as Kunene, people are constrained to adapt to climate change on the household level because they lack infrastructure and capital. While the state and NGOs encourage and try to enable some transformations, these are often based on assumptions that contradict local norms and values, making it not plausible that they will become a long-term adaptive strategy. However, while livelihoods have indeed worsened due to global warming, most people in such marginalized economic and political environments experience plenty of ups and downs in their lives regardless of climate change, making the situation emotionally more easily bearable, at least from what we observe.

Take-home message

Rural communities in Namibia are highly vulnerable to climate change due to their heavy dependence on natural resources. As the region faces more frequent droughts and heat waves that threaten food security and rural livelihoods, climate adaptation measures are urgently needed. However, the adaptive capacity of these communities is limited by economic marginalization and a legacy of colonialism.

5.9

Coastal Adaptation in North Frisia, Germany

North Frisia is situated in the northwesternmost part of Germany along the North Sea coast, where it adjoins the North Frisian Wadden Sea. The Wadden Sea extends along the entire German Bight coastline, stretching from the northern Netherlands up to Blåvands Hook on the southwestern tip of Denmark. Geologically speaking, the formation of the North Sea, and in fact the entire North European region, is shaped by past ice ages and glacial deposits. The extent of the North Sea we see today results from developments after the last ice age when the then dry area of the North Sea Basin was flooded by water released from the ice shields (Stadelmann, 2008). In the post-glacial climate between 7000 and 5000 B.C., the ice was melting quickly, causing an average sea level rise of 1.25 m per century (Behre, 2008). After this rapid rise, sea level change slowed down, allowing the relocation of sediments in the area of the Wadden Sea. This led to the formation of the first tidal flats (MELUR, 2015), which still characterize the coastal landscape in the Wadden Sea today. The natural origin of the Wadden Sea can thus be dated back to some 4000 years ago when the rate of sedimentation exceeded sea level rise.

Against the background of this natural development, early settlers in the North Frisian Wadden Sea were exposed to the dangers of storm surges from the North Sea without any protection (Brandt, 1992; Knottnerus, 2005). To be able to sustain a living under these difficult circumstances, they had to adapt to their coastal environment. Hence, people along the coast developed measures and structures to secure their lives and belongings from the floods; in particular, they began to construct small dwelling mounds and dikes (Küster, 2015). This century-long interaction with the challenging waters and the ensuing socio-historical settlement process resulted in a perspective on coastal protection and the coastline in North Frisia that is still characterized by the proverb "God created the sea, the Frisians the coast". The natural environment was partly tamed, influenced to one's advantage, gradually turning the coast into a more cultural environment (e.g., man-made brushwood fences and stalk plantings, to strengthen and secure the natural dunes as shown in Figure 5.8).

Figure 5.8: Amrum, Germany: Fresh stalk plantings and sand trapping fences to secure and further build up the coastal dunes that protect the island of Amrum, Germany. Photo: Philipp Jordan.

The sea represents a risk to the people in North Frisia, and fear of the sea is deeply ingrained. Over the past centuries, this initiated an innovation boost during which techniques of diking and other measures of coastal protection were developed (Fischer, 2021). The present image of the "free Frisian" is based on the constant battle with coastal waters (Rieken, 2005; Rheinheimer, 2003); it is also mirrored in the regional and local sense of place or "Heimat", which reflects a deeply rooted interrelationship between the coastal inhabitants, the landscape, and the dikes (Ratter and Gee, 2012; Döring and Ratter, 2015; 2018; 2021; Steensen, 2020; Holzhausen and Grecksch, 2021).

Today, the region of North Frisia has to cope with demographic change, a declining agricultural sector, a practically no longer existing shipping sector, and a shrinking fishing industry. Renewable energy production represents a new and promising area for unprecedented economic growth. In the future, the whole region may come to rely on both tourism and energy production in the form of wind power and hydrogen production.

Climate, climatic change, and society in North Frisia

North Frisia's climate can be characterized as an Atlantic climate that is showing the effects of climate change. Numerous studies show a warming of about 0.8 °C in northern Germany within the reference period of 1961–1990 (Meinke, 2020). Along with this, the frequency of extreme events has also changed. In particular, summer days (> 25°C) and hot days (> 30°C) have become more prevalent during the summer months. In winter, ice and frost days have decreased significantly, and the thermal growing season has lengthened considerably. More than 120 regional climate scenarios have been evaluated as part of the North German Climate Atlas; they all agree that the warming already taking place in northern Germany will continue in the 21st century. Depending on future greenhouse gas emissions, northern Germany may warm by about 1–5°C by the end of the 21st century (from the optimistic RCP 2.6 scenario to the pessimistic RCP 8.5). In the future, significantly amplified precipitation is expected, especially (but not exclusively) in the winter months, with increases potentially as high as 40% by the end of the 21st century. In summer, the duration of dry periods is estimated to roughly double by the end of the century.

Contrary to what is often claimed, no long-term trend of increasing mean wind speed or storms has yet been observed. A storm season today produces neither more violent nor more frequent storms than 100 years ago (Krueger et al., 2019; Krieger et al., 2020; Olonscheck et al., 2023). Future trends in storm activity are unclear from today's perspective. Looking toward the end of the century, the strongest changes in storm activity in northern Germany are expected for the winter months (Feser et al., 2021; Krieger et al., 2022). During this season, storm intensity may increase by up to 10%, and the number of storm days could almost double (Meinke et al., 2018). The sea level in the German Bight has risen by about 15–20 cm within the last 100 years and is not showing signs of unusual acceleration. Depending on future greenhouse gas emissions, the potential sea level rise in the North Sea by the end of the century (2081–2100) is therefore expected to lie within the global range of 30–80 cm. This makes sea level rise the main driver of higher water levels and storm surges (Arns et al., 2017; Jordan et al., 2021; Liu et al., 2022). Projections whether future extreme wind speed will increase or decrease in the German Bight still vary significantly (Quante and Colijn, 2016), but a projected shift in the predominant wind directions might be another additional driver for higher water levels at the end of the century (Sündermann and Pohlmann, 2011).

To deal with these impacts of climate change, a governmental coastal defense plan (General Coastal Protection Plan) has been developed and adjusted over the past decades (MELUND, 2022). It regularly assesses the status of dikes, determines restoration work to be executed, and develops adaptation measures to be taken on the mainland and on the islands. All measures undertaken are based on RCPs 2.6, 4.5, 6.0, and 8.5 from current IPCC (2019) reports and complemented by measurements of water levels and degrees of sedimentation in the North Frisian Wadden Sea carried out by local and regional authorities. Both RCPs and measurements inform local adaptation plans and aim at improving the current state of the art of coastal protection and adaptation measures (Gemeinde Helgoland, 2013; MELUR, 2014). All plans and activities are negotiated with regional actors, administratively supported, politically endorsed as outlined in the Climate Protection Concept North Frisia (Wagner et al., 2011), and promoted by the Climate Alliance North Frisia. On the level of the federal state of Schleswig-Holstein, the General Coastal Protection Plan (MELUND, 2022) is complemented by various sectoral adaptation plans for forest or water management, agriculture and the Strategy Wadden Sea 2100 (MELUR, 2015). On a national level, the Federal Environment Agency promotes climate change adaptation via various programs and funding initiatives, as already outlined in the Climate Change Adaptation Strategy Germany (Bundeskabinett, 2008).

Recent research on the regional and local perception of climate change in North Frisia paints a multi-layered picture. Variations in seasonal weather patterns experienced by locals, changes in the local composition of flora and fauna as well as regional intensification of storms and storm surges are attributed to climate change. Climate change adaptation strategies exist on various scales within society, ranging from individuals and neighborhoods up to parishes. Individual measures taken range from insurance against damage caused by extreme weather events to behavioral adaptation to protect premises or using weather apps to be informed about imminent weather conditions (Döring and Ratter, 2018). On a neighborhood and community level, mitigation strategies such as options for green energy generation are negotiated and jointly implemented (Süsser et al., 2017; Süsser and Kannen, 2017) while telephone chains exist to check if neighbors are safe during serious weather conditions. On the parish level, climate change adaptation in terms of diking and other comprehensive measures are mostly relegated to regional authorities, but advantage is taken of state and national funding programs to, for example, locally finance power supplying devices to secure energy provision in case of larger-scale power failures. Relocation within or moving away from the region are not generally considered an adaptive option because of strong intergenerational ties to local places (Mulligan, 2014; Döring and Ratter, 2018).

Climate change responses

Today, it is mainly the federal states that are responsible for protecting their citizens against the dangers of the sea (Jordan et al., 2019). Concepts of coastal defense are constantly re-evaluated while preventative measures are being developed with the aim of anticipating possible climate-induced storm surges to avoid damage (FAIR, 2020). Planning climate change adaptation in a socially and economically sound way and making the right decisions appears to be tricky for those in charge of coastal protection. Knowing that climate change will affect coastal safety (IPCC, 2019), but uncertain as to how much and when, makes it tough for decision-makers to make technically appropriate and socially acceptable choices. This situation becomes even more difficult due to evolving societal, technical, and ecological requirements. Within the UN decade of ecosystem restoration for instance, adaptive solutions are being called for that frame coastal ecosystems as sensitive entities. As a consequence, tension is growing between the established ways of doing coastal protection and the need to implement nature-based solutions (Jordan and Fröhle, 2022; Kiesel et al., 2023).

Diking has been a visible and effective form of protection in North Frisia. Consequently, citizens have much confidence in the authorities responsible for diking, while there is much less confidence in nature-based solutions (González-Riancho et al., 2017). This has made it easier for those responsible for coastal protection to continue with the diking rationale as the main pathway of climate change adaptation. The concept of the so-called Climate Dike (Reise, 2015; Hofstede, 2019a; Hofstede, 2019b; MELUND, 2022) is an example of this; it widens the dike crest so that the dike can be raised by means of an additional cap to be placed on top. While this clearly responds to estimated sea level rise and the growing intensity of storm surges, there is increasing awareness among practitioners that it represents a one-sided approach to the problems coastal dwellers will be facing. On the one hand, this incremental, path-dependent climate change adaptation measure successfully concentrates on the aspect of protecting lives and livelihoods for another 50–70 years; on the other, it lacks the ability to incorporate possible climatic developments beyond its 70-year design life and to take into account ecological concerns.

Although they have been overshadowed by diking, nature-based solutions exist (Jordan and Fröhle, 2022) and have been applied in the North Frisian Wadden Sea for decades, if not centuries (Jordan et al., 2023). A salt marsh in the dike foreland, for example, can dampen waves and thereby protect the dike foot while also providing a habitat for flora and fauna, thus promoting biodiversity. Experiences with nature-based solutions such as brushwood groins to generate foreland have been taken up by the politically driven Strategy Wadden Sea 2100 (MELUR, 2015), which was adopted by the state government. Here, a climate change adaptation plan was cooperatively developed by authorities and other actors with the dual aim of protecting the Wadden Sea National Park in front of the dike and the livelihoods behind it (Hofstede and Stock, 2018). The concept envisions sediments (naturally occurring or artificially put there via nourishments) to be relocated by the coastal currents, instigating a process of sediment accretion to protect the region against future sea level rise and storm surges. The idea of a naturally growing seabed that prevents natural and cultural landscapes from drowning was appreciated by all participants involved because it reunited the often conflicting parties of nature conservation and coastal protection. The Strategy Wadden Sea 2100, in combination with pilot projects based on or following this strategy, such as the Sandy Coast St. Peter-Ording project, clearly represents a way of transformative climate change adaptation and coastal protection.

Enabling and constraining factors

Diking still represents a technically feasible, socially accepted, and administratively established way of doing coastal protection in North Frisia. Local social trust in the authorities responsible for diking is high; hence the climate dike, with its central focus on the safety of the coastal population, has been developed as the primary climate change adaptation concept. Path dependencies and a medium-term planning horizon of around 50–70 years are enabling factors that support this particular way of coping with the estimated sea-level rise in the region. This, however, is not always seen in a positive light. Nature conservation authorities and environmental NGOs perceive dikes as ecologically disruptive entities in what they regard as a largely natural landscape. The conflicting ideologies between nature conservation and coastal protection disclosed by our interdisciplinary interview study between 2019–2023 (Jordan et al., 2023) clearly represent a constraint for climate change adaptation, which is also evident in the tense and almost non-existent collaboration between both parties. Sectoral thinking and handling of climate change adaptation with almost no attempt to cooperatively explore existing or new ideas currently represents a constraining factor.

Against this background, projects and initiatives such as the Strategy Wadden Sea 2100 represent enabling factors. They are an opportunity to meet outside of the existing cultures of conflict. Open and transparent interaction, acceptance of different ways of knowing, and constant communication about common objectives and achievements among all the parties involved resulted in a cooperatively developed climate change adaptation concept which was adopted by the federal government of Schleswig-Holstein. It currently awaits its broadscale implementation, with first pilot projects being launched already.

Take-home message

Coastal protection, understood as sustainable climate change adaptation, is a socio-technical endeavor. It is structured by social processes, administrative path dependencies, and lock-ins in established approaches that limit the scope of what might, could, or should be done to technically or naturally protect the coast from estimated climate change impacts. Although diking is associated with a low degree of uncertainty, physical feasibility, and established ways of implementation, it is important to develop projects that enable the building of communities of practice where experimenting with alternative or new ways of doing coastal protection can be scientifically assessed, technically tested, and—most importantly—socially experienced and negotiated.

5.10

Small Islands Adaptation in the Maldives

The tropical atoll state of the Maldives lies in the Indian Ocean between the latitudes of 0° and 7°. With an overall area of 923,322 km^2 and only 298 km^2 of land area, the Maldives is represents one of the smallest countries in Asia. At the same time, it is one of the geographically most dispersed countries in the world. Out of 1190 islands, stretched out in a double chain of 26 atolls, 187 are currently inhabited by a population of 521,457 (2021). In 2022, according to World Bank data, the GDP per capita was USD 11,963, ranking the Maldives 71st out of 196 countries (Country Economy, 2022). The Gini index, which measures relative degrees of social inequality, stands at 29.3 (2019) for the Maldives, slightly higher in the capital Male' than in the atolls of the rest of the country. About 100 islands are exclusively used as tourist resorts. As a country, the Maldives is characterized by smallness, remoteness, scarce resources, high population pressure, threats to biodiversity, and high dependence on healthy terrestrial and marine ecosystems (Petzold et al., 2023bs). Environmental resources play a significant role in the state's development, especially in tourism, fisheries, and agriculture, as do international trade links and dependence on international relations.

The Maldivian coralline islands are only 0.5–2.3 m above sea level (Wadey et al., 2017); as such, they are considered particularly vulnerable to the effects of anthropogenic climate change (Magnan et al., 2022; Mycoo et al., 2022; Storlazzi et al., 2018). Coralline islands, coral reefs, and surrounding sand sediments are all morphologically dynamic, driven by the seasonally changing winds, waves, and ocean currents (David and Schlurmann, 2020; Kench, 2012; Kench et al., 2018). It has been shown that natural factors can cause erosion but also accretion of atoll islands, meaning that land areas on atolls can expand despite rising sea levels (Magnan and Duvat, 2020; Masselink et al., 2020; Kench et al., 2018). Magnan and Duvat (2020) calculated that between 2005 and 2015, 41% of the atolls in the Maldives were stable, 0% decreased and 59% increased in size. Functional, ecologically intact coral reefs that surround each atoll are crucial to protect the islands (Ryan et al., 2019): A healthy coral reef provides sand for the islands through biodetritic production and serves as a brake on marine wave energy (Aslam and Kench, 2017). Threats to the reefs originate from global developments (thermal stress, ocean acidification) but also from local activities like pollution, overfishing, and coastal construction activities.

Climate, climatic change, and society in the Maldives

Tropical cyclones rarely directly hit the Maldives, but the seasonally changing monsoon winds regularly lead to damage. The dominant wind systems result in strong swell waves that have varying effects along the length of the state (Wadey et al., 2017). Higher air temperatures lead to more evaporation, while changing rainfall patterns reduce precipitation where it is needed, threatening drinking water supplies. Rising water temperatures, ocean acidification, and marine heat waves lead to coral bleaching, threatening the important island-protecting reefs and their marine biodiversity. Despite these varied impacts of climate change, it is predominantly sea level rise that is at the center of political discussion in the Maldives.

The actual sea level change in the Maldives is difficult to assess as only three tide gauge stations operate along the island chain. Records from 1991–2015 indicate a rise of 3.46 ± 0.25 mm per year for Male' (Wadey et al., 2017) while the northern Indian Ocean sea level rose between 2.3 ± 0.09 mm per year in the period of 1993-2015 (Swapna et al., 2017). Sea level projections for the Maldives islands are extremely inaccurate due to their location in the middle of a vast open sea and the unknown tele-effects of the Himalayas, which makes downscaling of global projections difficult (Cazenave et al., 2018; Palanisamy et al., 2014). Current estimates assume a sea level rise of approximately 7 mm per year, slightly faster than the global average (World Bank Group, 2021b). Sea level rise leads to rising wave heights, while a damaged reef flat leads to an increase in wave power and thus to more erosion.

Numerous scientists consider the expected sea level rise a major threat to low-lying coastal areas and islands (Hoegh-Guldberg et al., 2018; Li et al., 2020; Mycoo et al., 2022; Oppenheimer et al., 2019). Although Gussmann and Hinkel (2021) find it a non-immediate existential threat, it is important to account for the cumulative effects of climate change impacts, such as the frequency of storm surges, accretion, heavy rainfall, and tidal waves, on top of sea level rise. Coastal and marine environments are highly susceptible to global warming, implying that coastal vulnerability needs to be frequently assessed to better understand the actual risks climate change poses to the populations living on the islands and the biodiversity they depend on (Abijith et al., 2023). A key problem is the uncertainty of exactly when, how, and where the rise of sea levels, acting in combination with other climate change effects, will have an impact on islands, as this depends on many factors. Site-specific management of climate change impacts, ecosystem services, and adaptation measures is critical. Coastal adaptation measures, in particular grey or hard coastal protection, are expensive, and financial resources are often limited. Options for action therefore need to be kept open for as long as possible until more is known about local implications of sea level rise to make measures as (cost-)effective as possible (Hinkel et al., 2021; 2023).

Coastal floods caused large-scale destruction in Male' and on 15 other islands in 1987 and 1988 (MHE, 2011). Yet, the key historical event was the 2004 tsunami, in which 83 people were killed and 25 reported missing. 10% of the population were displaced, and about 8000 homes were damaged; the inhabitants of two islands were re-settled (Azfa et al., 2022; Gussmann and Hinkel, 2021; Kothari et al., 2023).

Climate change responses

Between 2013 and 2017, the government spent USD 38.7 million on coastal protection measures–a fraction of the investment that was actually needed (MEE, 2017). Maladaptive practices further exacerbated the problem (David et al., 2021; Kench, 2012; MEE, 2015a): Coastal modifications such as reducing reef widths by claiming new land within the reef flat and building fixed coastal infrastructure on the shorelines is widespread in the Maldives (Hinkel et al., 2023). Standard protection measures have often been poorly implemented, and not all islands in need of protection receive the necessary support. Frustration and disappointment on remote peripheral islands are coupled with a loss of trust in central government (Ratter and Hennig, 2020).

The political aspect of adaptation becomes highly apparent in the Maldivian example. Changes of government have repeatedly led to changes in the understanding of climate change and the strategies adopted. In 2009, former president Nasheed held an underwater cabinet meeting to draw international attention to the archipelago's plight. Sea level rise was clearly seen as the biggest challenge related to climate change, following the dominant narrative that developed countries are responsible for climate change and small islands its victims.

Under President Nasheed (presidency 2008-2012), a plan was proposed to make the Maldives carbon-neutral within a decade (Clark, 2009). The first national climate adaptation program was adopted in 2007 (Abdulla et al., 2007). The National Adaptation Plan of Action was revised in 2012 as well as in 2016 (The Republic of the Maldives, 2020) and then followed by other strategic plans for dealing with climate change. These include the Safer Islands Strategy (MEEW, 2007), which aims to re-settle populations of smaller, more vulnerable islands to larger, protected islands; building codes; Environmental Impact Assessment Regulations; and the Strategic National Action Plan for Disaster Risk Reduction and Climate Change Adaptation 2010–2020 (Gussmann and Hinkel, 2021; Hennig, 2020; Malatesta and Schmidt di Friedberg, 2017). President Nasheed even considered migrating the entire population to Australia, Sri Lanka, or India if sea levels continued to rise. The subsequent government under President Abdulla Yameen recentralized power at the highest levels of government (Robinson, 2015) and shifted its focus toward economic development, neglecting environmental protection (Malatesta and Schmidt di Friedberg, 2017). The current government under Ibrahim Mohamed Solih committed itself back to democratic values and social engagement. However, politics remain volatile, and decisions are often taken based on expected political gains. The presidential election race in 2023 represents the latest critical juncture (Amjad, 2023).

Coping strategies to deal with sea level rise and other climate change impacts are urgently required at different levels. The central government focuses on technical solutions but does so based on political favors instead of prioritizing according to need (ADB, 2015). Large-scale investment projects—financed by China and India—reflect major external geo-strategic interests but cause huge environmental damage (Amjad, 2023).

Different climate change adaptation strategies apply in the capital as the political center, on tourist resort islands, and on islands with a local population.

The capital city of Male', home to 47% of the total population in 2019, was protected from flooding after the 1987 and 1988 high wave events with Japanese aid (JSCE, 2022). This included fortification of the reef edge in the form of a sea wall, revetments, tetrapods, and groynes, as well as rehabilitation of local infrastructure, particularly ports.

New land reclamation combines development goals with protection against erosion and sea level rise (van der Pol et al., 2023); non-binding guidelines state that new land should be created at a level of 1.5–1.8 m above current mean sea level (MEE, 2015b). The largest Maldivian land reclamation project took place in Hulhumale' ("City of Hope") in 1997 and 2015, raising two artificial islands of 400 ha (4.3 km^2) to 1.8–2.0 m above mean sea level. The aim was to alleviate population pressure in the capital and prepare for the resettlement of 240,000 people from other parts of the country (Bisaro et al., 2020). Brown et al. (2023) found that these islands would be safe into the 2090s even under a high emissions scenario and much longer under a low emissions scenario.

Another large infrastructure project, the Greater Male' Connectivity Project of 2021, will promote further urban development, although it requires significant shoreline protection measures (Brown et al., 2023; Gussmann and Hinkel, 2021), indicating that environmental aspects are not taken into consideration.

Tourism islands, catering for international luxury tourism (dell'Agnese, 2021), are mostly managed by private enterprises. Given their larger financial budgets and explicit interest in protecting the pristine environment, resort islands have both a growing interest and the necessary financial means to test new approaches that could help in keeping the islands attractive (Brown et al., 2023; Hosterman and Joel, 2015; MoT, 2015; Ratter et al., 2019; Shakeela and Becken, 2015).

On the islands populated by locals, coastal erosion and flooding have been widespread phenomena in recent decades. Island societies have traditionally protected their settlements against flooding with a slightly higher barrier of dense trees and shrubs (heylhi) around the inner island settlements (Bremner, 2017). This green belt was jointly maintained by the island communities, using the ecosystem services of vegetation to protect against flooding and to contribute to sediment accumulation. With modernization, almost all of these local heylhi have disappeared or are threatened.

Addressing erosion and coastal engineering is now a key responsibility of the Ministry of Environment, Climate Change and Technology. In 2004, 64% of the inhabited islands reported serious erosion problems, and the government expected the problem to worsen due to the impacts of sea level rise (MEE, 2015b). A so-called ministerial red list is used to prepare the annual fiscal budget for erosion protection, with projects funded on the top-ranked islands (Gussmann and Hinkel, 2021). Prioritization is key due to the limited resources, and as detailed surveys cannot be conducted everywhere, pragmatic choices need to be made (Hinkel et al., 2023). Coastal protection in general is characterized by a preference for hard measures, such as revetments or sea walls (Kench, 2012; MHE, 2011). Problems resulting from these measures often result from poor design and construction due to insufficient financial, human, and technical capacity (Kench, 2012; Ratter et al., 2019).

Figure 5.9: Beach of Fuvahmulah, Maldives: Fallen palm trees, erosion, and green belt on the eastern beach of Fuvahmulah, Maldives. Photo: Beate Ratter.

An interdisciplinary study on the southern island of Fuvahmulah demonstrates how inappropriate coastal development can be detrimental not only to the island's coasts but also to the trust and support of the local population toward central government decisions (David et al., 2021; Hennig, 2020). A newly constructed harbor on the southern tip of the island impedes sediment transport; in addition, the breakwater reaches up to the reef edge so that sediment is redirected off the reef and lost to the dynamic sediment system. In consequence, the east coast of the island suffers dramatic coastal erosion (see Figure 5.9). The visible destruction of the beach face is identified by the local community as the most pressing issue on the island. Interestingly, almost a quarter of the population attribute the erosion processes on Fuvahmulah to the construction of the harbor (Ratter et al., 2019). The harbor development resulted in further local skepticism toward central government and especially against its narrative of the Maldives being highly vulnerable to climate change-induced sea level rise. A grant agreement the Ministry of Environment and Energy signed with the Netherlands to finance a coastal protection project on Fuvahmulah's east coast in 2017 left the island council in despair because it has been shown that the planned use of revetments to prevent erosion may actually exacerbate the process in the longer run, leading to a higher risk of erosion along the island's edges (David et al., 2021).

Enabling and constraining factors

Adaptation measures in the Maldives are currently mainly geared toward the development interests of the state and disregard ecological contexts as a prerequisite for sustainable climate adaptation. Objective knowledge related to the biophysical aspects of climate change is often tightly intertwined with subjective opinions related to preferences, adaptation goals, and policy priorities (Hinkel et al., 2023). In addition to sea level rise and other natural factors that determine sediment dynamics, human modification of the shoreline is a crucial factor that can either support or hinder sustainable development.

Coastal adaptation decisions depend on multiple criteria, involving, for example, the safety of coastal residents, coastal infrastructure, and social acceptance (Oppenheimer et al., 2019). Responsibility perception among the island's population plays an important role for the stated willingness to support protective measures (Adloff and Rehdanz, 2024). Trade-offs have been made in focusing on selected islands and also in the continuation of a hard protection strategy for those islands that are already heavily protected, causing a lock-in effect, reinforcing feedback loops, and leaving the Maldives ill-prepared to deal effectively with rising sea levels (Gussmann and Hinkel, 2021). Sea level rise is only marginally integrated in existing sectoral policies, and there is little coherence between climate policy objectives and corresponding measures – and even less compliance with agreed measures. The current static management approaches are counterproductive in the dynamic environment of the Maldivian atolls. Apart from being socially unjust, they affect other societal and ecological goals, for example by reinforcing center-periphery differences and conflicts. Outer atolls have less access to resources, meaning that climate change adaptation remains a more difficult problem for rural, peripheral islands (McNamara et al., 2019).

Take-home message

The stereotype of small, vulnerable islands as victims of sea level rise is too simplistic. Adaptation to the impacts of climate change in the Maldives needs to consider the socio-political framework, anthropogenic pressures on the islands, and locally specific climate change impacts. Generic hard protection measures often reinforce negative feedback loops at the expense of sustainability and biodiversity. While Maldivian atolls have expanded their land area despite regional sea level rise, ecologically intact coral reefs remain crucial as a means of natural protection for the islands. Maladaptation increases unsustainable development even further and risks the habitability of the islands at large.

5.11

Coastal Adaptation in Taiwan

Taiwan is surrounded by the sea and has a total coastline of 1139 km (Yang et al., 2012; Lin et al., 2021). Its total area is 36,197 km^2 (Ministry of Foreign Affairs, 2024). The western coast has comparatively shallow waters with an average depth of 60 m. In contrast, the eastern coast is very steep, with water depths rapidly increasing to several thousand meters. More than half of the coastline is protected by seawalls (Yang et al., 2012). The coast was a restricted area for military purposes until 1987, when the martial law was lifted (Shih, 2017). Since then, there has been rapid development growth in the coastal area. While Taiwan's trade-dependent economy is driven by a competitive manufacturing sector that includes electronics, machinery, petrochemicals, and information and communications technology products, agriculture and fishing are the main economic activities along the coastal region.

Tectonically, Taiwan presents shattered subduction trench lithologies, rapid uplift, regular earthquakes, and intense monsoon and typhoonal rains, which combine to produce rapid erosion rates. This makes Taiwan one of Earth's most geologically active areas. The island's topography includes the flat to gentle plains in the west and the mostly forest-covered mountains in the eastern two-thirds, reaching as high as 3952 m. Two-thirds of Taiwan is mountainous, with only one-third being comparatively flat. Approximately 80% (Lin et al., 2021) of the total population of more than 23 million are living in the flat coastal areas in the western part, which are particularly vulnerable to hydro-meteorological extreme events. These events are caused by high precipitation over the island combined with typhoons and storm surges bringing extremely high waves from the sea (Lin et al., 2021).

Taiwan has a fully democratic system, with the democracy index ranking Taiwan 1st in Asia and 10th globally (EIU, 2023). Politics in Taiwan is characterized by its unique status, and ongoing tensions, with mainland China. Officially known as the Republic of China (ROC), Taiwan considers itself a sovereign state with its own government, military, and constitution. However, China considers Taiwan part of its territory and claims sovereignty over the island. This results in a difficult political situation, with most countries recognizing China rather than Taiwan diplomatically.

Climate, climatic change, and society in Taiwan

The island's climate is subtropical, except for the very southern part, which has a tropical climate. Due to the highly orographic monsoon climate that is dry in winter and wet in summer, the average annual precipitation is about 2200 mm in plain areas and 3800 mm in mountain areas. Typhoons (tropical cyclones) regularly strike the island during the summer season, bringing both extreme meteorological and extreme oceanographic conditions with heavy rainfalls, extremely high wind velocities and, consequently, extremely severe waves conditions. During typhoons, the 24h rainfall can easily reach values of 1000 mm or more (Central Weather Administration; Chien and Kuo, 2011), and significant wave heights of more than 20 m have been observed at the east coast of Taiwan (Doong et al., 2008).

Climate change is already affecting Taiwan, and its impacts are expected to increase in the future. According to Water Resources Agency (2020), the average sea level rise rate near the Tainan area is 5.5 mm per year (water level observations between 1993 and 2012). In addition to the effects of sea level rise, the main consequences of climate change are related to changes in typhoon frequencies and typhoon intensities, as well as general influences on the monsoon-climate. Both factors are expected to have severe impacts on Taiwan. Increased typhoon intensities are causing more precipitation, even torrential rains and floods as well as more extreme wave impacts on the coasts due to higher wind velocities. A shift in monsoon precipitation patterns combined with heat waves is causing droughts. The recorded annual precipitation in Tainan in 2021 was 1001 mm, less than half of the average annual precipitation.

The people of Taiwan are generally familiar with natural disasters such as typhoons, floods, and earthquakes, which has led to a high level of public risk awareness. Typhoon Morakot in 2009 was one of the most catastrophic events in the country's history. Over a period of three days, more than 3000 mm of rainfall was recorded in southern Taiwan, resulting in enormous mudflows, landslides, and severe floods throughout the region. This disaster destroyed the entire village of Xiaolin and resulted in 677 deaths (e.g., Chien and Kuo, 2011). This served as an eye-opening event, encouraging more active thinking and strategy development among government bodies. Since then, government at all levels in Taiwan has shifted its focus of engineering-oriented flood management (see Figure 5.10) to a combination of engineering and non-engineering strategies. These include engaging local communities in capacity building through emergency response and disaster preparedness, as stated in the Disaster Prevention and Protection Plan by the Executive Yuan (2013).

However, while disaster risk perception is generally high, climate risk perception is not as widespread, partly due to lack of information transparency and effective communication (Chou, 2013). Historically, there has been a noticeable lack of experience in collaboration between the government and the public, particularly in public hearings. The process of constructive dialogue, effective communication (both talking and listening), and patience were not consistently practiced, contributing to the disconnect between interested stakeholders. This led to a perception among citizens that most public engagement in Taiwan is superficial, with no real expectations of changes in plans or processes following public comments. This created an environment of distrust and disempowered communities from participating in the process. However, there has been significant improvement in recent years, with more participatory practices being implemented (Wang et al., 2018).

Climate change responses

The first official document about climate change adaptation in Taiwan is the Adaptation Strategy to Climate Change in Taiwan, announced in 2012 by the National Development Council (Executive Yuan, 2012), the leading authority of political decision-making processes. To enhance societal resilience and minimize the impacts of climate change, the guidelines include eight different sectors: disaster, infrastructure, water resources, land use, coast, energy supply and industry, agricultural production and biodiversity, and public health. Each sector is overseen by a designated authority in the central government and is required to develop a sectoral national climate change adaptation action plan. These plans outline general measures to be implemented over the following five years and mandate the publication of a sectoral achievement report every five years. For example, the disaster sector is organized by the National Science and Technology Council, while the water resource sector and the coast sectors are led by the Ministry of Economic Affairs and the Ministry of the Interior, respectively. At the local level, a city or county climate change adaptation action plan is required following the sectoral action plans. For instance, Tainan City published "Tainan City Climate Change Adaptation Project" in 2015, which was updated in 2020 (Tainan City Government, 2020). The 2020 "Tainan City Climate Change Adaptation Project" lists 62 action plans; each is categorized as either short-, mid-, or long-term action. Currently, the third phase of the National Climate Change Adaptation Action Plan is being prepared for 2023-2027.

Climate Change Adaptation in Taiwan addresses a variety of events, including slow-onset and sudden events as well as compound events. These include both climate-induced and non-climate-induced phenomena, such as typhoons, sea level rise, extreme precipitation, heatwaves, droughts, land-use changes, and ecosystem degradation. In 2010, a national platform known as the Taiwan Climate Change Projection Information and Adaptation Knowledge Platform (TCCIP) was launched. It is coordinated by the National Science and Technology Center for Disaster Reduction and aims to build up a climate change dataset, supply projected climate change downscaling data, and provide the climate change scientific data services related to climate change. However, a consensus has not yet been reached on a specific climate scenario for consideration in the action plan, nor is there a fixed time frame for adaptation.

The primary goal of climate change adaptation in Taiwan's coastal areas is to mitigate coastal hazards and ensure the sustainability of marine resources. Most action plans to date have been adapted from existing sectoral plans and strategies. For example, the 2020 "Tainan City Climate Change Adaptation Project" specified the main strategies such as controlling coastal erosion through beach nourishment and enhancing coastal protection. This approach is partly due to the challenges in envisioning futures for climate change adaptation, especially in the absence of a selected climate scenario or an officially endorsed fixed time period (Wang et al., 2023). Additionally, the action plans tend to be more single-sectoral and focus on coping and incremental adaptation, highlighting the need for more collective and transformative efforts as well as increased collaboration across agencies.

It is noteworthy that there have been two important milestones supporting climate change adaptation for coastal areas in Taiwan. The first occurred in February of 2015, when the Coastal Zone Management Act (Executive Yuan, 2017) was implemented. This act enabled the creation of an Integrated Coastal Zone Management Plan, specifying conservation zones and protection zones and assigning responsible agencies to develop and execute these plans. Following this, the Water Resources Agency (WRA) under the Ministry of Economic Affairs announced the Coastal Protection Plan. This plan categorizes the coast's protection level based on the risk level of four types of hazards: storm surge, floods, coastal erosion, and tsunami. In 2020, the WRA also published the first assessment of coastal risks to include climate change impacts, identifying five levels of risk (Water Resources Agency, 2020).

The second milestone occurred in January 2023, when the Climate Change Response Act became law, mandating the implementation of climate change adaptation measures. This act specifies that an adaptation scenario will be established to guide risk assessment and adaptation strategies for the next 20 and 40 years. The strategies in the 2023-2027 National Climate Change Adaptation Action Plan for the coastal sector include (1) establishing appropriate prevention facilities or mechanisms to mitigate coastal disasters, such as sand nourishment or nature-based solutions; (2) protecting marine resources and marine habitats and fostering sustainable ecosystem development; and (3) enhancing monitoring and an early warning system to respond to coastal hazards and change (Executive Yuan, 2023). While these strategies are mostly technical and political, they also include some measures to encourage social cohesion in the context of climate change adaptation. These include public awareness and education, community engagement (involving NGOs and civil society groups), collaborative governance, research and innovation, and international cooperation, as outlined in the Climate Change Adaptation Action Plan. This approach may enhance climate risk communication and perception (Wang et al., 2023). A notable example is the sandbar restoration on the Tainan coast, where the Taijian National Park, the Tzu Chi Foundation, and the Tainan City government collaborated to use soft measures like geotextile tubes and bamboo fences as well as the planting of over 70,000 trees over three years starting in 2021, whilst also recognizing sandbars as natural forms of coastal protection (Tse-Xin Organic Agriculture Foundation, 2021).

Figure 5.10: Tainan, Taiwan: A typical coastal community in Tainan protected by a sea dike with protection level of 50-year storm surge, air-drone photo, Taiwan. Photo: Hsiao-Wen Wang.

Enabling and constraining factors

Over the past forty years, following the lifting of martial law, the need for economic development and disaster prevention has placed a crucial emphasis on safety in Taiwan, particularly influencing social awareness of coastal areas. The dominant strategy for coastal protection has been a hard protection approach, aimed at holding the coastline. This has been achieved primarily through the construction of hard engineering structures such as seawalls, groynes, and armor units along the coastlines (Yang et al., 2012). However, the overuse of coastal regions can lead to coastal erosion and shoreline retreat, threatening the inherent life and property of these areas (Lan and Hsu, 2021). Additionally, there is a strong competition for land between fish farming, renewable energy, and other types of development and nature conservation in coastal areas. This often results in conflicts between the interests of nature conservation and coastal protection, leading to delays in implementing urgent coastal protection measures due to concerns raised by nature conservation advocates.

In general, the main constraining factors in climate change adaptation in Taiwan include fragmented administration, sectoral thinking, and the many layers of bureaucracy. For instance, due to the sectoral routines, the two pillars of the Coastal Management Plan—the Coastal Protection Plan and the Coastal Conservation Plan—, do not seem to have holistic interdisciplinary strategies. Additionally, the need for long-term planning and a lack of knowledge and experience in dealing with uncertainty are other significant factors constraining the adaptation efforts.

However, the national projection information and adaptation knowledge platform TCCIP, which frequently updates data and selected climate change practices and is set to enhance its climate services by supporting the adaptation scenario, is seen as an enabling factor through the integration of diverse ways of knowing. In a recently released report co-published by National Science and Technology Council and the Ministry of Environment (2024), the 2.0°C warming scenario is used for evaluating potential impacts and national adaptation planning. Most of the strategies stated in the Climate Change Adaptation Action Plan are simply adopted from the existing sectoral plans, particularly from the disaster response plan, and are not actively reducing risks and vulnerability by considering future climate conditions. Additionally, other factors, such as the prioritization of the economic potential, the lack of adequate funding support, and a lack of participatory approaches in coastal climate change adaptation, also play a role. Consequently, in coastal areas where the flood potential is high and could be impacted by sea level rise, there are still new developments (e.g., solar panel farms) and new hard protection being built that only meet the current needs. This can lead to unexpected consequences, ultimately increasing vulnerability.

Take-home message

After the lifting of martial law around forty years ago, there has been a strong competition for land between fish farming, renewable energy, and other types of development and nature conservation in Taiwan's coastal areas. Taiwan's frequent experiences with extreme events have generally heightened disaster risk perception, with safety playing a crucial role in influencing social awareness of the coasts. Although climate change adaptation in Taiwan is mainly informed by existing sectoral plans and strategies, the experiences gained from disaster preparedness and emergency response provides opportunities to enhance climate risk perception. This enhancement can enable improved adaptation to climate change by more effectively leveraging synergies with broader work. Site-specific climate scenarios, as required by the Climate Change Response Act, are serving as anticipatory corridors and allow the development of site-specific adaptation strategies tailored to future climate conditions.

5.12

Conclusion and Assessment

The case studies in the previous sections have provided an empirically grounded and systematized assessment of the various conditions of climate change adaptation in urban, rural, and coastal areas. They addressed specific manifestations of the wheres, whens, and hows of place-specific incidents and the emerging problems that need to be tackled by current and future sustainable climate change adaptation. The case studies have also considered the role and importance of diverse ways of knowing in shaping adaptation responses and local practices in the context of climate change (Petzold et al., 2021; Wiener et al., 2023). Despite the limitations stemming from the selection of case studies from around the world, the theoretical frameworks used, and the methods applied, some general convergences and divergences emerged. They can be summarized in the three thematic areas of (1) climate change adaptation and locality, (2) climate change adaptation and the politico-administrative context, and (3) climate change adaptation and the intangible socio-cultural dimension. Rather than separate, these areas should be considered as intersecting if not mutually enmeshed. Based on the empirical and conceptual work, the following sections summarize the insights gained and, where possible, assesses what could be learned from the case studies about the conditions under which sustainable climate change adaptation might be plausible.

Climate change adaptation and locality

This chapter has shown that climate change and adaptation are more than purely evidence-based or rational entities. Adaptation in particular is a genuinely localized and socialized endeavor that is carried out against the backdrop of a unique regional culture. That culture includes local history, place-based contingencies of everyday life, and an existing physical and social environment with its place-specific conditions. Hence, the physicality of climate change merges with an emplaced experience of climate. To paraphrase Booth (2008, p. 299, [addition by authors]): "As we experience place [and climate change] we experience an intertwining of ourselves with that place [and climate change]; an intertwining of memories, both personal and collective, with the physicality of place [and climate change]. This interlacing of place [, climate change] and memory can be said to infuse memory with physicality, place with [social] mentality." This conceptual understanding was encountered in all case studies, leading to possibilities for sustainable climate change adaptation. The aspect of place-based or local perception of climate change is outlined in the greatest detail in the cases of Lower Saxony, Nepal, Namibia, and North Frisia. Here, localized perceptions not only set the scene for adaptation to be perceived as a generally relevant and necessary concept, but also lead to what could, should, and already is being done. In the case of Nepal, certain local adaptation measures such as irrigation procedures clearly evolved out of the specific place-based interaction with climate change. The same holds true for Namibia and Lower Saxony where, although in different cultural and natural contexts, crop rotation is practiced in farming as a response to climate change. In North Frisia, climate change perception is not actively used to adapt to current climate change but forms an important backbone to diking as an existing form of dealing with climate change impacts. In Hamburg, perception and adaptation are separate in that perception does not seem to inform adaptation measures as such.

It is important to note here that local ways of perceiving and adapting to climate change are in fact place-based ways of experiencing and dealing with climate change. These place-based ways of knowing are rarely taken into consideration during so-called stakeholder dialogues, as they often run counter to the established and institutionalized rationale of informing the public based on scientific evidence (for more details on our approach to diverse ways of knowing in a changing climate, see Petzold et al., 2021; Wiener et al., 2023, pp. 22-24; see also Chapter 2). Place-based climate perception and the resulting knowledges, however, are in themselves legitimate social facts and clearly represent an enabler of climate change adaptation. They could contribute to more experiential and localized ways of knowing, in contrast to more abstract and scientific ways, and assist in tailoring adaptation measures to local or regional conditions. At the same time, it is important to acknowledge that the natural environment and its associated local processes set some clear boundary conditions (for assessments of the impact of climate variability and extremes on climate adaptation, see Chapter 4). It therefore matters greatly in terms of sustainable adaptation options and measures whether one lives on a small island in the Maldives or in the middle of a megacity such as São Paulo.

Engaging with and "doing" climate change adaptation is therefore closely linked to social traditions, histories, and local experiences, all of which are deeply embedded in, and in constant interaction with, places. The enabling potential of the place and climate change nexus is, however, constrained by aspects of the politico-administrative system, as explored in the following section.

Climate change and the politico-administrative context

The case studies reveal that strategies of climate change adaptation are often constrained by policies, governance systems, legal regimes, administrative structures, and routines. National, federal, regional, and local adaptation plans represent enabling factors in almost all cases as they officially acknowledge climate change and the need to adapt to it. They can result in politically binding action plans and the release of financial resources to fund adaptation, meaning that community adaptation plans could be developed, such as in Nepal. On the downside, these resources are often laborious to access, as shown in the case of Lower Saxony, where farmers mentioned the bureaucracy involved in obtaining subsidies for changing from extensive to organic or precision agriculture. This indicates that changes in adaptive rationales are tricky to handle because existing political, legal, and administrative structures lack the necessary flexibility to enable new solutions for newly evolving climate challenges.

Comparable aspects can also be seen in the case of Hamburg. Although the city is a German role model for climate change adaptation, practical implementation—as in the Taiwan and Ho Chi Minh City cases—is often constrained by sectoral thinking and the separation of responsibilities for adaptation and mitigation between different administrative bodies, or even between units within the same administration. Furthermore, the mandate of political, administrative or other bodies to issue directives is often unclear, resulting in situations like São Paulo, where municipalities only hold an advisory role and have insufficient political or administrative power. Changes in administrative personnel, unclear institutional responsibilities, unstable political regimes and center-periphery differences—see Taiwan and the Maldives—represent added constraining factors. The various organizational, administrative, and institutional lock-ins at work here clearly lead to a preference for coping strategies and limit incremental or even transformative change in climate change adaptation. They often result in the perpetuation of well-known technical solutions and structural forms of adaptation. This can be seen in the case studies on Ho Chi Minh City, Taiwan, São Paulo, North Frisia, and the Maldives, where such measures are conceived as feasible and fine-tuned to reflect the prevalent administrative and political rationales. Yet they are not really fit to deal with current or future climate change and the goal of sustainable climate change adaptation—with the cases of the Maldives and Ho Chi Minh City also displaying examples of maladaptation and negative trade-offs.

Furthermore, it is often overlooked that from a political point of view adaptation should be conceived as a social and participative process. Ideally, such processes should address social inequalities that should not be framed as a threat to existing policy rationales and administrative practices. On the contrary, participation should be seen as an enabler of sustainable climate change adaptation, as shown in the example of Nepal. This goes hand in hand with acknowledging the potential of diverse ways of knowing in the context of stakeholder dialogues and participation, as alluded to in almost all case studies. The need for genuine, sincere, and trustful involvement of actors in the development and implementation of adaptation measures is important. This goes beyond the raising of awareness, so-called knowledge transfer, or cursory public outreach. Failure to do so can result in structural misalignment of climate change adaptation, as in the case of the Maldives.

Regarding the political and administrative environment of adaptation efforts, many aspects thus need to be considered. They revolve around governance systems, legal regimes, and administrative structures, for example in terms of available action plans, but also less tangible factors such as political stability, bureaucracy, sectoral thinking, staff continuity, and the need to engage in real participation. The implementation gaps detected here are striking, and there is convergence with other gaps identified (see Chapter 6). The political-administrative context can therefore be seen as a key barrier to sustainable climate change adaptation because its charactersitics as outlined above encourage the use of coping strategies.

Climate change adaptation and the intangible socio-cultural dimension

Lastly, the intangible socio-cultural dimension emerged as an important issue in almost all case studies. Strongly intersecting with locality and the respective policy context, its potential has often been downplayed as "only" social and therefore less relevant or impactful. Yet, socio-cultural practices represent an important intangible anchor for the social dimension of adaptation. The long-standing historical experiences and diverging ways of dealing with natural hazards based on diverse ways of knowing clearly represent an enabler. They contain socially established ways of problem-solving, which have become materialized in natural infrastructures such as breakwaters or stalk plantings, as seen in North Frisia. The traditional scrub and tree management for island protection in the Maldives or the division between commercial and household work as in Namibia are further examples for socio-culturally embedded coping strategies. On the other hand, technical infrastructure inevitably leads to path dependencies due to the need to maintain and develop this infrastructure at the level of administration, governance, and civil society, as in the case of North Frisia, where the emblematic dike is as much a socio-cultural as a physical entity. Comparable aspects are also mirrored in the lack of willingness to change farming business habits in Lower Saxony. This can be interpreted as a constraining factor resulting from intergenerational habitus, leading to path dependencies. Such elements represent coping, while incremental efforts as outlined in irrigation strategies as seen in the example of Lower Saxony display a small degree of flexibility.

Besides these social, economic, and political aspects, diverse inequalities represent an important issue that is closely related to the vulnerability of different population groups. Living in specific parts of the city in line with income and the affordability of housing is not only a matter of social status, but also related to the impact of climate change, as can clearly be seen in the unevenly distributed deaths by heat in Ho Chi Minh City or in the fatalities of flooding in São Paulo and Hamburg. Women represent a specifically vulnerable group, as they use space differently, perform work that is often overlooked in male-driven emergency plans, and are not explicitly addressed in climate change communication. For example, communication devices such as adaptation platforms, as shown in the Taiwanese case, do not integrate diverse and gendered ways of knowing. This fosters the non-participation of women and other vulnerable groups, exacerbating inequalities.

Considering all the various aspects mentioned here, the relevance of intangible socio-cultural aspects such as diverse ways of knowing on various levels, social affiliation in connection to vulnerability, and gender issues becomes obvious. Generally, they hold an enabling potential for sustainable climate change adaption that is so far rarely considered, officially addressed, or practically used. In fact, most of the aspects mentioned here are currently overlooked or neglected. The consequence is that considerable potential for climate change adaptation—in particular for facilitating more sustainable adaptation—is, sadly, lost.

Assessment of results and concluding remarks

The plausibility of sustainable climate change adaptation depends not only on the physical conditions of the impact of climate change, but also on the context-specific limits to adaptation as encountered in this chapter. Limits are contingent and can be shifted through innovation. The case studies show that they ultimately depend on prioritization, availability, and allocation of resources, as well as on what is acceptable in a specific socio-political setting. Against the background of growing empirical evidence, it is crucial to acknowledge the risk of maladaptation inherent in technical adaptation efforts, but also the spatial, societal, and political context of successful adaptation. There is a growing tendency to consider disaster risk prevention a form of climate change adaptation, even though successful adaptation measures only prove themselves during the next disaster situation. Even then, there are limits to adaptation that have to be kept in mind. These can be divided into soft and hard limits, the former understood as those for which no further adaptation options are currently available but might exist in the future; and the latter where adaptation options are neither effective today nor conceivable in the future (Thomas et al., 2021). As the case studies have illustrated, innovation can bring unforeseen options; in some circumstances, there are even ways to overcome seemingly insurmountable lock-ins on different levels (see e.g. the case studies North Frisia and Maldives).

Climate Change Adaptation Assessments

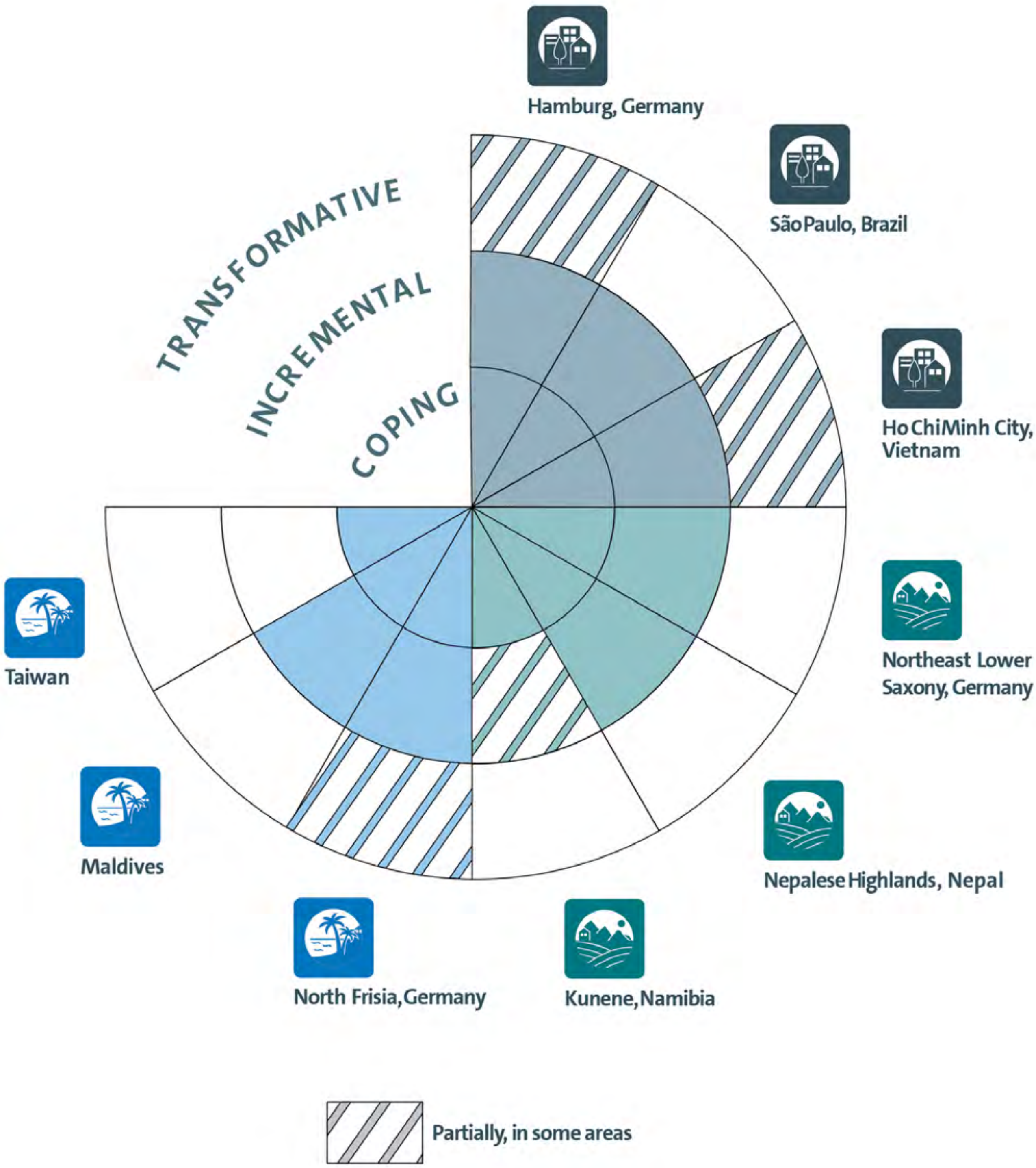

Figure 5.11: Climate change adaptation assessment (please read in clockwise direction and from the center to the periphery) in urban (dark grey), rural (green) and coastal areas (blue) investigated in this chapter. They are divided into the sections of coping, incremental, and transformative. The hatched areas indicate a tendency toward but not fully achieved state, while blanks indicate that such processes were not revealed at all by the analyses in this chapter. Colored areas indicate that, for example, the process of coping is prevalent and well-established.

The limits also concern the degrees of freedom and flexibility as well as the power of political, economic, and social interests to implement adaptation strategies and to decide which form of adaptation is adequate in one's own situation between exposure and vulnerability. The case studies show that the different categories of adaptation responses—(1) coping, (2) incremental adaptation, and (3) transformative adaptation—are not always clearly distinguishable. The vast majority of adaptation responses are trapped in a governance and technical path dependency in that it is predominantly conventional approaches that are used to deal with the challenges of climate change adaptation. Depending on the experienced or anticipated severity of climate change impacts on social and economic systems, these are primarily coping strategies (the Maldives, Taiwan, Namibia, Ho Chi Minh City, and São Paulo) coupled with attempts to slightly adapt incrementally (Lower Saxony, Hamburg, North Frisia, Nepal). Only very few cases aim at full-scale transformation, and then only with regard to singular measures (e.g., water storage capacity in Hamburg, the sponge city; testing of nature-based solutions along the Frisian coast; developing park gardens to capture incoming water in Ho Chi Minh City). In some cases, transformative approaches to climate change adaptation can be detected only in some sectors, while in others it sticks to mostly incremental approaches or exists only as plans, strategies, and declarations of intent. In such cases, it is not possible to uniformly classify existing adaptation as coping, incremental, or transformative as in Hamburg, Ho Chi Minh City, or the Frisian coast (see Figure 5.11). This implies that the sustainability aspect of adaptation strategies is only being insufficiently considered. Indeed, real sustainable pathways could not be detected in the case studies. At the same time, transformation may not always be positive, desirable, and worthwhile either. More conceptual work is needed to critically reflect on the implications of coping, incremental, and transformative adaptation against the backdrop of empirical results over time.

With regard to the plausibility of sustainable climate change adaptation, four main lessons can be drawn from the case studies. Firstly, laws, regulations, and adaptation plans are crucial steps toward sustainable climate adaptation. Overcoming persistent political conflicts, social inequalities, and other structural challenges on various scales are also key here, as they are fundamental obstacles to the implementation of climate adaptation measures, let alone sustainable climate change adaptation strategies. Secondly, goal-setting strategies for climate action are only effective if they establish clear indicators and measurable goals and are developed in a participative, trustful, and mobilizing way. This should not only engage social actors and communities at large, but also support social actors in holding policymakers accountable for any commitments made. Thirdly, local and national governments with their respective political agendas have substantial influence on the implementation of climate adaptation measures (or lack thereof). A lack of clarity with regard to political and administrative responsibilities results in mismatches between adaptive capacities and local climate vulnerabilities. Integrated policies on different scales as well as efforts to strengthen internal relations and adopt a more horizontal way of working are critical to progress toward sustainable climate change adaptation. Finally, there is enormous yet rarely tapped potential for societal mobilization and co-production of knowledge on the barriers and opportunities for sustainable climate change adaptation. This could, for example, draw on historically accumulated experiences in dealing with extreme weather events and climate-related risks and vulnerabilities. Public policies for sustainable climate change adaptation could be informed by this, exploring synergies between the need to adapt to climate change on the ground and socio-economic development as well as human health and well-being.

Against the background of the contextual conditions scrutinized in the case studies, it is clear that political and administrative structures are not currently equipped to deal with the local, political, and social dimensions of climate change adaptation. This applies at the conceptual, social, legal, administrative, and practical level. Only some rare cases show glimpses of the necessary flexibility and openness that allows for diverse ways of knowing to be integrated into participation and place-based implementation of climate change adaption. In North Frisia, one such example is the Strategy Wadden Sea 2100, which is a cautious attempt at bringing together citizens, administrators, and scientists. As it stands, structure and agency confront each other in the context of climate change, primarily leading to the reproduction of a coping rationale that merely reacts to the next disaster or climate related event. The increased accumulation of better data for more scientific knowledge is often seen as a remedy or as a solid evidence base for improved and more suitable sustainable climate change adaptation. However, this is not always the case. Anticipatory planning and dealing with possible and plausible climate futures is still limited, as climate action still largely relies on the rationale of "wait and act" (Aall et al., 2023). A "reflect and act" rationale might be more suitable in view of the results outlined here. What the chapter clearly indicates is that policy and administration have to take much greater account of localities, the politico-administrative systems, and the intangible socio-cultural environments. The different ways of knowing, the potential of societal mobilization inherent in knowing, and the need to redistribute power across the areas explored can contribute to making climate policies more tailored and therefore fit for the future. Only then will sustainable climate change adaptation become plausible.

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