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ADAPTING TO UNCERTAINTY: Exploring the Intersection of Climate Change Adaptation, Social Justice, and Stormwater Challenges in Lillestrøm, Norway.

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Landscape Architecture for Global Sustainability

ADAPTING TO UNCERTAINTY

Exploring the Intersection of Climate Change Adaptation, Social Justice, and Stormwater Challenges in Lillestrøm, Norway.

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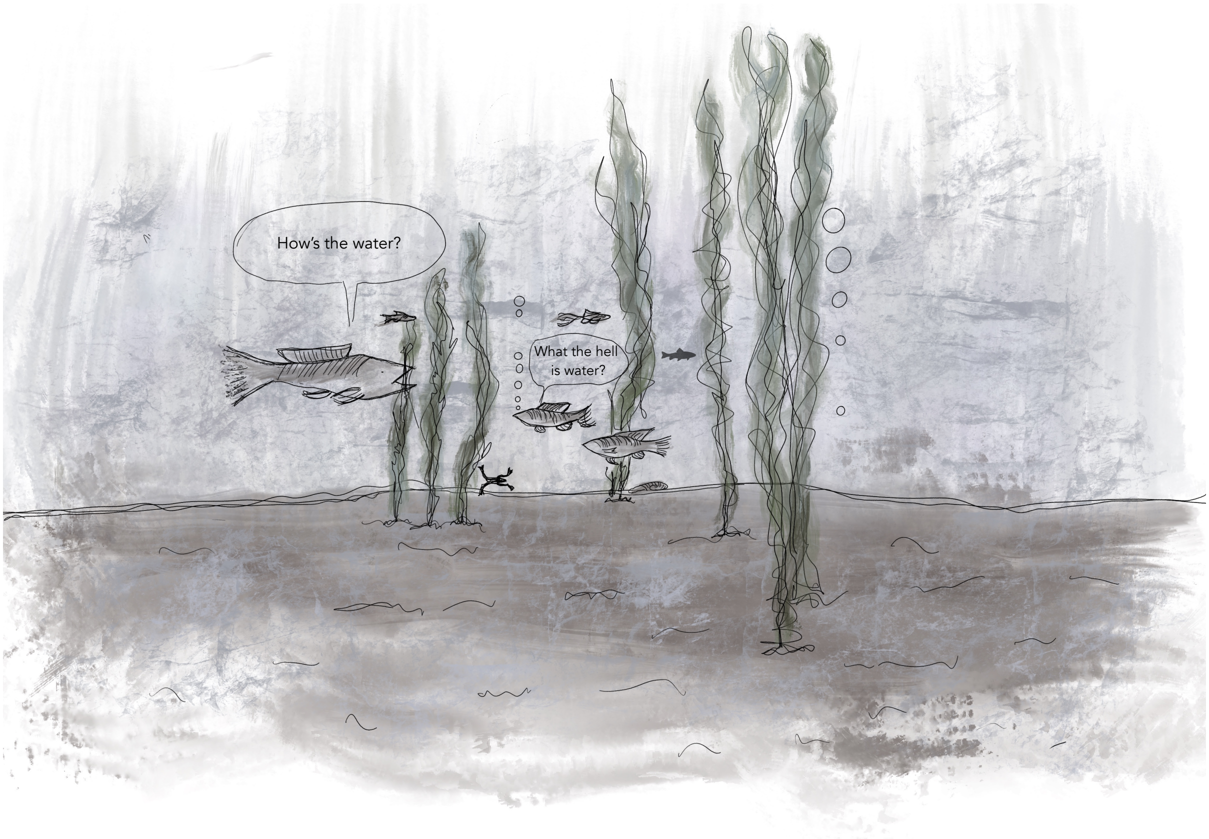
How's the water?
What the hell is water?

PREFACE

The inspiration for this thesis springs from a story relayed by David Foster Wallace in his 2005 commencement speech, "This is Water" (Farnam Street Media Inc., n.d). He shares a conversation between two young fish and an older one; the elder fish greets them, saying, “Morning, boys. How’s the water?”, a question that confuses the younger fish, leading them to ask, “What the hell is water?”. This simple tale underscores the critical need for us to recognize and understand the often unseen and intricate systems—our 'water'—that define our lives without us recognizing them.

This thesis springs from a desire to delve into such unseen systems—our 'water'—particularly as they relate to climate change, social justice, stormwater management, and adaptive mechanisms. Furthermore, it explores these themes through an intersectional lens, recognizing the interconnected and interdependent systems of societal categorizations that add layers of complexity to these issues.

One intriguing study that brings these complexities to the fore is the *Michigan Fish Test (Commisceo Global, n.d)*. It demonstrates how cultural perceptions can profoundly shape our understanding of these systems. The test involves American and Japanese respondents interpreting an underwater scene, and their interpretations vary significantly. American respondents, embodying more *individualistic* cultural values, focused primarily on the larger fish, describing it in detail. Conversely, Japanese respondents, reflecting their culture's *collectivist* values, described the scene more holistically, including not only the large fish but also the smaller ones and the overall context. This suggests that an individual's cultural context can considerably color their perception of their surroundings. In the face of complex issues like climate change, we must recognize not only the 'big fish'—the evident climate transformations—but also the socio-economic and political 'waters' in which we swim, related to systems thinking.

My personal and professional trajectory—from sailing adventures in the Caribbean and the Mediterranean to service in the Royal Norwegian Navy, to a career in landscape architecture—has exposed me to these complex systems. During my sailing experiences, two core principles emerged: "If the landscape doesn't match the map - the map is wrong," and

"There is never anything that is always." These tenets underscore the importance of questioning established paradigms and cultivating adaptability amidst change.

Navigating across the Atlantic, I realized that skillful sailing transcends reliance on instruments or maps. It's about active engagement with the environment, interpreting the rhythms of the sea and sky, adjusting sails in response to changing water currents and accounting for subtle elements like magnetic declination. Analogously, our response to complex issues such as climate change necessitates continuous adaptation and dynamic interaction with our world. Failing to recognize the nuances, like ignoring magnetic declination, can lead us astray—sometimes by miles—from our intended path, or a sustainable future.

In "How to Read Water," Tristan Gooley suggests that even small bodies of water, like puddles and streams, can provide profound insights (Gooley, 2016). This analogy resonates with our contemporary challenges—climate change and social justice—wherein the less conspicuous elements within our socio-political and economic landscapes can bear significant implications.

Landscape architecture, much like sailing, demands more than interpreting static maps. It requires an understanding of the dynamic ecosystems and climates we inhabit. Donna Haraway frames the Anthropocene as a 'boundary event,' emphasizing its dynamic and ongoing forces, a perspective aligning with landscape architecture's emphasis on dynamic, open ecosystem design (Haraway, 2016). This idea of a continuously changing world guided my academic journey from International Environment and Development Studies to Landscape Architecture, despite the abstract challenges it presented.

One of these challenges was to balance the need for practical solutions with the need to acknowledge and address the complex and intertwined socio-ecological systems. For instance, the technical solution to stormwater management—such as the construction of runoff infrastructure—may seem straightforward, but it unfolds within a broader system that includes political decisions, social behaviors, and environmental impacts. Such intricate challenges, while sometimes daunting, are central to this thesis, providing a context for exploring the adaptive mechanisms necessary for navigating our changing world.

Figure 1 Atlantic Crossing N37 41.346', W33 31.393', 14/05/2017 Picture of the nautical chart outside of the Azores, Portugal.

ACKNOWLEDGEMENTS

This thesis embodies the theories and practical lessons I acquired during my Bachelor of International Environment and Development Studies and my Master's in Landscape Architecture for Global Sustainability. This rich blend of theory and practice provided a holistic understanding of landscape design that I am profoundly thankful for. It shaped my views on the climate crisis and socio-ecological factors.

I am deeply indebted to the Faculty of Landscape and Society, my peers, and my professors for this privilege. I extend my gratitude to the professors at NORAGRIC for instilling in me critical thinking and academic writing skills, and to the faculty at GLA for fostering a creative, design-focused learning environment.

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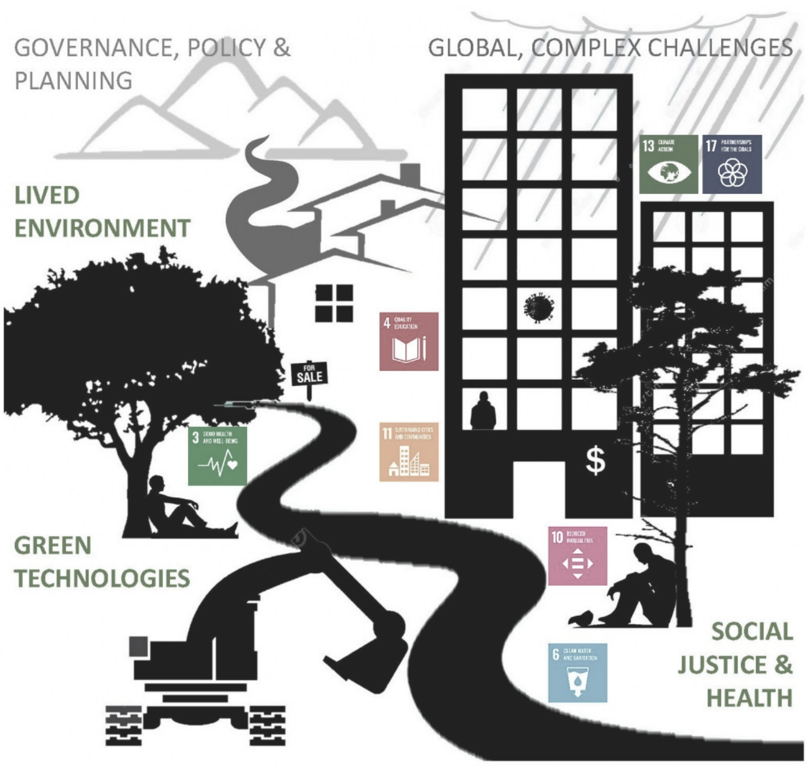
This journey has been deeply enriched by each one of your contributions, and I am forever grateful. Thank you.

NMBU SUSTAINABILITY ARENA

The interdisciplinary "TOWARDS" project at the Norwegian University of Life Sciences (NMBU) seeks to promote sustainable and socially just urban development. Amid global challenges like climate change and rapid urbanization, the project focuses on social belonging, everyday interaction, and environmental quality. It encourages green technology experimentation, policy and planning innovation, and discussion of ethical dilemmas related to sustainability (NMBU, 2023).

This thesis, "Adapting to Uncertainty: Exploring the Intersection between Climate Change Adaptation, Social Justice in Stormwater Problematics in Lillestrøm", aims to contribute to TOWARDS' objectives. It will scrutinize climate-induced changes in stormwater patterns in Lillestrøm and their social justice implications, examine the diverse socio-economic and environmental effects, and identify sustainable and equitable stormwater management strategies. Through this examination, the thesis intends to enhance the understanding of how cities can effectively navigate climate change adaptation and social justice for sustainable futures.



ABSTRACT

As climate change presents escalating challenges in urban environments, the criticality of effective stormwater management intensifies. This study investigates the potential role of landscape architecture in amalgamating principles of social justice, sustainability, and adaptive capacity, aiming to ensure an equitable distribution of adaptation benefits and burdens.

Adopting an interdisciplinary methodology and utilizing systems thinking, this research assesses current climate-related strategies, identifies potential areas for improvement, and explores the complexities of implementing nature-based solutions in urban areas at risk. The study integrates methodologies from multiple disciplines, including a comprehensive literature review, detailed document analysis of prevailing laws and local guidelines, and advanced spatial analysis employing Geographic Information Systems (GIS) and landscape architecture spatial analysis methods, such as the SCALGO Live tool for analyzing hydrological risk. Through these methods, it seeks to highlight physical vulnerabilities in the landscape that significantly impact homeowners and residents under the existing stormwater management legislation.

The case study of Lillestrøm, Norway—a city grappling with high homeownership rates, rapid urban densification, and vulnerable topography—provides the context for examining how socioeconomics, urbanization trends, and legal definitions intersect with climate change adaptation strategies. The research elucidates the implications of the emerging privatization trend in stormwater management, emphasizing its potential to increase hazard exposure and vulnerability among a significant portion of the population to cloudbursts and extreme rainfall events.

Results suggest that although nature-based solutions contribute to sustainable urban development, their effectiveness is impeded by the lack of a shared understanding and clarity in management frameworks. Therefore, this study advocates for a common language and consensus on the principles of climate change adaptation, social justice, and sustainability within the field of landscape architecture.

While the insights gleaned from this research are rooted in the specific context of Lillestrøm, they offer broader relevance, contributing to a nuanced understanding of urban climate change adaptation challenges on a global scale, and providing valuable insights for future climate justice and adaptation strategies.

***Keywords**: climate change adaptation, social justice, environmental justice, intersectionality, earth system science, urban flooding, cloudburst, nature-based solutions, vulnerability, climate risk, hazard, landscape architecture, adaptive capacity, maladaptation, systems thinking, GIS, SCALGO.*

BIOMASS < ANTHROPHOCENIC MASS

Chapter 1

INTRODUCTION

Setting The Context

Landscape architecture, a contextually specific term with multiple identities across different disciplines, has evolved from its artistic origins to straddle the intersection of art, science, and the built environment. The term 'landscape,' far from being simply "a portion of the earth's surface that can be comprehended at a glance" (J. B. Jackson, 1984), has a more complex interpretation within landscape architecture. Now, the profession intertwines 'city' and 'nature,' reflecting evolving conceptualizations of space (Gandy & Steiner, 2019).

With climate change exacerbating profound environmental challenges, such as the increasing frequency of extreme rainfall events leading to urban flooding, landscape architecture and urban planning stand at a crossroads. Cities, with their majority of impervious surfaces, are particularly vulnerable and have become hotspots of climate vulnerability (United Nations, 2019). These challenges are further compounded by social justice concerns and regulatory inadequacies (Tauböll, 2018).

Understanding Sustainability, Sustainable Landscape Architecture, and Social Justice

Sustainability refers to the balance between economic growth, social development, and environmental protection. In this context, sustainable landscape architecture is about managing land in ways that minimize environmental damage, protect ecosystem functions, and foster human well-being, all within the realm of social justice (Egoz, 2019).

The notion of a clear divide between urbanity and landscape is blurring. Scholars recognize that landscape architects deal as much with the built as with the grown, intertwining 'city' and 'nature'. This reflects the myriad forms of modernity and the evolution of space, both physically and conceptually (Gandy & Steiner, 2019).

The Climate Change Conundrum: Urbanity and Vulnerability

Urban areas are facing an increasing frequency of extreme rainfall events leading to flooding, exacerbated by the prevalence of impervious surfaces. The rapid growth of our built environment is a testament to our profound impact on Earth's ecosystems (Elhacham et al., 2020). Cities, with the majority of the world's population, are especially vulnerable to climate change (United Nations, 2019).

The intersection of climate change, adaptation, outdated stormwater management systems, and social justice issues is complex and further complicated by inadequate national legislation and the privatization of cost responsibilities (Taubøll, 2018). Landscape architecture, through its focus on nature-based solutions and social and political dimensions, offers a promising pathway to navigate this complex matrix.

Landscape Architecture Definition and Commitment to Adaptation

Landscape architecture involves aesthetic and scientific principles applied to a multitude of aspects, including ecological sustainability, landscape quality, collective memory, and territorial justice (International Federation of Landscape Architects, 2023). Landscape architects carry out a range of responsibilities, from developing and managing landscapes to conducting sustainable design research, highlighting their significance in shaping the environment and society.

International Agreements and Policy Context of Climate Change Adaptation

International agreements like the United Nations Sustainable Development Goals (SDGs) emphasize the importance of social justice and equity in responding to climate change. SDG 13 and SDG 11 in particular aim to combat climate change and make cities and human settlements inclusive, safe, resilient, and sustainable (United Nations, n.d.).

Landscape Architecture Definition and Commitment to Adaptation

Landscape architecture extends beyond mere planning, design, and management of the natural and built environments(Egoz, 2019). According to IFLA, it involves applying aesthetic and scientific principles to address a multitude of aspects (International Federation of Landscape Architects, 2023). These aspects range from ecological sustainability, the quality and health of landscapes, collective memory, and heritage to culture and territorial justice.

Another critical aspect is the tasks that landscape architects perform as part of their professional duties. IFLA lists a range of responsibilities, including developing and managing landscapes, conducting research for sustainable design, and engaging communities in decision-making. These roles underscore the significance of the profession in shaping the environment and society. In the following sections, we will delve into these tasks and their implications in a world impacted by climate change. The intersection of climate change, adaptation, outdated stormwater management systems, and social justice issues is complex exacerbated by outdated national legislation definitions and privatization of the cost responsibility (Taubøll, 2018). This unintentional consequence of inadequate stormwater management systems signals a need for climate justice, recognizing and addressing the socio-economic disparities that climate change accentuates. In urban contexts, these disparities can present as varied exposure to stormwater hazards and resilience to stormwater flooding, thereby widening the adaptation gap.

In this complex matrix of challenges and vulnerabilities, landscape architecture, nature-based tools, and social and political dimensions offer a promising path for the exploration of socially just climate change adaptation.

Navigating the *uncertainties* of climate change has always been a challenge inherent to landscape architecture, as Egoz (2019) underscores. This thesis aims to grapple with this challenge through a detailed exploration of the township of Lillestrøm. It aims to delve into how design and spatial planning can help cities adapt to the uncertainties of climate change, weaving together the threads of resilience, equity, and environmental integrity.

Landscape architecture's role in promoting environmental sustainability is straightforward, as Egoz notes. However, the social and economic aspects of sustainability are less clear-cut. This thesis aims to explore the nebulous realm of social sustainability in particular, echoing Egoz's assertion that social dimensions are instrumental in achieving sustainability (Egoz, 2019).

Objectives And Research Questions

The objectives of this research are twofold

1) *To explore the intersection of climate change adaptation and social justice within landscape architecture, stormwater management, and nature-based solutions.*

2) *To analyze the vulnerabilities to hazards and risks, to stormwater issues specifically in the context of Lillestrøm.*

The Research Question

1) *What are the specific vulnerabilities related to stormwater issues in Lillestrøm, and how can the intersection of climate change adaptation, social justice, and landscape architecture, particularly through nature-based solutions, address these?*

Aim of the thesis

This study aims to critically analyze the vulnerabilities and adaptation gaps in urban settings facing climate-related stormwater issues, focusing particularly on the case of Lillestrøm, Norway. Leveraging the interdisciplinary approach of landscape architecture and spatial analysis tools, the research integrates theoretical insights with practical applications to explore the city's topography and built structures potential vulnerabilities. Through the examination of existing literature, spatial data, and policies, the thesis identifies opportunities and challenges to interweave climate change adaptation and social justice within landscape architecture, with an emphasis on the potential of nature-based solutions.

Hence, the goal is to explore how landscape architecture, bridging the gap between natural and social sciences, as well as design, can serve as a catalyst for resilient, equitable, and sustainable urban development amidst escalating climate change impacts.

Scope And Limitations

This thesis concentrates on the issues of stormwater management and pluvial flooding in Lillestrøm, Norway, exploring the intricate junction of climate change adaptation and social justice. The research is designed with a specific focus on pluvial flooding, primarily caused by heavy rainfall or cloud bursts, a significant concern in contemporary urban planning.

The case study area, Lillestrøm, presents a unique scenario due to its geography and topography, being susceptible to both pluvial and fluvial flooding. Despite this dual vulnerability, the thesis intentionally narrows its focus on pluvial flooding. This decision is driven by the insurance dynamics in Norway, wherein pluvial flooding, unlike fluvial and tidal floods, is not typically covered as it's not classified as a natural disaster. The specifics of these legal definitions and their implications will be elaborated in the literature review.

While acknowledging the severity and impact of past fluvial flooding in Lillestrøm, this aspect has been deliberately excluded from the study to maintain its central objective and prevent complications.

It should be noted that while this study highlights the complexities and potential improvements in stormwater management in Norway, it does not intend to propose legislative changes. Instead, our goal is to provide a comprehensive understanding of the current situation, thereby providing a foundation for future research and potential policy refinements.

These scope and limitations underline the focus of the thesis, ensuring its conceptual clarity, while also suggesting potential avenues for future research. The unexplored interplay between different types of flooding, particularly in unique topographical contexts like Lillestrøm, and their impact on urban resilience and social justice present intriguing questions for further studies.

Finally, while the thesis explores the role of nature-based solutions in adaptation measures, the principal focus is not to delve deeply into the practical sphere. Instead, the intention is to explore the connections between the social and political spheres, in relation to earth system science

Chapter 2

METHODOLOGY

Chapter 2 presents the research methodology used in this thesis. It begins by outlining the broad research approach, then presents a detailed breakdown of the specific methods utilized throughout the study, from the literature review to the conclusion. Each step is vital in addressing the research objectives, and ultimately contributing to the knowledge on the intersection of climate change, social justice, and landscape architecture. The structure of the thesis is illustrated in the following table, with each section having a unique role in the research process.

Two key methods underpin this research - the Grounded Theory Approach and the Data Collection strategy. Grounded Theory is a research paradigm popular in social sciences, where theory is developed through rigorous data collection and analysis. Data Collection, on the other hand, involves amassing qualitative and quantitative data through various sources and tools. The following sections elaborate on these methods and their application in this study.

1 Introduction
Contextualises the problem of climate change adaptation, defines the research problem, outlines objectives and research questions, discusses scope and limitations, and provides an overview of the thesis.

2 Methodology
Describes the research design (Grounded Theory approach), data collection techniques (Quantitative Secondary Data Analysis, Spatial Analysis), and discusses ethical considerations, validity, and reliability.

3 Literature Review
Reviews existing literature on climate change, social justice, and landscape architecture, highlights important theories and identifies knowledge gaps.

4 Case Vulnerability Analysis of Lillestrøm
Provides a detailed analysis of the specific climate change and stormwater management issues in Lillestrøm.

5 Findings and Analysis
Presents and interprets the data collected,, and synthesises the results from chapter 3 and 4 in relation to the research questions and objectives.

6 Discussion
Reflects on the findings, addresses research questions, discusses the implications of findings, and revisits the study objectives.

7 Conclusion
Summarizes key takeaways, discusses the contribution to knowledge, recommends future research, and shares final thoughts on the research process and outcomes.

Grounded Theory Approach

This research adopts a Grounded Theory approach, which is esteemed for its use in the social sciences. This approach is characterized by generating theories through systematic data gathering and analysis (Bryman, 2012). Distinctively, Grounded Theory does not start with a hypothesis; instead, it begins with an area of study, allowing relevant insights to emerge. This method involves iterative stages of data collection and analysis until a theory, explaining a process, action, or interaction, can be derived from the data. Thus, this approach has enabled the 'emergence' of themes and theories from the data, providing a comprehensive understanding of the phenomena at the intersection of climate change adaptation and social justice.

Grounded Theory Permits The Emergence Of Relevant Themes

This process involves iterative stages of data collection and analysis. The initial data collection informs the focus areas for subsequent data collection and the cycle continues until a theory, explaining a process, action, or interaction, is derived from the data. In this research, the grounded theory approach entails gathering data (for instance, via informal discussions with stakeholders, document analysis, spatial analysis, and literature review) devoid of preconceived notions or hypotheses about potential findings.

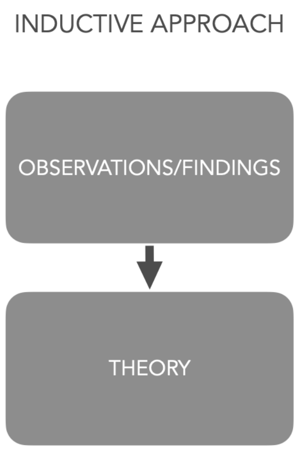


Figure 2 Explaining the process of grounded theory: the nature of the relationship between theory and research, in particular, whether theory guides research or whether the theory is an outcome of research.

Data Collection Strategy

The data collection strategy in this research hinges on qualitative approaches, specifically the ability to pursue unexpected themes and amass nuanced data. This strategy is a method well-received in qualitative research (Bern et al., 2017; Bryman, 2012). Rather than engaging in structured interviews, this methodology favors spontaneous conversations, which engendered experience-based data on stormwater management from domain experts ("fagpersoner") involved in the TOWARDS project in Lillestrøm, Norway through the University of Life Sciences (NMBU), as mentioned at the beginning of this thesis (page x).

Concurrent with these dialogues, document analysis, and literature review were conducted to extract vital contextual insights and perspectives from a range of stakeholders, including legislative, academic, and professional contributors. This has resulted in obtaining research on urban flooding from NMBU from the Water & Sewage Sciences, as well as Law.

Document Analysis

The document analysis process involved scrutinizing governmental reports, legal texts, scientific articles, and news articles to comprehend the broader context and legislative framework of stormwater management in Norway, especially in Lillestrøm. Among these documents, governmental reports and legal documents were primary sources, offering insights into the legal and administrative aspects of stormwater management. Relevant literature and documents were collected through the TOWARDS project.

In alignment with the Grounded Theory approach, document analysis was carried out to extract critical contextual insights and perspectives from a range of stakeholders, including legislative, academic, and professional contributors. The process involved reviewing governmental reports, legal texts, scientific articles, and news articles to comprehend the broader context and legislative framework of stormwater management in Norway, specifically Lillestrøm.

Scientific articles illuminated the latest research within the field, thereby aiding in the collection of relevant data and information. They also shed light on different facets of stormwater management, such as technical solutions, ecological impacts, and socio-economic factors. News articles and reports from non-governmental organizations contributed to the understanding of public discourse around stormwater management and presented diverse perspectives, cases, and arguments.

Quantitative Secondary Data Analysis

To supplement the document analysis, secondary data analysis was conducted, providing concrete data on various aspects of stormwater management, such as precipitation patterns, infrastructure development, and financial considerations. This data was primarily obtained from official statistics from the Norwegian Meteorological Institute, Finance Norway, the Norwegian Environment Agency, and Statistics Norway.(Bryman, 2012).

Data Source: Kunnskapsbanken

Kunnskapsbanken, an online knowledge platform established by the Norwegian Directorate for Civil Protection (DSB), offered a vast array of data on the risks and vulnerabilities associated with natural disasters, in an online GIS version with detailed maps. While access to some parts of Kunnskapsbanken was limited due to national security concerns, the available information offered valuable insights into the extent and implications of water damage in Lillestrøm.

Digital Tools and Techniques for Spatial Analysis

The aim of the spatial analysis was to reveal vulnerabilities and opportunities in the physical landscape and environmental conditions, such as temperature, precipitation, and sunlight patterns, in relation to urban infrastructure and topography. Inspiration for the spatial analysis methodology was drawn from the field of "forensic architecture," which applies architectural techniques and technologies to investigate human rights abuses.

Tools such as Google Earth Pro and SCALGO Live were employed alongside GIS tools to conduct the spatial analysis. While these tools have their limitations, they played a significant role in the understanding of uncertainties related to rainfall patterns, drought dynamics, and potential vulnerabilities associated with natural disasters. Despite the scarcity of updated imagery, Google Earth Pro aided in exploring the study area and understanding its geographical context, especially how rainfall events and consequent flash flooding could affect the landscape.

SCALGO Live, a web-based platform specializing in large-scale data analysis for hydrological modeling, was extensively used for its Flash Flood Map function. This tool, by calculating surface runoff and potential flash flood areas during specified rain events, played a pivotal role in identifying depressions or low-lying areas where water could accumulate during rain events. Taubøll and Paus (2022) advocate SCALGO Live, a terrain-based tool, for its accessible and efficient stormwater risk assessment, making it an essential addition to methodology in this field.

In conducting this research, the integration of various visual digital tools was pivotal in handling, processing, and visually representing the data. QGIS, a powerful open-source geographical information system, was employed to understand the geographical trends, relationships, and patterns within the data. This spatial perspective offered an enriched view of the climate change effects and corresponding adaptations from a geographical standpoint. QGIS's flexibility also facilitated the amalgamation of data from diverse sources, which considerably broadened the depth of the spatial analysis.

Furthermore, digital photo editing tools served as a critical resource in refining and manipulating images for optimal clarity and effective presentation. These tools allowed for precise alterations in the visual elements, ensuring the imagery effectively communicated the intended message and conformed to the context of the study.

The digital drawing tool, Morpholio Trace, and the digital illustration app, Procreate, were invaluable in the creation of detailed, layered visual content. Morpholio Trace's capabilities, specifically designed for architectural and design projects, were crucial in producing layered sketches. This feature enabled accurate tracing and detailing of underlying layers, which proved particularly useful when visually synthesizing the data gathered in this study. The system allowed for individual elements to be independently adjusted and composed, offering a greater degree of control over complex compositions.

Together, these digital tools significantly enriched the research methodology, enhancing not only the depth of analysis and comprehension of spatial vulnerabilities and topographical components but also the presentation of findings. Their usage underscores the growing importance of technology in bolstering research methodologies and enhancing outcomes in the field of climate change studies.

Chapter 3

LITERATURE REVIEW

Understanding Landscape Architecture at the Intersection of Climate Change Adaptation and Social Justice

This literature review explores the multifaceted issues related to climate change, social justice, and the role of landscape architecture in these intersecting realms. The aim is to build a comprehensive theoretical foundation and offer valuable context to the subsequent research. The review is divided into four interconnected sections, each exploring a specific theme.

Part I discusses the theoretical framework of understanding climate change, its impact, and our responses. It delves into Earth System Science, underscoring the significance of the biosphere and humanity's role in disrupting it. It further elaborates on the concepts of systems thinking and resilience. Then climate risk, vulnerability, and adaptation, and examines how these aspects interplay with climate justice.

Part II shifts the focus towards the field of landscape architecture and its potential role in mitigating climate change impacts and fostering social justice. It explores the intersection of landscape architecture, climate adaptation, and social justice, providing a fresh perspective on how landscape architecture can contribute to sustainable and equitable solutions. This section also discusses the rise of urban resilience thinking and its influence on climate change adaptation in landscape architecture.

In Part III, the review takes a specific turn towards the case study of Norway. It examines the unique challenges and policies that characterize Norway's approach to climate change adaptation, particularly focusing on the complex issue of stormwater management. This part provides a rich insight into the policy, economic, and environmental dimensions of climate adaptation in a real-world context.

Lastly, **Part IV** investigates the concept of nature as a critical infrastructure for national security. It presents a detailed overview of nature-based solutions (NbS), their advantages, risks, and social dynamics. This section serves as an exploration of how nature can be leveraged for climate adaptation while promoting socio-ecological resilience and security.

Climate Change Overview

Climate change poses tangible threats to individuals and societies, potentially affecting where people can live, what they can eat, and their overall life experiences (Leichenko & O'Brien, 2019). Material damage and displacements due to climate-induced phenomena such as sea-level rise, droughts, or floods have already been observed. Furthermore, climate change is a potential threat to national security in many countries, potentially stressing agricultural and water resources or causing population displacement and migration. The impacts of climate change are not only confined to humans but extend to other species and ecosystems (Elhacham et al., 2020; Leichenko & O'Brien, 2019).

The Intergovernmental Panel on Climate Change (IPCC) has identified key reasons for concern about climate change, including risks to unique and threatened systems, extreme weather events, distribution of impacts, global aggregate impacts, and large-scale singular events. Yet, these global concerns do not fully account for variations in exposure and vulnerability of socio-ecological systems over time, which are further influenced by societal conditions (Karen O'Brien et al., 2022; Leichenko & O'Brien, 2019).

Equity and ethics in climate change is another important area to explore. Climate change impacts and policies raise profound equity concerns, with a foundational issue being that those least responsible for causing the problem are most vulnerable to its impacts (Eriksen et al., 2011; Leichenko & O'Brien, 2019; Magnan et al., 2016). The equity dimension of climate change also extends to future generations. Described as a 'perfect moral storm', climate change's complexity can serve as a convenient excuse for current and successive generations to take weak and largely ineffective actions.

Part I: Theoretical Framework

Intangibles of Climate Change through Earth System Science

To fully comprehend climate change, we must recognize Earth as an interconnected system. Earth System Science encapsulates this view, highlighting the intricate links between the atmosphere, hydrosphere, cryosphere, biosphere, and lithosphere (Steffen et al., 2005)Today's Earth System model, influenced by Bretherton's diagram, acknowledges humans as an integrated part of the system, influencing and being influenced by all other components (Steffen et al., 2004).

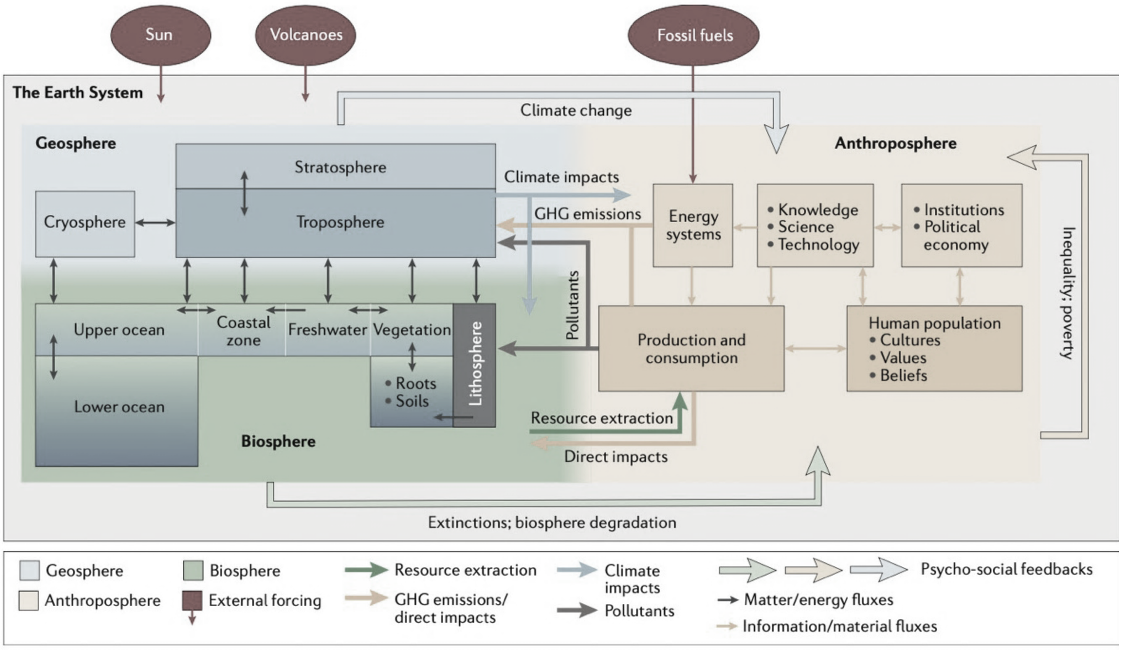


Figure 3 Conceptual model of the Earth System. (Steffen et al., 2020) Key Earth-System processes, their interactions, and nonlinear behaviors. Source: Steffen et al. (2020).

The Critical Role of the Biosphere

A fundamental piece of the Earth System is the biosphere, the sum of all ecosystems, which safeguards planetary stability. Sala (2020) advocates for the preservation of these ecosystems due to their intrinsic biodiversity value, vital role in climate regulation, and capacity to mitigate climate change. He emphasizes that loss of biodiversity threatens ecosystem resilience, hence contributing to climate disruption(Sala, 2020; Steffen et al., 2020).

Humanity's Role in Climate Change

In the fields of epistemology, ontology, and meta-ethics, several important considerations emerge regarding climate change and our responses to it. Epistemologically, we grapple with the knowledge and understanding of climate change. Aligned with Wittgenstein's philosophy, it is asserted that the comprehension and articulation of the concept of climate change are prerequisites to any tangible adaptations. As Wittgenstein stated, "The limits of my language mean the limits of my world" (Wittgenstein, 1922) underscoring the idea that our understanding of reality is mediated by our use of language. In this sense, we must adjust our terminology and concepts to effectively grasp the reality of climate change.

Significant sociocultural shifts in the last half of the 20th century have disrupted traditional space-time connections, requiring new theoretical frameworks. This time-space dissociation is continuously evolving, substantially heightened in the contemporary era, reshaping our worldviews. Phenomena such as globalization and the associated environmental changes (Leichenko and O'Brien 2008) urge us to reevaluate our approaches. A notable example is Schellnhuber's (1999) call for a *'Copernican revolution'* in Earth studies(Steffen et al., 2005). To adapt to climate change, it becomes imperative to adopt a holistic, systemic view that acknowledges "planetary boundaries" (Rockstrom et al. 2009).

From an ontological perspective, climate change epitomizes a significant shift in the relationship between humanity and the environment. The advent of the Anthropocene signifies that human activities now hold the potential to alter our planet profoundly, competing with nature's major forces (Crutzen 2002; Zalasiewicz et al. 2010). This era introduces a novel human-biosphere relationship and challenges us to view ourselves as agents capable of manipulating critical global processes.

Regarding the meta-ethical level, we confront the potential influence of climate change on the very feasibility of ethical thinking. The most extreme warming scenarios question our ethical responsibilities regarding the potential collapse of civilization or even life on Earth (Hansen 2009; Schellnhuber 1999). The mere possibility of such extreme outcomes underscores our moral obligations.

These discussions suggest two main adaptation challenges: 1) the need for a holistic view of the Earth system to understand the ongoing changes (epistemological level), and 2) the need to perceive ourselves as potent actors capable of influencing essential global processes (ontological level).

Understanding Our Impact through Earth System Science

Scientists and researchers use the term "Anthropocene" to describe our current epoch—an era characterized by humans as the dominant influence on our environment and climate. Our individual and collective behaviors significantly contribute to the ongoing changes we are observing in our global climate system.To better comprehend the intricate dynamics of our planet, let's examine the Earth System wiring diagram. This diagram, inspired by artist Tone Bjordam's rendition of the renowned "Bretherton Diagram", represents the complex relationships within the Earth System.

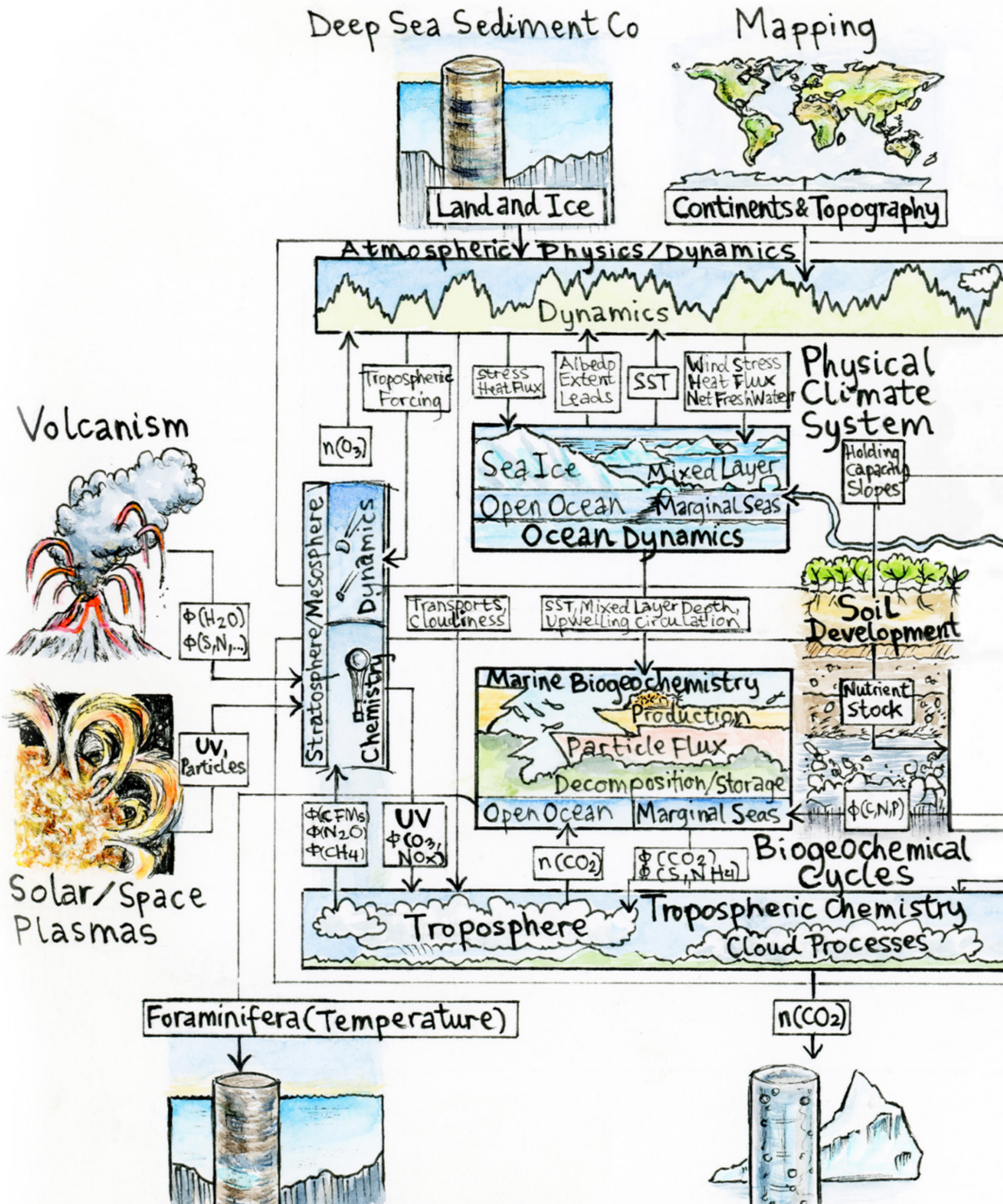
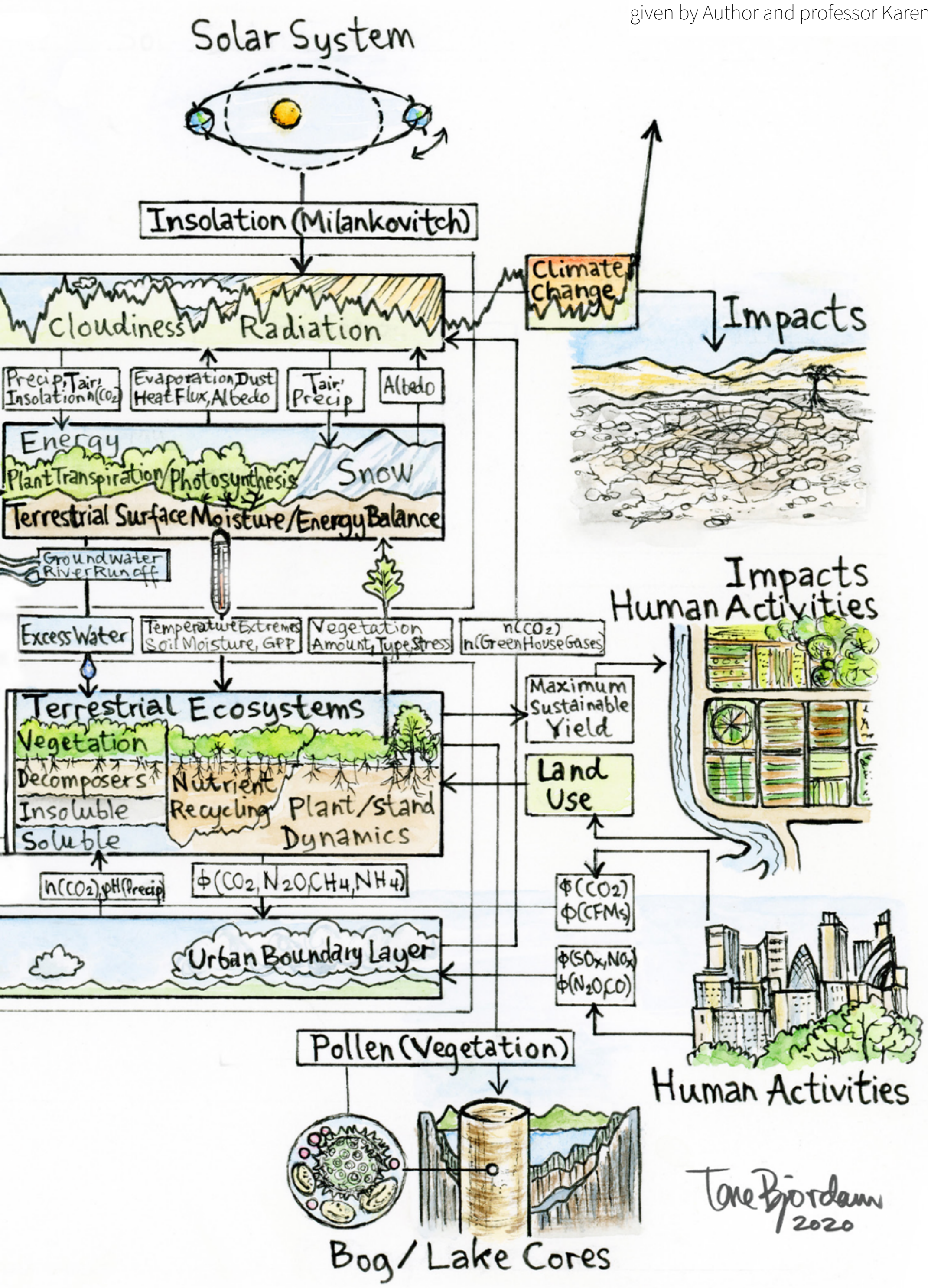


Figure 4 The Earth System "wiring diagram", Artist and rights Tone Bjordam in You Matter More than You think (O'Brien et al., 2022). Permission to use illustration for the thesis given by Author and professor Karen O´Brien.



Approaches to Climate and Biodiversity Challenges

The Three Spheres of Transformation

To confront multifaceted global challenges such as climate change and biodiversity loss, an integrative strategy is paramount, superseding traditional responses. The Three Spheres of Transformation is one such framework providing a comprehensive structure to both understand and instigate transformative change (O'Brien et al., 2022). This model acknowledges the interconnectedness of practical, political, and personal domains of transformation, necessitating profound shifts in form, structure, and processes of meaning-making (Karen O'Brien et al., 2022).

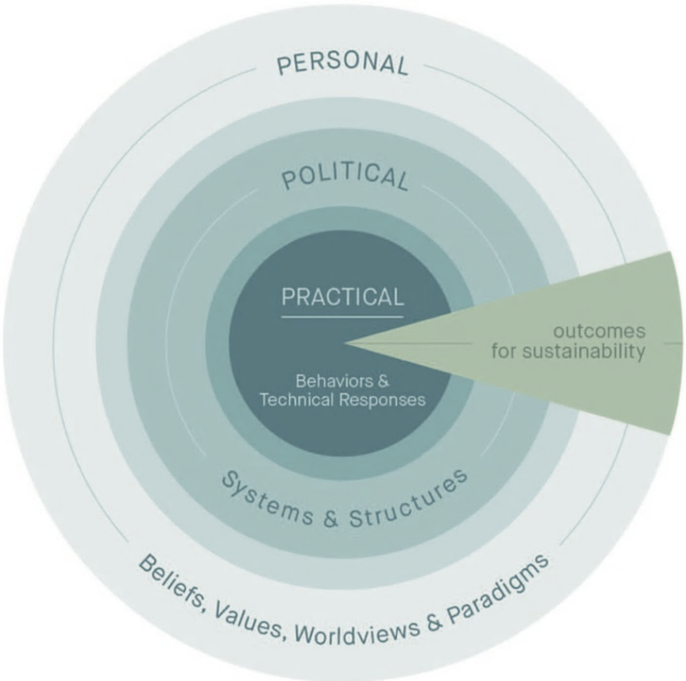


Figure 6 The three spheres of transformation (after Sharma, 2007) (O'Brien & Sygna, 2013)

Beyond an isolated model, the Three Spheres framework corresponds with various theories of change and approaches, engaging with social-ecological transformations. The framework's utility extends beyond academia to education, where it aids in designing curricula that underline the nexus between individual and collective agency and systemic change. It has been employed by practitioners, non-profit organizations, and academic institutions to devise actionable interventions that yield results across different scales. Such interventions, which holistically encompass all three spheres, promise to initiate non-linear transformations, leading to socially equitable and environmentally sustainable outcomes (O'Brien et al., 2022).

Systems Thinking and Intersectionality

Building on this, systems thinking serves as an analytic methodology that emphasizes interrelationships among system components and their collective impact on overall system behavior (Meadows, 2008). This holistic perspective is vital when investigating complex phenomena like climate change, social justice, and stormwater management.

In the context of Earth System Science, systems thinking facilitates understanding the cascading impacts of anthropogenic changes on Earth's various components, promoting an integrated understanding of Earth's complex system (Steffen et al., 2004). Similarly, in the realm of urban systems, systems thinking underlines the principles of urban resilience and socio-ecological thinking. It guides us to perceive the city as an interwoven socio-ecological system (Gunderson & Holling, 2003).

The reach of systems thinking extends to the concept of intersectionality. (Crenshaw, 1989)This concept underscores the interlocking nature of social categorizations like race, class, and gender, suggesting these are interdependent components within a complex system of discrimination. Recognizing these intersections is crucial for creating socially just and equitable adaptation strategies.

The Intersectionality of Science, Engineering, Design, and Art

The "Krebs Cycle of Creativity" (KCC) introduced by Oxman (2016) serves as a significant theoretical underpinning for the intersection of science, design, and social justice. This model presents the modalities of human creativity—*Science, Engineering, Design, and Art*—as interconnected and transformative, each contributing to the continuous cycle of knowledge production and innovation (Oxman, 2016). In this research, the KCC provides a valuable framework for understanding the interplay of social justice, climate change adaptation, and landscape architecture. These domains map onto the KCC modalities: the science of climate change and adaptation strategies provides knowledge; the engineering component encompasses the technical aspects of landscape architecture; the design is reflected in the creation of physical spaces; and the art represents the potential of these spaces to foster social justice and transform our relationship with the environment.

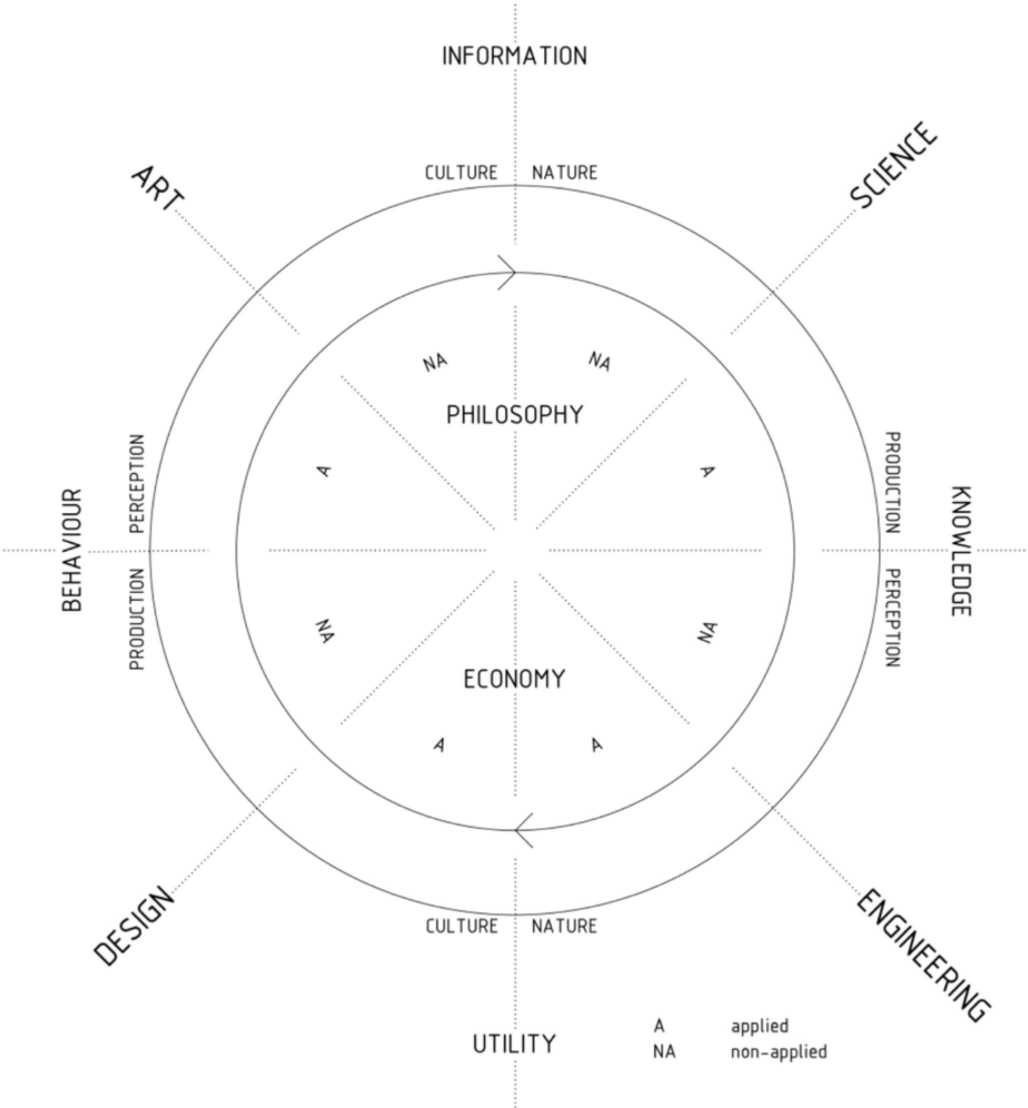


Figure 7 The Krebs Cycle of Creativity (KCC) is a map that describes the perpetuation of creative energy. The four modalities of human creativity—Science, Engineering, Design, and Art transform into another (Oxman, 2016).

To illustrate, the Three Spheres of Transformation can fit into the KCC's conceptualization of human creativity. The 'practical' sphere aligns with the Engineering aspect of the KCC, where knowledge is transformed into utility. The 'political' sphere can be seen in the Design modality, as it involves applying utility to shape behavior. Lastly, the 'personal' sphere correlates with Art, translating behavior into new perceptions. This alignment shows that practical, political, and personal transformation are all integral parts of the creative cycle.

Adaptation, More Than a Practical Solution

What *is* Adaptation?

Adaptation, refers to *the process of modifying something to suit a new purpose or situation*. In the context of climate change, adaptation takes on a deeper and more complex meaning Adaptation, a cornerstone in the field of climate change, can be described as a response to changing conditions (O'Brien & Selboe, 2015). This may include a wide variety of conditions, ranging from environmental to political, social, economic, cultural, technological, psychological, and even emotional alterations (O'Brien and Selboe, 2015).

The discourse on climate change adaptation has evolved dramatically over the past few decades. Initially, the predominant focus was on the mitigation of greenhouse gases (IPCC, 2014), yet it gradually transitioned towards embracing adaptation as an equally critical response strategy, particularly due to the inescapable impacts of climate change. Adaptation, according to the Intergovernmental Panel on Climate Change (IPCC), encompasses adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities (IPCC, 2014).

Adaptation in response to climate change can involve the application of novel behaviors and ideas, possibly perceived as radical or a significant shift from traditional practices (Hetherington & Reid, 2010), and outlined four types of novel adaptations in biological programs, further emphasizing the importance of cultural, social, and human processes in adaptation.

However, a deeper exploration of the literature reveals a systematic critique of current understanding and practices of adaptation. O'Brien and Selboe (2015) argue that the full scope of climate change adaptation is not confined to changes in climate parameters alone but involves multiple interacting processes that influence the capacity to perceive and respond to change at various spatial and temporal scales. They point out that concurrent transformations in environmental, economic, social, technological, institutional, and political systems influence the potential consequences of climate change (O'Brien & Selboe, 2015).

Indeed, adaptation research, policy, and practice to date have been primarily focused on identifying actions to combat the impacts of climate change, often adopting a 'to-do list' approach (Biagini et al., 2014; Ford et al., 2011). This approach, while practical, rarely addresses the wider and deeper systems and structures contributing to risk and vulnerability. O'Brien and Selboe (2015) thus argue for the need to redefine climate change adaptation, with an emphasis on transformative changes to an equitable and sustainable world.

O'Brien and Selboe (2015) caution against a strictly *technical* interpretation of adaptation, noting that it frequently overlooks deeper systemic issues contributing to climate change risk and vulnerability. The authors propose that climate change should be viewed as an adaptive challenge requiring transformative changes in our social, political, and technical systems. In essence, their perspective resonates with the principles of social-ecological systems and resilience thinking, emphasizing the need for comprehensive, systemic, and transformative approaches to climate change adaptation.

Strategies for Addressing Climate Change: Mitigation and Adaptation

The climate change discourse is dominated by two primary strategies: mitigation and adaptation (UNFCCC, 1992). Mitigation encompasses strategies to reduce anthropogenic influences leading to climate change, such as decreasing greenhouse gas emissions (IPCC, 2001). On the other hand, adaptation involves adjusting human systems in response to climate change impacts (IPCC, 2001). The current discussion on climate change adaptation involves assessing the possibilities and constraints of physical adaptation measures such as sea walls and societal adaptations like modifications in agricultural practices (Adger et al., 2007). Both strategies, mitigation, and adaptation, are vital for a comprehensive response to climate change. However, a multifaceted debate persists over whether adaptation and mitigation are substitutes or complements to each other (Klein et al., 2007; O'Brien & Selboe, 2015).

Understanding Adaptation in the Context of Climate Change

Climate change adaptation can be described as the adjustment process to actual or anticipated climate change impacts, aiming to minimize harm and seize beneficial opportunities (IPCC, 2014). This is not a novel concept; humans have been adapting to various climate conditions throughout history. However, the unprecedented pace of current climate change demands innovative and effective adaptation strategies (Barros et al., 2014; IPCC, 2014).

Historically, societies employed passive adaptation strategies like migration. Still, with growing permanent human settlements and globalized societies, such strategies have become less feasible and more disruptive (Adger et al., 2005). Thus, active adaptation strategies that directly tackle climate change's root causes and impacts, from constructing seawalls to introducing climate-smart agriculture practices, are gaining prominence (Adger et al., 2005).

Adaptation strategies also interconnect with sectors like disaster risk reduction, land-use planning, and water management. These intersections underline the need for an integrated approach to climate change adaptation (IPCC, 2014). This interconnectedness and complexity are reflected in the many facets of adaptation that will be further explored in this chapter.

Defining Adaptation: From Traditional Understandings to Current Perspectives

Human adaptation to climatic variations is evident throughout history, as shown by archaeological findings (Hetherington & Reid, 2010; Orlove, 2009). However, our traditional understanding of adaptation must be reevaluated in the face of the current climate crisis. A narrow, technical interpretation of adaptation may overlook the systemic vulnerabilities contributing to climate risk. As such, O'Brien and Selboe (2015) call for an expanded understanding of adaptation that acknowledges the need for transformative changes to social, political, and technical systems. This revised perspective suggests that successful climate change adaptation may require more than a ‘to-do list’ approach that focuses on combating climate change impacts (Klausen, J. et al., 2015). Instead, it could involve addressing broader systemic issues that contribute to climate change risk and vulnerability (O'Brien & Selboe, 2015).

Considering the Adaptation-Mitigation Relationship

Both are critical strategies for addressing climate change, but their interplay is complex. The IPCC’s Third Assessment Report (2001) initially framed adaptation and mitigation as two separate strategies. However, more recent studies argue that these strategies can and should be integrated, with one potentially supporting the other (Klein et al., 2007).

For instance, some adaptation actions could simultaneously contribute to mitigation efforts. While they are distinct strategies, their implementation can often be interrelated (Klein et al., 2007; O'Brien & Selboe, 2015). For example, some actions can provide both mitigation and adaptation benefits, such as the restoration of natural ecosystems, which can sequester carbon (mitigation) and enhance resilience to climate impacts (adaptation) (Orlove, 2009). However, there can also be trade-offs, where actions that support one may hinder the other. In essence, these complex questions underpin the ongoing research and policy discussions on the best ways to respond to climate change. They highlight the need for comprehensive, context-specific, and flexible strategies that can navigate the complexities and uncertainties of climate change and its impacts.

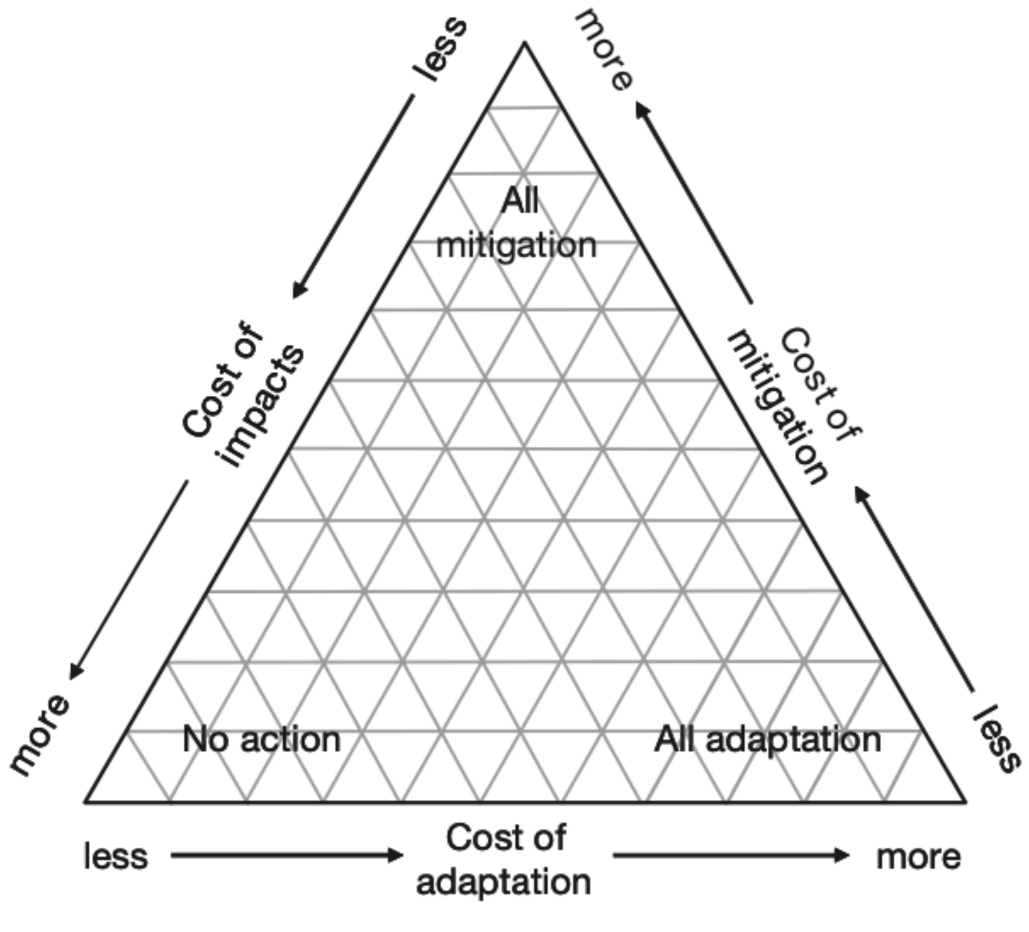


Figure 8 schematic overview of the inter-relationships between adaptation mitigation and impacts of climate change, following the life-zone classification scheme proposed by Holdridge (1947,1967) (Klein et al., 2007)

Institutionalizing Adaptation Responses

At the international level, the United Nations Framework Convention on Climate Change (UNFCCC, 1992) recognizes adaptation as a crucial response to climate change. However, it initially provided little guidance on how countries should implement adaptation actions. Over the years, the global community has worked to provide clearer frameworks for adaptation, leading to the development of National Adaptation Plans and strategies under the Paris Agreement (IPCC, 2022).

In the European context, the EU Taxonomy for Sustainable Activities (European Commission, 2019) has offered a new approach to classify environmentally sustainable economic activities, thereby encouraging investment in climate change adaptation measures. Furthermore, the “Towards an EU Research and Innovation Policy Agenda for Nature-Based Solutions & Re-Naturing Cities” report (European Commission, 2020) emphasizes the importance of urban greening and nature-based solutions for adaptation efforts.

At the national level, adaptation actions are increasingly being integrated into policies and development plans. While many of these efforts are led by governments, it’s also recognized that effective adaptation often involves a wider range of stakeholders, including local communities, non-governmental organizations, and the private sector (Biagini et al., 2014).

Hazard + Vulnerability + Exposure = Risk

Over time, the IPCC’s understanding of risk has evolved. In earlier reports, the risk was primarily considered regarding *physical* hazards and vulnerability. However, in AR5 (Barros et al., 2014), the risk is viewed as the ‘product’ of h*azard, vulnerability, and exposure*, emphasizing the importance of considering social, economic, and institutional factors when assessing climate change impacts (IPCC, 2022).

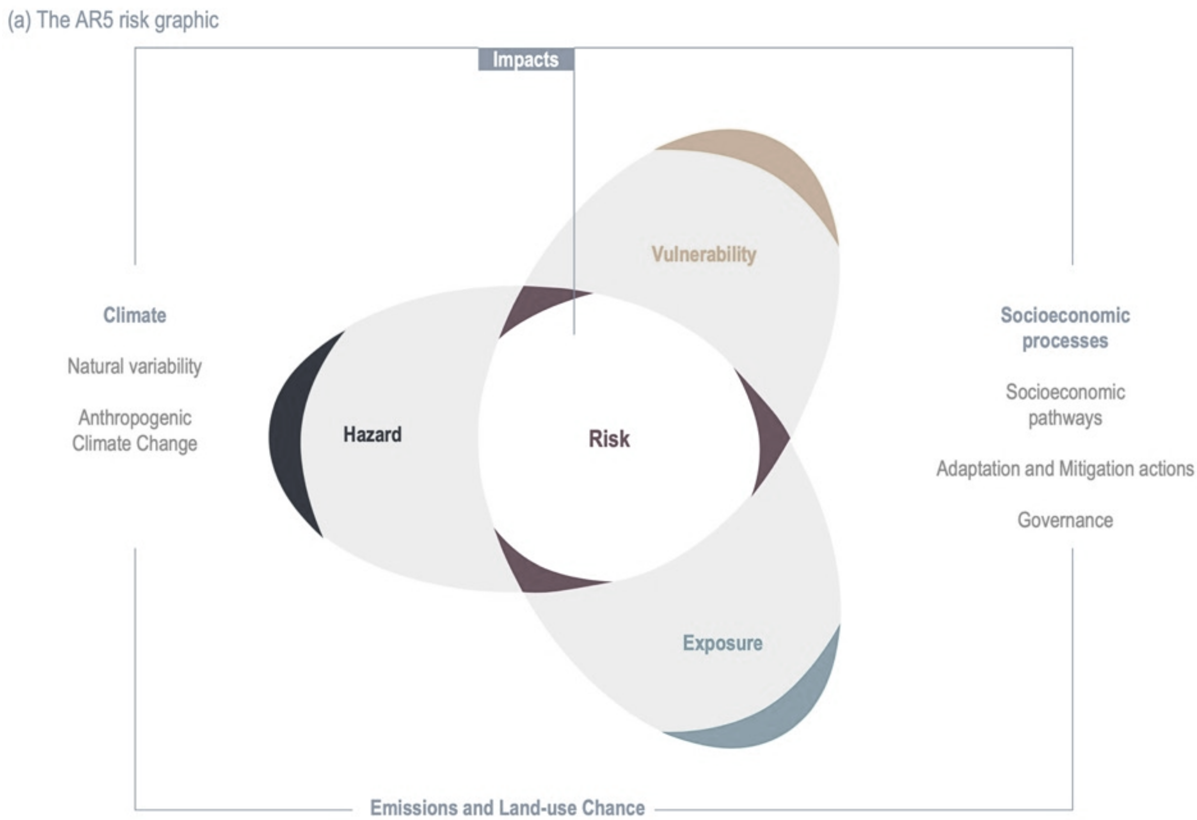


Figure 9 The AR5 risk graphic (IPCC, 2022)

The Power of Adaptive Capacity

The concept of adaptive capacity, or the *system's ability to adjust to climate change*, is fundamental to this discourse. Notably, adaptive capacity is not uniformly distributed across society. Certain groups, due to their socio-economic conditions, geographical location, or access to resources, may have less capacity to adapt and therefore are more vulnerable to climate change impacts (Adger, 2006).

Interpreting Two Types of Vulnerability in Climate Change: Outcome and Contextual

The concept of vulnerability has been widely recognized in climate change discourses and its interpretations vary significantly, affecting how climate change adaptation strategies are formulated and implemented (O'Brien et al., 2007). The two major interpretations of vulnerability identified by O'Brien et al. (2007) are *'outcome vulnerability'* and *'contextual vulnerability'*, each associated with a distinct framing of the climate change problem.

The 'outcome 'ulnerability' interpretation is closely tied to a scientific framing of climate change. It predominantly involves quantifiable measurements and assessments based on exposure, sensitivity, and adaptability to climate change impacts. This perspective is primarily concerned with the potential future outcomes of climate change on regions, sectors, ecosystems, and social groups.

In contrast, the 'contextual vulnerability' interpretation stems from a human-security framing of climate change. It emphasizes the socio-political and economic context in which vulnerability arises. This perspective recognizes that vulnerability is not just a function of environmental risk but also a product of socioeconomic conditions, inequities, and power dynamics. It thus argues for a more holistic approach that considers these wider social structures and influences.

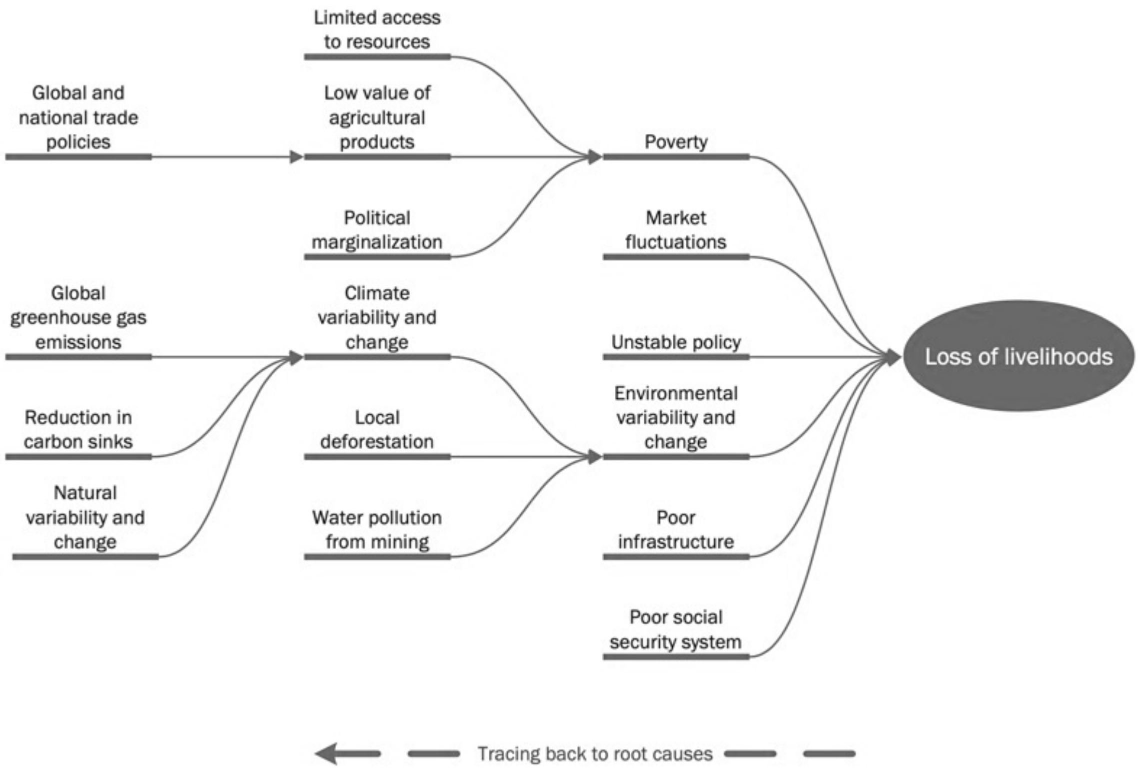


Figure 10 Scoville-Simonds and O'Brien (2018), provides a visualization of the process of tracing vulnerability's root causes. It illustrates how outcomes can be linked to multiple causative factors, extending from local to global scales (Scoville-Simonds & O'Brien, 2018)

The evolution of the understanding of vulnerability has been varied and complex, as indicated by a broad array of scientific and policy literature. This multifaceted conception of vulnerability is informed by different disciplinary perspectives and the value-based assumptions each holds, ultimately shaping the response strategies that are proposed (Bassett and Fogelman, 2013 as cited in Scoville-Simonds and O'Brien, 2018).

Two primary analytical viewpoints of vulnerability emerge: an 'endpoint' or 'outcome' perspective, and a 'starting point' approach. The former perceives vulnerability because of environmental impacts, thereby favoring technological and infrastructural solutions. In contrast, the latter view treats social vulnerability as a foundational element and emphasizes socio-economic and political factors that contribute to vulnerability (Kelly and Adger, 2000; O'Brien et al., 2007 as cited in Scoville-Simonds and O'Brien, 2018). The choice between these perspectives can significantly influence the range of solutions proposed and those disregarded.

It is noteworthy that vulnerability analysis departs significantly from impact analysis. The latter begins with an identified environmental change and projects possible future impacts. Vulnerability analysis, on the other hand, links specific outcomes to a multitude of causes, both social and biophysical (Ribot, 2014 as cited in Scoville-Simonds and O'Brien, 2018).

The figure above by Scoville-Simonds and O'Brien (2018), provides a visualization of this process of tracing vulnerability's root causes. It illustrates how outcomes can be linked to multiple causative factors, extending from local to global scales. These factors require comprehensive contextual studies to pinpoint the most significant conditions, processes, and root causes for potential intervention.

Increasingly, research has recognized that vulnerability is associated not only with immediate biophysical threats but also with the social and political processes that expose individuals and groups to risk. These processes affect the resources and choices available to those at risk. This shift in understanding invites a more nuanced study of vulnerability, emphasizing the need to identify not just who is vulnerable, but why and how. This approach necessitates a critical examination of vulnerability production in specific contexts, connecting processes from local to global scales. This development has been a pivotal stride in vulnerability research, highlighting the underlying politics of vulnerability (Scoville-Simonds and O'Brien, 2018).

Understanding these interrelated components of risk is crucial to developing effective climate change adaptation strategies, as it allows for targeted interventions aimed at reducing hazard, limiting exposure, and minimizing vulnerability.

What is Justice, in theory?

Social justice is Understanding risk components is vital for targeted climate change adaptation strategies, addressing hazard, exposure, and vulnerability. This understanding underpins the principle of social justice, ensuring equitable distribution of the benefits and burdens arising from climate change adaptation (Atapattu & Schapper, 2019).

Justice in climate change adaptation involves various facets. Distributive justice focuses on fair resource allocation (Schlosberg, 2013). While procedural justice emphasizes fair and transparent decision-making processes (Rawls, 1971). Contextual justice goes beyond these, acknowledging the wider socio-political and cultural contexts that shape resource access and influence (Juhola et al., 2022). Recognitional justice adds another dimension by stressing the respect for diverse identities, cultures, and knowledge systems (Preston & Carr, 2021)

Social justice in climate change adaptation underscores people's right to a healthy and safe environment, addressing areas such as risk reduction, resilience, and resource access (Bulkeley & Newell, 2010). It also recognizes the historical responsibility of industrialized nations for climate change, emphasizing the need for fairness in distributing responsibilities and benefits (Caney, 2010).

Climate justice and environmental justice, extensions of social justice, focus on equity in dealing with climate change causes and consequences, and the right to protection from environmental and health hazards, respectively (Mary Robinson Foundation – Climate Justice, 2019; Schlosberg, 2013). The concept of climate injustice further emphasizes addressing the root causes of vulnerability and avoiding the exacerbation of existing inequalities (Schlosberg, 2013).

Therefore, integrating social justice, climate justice, and environmental justice provides a comprehensive framework for equitable, just, and respectful climate change adaptation.

Part III: Landscape Architectures Role in Climate Change Adaptation and Social Justice

The Evolving Role of Landscape Architecture in Contemporary Times

Landscape architecture, traditionally seen as the design and management of outdoor spaces, has progressively expanded to encompass a more diverse array of roles and responsibilities. Steiner and Gandy (2016) shed light on this evolution, emphasizing the increasing complexities that landscape architects must navigate. The authors underscore the growing sophistication of mapping and related technologies, such as GIS and remote sensing, which enhance analytical abilities and introduce new challenges (Gandy & Steiner, 2019). For example, they point out that these technologies often present a *simplified* representation of reality, which can limit our understanding of the *actual* intricacies of urban spaces.

More recently, the development of citizen science and the involvement of the public in data collection has broadened the scope of landscape architecture. Despite the tremendous value of these collaborations, Steiner and Gandy also highlight the potential tensions and ethical considerations associated with commodifying public-generated data. The authors also discuss the rise of 'big data' sets and the opportunities and challenges they present, particularly when such data is commercialized.

They argue that landscape architects need to embrace a broader, more nuanced understanding of urban spaces and their associated socioecological dynamics. This perspective includes acknowledging the limitations of their expertise and the importance of collaboration with a wide range of other actors, including vernacular knowledge holders and technical or scientific experts. This reinforces the view of landscape architecture as an 'orchestra of experts' where diverse contributions are essential in addressing common challenges.

Furthermore, Steiner and Sandy propose a revision of the traditional human-centric approach to landscape architecture. They suggest that the orchestra should be expanded to include non-human participants, indicating a shift towards more inclusive, eco-centric practices. They also hint at the need for landscape architects to critically engage with the complexities of capitalist urbanization and reflect on their work's potential ethical and political implications.

This evolution of the field underscores the need for landscape architects to balance technical expertise, ecological sensitivity, and ethical consideration in their work, suggesting a shift towards a more holistic, interdisciplinary approach.

From Traditional to Modern Practices

Landscape architecture is a broad discipline, with having social, practical, technical, and political elements to the fore. One aspect of landscape architecture is that is highly interlinked with resource and land use, and as mentioned above in the section political economy, this entails property-rights. Hence, exploring the complexities of historical land-use and resource management in an urban context will serve as a historical overview and nuanced element to the literature review.

The role of landscape architecture in addressing climate change has evolved over time. Traditional landscape practices often aimed to conquer and dominate nature, with little regard for long-term environmental sustainability (Berger, 2002). However, modern landscape architecture recognizes the critical need for sustainable design and planning, given the pressing challenges of climate change.

Contemporary landscape architecture focuses on creating resilient spaces that can adapt to environmental changes while improving the quality of life for all residents, irrespective of their socio-economic status (Berger, 2002)As such, landscape architecture has become a critical tool for climate change adaptation, helping cities navigate environmental challenges while also addressing issues of social justice.

The Industrial Divorce to Nature

Traditionally guided by principles of harmony with nature and aesthetic appeal, landscape architecture has often been manipulated by the march of industrialization, particularly in the context of river settlements. This section will review the literature examining this intersection of landscape architecture and urban development, particularly emphasizing river settlements and their transformation from traditional harmony with nature to the modern reality of industrialization and ecological neglect.

In the dawn of the modern era, Enlightenment thinkers such as Sir Isaac Newton (1642-1727) began to reconceptualize nature as a machine, a shift that marked the advent of a new form of human rationalism (Williams, 2000). This perspective gradually supplanted the previous beliefs in animism, astrology, alchemy, and magic, eroding the intellectual bonds that linked humans with nature. As technology advanced, humans began to exert more control over their environment, viewing nature as a reserve of raw materials waiting to be exploited for human use (Worster, cited in Williams, 2000). Simultaneously, Enlightenment rationalism paved the way for a vision of an environment dominated by technology. This vision promoted modernization and progress, severing humans' ancient connections with nature and redefining nature as an object of scientific inquiry (Williams, 2000). As technology increasingly became science-based, humans developed tools to control and manipulate nature in their quest for modernity.

Many urban centers have strategically evolved around rivers, a phenomenon widely recognized throughout history and across geographies (Francis, 2012). These developments have typically prioritized economic progress and urban growth, often sidelining ecological considerations in their urban planning strategies (Chen et al., 2022). Many urban centers evolved in strategic locations for resources and transport, with a particular focus on rivers due to their significance for agriculture, transport, and trade. This is exemplified by settlements ranging from the ancient Nile Valley in Egypt to modern cities such as Berlin, London, and New York (Francis, 2012).

The Industrial Revolution further exemplified the utilitarian use of catalyzed rivers, transforming them into channels for waste disposal and energy sources for mills and factories (Francis, 2012), and these industrial activities catalyzed profound landscape alterations and environmental degradation. Such a narrative of exploiting natural resources for human advantage has often led to a modernist paradigm of dominance and manipulation of nature, profoundly influencing landscape architecture and our interaction with the environment (Williams, 2000)

Figure 11 “The March of Intellect” 1828(9) (Heath, 1828)

This trend can be observed through the lens of the satirical piece “*The March of Intellect*” (Heath, 1828) which playfully critiqued the unbridled optimism of the Industrial Revolution, while paradoxically illustrating the disregard for the natural environment in the face of human progress (Bower, 2002). This disregard for nature in river settlements and the subsequent impact on landscape architecture serves as a critical point of discussion for this literature review.

Throughout history, the relationship between humans and their environment has often been characterized by utilitarian views, where nature was perceived as a resource to be tamed and exploited (Higgs, 2003).This is particularly evident in the development of river settlements, from ancient civilizations around the Nile to modern cities such as Berlin, London, and New York, where rivers have often been treated as conduits for transportation and trade, rather than ecological systems worthy of preservation (Wohl, 2004).

In the following sections, the literature review will delve into these complexities, examining the historical evolution of river settlements, the rise of industrialization, and the resulting impact on landscape architecture and the environment.

From Dualism to Entanglement: Rethinking Landscape Architecture in The Anthropocene Epoch

The field of landscape architecture is influenced heavily by its era's prevailing philosophical and environmental conditions. The modernist approach, which has historically underpinned this discipline, is characterized by a dualistic perspective that often separates human and non-human entities (Doherty & Waldheim, 2016; Martin Prominski & Daniel Stimberg, 2012). Prominski (2019) critiques this view, arguing that it fails to acknowledge the intricate entanglements that exist between humans and their natural environment.

This perspective finds echoes in Waldheim and Doherty's (2016) work, where they elucidate that landscape architecture is a product of cultural, economic, and social conditions specific to the industrial modernity of Western Europe and North America. Here, they highlight that industrialization has transformed physical landscapes and our perceptions of them, reinforcing a dichotomous view that distinguishes between nature and culture, human and non-human, and urban and rural.

The Anthropocene epoch, defined by human activities significantly influencing Earth's ecosystems, presents unique challenges that necessitate a shift from the dualistic perspective inherent to modernist landscape architecture (Prominski, 2019). Spirn's (2016) ecological urbanism proposes such a shift, advocating for a framework that recognizes the reciprocal relationships between human systems and natural processes.

Prominski (2019) also calls for an entanglement landscape design perspective that surpasses human/non-human dualism, acknowledges the impacts of industrialization, and incorporates ecological, temporal, and social dimensions. This perspective, in alignment with Spirn's (2016) ecological urbanism, has the potential to create landscapes that are resilient and responsive to the needs of human and non-human communities in an ever-changing environment.

In the Anthropocene, issues of social justice become inextricably linked to natural phenomena of adaptation ((Klein et al., 2007)Environmental changes, driven by factors such as climate change, have societal responses that are seldom evenly distributed, thus exacerbating existing inequalities (Klein, 2014). This reinforces the argument that adaptation strategies must encompass socio-political dimensions to prevent the inadvertent perpetuation of injustice.

Literature on climate change adaptation also critiques nature-society dualism, highlighting the impracticality of separating climatic drivers of change from the social ones (Nightingale et al., 2019). An integrated socio-natural perspective, which views nature and society as inseparable elements of a co-produced socio-natural system, is thus recommended (Noble et al., 2014). This perspective aims to develop more equitable strategies for climate change adaptation, factoring in the deeply interconnected social and climatic changes.

In summary, the literature suggests that a shift in perspective is required in landscape architecture to address the complex challenges posed by the Anthropocene epoch. Such a shift involves moving beyond the dualistic view and embracing a perspective that recognizes the entangled nature of human and non-human systems and the intertwined socio-natural dynamics of our landscapes.

Urban Resilience and Climate Change Adaptation: A Shift Towards Socio-ecological Thinking

An important area of literature central to this research concerns the relationship between urban resilience and climate change adaptation, with a special emphasis on the need for a shift towards socio-ecological thinking in the face of the Anthropocene.

Holling's introduction to the Panarchy book emphasizes that there are several distinct scales, each with its unique patchiness, attributes, and textures. This refers to the systems and groups where one influences the other through dynamic interactions, forming a 'nested adaptive cycle' (Holling, 1973).

When applied to urban environments, the Panarchy concept reflects intricate cross-scale impacts among neighborhoods, suburbs, and metropolitan regions (Costanza et al., 2017). Moreover, regional resilience can be understood as a region's capacity to effectively bounce back from various types of shocks (Costanza et al., 2017)See Figure above.

Urban resilience refers to the capacity of a city or an urban system to survive, adapt, and grow despite the stresses and shocks they encounter (Resilient Cities Network, 2023). According to Meerow, Newell, & Stults (2016), resilience in urban areas must embrace two main components: the capacity to withstand shocks or stresses (absorptive and resistant capacities), and the ability to learn, adapt, and transform in response to change (adaptive and transformative capacities)(Meerow et al., 2016). This dual focus is crucial in the context of climate change, where urban systems need to not only be prepared to absorb shocks (such as extreme weather events) but also be flexible enough to adapt to changing circumstances and bounce forward in beneficial directions (Béné et al., 2012).

Understandably, resilience thinking is a prominent thread in climate change adaptation literature (Adger et al., 2005). What is increasingly being recognized, however, is the need for a socio-ecological perspective that acknowledges the interconnectedness of social and ecological systems in the urban context (Ernstson et al., 2010). This perspective aligns with the entanglement and systems thinking discussed earlier, underlining the need for a holistic view that considers not only the physical impacts of climate change, but also the social, political, and economic dynamics at play.

Resilience in this context is therefore not about simply bouncing back to a previous state after a shock but about learning, innovating, and transforming in ways that enhance the system's ability to deal with future change (Folke, 2006). This understanding of resilience is fundamentally about managing change, and it has clear implications for landscape architecture, urban planning, and design. For instance, Ahern (2011) suggests that resilient cities should be viewed as complex adaptive systems and that landscape architecture and urban planning need to integrate ecological and social resilience principles into design processes to enhance urban resilience to climate change (Ahern, 2011).

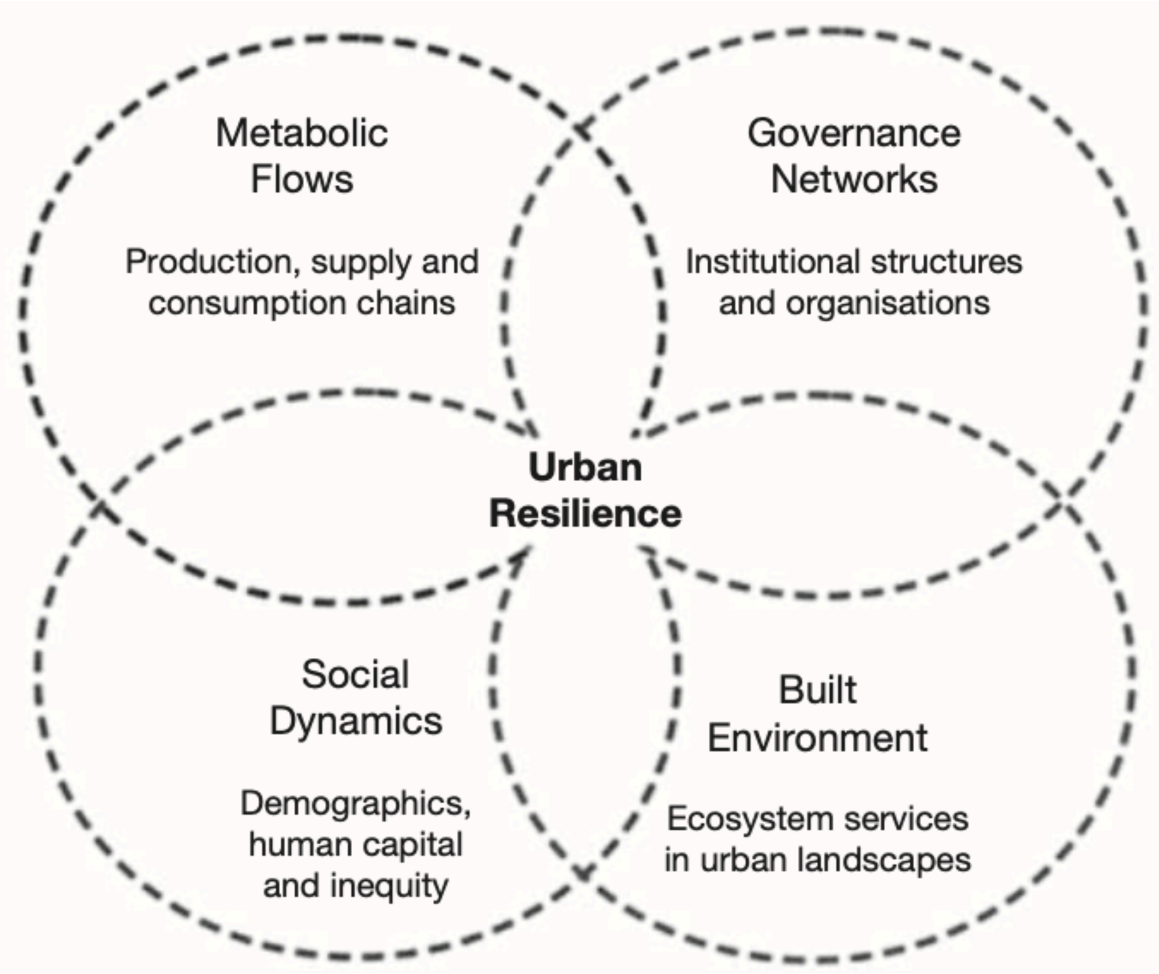


Figure 12 Urban Resilience framework from Resilience Alliance Project prospectus 2007.(Whiteman et al., 2011)

Additionally, it's also argued that resilient cities are ones that not only survive and adapt but are also equitable and inclusive (Anguelovski et al., 2016). This touches on the theme of social justice and highlights the critical role of landscape architecture and design in fostering not just ecological resilience, but social resilience as well.

In conclusion, the literature points to a need for a more integrated socio-ecological perspective that acknowledges the intertwined nature of human and non-human systems and the complex socio-ecological dynamics that characterize the Anthropocene. It also highlights the central role that landscape architecture and design can play in fostering urban resilience to climate change, emphasizing the need for a holistic, system-oriented approach that also integrates social justice considerations.

Ethical Debate on Social Sustainability and Landscape Architecture

In exploring the concept of social sustainability within the scope of landscape architecture, a valuable perspective is offered by Egoz (Egoz, 2019). Egoz leverages a broad range of scholarly works to establish the importance of this discourse, including seminal pieces such as McHarg's 'Design with Nature' (McHarg, 1969) and Bauman's explorations into the modern age (Bauman, 2000, 2007). Egoz highlights the multidimensional role that landscapes play in promoting social justice and well-being, drawing on research that explores the intersection of landscape, social equity, and migrant welfare (Egoz & De Nardi, 2017). the landscape.

The concept of social sustainability, as highlighted by Shelley Egoz in her chapter, underscores the importance of promoting equity, democracy, and social justice within societies (Egoz, 2019). This is particularly critical in the face of growing wealth disparities and economic gaps worldwide. Egoz urges the establishment of a just economic and political system where these values are not only discussed but are implemented and maintained effectively (Egoz, 2019).

In relation to the International Federation of Landscape Architects (IFLA) and its International Landscape Convention, these principles are accentuated with the aim of fostering a more holistic, democratic approach to sustainable development. Egoz outlines the significant role of landscape architects in instigating landscape changes in public spaces, emphasizing their inherent political role (Egoz, 2019). This comes with the responsibility to ensure that their works align with and propagate the principles of equity, democracy, and social justice.

Egoz references critiques such as Brown and Jennings, who have pointed out a denial or lack of acknowledgment of this political role within the field of landscape architecture, especially regarding social justice matters (Egoz, 2019). They champion education that raises social consciousness within the profession.

Egoz notes the evolution of discourse on landscape justice and landscape democracy, where definitions and precise parameters are still being solidified (Egoz, 2019). This is reflected in the context of the European Landscape Convention (ELC), which endorses the Council of Europe's humanist and democratic values. This sets high standards for landscape architects, especially when operating in environments marked by economic and social uncertainties and increasing economic disparity.

In an attempt to address social sustainability effectively, Egoz proposes claiming landscape as a crucial element for well-being (Menatti et al., 2022).This involves the introduction of the idea of the "right to landscape." This concept implies that access to, and interaction with, sustainable and beneficial landscapes should be regarded as a fundamental human right. It acknowledges the significant contribution of landscapes to individuals' and communities' quality of life, and psychological and physical well-being (Menatti et al., 2022).

By concentrating on the "right to landscape," Egoz suggests that landscape architects can play a pivotal role in promoting and upholding social sustainability (Menatti et al., 2022). This can be achieved not only through the landscapes they design but also through their advocacy for more inclusive, equitable, and democratic policies and practices related to landscapes and the built environment.

Green Infrastructure for Social Life

Green infrastructure, defined as an interconnected network of natural areas including waterways, wetlands, woodlands, wildlife habitats, parks, conservation areas, and other green spaces, has become increasingly significant in sustainability discourse and practice (Egoz, 2019). This model, which emphasizes multifunctionality, was inspired by the pioneering works of landscape architects like Olmsted and McHarg, as well as the integration of ecology into contemporary landscape design. Green infrastructure is applauded for its ecological biodiversity value and its potential social and economic benefits, including sustainable engineering solutions for stormwater management and air quality improvement (Egoz, 2019).

As Benedict and McMahon argue, green infrastructure inherently embeds values of social sustainability, with its benefits accessible to all and its strategic placement reducing the need for conventional infrastructure, freeing public funds for other community needs ((Egoz, 2019). However, Egoz points out that its neutrality and supposed apolitical nature could be pitfalls in terms of landscape justice. She brings up the issue of 'green gentrification,' where the creation of green amenities in a city leads to an increase in l'ving costs, thereby resulting in social injustices (Egoz, 2019).

Egoz cites environmental psychologist Melissa Checker's exploration of the "paradoxical politics of urban sustainability" and the phenomenon of environmental gentrification, arguing that such processes subordinate equity to profit-driven development

(Egoz, 2019). Egoz also refers to Slavoj Žižek's concept of the 'post-political era,' where politics are practiced by professional experts, and Zygmunt Bauman's theory of 'liquid modernity,' which describes a state of constant flux and fragmentation in structures. In this context, landscape architects could unwittingly join the ranks of 'enlightened technocrats' and contribute to the depoliticization of the field (Egoz, 2019).

The inherent acceptance of the intrinsic value of nature, embedded in both sustainability and landscape, may conceal or even legitimize discriminatory dimensions. Egoz cautions that sustainability planning can become part of a 'post-political project' that sidelines real political inclusion and justice (Egoz, 2019). The technical aspects of sustainability, including green infrastructure planning, form the core of landscape architecture's professional practice, serving as a crucial means to materialize environmental sustainability. However, they often compromise the social component, disassociating sustainability from justice (Egoz, 2019).

In conclusion, Egoz reiterates the importance of recognizing landscape as infrastructure for social life and the potential naïveté of decoupling landscape and politics. This theme also underlies the concept of landscape urbanism, a controversial suggestion for a new, ecologically driven method for organizing cities (Egoz, 2019).

Part III: Climate Change Adaptation in Norway

The issue of climate change adaptation has been gaining global attention, and urban areas, undergoing rapid changes due to urbanization, are at the forefront of this shift (Klausen, J. et al., 2015). In Norway, this trend is accentuated due to a specific policy direction called the 'compact city' planning paradigm. While this paradigm is designed to foster sustainable urban forms, it has the potential to expose densely populated areas to climate change impacts such as heavy rainfall and flooding. As mentioned in the introduction, there is a 55% rise in water damage incidents since 2008 signifies the urgency of prevention measures (Finance Norway, 2023). Therefore, understanding the dynamics of public-private partnerships and their implications for climate change adaptation strategies is crucial.

The Challenge of Urban Stormwater Management

Stormwater management in Norway, also known as "overvannshåndtering," involves the careful allocation, secure discharge, and potential treatment of stormwater. This approach intends to safeguard health, environmental and infrastructural elements while simultaneously considering stormwater as a resource (Miljødirektoratet, 2023). The methodology emphasizes harm prevention through strategies that enable maximum groundwater infiltration or water collection and its gradual discharge. Such solutions, which adhere to the water's natural cycle, can minimize the effects of potential damage while contributing positively to the urban environment (Miljødirektoratet, 2023)

However, the effectiveness of such strategies can vary depending on local conditions, requiring stakeholders to carefully assess the suitability of various stormwater management measures. Consequently, all entities that influence or are affected by stormwater, including individuals, households, private corporations, and governing bodies, are compelled to engage in stormwater management (Miljødirektoratet, 2023)

Furthermore, it is crucial to apply knowledge about climate change and its expected impacts to inform stormwater management strategies. This is stipulated in the state planning guidelines (SPR) for climate and energy planning and climate adaptation, specifically in Chapters 4.1 and 4.2 (State Guidelines for Climate and Energy Planning and Climate Adaptation, 2018)

The statutory guidelines for climate and energy planning and climate adaptation provide a comprehensive framework for addressing these challenges in Norway. However, they also present difficulties concerning interdisciplinary assessments and municipal capacities. Issued under the Planning and Building Act, these guidelines are designed to ensure that climate adaptation is integrated throughout planning processes, highlighting the vital role of municipalities in this respect (State Guidelines for Climate and Energy Planning and Climate Adaptation, 2018).

A noteworthy aspect of these guidelines is the endorsement of nature-based solutions (NbS) for climate change mitigation and adaptation where feasible, with clear justification required if NbS are not implemented. As the guidelines specify:

> *Conservation, restoration, or establishment of nature-based solutions (such as existing wetlands and natural streams or new green roofs and walls, artificial streams, and pools, etc.) should be considered. If other solutions are chosen, it should be justified why nature-based solutions have been disregarded" (State Guidelines for Climate and Energy Planning and Climate Adaptation, 2018) (Chapter 4.3).*

In addition to mitigating adverse impacts, stormwater can also be harnessed as a beneficial resource. The planning and implementation of nature-based solutions can yield economic benefits and positive effects on both the natural environment and public health. Examples of such measures include the creation of open ponds and streams, which not only act as flood barriers but also enhance the urban landscape (Miljødirektoratet, 2023)

Green infrastructures can aid in stormwater retention through ground infiltration and plant uptake, reducing runoff and maintaining groundwater levels. Nature provides invaluable ecosystem services, such as flood mitigation and water and air purification. Municipalities can produce positive outcomes for both the environment and residents by aligning with nature and facilitating natural processes (Miljødirektoratet, 2023)

Urbanization Trends Leading to Vulnerability to Stormwater

In the context of urban policy agendas, the process of adapting to climate change has begun to command considerable attention, a trend observed not just in Norway, but also on a global scale (Klausen, J. et al., 2015). As the climate transitions, new factors necessitate their integration into urban planning and development. Such considerations are becoming increasingly pertinent for a range of stakeholders, including governments and developers.

Norway, like many other countries worldwide, is witnessing an enduring trend of urbanization, intensifying the burden on limited urban spaces (Klausen et al., 2015). This strain is further exacerbated by the prevailing “compact city” planning paradigm, discernible in the national planning guidelines advocating integrated land use and transport, as well as in the adoption of local densification policies (Petter Næss et al., 2009). This paradigm responds strategically to the challenge of cultivating a sustainable urban form, with a focus on, among other objectives, reducing carbon emissions from the transport sector (St. meld. Nr. 31 1992-93)(Petter Næss et al., 2009).

Consequently, municipal densification policies have spurred the development of centrally located brownfield areas, which often encompass former harbor locations and deserted industrial zones situated along rivers and the sea (Klausen, J. et al., 2015). These locations have garnered considerable interest from potential homeowners and profit-driven developers.

The shift towards the compact city planning paradigm, however, has led to increased densification and subsequently heightened vulnerability of urban spaces to climate change impacts. While it is recognized that climate change adaptation measures are slowly being integrated into urban planning and development initiatives in Norway, progress has been inconsistent and reliant on the capacity and willingness of both public and private actors.

Climate predictions indicate an uptick in the frequency of heavy rainfall and rising sea levels in Norwegian cities, which could potentially trigger landslides and flooding in densely populated areas characterized by impervious surfaces (Hanssen-Bauer et al., 2009). As a result, the most desirable development areas may become increasingly susceptible to climate change impacts.

The role of public engagement in urban planning and development in Norway is changing, with an evolving dynamic of negotiations between private and public entities. Given that private actors develop between 80 to 90 percent of approved and legally binding plans, there is a move towards a more reactive public role. Klausen et al.’s study underscores that this transition necessitates robust collaborations between the public and private sectors to address climate change adaptation effectively (Klausen et al., 2015).

The Office of the Auditor General of Norway's Critique of the Norwegian Government's Climate Adaptation Efforts

Building upon the discussion about the critical role of public and private actors in urban climate change adaptation, the critique from the Office of the Auditor General of Norway (Riksrevisjonen) adds an important dimension. In a recent report, Riksrevisjonen criticized the government's climate adaptation efforts, identifying several key areas needing improvement, such as insight into climate adaptation status, interdepartmental coordination, and information provided to the Norwegian Parliament (Stortinget) (Riksrevisjonen, 2023).

Riksrevisjonen criticized the lack of comprehensive oversight of climate adaptation within individual sector departments and highlighted the challenges faced by municipalities in implementing protective measures against natural hazards for existing buildings and infrastructure. It specifically called out the Ministry of Transport and Communications (Samferdselsdepartementet) for insufficient knowledge about the vulnerability of existing transport infrastructure to future climate changes. Riksrevisjonen also critiqued the Ministry of Climate and Environment (Klima- og miljødepartementet) for inadequate reporting in its annual budget proposal, making it difficult to assess progress towards the broader goal of bolstering the country's resilience against climate change (Riksrevisjonen, 2023)

A lack of cross-sectoral strategy or plan was identified as a key failing in the government's climate adaptation approach. The weak coordination between departments and the absence of an updated cross-sectoral plan for climate adaptation was criticized (Riksrevisjonen, 2023).

Highlighting the lack of a cross-sectoral strategy or plan, Riksrevisjonen recommended that the government develop such a plan, improve reporting to Stortinget, and undertake measures for better mapping of natural hazards and protecting existing infrastructure against future climate changes. The critique underscores the need for a more coordinated and proactive approach to climate adaptation, necessitating comprehensive planning, better status overviews, and concrete reporting on results and challenges in climate adaptation work (Riksrevisjonen, 2023).

Policy and Regulations for Stormwater Managemet

"Polluters-Pay-Principle" (PPP) And the Unintended Consequences on The Many

Considering the above discussions, the legal dimensions of climate change adaptation and stormwater management in Norway acquire significant relevance. Addressing climate change impacts, such as stormwater management, transcends planning and development concerns and extends to legal responsibilities. The legal debate often revolves around the ambiguity of roles and responsibilities in this context, which this section will explore further.

The legal framework for addressing flooding caused by surface water is complex and multifaceted. Addressing the effects of climate change, such as stormwater management, is not merely an issue of planning and development but also a matter of legal responsibility, as one of the critical points of contention in the legal debate is the ambiguity of roles and responsibilities (miljødepartementet., 2015; Taubøll, 2018; Taubøll & Paus, 2022).

Norway's stormwater management is currently governed by a complex web of statutes, regulations, and guidelines. These include but are not limited to, the Planning and Building Act, the Water Resources Act, and the Pollution Control Act. However, these statutes have been criticized for their complexity and the ambiguities they produce, notably around the assignment of roles, responsibilities, and liabilities in the face of stormwater-induced damages.

The complexities around stormwater management are further pronounced by the nature of the 'Naturskadeforsikringsordningen' – the Natural Disaster Insurance Scheme. Under this scheme, all properties with fire insurance are automatically covered for natural disasters, including storms, landslides, floods, storm surges, earthquakes, and volcanic eruptions. From 2023, meteorite impacts and tidal waves are also considered as natural disasters(Finance Norway, 2023). Yet, surface water flooding, often resulting from inadequate stormwater management and increasingly frequent with climate change, is not classified as a natural disaster and is therefore not covered by the Natural Disaster Insurance Scheme.

Instead, it's deemed a pollutant, implying the need for effective management to prevent damages. This distinction complicates the allocation of liability as the pollutant, i.e., water, moves through the territories of different responsible entities before causing harm.

Intricacies arise when considering the principle that landowners are liable for managing stormwater on their premises. This principle, derived from the *'polluter-pays principle'* [1]of environmental law, may not fully apply to stormwater management due to the distinctions between the general scope of environmental regulation and the more specific challenges of stormwater (Bugge, 2019; Skullerud, 2022).

This situation is further complicated by the fact that surface water flooding can be influenced by human activities, such as urban planning involving various stakeholders. Therefore, determining liability becomes more convoluted as the water, considered a pollutant, flows through the territories of responsible entities before inflicting damage.

Taubøll and Paus (2022) argue that stormwater, under specific circumstances, can be as destructive as natural disasters, further complicating the intertwined nature of natural and human-influenced factors. They recommend improved understanding and management of these overlapping considerations to ensure effective mitigation and adaptation strategies for climate change effects.

While these guidelines offer a comprehensive framework, they do not eliminate the ambiguities and challenges associated with stormwater management. In addition to the need for interdisciplinary evaluations that intertwine scientific assessments, vulnerability analyses, and economic considerations, there's also a critical need to augment municipal capacities for effective local management of climate adaptation.

Moreover, the recent provision in the 'Lov om endringer i sivilbeskyttelsesloven mv'. (Changes in the Civil Protection Act) introduces a new possibility in stormwater management, with the ability to use valuable insurance data for risk and vulnerability analysis. However, this provision also brings up questions about privacy and data protection, which will need to be addressed.

Social and Political Implications of Current Policy

The Norwegian Ministry of Local Government and Modernization, the Environment Agency, and the Directorate for Building Quality proposed new regulations for stormwater handling. The proposed regulations, which are rooted in the Norwegian Building Regulations, or TEK 17, lay out specific measures for managing stormwater to mitigate flooding risks due to increased rainfall intensity, a direct consequence of climate change. The TEK 17 is a vital document that stipulates the technical requirements for building works to

[1] The 'polluter-pays principle' is a major tenet of environmental law, stipulating that the party responsible for producing pollution should bear the costs of managing it to prevent damage to human health or the environment (OECD, 1972).

ensure that these meet essential health, environmental, safety, and energy measures (Norwegian Building Authority, 2017). The proposed changes to TEK 17 aim to strengthen the regulations regarding the management of stormwater to prevent flooding and its potential destructive impacts.

These regulations for stormwater handling have led to significant criticism, due to potential financial burdens (Gyldenskog, 2020; Høiseth-Gilje et al., 2018; Huseierne, 2020). These proposed regulations provide a compelling example of how climate change adaptation strategies, such as stormwater management, can be intertwined with socioeconomic and regulatory frameworks. This highlights the need to balance the efficacy of adaptation strategies with their financial impacts and policy implications for stakeholders.

However, Huseierne, representing homeowners' interests, expressed reservations about some aspects of these proposals. They expressed concern over the burden of the financial implications and the requirement of homes needing to withstand 200-year rainfall, which they deem as an overestimation that might lead to unnecessary costs (Huseierne, 2023). The regulation changes may inadvertently place a disproportionate financial responsibility on homeowners, with costs potentially running into hundreds of thousands of Kroner (Gyldenskog, 2020). These reservations echo the concerns raised by Gyldenskog (2020) about the potential financial burden on homeowners due to these regulatory changes.

While it is understood that the government's primary motive for these regulatory changes is to ensure the safety and protection of properties and lives, it is crucial to consider their potential socioeconomic impacts on stakeholders, mainly homeowners. The introduction of these stringent measures could have significant financial implications for homeowners, particularly when they are required to retrofit their properties to comply with the new regulations. Hence, it is critical that the government ensures a balance between ensuring the efficacy of these adaptation strategies and the potential financial impacts on homeowners.

Part IV: Nature-Based Solutions (NbS) as a Means for Equitable Adaptation

Nature-Based Solutions (NbS) have been integral in landscape architecture and urban planning, reflecting their increasing importance in response to climate change adaptation efforts, particularly in the realm of stormwater management (Brink et al., 2016). Despite not being a novel concept, NbS continue to be strongly advised in policies across various scales (European Commission, 2020; Miljødirektoratet, 2023; State Guidelines for Climate and Energy Planning and Climate Adaptation, 2018; UN-Habitat, 2022). In this light, this section delves into the strengths and weaknesses of employing NbS within such contexts, in addition to examining them from a systems thinking perspective (Liu et al., 2007).

Understanding Urban Ecosystem Functions

A primary motivation for employing NbS lies in the fact that they are underpinned by natural ecosystem services, which was first discussed in conservation biology and referred to as “Natures Services: Societal Dependence on Natural Ecosystems” (Loomes & O'Neill, 1997). The wording that an ecosystem has a service underlies that it is in service of someone or something. In urban contexts, these solutions are often perceived as technical, utilitarian, and instrumental in providing essential “services” (Williams, 2000). From a system thinking perspective in social sciences, ecosystem functions are regarded as having intrinsic value, rather than simply being harnessed for specific services (Liu et al., 2007). This will use the term ‘functions’, however, some literature is still embedded in the ‘services’ terminology, as it is well established in the natural sciences.

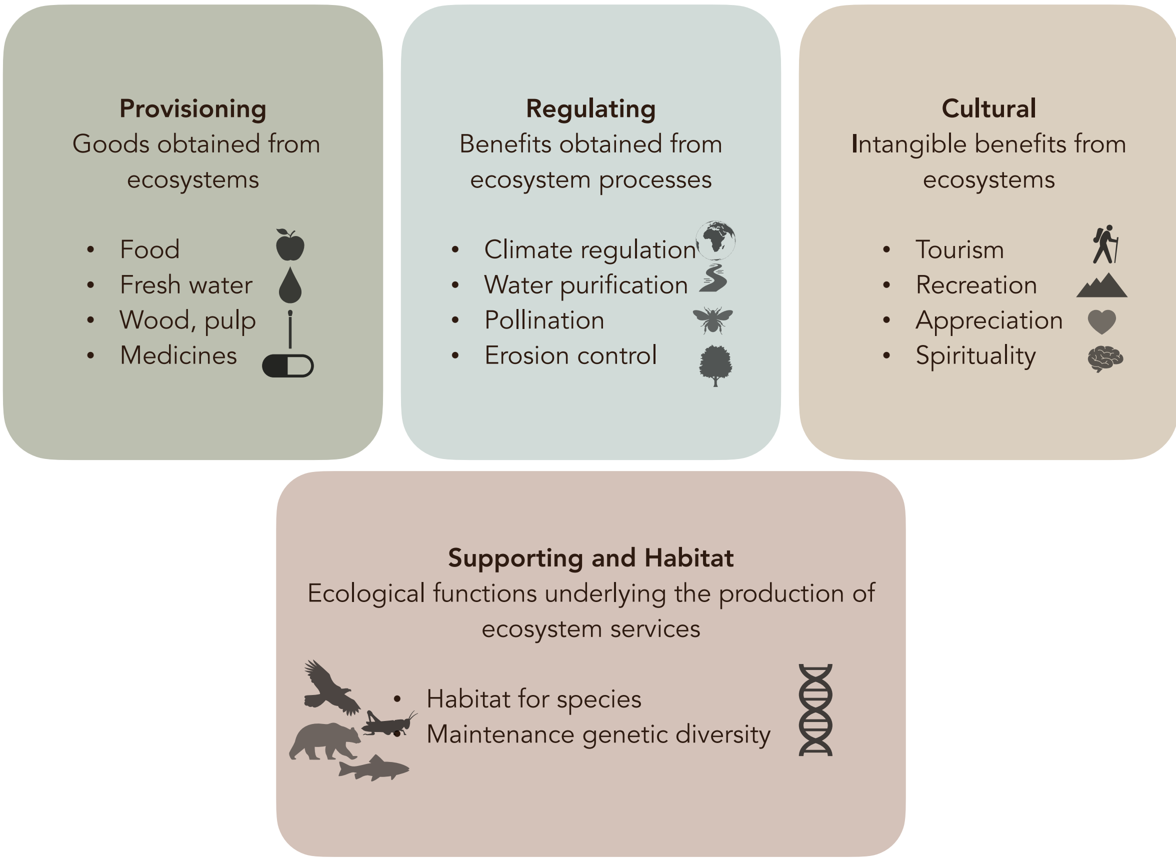


Figure 13 The classification of ecosystem services is based on the Millennium Ecosystem Assessment (MA 2005) and the Economics of Ecosystems and Biodiversity initiative (TEEB 2012).

Informed by prior ecosystem services categorizations (Daily 1997; de Groot et al. 2002), both the Millennium Ecosystem Assessment (MA 2005) and The Economics of Ecosystem Services and Biodiversity (TEEB 2010), ecosystem services can be divided into four principal categories: provisioning, regulating, habitat, and cultural and amenity services (TEEB, 2010). The multifaceted nature of ecosystem services necessitates comprehensive valuation across varied dimensions, including monetary, biophysical, socio-cultural, health, and insurance values (Gómez-Baggethun et al., 2013).

Exploring environmental justice values, it is apparent that social practices influence not only which ecosystem services are produced, but also *who* benefits from them (Andersson et al., 2007). Environmental justice, as explored within urban political ecology, concerns balanced access to ecosystem services and equitable distribution of exposure to pollution (Hofrichter, 1993; Ernstson, 2012). Urban growth often necessitates the appropriation of ecosystem services from the surrounding environment, creating ecological distribution conflicts (Hornborg, 1998). Hence, an important value of urban ecosystem services is their potential to reduce the ecological footprint of cities (Folke et al., 1997; Rees, 1992). Gutman (2007) emphasizes this, calling for a new urban-rural compact that balances sustainable ecosystem services provision and economic opportunities.

Turning to insurance values, urban ecological infrastructure, and ecosystem services contribute significantly to city resilience, enhancing their capacity to adapt to disturbances, climate change, and other global shifts (Gómez-Baggethun and de Groot, 2010). Crucial ecosystem services such as urban temperature regulation, water supply, runoff mitigation, and food production can serve as a form of insurance, reducing the vulnerability of cities to shocks. For instance, urban temperature regulation can mitigate the effects of heat waves (Lafortezza et al., 2009), and urban vegetation can reduce the likelihood of damage by flooding and storms (Villarreal and Bengtsson, 2005).

Given the essential role of urban ecosystem services in promoting environmental justice and bolstering city resilience (Gómez-Baggethun et al., 2013), it becomes clear that nature-based solutions (NbS) represent a vital tool for sustainable urban development (European Commission, 2020; UN-Habitat, 2022). As cities grapple with the intersecting challenges of climate change, growing population densities, and socio-economic inequities, it is of paramount importance to leverage the intrinsic functions of ecosystems in a manner that serves the collective and reduces our impact on the surrounding environment (Liu et al., 2007).

NbS offer a strategic avenue to harness the insurance value of ecosystem services, transforming the traditional urban fabric into a dynamic, resilient system capable of withstanding environmental disturbances and climate shocks (Gómez-Baggethun and de Groot, 2010). The core philosophy underpinning NbS revolves around working with nature, instead of against it, ensuring a symbiotic relationship between urban life and the natural environment (Brink et al., 2016).

The Intricacies of Nature-Based Solutions (NbS) for 'Regulating' Ecosystem Functions

Nature-Based Solutions (NbS) not only incorporate elements of the natural environment into urban planning, but they also aim to mimic the complex interactions and resilience of natural ecosystems. One such interaction is demonstrated in the network of connections within forests. Trees, through an intricate underground web of fungi, exchange nutrients and sugars, relay stress signals, and support each other in a symbiotic relationship, demonstrating the potential of NbS for efficient resource sharing and resilience against environmental stresses (Sala, 2020; Bowman, 2020).

Figure 14 The symbiotic network within forests – a model for NbS. Created by the author of theisis. Ecology principles from Bowman and Sala (Bowman, 2020; Sala, 2020).

This ecological network found within forests symbolizes the core of NbS: leveraging natural, cost-effective, and renewable processes to address urban environmental challenges. They can offer cities various benefits, such as improved stormwater management, urban temperature regulation, and enhancement of urban biodiversity (Kabisch et al., 2016; Lafortezza et al., 2009; Villarreal and Bengtsson, 2005). Furthermore, the introduction of NbS can reduce the ecological footprint of cities, leading to a balance of sustainable ecosystem provision and economic opportunities (Folke et al., 1997; Rees, 1992; Gutman, 2007).

The last two last illustrations in this section highlight the difference between the natural hydrology leveraged by NbS and the typical hydrology of urban areas with non-permeable surfaces. In the conventional urban layout, impermeable surfaces and shallow pipes restrict root growth and neglect the natural water flow processes. However, NbS aim to change this scenario by creating permeable surfaces that promote deep root growth and mimic natural hydrological flows, which can significantly reduce stormwater runoff and enhance urban resilience.This topic exceeds the thesis aim, but it is worth mentioning that increased biodiversity and ecosystem health is crucial for achieving nature based solutions that can have a regulating ecosystem function.

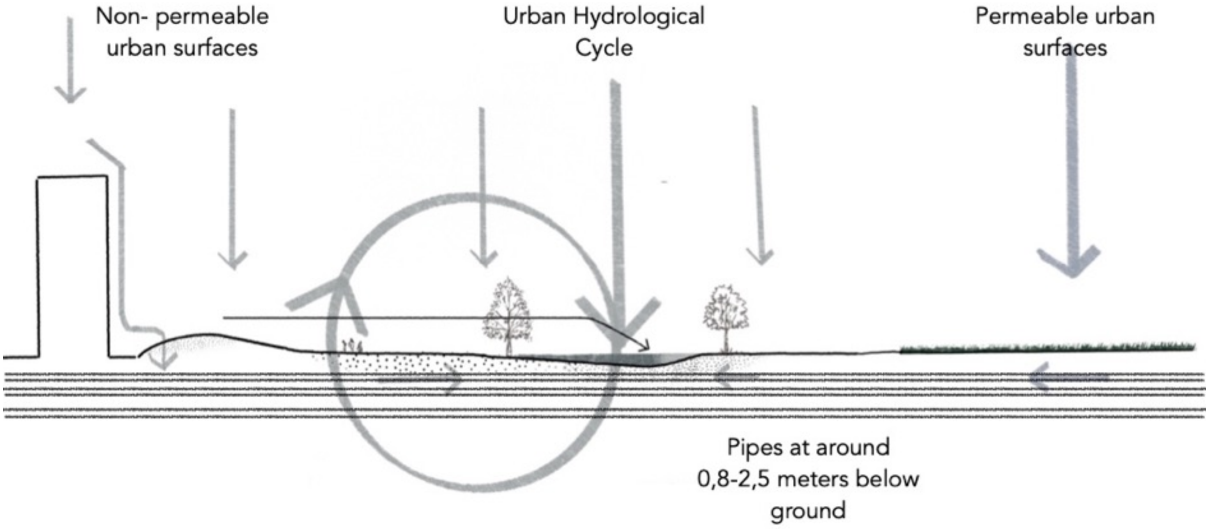


Figure 15 Illustration of urban hydrology with non-permeable surfaces and shallow pipes. Created by thesis author.

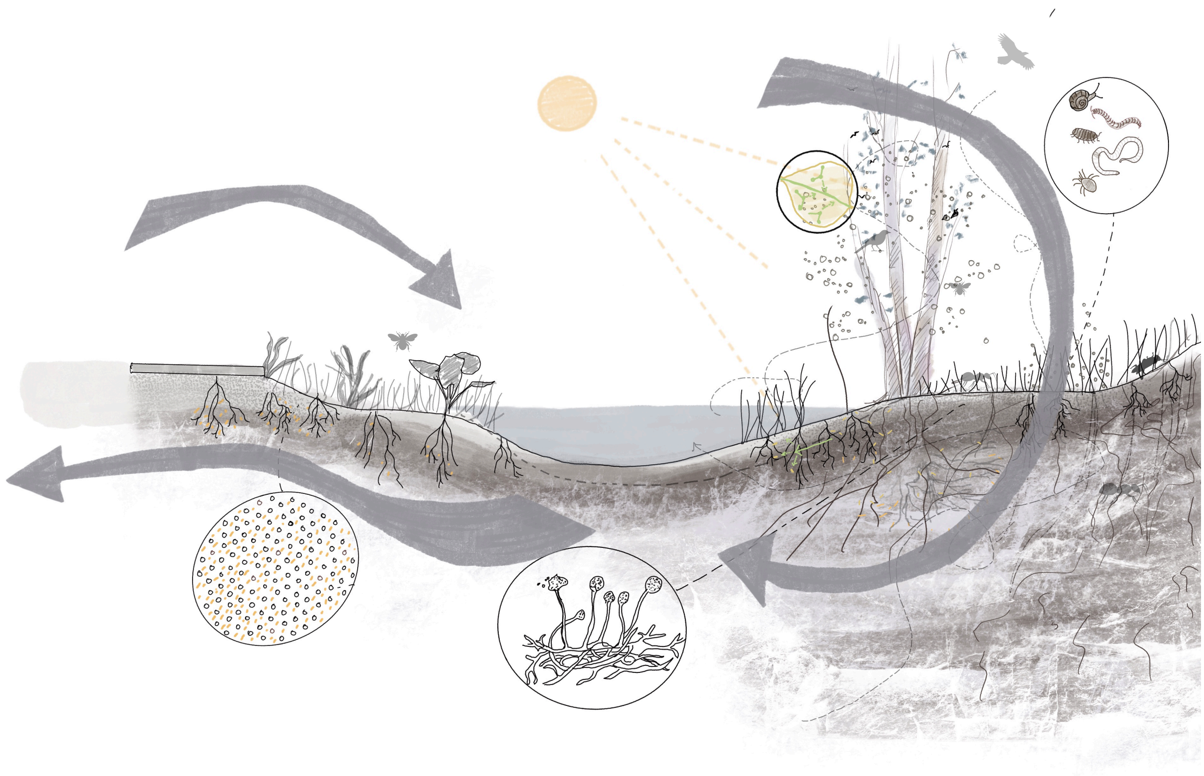


Figure 16 Illustration of natural hydrology in NbS. Created by thesis author.

The Norwegian “tretrinnsstrategistrategi”

Or the three-step strategy exemplifies NbS in open stormwater management. This strategy underscores the preference for NbS over conventional ‘grey’ infrastructure, aligning with the ethos of NbS (NOU, 2015:16; Oslo Municipality, 2014).This strategy is designed to handle rainwater locally, in a way that mimics natural processes (NOU, 2015:16)s. The three steps involve:

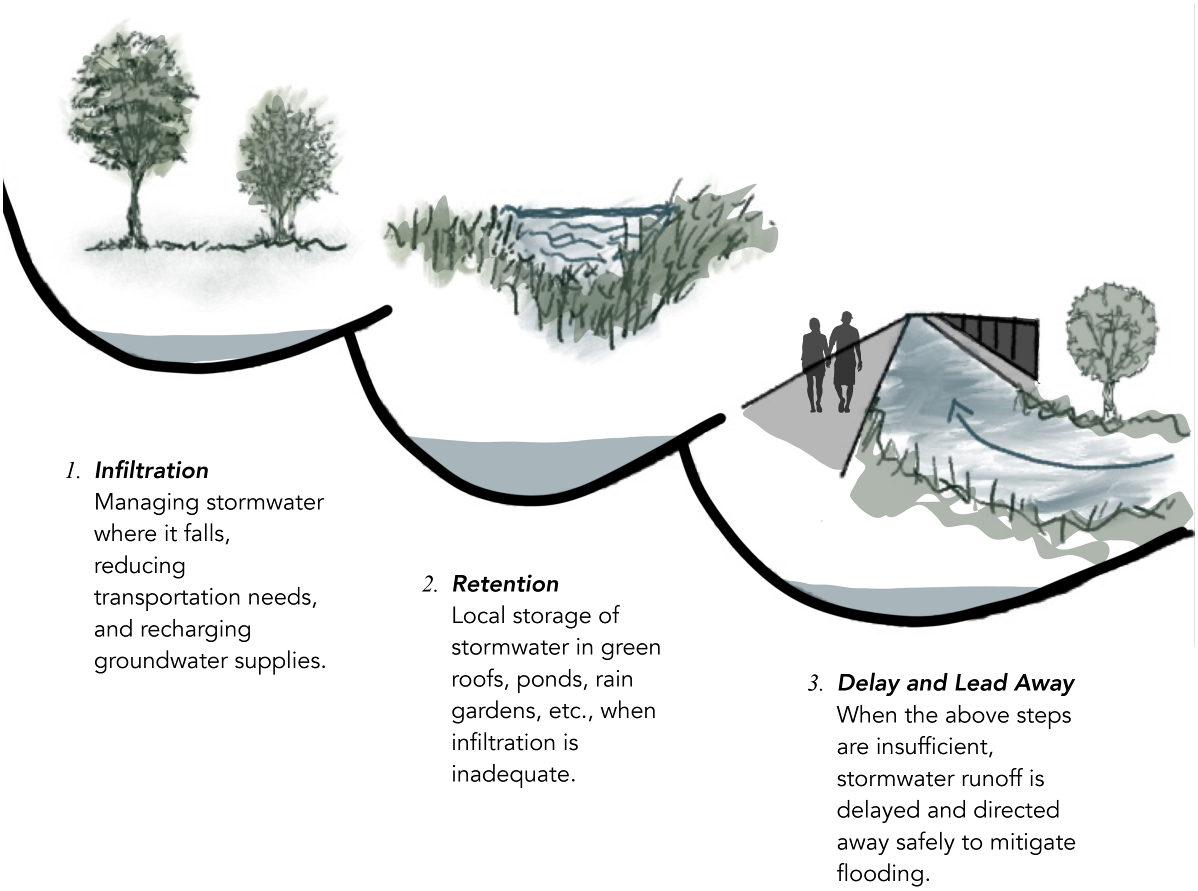


Figure 17 The Norwegian concept of “trinnvis strategi” or the three-step strategy exemplifies NbS in open stormwater management – Mimics the natural process. Created by thesis author, based on concepts on national stormwater management (Oslo Municipality, 2014)

Social Dynamics of NbS

The ecological benefits of NbS are indisputable. However, their influence extends beyond the environment, touching the very social fabric of communities they inhabit. NbS, such as green spaces, urban forests, or bioswales, can significantly improve air and water quality, moderate local temperatures, provide recreational spaces, and even enhance local real estate values (Tzoulas et al., 2007; Pataki et al., 2011). However, these benefits do not always accrue equitably among different societal groups.

In a study by Wolch, Byrne, & Newell (2014), they argue that the distribution of green spaces often favors affluent neighborhoods, inadvertently contributing to social inequality. A similar observation was made by Boone et al. (2009), who highlighted disparities in access to green spaces between different socio-economic groups in Twin Cities, Minnesota. In Norway, the data suggest no different, with green spaces linked to a higher property value The stark contrast in green space availability between wealthy and less affluent neighborhoods underscores the urgent need to consider social justice in NbS deployment.

The prospect of nature-based solutions in urban environments has implications for social justice. As Cucca et al. (2023) argue in their comprehensive review of the literature, green urban development, while generally positive, can have potentially overlooked community trade-offs. A particular concern is a process of "*green gentrification*", where an environmental planning agenda may result in the displacement or exclusion of economically vulnerable populations(Cucca et al., 2023).

Moreover, their review shows that the role of other nature-based solutions like green facades, green roofs, or blue infrastructure in driving green gentrification has not been thoroughly examined. This reveals a significant gap in current knowledge and points to the necessity of exploring these areas further. This observation further supports our previous statement about the potential social implications and challenges of implementing nature-based solutions.

However, deploying NbS is not merely a *technical task*, it is also an exercise in the socio-ecological governance (Karen O'Brien et al., 2022; Klausen, J. et al., 2015). As we incorporate NbS into our urban landscapes, it's crucial that we acknowledge the environmental justice implications, ensuring equitable access to the benefits of ecosystem services and mitigating any disparities in exposure to environmental hazards (Hofrichter, 1993). Furthermore, we should consider the interdependencies between urban centers and their surrounding rural environments (Folke et al., 1997; Rees, 1992). To cultivate sustainable cities, we must foster a new urban-rural compact (Gutman, 2007), one that not only ensures the sustainable provisioning of ecosystem services but also facilitates economic opportunities for the rural areas.

Challenges and Risks of NbS

Despite their advantages, implementing Nature-Based Solutions (NbS) isn't without challenges. While NbS have potential for economic efficiency compared to traditional 'grey' infrastructure, quantifying their impacts, particularly in areas such as stormwater management, can be a significant challenge due to their complexity and inherent variability (Brown et al., 2015).

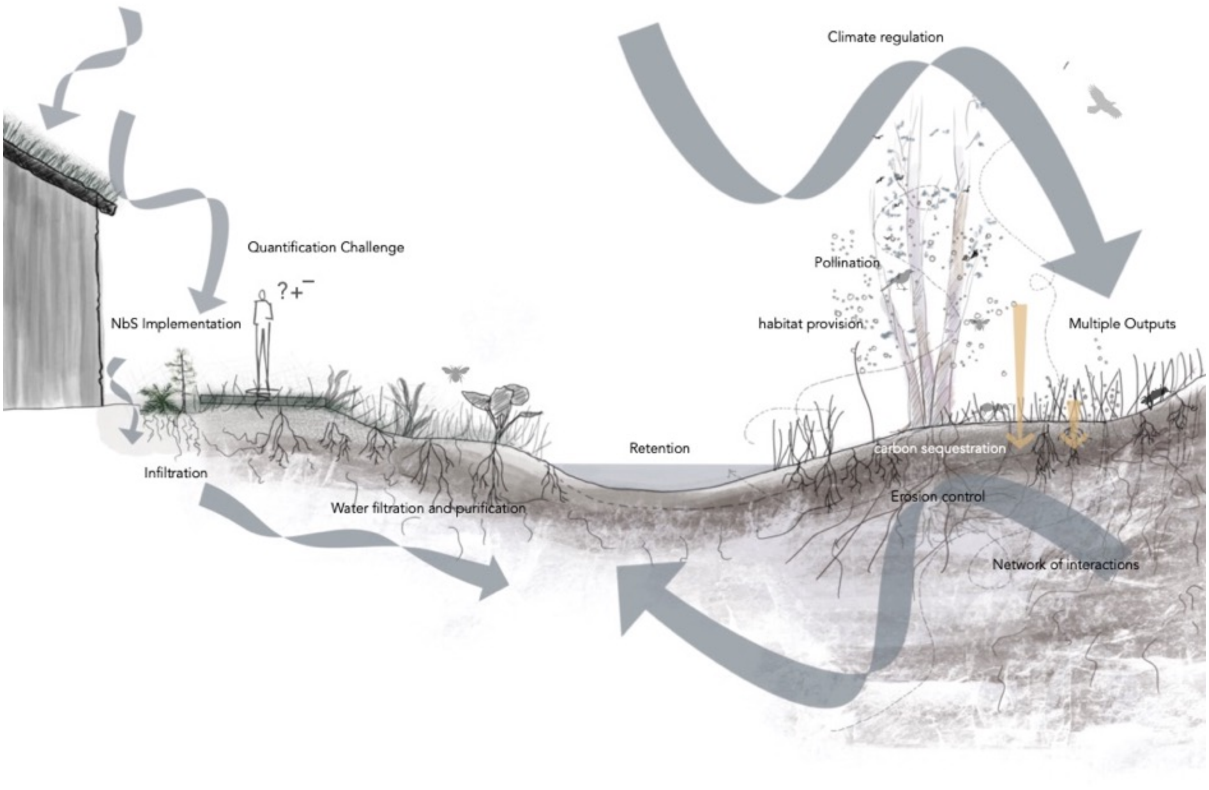


Figure 18 Figure 14: Diagram depicting the complex interactions within NbS and their challenge for quantification. Created by the author.

The scientific understanding of NbS is still evolving, and the unpredictability of their performance may deter their inclusion in larger projects or municipal plans (Ralph & Souter, 2015). Consequently, uncertainty is a fundamental limitation and risk in the application of NbS, which requires further research to resolve.

Furthermore, as highlighted by Nathalie Seddon, the financing of NbS projects poses another challenge. Market-based mechanisms often drive the funding for NbS, but these could be insufficient to cover the comprehensive costs associated with the long-term maintenance and management of these solutions (Seddon et al., 2019).

Importantly, NbS also have social implications. Some indigenous communities view NbS as potential tools for greenwashing or threats to their rights and local biodiversity (Seddon et al., 2019). Despite these challenges, NbS hold significant potential for urban resilience and climate change adaptation.

Trade-offs

The Case of Nature-based Solutions Technical responses to adaptive challenges, such as stormwater management, often result in tradeoffs. A popular effort to address such tradeoffs is the employment of nature-based solutions. These solutions are defined as "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (O'Brien et al., 2022, p.43). Nature-based solutions have been broadly promoted in both climate change mitigation and adaptation strategies.

Increasingly, integrated solutions are sought in sustainability efforts. Conservation funders, for instance, are integrating climate change adaptation into biodiversity loss strategies, as they consider this essential for sustainability (O'Brien et al., 2022). The IPCC special report on Climate Change and Land asserts that "Ecosystem-based adaptation can, in some contexts, promote nature conservation while alleviating poverty and can even provide co-benefits by removing greenhouse gasses and protecting livelihoods" (O'Brien et al., 2022, p.46). Furthermore, some argue that nature-based solutions can contribute to transformative change as they center on people and nature (O'Brien et al., 2022).

Despite the promise of nature-based solutions in helping to cool the planet and manage environmental challenges, it is important to note that these solutions can also be problematic if not carefully designed and implemented. For example, planting non-native trees or vegetation ill-suited to the local climate can adversely affect cities by threatening local species and water supplies. Similarly, coastal interventions such as 'natural' seawalls and sand reclamation can impact species diversity in the area (O'Brien et al., 2022).

Moreover, research has shown that if nature-based solutions are rooted in current socio-economic systems and neoliberal policies, they are unlikely to result in just socio-ecological futures and transformative change. A majority of these solutions are financed through carbon markets, expected to provide a financial return on investment. If these solutions are designed and implemented within current socio-economic paradigms, their transformative potential may be limited (O'Brien et al., 2022).

It is also crucial to consider the role of human agency in discussions of nature-based solutions, particularly in terms of who has power in deciding on the types, qualities, locations, and implementation of these solutions. The communication around these solutions and the role of human and non-human agency in their design and implementation is also significant. This again emphasizes the need for integrative approaches to transformations (O'Brien et al., 2022).

This body of research and evidence underscores the potential of nature-based solutions to address stormwater management challenges in Lillestrøm, as well as the potential drawbacks and limitations of these solutions. It adds an important dimension to the analysis, demonstrating that not only do technical and physical factors matter, but socio-economic systems and human agency also play a significant role in shaping the success and effectiveness of these solutions.

Chapter 4

Case Analysis of Lillestrøm

Lillestrøm, once a rural district, has transformed into a significant hub due to industrial and commercial evolution, especially after the railway's expansion in the 19th century (Askheim, 2023). The recent formation of Lillestrøm as a municipality provides a unique lens to study urban planning, economic development, and public service management. Geographically advantageous due to its proximity to Oslo, Lillestrøm has become an appealing location for commuters and businesses, thus offering insights into leveraging geographical advantages for economic growth.

However, the shift from industrial activities to increased urbanization, coupled with Lillestrøm's topographically exposed position, has amplified the city's vulnerability to stormwater challenges—a situation further magnified by climate change. This chapter explores these transformations, their implications for stormwater management, and the heightened vulnerability of the city to related issues.

Practical Facts

Lillestrøm, located in Akershus County, Norway, became a commercial hub following railway expansion in the 19th century. Its landscape comprises river courses, forest ridges, and varied terrain, including a rich nature reserve. Economically diverse, it's home to traditional industries, wholesale operations, Norway's largest exhibition and convention center, and significant agriculture. However, over half of the working population works outside the municipality. Lillestrøm's robust transportation network, with roads and railway routes, facilitates convenient commuting and strong connectivity to the urban node of Oslo.

Figure 19 Satellite Map, Google Earth Pro 2023, Lillestrøm City, approx. 17 kilometers areal distance.

The name Lillestrøm means “the little stream”, which refers to Nitelva, a small river flowing through the town. The city is known for its football club, Lillestrøm Sportsklubb, and its annual trade fairs. Lillestrøm’s proximity to Norway’s capital, Oslo, makes it an attractive location for commuters and businesses (Askheim, 2023)

Lillestrøm’s diverse landscape includes areas around the lower courses of the rivers Leira, Nitelva, and Sagelva as well as the forest ridges between these rivers. It has a varied terrain, featuring gneiss bedrock, marine clay, sand, and gravel. In the lower areas, peat bogs often get flooded in the spring. The municipality is also home to Nordre Øyeren nature reserve, which houses a unique array of plant and animal life and boasts significant fish stocks and over 250 bird species.

In terms of economy, Lillestrøm is quite diverse, featuring both traditional and relocated industry alongside wholesale and storage operations from Oslo. Despite this, over half of the working population works outside of the municipality. Lillestrøm is home to Norway’s largest exhibition and convention center, Norges Varemesse. Agriculture also plays a significant role in the municipality, with farms in Skedsmo having the largest average area in the country.

Historical Land-Use Changes

The historical land use changes in Lillestrøm have contributed to the city's vulnerability to stormwater management challenges. By understanding the implications of these changes and conducting spatial analysis to identify vulnerable areas, planners and policymakers can develop targeted interventions.

The industrial and commercial evolution of Lillestrøm, from a rural district to a significant hub, offers compelling insights for the case study. This transformation, triggered by the expansion of the railway in the 19th century, may serve as an intriguing example of how regional industrialization can catalyze profound economic and societal change (Askheim, 2023). Moreover, Lillestrøm's recent designation as a municipality provides a distinctive context for examining urban planning, economic development, and public service management within a newly formed municipality. The unique challenges and opportunities that stem from such a recent formation could inform broader discussions around effective municipal governance. Additionally, Lillestrøm's geographical advantage, due to its proximity to Norway's capital, Oslo, shapes its identity as an attractive location for commuters and businesses alike. This strategic positioning could offer valuable insights into how municipalities can leverage geographical advantages to foster economic growth and societal development (Askheim, 2023)

Lillestrøm's history is marked by a shift from an industrial base to a service-oriented urban center. Initially founded on sagbruksprivilegier (sawmill privileges) in the 1500s, the city experienced significant growth in the late 19th century with the establishment of railway services and industries, such as weaving factories, soap factories, ski factories, and dairies. By the late 20th century, Lillestrøm transitioned from an industrial city to a hub of commerce and services, leading to increased population density and urbanization (Lillestrøm Municipality, 2021).

Figure 20 Photo of Sawmill industry in Lillestrøm taken from the National Library's photo collection (Unknown Author, N.A)

Figure 21 Lillestrøm, By "Nitelven" River 1925(Carl Normann, 1925).

Urban Development

1775 Agricultural Society

What is today known as Lillestrøm was primarily a large marshland area. The area was uncultivated and very few people settled here. There were only a few farms and cottages.

1875 Industrialization and railway

From around 1850, many sawmills were established by the Nitelva river. The opening of the railway in 1854 made the transport of timber more efficient, which contributed to increased production.

1900 Growth, industry

Due to the large production in Lillestrøm, the city grew and new industries were established, including a weaving mill, soap factory, ski factory, and dairy

1956 Post-war period and 1947-plan

The city plan from 1947,vbased on the existing streets between villas made way for a number of new blocks. From industrial city to trade and service center. 1912, Norway's first airport opened at Kjeller.

1975 City Center Plan and Traffic Efficiency

In the 80s, there were expectations that Lillestrøm would be the regional center in Nedre Romerike. This also assumed a significant improvement and expansion of the traffic system. The city center plan for Lillestrøm (1987) placed great emphasis on traffic efficiency and the introduction of a city center ring with roundabouts.

2003 Trade Fair and Gardermoen Line

National Road 159 opened with a continuous tunnel through Lørenskog and to Oslo. The opening of the Gardermoen railway in 1997. Norges Varemesse opened the same year the "City Development and Urban Strategy - 2050 Perspective" was adopted.

2020 Strong Growth

Until 2011, the norm for building height in Lillestrøm was a maximum of 4 + 1 set back floor. After the municipal plan 2011-2022 opened for certain landmarks and signature buildings, and for variation in building height according to certain criteria, heights and volumes have varied.

Figure 22 Urban Evolution: The Journey of Lillestrøm from Marshland to Regional Hub. Adapted and translated from maps sourced from Lillestrøm Municipality (2021), 'Byutviklingsplan for Lillestrøm by Del 1' [Urban Development Plan for Lillestrøm City Part 1]. All rights reserved to the original source of maps, fitted and modified for thesis

Current Urban Context and Demographics

Figure 23
Aerial photograph from June 14th, 2015.
Part of city of Lillestrøm (Norway) with river Nitelva in the foreground.)
(GAD, 2015)

Housing and Living Conditions

As of 2023, the majority of residents (67%) own their homes, with most dwelling in detached houses (14,328) compared to apartment living (11,051). This housing typology may increase population vulnerability to weather-related disasters, as detached homes are often more exposed to elements than multi-family buildings (Statistics Norway, 2022).

Land Use and Infrastructure

The land use and built environment in Lillestrøm Municipality are significant factors to consider when analyzing vulnerabilities. Notably, the area has a high urban population, with 92% of residents living in urban areas in 2021 (Statistics Norway, 2022). This urban density, combined with an infrastructure that includes 7.13 km^2 covered by roads and 6.73 km^2 covered by buildings (Statistics Norway, 2022), may heighten vulnerability to urban heat[2] island effects and flooding due to reduced permeability[3].

[2] Urban heat island effect refers to the phenomenon where urban areas experience higher temperatures than surrounding rural areas due to human activities and the prevalence of built surfaces which absorb and re-radiate heat.
[3] Flooding due to reduced permeability arises when the number of impermeable surfaces (e.g., concrete, asphalt) in an area increase, reducing the soil's capacity to absorb water. This can lead to higher runoff volumes and speeds during heavy rainfall, increasing the risk of flooding.

Financial Data

The financial profile of Lillestrøm Municipality also provides insights into socio-economic vulnerabilities. In 2022, the community allocated a considerable portion of its budget to health and social care, at 30.1% and 4.5%, respectively (Statistics Norway, 2022). These sectors, which are already receiving a significant share of the municipality's resources, may be particularly vulnerable to the added stressors brought on by climate change.

Population Data

Finally, the size of the population of Lillestrøm Municipality, reported at 92,324 residents in the first quarter of 2023 (Statistics Norway, 2022)might intensify the scale of the vulnerabilities. Managing the impacts of climate change could be particularly challenging for larger populations, especially if resources are already strained.
This analysis is a preliminary overview of potential vulnerabilities in Lillestrøm Municipality. It should be used as a foundation for further research and planning to address climate change's specific impacts and challenges in this community.

Stormwater Challenges

As the city continues to densify, more land is covered with impervious surfaces, exacerbating stormwater management challenges. This densification trend is evident in practices such as the Apple Garden principle, where old villas are sold to large entrepreneurs and rebuilt into densified apartment blocks. The transformation from industrial land to urbanized areas has led to a decrease in natural drainage systems, such as wetlands and permeable soils, which can absorb and filter stormwater. The loss of these systems places greater strain on the city's stormwater management infrastructure and increases the risk of flooding. The reduction of natural vegetation also plays a crucial role. With its ability to absorb and filter rainwater, vegetation forms a key element of the natural stormwater management system. Its loss due to urban development and densification further intensifies the city's vulnerability to stormwater management challenges.The growing urban footprint of Lillestrøm, driven by the increasing demand for housing and commercial spaces, underscores the need for more effective stormwater management strategies. Future urban planning efforts must consider these environmental impacts to ensure Lillestrøm's continued resilience in the face of climate change and urbanization.

Lillestrøm’s Green Infrastructure and its Connection to Garden City Principles

The origins of Lillestrøm’s cityscape can be traced back to the Garden City model implemented in 1947. The essence, as noted by Swensen and Berg (2020), is the harmonious integration of the built environment with green spaces, aiming to cultivate healthier, balanced communities. The Garden City model’s principles have influenced the urban development contributing to its unique fabric where green and grey spaces coexist. However, the Garden City is not a static model, rather, it should adapt and evolve over time to accommodate changing societal and environmental contexts (Swensen & Berg, 2020). They propose this concept as a key element of the green infrastructure of the future, learning from past practices and integrating them into modern urban planning strategies.

Figure 24 Observed areas with gardens or the potential with gardens, based on the article ‘The garden city’ (Swensen & Berg, 2020).

In the context of Lillestrøm, this implies a forward-thinking approach to urban development, which involves maintaining the historical principles of the Garden City model, while simultaneously integrating contemporary urban planning strategies. This can be seen as a continual learning process, where past practices guide present and future decisions, ensuring the preservation of Lillestrøm's unique characteristics while meeting the needs of the modern urban dweller.

Figure 25 Observed green spaces from GIS tools and satellite images.

Current Climate Plan

At present, Lillestrøm Municipality does not have a dedicated plan for climate adaptation and mitigation to access, but is in the process of developing a forward-looking climate plan (Lillestrøm Municipality, 2023b). This plan aims to outline how Lillestrøm municipality should prepare itself on the path toward a low-emission society. A crucial focus area for Lillestrøm municipality will be to participate in creating markets for green solutions within construction, transport, food, and more. The new plan will build upon the work carried out in the three municipalities of Fet, Sørum, and Skedsmo before the merging of these local governments.

Flood Protection Infrastructure

In assessing the spatial factors contributing to pluvial flooding vulnerability in Lillestrøm, it is crucial to understand the city's established infrastructure for flood protection.

The city's flood protection system, centered around the Nitelva River, is a testament to Lillestrøm's adaptive capacity to flooding risks. Historically susceptible to floods, the city responded to the major Eastland flood in 1995 by constructing an extensive system of flood barriers ((NVE), 2021).This system, comprising a 7 km flood barrier, showcases how Lillestrøm has fortified itself against river flooding. The pump stations are a crucial element of the infrastructure, designed to prevent flooding by pumping rainwater and leakage water. To reduce disturbance and consider existing buildings, the crown of the flood barrier in certain areas is set one meter lower than the general flood barrier height. In these sections, it is anticipated that the barrier height can be increased as an emergency measure during significant floods. A drivable pedestrian and bicycle path has been established atop the flood embankment, adding a societal benefit to the protective infrastructure ((NVE), 2021).

Spatial Analysis In Lillestrøm

A spatial analysis of Lillestrøm was conducted to identify areas most vulnerable to stormwater-related problems. This analysis utilized GIS tools, Scalgo Live, Google Earth Pro, Kunnskapsbanken, SSB, to assess the distribution of impervious surfaces, drainage patterns, and flood-prone areas.

The Impact of a Flat Topography

Understanding the variables contributing to Lillestrøm's susceptibility to pluvial flooding and stormwater issues necessitates comprehensive site analysis. Naturally, drainage lines follow gravity's pull downhill. As indicated by the elevation map, Lillestrøm's topography is almost as flat as the river. The water table is another crucial factor influencing the city's capacity to manage stormwater effectively. As explained in "How to Read Water" (Gooley, 2016), rainwater filters through the earth until it hits an impervious rock layer where it accum'lates, constituting the water table.

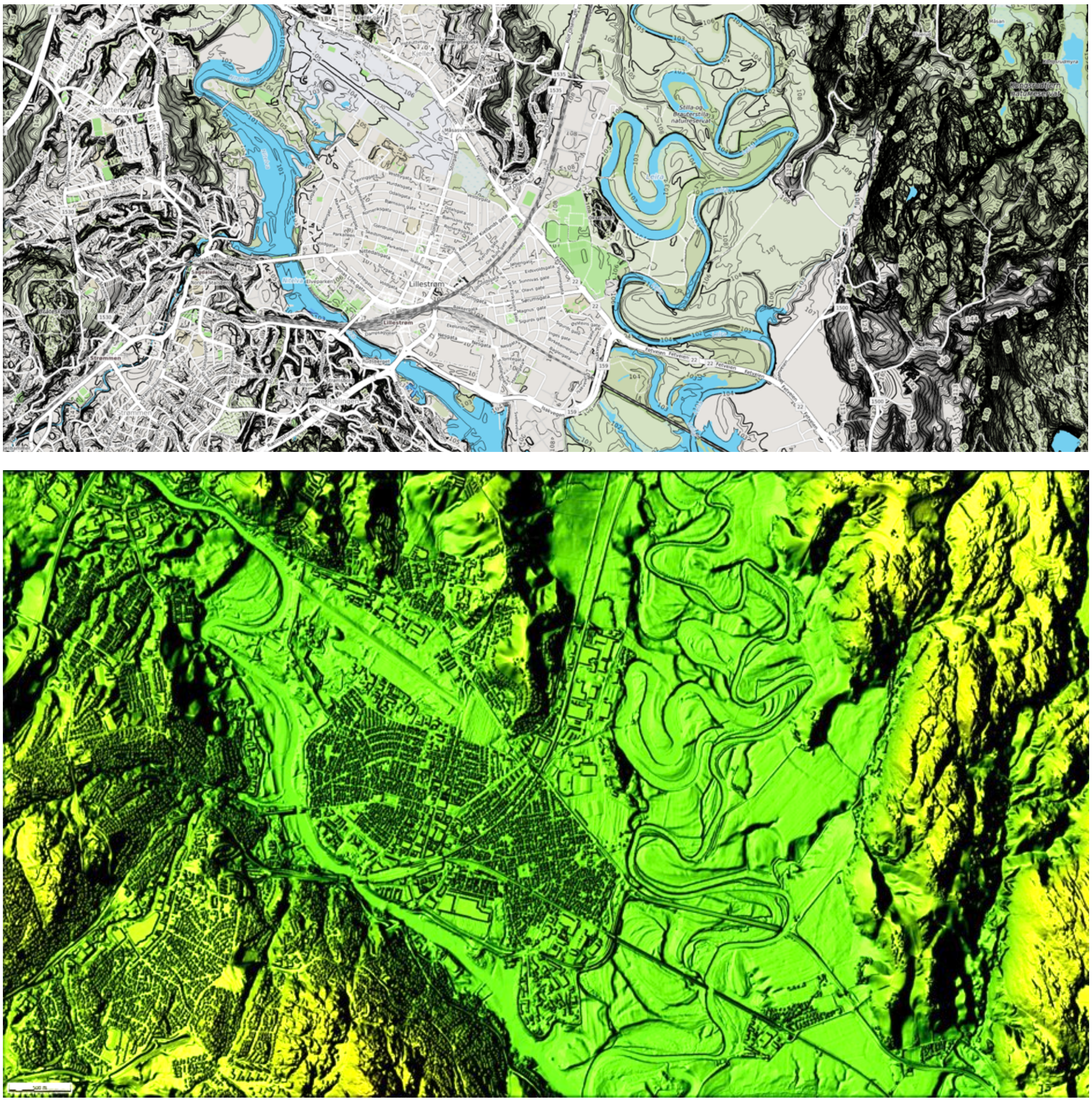


Figure 26 Elevation profile, terrain, and building contours of Lillestrøm, Norway. Using GIS tools in Scalgo Live as well as editing colors to enhance contrasts. Light green shows a lower elevation, and yellow a higher elevation profile. Depicts a clear flat topography in the city center, as well as the river – with surrounding hillsides.

Water Table Dynamics

The flat topography of Lillestrøm, coupled with the city's proximity to the river, could potentially heighten the risk of flooding and associated stormwater issues. . This flatness can significantly impact the soil's saturation capacity(Rasheed et al., 2022; Zhou et al., 2012), as flat urban landscapes with high water tables are more prone to stormwater complications. During river floodings, or fluvial floodings, this might also influence the water table in the surrounding areas. As a result, water saturation could increase and capacity could decrease, thereby generating a heightened vulnerability in the event of cloud bursts.

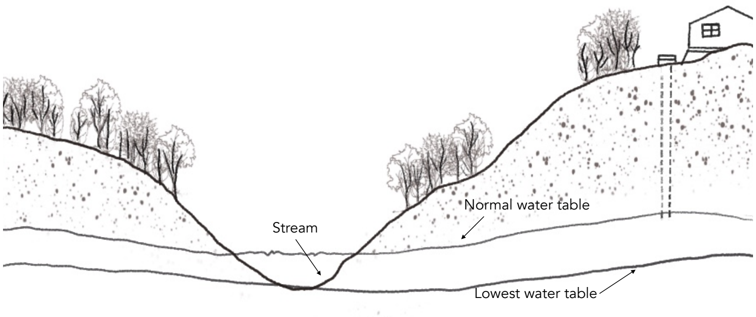


Figure 27 Predicting the depth of the highest water table reading nearby rivers. Created based on the principles in "How to read Water" (Gooley, 2016)

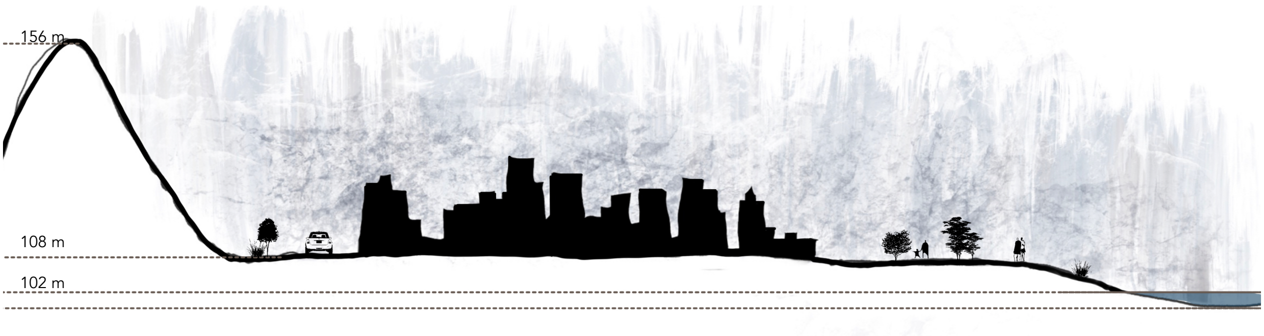


Figure 28 Section of Lillestrøm, Nitelva (river), on the west-southwest side and hillside (Sørumterrassen) at the north-northeast of the city. The highest and lowest water table is around 5-8 meters from the urban surface.

The Impact Of A Northern Climate On Saturation Capacity: Frozen Ground On Urban Drainage Systems

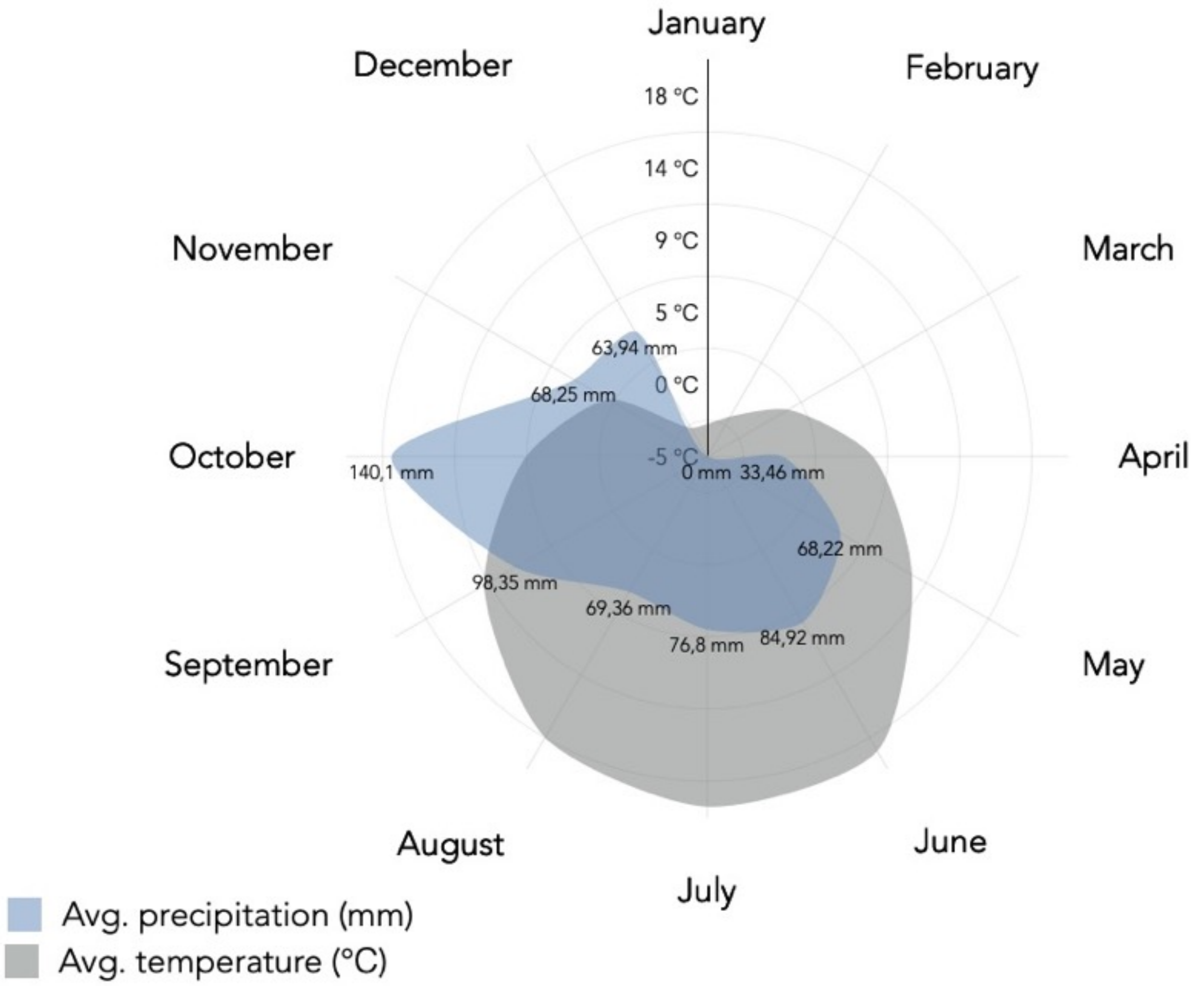


Figure 29 Annual cycle for Skedsmo. Average precipitation and temperature the last 5 years to visualize rainwater compared to temperature, and when to anticipate a frozen ground for reduced capacity .(Klimaservicesenter, 2023). Snow debt is not available but would be useful.

Colder climates, particularly in densely built urban areas, can face increased stormwater issues due to reduced ground water infiltration during winter. This is especially problematic during the transition from winter to spring (March-May), when ground thaw and rainfall coincide, leading to an elevated vulnerability to cloudbursts. This is evidenced by the record rainfall on April 25th (Aftenposten, 2023). Further investigation could include collaboration with insurance companies to better understand patterns of stormwater-related damages.

Insurance Data from Kunnskapsbanken and GIS Analysis

Two critical resources have been utilized to assess the risks and vulnerabilities associated with stormwater management in Lillestrøm: Kunnskapsbanken and a GIS analysis by Scalgo. The information from Kunnskapsbanken reveals that, as of 2021, Lillestrøm has recorded 3,541 cases of water damage with an insurance payout of around NOK 248,509,497 (Kunnskapsbanken, 2023). Given that Lillestrøm has a total building stock of 38,324 buildings, this data suggests that about 9.24% of all structures in the city have encountered water damage(Kunnskapsbanken, 2023)..

Meanwhile, the Scalgo GIS analysis identifies areas within the city that are highly susceptible to stormwater issues (Scalgo, n.a)Interestingly, many locations with a high incidence of water damage align with the areas that the GIS analysis marks as vulnerable to stormwater.

Despite these valuable insights, the data presents some limitations. For instance, the insurance data only accounts for reported insurance claims, implying the actual prevalence of water damage may be higher. This limitation particularly affects uninsured or underinsured households, whose damages are likely underrepresented.

Furthermore, the GIS analysis doesn’t incorporate other influential factors beyond rainfall, limiting its scope. Therefore, to comprehend fully the city’s vulnerabilities and to develop effective stormwater management strategies, further research and extensive data collection are necessary. Nevertheless, the current findings provide a crucial foundation for understanding Lillestrøm’s stormwater-related challenges and developing targeted mitigation strategies.

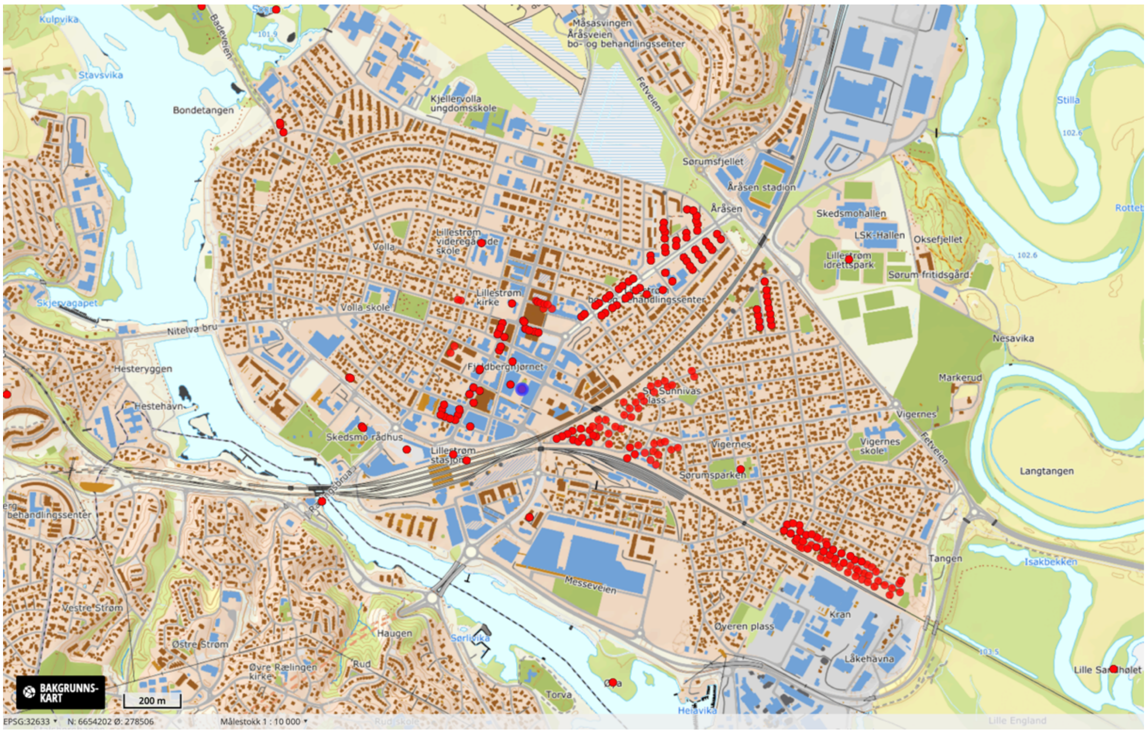


Figure 30 Data from Kunnskapsbanken.no depicting Insurance cases (Waterdamages, in claims)(Kunnskapsbanken, 2023)

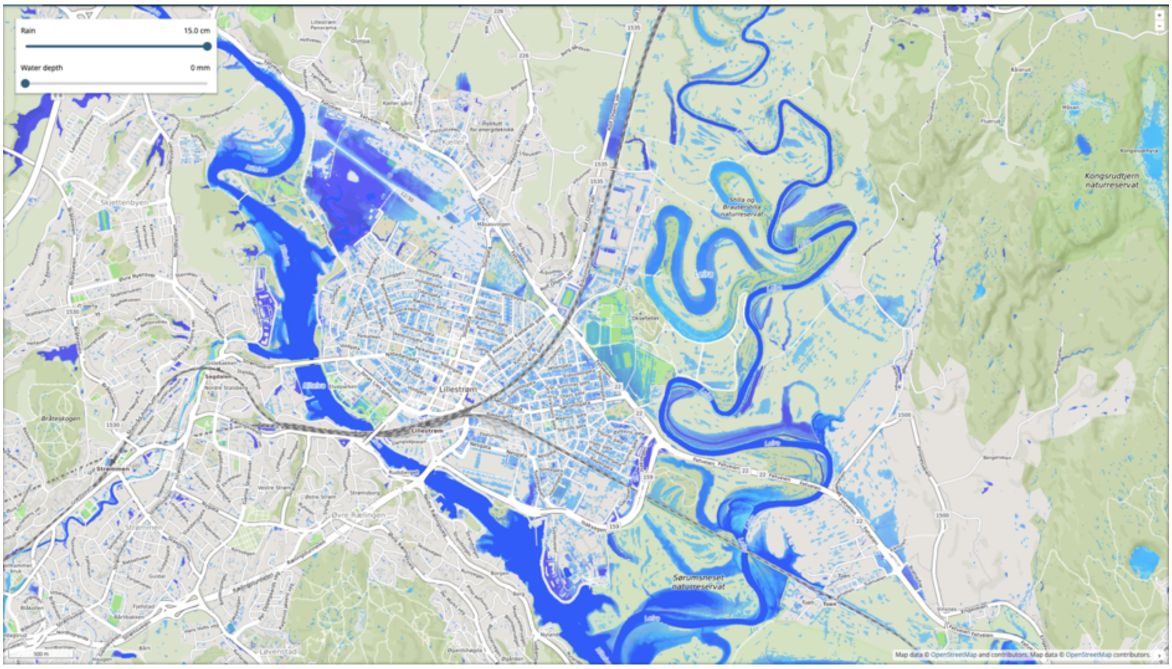


Figure 31 Flash Flood map analysis in Scalgo Live in Lillestrøm. Clearly, the entire area in the city is blue during extreme rainfall. This is not calculated for other factors and is anticipation(Scalgo, n.a).

Chapter 5

FINDINGS

Analysis Summary: Unveiling the Connections

This analysis employed a systems thinking approach, consistent with the principles of Earth System Science (Steffen et al., 2004), aiming to offer a holistic understanding of the situation. The study also adopted O'Brien et al.'s (2007) perspective on the root causes of vulnerability, emphasizing the inherent social and political constructs that exacerbate climate-related vulnerabilities.

Key findings revealed a complex web of connections and impacts across these spheres. In the social sphere, it was underscored how social vulnerabilities and injustices often intersect with the physical impacts of climate change, thereby amplifying the susceptibility of certain communities to stormwater issues.

In the political sphere, although Norway boasts robust climate change adaptation and mitigation strategies, the analysis illuminated certain ambiguities and complexities within the policy and legal framework that present challenges to effective stormwater management. Furthermore, the study highlighted the need for a clearer delineation of responsibilities and liabilities for stormwater management.

In the practical sphere, while nature-based solutions hold promise for adapting to and mitigating stormwater issues, it became evident that the interconnectedness of social and political factors can greatly influence the success and implementation of these solutions.This section covers key findings about the physical and technical aspects of stormwater management in Lillestrøm, discussing potential improvements or challenges identified, particularly in relation to the implementation of nature-based solutions.

In the following sections, this research delves deeper into each of these findings, elucidating how they interrelate within the broader stormwater management system and contribute to the overall vulnerability of Lillestrøm to climate-related stormwater issues.

Political Sphere Findings

The increasing concern for climate change adaptation, spurred by rapid urbanization, is prominent in densely populated areas. In Norway, this situation is underscored by the 'compact city' planning paradigm, a distinctive policy direction aimed at promoting sustainable urban forms. However, this paradigm also has the potential to expose population-dense areas to the impacts of climate change, such as intense rainfall and flooding. Given a 55% rise in water damage incidents since 2008, the urgent need for effective prevention measures is clear (Finance Norway, 2023). Hence, understanding the public-private partnership dynamics and their implications for climate change adaptation strategies becomes critical.

In Norway, the strategic allocation, safe discharge, and potential treatment of stormwater or "overvannshåndtering," is a crucial aspect of urban management. It's designed to safeguard the health, environment, and infrastructure while also recognizing stormwater as a beneficial resource (Miljødirektoratet, 2023). The approach emphasizes damage prevention strategies that align with the water's natural cycle and can mitigate the potential damage while positively impacting the urban environment (Miljødirektoratet, 2023).

However, the effectiveness of these strategies can vary based on local conditions, hence necessitating a meticulous assessment of various stormwater management measures by all entities influencing or affected by stormwater (Miljødirektoratet, 2023). This includes individuals, households, private corporations, and governing bodies.

In this context, it is crucial to apply the knowledge of climate change and its projected impacts on these strategies, as directed by the state planning guidelines (SPR) for climate and energy planning and climate adaptation (State Guidelines for Climate and Energy Planning and Climate Adaptation, 2018). These guidelines, although comprehensive, pose challenges concerning interdisciplinary assessments and municipal capacities. Notably, the guidelines promote nature-based solutions (NbS) for climate change mitigation and adaptation, necessitating a clear justification if NbS are not employed.

The planning and implementation of these nature-based solutions can provide economic benefits and significantly enhance both the natural environment and public health (Miljødirektoratet, 2023). Notable measures include the development of green infrastructures, such as open ponds and streams, which can serve as flood barriers and enhance the urban landscape. These infrastructures aid in stormwater retention, reducing runoff, maintaining groundwater levels, and providing invaluable ecosystem services including flood mitigation and water and air purification. Therefore, by aligning with nature and facilitating these natural processes, municipalities can deliver beneficial outcomes for both the environment and residents (Miljødirektoratet, 2023).

As climate conditions evolve, new considerations for urban planning, particularly in stormwater management, are imperative. This is a trend that is not just observable in Norway, but globally (Klausen et al., 2015). The significant challenge now lies in effectively integrating these considerations into planning and management strategies. The case study of Lillestrøm can provide valuable insights and lessons for other urban areas facing similar issues.

The study has spotlighted several significant policy gaps and promising opportunities related to stormwater management in Lillestrøm, Norway. These findings are particularly salient for climate change adaptation and mitigation.

A key policy gap identified is the fragmentation of the legislative landscape for stormwater management. Multiple agencies and government levels have overlapping responsibilities, leading to gaps and redundancies, and thus compromising the effectiveness of the overall management system (Taubøll & Paus, 2022). Streamlining these responsibilities and fostering enhanced inter-agency cooperation could markedly bolster the system's efficacy, enabling better mitigation and adaptation to the rise in stormwater due to climate change.

A second considerable gap relates to the unclear delineation of responsibilities and liabilities in stormwater management, which may provoke conflicts and inefficiencies, thereby obstructing effective and adaptive stormwater management (Bulkeley, 2010). It is crucial to ensure a clear delineation of responsibilities to promote accountability and facilitate effective management, adapting to the evolving climate realities.

The study also underscores the opportunity for a broader application of nature-based solutions in stormwater management. These solutions are beneficial as they enhance local biodiversity, offer recreational spaces, and aid in climate change mitigation by sequestering carbon (European Environment Agency, 2019). However, their incorporation into traditional water infrastructure is challenging due to legislative, institutional, and discursive constraints. Reconsidering these constraints could unveil new avenues for climate change adaptation and mitigation.

The need for a proactive and coordinated approach to climate adaptation, as indicated by the Office of the Auditor General of Norway, emphasizes another significant policy opportunity. Comprehensive planning, improved status overviews, and detailed reporting on results and challenges in climate adaptation work would markedly contribute to climate change adaptation and mitigation efforts (Riksrevisjonen, 2023).

The study has also revealed that the current policy framework Inadequately addresses the unique challenges of stormwater as a pollutant. The existing 'Polluter-Pays-Principle' applied to stormwater management presents an opportunity for policy reform. A reform to reflect the unique characteristics of stormwater pollution could help in its more effective management, contributing to climate change adaptation.

Furthermore, the application of the 'Polluters-Pay-Principle' may not currently align with the complexities of stormwater within environmental law (Skullerud, 2022)Given stormwater's multifaceted nature, placing the full responsibility on individual property owners may be unjust and inefficient, especially considering the significant role climate change, a global issue, plays in escalating stormwater volumes. Hence, a reevaluation of this principle's application, potentially developing a more nuanced, context-specific approach, could be beneficial.

Concurrently, the study illuminated potential opportunities for improving stormwater management in Lillestrøm. A commitment to sustainability, resilience, and climate adaptation in national and international political discourses is a critical backdrop for local decisions (Adger et al., 2005). However, translating these commitments into actionable local policies and actions necessitates addressing the aforementioned gaps. Additionally, changes in the Civil Protection Act present potential data sources for risk and vulnerability analysis, although they also raise privacy and data protection concerns.

The shift towards more sustainable, nature-based solutions presents an opportunity to mitigate climate change impacts (Braskerud & Paus, 2018; Seddon, 2022; Swensen & Berg, 2020). Such a shift could harmonize Lillestrøm's stormwater management practices with broader sustainability and resilience goals.

In conclusion, the study has shed light on several policy gaps, and concurrently, identified opportunities for bolstering stormwater management in Lillestrøm, particularly in the context of climate change adaptation and mitigation. Addressing these gaps and capitalizing on the identified opportunities necessitates a joint effort from all pertinent stakeholders, including policymakers, practitioners, and the broader community. Further exploration of these aspects will be undertaken in the subsequent sections on the practical and social spheres.

Practical Sphere Finding

This chapter sheds light on the practical aspects of stormwater management in Lillestrøm, Norway, incorporating a comprehensive analysis of the city's spatial characteristics, socioeconomic factors, flood infrastructures, topographic and geological influences, climate impacts, and landscape architecture's role in promoting climate change adaptation.

Spatial Analysis of Lillestrøm

Spatial analysis, facilitated by an array of GIS tools, Scalgo Live, Google Earth Pro, Kunnskapsbanken, and SSB, revealed critical vulnerabilities associated with stormwater management in Lillestrøm. The city's impervious surface distribution, drainage patterns, and flood-prone areas are key factors contributing to these vulnerabilities (Guerry et al., 2015).

Industrial Development and Flood Infrastructure

Lillestrøm's flood susceptibility is amplified by industrial development around the Nitelva River and the city's flat topography. In response to the 1995 Eastland flood, the city established an extensive flood protection system, comprising a 7 km flood barrier, 14 pump stations, 6 km of pipes, and 15 discharge manholes (NVE, 2021). However, the effectiveness of these measures in controlling pluvial flooding, particularly in the face of increasing urbanization and associated impervious surfaces, remains under-researched (Jha, Bloch & Lamond, 2012).

Stormwater Damages

Data from Kunnskapsbanken indicates that Lillestrøm faced 3,541 instances of water damage in 2021. This led to insurance payouts amounting to NOK 248,509,497, implying that nearly 9.24% of the city's insured buildings suffered from water damage (Kunnskapsbanken, 2023). However, as these figures only capture insured buildings, the actual extent of water damage may be underestimated. These incidents can disproportionately impact low-income households, thus underlining the importance of implementing inclusive and equitable stormwater management strategies (Walker & Burningham, 2011).

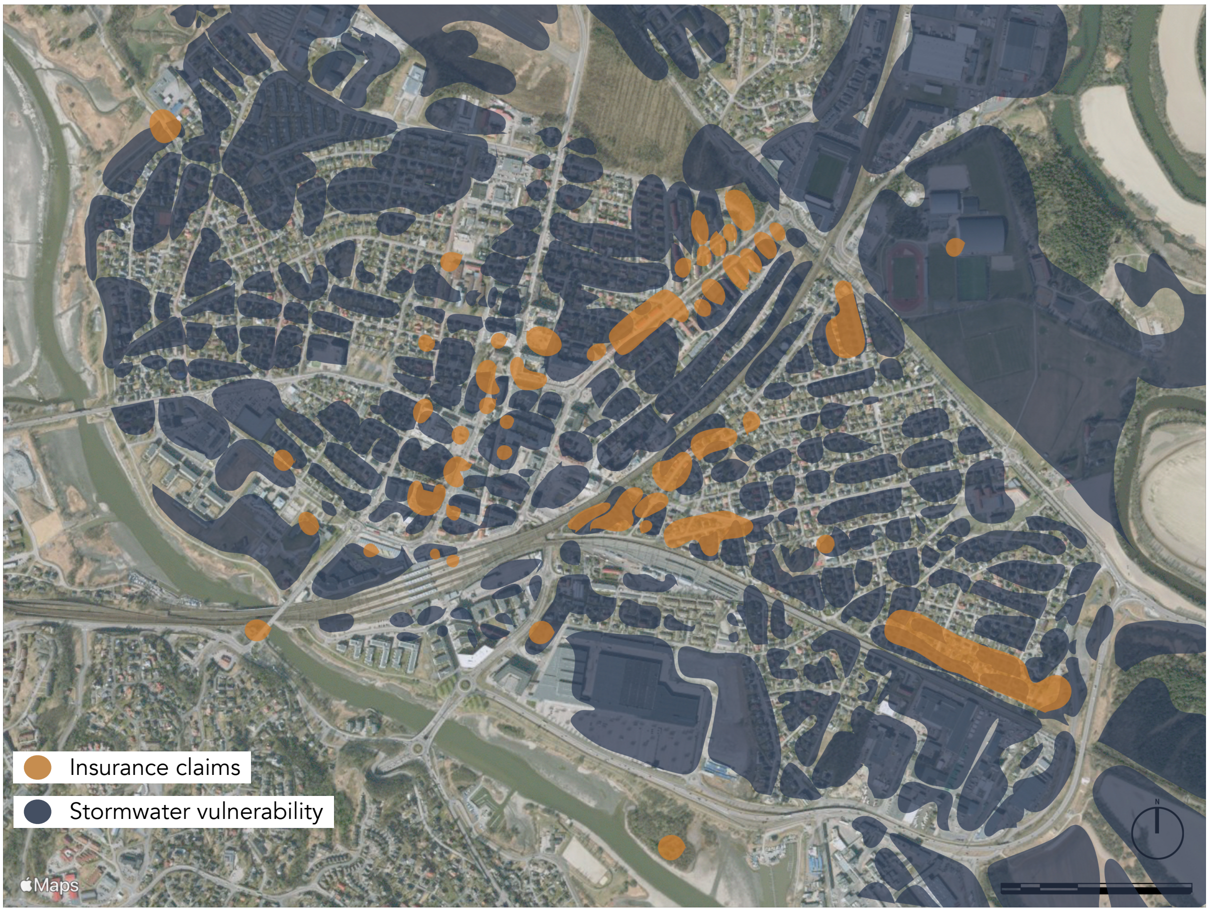


Figure 32 Data from both Kunnskapsbanken on reported insurance cases and Scalgo Live GIS analysis present a clear picture of Lillestrøm's risk and vulnerability related to stormwater management.

The Influence of Topography and Water Table Dynamics

Lillestrøm's flat topography coupled with high water table dynamics significantly increase its vulnerability to pluvial flooding and stormwater issues. Flat urban areas with high water tables are more prone to stormwater problems (Liu & Xia, 2004). The city's river proximity and flatness can increase soil saturation capacity, thereby escalating flooding and stormwater-related risks.

Geological Conditions: Role of Marine Clay and River/Fjord Deposits

Geological factors, specifically the distribution of marine clay mapped using GIS, significantly contribute to stormwater-related vulnerabilities in Lillestrøm. Marine clay, characterized by high water content and low permeability, accelerates surface runoff during heavy rainfall events (Wanielista et al., 1997).

Climate Impacts on Saturation Capacity

Lillestrøm's northern climate exerts a significant influence on its stormwater management. During colder months, the ground's water capacity decreases, inhibiting the infiltration process (Marsalek et al., 2003). Lillestrøm's cyclical temperature changes, combined with its average precipitation patterns, heighten the city's vulnerability to cloudbursts, especially between March and May.

Urban Drainage and "Pool" Formation

The city's flat topography, coupled with the inability of the existing flood infrastructure to efficiently drain excess water, transforms Lillestrøm into a 'pool' during cloudburst events. This situation underscores the urgent need to address the dual concerns of impervious surfaces and stormwater infrastructure capacity in urban planning and development strategies.

Landscape Architecture and Equitable Climate Change Adaptation

Landscape architecture plays a pivotal role in promoting equitable climate change adaptation in Lillestrøm. Although densification— a common trend in modern urban development—exacerbates stormwater management challenges, Lillestrøm is proactively implementing nature-based solutions, thereby demonstrating its commitment to sustainability goals. Despite the city's topographical and infrastructural challenges, there are abundant opportunities to harness nature-based solutions as the city continues to seek ways to establish a sustainable and clima'e-resilient urban environment.

In conclusion, the practical spatial analysis of stormwater management in Lillestrøm highlights multifaceted vulnerabilities, which span across spatial, geological, climatic, and socioeconomic domains. Industrial development in close proximity to rivers, while a common trend, intensifies these vulnerabilities, thereby highlighting the need for an integrated approach to urban planning and disaster management. The findings from this research provide crucial insights into the existing challenges and potential solutions to mitigate the stormwater-related risks facing Lillestrøm.

Implementation and Impact of Nature-Based Solutions in Lillestrøm

The empirical findings underscore the importance of Nature-Based Solutions (NbS) as a fundamental tool in the climate change adaptation strategy of Lillestrøm. The city's efforts align with the growing international trend towards NbS (Lillestrøm Municipality, 2021; Lillestrøm Municipality, 2023a), as highlighted in various policies and guidelines (European Commission, 2020; UN-Habitat, 2022; State Guidelines for Climate and Energy Planning and Climate Adaptation, 2018; Miljødirektoratet, 2023).

Implementing NbS in Lillestrøm can potentially leverage natural ecosystem services, which would transform the urban landscape into a dynamic system capable of withstanding environmental disturbances. According to Gómez-Baggethun et al. (2013), urban parks and green roofs, examples of NbS, have the potential to play a pivotal role in stormwater management and urban temperature regulation.

However, the spatial analysis of Lillestrøm's garden city model revealed potential challenges, including a prevalence of grass monocultures instead of biodiverse green spaces that could optimally manage urban hydrological processes. These findings echo the literature's emphasis on the necessity of NbS in addressing urban environmental challenges and highlight the importance of biodiversity in enhancing the resilience of NbS (Brink et al., 2016; Kabisch et al., 2017).

Interestingly, the findings also revealed some disparities in the distribution and access to these NbS. Some neighborhoods appeared to benefit more from ecosystem services than others, echoing the environmental justice concerns discussed in the literature (Elmqvist et al., 2019). Therefore, future planning and governance processes in Lillestrøm should strive for equitable access to NbS and consider the socio-cultural nuances of the city's diverse neighborhoods.

From a systems thinking perspective, the potential use of NbS in Lillestrøm reveals the inherent value of ecosystem functions. NbS are not merely seen as service providers but are appreciated for their intrinsic ecological worth, aligning with Liu et al.'s (2007) argument for recognizing the intrinsic value of ecosystem functions beyond their utilitarian benefits.

The insurance value of NbS in promoting city resilience has been emphasized in literature. For instance, urban green spaces can potentially serve as temperature regulators during heatwaves, mitigating climate change impacts (Chan et al., 2016; Gómez-Baggethun et al., 2013).

Lillestrøm's deployment of the Norwegian "trinnvis strategi" in stormwater management exemplifies the city's commitment to NbS. The three-step strategy focuses on handling rainwater locally and mimicking natural processes, reinforcing the core philosophy of working with nature (NOU, 2015:16; Oslo Municipality, 2014).

Despite the potential benefits, the implementation of NbS can encounter challenges related to socio-ecological governance and the balance between urban development and ecosystem preservation (Karen O'Brien et al., 2022; Klausen et al., 2015). This underscores the need for an integrative approach, melding technical, ecological, and social considerations in implementing NbS.

In essence, the Lillestrøm case study illustrates the potential and challenges of NbS, shedding light on how they can be effectively harnessed to achieve urban resilience, environmental justice, and sustainable urban development. This case study serves as a tangible example of how cities can potentially become thriving urban ecosystems that are harmoniously integrated with their natural environment, offering lessons for other cities navigating the complexities of climate change adaptation in the Anthropocene.

Social Sphere Finding

The context of Lillestrøm, Norway, showcases that social dimensions are crucial in building climate resilience, especially concerning stormwater management. Outcome vulnerability, identified in the practical and political analysis, is intrinsically tied to social structures, communities, and individuals and their role in stormwater management efforts (Niemczynowicz, 1999; Adger, 2006).

Impacts on Social Structures

As evidenced in Lillestrøm's stormwater management initiatives, these projects impact social structures in profound ways. Engaging various organizations, community groups, and governmental bodies is necessary for coordinated implementation of climate resilience efforts. The structured collaboration between these entities is indicative of the potential for increased resilience to climate change (Wamsler and Brink, 2014).

Impacts on Individuals and Outcome Vulnerability

Individuals' response to stormwater management strategies is tied to the outcome vulnerability, as identified in the practical and political analysis. This includes alterations in daily practices, adapting to infrastructure changes, and receptivity to new policy implementations. Highlighting the role of public education in facilitating behavioral changes, the analysis emphasizes the need to instill a sense of individual responsibility towards climate change adaptation (Moser, 2014; Adger, 2006).

Social Resilience or Vulnerability to Climate Change

The social sphere in Lillestrøm is closely linked to its climate resilience, as the active participation of social structures, communities, and individuals shapes the city's climate change response. Furthermore, the outcome vulnerability, revealed in the political and practical analysis, underscores the importance of factoring in social considerations into future adaptation strategies (Pelling, 2011; O'Brien et al., 2007).

Recommendations for Future Initiatives

Reflecting on these findings, future initiatives should prioritize fostering strong collaboration among social structures, increasing community engagement, and empowering individuals through education. Implementing these measures, while being aware of the outcome vulnerabilities, can enhance the social resilience of Lillestrøm, better equipping it to handle the impacts of climate change (Adger et al., 2005).

Synthesis

Systems Thinking in Practice

The intersections between the social, political, and practical spheres of stormwater management become increasingly apparent, illustrating a complex system in alignment with the principles of systems thinking and earth system science.

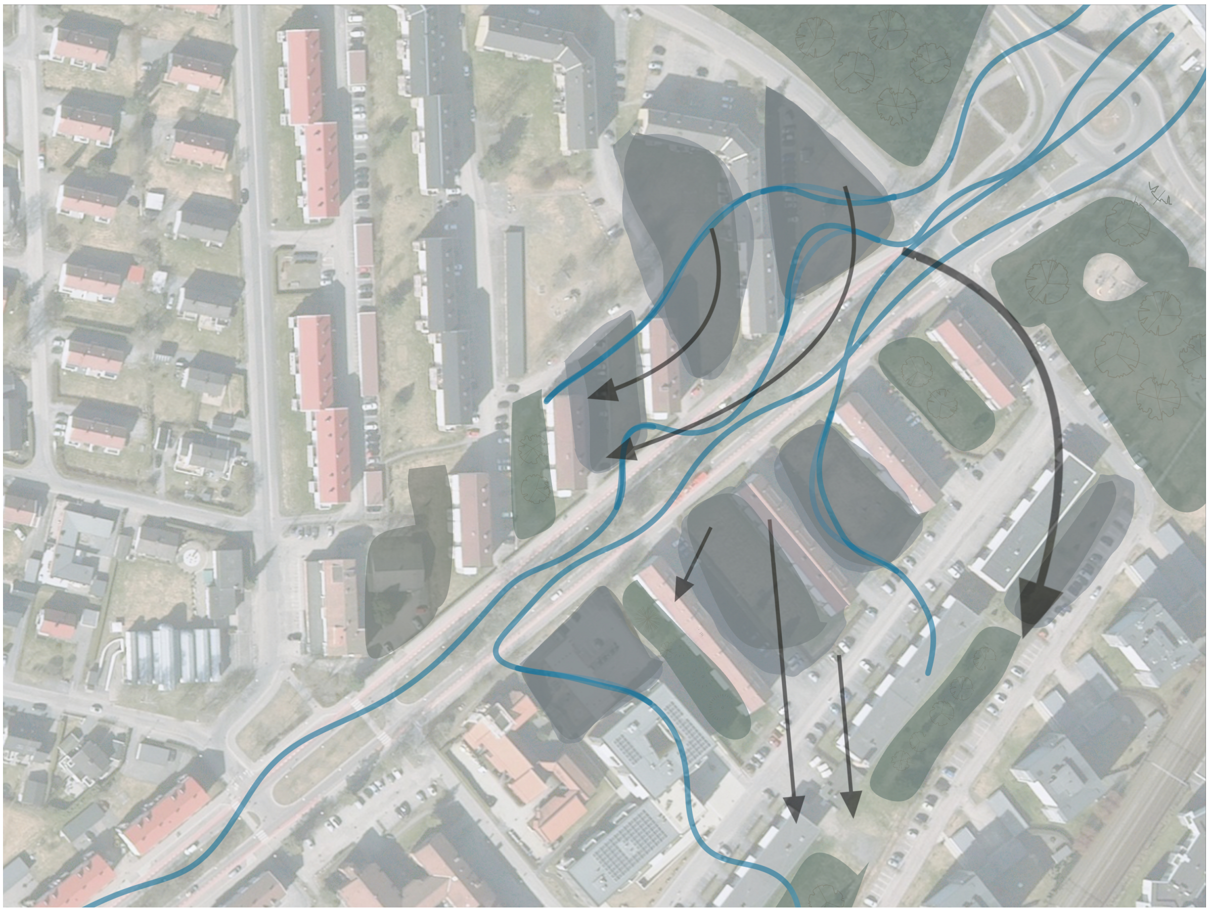
Private actors' involvement in urban development, driven primarily by profit, introduces a vulnerability when climate change adaptation criteria in regulations are ambiguous(Klausen et al., 2015; Taubøll, 2018). This vulnerability can propagate through the urban ecosystem, affecting various scales - from individual properties to the national level. It illustrates the cascade effect of vulnerability within stormwater management, where individual decisions or conditions can disproportionately affect entire communities.

Specifically, stormwater vulnerabilities can vary within a street due to factors such as topography, soil conditions, or hard infrastructures with low infiltration capacity in up-hill drainage lines. These variables can contribute to a cumulative impact that extends beyond individual properties, manifesting in broader vulnerabilities that span streets, blocks, cities, and even entire municipalities.

Furthermore, if the responsibility and costs for stormwater management are shouldered primarily by individual property owners, a large-scale vulnerability emerges. This

vulnerability arises from the fact that the impacts of stormwater runoff are not confined to individual properties but can extend to adjacent areas and communities.
The concept of water flowing through several properties with varying permeability and infiltration capacities is critical here. For instance, a property that has implemented nature-based solutions (NbS) for stormwater management could still suffer from flooding if up-stream properties fail to implement effective stormwater controls. This scenario underscores the interconnectedness of stormwater management and the potential consequences of fragmented or isolated adaptation measures.

This interconnectedness, emphasized in the principles of systems thinking and earth system science, reaffirms the importance of comprehensive and coordinated adaptation measures. Recognizing that individual actions can influence broader system dynamics is crucial. These findings underscore the need for clear climate adaptation regulations, collaborative efforts, and equitable responsibility and cost distribution mechanisms to reduce vulnerabilities in stormwater management effectively. Such considerations ensure that the effects of climate change do not disproportionately burden individual property owners and that communities can collectively and proactively address the impacts of stormwater runoff.



Vulnerability Root Causes

An analytical interpretation of our findings, on the root causes of vulnerability (O'Brien et al., 2007; Scoville-Simonds & O'Brien, 2018)unveils how these foundational factors can not only influence the system of stormwater management in Lillestrøm but also dictate its resilience in the face of climate change. In addressing these root causes, a pathway emerges for constructing stormwater management practices that are both sustainable and equitable, and that effectively mitigate vulnerability.

The essence of vulnerability in this context doesn't solely reside within the confines of environmental risk and the physical impact of climate change. Instead, it percolates through the layers of societal structure and dynamics, which strongly resonate with delineation of 'contextual vulnerability'. This perspective captures the unequal societal structure and power relations, which can inadvertently predispose certain sections of society to be more vulnerable to climate change (O'Brien, 2006).

These interpretations of vulnerability - 'outcome vulnerability' that primarily targets environmental risks and 'contextual vulnerability' that underscores societal inequalities - aren't antithetical but rather supplement each other (O'Brien & Leichenko, 2000). These dual perspectives shed light on various facets of climate change and its societal implications. In this respect, a balanced approach acknowledging these intertwined perspectives could enable a holistic response to the challenge of climate change adaptation.

Conclusion

Hazard + Vulnerability + Exposure = Risk

In the context of climate change, risk is understood as a product of hazard, exposure, and vulnerability. These components are not separate entities but are rather interconnected and interrelated, displaying characteristics of intersectionality and complex systems, akin to Oxman's Krebs Cycle of Creativity (Oxman, 2015).

Hazard relates to the potential for destructive events or trends that can cause harm to people and the environment. Exposure refers to the presence of valuable assets in areas potentially affected by these hazards. Vulnerability refers to the susceptibility to harm from these hazards, and a lack of capacity to cope and adapt. The vulnerability of an area is not merely a consequence of its exposure to climate-induced hazards, but is closely tied to its socio-economic and institutional conditions (IPCC, 2014).

Applying a systems thinking approach illuminates the interconnectedness and interdependence of these components. Like Oxman's Krebs Cycle of Creativity, which visualizes the interplay and feedback loops between nature, science, engineering, and design (Oxman, 2015), the elements of risk – hazard, exposure, and vulnerability – interact in a complex system. Changes in one aspect will invariably influence the others, and understanding this complex interplay is crucial for effective climate change adaptation strategies.

In a similar vein, the principles of Earth System Science underline the need to see the components as parts of a broader, interconnected system. Earth System Science adopts an integrated approach, viewing Earth as a single system where the atmosphere, hydrosphere, biosphere, and geosphere interact in complex ways (Steffen et al., 2004). Analogously, the elements of risk are intertwined, each influencing and being influenced by the others.

Thus, addressing climate risk necessitates not just a reduction of the hazard or exposure but also a reduction of vulnerability. Effective adaptation strategies, therefore, must go beyond physical measures. They should be rooted in social justice and must address socio-economic inequalities that increase vulnerability. Importantly, the solutions devised should be mindful of their cascading effects and the feedback loops within this complex system.

In conclusion, understanding the intricate interplay between hazard, exposure, and vulnerability—comprehending them not as separate, isolated components but as parts of a complex, interconnected system—is crucial to formulating effective, sustainable, and just climate change adaptation strategies. By adopting a systems thinking approach and an Earth System Science perspective, we can better comprehend these complexities and devise strategies that are not just reactive but also proactively reduce risk and build resilience.

Chapter 6

DISCUSSION

The previous chapters have provided an in-depth examination of the complex interactions between urban planning, climate change adaptation, and social justice in the city of Lillestrøm. The findings have revealed significant implications for the manner in which we approach these interrelated issues. As we delve into the discussion of these findings, it is essential to recognize that there are areas left unexplored in our analysis.

Despite the thorough investigation of Lillestrøm's flood management system and its socio-economic impacts, there remain facets of the case study that warrant further exploration. These include the potential role of green infrastructure in mitigating pluvial flooding risks and the intricacies of integrating climate adaptation measures with broader urban development goals. In addition, the political dynamics underlying these processes and their implications for social equity have not been exhaustively covered.

The purpose of this discussion is not only to illuminate the findings from our study, but also to recognize these knowledge gaps, which may serve as the starting point for future research. We will delve deeper into the socio-economic implications of our findings and draw broader conclusions that could inform more equitable, comprehensive, and effective strategies for urban planning and climate change adaptation. The following sections will reflect on the core themes identified in our study, and explore how these findings can be employed to inform policy decisions in Lillestrøm and beyond.

Critical Infrastructure of Nature

The integration of nature as critical infrastructure in the discourse of climate change and security brings about a new perspective in the strategies and policies for climate change adaptation and mitigation. Recognizing nature as such implies a shift from the traditional view of infrastructure as man-made structures like bridges, roads, and buildings, to a broader understanding that includes natural ecosystems.

This shift is crucial in developing holistic strategies that address not just the symptoms, but the root causes of climate change. It emphasizes the interconnectedness of human and natural systems and underscores the need for an approach that protects both. Moreover, acknowledging the role of nature as critical infrastructure also brings attention to the importance of natural resources management in conflict prevention and peacebuilding. Resource scarcity, often exacerbated by climate change and poor management, can trigger conflicts. Therefore, ensuring sustainable and equitable access to natural resources is vital in promoting peace and social justice.

However, this paradigm shift also poses challenges. It requires substantial adjustments in legal, economic, and political frameworks that traditionally segregate natural resource management from infrastructure development. It also requires finding a balance between utilizing natural resources for human needs and preserving ecosystems for their intrinsic value and long-term sustainability.

In the end, treating nature as a critical infrastructure is not just about protecting the environment. It is about reshaping our societies and economies to be more resilient, equitable, and sustainable. It is about ensuring that future generations can continue to rely on the critical services nature provides.

Nature As Critical Infrastructure for National Security

The understanding of infrastructure and security has significantly evolved over the years. O'Brien (2018) pushes for a more expansive conceptualization of infrastructure that includes the practical, political, and personal aspects. As such, the scope of infrastructure has broadened to include natural systems and landscapes, particularly as the impacts of climate change become increasingly prominent.

The World Economic Forum (WEF) repeatedly recognizes environmental risks as some of the most significant global risks in their annual Global Risks Reports. This recognition signifies the importance of ecosystems such as forests, wetlands, and coastal habitats as essential components of a nation's infrastructure (WEF, various years).

Similarly, the Intergovernmental Panel on Climate Change (IPCC) consistently emphasizes the environmental dimensions of security risks. The degradation of a nation's natural infrastructure, such as the health of its forests, rivers, and soils, directly impacts its security. The deterioration of these natural systems can increase vulnerability to climate change impacts and exacerbate risks such as flooding, wildfires, and extreme weather events (IPCC, various years). Protecting and restoring natural infrastructure, as highlighted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, various years), can enhance resilience and mitigate these risks.

The Norwegian government document "Meld. St. 26 (2022 – 2023) Melding til Stortinget Klima I endring – sammen for et klimarobust samfunn" acknowledges the role of climate change in increasing a nation's vulnerabilities. Increased precipitation, frequent flooding, landslides, and damage to infrastructure and cultural environments are just some of the direct impacts of climate change. However, climate change also influences nations indirectly through cross-border impacts, such as those transferred through trade, global value chains, financial systems, and shared ecosystems. For instance, a potential reduction in global food production due to climate change can trigger supply failures and escalate the prices of imported food products. This global interdependence underscores the importance of maintaining healthy ecosystems as part of a nation's critical infrastructure to ensure national security.

Moreover, the document highlights that the impacts of climate change are not uniformly distributed. They often disproportionately affect certain communities, potentially exacerbating existing social inequalities. For example, rising food prices due to climate change can disproportionately burden lower-income populations, leading to adverse impacts on public health and nutrition. This emphasizes the need to integrate a social justice perspective into climate change adaptation and mitigation strategies.

From this perspective, nature can be seen as a crucial function of society. As defined by the Norwegian Department of Justice and Emergency Preparedness, a critical function encompasses those societal functions deemed vital from a cross-sectoral perspective. Nature, with its integral role in maintaining the balance of various ecosystems, directly and indirectly impacts the health, economy, and overall sustainability of society.

Nature serves as a critical buffer against climate change impacts by acting as a carbon sink, reducing flood risks, and supporting biodiversity. It also supplies essential resources such as food, timber, medicinal plants, clean air, and water. When natural ecosystems are compromised due to climate change or other factors, these vital services are disrupted. Thus, viewing nature as a critical infrastructure underlines the importance of its protection and sustainable management.

Security forms an essential aspect of maintaining nature's critical function. This includes measures to protect and restore natural ecosystems, monitor environmental changes, and manage resources sustainably. The Norwegian Directorate for Civil Protection's document "Vital functions in society" offers an example of such measures by describing the monitoring of flood and landslide avalanche risks. This involves maintaining established systems for monitoring and reporting on flooding in waterways of all sizes, along with avalanches, slush avalanches, landslides, and rockslides.

Lastly, the perspective of nature as critical infrastructure also encompasses social justice. Vulnerable communities often rely more directly on natural resources for their livelihoods, making them more susceptible to the impacts of climate change and less capable of adapting. As such, sustainable management of nature is not only vital for maintaining its functionality but also for promoting social equity and justice

Entangled Landscapes: Navigating Dualism, Adaptation, and Social Justice in the Anthropocene Era

In his insightful chapter, "Designing Landscapes of Entanglement," Prominski (2019) critiques the dualistic view inherent to the modernist landscape architecture approach, which often treats humans and non-humans as separate entities. He points out that the Anthropocene epoch necessitates a shift in perspective to acknowledge the intricate entanglements between human and non-human systems in landscapes (Prominski, 2019).

This point resonates with Waldheim and Doherty's (2016) assertion that "the origins and aspirations of landscape as architecture emerge from very specific cultural, economic, and social conditions attendant to western European and North American industrialized modernity." Industrialization not only led to profound transformations in the physical landscapes, but also influenced the perception and design of these landscapes. It fostered a dualistic view wherein nature and culture, human and non-human, and urban and rural are seen as distinct and separate.

However, as we move further into the Anthropocene, it becomes increasingly clear that this dualistic perspective is not sufficient to address the complex and interrelated challenges we face. Spirn's work on ecological urbanism provides a useful perspective in this context. She argues for an integrated approach that recognizes the reciprocal relationships between human systems and natural processes (Spirn, 2016).

As such, designing landscapes in the Anthropocene demands an entanglement perspective that transcends the human/non-human dualism, acknowledges the impacts of industrialization, and incorporates ecological, temporal, and social dimensions. Such a perspective can led to more resilient and responsive landscapes that cater to the multifaceted needs and aspirations of human and non-human communities in the context of an ever-changing environment.

Adaptation, as Charles Darwin (1859) illuminated, is not inherently ethical or unethical but is a response to environmental circumstances and available resources. Richard Dawkins (1976) re-emphasized this perspective by arguing that the evolution of species is dependent on their environment and the DNA they pass on.

This natural phenomenon of adaptation takes on a nuanced layer of moral significance in the human context, especially as we grapple with the Anthropocene and its implications. It becomes a fulcrum on which issues of social justice teeter. Societal responses to environmental change, such as those presented by climate change, are seldom evenly distributed, creating winners and losers and, in many instances, reinforcing existing inequalities (Klein, 2014). Therefore, adaptation strategies must not only consider ecological and biological factors but also socio-political dimensions to ensure that efforts to foster resilience do not inadvertently perpetuate injustice.

Indeed, the connection between adaptation and social justice is underscored by the Anthropocene, a geological epoch where human activities have become the dominant force shaping our planet's future. As the impacts of climate change continue to escalate, affecting societies and ecosystems worldwide, a neoliberal approach to resource management has shown itself to be not just environmentally disastrous but also socially unjust (Klein, 2014).

The profound transformation brought by climate change calls for a reassessment of our relationship with nature, with solutions grounded in naturally existing adaptation measures—nature-based solutions (Cohen-Shacham et al., 2016). While these solutions are neutral—neither good nor bad, just nor unjust—they are pivotal to building a resilient ecosystem. Moreover, their implementation should be approached with an equity lens to prevent exacerbating social disparities.

Our perception of ourselves in relation to nature plays a significant role in this shift toward a more just adaptation. History reveals a narrative of dualism, with humans perceived as separate from nature—a view that is gradually changing as the climate crisis unfolds (Braae & Steiner, 2019). This shift necessitates integrating nature into our urban landscapes and consciously planning for adaptation that considers ecological, economic, and social dimensions simultaneously.

Challenging The Nature-Society Dualism In Climate Change Adaptation

In the literature on climate change adaptation, a recurring critique is the tendency to conceptualize climatic threats as separate from social processes. This view termed the nature-society dualism, posits that we can distinguish the 'climatic' drivers of change from the 'social' ones, which in turn enables the creation of policies specifically targeting climate change — adaptation and mitigation — separate from broader trajectories of socio-environmental change (Nightingale et al., 2019)

However, such a dualistic perspective is increasingly challenged. It is argued that this separation is scientifically impractical, as climatic, and social changes are deeply intertwined, making it challenging to isolate one from the other. Moreover, it is politically charged, often resulting in policies that address climate change in isolation from other socio-environmental issues, thereby perpetuating the status quo (Noble et al., 2014).

This critique points to the need for a more integrated socio-natural perspective in climate change adaptation. Such an approach does not separate 'nature' from 'society' but rather sees them as inseparable elements in a co-produced socio-natural system. By acknowledging the deep interconnections between social and climatic changes, we can develop more effective and equitable strategies for climate change adaptation.

The Trap Of Technological Solutions In Climate Change Adaptation

In their article "Beyond Technical Fixes: climate solutions and the great derangement," (Nightingale et al., 2019) presents a compelling critique of the prevailing approaches to climate change adaptation and mitigation. They argue that these approaches are overly focused on the identification of external climatic threats and the development of technical solutions for them, such as building adaptive capacity, forging resilience, and carbon capture (Nightingale et al., 2019)

Such a technocentric approach, according to Nightingale et al., undermines the potential for truly transformative change, which they suggest is only possible through a profound alteration of our *knowledge systems* and an opening of space for deliberation on alternative futures. This is because the technical approach operates on a faulty premise – that climate change is an external stressor acting upon human and natural systems, and that these systems can be managed effectively with technical interventions informed by scientific knowledge (Nightingale et al., 2019).

Furthermore, the current technical approach is said to create "moments of concealment" where the interconnectedness of social-environmental dynamics is obscured. As a result, these approaches fail to adequately consider the political, cultural, and economic factors that influence and are influenced by climate change (Nightingale et al., 2019).

The authors' critique has significant implications for stormwater management in Lillestrøm. If we subscribe to their argument, then a simple technical solution to stormwater management, such as building better drainage infrastructure or creating more green spaces for water absorption, may not be sufficient. Instead, we need to also consider the social and political dimensions of stormwater management, including the distribution of power and resources in the community, public perceptions and attitudes towards stormwater and climate change, and existing local knowledge and practices related to water management.

In summary, Nightingale et al.'s (2019) critique of the prevailing technocentric approach to climate change adaptation and mitigation serves as a powerful call for a more integrated and socially conscious approach to climate change issues, including stormwater management in Lillestrøm. This approach would involve not only the application of scientific knowledge and technical solutions but also the inclusion of social, political, and cultural considerations, as well as a willingness to question and rethink established assumptions and paradigms.

Exploring Modernity, Dualism, and the Anthropocene in Landscape Architecture

As the impacts of the Anthropocene, the epoch characterized by human activities influencing the earth's ecosystems, become more pronounced, the role and approach of landscape architecture need reassessment. Prominski's critique of the dualistic perspective of humans and nature in landscape architecture, grounded in modernist philosophy, is shared by other academics (Prominski, 2019). Corner (1999) argues that such a perspective overlooks the interconnectedness of human and natural systems. Waldheim and Doherty (2016) note that the "origins and aspirations of landscape as architecture emerge from very specific cultural, economic, and social conditions attendant to western European and North American industrialized modernity." Despite the progress brought by modernity in architecture and urban planning, it often struggles to encapsulate our interconnected existence, particularly in the Anthropocene era (Prominski, 2019).

Anthropocene Era and Landscape Architecture

The Anthropocene era presents unique challenges and demands an urgent shift from the dualistic paradigm of humans and nature being separate entities. Prominski (2019) proposes a recognition of our intertwined existence and argues for landscape designs that embrace this entanglement. This perspective aligns with Spirn's (2016) argument for an ecological urbanism, where human and non-human systems interact seamlessly. The Anthropocene era necessitates that landscape architecture act as a key tool to address these complex environmental issues.

The Role of 'Commoning' and Public Participation

Prominski (2019) underlines the significance of public participation in landscape architecture, introducing the concept of 'commoning'. It aligns with recent research advocating for a democratic and participatory approach to landscape transformation (Bishop & Phillips, 2014). This practice marks a departure from traditional top-down approaches, instead championing an inclusive process that resonates with the ethos of the Anthropocene era.

The Temporal Dimension of Landscapes

Prominski (2019) highlights the temporal dimension in landscape architecture, asserting that landscapes evolve over time and interact with a variety of factors. This perspective is supported by Corner's (1999) emphasis on the processual nature of landscapes and reinforces the understanding of the Anthropocene's complex dynamics.

Through an analysis of Prominski's work and related literature, we have explored the impacts of modernity, dualism, and the Anthropocene era on landscape architecture. Prominski (2019) challenges traditional perspectives and presents an interconnected approach more suited to the complexities of the Anthropocene. As we navigate this era, embracing an interconnected approach to landscape design, participatory democracy, and temporal considerations could be instrumental in designing landscapes that reflect our intertwined existence with the natural world.

> *Uncertainties have always been an innate challenge of landscape architecture as an agent of change. Dealing with landscape transformations necessitates addressing the intricate nature of ecological systems. It requires considering the complex unforeseen consequences of local and global social, economic, and political drivers, and their impact on landscape (Egoz, 2019)p. 219*

Chapter 7

CONCLUSION

The conclusion of this thesis reiterates the intricate interplay of urban planning, climate change adaptation, and social justice, underscored through the case study of Lillestrøm. The exploration herein attests to the complexity intrinsic to these interconnected issues and emphasizes the necessity for multifaceted, integrated strategies to address them. The analyses revealed the profound impact of urban planning on the adaptive capacity of a city against escalating climate change threats. These findings underpin the pivotal role of embedding climate adaptation initiatives within urban development frameworks. Concurrently, the study illuminated potential pitfalls and unintended consequences that might emerge, such as the heightened vulnerability to pluvial flooding, demonstrating the necessity for a more holistic and careful approach.

This study offers a fresh perspective on the role of nature-based solutions, showcasing their potential in mitigating the impacts of climate change while bringing ancillary benefits to urban residents. However, they are not a panacea, and their implementation needs to be carefully tailored to the specific socio-ecological contexts of each urban area, taking into account the local culture, ecology, and socio-economic realities.

Social justice emerged as a core theme throughout the research. The impacts of climate change and adaptation efforts are not uniformly distributed among different social groups. Equity, access, and the "polluter-pays" principle need to be central to the discourse on climate change adaptation and stormwater management, ensuring that strategies implemented do not inadvertently exacerbate existing social disparities.

The "right to landscape" concept and the systems thinking perspective provide insightful theoretical lenses to examine these issues. They emphasize the crucial role of landscapes in supporting human well-being and highlight the importance of understanding the complex interdependencies and dynamics within our socio-ecological systems.

As in any research, this study has limitations, which should be seen as opportunities for future research. The multifaceted nature of climate change impacts and urban systems suggest that there are always additional layers and dimensions to explore. This work merely scratches the surface of an intricate web of interactions that shape the outcomes of climate change adaptation efforts.

Lastly, this thesis underlines the importance of integrating climate change adaptation into urban planning and policy-making processes. It calls for a reconceptualization of current approaches to make them more inclusive, equitable, and resilient. It suggests that achieving this might require an expanded dialogue between researchers, policy-makers, urban planners, and the community at large.

In essence, this thesis has argued for an approach to climate change adaptation that is not only scientifically informed and practically effective but also grounded in principles of social justice and ecological sustainability.

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Definitions of Key Concepts

Key Concept	Definition
Climate Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognized as a function of hazard, exposure, and vulnerability (Barros et al., 2014)).
Climate Vulnerability	The propensity or predisposition to be adversely affected, encompassing sensitivity or susceptibility to harm and lack of capacity to cope and adapt. Vulnerability is a function of social, economic, and institutional conditions, and it varies over time, space, and with the context under consideration (IPCC, 2014).
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources (IPCC, 2014).
Exposure	The presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC, 2014).
Adaptive Capacity	The system's ability to adjust to climate change, variability, or extreme events and to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. This capacity is not uniformly distributed across society, with certain groups potentially more vulnerable due to socio-economic conditions, geographical location, or access to resources (Adger, 2006).
Outcome Vulnerability	A perspective of vulnerability linked to the scientific framing of climate change, predominantly involving quantifiable measurements and assessments based on exposure, sensitivity, and adaptability to climate change impacts (O'Brien et al., 2007).
Contextual Vulnerability	A perspective of vulnerability linked to the human-security framing of climate change, emphasizing the socio-political and economic context in which vulnerability arises (O'Brien et al., 2007).

Key Concept	Definition
Climate Justice	A concept that underscores the ethical and justice issues raised by climate change, linking social and environmental considerations. It acknowledges that the causes and impacts of climate change are not evenly distributed, and it calls for a fair treatment of all people with respect for their rights (Schlosberg, 2013).
Nature-Based Solutions	Actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (IUCN, 2020).
Climate Change Adaptation	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate change (IPCC, 2014).
Resilience	The capacity of social, economic, and environmental systems to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (IPCC, 2014).
Climate Change Mitigation	An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2014).
Social Justice	A foundational principle that underpins climate change adaptation efforts, ensuring that the benefits and burdens arising from climate change adaptation are equitably distributed among all people, with a focus on vulnerable and marginalized populations (Atapattu & Schapper, 2019).
Distributive Justice	Involves the equitable allocation of resources, opportunities, and burdens. In the context of climate change adaptation, it necessitates fair distribution of resources for adaptation efforts and fair apportioning of burdens, including the negative impacts of climate change and adaptation strategies (Schlosberg, 2007).
Procedural Justice	Concerns fair and transparent processes in decision-making and the execution of actions, emphasizing participation from all stakeholders, especially marginalized and vulnerable groups, in decision-making processes around adaptation strategies (Rawls, 1971).

Key Concept	Definition
Contextual Justice	Focuses on the larger socio-political, cultural, and historical contexts in which distribution and procedural processes take place. It pushes for understanding these broader contexts to ensure that they do not perpetuate or exacerbate inequalities (Whyte, 2011).
Recognitional Justice	Acknowledges and respects diverse identities, cultures, and ways of knowing in shaping and implementing climate change adaptation strategies. This concept considers factors often overlooked in traditional justice frameworks, such as relationships, context, power, vulnerability, narrative, and affect (Preston & Carr, 2021).
Climate Justice	An extension of environmental justice, emphasizing the need for equity and fairness in dealing with the causes and consequences of climate change. It demands a just transition to a low-carbon economy, with particular attention to the needs of developing countries that are disproportionately affected by climate change (Mary Robinson Foundation - Climate Justice, 2019).
Environmental Justice	Asserts that all people, regardless of race, color, national origin, or income, have the right to enjoy the same degree of protection from environmental and health hazards. It is deeply intertwined with climate justice, as climate change can exacerbate environmental inequalities by disproportionately affecting disadvantaged and marginalized communities (Schlosberg, 2013).
Climate Injustice	Refers to the unequal distribution of climate change impacts and the limited adaptive capacity of disadvantaged communities. It highlights the need to tackle the root causes of vulnerability and ensure that adaptation policies do not worsen existing inequalities or create new ones (Schlosberg, 2013).

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