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Anna Ternell

University of Pécs, Faculty of Sciences, Doctoral School of Earth Sciences

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DOCTORAL SCHOOL OF EARTH SCIENCES

AN INTEGRATED, TRANSDISCIPLINARY APPROACH TO THE MANAGEMENT OF AQUATIC CULTURAL LANDSCAPES

Anna Ternell

Supervisor: Dr. habil. Sándor Némethy

University of Pécs, Faculty of Sciences, Doctoral School of Earth Sciences

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SUMMARY

Rapid urbanization, climate change, and unsustainable practices are posing significant challenges to the preservation and management of water in the landscape. These interconnected factors place immense pressure on water resources, leading to water scarcity, pollution, and ecosystem degradation. To address these challenges, it is essential to adopt sustainable practices that prioritize water conservation, promote integrated water management, and protect natural ecosystems.

This thesis is looking at aquatic cultural landscapes, which represent the complex relationship between human society and natural ecosystems. The definition of these landscapes and their importance in representing biological systems, cultural diversity, and human history are highlighted early in the study. It makes the case that managing these landscapes requires a holistic approach that integrates stakeholder engagement, environmentally sound management, and heritage preservation.

The thesis explores the challenges posed by rapid urbanization, climate change, and unsustainable practices on water resources management. It discusses the resultant water scarcity, pollution, and ecosystem degradation, advocating for sustainable practices that prioritize water conservation, integrated water management, and natural ecosystem protection.

Recognizing the complexity of managing aquatic cultural landscapes, the thesis advocates for a multidisciplinary approach. This perspective is vital for addressing the challenges inherent in the preservation and management of these unique landscapes. The approach combines principles and practices from various fields, emphasizing the interconnectedness of ecological health, cultural heritage, and sustainable community development.

The research methodology is fundamentally multidisciplinary, drawing on concepts from agriculture, regional, local, and urban planning, cultural heritage conservation, ecology, and economics. This synthesis of information from several sectors strives to produce comprehensive strategies for aquatic landscape management that consider the ecological, cultural, and economic elements. The methodology emphasises the importance of developing successful management methods based on a full understanding of these environments.

The thesis provides a thorough review of existing literature and historical practices in water management, land use, agriculture, and cultural heritage conservation. It analyses the evolution of theories and practices in these fields, setting the stage for understanding the current challenges and opportunities in managing aquatic cultural landscapes.

A significant focus of the thesis is on exploring nature-based solutions (NBS) for water retention and their transformation into small-scale, multifunctional agricultural systems with particular emphasis on urban and peri-urban agriculture. This exploration is crucial for addressing pressing issues such as effective water management, cultural heritage conservation, and fostering sustainable urban-rural development. The thesis evaluates the potential of NBS to provide sustainable alternatives to conventional water management methods, particularly in the context of increasing environmental challenges.

Another essential aspect of the thesis is the examination of the impacts of climate change on water resource management. It contrasts traditional grey infrastructure methods with more sustainable NBS, highlighting the benefits of the latter in mitigating flood hazards, enhancing biodiversity, and providing recreational benefits. The study acknowledges the growing recognition of NBS as a complementary approach to traditional methods, particularly in the context of escalating climate-related water hazards.

A novel aspect of the research is the development of a mechanism that encourages collaboration among various stakeholders, particularly in the context of NBS. This mechanism, where beneficiaries downstream compensate suppliers upstream for NBS, promotes a collaborative approach to water management and landscape preservation.

The thesis highlights the need for informed policy initiatives to promote the adoption of NBS. It emphasizes the role of NBS not only in climate adaptation but also in mitigation. The study concludes by suggesting areas for future research, particularly in refining and expanding NBS strategies, and exploring their broader applications in different geographical and cultural contexts.

The results of this research can have significant effects on multiple levels. Firstly, they can inform water management practices by demonstrating the potential of nature-based solutions for water retention and their role in supporting sustainable agricultural practices. This can contribute to more efficient and effective water resource management, promoting environmental sustainability and resilience. Secondly, the research outcomes can help in the preservation and safeguarding of cultural heritage. By integrating nature-based solutions with cultural heritage values, the research can provide insights into how water management practices can respect and promote cultural heritage, fostering a sense of place and community identity. Lastly, the research can contribute to sustainable urban-rural development by identifying opportunities for small-scale multifunctional agriculture. By optimizing the use of water resources and integrating diverse agricultural practices, the research can enhance agricultural productivity, promote economic viability, and support the overall well-being of rural communities.

The importance of an integrated, multidisciplinary approach to managing aquatic cultural landscapes is reaffirmed in the thesis' conclusion. It emphasises how important NBS is to tackling issues with water management, cultural heritage protection, and urban-rural development both now and in the future. The study advances our knowledge of these landscapes and provides workable, long-term management strategies that will protect them for coming generations.

1. Introduction

1.1. The Importance of the Topic and the Investigated Area

Considering the increasing recognition of the decline of aquatic ecosystems as a major threat to global biodiversity, loss of unique cultural landscapes and the urgent need for sustainable water resource management (UNESCO, 2023), (Tickner et al., 2020), this research issue holds great relevance and significance. Tickner et al. (2020) explains that freshwater ecosystems, although modest in size, contain a remarkable amount of biodiversity, including around one-third of all vertebrate species.

However, this richness is decreasing significantly. Moreover, wetlands are widely acknowledged as the most biologically varied ecosystems, playing a crucial role in the reproduction of almost 40 percent of the planet's plant and animal species (Davidson, N. C., et al. 2023). Nevertheless, the unsustainable utilisation and inadequate governance of wetlands not only lead to the depletion of crucial ecological services but also provide immediate hazards, such as the transfer of diseases (Finlayson et al., 2019). In addition, the deterioration of wetlands results in the release of stored carbon, which contributes to climate change (Davidson N. C. et al., 2023). The rate at which wetlands are disappearing is three times greater than the rate at which forests are disappearing. Additionally, populations of freshwater vertebrates have seen a reduction that is more than twice as fast as the decline of terrestrial or marine species (Greb et. al., 2006; Tickner et al., 2020).

Other water-related ecosystems, such as lakes, rivers, and reservoirs, are also changing rapidly around the world. According to statistics, one in every five river basins has experienced major deviations from natural patterns in surface water changes in the last five years (World Wildlife Fund, 2020). This alarming trend can be ascribed to a variety of variables, including population growth, changes in land cover and land use, and the impact of climate change. These consequences for water-related ecosystems need immediate and coordinated actions to safeguard and sustain these vital biological habitats (United Nations, 2018). It is possible to protect these ecosystems from further degradation and maintain their long-term health and resilience for future generations by implementing appropriate conservation strategies.

Water management and sustainable landscape development research are critical to addressing the concerns while also protecting the environment and fostering economic growth (World Bank, 2021), (European Commission, 2020), (UNESCO, 2018). This concerns a diversity of functionalities, for example, to treat agricultural runoff and municipal wastewater, to filter river input to ecologically sensitive lakes and to function as buffers for flood prevention. The construction and reconstruction of aquatic environments, in particular wetlands, is also crucial for maintaining biodiversity and restoring valuable cultural landscapes.

In addition to the ecological significance of restoring and protecting aquatic environments, the presence of aquatic landscapes can also contribute significantly to the ability of rural areas to retain their population (Scanlon, B.R., Fakhreddine, S., Rateb, A. et al., 2023). Rural areas possess most of the Earth's natural resources, including water, land, and forests. The connection to the rural environment is linked to studies on the decline in rural population, as well as the resulting ecological, social, and cultural impacts, and the interaction between population and the environment from a historical perspective. Rural depopulation is caused by two factors: large-scale industrial agriculture, which is typically linked to the drainage and degradation of wetlands and other aquatic habitats and limited economic opportunities.

The rural and peri-urban landscapes have been described as a blind spot in regional economic strategies (Nefs et al., 2016). It is not surprising that the significant potential of peri-urban and rural hinterlands to contribute to biodiversity and address the climate emergency is frequently overlooked (Zasada, I. et al., 2013). The value of these landscapes is often unrecognized due to fragmented ownership, conflicting designations at various scales, and complex governance structures, policy requirements, and regulatory frameworks (Reed, M. S., 2008). Consequently, city climate strategies are often developed without considering their impact on the surrounding territories, environments, and agricultural land, leading to inadequate outcomes.

Given the escalating climate emergency and the imperative to address water security, innovative approaches are needed to effectively address the urban, peri-urban, and rural terrains (United Nations, 2019). Integrated strategies that consider the interdependencies and interactions between these areas are essential to tackle these challenges (Kabisch, N, et. al., 2017).

This PhD research aims to address aquatic cultural landscape management, safeguarding cultural heritage, and fostering sustainable urban-rural development. As such, case studies have been carried out in the following areas: i) the potential of nature-based solutions for water retention, ii) conversion to small-scale multifunctional agriculture and iii) advancing landscape management through landscape observatories.

The scientific background of the research problem is diverse, based on the complex, transdisciplinary approach of Earth System Science and includes ecological studies of landscapes with aquatic habitats, aquatic landscapes, multifunctional land-use, cultural heritage, urban and rural development studies, and analyses of urban-rural gradients. The research problem builds upon the insights of previous research, but it also represents an innovative approach that seeks to integrate multiple perspectives. The research problem also has significant precedents in the fields of sustainable organic agriculture, urban agriculture, ecosystem remediation and water management, however, it presents a novel combination of these perspectives and attempts to explore their synergies on system level.

This research can contribute to the development of new, comprehensive management systems for nature-based solutions, urban and rural landscapes that promote sustainable management of natural resources, enhance conservation of cultural heritage and landscapes. The new approach has several practical applications, including initiatives that incorporate multifunctional agriculture and the creation of new policies and governance structures that support sustainable urban-rural development. The findings of this study can have broader implications for the field of sustainability science, as it aims to integrate ecological, cultural, and economic dimensions in a holistic approach to landscape management.

1.2. Aquatic Cultural Landscape Management

Aquatic cultural landscapes comprise the unique relationship between human societies and water environments, highlighting the complex interplay among cultural, social, and ecological factors (Harvey D., Wilkinson T.J, 2018). As centres of human activity for centuries, they have served as sites for commerce, transport, the production of food, and cultural landscapes. However, rapid urbanization, climate change, and unsustainable practices pose significant challenges to the preservation and management of these invaluable heritage sites. As the world's population continues to grow and cities expand, the demand for water increases, placing additional stress on already limited water resources (United Nations, 2019). Simultaneously, climate change is altering precipitation patterns, exacerbating droughts and floods, and further impacting water availability and quality. Furthermore, unsustainable practices, such as inefficient water management systems, pollution, and habitat destruction, further strain water resources.

The growth of cities and the increasing population density associated with rapid urbanization have led to unprecedented expansion. As cities expand, natural landscapes are converted into impervious surfaces like roads, buildings, and pavements, disrupting the natural water cycle. Consequently, rainwater runoff increases, diminishing groundwater recharge and contributing to urban flooding. Moreover, the construction of dams and reservoirs to meet urban water demand often results in the displacement of communities and the degradation of ecosystems (Bates et al., 2008). Additionally, urban areas generate large volumes of wastewater and pollutants, putting pressure on aging sewage infrastructure and contaminating water bodies.

Climate change exacerbates the water problems resulting from growing urbanisation. With the increase in global temperatures, there is a corresponding rise in evaporation rates. This alteration in evaporation rates leads to changes in rainfall patterns and exacerbates drought conditions. Prolonged droughts diminish the quantity of accessible water, hence impacting agriculture, freshwater ecosystems, and human groups. Conversely, excessive precipitation and increased frequency of storms can lead to flooding, overpowering urban drainage systems and contaminating water sources (IPCC, 2021).

Unsustainable practices further compound the water challenges associated with urbanization and climate change. The misuse of water in agriculture, particularly through inefficient irrigation methods, contributes to considerable water wastage. Precision agriculture is emerging as a solution to reduce water wastage by using technology to ensure water is distributed efficiently and only as needed. Techniques like minimal or no-tillage and cover crop cultivation help conserve water by reducing evaporation and improving soil moisture retention (Holembovska T. 2021)

Moreover, industrial activities releasing untreated or poorly treated wastewater into water bodies pose a serious threat to ecosystems and human health. Heavy metals and pathogens in untreated wastewater used for irrigation can contaminate soil and crops, leading to health risks. For instance, various microorganisms in wastewater, including bacteria, helminths, protozoa, and viruses, can survive in soil and water for extended periods, causing diseases such as diarrhoea and cholera (Rusănescu C.O. et al, 2022)

Sustainable land management practices, including sustainable forest management, can help avoid or reduce land degradation and deforestation. These practices are critical for maintaining ecosystems that regulate water flow and filter pollutants. While transitioning from primary forests to sustainably managed forests may result in initial carbon emissions and biodiversity loss, sustainable management in degraded forest areas can increase carbon stocks and biodiversity. Early action towards sustainable land management can provide both local and global benefits through climate change mitigation (IPCC, 2019)

The over-extraction of groundwater for agricultural, industrial, and domestic purposes has significant consequences, including aquifer depletion, saltwater intrusion, and land subsidence. These impacts have been documented across various regions, reflecting a global challenge in sustainable water management (U.S. Geological Survey, 2018).

Managing aquatic cultural landscapes requires multidisciplinary and integrated approaches to ensure sustainability (Harvey D., Wilkinson T.J, 2018). It involves various aspects, including heritage preservation, sustainable development, environmental stewardship, and community engagement. For effective management, achieving a balance between preserving cultural resources and promoting sustainable development is crucial. The Millennium Ecosystem Assessment (2005) emphasizes the relevance of ecosystem-based management principles to the long-term viability of aquatic cultural landscapes and the communities dependent on them. Incorporating these principles, such as maintaining water quality, preserving biodiversity, and fostering sustainable resource use, can ensure the longevity of these landscapes and the well-being of the communities they support.

Community participation is also vital for the successful management of aquatic cultural landscapes. Local communities possess intimate knowledge and understanding of the historical, cultural, and ecological dynamics of these landscapes. Empowering communities through involvement in decision-making processes, the preservation of cultural practices and traditional knowledge, and the promotion of sustainable practices can transform them into active stewards of their heritage. Collaborations between government agencies, local communities, academic institutions, and non-governmental organizations are essential for the administration and conservation of aquatic cultural landscapes (Ternell et al., 2020).

This research topic holds great importance as it addresses water management, cultural heritage preservation, and sustainable urban-rural development. It builds upon existing scientific knowledge, incorporates cross-disciplinary approaches, and aims to provide practical solutions. The results can have positive effects on water management practices, cultural heritage preservation, and rural development, contributing to a more sustainable and resilient future.

1.3. Cultural Heritage and Conservation

Cultural heritage is according to the Faro-convention (Council of Europe, 2005) a group of resources inherited from the past which people identify, independently of ownership, as a reflection and expression of their constantly evolving values, beliefs, knowledge and traditions. It includes all aspects of the environment resulting from the interaction between people and places through time. This heritage includes a wide array of physical artifacts such as buildings, monuments, landscapes, books, works of art, and artifacts, as well as intangible aspects like traditions, language, and knowledge. The conservation of this heritage is crucial for maintaining cultural identity and historical continuity within communities.

Cultural heritage can be broadly categorized into tangible and intangible heritage. Tangible heritage includes physical objects and structures, such as historic buildings, monuments, and artifacts. These items are valued not only for their aesthetic and historical significance but also for their educational and economic contributions to society. Intangible heritage, on the other hand, encompasses practices, expressions, knowledge, and skills that communities recognize as part of their cultural heritage. This includes oral traditions, performing arts, rituals, and festive events.

The interplay between tangible and intangible heritage is crucial for a holistic understanding of cultural heritage. For instance, traditional craftsmanship involves both the physical creation of objects and the transmission of skills and knowledge through generations. Cultural heritage plays a vital role in the social and economic well-being of communities. It fosters a sense of identity and continuity, providing a tangible link to the past. Engaging with cultural heritage can enhance social cohesion by promoting understanding and respect for diverse cultures and histories (Charter project, 2023).

Despite its importance, cultural heritage faces numerous threats. The Charter project (2023) describes that these include natural disasters, environmental degradation, urbanization, and conflicts. Human activities, such as vandalism, looting, and unsustainable tourism practices, can also pose significant risks to cultural heritage sites and artifacts. It further provides an example of how modern developments can impact cultural landscapes. The transformation of rural areas under the influence of industrialization and urbanization illustrates the need for adaptive strategies that balance development with the preservation of cultural heritage.

Conservation is an integral part of preserving cultural heritage, aiming to maintain and manage cultural resources for future generations. This involves a comprehensive approach that includes social, economic, legal, and cultural considerations. The goal is to ensure that cultural heritage, both tangible and intangible, remains accessible and meaningful to future generations. Rosvall, J and Aleby, S, (ed. 1988), defines it as a dynamic field that requires ongoing assessment and intervention to address various factors that contribute to the degradation of cultural resources. These factors include natural processes like weathering and biological decay, as well as human-induced threats such as pollution, vandalism, and poor conservation practices.

A key principle in conservation is the respect for the authenticity and integrity of cultural heritage. This involves using techniques and materials that do not impede future treatment or examination, ensuring that any intervention is reversible and does not compromise the original material. The aim is to reduce the rate of decay while preserving the historical and cultural significance of the heritage (Lagerqvist, B. (1999).

Lagerqvist B. (2022) argues that effective conservation strategies require a comprehensive understanding of the cultural, scientific, technical, and natural values of heritage. This understanding is achieved through rigorous documentation, research, and the application of appropriate conservation techniques. Documentation serves as a fundamental component, enabling the monitoring of the condition of heritage items and guiding future interventions.

The conservation of cultural heritage faces various challenges. Natural processes like weathering and biological decay, as well as human-induced threats such as pollution, vandalism, and poor conservation practices, constantly threaten cultural resources. Additionally, the dynamic nature of cultural heritage, which evolves with society, necessitates a flexible and adaptive approach to conservation.

The Charter project (2023) highlights the transformation of rural landscapes under the influence of modernity, illustrating how cultural heritage can be both preserved and adapted to contemporary needs. This requires an interdisciplinary approach that considers the historical, social, economic, and political contexts of cultural landscapes. Moreover, an integrated approach to conservation, as discussed in the project report, emphasizes sustainable management practices that consider the interconnectedness of natural and cultural heritage. This approach advocates for a holistic perspective, addressing the dynamic processes of change within cultural landscapes and enhancing their resilience and sustainability.

1.4. Cross-Disciplinary Areas

Integrated Water Resources Management (IWRM) is a comprehensive approach that promotes the coordinated development and management of water, land, and related resources to maximize economic and social welfare while safeguarding vital ecosystems and the environment (Global Water Partnership, 2000). Water is an indispensable resource for human survival and well-being, serving as a critical input for food production, agricultural systems, healthy ecosystems, biodiversity, and industrial processes (Global Water Partnership, 2000). The Figure 1 below illustrates the components of IWRM.

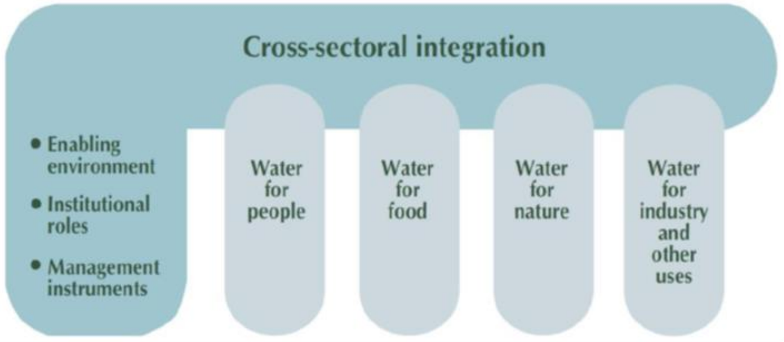

Figure 1. Integrated Water Resources Management (IWRM) and its cross-sectoral integration. (Source: Global Water Partnership, 2000)

Recent advancements and studies in the realm of IWRM have expanded upon these foundational concepts. For instance, research by Singh et al. (2021) highlights the importance of adopting IWRM approaches in addressing the challenges posed by climate change and increasing water scarcity. The study emphasizes the need for sustainable water management practices that are adaptable to changing environmental conditions.

In the context of food production, water's role cannot be overstated. It is vital for irrigation, livestock sustenance, and post-harvest processes. The relationship between water management and agricultural productivity is crucial, especially in the face of growing populations and climate change. Studies by Bwambale E. et al. (2022) illustrate how innovative irrigation techniques and efficient water use in agriculture can significantly enhance food security.

The significance of water in maintaining healthy ecosystems and supporting biodiversity is also increasingly recognized. As described by Priya A. K, et.al. (2023), aquatic ecosystems like rivers, lakes, and wetlands are not just habitats for various species but are also crucial for ecological balance and biodiversity conservation. Their research stresses the importance of preserving natural water flows and maintaining water quality to protect these habitats.

Furthermore, the integration of agriculture and cultural heritage into water resource management is gaining attention. This interdisciplinary approach, as explored by Hein, C. et al. (2020), acknowledges the socio-cultural and economic dimensions of rural communities, offering holistic and sustainable water management solutions.

Regarding renewable energy, the link between regional production, water resource management, and sustainability is critical. The potential of renewable energy sources like bioenergy, solar power, wind, and geothermal energy in ensuring economic and environmental sustainability is enormous. Research by FAO (2021) on integrating renewable energy production with agriculture and water management illustrates the potential for achieving sustainability in energy production without compromising food security.

The tourism industry's relationship with lake ecosystems presents both opportunities and challenges. Mass tourism poses risks to natural ecosystems, yet sustainable cultural tourism can foster regional development. Strategies for sustainable tourism, as discussed by Baloch, Q.B., Shah, S.N., Iqbal, N. et al. (2023), involve developing heritage-based touristic products and participatory cultural tourism management systems. These strategies emphasize the importance of balancing tourism development with the carrying capacity of touristic destinations, ensuring that the growth of the tourism sector does not detrimentally impact the natural and cultural heritage of the regions.

IWRM shows a rising realisation of water management's connectivity with other sectors, as well as the need for a comprehensive strategy. The integration of sustainable practices in agriculture, industry, energy generation, and tourism are critical for addressing the varied difficulties of water management. This method tries not just to protect water supplies, but also to balance economic development, environmental conservation, and social well-being. As global concerns such as climate change and population expansion worsen, the concepts of IWRM become more important, directing policymakers and stakeholders towards sustainable and equitable water resource management.

2. Literature review

2.1. The Relevance of Aquatic Cultural Landscape Management

Aquatic cultural landscape management is an interdisciplinary field that aims to preserve and sustainably manage the cultural and natural resources associated with aquatic ecosystems. To understand the current state of research in this field, a critical analysis of the literature reveals several key findings.

Firstly, there is a growing emphasis on the need for sustainable water management and the integration of knowledge from multiple disciplines. This aligns with the broader scientific development in the field, which recognizes the interplay between water resources, environmental sustainability, and socio-economic factors. The integration of these diverse perspectives is crucial for developing comprehensive strategies that address the complex challenges of aquatic cultural landscape management.

Furthermore, the literature highlights the importance of striking a balance between the preservation of cultural heritage and the implementation of sustainable development practices. This includes activities such as farming, tourism, and recreation. The objective is to ensure the long-term conservation of cultural assets while also supporting local economies and communities. This approach recognizes the value of cultural heritage in promoting social well-being and providing tourism amenities.

The literature also underscores the need for a holistic management system that considers the ecological, cultural, and economic dimensions of aquatic cultural landscapes. This involves understanding the landscape character, natural and cultural heritage of rural environments, and the carrying capacity of these areas. By incorporating these aspects, it becomes possible to develop innovative and sustainable solutions that meet the needs of both present and future generations.

One notable research gap identified in the literature is the lack of a systematic and comprehensive approach to aquatic cultural landscape management. While there are studies assessing the potential for effective conservation of these resources, they often focus on specific aspects and fail to integrate the various dimensions into a single system. This highlights the need for an integrated approach that considers the scientific study of nature conservation, management, restoration operations, as well as the social, cultural, and economic aspects.

Moreover, the literature highlights the significance of cultural ecosystem services in aquatic cultural landscape management. Reckendorfer et al., (2013) points out that while the quantification and valuation of ecological and economic ecosystem services are increasingly recognized in conservation and regional planning, little attention has been given to the cultural ecosystem services of the landscape. Cultural ecosystem services play a vital role in public life, social well-being, and tourism amenities. Therefore, their inclusion in management and remediation efforts is essential.

2.2. Literature Gaps

The continuity of rural-peri-urban-urban transition zones in aquatic environments presents a critical yet underexplored area in environmental and urban studies. As identified by Grimm N. B. et al. (2008), these zones are crucial interfaces where urbanization, ecological dynamics, and socio-economic factors intersect, affecting the management and sustainability of aquatic ecosystems. The complexity of these transition zones, comprising gradients of land use changes, socio-economic shifts, and ecological transformations, poses significant challenges to researchers aiming to understand their multifaceted impacts. To bridge these gaps, future research initiatives could include:

- Interdisciplinary Integration: One of the primary gaps in existing literature is the lack of interdisciplinary approaches that integrate ecological, urban planning, and socio-economic perspectives. Effective study of transition zones in aquatic environments requires the synthesis of diverse methodologies—from hydrological modelling to socio-economic analysis—to fully understand the impacts of urbanization on these sensitive ecological areas.

- Dynamic Urbanization Processes. The rapid and often unpredictable nature of urbanization processes complicates the study of these transition zones. There is a need for more dynamic models that can accurately simulate the ongoing changes in land use, infrastructure development, and their ecological impacts. Current models often fail to capture the transient, yet impactful, nature of urban sprawl and its immediate effects on water quality, habitat disruption, and biodiversity loss in aquatic settings.
- Pollution and Hydrological Modifications: Pollution load from urban and peri-urban areas and its management is poorly understood in the context of aquatic transition zones. Studies need to specifically address how urban runoff and effluents affect water quality and ecosystem health. Additionally, alterations in natural water flow due to urban development—such as the construction of stormwater systems and impervious surfaces—require further exploration to assess their impacts on hydrological regimes and aquatic habitats.
- Land Use Practices: There is an evident lack of comprehensive data linking land use practices in transitional zones to changes in aquatic ecosystems. Future research should focus on how agricultural practices, urban landscaping, and recreational land use contribute to nutrient loading and habitat fragmentation in these zones.

To address these research gaps, future studies should focus on examining the continuity of rural-peri-urban-urban transition zones specifically in aquatic environments. The exploration of urban-rural linkages through the lens of NBS and integrated water resources management (IWRM) presents a novel contribution to understanding how these areas can be managed cohesively. This would involve investigating the interactions between urbanization, land use practices, pollution, and hydrological modifications in shaping aquatic ecosystems. Developing long-term ecological research sites within these transition zones could provide invaluable data on temporal changes and help in understanding long-term urbanization impacts. Moreover, examining the role of policy frameworks and governance structures in managing the transition zones effectively. Studies could explore how urban planning decisions influence ecological outcomes and vice versa. Investigating the role of community knowledge and stakeholder engagement in managing transition zones. Understanding local perceptions and practices can aid in crafting more effective conservation strategies.

Creating a method to promote collaboration across stakeholders, particularly in the context of NBS, is a crucial feature of the research. This method not only encourages a more sustainable and inclusive water management strategy but also contributes to the preservation of the landscape. This study addresses a notable deficiency in current research by effectively implementing stakeholder engagement, a concept that has been widely recommended in theory but rarely put into practice (WWAP, 2018, Seddon et. al. 2020).

The critical analysis of the literature on aquatic cultural landscape management reveals the need for sustainable water management, the integration of diverse disciplines, and the balance between cultural heritage preservation and sustainable development practices. It emphasizes the importance of a holistic management system that considers the ecological, cultural, and economic dimensions. The analysis also identifies research gaps related to the lack of a comprehensive approach, the inclusion of cultural ecosystem services, and the continuity of rural-peri-urban-urban transition zones in aquatic environments. Future research should address these gaps to further advance the field of aquatic cultural landscape management.

2.3. Contribution to Research Projects

In addition to the literature review described above, I have directly contributed to the development of the research reports, as indicated by my role as a lead contributing author in each of the five expert groups that created the research reports listed in Appendix 1. Participating in these expert groups gave me in-depth exposure to cutting-edge research and techniques, which improved the quality and relevance of my thesis. Working with a varied group of experts gave me invaluable insights into complex environmental concerns, particularly those affecting aquatic cultural landscapes. As such, the research integrates local knowledge and experiences, particularly through the inclusion of case studies from the Västra Götaland Region in Sweden, Tisza Lake, and Little Balaton Nature Reserve in Hungary. These topics were chosen based on my previous work and relationships, to ensure that the research is anchored in real-world contexts and practical experience.

My contributions to these expert panels are thoroughly integrated throughout the thesis, particularly in discussions about the latest methodologies and findings in the field. These contributions ensure that the thesis is not only informed by current research but also shaped by practical insights gained through my collaborative work with leading specialists. This blend of theoretical and practical knowledge underscores the thesis's relevance and applicability to real-world environmental challenges.

2.4. Critical Evaluation

The study incorporates interdisciplinary knowledge, combining views from environmental science, economics, sociology, and cultural heritage studies. Adopting this method is crucial for tackling the complex difficulties of managing aquatic cultural landscapes. Nevertheless, the complex method of incorporating many approaches and theoretical frameworks presents difficulties, which could result in oversimplifications or misinterpretations.

The key research findings contribute substantial value to the thesis through the provision of empirical evidence and practical applications. This encompasses data gathered from interviews, workshops, and field investigations carried out across several European places. The discovery of these results is essential for confirming theoretical concepts and demonstrating the practicality of suggested management solutions in real-world scenarios.

The research recognizes the evolving nature of social relations and cultural practices, which can change rapidly in response to contemporary global challenges. The dynamic nature of this component can pose a challenge to comprehensively capture during a limited study period, emphasising the necessity for continuous research and adaptable management techniques.
Aquatic ecosystems are sensitive to environmental factors such as climate change, pollution, and human intervention. The variability and unpredictability of these factors can limit the ability to draw definitive conclusions about cause-and-effect relationships. The research attempts to address these challenges by proposing adaptive management strategies that incorporate Nature-Based Solutions (NBS) tailored to local conditions.

Effective stakeholder engagement and governance structures are emphasized as critical components for sustainable management. The research provides detailed models and examples of participatory governance, showcasing successful implementations in various projects. These models highlight the importance of involving local communities, government agencies, and other stakeholders in decision-making processes to ensure comprehensive and equitable management practices.

2.5. Articles

This study is based on a broad and comprehensive collection of articles that look into numerous environmental and ecological subjects, demonstrating the breadth and interdisciplinary character of environmental research. The collection includes eight publications published between 2020 and 2024, each of which adds new viewpoints and conclusions to the greater discussion of sustainable development, climate change adaptation, and aquatic landscape management.

1. "Possibilities and Challenges for Landscape Observatories" by Ternell et al., published in March 2023 in the Ecocycles Scientific journal, examines the potential and hurdles associated with landscape observatories. This piece contributes significantly to the understanding of landscape-level environmental monitoring and management (Ecocycles, 2023; https://doi.org/10.19040/ecocycles.v9i1.267

2. "Environmental Viability Analysis of Connected European Inland–Marine Waterways and Their Services in View of Climate Change" by Némethy, Ternell, et al. released in June 2022 in Atmosphere, provides an insightful analysis of European waterways in the context of climate change, highlighting the importance of sustainable water resource management (Atmosphere, 2022; https://doi.org/10.3390/atmos13060951.

3. "Urban Farming Models, Ecosystems and Climate Change Adaptation in Urban Environments: The Case of SATURN Pan European Programme" by Nikologianni et al., published in January 2022 in the Athens Journal of Sciences, explores innovative urban farming practices and their role in climate change adaptation, emphasizing the integration of urban agriculture into city planning (Athens Journal of Sciences, 2022. https://doi.org/10.30958/ajs.9-1-1).

4. Némethy, S., Ternell, A., Lagerqvist, B., Remenyik, B. (2022). Sustainable agritourism based on multifunctional organic agriculture and local organic products: the Azienda Agricola Model developed on the basis of good practices in Italy and Alsace in France. Zeszyty Naukowe Wyższej Szkoły Turystyki i Ekologii, ISSN: 2084-8722 http://wste.edu.pl

5. "Public-private Partnerships for Multifunctional Sustainable Land Use in Peri-urban Areas to Mitigate the Adverse Effects of Climate Change" by Ternell et al., published at the end of 2020 in the Ecocycles Scientific journal, discusses the role of public-private partnerships in promoting sustainable land use in areas adjacent to urban regions, a crucial aspect of urban resilience planning (Ecocycles, 2020; https://doi.org/10.19040/ecocycles.v6i2.180).

6. "Financial Instruments for Nature-based Solutions to Reduce Risks for Flooding and Drought" by Ternell et al., published in September 2020 in the Ecocycles Scientific journal, addresses the financial mechanisms required to implement nature-based solutions for managing flood and drought risks. This article is particularly relevant in the context of increasing climatic extremes and the need for sustainable financial strategies in environmental management (Ecocycles, 2020. https://doi.org/10.19040/ecocycles.v6i2.161)

7. "New Integrated Approaches to Climate Emergency Landscape Strategies: The Case of Pan-European SATURN Project", published in October 2020 in *Sustainability* - MDPI Open Access Journals, presents an innovative approach to addressing the climate emergency through landscape strategies, focusing on the Pan-European SATURN project. This work underscores the necessity of integrated, cross-disciplinary approaches in tackling the multifaceted challenges posed by the climate crisis (MDPI, 2020; https://www.mdpi.com/2071-1050/12/20/8419).

8. “Multifunctional Land Use and The Role of Ecosystem-Centred Spatial Planning and Urban Agriculture in Landscape Conservation” submitted to the MDPI open access journal Land in April 2024, is dealing with the new concept of landscape conservation, which requires the system-level understanding of the natural world and the human environment, making a paradigm shift in three levels: shift in geographic scale where we abandon site specific arbitrary boundaries to maintain biodiversity and climate resilience, shift in perspectives to define the landscape as a whole with all types of land uses, habitats, urban and rural areas in an integrative manner, and shift in the conservation process based on collaborative governance structures and community participation. In urban areas with mainly grey infrastructures and very limited green areas the ecosystems are deficient, since natural producers and decomposers are missing, reduced, or altered.

2.6. Hypotheses

2.6.1. Hypotheses on Nature-Based Solutions (NBS) and Water Management

The increasing frequency and severity of water-related challenges, including flooding, droughts, and pollution, underscore the urgent need for innovative and sustainable water management strategies. Traditional grey infrastructure, while effective to a certain extent, often falls short in addressing the multifaceted nature of these challenges, leading to a growing interest in nature-based solutions (NBS). The hypothesis on the efficacy of NBS in water management proposes that NBS are not only necessary but also advantageous to traditional approaches in terms of increasing water retention, lowering flood risks, and contributing to the overall resilience of aquatic cultural landscapes. The hypothesis is mainly addressed in chapter 4.1, 4.2 and 4.7, but is also mentioned throughout the research results.

Detailed Hypothesis on NBS Efficacy in Water Management

- NBS as Multifunctional Water Management Tools: Nature-based solutions, through the reconstruction or establishment of wetlands, serve multiple water management functions simultaneously. Wetlands act as biological filters, purifying water by absorbing pollutants, thus improving water quality. They provide new habitats for biodiversity, enhancing ecosystem services and resilience. Moreover, it mitigates the effects of climate change as being a natural flood buffer system. They absorb excess rainfall, reducing flood peaks and mitigating flood risks.

- Cost-effectiveness and Sustainability: NBS offer a cost-effective alternative to traditional grey infrastructure by leveraging natural processes to manage water. The maintenance and operational costs associated with NBS are often lower, and they contribute to long-term sustainability by enhancing ecosystem services and biodiversity. A shift to a near-natural economy could generate up to $10 trillion a year in additional revenue and cost reductions and create 395 million new jobs by 2030 (WEF, 2020). This aspect is crucial in a time when financial resources for environmental management are limited and need to be allocated efficiently.
- Resilience and Disaster Risk Reduction: NBS enhance the resilience of water management systems by making them more adaptable to changing conditions, including climate change. By restoring natural buffers, communities are better prepared to cope with and recover from disasters. Nature-based solutions are particularly important for sectors heavily dependent on ecosystems and natural resources, offering a way to reduce disaster risk, increase community resilience, and mitigate future vulnerability.
- Social and Economic Co-benefits: Beyond water management, NBS offer major social and economic benefits. They promote public health by providing green places for physical activity and mental wellbeing. Furthermore, they offer recreational areas for residents and tourists, contributing to social well-being and economic benefits through eco-tourism. They also assist cultural services such as education and the preservation of local heritage.

2.6.2. Hypotheses on Mitigation of Climate Change Impacts

To successfully reduce the negative impacts of climate change, especially on aquatic cultural landscapes and areas with important aquatic habitats, it is essential to implement strong adaptation methods. These measures encompass the use of nature-based solutions (NBS) and the improvement of water management methods. NBS, particularly in urban areas, are effective strategies to combat the various complex challenges posed by climate change, such as the decline in biodiversity, severe temperatures, flooding, and concerns to water and food security. In addition to their positive impact on the environment, urban NBS also offer significant social and economic benefits.

The pursuit of climate resilience and sustainability is greatly enhanced by the synergistic effects of adaption techniques and stakeholder collaboration. By utilising the advantages of NBS and promoting inclusive governance, communities may effectively address and negotiate the difficulties posed by climate change. This strategy is not solely focused on implementing creative ideas, it also requires a coordinated commitment involving all sectors of society. Collective action is crucial in protecting our environment and preserving the welfare of future generations.

By integrating efficient water management and the strategic implementation of NBS, while fostering collaboration among different stakeholders, we establish an approach that addresses both immediate needs and ensures the long-term sustainability of the environment. The core of these efforts lies in recognising the interdependence of environmental health, social welfare, and economic success, thus creating a robust structure that can endure the challenges posed by climate fluctuation and change.
The hypothesis is mainly addressed in chapter 4.1.

2.6.3. Hypotheses on Cultural Heritage Conservation and Community Engagement

The integration of NBS in the management of aquatic cultural landscapes not only preserves cultural heritage but also engages communities and yields significant economic benefits. This holistic approach to conservation highlights the interconnectedness of natural and cultural values, emphasizing the importance of participatory governance and the potential for heritage sites to act as catalysts for sustainable development. The hypothesis is primarily addressed in chapter 4.3 and 4.5.

Incorporating NBS into the management of aquatic cultural landscapes not only protects the natural environment but also supports and encourages the inherent cultural values contained within these landscapes. NBS provide a means to preserve the ecological balance and aesthetic value of sites that hold historical and cultural importance. This is achieved by integrating features such rehabilitated wetlands, green infrastructure, and sustainable water management practices. This integration of natural and cultural management fosters a deeper awareness and understanding of a community's legacy, enhancing the ability of cultural landscapes to endure environmental shifts and human influences.

Active involvement of the community and participation of stakeholders are essential elements in the sustainable management and preservation of aquatic cultural landscapes. The involvement of local communities, and other stakeholders in decision-making processes increases the likelihood that the outcomes will accurately represent the varied values and needs of individuals who have a direct connection to the area. This participatory method cultivates a feeling of possession and accountability among members of the community, resulting in conservation initiatives that are not only more efficient but also respectful of cultural values. Involving communities in the conservation of their cultural heritage facilitates the preservation of traditional knowledge and practices, guaranteeing the transfer of these invaluable resources to future generations.

The conservation of cultural heritage in aquatic settings, notably using NBS, has significant economic benefits. These settings become tourism hotspots, attracting visitors who want to experience the rare combination of natural beauty and cultural richness. This, in turn, benefits local economies by increasing spending in the region, creating jobs, and promoting local crafts and products. Furthermore, successful historical protection can encourage community-led projects by instilling a stronger sense of identity and pride. The economic benefits of protecting cultural heritage go beyond obvious financial gains, resulting in a more united and resilient community.

2.6.4. Hypotheses on Urban Living Labs

Urban living labs enhance the efficacy of sustainable urban development projects by fostering innovative collaboration between stakeholders and integrating real-time data and community feedback into the planning and implementation processes.

This hypothesis proposes that urban living labs, which serve as experimental and interactive platforms, have a substantial impact on the success of urban sustainability projects. They accomplish this by actively incorporating a wide range of stakeholders—including local communities, government agencies, and researchers—in the design and testing of new solutions in a real-world setting. The hypothesis is based on the idea that urban living labs not only provide a unique environment for innovation, but also allow for a more responsive and flexible solution to urban development concerns. These laboratories, by using all participants' aggregate expertise and feedback, are expected to develop more effective and broadly accepted urban solutions that are directly informed by the community's needs and behaviours.

The research addresses the hypothesis on urban living labs by emphasizing their potential to significantly enhance sustainable landscape management. It describes the Living Lab as an applied research and knowledge-transfer concept that involves a broad range of stakeholders. This participatory approach fosters knowledge transfer and the implementation of innovative products and services, which is crucial for reducing the adverse impacts of human activities on ecosystems. The conclusion highlights the importance of integrating sustainable business models, nature-based solutions, and community participation to ensure the economic and social viability of these regions. The hypothesis is discussed in chapter 4.6.

2.6.5. Hypotheses on Integrated Water Resources Management (IWRM)

Integrated Water Resources Management (IWRM) is a fundamental approach for effectively and sustainably managing water resources in aquatic cultural environments. By embracing a holistic approach that considers the interconnectedness of land, water, and ecosystems, IWRM plays a pivotal role in ensuring the vitality and sustainability of these unique environments. The hypothesis is primarily addressed in chapters 4.5.

IWRM and Ecosystem Health

Implementing IWRM solutions directly enhances the ecological well-being of aquatic cultural landscapes. IWRM promotes the fair and sustainable utilisation of water resources, considering the various requirements of all parties involved, including the environment. This approach acknowledges water as an essential element of the ecosystem, crucial for sustaining biodiversity, facilitating ecological processes, and safeguarding the cultural and historical authenticity of landscapes. IWRM, mitigates the negative effects of pollution, over-extraction, and habitat destruction on aquatic ecosystems. It achieves this by restoring natural water cycles and promoting sustainable water usage, which helps maintain the resilience and diversity of these ecosystems.

Policy and Governance for IWRM

The effectiveness of IWRM efforts is highly dependent on strong policy frameworks and governance systems. Effective governance entails the establishment of laws, regulations, and institutional frameworks that uphold the concepts of IWRM. The development, management, and conservation of water resources necessitate the involvement of several stakeholders, including government agencies and local communities. These cooperative efforts ensure that water management methods are comprehensive, fair, and in harmony with the overarching objectives of sustainability and ecosystem conservation. Moreover, it is imperative to implement policies that promote the integration of planning and management across all sectors and scales to effectively tackle the intricate issues that aquatic cultural landscapes encounter.

Cross-Disciplinary Approaches in IWRM

The complexity of water management in aquatic cultural landscapes necessitates a cross-disciplinary approach. By incorporating insights from environmental science, economics, sociology, and law, IWRM fosters a comprehensive understanding of the multifaceted relationships between human societies and water environments. This interdisciplinary perspective is essential for developing strategies that balance ecological health with economic development and social well-being. It enables the identification of sustainable solutions that address the root causes of water-related challenges, rather than merely treating their symptoms. Moreover, integrating knowledge from diverse fields encourages innovation and facilitates the adoption of practices that are both culturally appropriate and environmentally sound.

2.7. Theoretical framework

2.7.1. Introduction to the Theoretical Framework

Understanding the relationship between ecosystems and human well-being is crucial in achieving the goal of sustainable management of aquatic cultural landscapes. The research is based on the theoretical framework of the Millennium Ecosystem Assessment, which highlights the role of ecosystems in supporting life and fostering human well-being. This framework provides the conceptual basis for examining how ecosystems can sustainably support human activities while maintaining their ecological integrity.

The theoretical framework also revolves around the concept of ecosystem services, which refer to the advantages that humans get from ecosystems. The services provided encompass the provision of essentials like water and food, the regulation of natural phenomena such as floods and diseases, the cultural services such as recreational benefits, and the support of essential processes like nutrient cycling that sustain life on Earth. This study focuses on the integration of cultural ecosystem services into traditional assessments of ecological and economic issues, emphasising their substantial impact on human well-being and community identity.

Despite their importance, cultural ecosystem services are often undervalued and overlooked in environmental planning and policymaking. This approach aims to address this issue by incorporating these services within the wider context of ecosystem management. It questions the conventional division between the natural and cultural heritage sectors, promoting a comprehensive approach that acknowledges the inherent connections between people and their surroundings. Aquatic landscapes are particularly significant in this regard. They not only support biodiversity and provide essential ecosystem services but also hold cultural values that are critical for the communities dependent on them. The theoretical framework guides the exploration of how these landscapes can be managed not just for ecological and economic benefits but also as cultural heritage sites that contribute to the social cohesion of communities.

The objective of this research is to utilise this theoretical framework in the management of aquatic cultural landscapes. The framework will be used to assess and suggest sustainable strategies that prioritise both the ecology and cultural heritage. The goal is to offer an in-depth understanding of the intricate relationships within these landscapes, which will then be used to influence policy and practical strategies for their sustainable management.

2.7.2. SDG-17 Objectives: Emphasizing Systemic Interdependencies

The Sustainable Development Goals (SDG-17) emphasize the importance of partnerships and integrated approaches to solving global challenges. In the context of my research on aquatic cultural landscapes, it is crucial to underscore the interconnectedness of various sustainability challenges, particularly those relating to the "energy trilemma," "water trilemma," and "food trilemma." These trilemmas illustrate the complex and interdependent challenges of ensuring sustainable, equitable access to energy, water, and food resources.

The nexus between energy, water, and food is a critical area where the SDG-17 objectives can be applied to highlight the need for integrated management approaches. For instance, the production of energy, particularly through hydroelectric power, has significant implications for water availability. Conversely, the treatment and distribution of water consume substantial amounts of energy. Similarly, both energy and water are essential for food production, from irrigation to processing and transportation.

This interconnectedness suggests that any attempt to solve issues in one area without considering the others is likely to create imbalances or exacerbate challenges elsewhere. For example, enhancing water efficiency might reduce the energy needed for water pumping and treatment, subsequently lowering the overall carbon footprint of water utilities. On the food front, sustainable agricultural practices that reduce water and energy use can also contribute to achieving zero hunger and combatting poverty by lowering production costs and increasing food security.

I believe that while SDG-17's emphasis on partnerships and integrated management is beneficial, its broad scope can sometimes reduce the focus on specific ecological contexts. For aquatic cultural landscapes, it is essential to tailor these interdependencies to local environmental and cultural conditions to ensure effective implementation.

Several case studies within the thesis will explore these interdependencies. For instance, the U-Garden Project not only looks at urban agriculture but also considers how these practices can be optimized to use less water and energy, thereby contributing to a more resilient urban food landscape. Another example is the SATURN Project, which integrates urban and rural water management strategies to enhance the overall sustainability of agricultural practices within and around urban areas.

2.7.3. Ecosystem Services in View of the Millenium Ecosystem Assessment

The interconnection between ecosystems and human well-being is a key focus of many environmental studies, highlighting the essential role that ecosystems provide in sustaining life and supporting human prosperity. The Millennium Ecosystem Assessment (MEA) (Millennium Ecosystem Assessment, 2005) is an important study that comprehensively analyses the state of many ecosystems, with a particular focus on their capacity to provide support, resources, and regulation. This comprehensive assessment offers a solid foundation for understanding the complex interrelationships between ecosystems and the benefits they offer to humanity. However, it also highlights a significant gap in the current understanding and implementation of the integration of cultural ecosystem services and their influence on human well-being.

The Millennium Ecosystem Assessment is the result of 1400 researchers and five years of international collaboration. It has defined the state of ecosystem services, taken stock of the factors driving ecosystem change, and assessed the impact of these changes on people's well-being. The findings of the Millenium Ecosystem Assessment were the following:

1. Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fibre and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.
2. Changes that have been made to ecosystems have resulted in significant overall benefits to human welfare and economic development. However, these benefits have come at an increasing expense, including the deterioration of various ecosystem services, increased risks of sudden shifts, and the worsening of poverty for certain populations. If these concerns are not addressed, they will significantly reduce the benefits that future generations get from ecosystems.
3. The deterioration of ecosystem services is expected to worsen considerably in the first half of this century, posing a significant obstacle to the achievement of the Millennium Development Goals.
4. The challenge of reversing the degradation of ecosystem while meeting increasing demands for services can be partially met under some scenarios considered by the MEA, but will involve significant changes in policies, institutions and practices that are not currently under way. Many options exist to conserve or enhance specific ecosystem services in ways that reduce negative trade-offs or that provide positive synergies with other ecosystem services.

The main conclusion of the MEA results is that human activities are diminishing Earth's natural resources, putting such pressure on the environment that the capacity of the planet's ecosystems to support future generations can no longer be guaranteed. Simultaneously, the study indicates that it is feasible to halt the decline of numerous ecosystem services within the next 50 years through appropriate actions. However, achieving this goal necessitates significant policy and practice changes that are not currently being applied.

Overall, I believe that the MEA framework is highly relevant as it provides a holistic view of how ecosystem services strengthen human well-being, which is crucial for the sustainable management of aquatic cultural landscapes. By integrating cultural ecosystem services, the framework highlights the significant impact of these services on community identity and social cohesion.

The TEEB programme, known as The Economics of Ecosystems and Biodiversity, is a multi-year worldwide policy process that focuses on the development of the economics of ecosystem services and the economic assessment of these services. While sharing similarities in structure and process with the MEA, the outcomes of this study were documented in comprehensive technical papers. The TEEB findings indicate that the natural environment has a significant impact on various aspects and participants of economic activities. However, currently, the value of the natural environment is not fully integrated into business processes and is only reflected externally. Simultaneously, there is an increasing level of consumer consciousness, with a preference for products that are ecologically sustainable. The paper emphasises that the measures that economic players can use to safeguard biodiversity and environmental services can also have positive effects on other social policy goals.
(Figure 2).

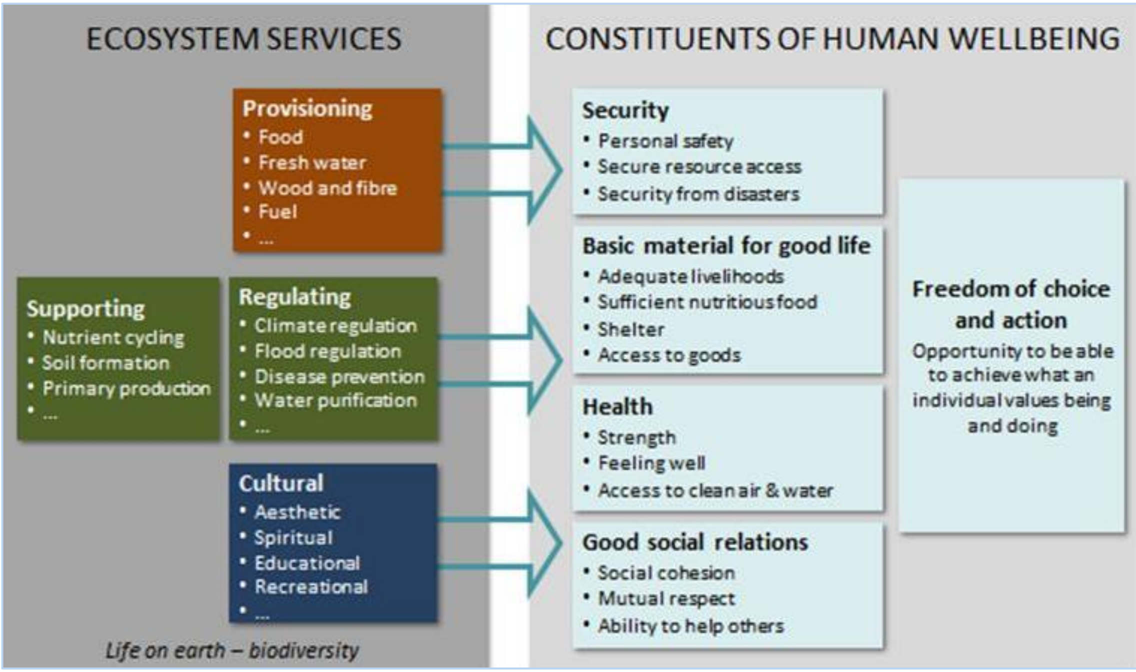

Figure 2. Connection between ecosystem services and the constituents of human well-being.
Source: https://doi.org/10.13140/2.1.1896.0968

Although cultural ecosystem services have a profound influence on our common and individual identities, they are often overlooked by more tangible options. This neglect might be attributed to an inherent barrier that separates the management of natural and cultural heritage within ecosystems. This barrier diminishes the visibility and perceived importance of cultural services.

Aquatic environments offer a diverse range of cultural benefits, such as aesthetic and spiritual aspects, educational opportunities, recreational activities, and agricultural contributions through crafts and skills. These landscapes facilitate the development of human culture and the formation of community social structure, all while preserving biodiversity and providing environmental services. They symbolise the mutually beneficial relationship between water and culture, showcasing how societies have developed in harmony with their aquatic environments.

Conservation approaches are complex, effective, and lasting, since they aim to achieve a harmonious integration of ecological, economic, social, and cultural objectives. This effort argues that aquatic conservation has the potential to go beyond traditional boundaries and emerge as a strong influence in safeguarding distinct cultural resources, enhancing community welfare, and protecting the environment for future generations. This revised perspective on aquatic cultural landscapes advocates for a holistic approach to conservation that acknowledges the inseparable connections between humans and their natural environment, while emphasising the significance of these locations as reservoirs of cultural heritage.

2.7.4. Biological, Ecological, and Economic Perspectives

An Ecosystem Approach is a technique for integrating activity into a wider ecosystem in order to promote long-term growth, equity, and resilience of interconnected social-ecological systems. To assess the condition and carrying capacity of an ecosystem in a given location, a variety of inventories are required to identify the resources that define the character and major components of the cultural landscape. Natural resources should be considered, including geodiversity, biodiversity, and water resources. Aquatic habitats may have distinct biodiversity based on the climatic zone, geological environment, and ecological health of these environments, which are closely linked to the use of ecosystem services.

Furthermore, these natural resources provide material for several trades and crafts, such as construction materials for buildings (e. g. different types of bedrocks, such as granite, gneiss, basalt, sedimentary rocks such as sandstone, limestone, shale, schist, etc.), woodwork, reeds for roofing (a still existing but already rare craft), collection and cultivation of herbs and spices, agricultural production.

Integrated Water Resources Management (IWRM) advocates for the coordinated development and management of water, land, and related resources to maximize economic and social welfare without compromising the sustainability of vital ecosystems.

This framework is highly applicable to my research as it promotes a balanced approach to managing water resources, essential for the sustainability of aquatic cultural landscapes. Its emphasis on stakeholder engagement and adaptive management aligns well with the research's goals of inclusive and resilient water management practices.

The ecosystem-approach is based on the awareness regarding the role of ecological cycles. The well-being of society has been long tied to the availability of the inexpensive resources and other elements that are essential to sustain life. Concentrations of these elements in soil, water, air, and in living organisms are determined by various self-regulating processes called ecological cycles. Today's "Ecocycle" strategy is centred on these processes and its goals are 1) to make these cycles free from toxic materials and 2) to create a resource-efficient society by reducing the ecological footprint in an economically sustainable way. Long-term health and productivity of the ecosystems can be assured by science-based management decisions through the understanding how local cycles fit into global ones. Ecological cycles provide viable models for our modern society in many ways and constitute the scientific basis of circular economies.

The most important goal of circular economies is to eliminate the concept of waste, thereby drastically improving resource efficiency. In circular economies two kinds of resources 1) biomass and nutrients and 2) abiotic materials are moving in two closely linked compartments: the biocycle and the technocycle, respectively. Circular economies require sustainable and fully compatible ecological and socioeconomical systems on a micro-regional scale, both in rural areas, peri-urban regions, and urban settlements, preferably by linking these very different structures with the provision and careful maintenance of adequately sized ecotones for greater resilience. An apparent requirement for successful circular economies is a strong public service network that supports the energy-product-zero waste model. Thus, the first step is to design items to be reusable, easily upgradeable, or recyclable. Understandably, local products that require minimal storage and transport are preferred. Finally, materials containing components that pose an environmental or health risk (e.g., infectious agents, greenhouse gases, and toxic compounds like persistent organic pollutants) must be removed from circulation.

2.7.5. Earth System Science

To fully understand the concept of sustainability, it is essential to understand the structure and cycles of earth systems, one of the most important components of which is a well-organised, complementary system of biogeochemical cycles. Earth System Science (ESS) is a relatively young synthetic discipline, in fact reflecting the holistic Gaia hypothesis, an application of the renaissance sciences to the earth sciences (Jacobsen et al., 2000). It primarily investigates the *dynamic* relationships and interactions of the Earth's "spheres" (atmosphere, hydrosphere, cryosphere, geosphere (lithosphere + pedosphere), biosphere, magnetosphere, anthroposphere). Such a detailed division of the Earth's spheres is strongly justified from a systems science perspective,[1] particularly regarding the impact of human activities on Earth systems.

I believe that the ESS is necessary for this research as it facilitates a multidisciplinary understanding of the dynamic interactions within aquatic cultural landscapes. Its comprehensive nature allows for a thorough assessment of both natural and anthropogenic influences on these ecosystems.

In a broader sense, earth systems science thus brings together the natural and social sciences into a practical system, using systems science to link (or more precisely, to emphasise the inherent links) between ecology, ecosystem science, geology, palaeontology, glaciology, meteorology, climatology, oceanography, space science, landscape architecture, economics, sociology, ecological sociology and cultural heritage conservation. It was this approach that led the renowned American meteorologist and systems scientist Francis P. Bretherton to create the famous Bretherton diagram, which sees the activities of human society as a single element that affects the earth's ecosystems, natural resources, and influences climate change (Figure 3).

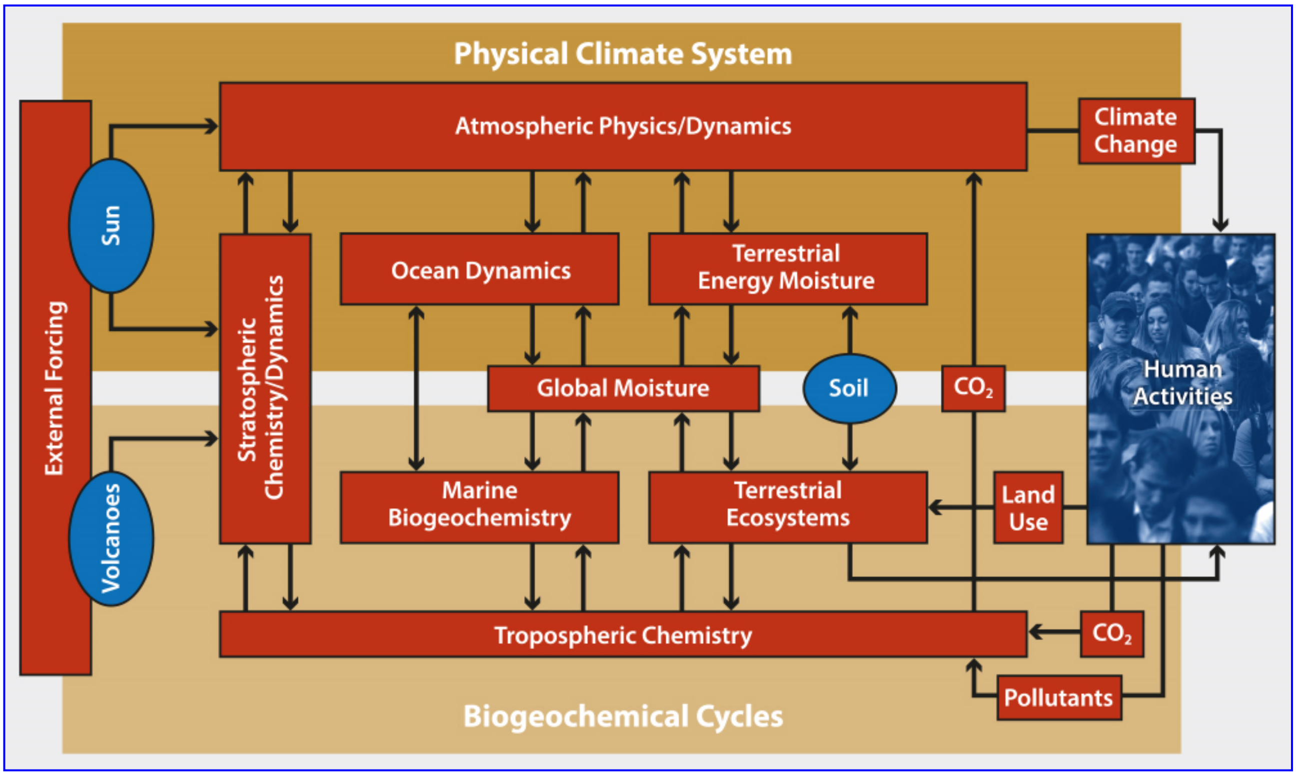

Figure 3. Simplified version of the Bretherton diagram. This concept allows an understanding of the interconnectedness of earth systems, the relationships and cycling of transport processes ("fluxes") and the role of human activities, "points of attack", without detailing social factors. Source: http://www.igbp.net/news/features/features/reflectionsonearthsystemscience.5.950c2fa1495db7081ecdc.html

[1] Many people discuss the atmosphere, the hydrosphere, the pedosphere and the lithosphere under the collective name of geospheres.

However, the impact of human society and human activities on earth systems, and their role in global change, can be better understood by trying to model socio-economic processes and their impact on earth systems, their cycles and the scale, direction, and balance of transport ('fluxes'). It is therefore essential to understand the human dimensions of global environmental change (Figure 4).

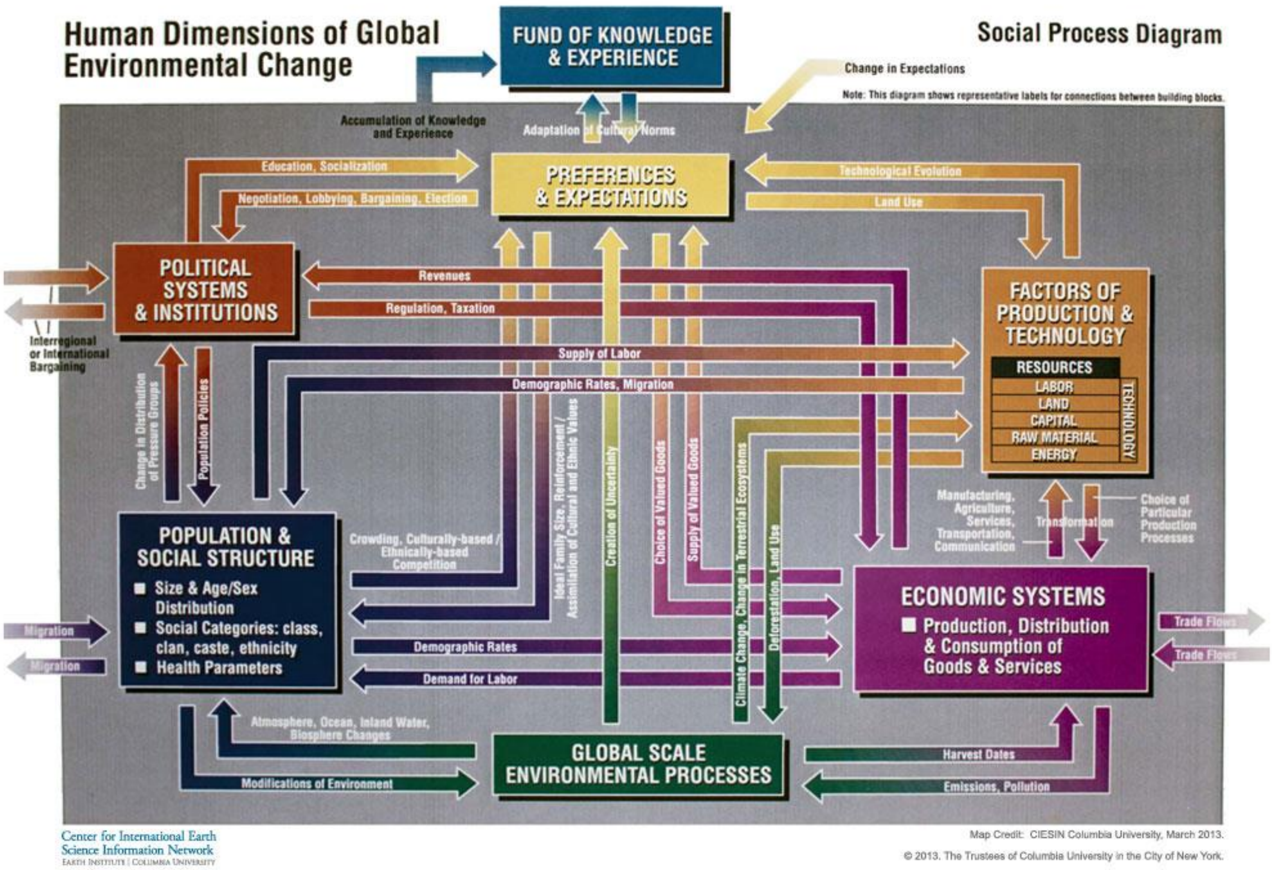

Figure 4. The Human Dimensions of Global Environmental Change. The Social Process Diagram, developed by a team of researchers at Columbia University, is an attempt to map the interactions of human societal systems as the most fundamental drivers of human-induced or human-influenced global environmental change. Source: Centre for International Earth Science Information Network, Earth Institute, Columbia University, New York. http://blogs.ei.columbia.edu/2013/03/04/a-road-map-towards-better-understanding-of-global-environmental-change/

The impact of human activities on the natural environment, human use (and, in many cases, depletion) of natural resources, ecosystem vulnerability, and the carrying capacity of ecosystem services must all be considered in regional planning, as well as the planning or permitting of environmentally hazardous economic activities and the remediation of damaged natural environments. The ecosystem services described above encompass all of the direct and indirect benefits that humans can obtain from ecosystems. Ecosystem services thus serve as a crucial link between humans and ecosystems. As a result, the sustainable management and environmentally responsible use of ecosystem services is critical. It is consequently critical that the carrying capacity of the environment be accurately assessed.

2.7.6. Maintaining Ecological Cycles in Rural and Urban Development.

Rural development and urban development should not really be discussed separately, since the use of natural resources is best discussed in a single rural-peri-urban-urban system, which seems to be completely illegitimate in the case of cities with a small population. Metropolitan areas with large populations also pose complex problems of resource production, transport, and use, as well as of resource recycling. Particularly complex problems are posed by ecosystems in specific urban environments, which are becoming increasingly central to research, not only in terms of spontaneously evolved ecosystems, often damaged, and plant and animal species adapted to urban environments, but also in terms of the design of artificial ecosystems (parks, vertical phytotron systems, urban aquaponics) for green cities seeking to create new, liveable environments. Rural development and urban planning will be discussed according to the holistic concept of sustainable use of ecosystem services and protection and maintenance of natural eco-cycles outlined above, without forgetting the requirements of economic and social sustainability. Rural development and urban planning strategies should therefore be developed in a much more holistic way than hitherto, taking into consideration the following aspects:

1. Identification of micro-regions of appropriate size and manageability, which can be managed in a coherent manner in terms of geography, ecology, natural resources, economic factors, infrastructural development potential, demographic and social conditions, after conducting an appropriate resource assessment and strategic environment analysis.
2. The use of renewable energy sources, the development of local and regional energy supply systems
3. Developing a complex system for the use and protection of water resources: surface water protection, groundwater protection, wastewater treatment, irrigation and bioenergy production
4. The development of waste management through the implementation of the energy-finished-product/service-supply-waste concept, which can be achieved through the development of waste-to-energy systems and waste recycling, can be applied in both rural and urban environments (Hammarby Model). Life Cycle Assessment (LCA) and at source sorting of waste is a prerequisite for sustainable waste management in the finished product and commodity sectors
5. To maximise support for the production and marketing of local products in food production and processing, and to develop a ready-made agriculture, with particular attention to ensuring the livelihoods of small and medium-sized farms.
6. Depending on production structures and local or regional social conditions, the creation of social cooperatives to reduce or ideally eliminate unemployment (often by organising training programmes adapted to the needs and possibilities of the target groups)
7. Revitalising local and regional crafts, ensuring a proper distribution chain for products and linking them to rural/agricultural/village/recreational tourism
8. Protection and, where necessary, remediation of the natural, built and spiritual heritage of cultural landscapes
9. Assessment of the tourism potential of the region, development of regional tourism taking into account the Carrying Capacity of potential destinations
10. Designing regional development strategies through the coordinated and sustainable use of resources and ecosystem services, relying on local and regional human resources and their maximum involvement in development programmes (stakeholder management)

The concept of maintaining ecological cycles is in my view essential for sustainable development. Ecological cycles are the backbone of environmental health and sustainability, directly impacting biodiversity, climate regulation, soil fertility, and water quality. Understanding and managing these cycles is crucial for both rural and urban development to ensure long-term ecological balance and resilience. Moreover, I strongly agree that rural development should integrate ecological cycle management to enhance agricultural productivity, biodiversity, and community resilience. Practices such as agroforestry, conservation tillage, and sustainable water management can significantly contribute to maintaining ecological cycles.

Agriculture is the backbone of the countryside, and it comprises the coordination of food production, waste management, water management, and renewable energy production. More than 1.5 billion people currently lack access to energy. Three billion people, or about half of the world's population, rely on unsustainable biomass-based energy sources such as firewood or agricultural wastes, animal manure, and other livestock byproducts to meet their daily cooking and heating needs. Even more people, including a sizable part of the population in advanced industrialised countries, rely on more expensive fossil fuels, which harm the environment in a variety of ways. (World Bank, 2024) Rural communities in developing countries, as well as people living in economically and socially deprived areas in developed nations, face especially difficult conditions.

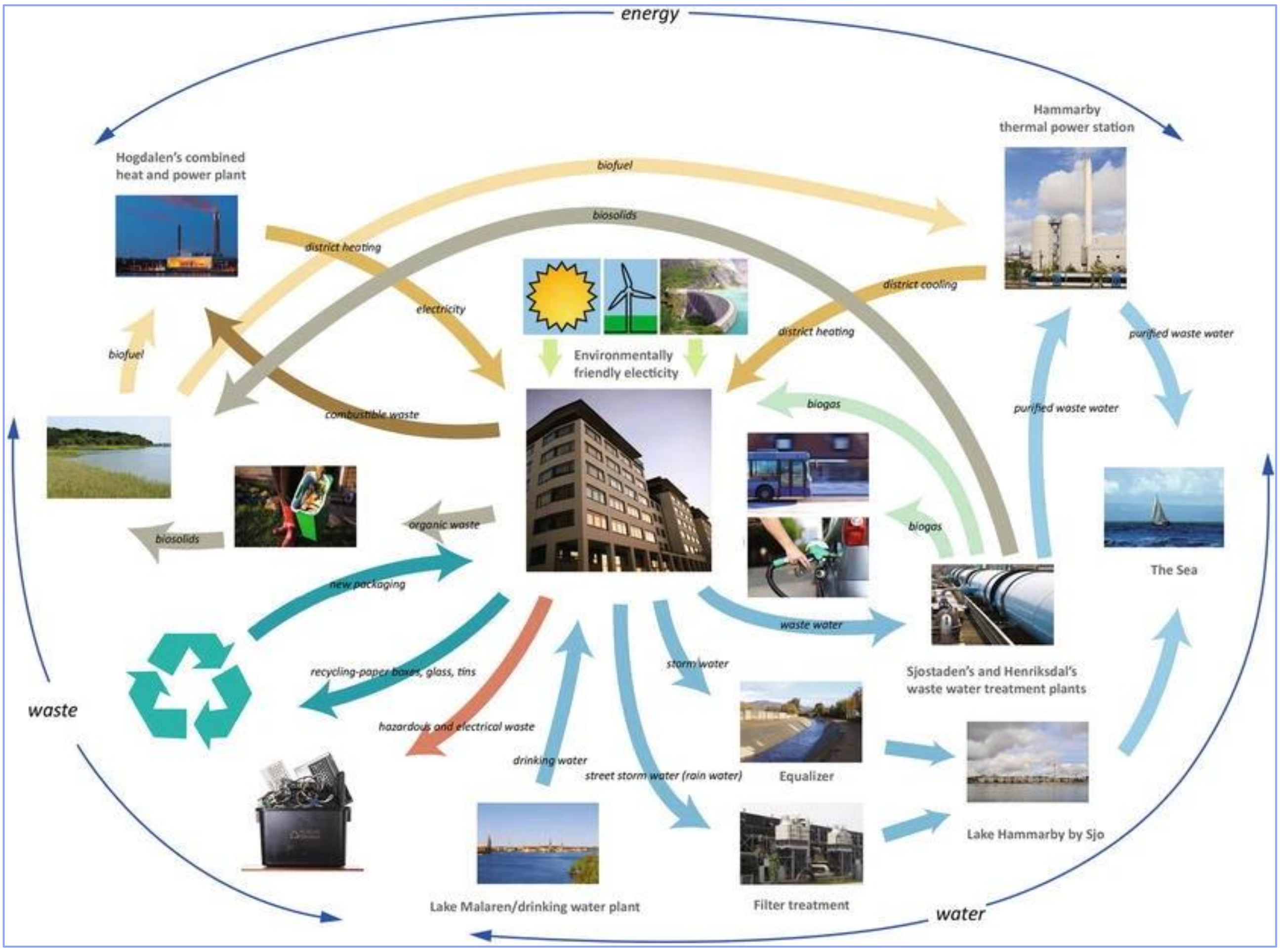

Figure 5. The Hammarby Model is indeed based on eco-cycles, achieving sustainable use of natural resources, energy management based entirely on renewable energies, energy-efficient construction, full processing of solid waste and complete elimination of landfills, waste-to-energy systems, linking wastewater treatment with bioenergy production and irrigation (Source: Glashus Ett, 2024).

Without sustainable energy sources, many communities are unable to secure food supplies, access essential amenities, education, or health care. The bulk of the world's energy-poor reside in rural areas and rely on agriculture for a living, but they frequently cannot fulfil their basic energy requirements.

Renewable energy production (bioenergy, sun, wind, and geothermal) is critical for all aspects of sustainability, including economic viability. Agricultural land covers 37% of the Earth's surface. Agriculture accounts for 52% of all anthropogenic methane emissions and 84% of methane emissions (Ritchie and Roser 2019). The most effective strategy to minimise greenhouse gas emissions is to replace fossil fuels with agricultural bioenergy sources (such as crop residues, animal manure, and bioenergy crops). In agriculture, it is possible to create integrated production systems that include organic farming, the use of bioenergy forests and other bioenergy crops as biofilters, the use of heavy metal-free biologically treated wastewater as nutrient solutions, and the production of biogas by digesting sewage sludge with fermentable organic waste.

Bioenergy crops increase the soil's carbon sequestration capacity, thus contributing to the reduction of global warming. In this way, it is possible to create complete ecological cycles that make optimum use of all energy sources and minimise waste. An excellent example of this can be found in Stockholm Hammarby Sjöstad in Sweden, where a former 'brownfield' industrial area has been transformed into a well-functioning eco-city, linked to the surrounding rural and forest areas, thus completing the link between rural, peri-urban, and urban regions (Figure 6).

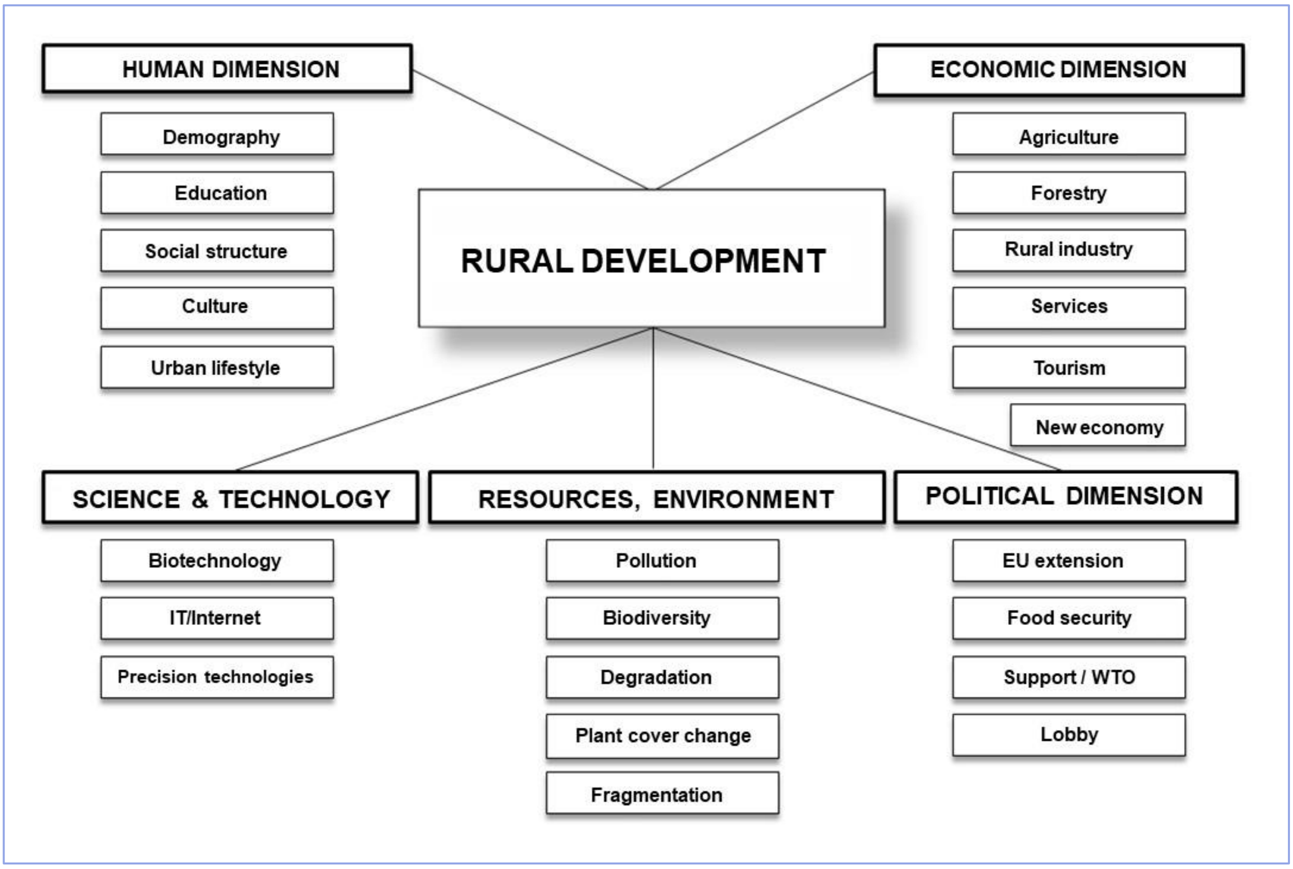

Figure 6. Dimensions of rural development. Source: Modified after Gábor Lenkey (Dinya L., 2011)

The goal is to create sustainable energy, food/product/service, and zero or low-waste systems that are always tailored to local conditions. Self-sustainable rural farms and village communities based on ecological cycles can be a solution, where the combination of sustainable energy sources, especially bioenergy production, the economical use of energy, food production, and waste management are in one ecological cycle, and the introduction of energy-saving building technologies using natural materials and the development of a socially strong, environmentally aware, cohesive community can ensure secure living. There are currently several rural development models, the diffusion and application of which depend largely on social, demographic, and political conditions, the degree of centralization in the country, the administrative structure and the degree of self-government of local authorities, the available local and regional resources, the state of the environment and support systems, and the degree of support.

A Top-Down Macroeconomic Approach

The prevailing economic development model in use today is generally adopted, with the basic idea being that macroeconomic measures are used to stimulate economic growth for industrial and other enterprises. The macroeconomic tools include measures such as inflation management, reduction of trade barriers, tax reforms, infrastructure development, and the attraction of foreign capital inflows, among others. Regional development, which involves tailoring strategies to specific regions, is also significant in this context. When integrated with other models, it becomes a valuable element in the economic development of municipalities and regions. However, if used independently, it can have detrimental effects on society. Overly centralised rural development programmes that solely prioritise macroeconomic factors often overlook local characteristics and increase social inequalities.

Making a Municipality or Region Attractive for Various Industrial Investments

This model has been playing an important role in our country for decades. It clearly has many positive elements, for example in terms of job creation. However, this model also has its dangers, if the only attraction for investing companies is the momentary tax breaks and/or cheap labour, then once these benefits are gone, they will move on, leaving a huge void and in many evenings changing local conditions in such a way that social and economic regeneration becomes extremely difficult or impossible. The benefits they can expect from their arrival should be made conditional on their activities being integrated into a long-term strategy for local economic development.

Local Economic Development Model

Its development goes back perhaps only two decades. Those regions and municipalities that had been excluded from the benefits of the macroeconomic model and had failed to attract inward industry began to realise that they had to rely primarily on local resources. Of course, the use of central subsidies is important here too, but these alone can never be sufficient to ensure sufficient prosperity. Among local resources, consciously tapping into local markets for local consumption is an important element, but encouraging productive or service enterprises to be set up to meet local needs is also a priority. An important element of this model is the establishment of a local and regional development programme and the creation of a non-profit organisation to coordinate and manage its implementation. The tasks of this organisation include, in addition to coordination, monitoring of tenders and mobilisation of other - preferably local - resources. In many cases, this model could be a starting point for sustainable micro-regional and local development start-ups, if the sustainability aspects mentioned above are taken into consideration.

Self-Organisation of Local Society

Programming focused on local economic development should at this point be complemented by the broadest possible social dimension and its institutionalised forms, such as a non-profit association, cooperative or federation. This is a credible ambition if the local authority takes the lead, but the range of stakeholders should be extended to include businesses, NGOs, schools, churches and all other relevant local groups. The whole of local society must be made aware of the need for action. All individuals must be enabled to participate in shaping the future - say by setting up a "Future Shaping Workshop". The shared vision that is formed here is one of the most effective means of building a sense of "we" and sustaining individual activity. The future of a society empowered by a 'we' consciousness can no longer be colonised under the guise of manipulated democracy at the ballot box, as is the case in many countries around the world. Indeed, the strengthening of civil society, with an appropriate awareness of sustainability and ecology, is the most important component of the human dimension of sustainable local and micro-regional development strategies.

Sustainable Development Synthetic Model - the Dinya Five Pillar Model

This development model is in fact a synthesis of all the above models, reflecting an approach that focuses on ensuring the livelihoods of future generations when any development idea is considered. Demographic processes, ensuring the sustainable functioning of the local economy, the efficient use of energy and local resources, sustainable and preferably ecological agriculture and clean food production practices, waste management, the preservation and progressive use of cultural heritage all play a role. One of the most comprehensive socio-economic models for the development of sustainable micro-regions is the so-called Five Pillar Model (Figure 7) by Prof. László Dinya. The combination of this socio-economic model and the Hammarby eco-cycle model will, by definition, guarantee the development of sustainable micro-regions, with a strong civil society and a well-organised, environmentally aware local society and economy as a very important component.

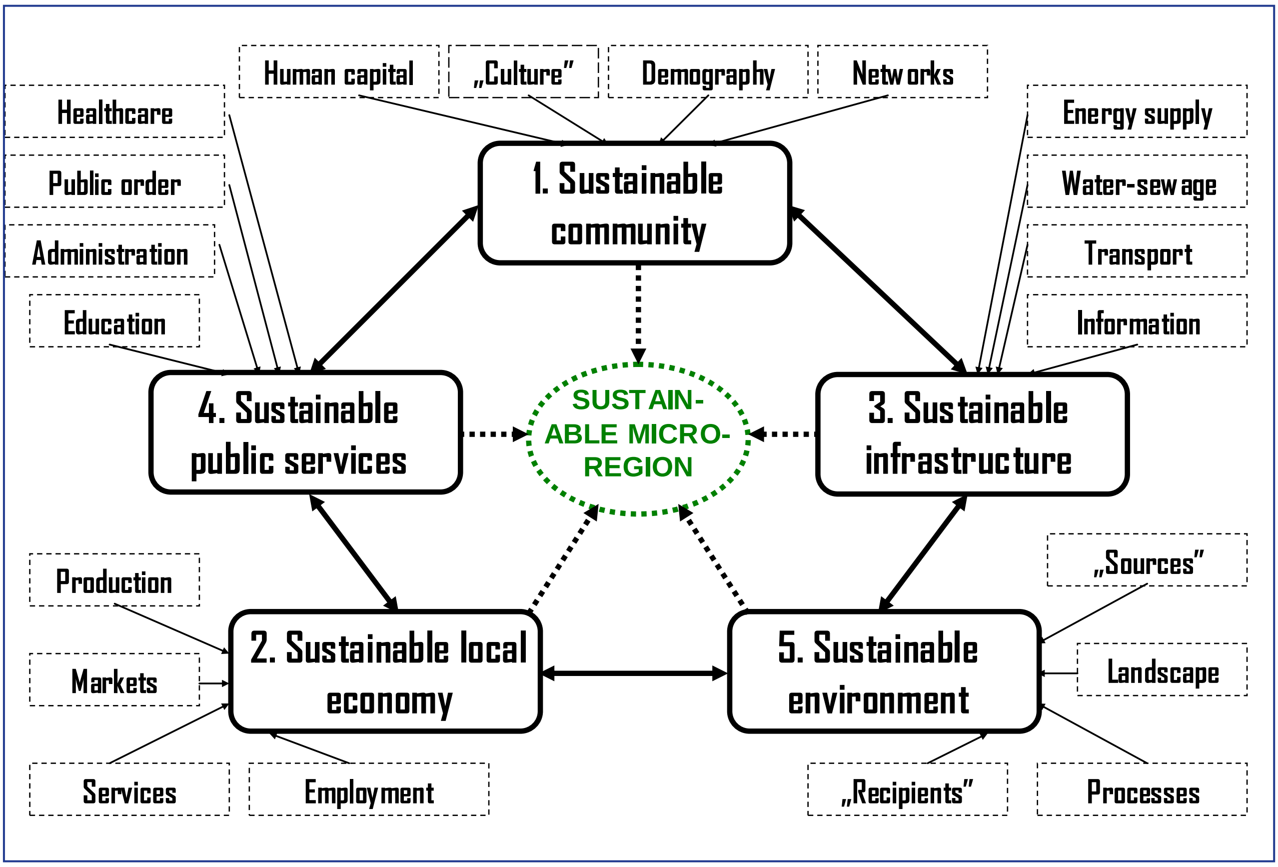

Figure 7. The Five Pillar Model Developed and Tested by Prof. László Dinya (Dinya L. (2011). It is based on five pillars that support a sustainable micro-region: 1. sustainable community, 2. sustainable local economy, 3. sustainable infrastructure, 4. sustainable public services and 5. sustainable environment. Each of these pillars is guaranteed by 4 key factors. The "green" local economy.

2.7.7. Management and Governance Structures

Governance is one of the most important factors for ensuring effective environmental management and conservation actions. Hence, the research examines the management and environmental governance approaches in general and look for common topics of the study areas and integrated research linkages and the discussions surrounding multi-stakeholder participation.

Management decisions should support or implement goals and values defined by governing bodies while governance structures should provide guidelines for management to support decision-making related to strategic direction, financial planning, and policies.

The concepts of data, information and intelligence need to be understood as components in processes for decision making in a system. The cognitive and decision processes enabling the conversion of data into intelligence, constitutes the behavioural patterns for decision making within a system. This behaviour is justified by four types of rationalities. The rationalities are concerned with the structure, content, form and ends, and need to be all present to achieve goal-oriented decision making. (Gigch, 1991, p. 335)

- *The structural rationality* guides the establishment of a structure of organizational decision making.
- *The substantive rationality* concerns question of 'content', 'substance' and 'knowledge' which guide the outcome of actions within a certain system.
- *The procedural rationality* concerns choices of procedures by which decisions within a certain system are taken.
- *The evaluative rationality* refers to the goals set up by decision makers and/or the criteria by which goal fulfilment is defined and evaluated.

I believe that the importance of robust management and governance structures cannot be overstated. Effective governance ensures that sustainable practices are implemented, stakeholders are engaged, and policies are enforced. This is critical for maintaining the ecological, cultural, and economic health of aquatic cultural landscapes. I also Fully support participatory governance. This approach is essential for managing aquatic cultural landscapes as it ensures that decisions reflect the diverse interests and knowledge of the community. Engaging local stakeholders helps in creating more resilient and accepted management practices.

2.7.8. Theories Related to the Topic

The described theories in this research and the theoretical framework in section 2.7 share a commitment to sustainable management, interdisciplinary approaches, stakeholder engagement, and climate adaptation. To compare the described theories related to the topic and the theoretical framework of the document, we can break down the common points and differences across the theories and frameworks mentioned.

This comparison highlights the comprehensive nature of the theoretical framework in capturing the complexities of managing aquatic cultural landscapes, offering a robust foundation for developing sustainable and resilient management practices.

Table 1. Theories related to the topic

Theories	Common Points	Differences
Emphasis on Sustainability and Ecosystem Services	Both the described theories and the theoretical framework emphasize the importance of sustainable management of aquatic cultural landscapes and the ecosystem services they provide. This includes provisioning (water, food), regulating (flood control, water purification), cultural (recreational, aesthetic), and supporting services (nutrient cycling)	The research results provide concrete examples and case studies of how these multidisciplinary approaches have been applied in different regions, showcasing real-world applications and outcomes.
Nature-Based Solutions (NBS) and Water Management	Both theories and the framework emphasize the importance of NBS in improving water management. They highlight that NBS can enhance water retention, reduce flood risks, and improve water quality. Multi-functionality: Both approaches view NBS as multifunctional tools that provide ecological, social and economic benefits, such as enhancing biodiversity and offering recreational opportunities.	The research results discuss in more detail the cost-effectiveness and long-term sustainability of NBS, emphasizing lower maintenance and operational costs compared to traditional grey infrastructure
Mitigation of Climate Change Impacts	Both theories and framework recognize the role of NBS in mitigating the impacts of climate change, including enhancing biodiversity, reducing flood risks, and providing ecosystem services that help communities adapt to climate variability. They both highlight the synergistic effects of combining adaptation techniques with stakeholder collaboration to effectively address climate change challenges.	The research results place a specific focus on urban areas and the role of urban living labs in addressing climate change impacts through participatory approaches and innovative solutions. Moreover, it provides more detailed strategies for climate adaptation and resilience, such as specific urban and peri-urban agriculture practices and community engagement models.

Cultural Heritage Conservation and Community Engagement	Both theories and framework emphasize the integration of cultural heritage conservation into the management of aquatic landscapes, recognizing the cultural, historical, and social values these landscapes provide. They both stress the importance of community engagement and participatory governance in preserving cultural heritage and promoting sustainable landscape management.	The research results explicitly discuss the economic benefits derived from cultural heritage conservation, such as tourism and local community identity enhancement. It outlines specific participatory models and the role of stakeholders in decision-making processes, which are less detailed in the described theories.
Interdisciplinary Approaches	There is a strong focus on interdisciplinary approaches integrating environmental science, economics, sociology, and law to understand and manage the complex relationships within aquatic cultural landscapes.	The research results provide specific examples of how systemic interdependencies have been managed in various projects, such as the U-Garden and SATURN projects.
Stakeholder Engagement and Governance	Both theories and framework stress the importance of stakeholder engagement and effective governance structures. They highlight the need for policies and frameworks that involve local communities, government agencies, and other stakeholders in decision-making processes to ensure comprehensive and fair management practices	The research results provide detailed models and examples of stakeholder engagement and participatory governance, showcasing how these have been implemented successfully in various projects.

3. Aim, Objectives and Methodology

3.1. Aim and Objectives

This thesis explores the complex dynamics within rural-peri-urban-urban transition zones in aquatic environments, with a specific focus on integrating diverse disciplines for sustainable water management and cultural heritage preservation. The aim is to evaluate the effectiveness of a holistic approach in managing these landscapes sustainably. To achieve this, the research is structured around several general objectives, detailed sub-goals, and specific research questions, all aligned with the results and conclusions drawn in the study.

The research incorporates case studies to explore the effectiveness of nature-based solutions for water retention and their transformation into small-scale multifunctional agriculture, particularly targeting water management challenges. These studies are conducted in Västra Götaland Region in southwestern Sweden, Tisza Lake and Little Balaton Nature Reserve in Hungary.

The study's relevance is emphasised considering the global concern regarding the deterioration of aquatic ecosystems and its consequences for biodiversity. It also assesses the current state and future trajectories of aquatic and semi-aquatic cultural landscapes considering climate change. The principal goal is to document, evaluate, and validate the feasibility of creating micro-regional and local development strategies applicable to rural, peri-urban, and urban areas. Adopting an evolutionary perspective, the study examines the interplay between urban and rural landscapes, aiming to formulate long-term strategies that integrate geographic and historical conservation considerations.

The objectives contribute to a holistic approach for managing aquatic cultural landscapes, emphasizing the integration of environmental conservation, cultural heritage preservation, community engagement, and sustainable development practices.

The main objectives include:

1. Nature-Based Solutions (NBS) for Water Management: The research explores how NBS can enhance water retention, mitigate flood risks, and transform small-scale agricultural systems. It underscores the multifunctional benefits of NBS, including their roles in water quality improvement, biodiversity enhancement, and flood mitigation, while also providing social and economic benefits like health improvement and boosting eco-tourism.

2. Impact of Climate Change on Water Resource Management: This area examines the challenges climate change poses to water management, especially in the context of increasing water scarcity, pollution, and ecosystem degradation. It contrasts traditional infrastructure methods with NBS, advocating for the latter's benefits in enhancing biodiversity, mitigating flood hazards, and providing recreational advantages.

3. Cultural Heritage and Community Engagement in Landscape Management: The study focuses on how integrating NBS into the management of aquatic cultural landscapes contributes to preserving cultural heritage and promoting community identity. It also explores the economic benefits derived from cultural heritage conservation, emphasizing tourism and enhanced community identity.

4. Integrated Water Resources Management (IWRM): The research advocates for IWRM approaches to improve the sustainability and health of aquatic ecosystems. It stresses the importance of effective policy frameworks, governance structures, and cross-disciplinary approaches, incorporating insights from environmental science, economics, sociology, and law for successful IWRM in aquatic landscapes.

5. Urban-Rural Development and Multifunctional Agriculture: By investigating NBS for water retention and their conversion into small-scale multifunctional agricultural systems, the thesis highlights the potential of these solutions to address effective water management, cultural heritage conservation, and sustainable urban-rural development.

6. Urban Living Labs for Urban Agriculture: This research aims to explore the establishment and operation of Urban Living Labs (ULLs) specifically tailored for urban agriculture. The objective is to investigate how these labs can serve as innovative, participatory platforms to foster local food production, ecosystem restoration, and the development of sustainable business models. Through this, the research seeks to enhance the economic viability of environmental policies.

3.2. Detailed and Specific Sub-Goals

The detailed and specific sub-goals aligned with the overarching objectives of the research on sustainable management of aquatic cultural landscapes include the following:

1. Enhance Water Management Efficiency Through Nature-Based Solutions (NBS):
   - Evaluate the role of NBS in improving water retention and mitigating flood risks in targeted regions.
   - Assess the impact of NBS on biodiversity enhancement and water quality improvement.
   - Develop guidelines for the implementation of NBS that can be scaled and adapted to different ecological and cultural contexts.

2. Assess the Impacts of Climate Change on Water Resource Management:
   - Study the current and future impacts of climate change on water availability and quality in aquatic cultural landscapes.
   - Compare traditional infrastructure-based water management approaches with NBS, focusing on their effectiveness in addressing climate-related water issues.
   - Propose adaptive strategies that enhance the resilience of water management systems to climate variability and extremes.

3. Cultural Heritage and Community Engagement:
   - Investigate how NBS can be integrated into the management of aquatic cultural landscapes to preserve and highlight cultural heritage.
   - Develop participatory models that involve local communities and stakeholders in the conservation and management processes.
   - Examine the socio-economic benefits of preserving cultural heritage through enhanced tourism and local community identity.

4. Implement Integrated Water Resources Management (IWRM):
   - Develop and promote policies that support IWRM principles in managing aquatic cultural landscapes.

- Facilitate multi-stakeholder engagement processes to ensure that water management strategies are inclusive and effective.
- Study the governance frameworks necessary for successful implementation of IWRM practices.

5. Promote Urban-Rural Linkages and Multifunctional Agricultural Systems:
   - Explore the transformation of NBS into multifunctional agricultural systems that support both conservation and agricultural productivity.
   - Assess the potential of these systems to support sustainable urban-rural development.
   - Develop business models that integrate ecological, agricultural, and cultural values.

6. Urban Living Labs for Sustainable Development:
   - Establish Urban Living Labs to test and refine sustainable urban development strategies.
   - Use these labs to engage stakeholders in real-world experiments, fostering innovation in urban agriculture and local food production.
   - Evaluate the effectiveness of Urban Living Labs in promoting sustainable business models and enhancing the economic viability of environmental policies.

3.3. Research Questions

1. How can nature-based solutions (NBS) be optimized to enhance water retention and mitigate flood risks in aquatic cultural landscapes, and what are their multifunctional roles in promoting biodiversity, water quality, and socio-economic benefits?
   This question aims to explore the efficacy and multifunctional benefits of NBS in aquatic landscapes, emphasizing their role in water management, biodiversity enhancement, and providing socio-economic advantages.

2. What are the impacts of climate change on the management of water resources in aquatic cultural landscapes, and how can integrated water resources management (IWRM) approaches be tailored to improve ecosystem health and sustainability in these landscapes?
   This inquiry focuses on understanding the specific challenges posed by climate change to water resource management in aquatic landscapes and examines how IWRM approaches can be effectively implemented to address these challenges.

3. In what ways does engaging local communities and stakeholders in the management of aquatic cultural landscapes contribute to sustainable and culturally sensitive conservation outcomes, and how can these collaborative efforts be enhanced?
   This question investigates the role of community engagement and stakeholder collaboration in achieving sustainable conservation of aquatic landscapes, seeking to identify strategies for enhancing these participatory approaches.

4. How do conservation efforts of cultural heritage within aquatic cultural landscapes stimulate economic benefits, particularly in relation to tourism and community identity, and what models can support the sustainable integration of these efforts?

This inquiry examines the economic benefits derived from the conservation of cultural heritage in aquatic landscapes, with a particular focus on tourism and community identity, aiming to identify sustainable models for integrating conservation efforts with economic development.

5. What innovative financial mechanisms and business models can be developed to support the adoption of nature-based solutions for water retention and the transformation of small-scale agricultural systems in urban and peri-urban areas of aquatic cultural landscapes?
   This question explores the potential for innovative financial mechanisms and business models to encourage the adoption of NBS and the development of small-scale multifunctional agricultural systems, focusing on urban and peri-urban contexts within aquatic landscapes.

6. How do Urban Living Labs enhance the efficacy of sustainable urban development projects through innovative collaboration among stakeholders and the integration of real-time data and community feedback in the planning and implementation processes?

3.4. Limitations

Aquatic cultural landscapes encompass a vast array of elements including marine coastal areas, salt marshes, lakes, watercourses, wetlands, and their associated riparian zones. While this research ambitiously addresses the interrelationships within these complex systems, it is important to acknowledge its inherent limitations. These limitations arise from the broad scope of the study, the challenges in integrating diverse disciplines, and the evolving nature of global environmental, population, and economic development issues.

These limitations should be recognised as inherent in the study and considered when evaluating its findings and conclusions. Future research could build on this work by addressing these limitations, possibly through more focused studies, long-term monitoring, and innovative methodologies that bridge disciplinary gaps.

Scope and Focus

1. Transdisciplinary Complexity: The transdisciplinary approach used in this study, which includes biological, ecological, and economic systems, offers a challenge in obtaining depth in each domain. While it provides a comprehensive view, there is a natural trade-off between scale and depth. The complexities of each discipline—biology, ecology, and economics—require substantial attention, which has not been possible within the scope of the studies carried out.

2. Geographic Specificity: The study focuses on specific types of aquatic landscapes, including lakes, springs, watercourses, wetlands, and riparian habitats. This specialisation, while required for in-depth investigation, limits the findings' applicability to other types of aquatic habitats or cultural landscapes. Moreover, the research focus on specific geographic areas, and the findings may not be directly applicable to other regions. Additionally, the research relied on self-reported data from stakeholders, which may introduce biases. However, efforts were made to mitigate these limitations through rigorous data analysis and triangulation of findings.

3. Temporal Constraints: Aquatic cultural landscapes are dynamic, continuously shaped by both historical and current evolutionary processes. This research, conducted over a finite period, can only capture a snapshot of these ever-evolving landscapes, possibly missing longer-term trends and shifts.

4. Methodological Considerations

- Data Limitations: The availability and quality of data for aquatic landscapes, especially in terms of long-term historical records and comprehensive ecological and economic parameters, have been limited. This restricts the study's ability to provide a complete and nuanced understanding of these complex systems.

- Interdisciplinary Integration: The integration of different disciplines—while necessary for a holistic understanding—poses methodological challenges. Reconciling different terminologies, methodologies, and theoretical frameworks across disciplines is complex and may lead to oversimplifications or misinterpretations.

5. Cultural and Social Dynamics

- Cultural Subjectivity: The concept of a 'cultural landscape' is inherently subjective, influenced by historical, social, and cultural perspectives. This subjectivity can lead to challenges in defining and interpreting cultural values and practices consistently across different regions and communities.

- Evolving Social Relations: Social relations and cultural practices are dynamic and can change rapidly. The research may not fully capture these evolving aspects, especially in response to contemporary global challenges such as climate change, migration, and technological advancements.

6. Environmental and Ecological Factors

- Environmental Variability: Aquatic ecosystems are sensitive to a range of environmental factors, including climate change, pollution, and human intervention. The variability and unpredictability of these factors can limit the ability to draw definitive conclusions about cause-and-effect relationships within these landscapes.

- Biodiversity and Ecosystem Services: While the study aims to integrate ecological aspects, the full extent of biodiversity and ecosystem services within aquatic landscapes is vast and complex. The research may not encompass all the ecological interactions and services provided by these ecosystems.

3.5. Research Methodology

3.5.1. Primary Research

Primary research is essential in this study because it provides first-hand, empirical data specific to the research context. This approach allows the collection of unique insights and evidence directly from the field, which are crucial for understanding the specific dynamics and intricacies of aquatic cultural landscapes. The primary research methods, such as interviews, workshops, and field investigations, offer several key advantages:

- Context-Specific Insights: Primary data collection ensures that the information gathered is directly relevant to the specific study areas, reflecting the real-time conditions and stakeholder perspectives.
- In-Depth Understanding: Methods like interviews and workshops facilitate a deep dive into the subject matter, uncovering nuanced details that secondary data might not reveal.
- Stakeholder Engagement: Engaging directly with stakeholders ensures that their voices and concerns are incorporated into the research, leading to more inclusive and actionable findings.

This dissertation presents an overview of the collective research efforts integrated into several pioneering projects aimed at enhancing urban sustainability through innovative environmental solutions. These initiatives, namely U-Garden, the SATURN project, Blue-green solutions projects, and various Agroforestry projects, have all contributed significantly to my understanding and development of sustainable urban practices and water management. Each project has been instrumental in addressing different aspects of urban environmental challenges, ranging from urban farming and landscape interactions to the implementation of blue-green infrastructure.

Numerous field studies, stakeholder interviews, workshops, and policy analysis have all been a part of the research undertaken for these initiatives, which has added to the collection of knowledge on sustainable urban development. Participating in these initiatives has made it possible to combine theoretical and practical knowledge in a novel way, producing workable solutions that will help cities all over the world deal with the challenges of urban growth while maintaining environmental resilience and sustainability. The most important projects that have been fundamental to my research is listed in Table 2. More details about the methodologies for each project are described in the following sub chapters.

The primary research phase involves the actual collection of empirical data. This step includes:
- Field Investigations: Conducting site visits to gather direct observations and environmental data.
- Interviews and Workshops: Engaging with stakeholders, including local communities, experts, and policymakers, to gather qualitative data.
- Data Recording: Systematically recording all data collected during field investigations and stakeholder engagements.
- Comparing with Literature: Comparing the findings with existing literature to identify consistencies and divergences.
- Drawing Conclusions: Formulating conclusions based on the integrated analysis of primary and secondary data.
- Submitting articles to academic journals and presenting findings at conferences to share the research with the broader academic and practitioner community.
- Writing the Thesis

Table 2. Projects and their short descriptions

U-Garden Project	Garden initiative focuses on urban agriculture and community gardening, aiming to reconnect urban populations with food production processes and green spaces. By integrating gardens into urban settings, the project not only seeks to improve local food security and reduce the carbon footprint associated with food transportation but also enhances community well-being and social cohesion.	2022-2025
SATURN Project	The SATURN (System and sustainable Approach to virTuous interaction of Urban and Rural Landscapes) project explores how urban and rural landscapes can interact more sustainably. Concentrating on the integration of urban farming models into the fabric of city planning, SATURN evaluates methods to mitigate climate change impacts and promotes resilience through enhanced urban greenery. This pan-European initiative involves multiple cities, each experimenting with different models tailored to their specific urban contexts.	2019-2021
Blue-green solutions for flooding and drought	Blue-green solutions have been at the forefront of reimagining urban landscapes to manage water more sustainably while providing ecological and social benefits. These projects involve creating synergies between water management and green infrastructure, aiming to tackle urban flooding, improve water quality, and increase urban biodiversity. Through naturalistic engineering, these solutions integrate features such as rain gardens, permeable pavements, and green roofs into urban planning.	2018-2019
Agroforestry Projects	Agroforestry projects merge agricultural and forestry technologies to create more diverse, productive, sustainable, and healthy land-use systems. These initiatives focus on the strategic placement of trees within agricultural landscapes to enhance productivity and biodiversity, improve soil health, and reduce vulnerability to climate change. The agroforestry approach is particularly effective in peri-urban areas where it helps buffer agricultural activities from urban encroachment and supports ecosystem services.	2016-2018

Simultaneously, good practices were studied through site visits at urban farms, green city centres, vertical farming facilities, eco-cities with circular economies and renewable energy production and well-functioning landscape observatories in Catalonia, Spain and in Västra Götaland, Sweden. The development work of Landscape Observatory Västra Götaland was followed and the results in terms of new planning strategies, public participation, creation, and the realisation of new, local, and regional business models were recorded by using questionnaires.

It is critical to understand that "good practices" identified in one context do not imply "best practices" for everyone. Each solution must be carefully tailored to the local conditions. It avoids the problems of replicating models that have proven successful in other contexts but may fail here due to differences in social dynamics, environmental conditions, or economic systems. This study emphasises the development and execution of specific solutions guided by a thorough awareness of local requirements and conditions, as well as ongoing engagement with community stakeholders.

For example, our approach to water resource management will incorporate techniques and policies that have been demonstrated to be effective in similar regional contexts but will be tailored to the biological and socioeconomic realities of the places under study. This will involve the implementation of Nature-Based Solutions (NBS) that are tailored to local biodiversity, land use patterns, and cultural heritage, ensuring that these solutions not only address environmental concerns but also promote social cohesion and economic sustainability.

3.5.2. Secondary Research

Secondary research complements primary research by providing a broader theoretical and contextual background. It involves the analysis of existing literature, datasets, and documents, which helps in several ways:

- Theoretical Foundation: Reviewing existing literature helps build a solid theoretical framework for the study, situating the research within the broader academic discourse.
- Contextual Understanding: Secondary data provides context and background information that helps interpret primary data more effectively.
- Identification of Gaps: Analysing existing research helps identify gaps in knowledge, guiding the focus of primary research efforts.

The secondary methodology approach utilised in this study consists of a comprehensive literature review and methodical data analysis. The secondary research focuses on diverse areas relevant to the management of aquatic cultural landscapes, including urban ecosystems, environmental contamination, infrastructure development, spatial planning, landscape conservation, and the integration of green infrastructures.

The literature review approach examined a wide array of publications, including academic journals, reports from the sector, policy documents, and case studies. The main aim was to gather existing information on water management, agroforestry, sustainable land use, and urban-rural relations, in order to establish a strong theoretical basis for the empirical study. The objective of the literature study was to integrate material from various sources to provide a thorough and comprehensive overview of present practices, historical developments and emerging trends in these disciplines.

The scope of the literature review included several critical areas:

- Urban Ecosystems and Environmental Pollution: Examining the interactions within urban ecosystems and the impact of pollution on these environments.
- Infrastructure Development and Spatial Planning: Understanding how urban architecture and spatial planning contribute to sustainable land use.
- Landscape Conservation: Evaluating strategies for conserving landscapes through grey-green and blue-green infrastructures.

- Urban Gardens and Farming: Investigating the role of urban gardening and farming in enhancing urban biodiversity and food security.
- Stakeholder Management: Analysing the involvement of various stakeholders in spatial planning and landscape conservation.
- Circular Economics: Exploring new value chains and the development of local food production systems.

The findings from the literature were systematically synthesized to draw comprehensive conclusions about the state of knowledge in these areas. This synthesis involved:

- Integration with Empirical Data: Theoretical insights from the literature were integrated with empirical data gathered from primary research methods, such as interviews and workshops. This integration provided a multi-layered understanding of the subject matter.
- Identification of Gaps: The literature review also helped identify gaps in existing research, thereby guiding the direction of empirical investigations to address these gaps.
- Supporting Hypotheses: Insights from the literature were used to support, contrast, or extend the research hypotheses, ensuring that the study's conclusions were well-grounded in existing knowledge.

Data Analysis and Documentation

Secondary data analysis involved examining existing datasets and documents, such as scientific texts, research reports, official documents, and press articles. This analysis aimed to extract relevant information that could complement the primary data and provide a more holistic view of the research topic. The literature studies also included a critical evaluation of:

- Urban Biodiversity: The diversity of plant and animal species in urban environments and their stress tolerance.
- Social Marketing and Capacity Building: Strategies for engaging and empowering disadvantaged communities through social marketing and capacity-building initiatives.
- Landscape Observatories: The development and potential of landscape observatories in monitoring and managing environmental changes.

Integration with Primary Research

The integration of secondary and primary research methodologies was crucial for validating the study's findings and ensuring their robustness. By triangulating data from multiple sources, the research was able to present a more nuanced and reliable analysis of the challenges and opportunities in managing aquatic cultural landscapes.

3.6. Description of Study Areas

To understand the importance and potentials of aquatic environments in Europe, a number of case studies has been studied across the continent covering north to south. The environment and other conditions in these areas vary, however, the research will draw from their lessons and find similarities to be able to present a common and scalable approach to heritage practices in a cross-disciplinary model development. The areas have been chosen according to a geographic, climatic, social, economic, and cultural diversity given that they have ongoing activities on aquatic landscape management development and even facing problems, which require system solutions based on an interdisciplinary, holistic approach.

I have connection to most areas through my previous work and they are therefore naturally chosen to the research studies. The case studies selected for this research encompass a diverse range of geographical and climatic conditions across Europe, specifically focusing on the Västra Götaland Region in Sweden, the Tisza Lake and Little Balaton Nature Reserve in Hungary. Each region presents unique challenges and opportunities in managing aquatic cultural landscapes, providing valuable insights into sustainable practices that can be applied more broadly.

Västra Götaland Region, Sweden

The Västra Götaland Region, situated in the southwest of Sweden, is distinguished by a diverse array of landscapes, including deep woods, agricultural areas, vast marshes, and a rough coastline. This region is specifically recognised for its efforts in incorporating nature-based elements into both urban and rural planning systems to tackle water management and improve biodiversity. The difficulties at hand involve effectively addressing the consequences of climate change, such as heightened levels of precipitation and flooding, which pose a hazard to both urban and rural regions. Innovative projects in this region have focused on sustainable urban drainage systems and the restoration of natural water bodies to buffer against extreme weather events, enhancing the region's resilience while preserving its cultural heritage.

Figure. 8 Landscape in Västra Götaland, Photo: Anders M. Nilsson

The research specifically examined the Säveå river. The river spans around 130 kilometres in length and has a catchment area of 1500 square kilometres. It includes five municipalities, as well as other cities and towns. The region encompasses nature reserves, Natura 2000 areas, and sections that hold national significance for nature conservation, outdoor activities, and cultural environmental preservation. The Swedish Civil Contingencies Agency has selected Säveå river as one of the 25 streams in Sweden that are at high danger of flooding.

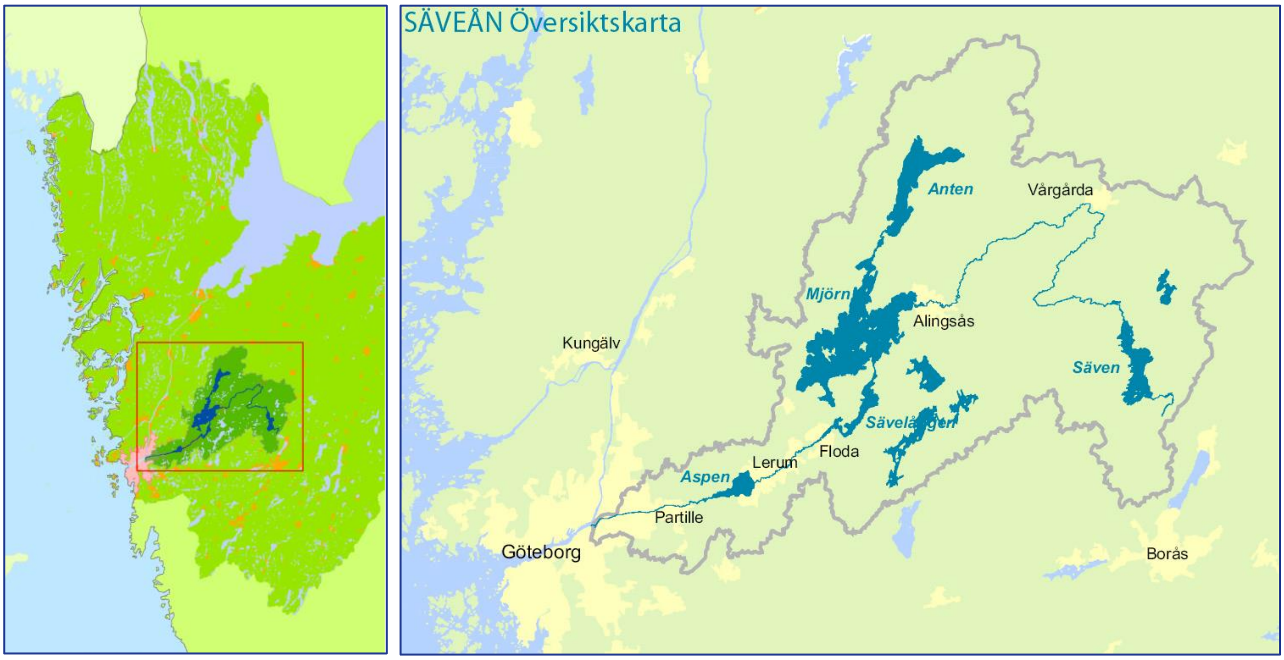

Figure. 9 Västra Götaland Region, Sweden

The county of Västra Götaland in western Sweden (Figure 9) is considered one of the areas in Sweden that will be the hardest hit by increased precipitation. Climate change will result in further increased risks for flooding with heavier rainfalls, increased sea and ground water levels and higher flows in the waterways1. This will mostly affect areas around lakes and streams, and in particular around the lake Vänern and along Göta Älv river that flows through the county.

The City of Gothenburg, which is the second largest city in Sweden, is located in the county of Västra Götaland. Gothenburg is the most flood-sensitive city in Sweden being located at the lowest point of the river of Göta Älv, next to the sea and built on former swampland. Large areas in Gothenburg and surrounding areas are prone to flooding and several extreme floods have occurred the last 20 years with severe and costly damages. In e.g. 2008, SOS Alarm system's switch board broke down causing serious disturbances due to flooding.

The experienced and future potential damages are emphasised mainly due to current existing water retention methods being under-dimensioned and that more and more surfaces are asphalted, retaining the rainwater on the surface. Moreover, the landscape's ability to retain water additionally decreases when wetlands are reduced. Over the last century, about 25% of Sweden's wetlands have disappeared due to ditching, lake abatement and cultivation. In the county of Västra Götaland, nearly 70% of the open wetlands have disappeared since the middle of the 1800s (146,000 ha of 210,000 ha)2. Development of road and railways have also resulted in land drainage and reduced areas with wetlands. Overall, the green infrastructure for the region's wetlands have become much more fragmented in recent centuries.

Figure. 10 Säveå River, Gothenburg. Photo: Anders M. Nilsson

Lake Tisza and Little Balaton Nature Reserve, Hungary

The Tisza Lake and Little Balaton Nature Reserve play a vital role in Hungary's landscape by preserving biodiversity and serving as a significant source of water for agricultural irrigation. These regions are experiencing considerable strain due to agricultural runoff, which causes eutrophication and the decline of indigenous species.

Figure 11. The major lakes and their hydrographic catchment areas in Hungary.

Lake Tisza

Lake Tisza, or Kisköre reservoir as it is officially known, is Hungary's second largest standing water of artificial origin. In the 1960s, the idea of creating a multifunctional surface water system was developed with the following objectives:

1. storing the surplus water brought by the flood waves on the Tisza River, thus relieving the area from flooding,
2. to provide irrigation water to the Central Tisza region, which was one of the driest areas of Hungary until then, through the Jászság and Nagykunság main canals,
3. to improve the energy supply of the region by meeting the water demand of the hydroelectric power plant built on the Kisköre Tisza section.

The hydroelectric power plant was put into operation in 1973, when the area was flooded for the first time, and for the second time in 1978, at which level the reservoir is still in operation today, but the planned third flooding was cancelled, and by now tourism and nature conservation objectives have also come to the fore. The resulting reservoir is Lake Tisza, with a surface area of 127 km^2, a mean water depth of 1.3 metres and a maximum depth of 17 metres. Its water level is regulated by the Kisköre hydroelectric power station, which also plays a major role in determining the water levels in winter and summer, with an average difference of 1.5 m between the two. The reservoir's water area is not contiguous and can be divided into five basins: the Abádszalók basin, the Sarud basin, the Poroszló basin, the Tiszavalk basin and the smallest Tiszafüred basin (in fact a part of the Tiszavalk basin), which run upstream (opposite) the Tisza.

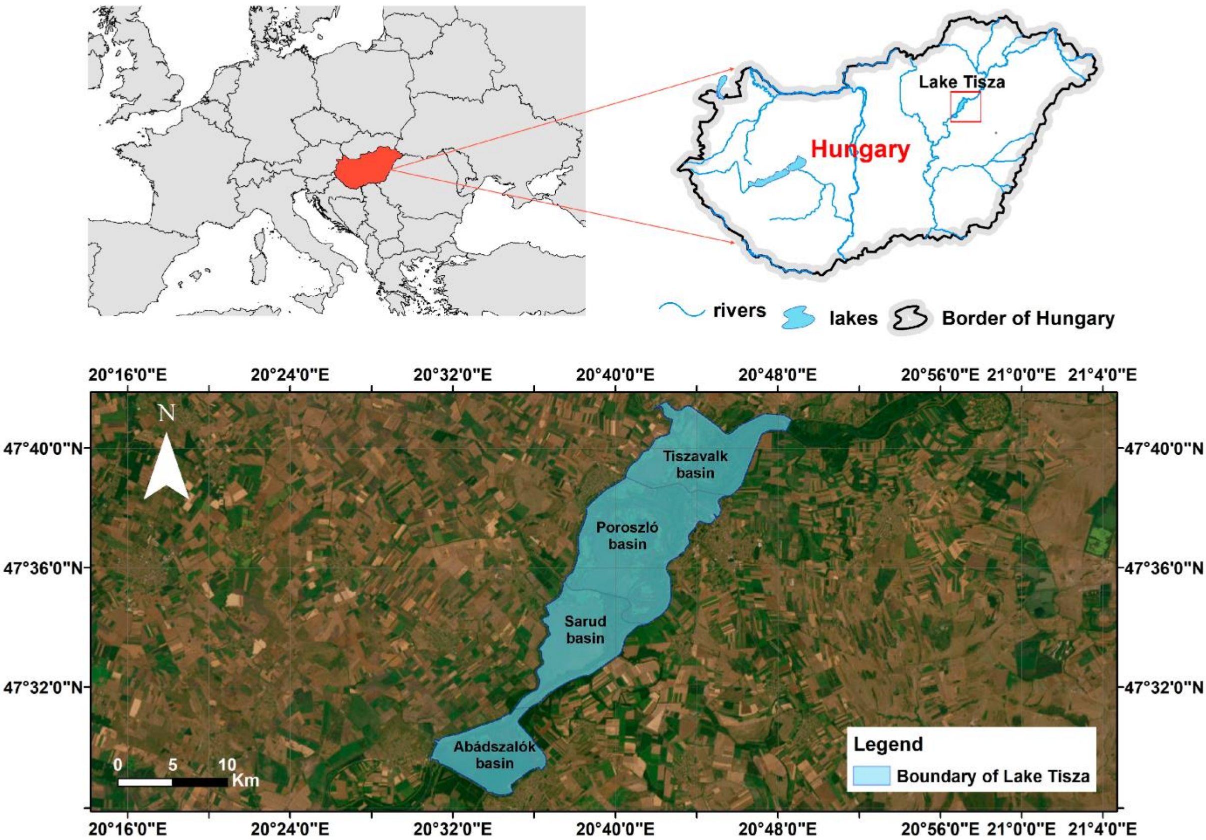

Figure 12. Location and the basin structure of Lake Tisza. Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

Some 17 years elapsed between the construction of the dam and the filling of the lake, with full filling completed in the 1990s. After recharge, an aquatic habitat was created which, due to its mosaic nature, is a very good feeding and nesting area, an important resting place for birds during migration, especially in autumn, when thousands of birds flock here.

The Lake Tisza Ecocentre is a completely new solution in Hungary, which has not been used anywhere before, there was no proven recipe for its exact technical and operational content, the ideas were incorporated based on individual design and by adapting well-established foreign examples to the domestic site. The aim was to create a visitor centre that is unique in Hungary, but also rare in Europe, where tourism and nature conservation are linked to each other in such a way that the role of Lake Tisza and its surroundings in tourism increases, and a positive living environment is created for the local population and businesses operating here, under conditions that do not further burden the environment and protect natural values.

Figure 13 Lake Tisza Ecocentre – a unique construction. Source: https://funiq.hu/848-tisza-tavi-okocentrum

The 1st and 2nd level of the main building of the Lake Tisza Ecocentre houses a freshwater aquarium system, which with its total volume of almost 750 thousand litres is the largest in Europe. The 535,000-litre giant aquarium offers an excellent opportunity to discover the secret life of the fish species that live here, completed by a demonstration-tunnel 5 metres underwater. In the aquariums, exhibition areas and permanent exhibition called the Night Forest, more than 50 species of fish native to Hungary and around a dozen species of amphibians and reptiles can be seen.

Due to the nature of the area, valuable protected aquatic plant communities have developed. The dryland forests are also important nesting sites for birds of prey and songbirds. The fish fauna of the reservoir is extremely rich. More than 50 fish species are currently known from the area. Due to its size and mosaic, Lake Tisza provides an opportunity to maintain and observe a diverse flora and fauna.

Figure 14. Lake Tisza – a complex aquatic ecosystem. Photo: Anna Ternell

The 7-hectare park around the visitor centre features animal shows, playgrounds, the 1884 Poroszló Country House, a fishing hill, an obstacle course and a traditional poultry yard. The Ecocentre's harbour provides a direct link to the Lake Tisza Water Trail and School, which has been operating since 2005, and is also the starting point for GPS-assisted water tours and boat trips.

Kis (Little) Balaton

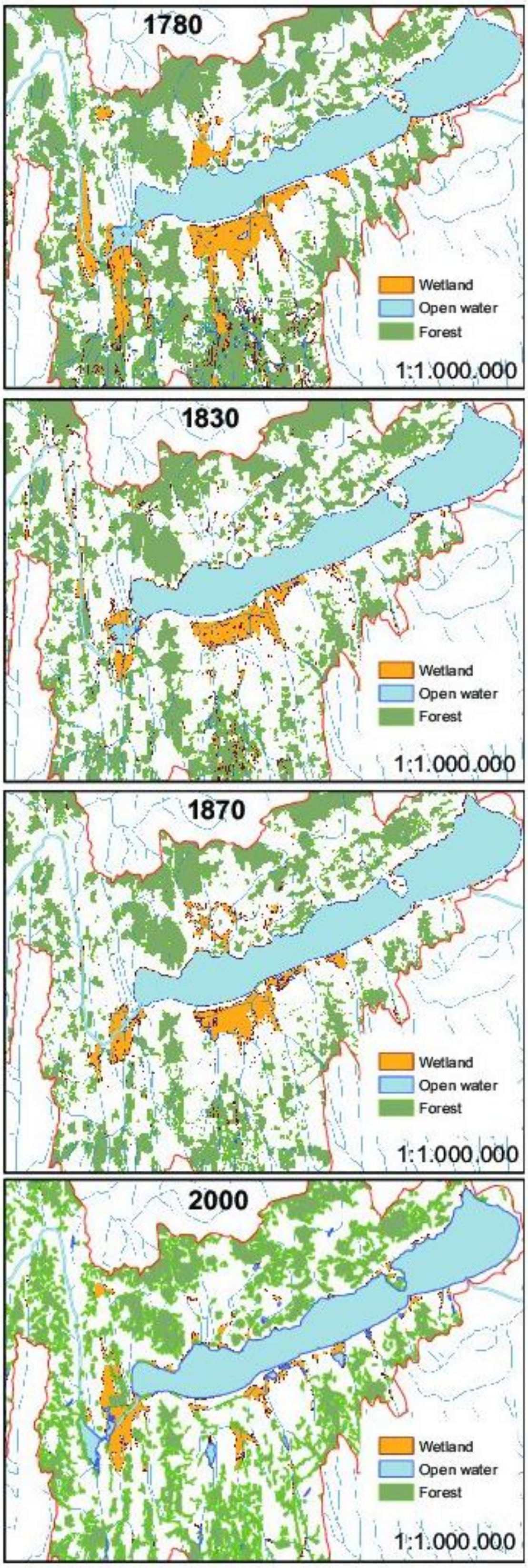

Figure 15. Historic extents of Lake Balaton catchment and its wetlands, forests and open water. Source: Zilinszky and Tímár, 2013. DOI: 10.5194/hessd-10-7733-2013

Lake Balaton is the largest lake in Hungary and Central Europe. It is 77 km long and 3-11 km wide, but only 1.5 km in the Tihany Strait. The average depth is 3-4 m; in the Tihany Strait it reaches 11-11.5 m. Its surface area, controlled by the level of the Siófok sluice, is 596 km^2. Its total hydrograhic catchment area is 5174 km^2.

Until the end of the 18th century, today's Kis-Balaton was a natural basin of Lake Balaton (Figure 15) Kis Balaton has always played an important role as a natural filter system by allowing the Zala to deposit its sediment and organic matter before entering Lake Balaton. The average water depth and volume of Lake Balaton has been halved since the end of the 18th century (Zilinszky and Tímár 2013), due to the construction of the Sió lock in 1863 and the water level regulation works carried out to protect the railway line from flooding along the southern shore of Lake Balaton. As a result, the higher parts of Lake Balaton were drained, and the area was only covered by water during the floods of the Zala river. In the 1920s, the Zala flood protection embankments effectively excluded the river's flood waters from Kis-Balaton. Subsequently, until the 1960s attempts were made to reduce and control the groundwater level by the construction of a canal system in order to allow agricultural activities in the area, which were not successful.

Thus, Kis-Balaton lost its natural filtering role, the nutrients that entered the lake with the large amount of sediment resulted in significant eutrophication processes, as the Zala no longer deposited its sediment in the marshy area of Kis-Balaton, but in the Keszthely Bay and the water quality of the entire Balaton deteriorated. Therefore, in the 1970s, in order to avoid an ecological disaster, the Western Transdanubian Directorate for Environmental Protection and Water Management developed a plan for the construction of the "Kis-Balaton Water Protection System", which involved the artificial reflooding of Kis-Balaton and the rehabilitation of the marshland. The basic idea was that by re-flooding the Zala valley, which used to exist as a bay or marsh, the marshland-reed area would be created to process the nutrients from the river Zala. With this water protection system, which is unique in the world, the processes that have been taking place in Lake Balaton, especially in the Bay of Keszthely, are transferred to the area of the water protection system being established in the lower Zala. This solution created conditions similar to the natural state that existed around 200 years ago (Tátrai et al. 2000).

The work was carried out in two phases (Figure 15) the first phase, the creation of the 1870-hectare Hídvégi Lake, was completed by 1985, and the second phase, the flooding of the 5000-hectare Fenéki Lake, was essentially completed by the end of 2014. The area has been heavily dammed, and a system of dikes and spillways has been built. The waters of the Zala meander through the area as planned.
In the first phase, in 1985, the 18 km^2 Lake Hídvégi was completed, with a water level 2 m higher than Lake Balaton. The waters of the Zala are spread over this area. The water level is maintained by the valley filling and the two-port sluice built into the embankment. The embankment on the right bank of the river has been dismantled in sections, allowing water to flow out onto the prepared area. To ensure that the water does not flow towards the sluice in a short time and by the shortest route, a diversion fill has been constructed. A 3.4 km^2 cassette was constructed in the flow cavity between the diversion fill and the Zala, with a reservoir and a drainage hollow. The incoming water stays here for about 30 days, during which time the dissolved nutrients are used by simple organisms living in the water to build their own bodies. The intake structure is capable of discharging 10 m^3 of water per second, so that high tides, for example, can be released relatively quickly and the embankments can be spared and discharged through the outlet structure. The cassette also has the capacity to clean and treat contaminated water. Laboratory testing of the water is carried out daily.

The largest structure of the first phase of the water protection system is the sluice, which will release the purified water of the Zala to the second phase. The sluice has two openings: a smaller one to regulate the water level, to divert small and medium water flows, and a larger one equipped with a tipping platform to divert flood waters and allow small floating equipment and watercraft to pass through.

The second phase of the water protection system is Fenéki Tó (Lake Bottom). It is designed to deliver water to Lake Balaton in about 90 days, bypassing two diversion loads over a flooded area of about 51 km^2. In November 1992, 16 km^2 of the planned system was flooded, this being the Ingó Berek. Here a marshy, reedbed habitat has been created that became a world-famous bird sanctuary. As expected, the marshland has regenerated rapidly, so that a large part of the area is now a specially protected habitat.

There is ultrasonic water flow detection equipment at several points in the water protection system. The values obtained from the ultrasound propagation velocities over a given distance are analysed by a computer, which calculates and records the water flow data based on the dimensions of the riverbed. The resulting data and the amount of nutrients dissolved in the water can be used to easily calculate how much nutrient is entering the Zala, how much is remaining in Lake Kis-Balaton and how much is entering Lake Balaton.

This wonderful aquatic world, almost destroyed by human activity, has been saved and its marshes, reeds and waterways repopulated (Figure 16). Since 1951, the 146.6 km^2 area of the Little Balaton has been a nationally protected closed nature reserve, from 1979 protected by the Ramsar Convention

(Convention on Wetlands of International Importance, especially as Waterfowl Habitat) and, since 2004, a priority site of the European Community's Natura 2000 network. Most of it can only be visited with a permit and to a limited extent. Hunting is strictly prohibited in its area.

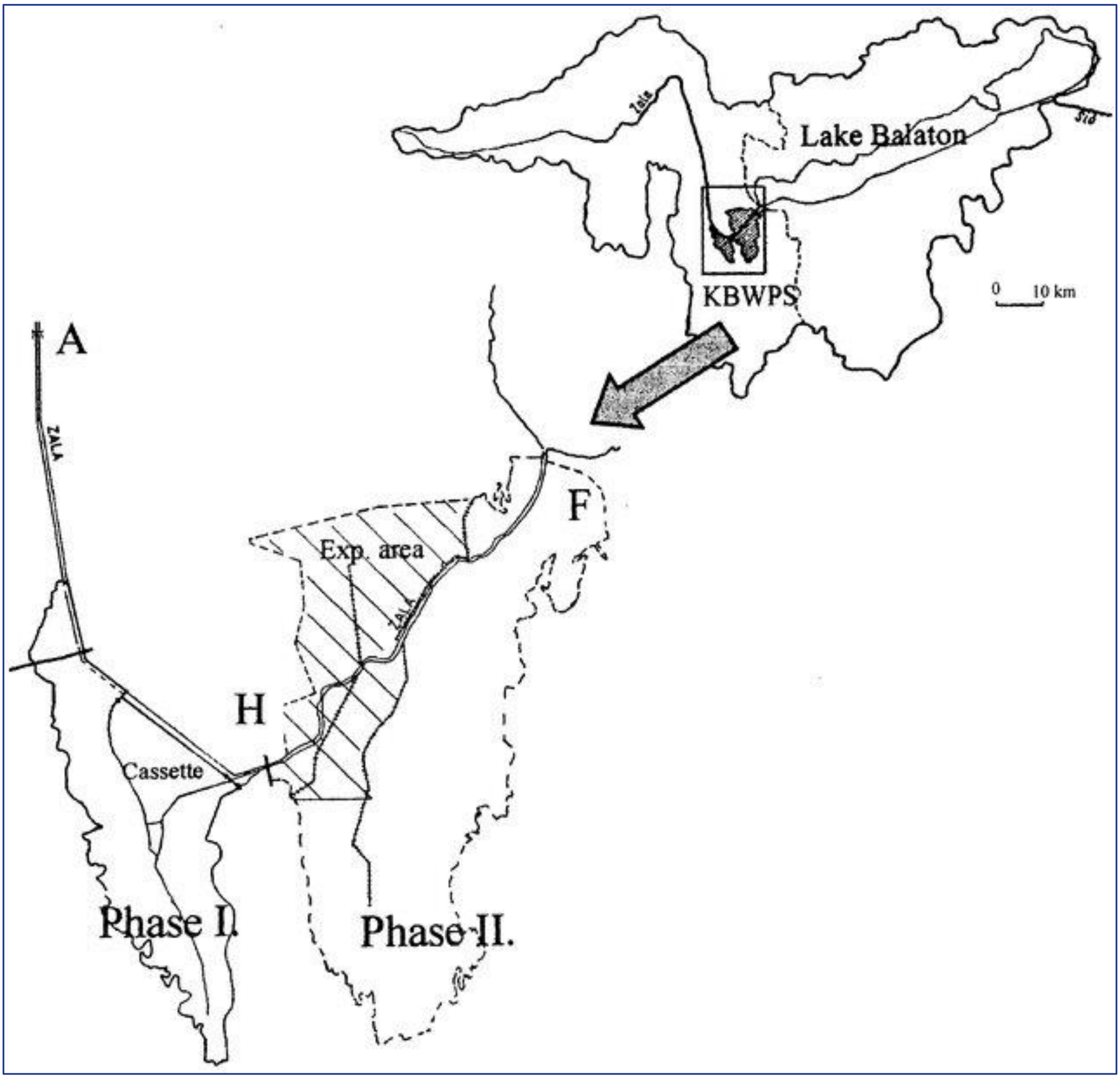

Figure 16. The structure and the phases of the Kis Balaton Water Protection System (KBWPS). Source: Tátrai et al. 2000. https://doi.org/10.1016/S0925-8574(00)00091-4

The renewal of Kis Balaton achieved three main objectives:

1. Protection of the water quality of Lake Balaton by trapping nutrients in the water protection system and by creating the possibility of a flexible operating schedule.
2. Nature conservation, reconstruction of aquatic ecosystems and creating new habitats are also met by flooding the Zalavár inland floodplain, reducing the load on the Ingó marshlands.
3. Reduced flood risk through increased reservoir volume and upgraded flood protection system. In addition, the technical possibility has been created to share the Zala water between the reservoir areas and, if necessary, to divert the Zala water directly to Lake Balaton by bypassing the reservoir areas.

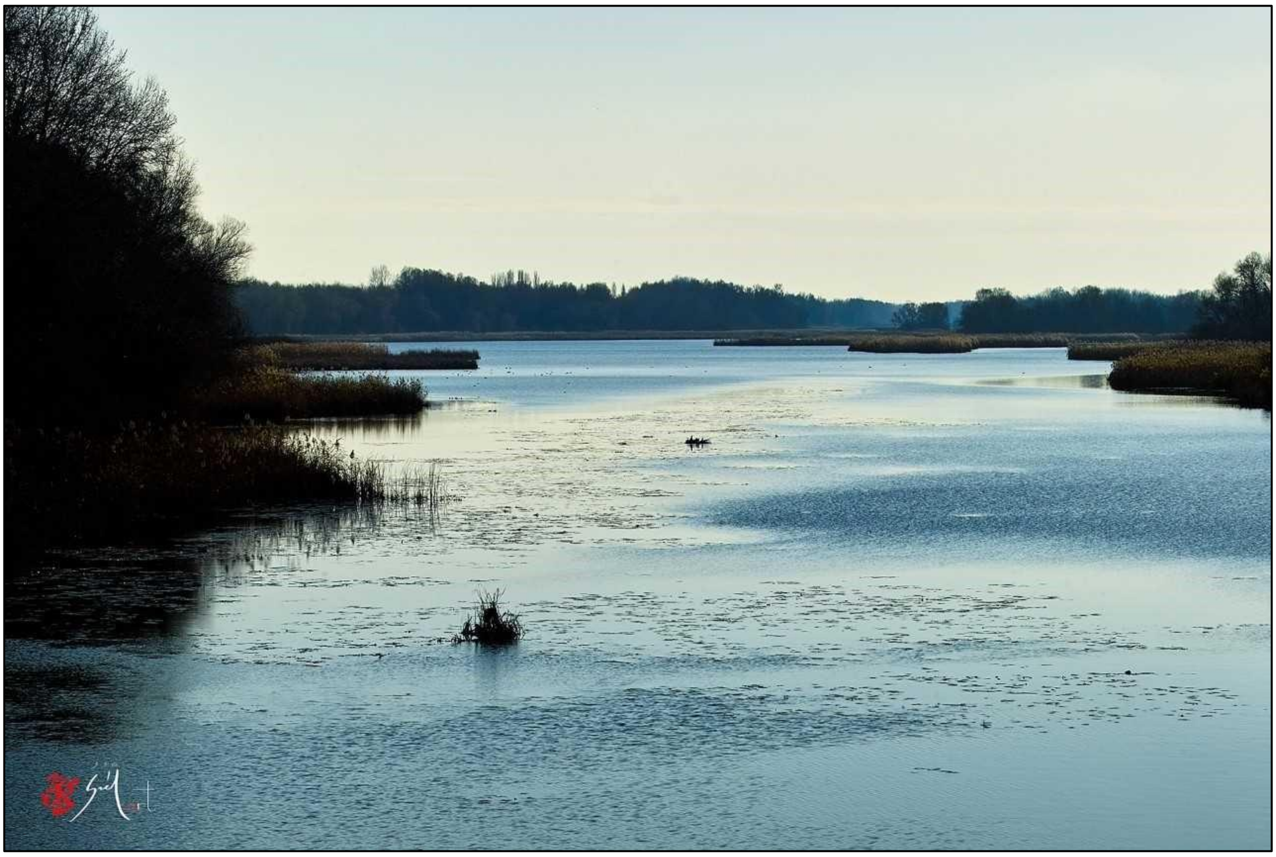

Figure 17. The restored Kis Balaton. Photo: Károly Szél (2021).

Other European areas

As part of the projects mentioned, other European areas have been looked at, including Trento, Birmingham, and Warsaw. Trento offers a distinctive blend of Alpine and Mediterranean influences, characterized by its diverse ecosystems that range from mountainous terrains to valley floors. The region focuses on sustainable tourism and agriculture, promoting practices that preserve its unique alpine biodiversity while supporting its agritourism industry. Trento's approach to urban farming and the integration of green spaces within and around its urban areas serves as a model for managing water resources and enhancing urban resilience to climate impacts.

Birmingham's approach to sustainable urban development is centred around its post-industrial landscape transformation. The city has been actively involved in integrating urban agriculture and green infrastructure to address urban sprawl and industrial decline. Initiatives like the creation of green corridors and community gardens aim to mitigate the effects of urban heat islands, manage stormwater runoff, and provide recreational areas for community engagement and biodiversity enhancement.

Poland’s study areas, particularly in its rapidly urbanizing regions, focus on the challenges of balancing urban expansion with the conservation of its rich wetlands and river systems. Efforts in Poland have been directed towards enhancing water quality and flood management through the restoration of natural landscapes that function as buffers against climate change impacts. The integration of nature-based solutions in urban planning and rural development strategies is also a significant focus, aiming to sustain the ecological and cultural heritage of the region.

These areas, each with their distinct environmental and cultural settings, contribute valuable insights into the integration of sustainable practices within diverse urban and rural contexts. They underscore the importance of tailored approaches that respect and leverage local characteristics and needs while addressing global environmental challenges. Despite the varied environmental and cultural settings, these regions share common challenges related to water management, biodiversity conservation, and the integration of cultural heritage into landscape practices. The research draws lessons from these areas to propose scalable and adaptable strategies for other regions facing similar issues. The cross-disciplinary model development adopted in this study highlights the need for integrated approaches that consider ecological, economic, and cultural dimensions simultaneously, ensuring sustainable management of aquatic cultural landscapes across different geographic and climatic contexts.

The detailed study of these diverse regions not only enriches the understanding of specific local issues but also contributes to the broader field of sustainable landscape management. By analysing these case studies, the research aims to develop holistic management practices that can be adapted and applied globally, ensuring the preservation and sustainable use of aquatic cultural landscapes for future generations.

3.7. Details of Research Projects

3.7.1. U-Garden Project

Within our ongoing project U-garden[2], based on a descriptive-comparative analysis, the benefits of multifunctional land use in regional planning strategies are evaluated for a better policy formulation that addresses the needs of contemporary cities to achieve sustainability. The goal is to formulate policies that address the needs of modern cities and promote sustainability. The methodologies include the identification of the area using cartographic techniques, its positioning in relation to the urban environment, as well as the location and spatial elements within it. It also considers the typological, morphological, and structural characteristics of the area, as well as the governance aspects such as planning, regulation, the actors involved, target groups, and socio-economic factors. Moreover, numerous case studies examining various urban gardening models have been carried out.

The study has been made through comprehensive literature review where information has been gathered on existing research and studies related to agricultural activities in cities and its impact on urban water management. This involved reviewing academic journals, government reports, and publications from international organizations and internet references. Furthermore, the primary research included interviews with stakeholders, site visits to filtration stations and agricultural lands, studies of natural land cover and cover crops used in agricultural production, and analyses of environmental contamination in soils. A policy analysis was conducted to understand the role of land rights and water infrastructure investments in the promotion or hindrance of urban agriculture for water management. This involved reviewing relevant policies and regulations, analysing their

[2] This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003758

implementation and impact, and identifying barriers and opportunities for supporting urban agriculture.

The study includes qualitative methodologies combined with evaluation research techniques, specifically using triangulation to collect and analyse data from various sources. Triangulation also included the team, which showed diversity in terms of research methodologies and backgrounds. This diversity allowed us to act as impartial observers, commentators, and/or regulators in relation to each other in terms of research implementation and articulation of results. Triangulation is an essential cognitive technique that enhances the accuracy, reliability, and credibility of research and facilitates the generalisation of the data produced during the research process.

The project applied the following research methods:

1. Analysis of existing data (desk research) encompassing a variety of documents (scientific and popular science texts, research reports, official documents, acts, press articles, etc.).

2. The main methods used to obtain the qualitative data for the study were interactive workshops and structured interviews. These carefully thought-out techniques were meant to encourage participants to openly share their thoughts, experiences, and perspectives in open-ended discussions. To ensure a wide range of viewpoints, interviews were done with a variety of stakeholders, such as residents, environmental activists, community leaders, and urban planners. In contrast, workshops were created to promote cooperative discussion, problem-solving, and knowledge co-creation. This allowed participants to discuss and examine the intricacies of urban sustainability in a group environment.

3. Individual in-depth interviews. Interviews were carried out among farmers**,** urban farmers, residents, and local and regional government officials were conducted to gather data on the use of agricultural activities for urban water management. Questions included the availability and effectiveness of green spaces, the use of recovered wastewater, the challenges faced in implementing wastewater recycling systems, and the impact of urban agriculture on water resources.

   These interviews were qualitative, "flexible, interactive, and continuous" as opposed to rigid and static, allowing for interaction between the researcher and the participant. The arrangement was designed to replicate a typical conversation by use informal language customised to the interviewee. The interviews were classified to some extent, based on a predetermined list of subjects to address throughout the interview. This methodology offered adaptability throughout the interviews while also permitting a certain level of standardisation in the gathered data.

   The interviews were conducted at locations chosen by the interviewees to ensure their comfort and freedom, lasting between 45 to 75 minutes, and were transcribed with the interviewees' consent. As part of the research project, 22 interviews were conducted with individuals utilizing plots in seven community gardens in Gothenburg: Lilla Änggården, Angereds gård, Backa trädgårdar, Jordad hand, Lilla jordbruket, and Botaniska Trädgården. These locations were specifically selected to reflect the diversity of Gothenburg's community gardens, also in terms of their location, infrastructure, size, and the demographics of the plot users.

4. Focus group interviews. The interviews were qualitative, with an active moderator who directed the discussion among a group focused on specific topics suggested by the moderator. The group discussions leveraged the dynamics of group interactions to foster greater activity and creativity.

5. Quantitative Information: The implementation of standardised questionnaires served as the foundation for the quantitative data gathering, which complemented the qualitative findings. These tools were specifically designed to extract quantifiable, targeted information from a wide participant base, allowing for the statistical analysis of the data to find trends, patterns, and correlations. The questionnaires encompassed a variety of subjects, such as land use patterns, involvement in sustainability projects, and the perceived effects of these practices on environmental health and community well-being.

6. The quantitative data fulfilled several vital purposes. Firstly, it provided empirical evidence to support or challenge the assertions and hypotheses developed through qualitative exploration. Secondly, it allowed us to establish baseline metrics against which the effectiveness of current and proposed sustainability practices could be evaluated. This included parameters such as land use optimization, levels of stakeholder engagement, and the tangible economic benefits derived from sustainable practices.

7. Participant observation. This method enabled me to closely interact with study participants while maintaining a clear role as observers, collecting data that isn't always accessible through other communicative means.

3.7.2. SATURN Project

The SATURN (System and sustainable Approach to virTuous interaction of Urban and Rural Landscapes) project, aimed at exploring how urban farming can be a tool for climate adaptation and mitigation in urban environments, employed a comprehensive methodology to evaluate and compare urban farming models in Gothenburg, Trento, and Birmingham. This paper presents and discusses the methodologies developed during the SATURN project, which tested various landscape challenges through alternative governance and stakeholder engagement strategies.

1. Data Collection and Case Study Development:

The SATURN project was structured around the development of case studies in three diverse urban contexts across Europe—Gothenburg, Trento, and Birmingham. These case studies were chosen due to their unique geographical, social, and economic characteristics and their innovative approaches to urban farming. Each city applied urban farming in a way that aligned with its local conditions and sustainability goals. Data were collected through a variety of methods:

2. Field Visits and Observational Studies:

Field visits were conducted in each participating city to observe and document the existing urban farming practices and their integration within the urban landscape.

3. Stakeholder Interviews and Workshops:

Interviews were carried out with a range of stakeholders, including city planners, community groups, and local farmers. These interviews helped to gather insights on the operational challenges and benefits of urban farming initiatives. Additionally, workshops facilitated discussions among stakeholders to foster knowledge exchange and collaborative problem-solving.

4. Review of Policy and Governance Frameworks:

An analysis of local policies and governance structures was performed to understand the regulatory and institutional frameworks impacting urban farming practices.

5. Comparative Analysis and Model Development:

The project utilized a comparative analysis approach to identify best practices and areas for improvement across the three case studies.

Each urban farming model was evaluated based on its effectiveness in contributing to climate change mitigation and adaptation efforts. The amount and quality of green space created or enhanced by urban farming projects were mapped using geographic information systems (GIS). This included changes in land cover, accessible green spaces, and the integration of green infrastructure elements like green roofs and walls. Spatial analysis was conducted to evaluate the connectivity and continuity of green spaces, which are critical for ecological networking and for providing recreational and health benefits to urban residents. The impact on green space was assessed against urban greening policies and standards, such as the percentage of city area covered by permeable, vegetated surfaces.

The models were assessed for their potential scalability and transferability to other urban contexts. This involved examining the adaptability of the farming techniques, stakeholder engagement processes, and governance structures developed in each city.

The socio-economic impacts of each model were analysed to determine their benefits in terms of community involvement, economic opportunities, and social well-being.

6. Knowledge Dissemination and Policy Recommendations:

The findings from the SATURN project were compiled into a set of recommendations for policymakers and urban planners. These recommendations aimed to facilitate the broader application of successful urban farming models and to encourage the integration of urban agriculture into sustainable city development plans.

3.7.3. Blue-Green Solutions for Flooding and Drought

Within the framework of the project titled “Financial instruments for nature-based solutions to reduce risks of flooding and drought”, and “Business model for blue green compensation to reduce risks for urban flooding”, data have been generated through field studies, workshops and interviews concerning the ecological and economic viability of urban greening, application of grey-green and blue-green infrastructures in cooperation with the County Administration of Västra Götaland. The aim has been to list several measures to reduce risks of flooding related to different sectors (forestry, agriculture) to reach benefits of restoring water in the landscape. The viability and social acceptance of related business models has been discussed in workshops and data were collected through questionnaires and deep interviews to reveal the perceived barriers to nature-based solutions (Ternell et. al 2018, Ternell et.al. 2020).

Our initial task involved identifying stakeholders relevant to the transformation towards sustainable land use in peri-urban areas. A key activity in this phase was conducting a workshop to identify existing business models and their value streams – essentially, understanding who creates value and for whom. This process led to the categorization of primary stakeholders, including landowners, forest owners, regional and city officials, citizens interested in gardening or food production, and professionals like carpenters and city farmers. Data collection was primarily conducted in the Västra Götaland Region, Säveå River area. Säveå river is part of the larger catchment of Göta Älv river, which is the river that ends in the city of Gothenburg. Säveå river was selected since it is relatively small, compared to the total catchment of Göta Älv river, and therefore it was considered feasible to meet with the key stakeholders within the scope of this pre-study. The methodology encompassed a multiapproach as illustrated in Table 3.

Table 3. Summary of Methodology for Blue-Green Solutions Studies

Primary Data Collection	Interviews and Dialogues: Engagements with key stakeholders, including landowners, municipal representatives, environmental agencies, and community groups, provided invaluable insights into the challenges and opportunities of implementing NBS.
	Site Visits: Visits to areas affected by flooding and drought, as well as existing NBS projects, offered firsthand understanding of the local contexts and the potential impact of proposed solutions.
	Stakeholder Workshops: A series of dialogue workshops facilitated the exchange of knowledge and experiences among stakeholders. These workshops served as platforms for identifying the needs, barriers, and drivers for adopting NBS.
Financial Instruments Analysis	The study explored various financial models to support NBS, focusing on mechanisms that enable downstream beneficiaries to compensate upstream providers for water retention measures. This included an in-depth analysis of existing and potential monetary systems, incentives, and public policy instruments.
Legal Framework Assessment	A critical examination of the legal barriers and possibilities for implementing NBS highlighted the need for legal adaptability and innovative governance structures. The study navigated through the complexities of national and EU directives, assessing their impact on NBS adoption.
Societal Values and Benefits	Understanding the multifaceted benefits of NBS was central to advocating for their adoption. The methodology involved quantifying the ecological, economic, and social values of NBS, thereby strengthening the case for their integration into water management strategies.

The methodical approach included stakeholder engagement with the purpose to enrich the project with diverse perspectives and ensure that the development of solutions was grounded in practical realities and stakeholder needs. The primary goal of this work was to facilitate ongoing dialogue with key stakeholders that began during the pre-study phase. This dialogue aimed to establish a common platform for collaboration and to test project ideas practically at a demonstration stage.

Stakeholders were categorized into three groups: beneficiaries, providers, and intermediaries. Beneficiaries primarily included municipalities that benefit from flood risk mitigation and have opportunities for land development. Providers, such as private and public landowners including farmers and forest landowners, were involved due to their roles in implementing blue-green interventions, receiving compensation, and benefiting from increased biodiversity and other indirect income-generating effects. Intermediaries consisted of organizations with various mandates in regional and local water management, offering expertise in technical assessments and negotiation of compensation schemes.

The Gothenburg area in Sweden and the Netherlands were the locations where key interviews were done with stakeholders. A total of 22 persons were interviewed representing the following institutions in 2018:

Table 4. Interview List for Work on Blue Green Solutions.

Organisation	Note
Sweden:	
Sportfiskarna	The Swedish Sport Fishing and Fisheries Conservation Association is a democratically structured non-profit organization
Vattenfall	Power utility
Partille municipality	Representatives from the Municipality
Säveåns water board	Representative from the water board
Lerums municipality	Representatives from the Municipality
Alingsås municipality	Representatives from the Municipality
Gothenburg City	Representatives stratetgic planning
Länsförsäkringar	Insurance company
Gothenburg Region	Representatives from the region
Netherlands	
Hoogheemraadschap Delfland	Representatives from Delfland Water Board
TU Delft Water Management	Representatives from Water Management department, Faculty of Civil Engineering and Geosciences
VP Delta, Green villages	VPdelta+ is the innovation programme for a climate-proof environment of TU Delft Innovation & Impact Centre, Erasmus Centre for Entrepreneurship (EUR) and Kansen voor West II.

A key event was a local workshop held on May 14, 2019, at the Region Västra Götaland. This workshop focused on financial models for nature-based solutions to reduce the risks for flooding and drought. It served as a platform for knowledge exchange among researchers, practitioners, and stakeholders. The discussions centred around experiences and challenges in using Nature-based Solutions to mitigate flood and drought risks. The workshop facilitated detailed group discussions and presentations by key organizations. A total of 36 participants, representing various public and private organizations including farmers' associations and regional water agencies, attended. Key outcomes included:

- Recognition of the importance of speeding up the adoption of NBS to prevent flooding and drought.
- Identification of the most valuable aspects of NBS in terms of ecosystem services such as increased resilience, water purification, biodiversity enhancement, and CO2 reduction.
- Discussions on the financial business model of the project, focusing on its feasibility, implementation barriers, and potential benefits.
- The initiation of a national network on flood and drought prevention, which was proposed to be further developed into a more formal network through potential future projects like Europe Brigade.

The findings and discussions from the workshop were carefully documented, contributing to the project's development of a robust financial model for NBS. Additional details from the workshop were compiled and attached to the study report, ensuring a comprehensive resource for future reference and continued stakeholder engagement.

A research tour to the UK, took place from May 15-17, 2019, offered a chance to directly meet with European individuals involved in comparable initiatives. The purpose of this journey was to facilitate the sharing of ideas and develop a foundation for the creation of a European network that would provide support for future collaborative project proposals. Moreover, in June 2019, a visit to the Netherlands provided valuable knowledge on water management strategies aimed at mitigating the dangers of urban flooding.

The methodology for the study was grounded in the Strategyzer approach[3], which integrates the Business Model Canvas (BMC) and the Value Proposition Canvas (VPC) suitable for circular economies (Lewandowski, M. 2016). This selection was driven by the appropriateness of these tools for exploratory research into customer value, as well as their efficiency in documentation and information sharing. The BMC has gained widespread acceptance in both industry and academia as a standard approach for communicating customer value and business model design.

The VPC served as a foundational template during interviews to identify current practices (customer jobs) and to highlight the challenges (pains) within the stakeholders' organizations. Concurrently, we identified current benefits (gains) that stakeholders associate with baseline practices, which was crucial for enhancing these gains or ensuring they are not negatively impacted as we address pains.
As the study progressed, the VPC was expanded into a complete BMC for a selected business case, along with a few supporting BMCs. This expansion allowed us to gain a comprehensive overview of the necessary processes and structures to deliver services to the core stakeholders effectively. While

[3] https://www.strategyzer.com/library/the-business-model-canvas

the VPC primarily focuses on customer values, the BMC encompasses the practical aspects of delivery and financing the venture.

Towards the end of the study, we engaged in a validation process with interviewees to confirm the selected business model. This step was crucial to ensure that the identified gain creators and pain relievers effectively support the stakeholder's needs. The validation process was a vital component in confirming the practical applicability of our findings.

3.7.4. Climate Smart Eco-Based Agroforestry with Green Business Models and Social Sustainability Project

The project studies had the objective is to link innovative models for ecosystem-based agroforestry as a key for new local strategies for sustainable interactive climate smart economic development (Ternell et. al. 2017). The studies utilised a mixed-methods approach to assess the viability and impact of agroforestry systems within the Gothenburg region, particularly focusing on peri-urban areas. The methodology was structured around three primary components: interviews, workshops, and an extensive review of relevant literature. Each component was designed to capture a different dimension of agroforestry practices, ranging from individual experiences to community-wide impacts and theoretical frameworks.

1. Interviews:
To gain insights into local perspectives on agroforestry, we conducted semi-structured interviews with a range of stakeholders, including local farmers, forestry officials, urban planners, and residents. These interviews were designed to collect qualitative data on the experiences, benefits, and challenges associated with integrating forestry and agriculture. The interview process involved:

- Selection of Participants: Stakeholders were selected based on their involvement or interest in local land use, their professional expertise, or their participation in local agroforestry projects.
- Interview Framework: The interviews focused on understanding stakeholder perceptions of agroforestry benefits, the practicalities of implementation, and the socio-economic and environmental impacts.
- Data Analysis: Thematic analysis was used to identify common themes and divergent views among the interviewees, which helped in understanding the nuanced impacts of agroforestry practices.

2. Workshops:
Workshops were held to facilitate broader community engagement and to gather collective insights into the development of agroforestry models suitable for the Gothenburg region. These included:

Ecosystem-Based Agroforestry Workshop was held December 6, 2016 at Mistra Urban Futures in Gothenburg City. A total of 28 participants attended the workshop representing people from public, private and social society. The main topic of the workshop Ecosystem-based agroforestry land uses in Gothenburg. The Subtopics of the workshop were: a) Climate-KIC and Pathfinder partners dialogue (COWI/Business Region Gothenburg, Stadslandet Gothenburg, Miljöförvaltningen, Real Estate City of Gothenburg (Fastighetskontoret), Silvaskog and EAC), and b) Ideas and final remarks for next Gothenburg Agroforestry forums, insights on Forestry workshop in Helsinki 2017, future research, Agroforestry Centre Gothenburg participation, demo areas, international exchange and cooperation. The workshop methodology included:

- Planning and Organization: Workshops were structured around specific themes Each session was designed to encourage active participation and collaborative problem-solving.
  Activities: Activities included group discussions, and interactive sessions where participants could propose and refine ideas related to agroforestry practices.
- Outcome Documentation: The workshop's outcomes included important conclusions about the ongoing significance and work of agroforestry issues, the creation of a Swedish network and contacts for upcoming collaborations, and a suggested Agroforestry platform in the West for actual collaboration and exchange at the local and regional levels. The workshop's outcomes were recorded in a report.

The Agroforestry Conference 20 April 2017 at Angered, Gothenburg City. A total of 55 persons attended the conference, representing public, private and social society. The conference included three workshops to discuss the topics presented including a) Ecosystem-based agroforestry, b) Ecosystem services and business development, c) Tourism and destination development. The objectives were to develop and establish networks for ecosystem-based business development, destination development and agroforestry in urban and peri-urban areas. These workshops served as platforms for knowledge exchange and co-creation of solutions with active participation from multiple stakeholders. The workshop methodology included:

- Planning and Organization: Workshops were structured around specific themes such as sustainability models, integration strategies, and policy frameworks. Each session was designed to encourage active participation and collaborative problem-solving.
- Activities: Activities included group discussions, scenario planning, and interactive sessions where participants could propose and refine ideas related to agroforestry practices.
- Outcome Documentation: The outcomes of each workshop, including proposed models, identified barriers, and potential strategies, were documented in detailed minutes and summary reports. These documents contributed to the ongoing development of agroforestry strategies.

3. Literature Review:

An extensive literature review was conducted to complement the empirical data gathered through interviews and workshops. This review aimed to place local findings within a broader theoretical and practical context, examining:

- Scope of Review: The review covered academic journals, industry reports, policy documents, and case studies relevant to agroforestry, sustainable land use, and urban-rural interactions.
- Synthesis of Findings: Information from the literature was synthesized to provide a comprehensive overview of current practices, historical developments, and future trends in agroforestry.
- Integration with Empirical Data: Insights from the literature were used to support, contrast, or extend the findings from interviews and workshops, providing a multi-layered understanding of the subject.

3.8. Relationship between Hypotheses, Research Questions and Methodology

Table 5 summarise the relationship between the hypotheses, research questions, and the methodology used for the study:

Table 5. Relationship between the hypotheses, research questions and the methodology used for the study.

Hypothesis	**Research Question**	**Methodology**
Hypothesis on Nature-Based Solutions (NBS) and Water Management	How can NBS be optimized to enhance water retention and mitigate flood risks in aquatic cultural landscapes and what are their multifunctional roles in promoting biodiversity water quality and socio-economic benefits?	Primary research: workshops, structured interviews, questionnaires (incl. NBS and flooding projects) Secondary research: literature studies, site visits.
Hypothesis on Mitigation of Climate Change Impacts	What are the impacts of climate change on the management of water resources in aquatic cultural landscapes and how can integrated water resources management (IWRM) approaches be tailored to improve ecosystem health and sustainability in these landscapes?	Primary research: stakeholder interviews, focus groups, field visits. Secondary research: policy review, case studies.
Hypothesis on Cultural Heritage Conservation and Community Engagement	How do conservation efforts of cultural heritage within aquatic cultural landscapes stimulate economic benefits particularly in relation to tourism and community identity and what models can support the sustainable integration of these efforts?	Primary research: community surveys, stakeholder interviews Secondary research: literature review, analysis of historical records.
Hypothesis on Urban Living Labs	How do Urban Living Labs enhance the efficacy of sustainable urban development projects through innovative collaboration among stakeholders and the integration of real-time data and community feedback in the planning and implementation processes?	Case studies: SATURN Project, U-Garden Project. Field studies: observational studies, Stakeholder workshops
Hypothesis on Integrated Water Resources Management (IWRM)	What innovative financial mechanisms and business models can be developed to support the adoption of NBS for water retention and the transformation of small-scale agricultural systems in urban and peri-urban areas of aquatic cultural landscapes?	Primary research: interviews, questionnaires, workshops Secondary research: policy analysis, financial review.

4. Results

4.1. Resilience and Sustainability of Aquatic Cultural Landscapes in the Face of Climate Change

4.1.1. Introduction

In the face of escalating environmental challenges, particularly those exacerbated by climate change, traditional approaches to disaster risk management and resilience building are increasingly proving inadequate. This chapter focuses on the innovative application of NBS to enhance the resilience of water management systems and reduce disaster risks in vulnerable communities. NBS offer a dynamic approach to managing water resources that is fundamentally adaptive to changing environmental conditions. By leveraging the natural properties of ecosystems, such as wetlands, forests, and riverbanks, NBS foster a resilient water management infrastructure that can evolve in response to climatic shifts.

Aquatic cultural landscapes are complex, interconnected systems with enormous ecological and cultural value. They comprise a wide range of ecosystems, including rivers, lakes, and wetlands (IPCC, 2014). The maintenance of these ecosystems is crucial because they offer key services including recreational activities, water purification, and habitat for a variety of flora and fauna. However, the integrity of aquatic cultural landscapes is under a major threat due to the escalating impacts of climate change (IPCC, 2022). The need to address these issues urgently is demonstrated by recent studies.

Aquatic cultural landscapes are facing several difficulties because of climate change, endangering their delicate balance. Estuaries and low-lying coastal areas are seriously threatened by rising sea levels, which are linked to global warming (IPCC, 2014). The flow of freshwater into these ecosystems is impacted by altered precipitation patterns, which disturb hydrological cycles. In addition, there has been a noticeable rise in the frequency and power of extreme weather events like hurricanes and storms, which has resulted in significant harm to aquatic environments (IPCC, 2014). It is vital to protect aquatic ecosystems because of the threat that these climate-related changes pose to their composition and functionality.

In the case of the City of Gothenburg, the area is extra sensitive to flooding due to its location downstream and next to the sea. As the city is located on low-land area along the coast, coastal flooding occurs when sea surface rises, for example, because of strong winds or when the sea surface rises more permanently with respect to climate change. The effects from sea level rise are hard to avoid, while a reduction in upstream water flows from streams and rivers can be addressed through NBS. Figure 18 shows the development of precipitation from 1961 and estimated rainfall up to 2098 in Region Västra Götaland made by the Swedish Meteorological and Hydrological Institute (SMHI). The annual rainfall in Region Västra Götaland was 795 mm during the period 1961-1990. Most precipitation falls along the coast. Over the past 23 years, precipitation has increased slightly, mainly in the southwestern part of the region. The analysis further shows that precipitation is expected to increase, with between 12% and 25% to the end of the century. Similarly, the same analysis shows an increase in the annual run-off. From 1961 to 1990, the run-off increased with 5-15% in the area. This is estimated to continue towards the end of the century.

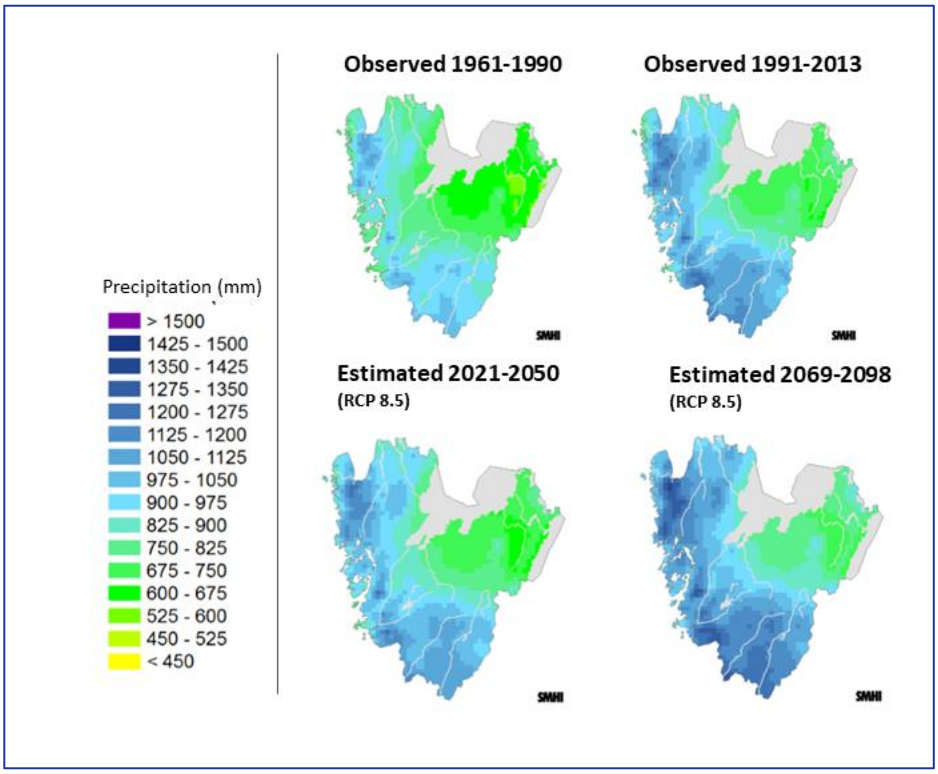

Figure 18. Annual mean precipitation in region Västra Götaland, 1961-2098, source: SMHI, 2015

Climate change has a direct impact on important lake system characteristics such as lake levels, water temperature, thermal stratification, water quality, productivity, and biodiversity (Jane, S.F., et al., 2021). Climate variables can have a direct impact on lakes through factors such as rising average temperatures and changes in extremes, which influence thermal stratification and nutrient cycling (O'Reilly C. M. et al., 2015). Changes in the temporal and spatial characteristics of precipitation also play a crucial role in lake inflows and levels, affecting water quality, productivity, and biodiversity (Huntington et al., 2022).

Large-scale effects, including variations in climatic oscillations like El Niño-Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO), might further complicate lake dynamics (Smol et al., 2019). Lake water levels may also be impacted by changes in other climatic factors as wind speed, radiation, cloud cover, and relative humidity (Hodgkins et al., 2020). These intricate relationships show how important it is to have an in-depth understanding of how the climate is changing lake ecosystems.

Furthermore, sedimentation processes and water quality, particularly the prevalence of toxic algae, can be impacted by climate change (Paerl, H. W., et al., 2016). Wind and currents can cause sediment resuspension, which can have an impact on nutrient cycling and the general metabolism of lakes. Biological water quality is also harmed, with rising temperatures and fertiliser additions favouring toxic algal blooms and eutrophication (Chorus, I., & Welker, M., 2021). These changes not only pose environmental and health hazards but also have economic ramifications, hurting tourism and drinking water supplies (Akinnawo, 2023).

In light of these recent findings, this research delves into the multifaceted challenges posed by climate change to aquatic cultural landscapes, presenting comprehensive solutions rooted in scientific research and policy frameworks, and underscoring the importance of stakeholder engagement in ensuring their resilience and sustainability. To ensure these essential ecosystems survive, we must constantly assess and respond to the changing effects of climate change.

To address the various complex issues posed by climate change, empirical evidence strongly supports the effectiveness of NBS. The literature highlights the significant contribution of NBS in promoting resilience and implementing cost-effective management approaches for flood and drought events (Cohen-Shacham et al., 2016). In addition to the immediate reduction of risks, NBS offer further sustainability benefits, such as enhanced biodiversity and expanded recreational opportunities (Costanza R. et al., 2017). Furthermore, the incorporation of NBS alongside conventional grey infrastructure introduces a novel phase in water management strategies, strengthening the effectiveness of systems and improving the safeguarding of communities (IPBES, 2018).

The combined problems of increasing urbanisation and climate change have put urban water management at an essential stage. Gothenburg and other low-lying coastal cities serve as prime examples of the greater vulnerability to both pluvial (caused by rainfall) and fluvial (riverine) floods. Rising sea levels and the frequency and intensity of extreme weather events are two variables that are aggravating this sensitivity (Millennium Ecosystem Assessment, 2005; Ternell et al., 2020).

As urban areas expand, the strain on water systems intensifies, highlighting not only the risk of flooding but also the sustainability of water resources. This scenario necessitates a fundamental rethinking of urban water management strategies. Transitioning to a holistic framework is essential, one that integrates considerations of land use, water supply, and the built environment (IPCC, 2014). This approach involves enhancing the resilience of water infrastructure through the adoption of green infrastructure solutions like green roofs, rain gardens, detention basins, and permeable pavements, which help manage stormwater and mitigate runoff (Fletcher et al., 2013; Kayhanian, M., 2019).

Moreover, the digital revolution offers unprecedented opportunities for improving water management. Advanced technologies such as sensors and real-time monitoring systems enable precise management and optimization of water resources (Abbaspour et al., 2015). However, the implementation of these Nature-Based Solutions (NBS) and integrated approaches faces significant challenges. Scalability, financial constraints, and socio-economic differences are substantial barriers, particularly in regions lacking the necessary financial or political support. Conflicts may also arise between water conservation initiatives and agricultural demands, underscoring the need for balanced water resource management.

To address these complex issues effectively, urban water management must evolve to incorporate innovative technologies, foster cross-sector cooperation, and actively engage stakeholders. This transformation will not only safeguard water supplies but also enhance the wellbeing, safety, health, and economic prosperity of urban populations. As climate change and urban growth continue to intersect, a resilient, sustainable, and adaptive urban water management system becomes crucial for securing a viable urban future.

4.1.2. Mitigation Strategies

Addressing the multifaceted challenges posed by climate change necessitates a holistic approach that spans multiple sectors. Climate adaptation measures, including the improvement of watersheds to ensure hydrological stability, stand as vital initiatives (Adger, W. N., et al., 2005).

Unlike rigid, engineering-based solutions, NBS inherently possess the ability to adjust to fluctuating conditions. For instance, the expansion or contraction of wetland areas in response to varying water levels can naturally adjust flood capacities without the need for human intervention. A case study illustrating the successful application of such adaptive capacities is the sustainable management of Germany's Rhine River floodplains (Geest G. van, 2002), which employ regenerated wetlands as a means of absorbing excess floodwater. Traditional flood control methods included building levees and other physical structures to regulate water flow, which frequently had unanticipated hydrological and ecological effects. The late 1990s saw the beginning of a turn towards NBS in response to these difficulties, notably the restoration of floodplain areas along the Rhine. Restoring natural hydrological regimes and letting the river spread out into its floodplain during peak floods were the two main components of this strategy. The Rhine River floodplains have successfully mitigated multiple flood occurrences since these NBS were put in place, greatly lowering the possibility of damages to metropolitan areas. Increased biodiversity in the floodplain areas has resulted from the initiative, including a revival of species that were previously uncommon or extinct in the area. The local communities now use the restored floodplains as well-liked recreation sites, which improves quality of life and offers opportunity for teaching about natural flood control.

As the project illustrates, protection of aquatic and terrestrial vegetation and the establishment of blue-green areas (e.g. wetlands) have resulted in notable improvements in biodiversity (Millennium Ecosystem Assessment, 2005). These strategies have created habitats that support a diverse array of species, contributing to the overall ecological resilience of aquatic landscapes (Naeem et al., 2016).

In sectors heavily reliant on natural resources like agriculture, fisheries, and forestry, the impacts of climate change pose significant challenges. These industries are vulnerable to disruptions in ecosystems and resource availability. NBS offer a promising approach to safeguarding these sectors by stabilizing ecosystems and ensuring sustainable resource management.

The preservation and restoration of natural buffers, which offer vital ecosystem services that lessen the effects of natural disasters, are the basis of NBS. Communities are better protected against events like landslides and floods when these barriers are restored. Moreover, maintaining biodiversity depends on safeguarding both terrestrial and aquatic vegetation (Millennium Ecosystem Assessment, 2005).

This integrated approach not only supports the resilience of natural systems but also strengthens the foundation for sustainable resource management in sectors critical to human well-being. By embracing NBS, communities can adapt to climate challenges while fostering biodiversity conservation and ensuring the long-term viability of essential industries.

Research Insights and Collaborative Approaches

Collaborative research in the field of ecohydrology offers invaluable insights into the intricate relationship between hydrological processes and ecological responses (Scheffer, M., et al., 2015). This interdisciplinary approach enables the development of predictive models that anticipate ecosystem reactions to modifications in land use and climate conditions. To manage water resources effectively, understanding the complex interplay between hydrological processes and water level dynamics is crucial (Gleick, 2003). Human-induced land cover changes, including urbanization and deforestation, further complicate the hydrological responses of these ecosystems (Foley, J. A., et al., 2005).

Balancing Preservation and Utilization

To effectively address the challenges of ecological restoration and flood avoidance, a comprehensive management framework that integrates these two objectives is imperative (Vörösmarty et al., 2010). Ecologically focused water level regimes, restoration of natural water-level patterns, and the establishment of wetlands can significantly improve water quality and boost biodiversity (Foley, J. A., et al., 2005). Nevertheless, achieving a harmonious equilibrium between the preservation of ecological resources and the fulfilment of socio-economic requirements is a fundamental obstacle. Extreme water level changes, driven by climate fluctuations, emphasize the criticality of protecting wetlands and implementing buffering reservoirs (Scheffer, M., et al., 2015).

Stakeholder Engagement and Resource Allocation

Sustainable development in proximity to lakes and aquatic cultural landscapes necessitates stakeholder-engaged management systems and holistic methodologies. The study by Gleick in 2003 explained the intricate dynamics, underscoring the importance of coordinated efforts. This mandates the allocation of substantial financial resources towards research, robust policy frameworks, and capacity-building initiatives. The value of investing in scientific research, policy foundations, and institutional augmentation geared toward aquatic biodiversity is underscored, vital as ecosystems and their encompassing watersheds strive to navigate the contours of climate-induced transformations (Foley, J. A., et al., 2005).

Innovative Solutions and Recent Advances

While the previously mentioned strategies provide a strong foundation for addressing climate change impacts on aquatic landscapes, recent research has highlighted innovative solutions that can further enhance our adaptive capacity:

1. Eco-Engineering: Recent advances in eco-engineering techniques, such as the development of bio-based materials and innovative construction methods, enable the creation of resilient aquatic habitats and wetlands that can adapt to changing conditions (Palmer M. A. et al., 2010).

2. Climate-Resilient Urban Planning: Integrating climate-resilient urban planning with aquatic landscape conservation can help create sustainable, water-sensitive cities that both mitigate climate impacts and protect valuable aquatic ecosystems (Haase et al., 2021).

3. AI and Remote Sensing: Leveraging artificial intelligence (AI) and remote sensing technologies, coupled with citizen science initiatives, can provide real-time data on water quality, habitat health, and climate impacts, enabling more informed decision-making (Baloch, Q.B., Shah, S.N., Iqbal, N. et al., 2023).

4. Blue Carbon Initiatives: Expanding blue carbon initiatives, which focus on the sequestration of carbon in coastal and aquatic ecosystems, can contribute significantly to climate change mitigation while enhancing ecosystem resilience (Duarte et al., 2020).

These innovative approaches, in conjunction with existing strategies, offer promising avenues for addressing the multifaceted challenges posed by climate change to aquatic cultural landscapes. By embracing a dynamic and adaptive framework that incorporates cutting-edge research and stakeholder engagement, we can safeguard these vital ecosystems for future generations while bolstering our collective response to the climate crisis.

4.1.3. Climate Change and Effects of Invasive Species on Water Quality in Freshwater Ecosystems

Freshwater habitats' water quality is greatly impacted by the interlaced problems of climate change and the invasion of invasive species. Together, these two stressors provide problems that affect biodiversity, aquatic habitats, and ecosystem health. Developing effective methods to reduce the combined effects of invasive species and climate change on water quality requires a thorough understanding of their synergistic effects.

Changes in temperature, precipitation, and extreme weather events are among the hydrological patterns brought about by climate change (IPCC, 2014). Freshwater systems are significantly impacted by these changes, which also have an impact on sedimentation rates, nutrient transport, and overall water quality (Sahoo G.B. et. al. (2015). The altered hydrological circumstances facilitate the emergence and spread of invasive species, exacerbating the difficulties encountered by freshwater ecosystems.

The spread, ability to reproduce, and competitiveness of invasive species in freshwater environments are all impacted by rising temperatures linked to climate change (Dudgeon et al., 2006; Weiskopf, S.R. et.al. (2020). Warmer temperatures have the potential to favour invasive species, such as zebra mussels and some aquatic plants, which could displace native species and change the patterns of nutrient cycling (Hussner et al., 2017). Changes in community makeup follow, which have an adverse effect on the quality of the water.

Variations in precipitation patterns impact nutrient loading and sediment transport in freshwater systems by altering runoff dynamics (Masoner J. R. et al., 2019). Water quality is further compromised by increased runoff, particularly in urbanised areas where it supports the spread of exotic species and transfers pollutants into water bodies (Hering et al., 2015; Roy et al., 2018).

The trophic status of freshwater ecosystems is influenced by invasive species, which frequently display distinct patterns of nutrient intake and cycling from native species (Jeppesen et al., 2005). Temperature and precipitation variations brought on by the climate can worsen eutrophication, and invasive species can lead to nutrient imbalances and toxic algal blooms (Paerl, H. W. et. al. 2016; Elser et al., 2007). These occurrences worsen the state of the water, reducing oxygen levels and harming aquatic life.

Integrated approaches are necessary for the effective management of freshwater ecosystems under the combined challenges of invasive species and climate change. In addition to sustainable land use practices that lessen the effects of climate change on hydrological patterns, adaptive efforts should include habitat restoration, early detection, and quick reaction to invasive species (Rahel and Olden, 2008; Simberloff et al., 2013). To fully understand the unique relationships between invasive species, climate change, and water quality dynamics, continued study is necessary to inform policies and management strategies.

4.1.4. Discussion

In addressing the critical need for resilience and disaster risk reduction in the context of climate change, this chapter has highlighted the indispensable role of NBS in safeguarding sectors reliant on natural resources, such as agriculture, fisheries, and forestry. The discussion underscores how NBS, through the restoration and maintenance of natural buffers and ecosystems, contribute not only to the stabilization of these sectors but also to the broader resilience of communities facing natural disasters.

The adaptive capacity of NBS to fluctuating environmental conditions offers a sustainable alternative to traditional, rigid infrastructural solutions. For instance, the restoration of floodplains and wetlands, as illustrated by the Rhine River floodplains in Germany, demonstrates how these systems naturally adjust to varying water levels, thereby enhancing flood mitigation without the need for constant human intervention. This capability is crucial for agriculture, where water management must be both flexible and resilient to support sustainable practices and ensure food security.

In forestry and fisheries, NBS such as the protection and strategic reforestation of watershed areas and the conservation of aquatic ecosystems play vital roles. These actions not only protect against erosion and enhance water quality but also provide critical habitats that support biodiversity and fish populations, which are essential for the livelihoods of communities dependent on these resources.

The protection and enhancement of natural buffers through NBS significantly reduce the vulnerability of communities to floods, landslides, and other climate-related disasters. By investing in these solutions, communities benefit from increased protection, which in turn contributes to their social and economic stability. This approach aligns with the hypothesis that NBS enhance the resilience of water management systems and provide effective disaster risk reduction strategies.

Moreover, the protection of aquatic and terrestrial vegetation is paramount for maintaining biodiversity and the associated ecosystem services, such as carbon sequestration and the natural filtration of water, which are critical under changing climatic conditions (Millennium Ecosystem Assessment, 2005; Costanza R. et al., 1998). These services are indispensable in the face of increasing environmental challenges, providing not just ecological benefits but also bolstering the resilience of human communities.

Looking forward, the integration of NBS into disaster risk management and climate adaptation strategies requires a focused and coordinated effort among policymakers, researchers, and community stakeholders. It involves scaling up successful case studies, enhancing policy frameworks, and increasing community engagement and education to understand and advocate for the benefits of NBS. The goal is to create a replicable model of success that can be tailored to different geographical and environmental contexts, ensuring broad-scale implementation, and maximizing the protective benefits of NBS globally.

The research results reaffirm the hypothesis that NBS are not merely supplementary but are essential strategies for enhancing ecosystem and community resilience. They offer a proactive approach to disaster risk management that is adaptive, cost-effective, and sustainable, making them crucial elements in the fight against the impacts of climate change.

4.1.5. Conclusion

> This chapter addresses the "Hypotheses on Mitigation of Climate Change Impacts," which posits that integrating nature-based solutions (NBS) within aquatic cultural landscapes significantly enhances their resilience against climatic impacts while sustaining biodiversity and cultural heritage. The study examines the management of aquatic cultural landscapes to bolster their resilience and sustainability amidst climate change. It underscores the critical role of NBS in mitigating climate change impacts, providing empirical evidence and practical examples that highlight their effectiveness. Through detailed case studies and real-world applications, the chapter illustrates how NBS, such as wetland restoration and green infrastructure, contribute to improved water retention, reduced flood risks, and enhanced water quality. These examples validate the hypothesis by demonstrating how NBS can effectively address climate-related challenges and promote long-term ecological and cultural health.

In the face of climate change, aquatic cultural landscapes have emerged as critical ecosystems that demand our attention and concerted efforts. The complex interplay between climate variations, hydrological processes, and ecological responses within these landscapes presents multifaceted challenges and opportunities. Through an exploration of various dimensions, including climate adaptation strategies, collaborative research efforts, innovative solutions, and their results, this dissertation has sought to shed light on the path forward in addressing climate change impacts on these invaluable ecosystems.

The research study concludes that within the domain of aquatic cultural landscapes, the phenomenon of climate change manifests significant impacts on shallow lakes. These ecosystems, comprising lakes, wetlands, rivers, and their surrounding terrestrial habitats, represent intricate, interconnected systems teeming with ecological and cultural significance. Climate change-induced shifts in precipitation patterns, rising temperatures, and extreme weather events place these landscapes at unprecedented risk (IPCC, 2014).

To confront these challenges effectively, a multidimensional approach is imperative. Initiatives focusing on improving watersheds, protecting vegetation, and establishing wetlands have yielded promising results in terms of improved hydrological stability, enhanced biodiversity, water quality, and resilience to extreme events (Adger W. N. et al., 2005; Millennium Ecosystem Assessment, 2005; Vörösmarty et al., 2010; Scheffer et al., 2015). These outcomes underscore the importance of ecosystem-based solutions in mitigating climate change impacts.

Collaborative research efforts in the field of ecohydrology have provided invaluable insights into the intricate relationship between hydrological processes and ecological responses. This interdisciplinary approach has led to the development of predictive models that help anticipate ecosystem reactions to land use changes and climate conditions (Scheffer et al., 2015). Moreover, stakeholder engagement has emerged as a linchpin in the management and preservation of aquatic cultural landscapes (Costanza et al., 1998). The active involvement of communities, policymakers, and scientists is essential to crafting sustainable solutions.

Innovation plays a crucial role in adapting to climate change impacts on aquatic cultural landscapes. Recent advances in eco-engineering, climate-resilient urban planning, AI, remote sensing, and blue carbon initiatives offer promising avenues to enhance the resilience and sustainability of these ecosystems (Palmer M. A. et al., 2010; Haase et al., 2021; Duarte et al., 2020). These innovative solutions complement traditional conservation approaches and can catalyse transformative change.

The Path Forward

Considering the various opportunities and problems that climate change brings to aquatic cultural landscapes, it is evident that a comprehensive, flexible, and cooperative approach is not only desirable but also necessary. The complexities of climate change affect many facets of our environment; therefore, our reaction needs to be just as complex and multidimensional.

One critical aspect is our understanding of the interplay between hydrological processes and water level dynamics. Effectively managing water resources in the face of climate-induced fluctuations necessitates a deep understanding of these complex interactions. Robust research efforts, informed by interdisciplinary collaboration, can provide the foundation upon which we build our adaptive strategies.

In these ecosystems, cooperation is in fact the cornerstone of our response to climate change. Our road towards sustainability and resilience requires collaborative research endeavours, policy creation that incorporates the knowledge of many stakeholders, and meaningful involvement with local communities. Developing effective policies and practices requires the active participation of people whose livelihoods depend on these aquatic ecosystems.

As we proceed, we must remain consistent in our dedication to undertaking scientific research, building strong policy bases, and strengthening our institutional capabilities. In light of climate change, these components will be the cornerstone for the protection and improvement of aquatic biodiversity. In order to maintain the health of these ecosystems for future generations, our efforts should go beyond the current problems and take the long term sustainability of these systems into account.

Furthermore, embracing innovative solutions and harnessing the power of technology and community engagement are essential components. Innovative approaches can help us adapt to rapidly changing conditions, while technology can facilitate data collection, analysis, and dissemination, enabling informed decision-making. Community engagement fosters a sense of shared responsibility and empowers local stakeholders to actively participate in the preservation of their cultural and natural heritage.

4.2. Blue-Green Solutions to Reduce Risks for Urban Flooding

4.2.1. Introduction

In urban landscapes, the integration of NBS plays a crucial role in addressing complex water management challenges exacerbated by dense populations and impervious surfaces. This chapter explores how the strategic reconstruction or establishment of wetlands within urban settings serves multiple vital functions—acting as biological filters, enhancing biodiversity, and mitigating climate change effects by functioning as natural flood buffer systems.

Floods and droughts are two of the major challenges that cities face in relation to climate change. These issues are complex and are caused by several processes, including climate change, urban densification, historical landscape transformation, and a physical and cultural detachment of urban areas from the river basin. Furthermore, administrative borders, land ownership, regulations, and other issues impede basin-scale work.

This level of complexity necessitates novel and collaborative approaches. Municipal strategies and plans to build urban resilience, on the other hand, are largely focused on the local urban context, failing to capitalize on the potential of taking a more systematic approach and working proactively on a basin scale in collaboration with other stakeholders. By doing so, the urban built environment could be relieved of some of the strain associated with climate adaptation, freeing up space and resources. Furthermore, organizational transformation toward a basin-based approach to water management could strengthen the link between urban, peri-urban, and rural contexts.

The objective of the project nature-based solutions to reduce flooding and drought (Ternell et.al. 2019) was to propose developments that can lead to business models and financial instruments that support the adoption of upstream water retention through nature-based solutions (NBS). The study has focused on subjects argued as central to provide a business value for upstream landowners to perform NBS measures. This includes:

- Strategic Planning: Aligning NBS with regional and local climate adaptation strategies.
- Financial Mechanisms: Developing business models and financial instruments that facilitate investment in NBS.
- Legal and Policy Support: Recommending legal adjustments and policy interventions to support NBS projects.
- Stakeholder Engagement:
  Establishing collaborative platforms for continuous stakeholder dialogue and co-creation of solutions.

The research was carried out between 2017-2022 and resulted in two comprehensive reports: Ternell et al. (2018) Business model for blue green compensation, Climate KIC report, Ternell, et al. (2019) Financial Instruments for Nature-based solutions to reduce risks of flooding and drought, Climate KIC report, Ternell, et al. 22 Sept. 2020, an article: Financial instruments for nature-based solutions to reduce risks for flooding and drought, Ecocycles Scientific journal for the European Ecocycles Society (http://www.ecocycles.net/ojs/index.php/ecocycles/article/view/161) and field visits to Västra Götaland län in Sweden, Tisza lake and Lake Balaton in Hungary, and the Netherlands.

4.2.2. Sustainable development goals

The Sustainable Development Goals (SDGs) provide a global framework for addressing critical issues like climate change, environmental degradation, and sustainable development. Nature-based solutions (NbS) play a crucial role in achieving these goals, particularly in the context of preventing floods and droughts. Key SDG targets such as 13.1, 13.2, 13.3, 15.1, 15.9, 15a, and 6.6 highlight the importance of integrating climate resilience, ecosystem conservation, and sustainable planning into broader policy frameworks:

TARGET 13.1	Target 13.1 Strengthen resilience and Adaptive Capacity to Climate Related Disasters	RELEVANCE: By creating the natural ability of the landscape to buffer large amounts of precipitation through wetlands and other nature-based solutions, the ability to adapt to extreme weather and its effects increases.
TARGET 13.2	Target 13.2 Integrate Climate Change Measures into Policies and Planning	RELEVANCE: The flooding model aims to be an integrated part of the policies and strategies and part of the planning in the municipalities. Creating a business model for managing floods will also be an incentive in a broader political context.
TARGET 13.3	Target 13.3 Build Knowledge and Capacity to Meet Climate Change.	RELEVANCE: Awareness and knowledge among institutions and planners will increase as the model will be tested and integrated into the planning processes.
TARGET 15.1	Target 15.1: Conserve and restore terrestrial and freshwater ecosystems	RELEVANCE: Although the business model primarily aims to simplify financial compensation to reduce major negative effects of high water flows, there are also several positive indirect benefits. Increasing the proportion of wetlands in the landscape brings great benefits to a large number of species that are dependent on them either for reproduction, foraging or other.
TARGET 15.9	Target 15.9: Integrate ecosystem and biodiversity in governmental planning	RELEVANCE: In spatial planning, it is important for decision-makers to realize that the major ecological values that nature-based solutions add are of major societal interest. In the master planning, and at an early stage in the decision making process, it is therefore important to identify possible areas for restoring and building wetlands and other solutions.
TARGET 15.A	Target 15a: Increase financial resources to conserve and sustainably use ecosystem and biodiversity	RELEVANCE: The possibilities of financing all climate measures through taxes will be difficult or impossible. Economic models or business systems could solve this dilemma by having the beneficiaries pay for the measures creating less flooding in their areas or that those who contribute to increase flooding elsewhere compensate for those who are affected by it, i.e. polluter pays principal.
TARGET 6.6	Target 6.6 Protect and restore water-related ecosystems	RELEVANCE: By restoring or creating wetlands, part of this goal is met.

Figure 19. Sustainable Development Goals (SDGs) Relevant to Blue-Green Solutions

4.2.3. Drought Risks and Sustainable Water Strategies in a Changing Climate

Drought is a prolonged period of dry weather that results in water scarcity, which can have significant impacts on natural ecosystems, agriculture, food security, and human populations. According to the United Nations (United Nations, 2019), over 500 million people are affected by drought annually, and this number is expected to increase as the impacts of climate change intensify. Rising temperatures increase evaporation and water needs and thus dry out soils and trees. A negative effect of this is also increased risk for fires. Further, drought negatively impacts groundwater recharge and stable water provision, which implies many challenges for the agricultural sector.

The Intergovernmental Panel on Climate Change (IPCC, 2022) has stated that climate change will likely lead to changes in precipitation patterns, causing some regions to become wetter and others drier. As the world warms, there will also be an increase in evaporation, leading to reduced water availability in many regions. In addition, population growth and economic development are putting additional pressures on water resources, leading to increased competition for water and the intensification of water demand.

The impacts of drought can be far-reaching, affecting many aspects of society. Drought can reduce crop yields and contribute to food insecurity, as well as increase the risk of famine and malnutrition. Drought also affects energy production, as it can reduce the capacity of hydroelectric dams and increase the demand for fossil fuels. Additionally, water scarcity can lead to conflict, as competing groups fight for access to dwindling resources.

To reduce the impacts of drought, effective adaptation strategies must be implemented. Improved water management practices, such as reducing waste and improving efficiency, can help to conserve water resources. Better access to drought early warning systems can help communities to prepare for and respond to water scarcity. Investment in drought-resistant crops can also help to increase food security in affected regions.

However, reducing greenhouse gas emissions and addressing the root causes of climate change is essential to mitigating the risk of drought in the future. The IPCC has stated that limiting global warming to 1.5°C above pre-industrial levels is crucial to avoiding the most dangerous impacts of climate change, including the intensification of drought.

The IPCC has stated that limiting global warming to 1.5°C above pre-industrial levels is crucial to avoiding the most dangerous impacts of climate change, including the intensification of drought. In conclusion, climate change is increasing the risk of drought globally, with far-reaching impacts on natural ecosystems, agriculture, food security, and human populations. Effective adaptation strategies and action to reduce greenhouse gas emissions are necessary to reduce the risks associated with drought and ensure a sustainable future for all.

4.2.4. Grey and Green Solutions to Address Water Risks

Grey infrastructure, characterized using concrete walls, quaysides, and water dikes, has long been the standard in flood-control measures. However, its limitations in adaptability and ecological impacts have led to a reconsideration of its role in sustainable water management. Recent studies indicate that solely relying on grey infrastructure may not be sufficient to address the complexities of contemporary water-related challenges (Ncube, S & Arthur, S 2021).

On the other hand, NBS, which includes the use of ponds, wetlands, and blue-green infrastructure, is increasingly being recognized internationally for its effectiveness in water resource management, disaster risk reduction, and climate change adaptation. NBS offers a more dynamic and sustainable approach to managing water-related risks. These solutions act as natural buffers against flooding by slowing down and reducing runoff, thereby enhancing the landscape's water retention capacity (Browder G. et.al. (2019). This not only helps in mitigating flood risks but also plays a crucial role in improving the overall health of water bodies.

The implementation of NBS contributes significantly to biodiversity conservation, as these natural landscapes provide habitats for various species (Green et al., 2023). Furthermore, NBS offers substantial social benefits, including recreational opportunities and aesthetic enhancements, thereby enriching the landscape and contributing to human well-being (Foster et al., 2022). An example is the Tisza Lake in Hungary, where a combination of wetland restoration and socioeconomic practices have led to improved water quality, biodiversity, and economic benefits for local communities. This case study could illustrate the practical application and benefits of integrating sustainable practices in water resource management.

Recent research has also highlighted the cost-effectiveness of NBS compared to traditional grey infrastructure. Studies by the Environmental Protection Agency (EPA, 2023) have shown that integrating NBS can lead to significant savings in long-term infrastructure costs, while providing resilient and adaptive solutions to water management.

The integration of nature-based solutions with traditional grey infrastructure presents a more holistic and sustainable approach to addressing the increasing water-related risks. This blend of green and grey approaches not only offers immediate benefits in terms of flood mitigation and water retention but also fosters long-term environmental sustainability. By embracing NBS, communities can enhance their resilience to climate change impacts, support biodiversity, and improve the quality of life for residents. This shift towards incorporating NBS in urban planning and water management policies is a vital step in developing adaptive and resilient infrastructures capable of facing the challenges posed by a changing climate and growing urban populations.

Table 6. Benefits of Grey and Green Solutions:

Benefits	**Grey infrastructure**	**Nature-based solutions (NBS)**
Flood Risk Reduction mechanisms	Reduced flooding risks	Enhanced water retention
Biodiversity Enhancement biodiversity	Typically reduces biodiversity	Promotes increased
Recreational Opportunities spaces	Limited recreational benefits	Provides recreational
Climate Mitigation for concrete and resource-intensive infrastructure	Often involves resource-intensive construction	Reduces the need

The study of integrating NBS with traditional grey infrastructure for water management makes a compelling case for a paradigm shift in how we address urban water-related concerns. The rising number of research, especially Browder et. al., (2019), highlights the difficulties of depending entirely on grey infrastructure, which has traditionally been defined by concrete and engineering solutions. These methods, while effective in some cases, frequently lack the flexibility and agility needed to respond to the dynamic nature of climate change and urbanization-related water concerns.

Nature-based solutions, as detailed in the studies by Green et al. (2023) and Foster et al. (2022), offer a multifaceted approach to these challenges. NBS not only serve as efficient mechanisms for flood mitigation and water retention but also provide ecological benefits, such as biodiversity enhancement and ecosystem restoration. The social aspects of NBS, particularly their contribution to recreational opportunities and aesthetic value, play a significant role in enriching urban landscapes and improving the quality of life for city dwellers. The study financial instruments for Nature-based solutions - To reduce risks of flooding and drought (Ternell et al. 2019) summarised the following benefits for NBS:

Table 7. Direct and Indirect Benefits of NBS

Direct benefits	
Increased resilience in water provision	Water provision delivers water services in the economy for both drinking and non-drinking purposes; reliability of supply and resilience to drought. Creation of nature-based solutions can improve aspects, such as infiltration, water accumulation by ecosystems and other benefits, enhancing the capacity of natural or anthropic systems to store water.
Groundwater recharge	It is important to increase the water's residence time in the landscape to improve the possibility of groundwater formation. Rapid drainage through hard surfaces reduces the ability to clean and form groundwater.
Slowing and storing runoff	The water is released at a slower rate than the original runoff, either back to surface water or infiltrating to groundwater. Features that slow the movement of surface water but without storage, for example by increasing surface roughness
Reducing runoff	Increasing storage within the canopy and increasing evapotranspiration reduce total runoff. E.g. afforestation Features that encourage the infiltration of rainfall and runoff to groundwater Improved storage of rainfall by increasing the capacity of soil to retain water, for example by increasing the organic matter content
Indirect benefits	
Improved biodiversity	Water retention creates special niches that are crucial for biodiversity. Biodiversity is furthermore critical to ecosystem services such as climate regulation, flood protection, soil fertility, pollination and the production of food, feed, fuel, fibre and medicines.
Nutrient retention	Soils that hold generous amounts of water are less subject to leaching losses of nutrients or soil applied pesticides. Wetlands act as biological filters and capture plant nutrients, such as nitrogen and phosphorus, which reduces the risk of eutrophication of marine environments.
Agriculture and forestry activities	Creation of water retention areas can have positive effects by enabling agricultural and forestry activities. Soil water holding capacity optimize crop production and reduce the risks for income loss at drought.
Amenities and recreation	Amenities associated to habitat protection (fish, birds and plants) as well as recreation and other activities are important for well-being and tourism. Wetlands are typically attractive from a recreational perspective.
Health and social improvements	NBS have impact on health by improving the water quality and control of waterborne diseases caused by flooding. Blue-green exertions could have a potential positive impact on social integration through jobs and leisure activities.

Furthermore, the economic perspective presented in the Environmental Protection Agency (EPA, 2023) report on the cost-effectiveness of NBS is particularly noteworthy. The long-term financial benefits of NBS, in comparison to grey infrastructure, suggest a more sustainable and economically viable approach to urban water management. This is crucial in an era where budget constraints are an ever-present consideration for policymakers and urban planners.

However, the discussion also highlights the need for a balanced and integrated approach. While NBS offer numerous benefits, they are not a panacea and should be viewed as complementary to grey infrastructure. The optimal solution in many cases may be a hybrid approach, leveraging the strengths of both green and grey strategies. This integrated perspective is essential for creating resilient and adaptable urban water management systems capable of facing the uncertainties of climate change and the complexities of urban expansion.

4.2.5. A Basin-Based Strategy for Building Urban Resilience to Floods and Droughts

A basin-based strategy for building urban resilience to floods and droughts can be designed and implemented and three main objectives for achieving this goal and promoting transformation is identified: 1) better understanding of the potential of restoration and nature-based solutions for mitigating urban flooding, 2) new approaches to involving urban stakeholders in basin-scale water management, and 3) supporting policymaking and organizational change. We illustrate these objectives with examples from different geographical contexts and suggest some recommendations for future research and practice.

The escalating risks of flooding and drought due to urban expansion and climate change necessitate innovative approaches to water management. Nature-based solutions (NBS) offer a holistic method to mitigate these risks while providing environmental, social, and economic benefits. This chapter delves into the methodology adopted in the study, emphasizing primary sources such as interviews, site visits, and stakeholder workshops to develop a robust framework for implementing NBS.

Urban water systems can be made smarter by incorporating upstream nature-based solutions (NBS) (e.g., meander restoration, wetlands restoration, riparian forest creation) as an integral part of flood management (Castellar et al. 2021). This necessitates a better understanding of the return on investment of various upstream measures in terms of reduced risk and social, economic, and environmental values and co-benefits, as well as how these differ depending on the scale at which these measures are implemented.

NBS are actions that use or mimic natural processes to address environmental challenges (European Commission, 2015). NBS can contribute to reducing flood risk by increasing infiltration, retention, storage and evapotranspiration of water in the landscape (Nesshöver et al. 2017). NBS can also offer multiple co-benefits, such as biodiversity, carbon sequestration, air quality, recreation, health, and well-being (Kabisch, N. et al. 2016).

In the project ‘Nature-based solutions for risk reduction of flooding and drought’ we listed several measures to reduce risks of flooding according to sector. For the forestry sector it can for example be of importance to increase or keep forest in the catchment area to increase evapotranspiration and reduce runoff. In the agricultural sector, measures with effect are for example catch crops and no-plough farming.

Table 8. Nature-Based Measures, Categorised by Sector, to Reduce Flooding, Source: Ternell et al. 2019.

Area of measures	**Benefits**
AGRICULTURE: Spring ploughing Catch crop No-plough farming Permanent tracks for vehicles Structure liming Low/no-till agriculture	- Increase infiltration - More organic materials in the soil - Increase biodiversity - Reduce runoff - Increase groundwater recharge - Reduce sediment and nutrients in water courses, lakes and sea
UNUSED ZONES: Protections zones Edge zones Buffer strips and hedges Forest-riparian buffers Integrated protection zones	- Slow high flows - Reduce erosion - Increase infiltration of water in the soil - Increase organic materials Increased biodiversity - Increase evapotranspiration - Less sediment and nutrients in water courses, lakes and sea
FOREST AND TREES: Increase or keep forest in catchment areas No clear-cut forest Land-use conversion Plant trees and shrubs in water-bearing slopes Meadows and pastures	- Delay snowmelt - increase evapotranspiration - Slow water flows - Increase ground water recharge - Reduce runoff - Reduce erosion - Increase biodiversity - Less sediment and nutrients in water courses, lakes and sea
MEASURES IN DITCHES: Avoid driving damage in forests, Open culverts, No cleaning of ditches Two-stage trenches Re-meandering	- Increase infiltration in the ground - Slower water flows - Increase water-holding capacity - Increase biodiversity - Less sediment and nutrients in water courses, lakes and sea
PONDS AND DAMS: Wetlands, Create detention basins and ponds, Let road banks curb high flows, Phosphor dams	- Increase infiltration - Increase evaporation - Reduce runoff - Increase ground water recharge - Reduced sediment and nutrients in water courses, lakes and sea - Sediment can be used for arable land as fertilizer - Less erosion - Increase biodiversity - Store water - Maintain water cycle
LARGE MEASURES Restauration of lakes Flood plane restauration	- Slow water flows - Store water - Increase infiltration - Increase ground water recharge - Increase biodiversity - Reduce sediment and nutrients in water courses, lakes and sea

A financial model, as developed as part of the research (Ternell, 2018), revolves around addressing the inefficiencies in managing flood and drought risks, primarily attributed to an over-reliance on downstream grey infrastructure solutions. The core of the model lies in integrating nature-based solutions (NBS) with traditional approaches, recognizing that upstream and NBS can significantly enhance cost-efficiency and effectiveness in climate adaptation.

To reduce flood risks in downstream municipalities, the water upstream needs to be stored or managed until there is room for water flows that do not exceed a level that causes unacceptable damages. A key factor for such solutions, and arguably even more so for blue-green water storage measures, the municipality and landowner need to agree on how to value the municipality's benefits to avoid flooding, and how any costs for landowners to retain water should be valued.

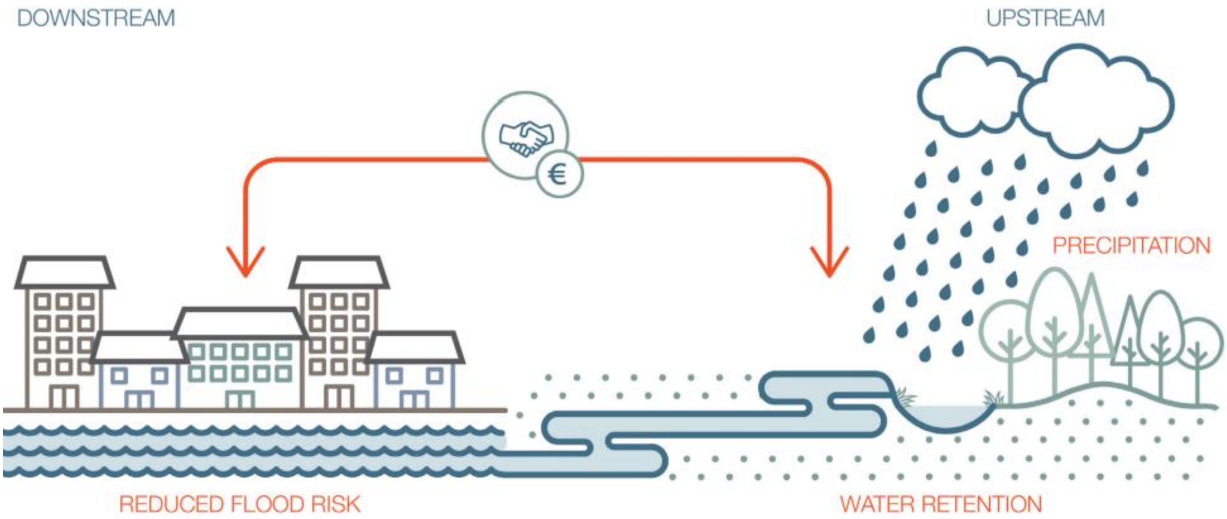

Figure 20. Vulnerable Downstream Areas Benefit from Upstream Flood Retention Services. Source: Business model for Blue-green compensation to reduce risks for urban flooding, ideation study, Ternell et. al. 2018

To address market failure and knowledge asymmetries over the value and feasibility of NBS, the model suggests a public policy framework. This framework is intended to encourage collaboration between upstream and downstream stakeholders, hence facilitating the implementation of NBS. It includes creating credible settings for financial instruments and transactions, which are critical in making NBS a feasible business case for upstream landowners.

Financial instruments within this framework are essential. They formalize agreements on financial arrangements, creating a marketplace for NBS. This approach allows landowners to consider NBS as a business opportunity, particularly in selling water-holding services to mitigate future flooding risks. The transition from a business case to a business model, however, is not automatic. Factors such as competence and tradition play a role in determining whether landowners incorporate NBS into their business portfolios. This necessitates robust systems for measuring, reporting, and verifying the measures implemented.

A critical aspect of the model is the complex financial compensation mechanisms. These require negotiations among beneficiaries and providers, with transparent cost-benefit evaluations aiding in establishing appropriate protection measures and compensation levels. The business case, thus developed, has the potential for scalability and application in various contexts, considering the specific needs and local/regional conditions.

To evaluate the potential of upstream NBS for flood management, it is therefore important to consider both the local and regional scale, as well as the different stakeholders' perspectives. This requires integrated models and tools that can quantify the costs and benefits of NBS in different scenarios and compare them with conventional solutions, such as dam, ditches and pumps. It also requires participatory processes that can engage the stakeholders in defining the problem, exploring the alternatives and reaching an agreement on the best solution.

4.2.6. New Approaches to Involving Urban Stakeholders in Basin-Scale Water Management

Water management from a basin viewpoint requires the participation of many stakeholders from many sectors, each with their own set of interests and agendas. The distribution of costs and gains from management initiatives is frequently uneven, necessitating the development of methods to handle competing interests, identify mutual benefits, and promote benefit transfers, such as downstream-to-upstream payments for ecosystem services. A recent innovation that improves collaboration is the introduction of collaborative models that incentivise local landowners to invest in Nature-Based Solutions by allowing them to benefit from ecosystem service supply.

One such innovative approach is the use of Water Funds, which are institutional platforms fostering investments in NBS for water management. These funds connect upstream landowners with downstream water users, a concept that has evolved since the early discussions by Goldman-Benner et al. in 2012. Water Funds operate on the principle of Payments for Ecosystem Services (PES), a concept described by Wunder in 2005 as voluntary transactions where service providers are compensated for maintaining or enhancing ecosystem services. These funds facilitate the transfer of resources from downstream beneficiaries to upstream landowners who implement NBS, enhancing water quality and quantity, reducing erosion, and mitigating flood risks. Downstream water users, including municipalities, utilities, and private businesses, contribute to a collective fund that finances upstream actions and the monitoring and evaluation of their impacts. The success of Water Funds lies in their foundation of scientific knowledge, multi-stakeholder governance, and long-term commitments.

Water Funds have been successfully implemented in various regions, including Latin America, Africa, and Asia, mainly to safeguard drinking water supplies for large urban areas (Abell et al., 2017). A notable example is the Quito Water Fund in Ecuador, established in 2000 to preserve water-protection areas in the mountains surrounding the capital. This fund has involved over 3,000 upstream landowners in implementing NBS such as reforestation with native species, livestock management, and erosion control. The Quito Water Fund has also helped establish a network of protected areas spanning over 600,000 hectares.

Financed by downstream water users like municipalities and private companies, the fund demonstrates cost-effectiveness and generates multiple co-benefits including biodiversity enhancement, carbon sequestration, food security, and rural development (Balvanera P., et.al. (2012).

Water Funds demonstrate how urban stakeholders might participate in basin-scale water management by offering incentives to upstream landowners to invest in NBS. To define the most appropriate NBS and build fair and sustainable payment systems, a thorough examination of local variables such as hydrology, ecology, socioeconomics, and institutional frameworks is required. Furthermore, it advocates for an inclusive and open process that fosters confidence and cooperation among varied stakeholders.

Recent research has highlighted the need of tailoring these approaches to local situations. Hein, C. et al. (2020) stress the need for adaptive governance structures in PES programmes to ensure their effectiveness in dynamic environmental and socioeconomic settings. This adaptability is critical to the long-term success and viability of Water Funds and other collaborative approaches in basin-scale water management.

4.2.7. Supporting Policymaking and Organizational Change

To initiate a transformative process toward an integrated basin perspective in the building of urban resilience, local authorities, such as municipalities, must first understand the institutional context and the drivers that are currently promoting a defined view of urban water systems and a systemic perspective on water management. Such comprehension enables the application of local policy and organizational change toward a more holistic, basin-scale approach.

Conducting an institutional analysis is a strategic step in this process. Such an analysis can chart the landscape of existing actors, rules, norms, and values that dictate water management at various levels. This approach has evolved since the foundational work of Ostrom in 2005, reflecting the increasing complexity and interdependence of urban water management systems. Recent studies emphasize the importance of this comprehensive mapping to understand the intricate web of governance in water management (Bohman A., Glaas E., Karlson M., 2020).

This analysis also plays a vital role in pinpointing the challenges and opportunities for advocating a basin-based strategy. For instance, there may be disjointed coordination among different sectors and jurisdictions overseeing various facets of water management, such as drinking water supply, wastewater treatment, flood control, and nature conservation (Brown & Farrelly, 2021). Furthermore, a common hurdle is the limited capacity and resources among local authorities to implement NBS or to engage with upstream stakeholders effectively. Resistance or hesitance from stakeholders to modify their behaviour or to share benefits is another significant barrier (Jiménez A. et. al., 2019).

In addition to institutional analysis, a comprehensive policy analysis is essential. This analysis can identify existing and potential policy instruments that bolster a basin-based strategy, a concept that has gained traction since Howlett et al.'s 2015 study. This analysis assesses the effectiveness, efficiency, and equity of these instruments in various scenarios. For example, laws, regulations, economic incentives, voluntary measures, and information-based tools are all viable strategies for managing water resources within a river basin (UNEP, 2018).

Contemporary research underscores the value of integrating these policy tools within a larger governance framework to address the multifaceted challenges of water management in urban settings (Hein, C. et al., 2020). This integration not only aids in the effective management of water resources but also contributes to building urban resilience in the face of environmental and socio-economic challenges.

In the realm of sustainable environmental management, particularly in the context of flood and drought risk mitigation, the integration of nature-based solutions (NBS) presents a paradigm shift. This shift, however, is impeded by a confluence of legal and policy challenges that require comprehensive understanding and innovative solutions.

4.2.8. Legal Complexities in Payment for Ecosystem Services

The variety of laws related to water management and associated activities leads to numerous legal complexities and dilemmas. Legal systems may have gaps where certain issues are not addressed, overlaps where a single issue falls under multiple regulations, or conflicting regulations that complicate the clarity of legal perspectives. The diversity in water-related regulations arises because laws concerning water and land use have developed over time with varied objectives. Historically, the focus was primarily on drainage, unless it pertained to hydropower. As a result, water-related laws cover a broad spectrum of interests, including energy, hydropower, water quality, agricultural and forest production, climate adaptation, and municipal needs for urban development.

The legal framework surrounding Payment for Ecosystem Services (PES) for water retention is a crucial component. The traditional PES system needs to be restructured to compensate those capable of water storage at the source. This necessitates the establishment of clear land-use agreements and a profound understanding of environmental regulations among stakeholders.

Swedish court cases provide insightful examples of how legal regulations influence the implementation of NBS. Disputes over emission permissions to water, especially when new dams are constructed, pose significant barriers. These cases often hinge on the courts' interpretation of 'no-fault liability' for potential downstream hazards. Such judicial precedents highlight the need for robust environmental impact assessments to support NBS initiatives.

An intriguing aspect is the conflict between different regulatory frameworks. The Water Framework Directive, which emphasizes the restoration of natural water habitats, often conflicts with the Flood Directive's focus on increasing upstream storage facilities. This dichotomy reflects a historical legacy in Sweden, where land drying practices have been legally and socially normative, further complicating the integration of NBS. The research proposes a public policy instrument that fosters financial arrangements between diverse landowners for implementing NBS. This instrument aims to address the difficulties in implementing intermunicipal NBS interventions and legal barriers that hinder the viability of financial instruments. The complexity of agreement law, especially in the context of property ownership changes, adds another layer of challenge in establishing long-term NBS.

Effective implementation of NBS on private and public land requires addressing several facets: economic considerations (compensation and incentives for flood retention services), property rights (permitting temporary flood storage on private land), public participation, and integration of flood retention in agricultural subsidies.

European policies, notably the European Landscape Convention (ELC, 2000) and the Flood Directive (Flood Directive, 2007/60/EC), play a pivotal role in shaping the legal and policy framework for NBS. These policies encourage local and regional authorities to adopt measures for landscape management and develop comprehensive flood risk management plans.

Administrative and economic challenges include conflicting legislation, complexities in establishing long-term contracts, valuation uncertainties of benefits and costs, and the need for cultural shifts in traditional land-use practices.

My project on Business model for blue green compensation (Ternell, et al. 2019) investigated the potential for implementing upstream Nature-Based Solutions (NBS) to enhance water retention and reduce downstream flooding. Such initiatives should align with regional flood plans, as stipulated by the Floods Directive. Västra Götaland, identified as one of Sweden's 18 vulnerable areas under EU Floods Directive and its corresponding national regulations (MSBFS 2013), incorporates these guidelines into its regional strategies. These strategies detail the coordination efforts as per the regulation on the management of aquatic environment quality (MSBFS 2013). This particular report highlights significant gaps in implementing flood prevention measures, primarily due to inadequate funding. It suggests that flood damage insurance and spatial planning should play a more significant role in managing flood risks.

Legal considerations for such solutions will vary based on land ownership (private/public) and the stakeholders involved, such as private landowners, citizens investing in water retention facilities, cooperatives, trusts, private and municipal companies. Four potential pathways are envisioned:

Path 1: Land Acquisition

- Purchase private land within the same or another municipality to develop water retention facilities like wetlands or ponds. This can occur within a detailed planned area (water treated as stormwater) or outside such areas (water treated as a water activity).

Path 2: Water Retention Services

- Similar to carbon emission offsets, this involves purchasing services like water retention capacity measured in cubic meters.

Path 3: Land-Use Agreements

- Develop agreements to lease land for water retention, either within a detailed planned area (treated as stormwater) or outside such areas (treated as water activity).

Path 4: Environmental Subsidies

- Engage different types of subsidies targeting the environmental impacts of land use, such as those from EU Common Agriculture Policies or local measures for better sea and water environments.

These pathways are not mutually exclusive and could be combined depending on the NBS implemented. Each pathway could trigger different regulatory areas, and here we highlight the most pertinent laws and regulations. For example, planned NBS could influence water quality (Environmental Code, Chapter 5), affect protected areas (Environmental Code, Chapter 7), be considered hazardous (Environmental Code, Chapter 9), or constitute a water operation (Environmental Code, Chapter 11).

4.2.9. Discussion

The analysis advocates for a more holistic understanding of urban water management, where the synergistic use of both nature-based and traditional grey infrastructure can lead to more sustainable, resilient, and cost-effective solutions. As urban areas continue to grow and face increasing water-related risks, the integration of NBS into urban planning and water management strategies emerges as a crucial step towards building more sustainable and liveable cities. As such, the research assesses the financial market potential of an upstream water retention business model for flood risk management in Gothenburg, Sweden.

Grey infrastructure currently has a clearer asset life, depreciation, and return on investment than green infrastructure. Grey infrastructure challenges include funding and public investment, maintenance, and increased urbanization. The introduction of more hard surfaces, such as concrete or asphalt, contributes to higher volumes of stormwater runoff due to a reduction in infiltration, posing a water management challenge. Grey infrastructure can be inflexible due to its relative size, construction requirements, and finite life. Green infrastructure presents challenges in terms of calculating return on investment, risk management, and urban effectiveness. Current regulation—or the lack thereof—

at the national or local levels also presents challenges, as many green infrastructure projects do not meet traditional standards or regulations.

The measures for green solutions can be small, simple, and inexpensive, but the effects can be significant in terms of other important societal benefits. Upstream water retention reduces surface runoff and water peaks while also reducing erosion and sediment and nutrient movement. Achieving more consistent water streams through natural solutions can provide benefits such as keeping groundwater basins well stocked to avoid draught problems in warmer climates. Increased water storage in the landscape benefits biodiversity, water quality, recreation, and agricultural and agroforestry activities. The financial case for considering green infrastructure is well-documented in areas such as lowering the cost of providing water-related services, but it varies depending on local conditions. As a result, service providers and their partners should conduct case-by-case assessments to assess financial impacts.

There are several ways to be compensated for water retention today, including applying for national funds. However, none of these include the complexities of inter-municipality and multi-stakeholder collaboration, so the study investigated the feasibility of developing such a business model through a financial marketplace. This can be achieved by compensating or paying upstream landowners by downstream landowners.

Market-based methods that foster collaboration have the capacity to effectively tackle complex environmental issues. This strategy illustrates how sustainable resource management can result from matching financial incentives with environmental stewardship. The success of the Quito Water Fund and related programmes highlight the significance of combining ecological and economic viewpoints, a notion that is strongly supported by Goldman-Benner et al. (2012) and Wunder (2005).

However, while Water Funds present a promising model, their implementation is not without challenges. The need for a thorough understanding of local hydrological, ecological, socio-economic, and institutional contexts, as suggested by Hein, C. et al. (2020), is crucial. This underscores that there is no one-size-fits-all solution in environmental governance. Each Water Fund must be tailored to its specific context, ensuring that it addresses the unique challenges and leverages the opportunities present in its environment.

Furthermore, the discussion around Water Funds brings to light the importance of stakeholder engagement and trust-building in environmental management. For these funds to be effective, they must involve a broad range of stakeholders, including upstream landowners, downstream water users, and local communities. This inclusive approach is vital for ensuring that the benefits of NBS are equitably distributed and that all voices are heard in the decision-making process.

The analysis also suggests that while Water Funds are a step in the right direction, they are part of a larger toolkit needed to tackle the multifaceted issues of water management. Integrating these funds with other policy instruments, technological innovations, and community engagement strategies can create a more robust and resilient approach to water resource management.

The study also emphasises how important it is to have a comprehensive grasp of the institutional and policy aspects of urban water management. This strategy aims to transform how cities engage with stakeholders and the environment, not merely manage water resources. The institutional analysis highlights the complex and frequently compartmentalised character of urban water governance. Due to its complexity, coordination and capacity issues must be addressed, multiple stakeholders must be identified and engaged, and rules and norms must be understood in their entirety.

The policy analysis also emphasises how crucial it is to choose the right policy tools. These tools need to be democratic, efficient, and successful in accomplishing water management objectives. The dynamic character of urban water management concerns, particularly in the face of pressures from urbanisation and climate change, is highlighted by the policy tool discussion.

This analysis also points to the need for adaptive governance structures that can respond to changing environmental and socio-economic conditions. The dynamic nature of urban water systems requires flexibility in policy and institutional frameworks to accommodate new technologies, such as Nature-Based Solutions, and emerging stakeholder needs.

Building urban resilience through an integrated basin perspective is a complex but achievable goal. It requires a deep understanding of existing governance structures, proactive policy development, and an unwavering commitment to stakeholder engagement and collaborative decision-making. By addressing these aspects, urban water management can become more sustainable, resilient, and adaptive to future challenges.

4.2.10. Conclusion

The hypothesis concerning the efficacy of Nature-Based Solutions (NBS) in water management is thoroughly examined and supported in this chapter. This hypothesis suggests that due to the increasing frequency and severity of water-related challenges, such as flooding, droughts, and pollution, innovative and sustainable water management strategies are essential. Traditional grey infrastructure, while beneficial to some degree, often does not fully address the complex nature of these challenges, highlighting the need for and advantages of NBS.

The chapter argues that NBS enhance ecosystem resilience, improve water retention capabilities, and reduce vulnerability to extreme weather events. It presents case studies and theoretical discussions that demonstrate NBS's role in not only addressing immediate environmental impacts but also in building long-term resilience through sustainable practices. It further states that NBS offer a crucial and advantageous alternative to traditional grey infrastructure by actively enhancing the natural capacity of landscapes to manage water, mitigate floods, and handle droughts. The conclusion also underscores the necessity of adopting NBS as part of a broader strategy to ensure the sustainability and resilience of aquatic cultural landscapes against current and future environmental challenges.

The analysis of integrating nature-based solutions (NBS) with traditional grey infrastructure in urban water management reveals a critical pathway towards sustainable and resilient urban development. The evidence presented by researchers like Ncube, S & Arthur, S (2021) and Browder G. et.al. (2019) illustrates that while grey infrastructure has its merits, it alone is insufficient to address the multifaceted challenges posed by climate change and urbanization. In contrast, NBS, as highlighted in the works of Green et al. (2023) and Foster et al. (2022), offer not only effective flood mitigation and water retention capabilities but also bring ecological and social benefits, enhancing biodiversity and improving quality of life in urban areas.

The economic advantages of NBS, underscored by the Environmental Protection Agency's report (2023), further bolster the case for their inclusion in urban water management strategies. The long-term cost savings and environmental sustainability of NBS present a compelling argument for their broader adoption and integration with grey infrastructure.

This analysis advocates for a balanced approach where the strengths of both NBS and grey infrastructure are harmonized to create robust, adaptable, and sustainable urban water management systems. Such an integrated approach is pivotal for addressing current and future water-related challenges in urban areas.

Looking ahead, incorporating NBS into urban planning reflects not only a strategic solution to environmental challenges, but also a commitment to creating healthier, more biodiverse, and liveable urban settings. As cities advance, adopting this hybrid approach to water management will be critical to ensure resilience and sustainability in the face of changing climate conditions and growing urban populations.

The research findings underscore the potential of creating a financial marketplace for upstream water retention as an innovative and cost-efficient solution to mitigate flood risks. This approach offers additional environmental and societal benefits, as evidenced by the preliminary study, and sets a precedent for similar regions grappling with flooding challenges.

Effective flood risk management necessitates strategies such as storing water upstream until the threat diminishes or implementing measures to increase capacity for high flows and reduce damage risk. Selecting the optimal approach depends on various factors, including the specific advantages and disadvantages of each method and the underlying business model. A critical aspect of this model involves negotiations between municipalities and landowners. It is essential for municipalities to recognize the value of flood protection benefits and for landowners to understand the costs incurred in storing water periodically. A fair compensation mechanism from the municipality to the landowner for providing water retention services is a reasonable expectation.

Economic policy instruments offer incentives to mitigate externalities. For instance, the European Union's greenhouse gas emissions trading scheme exemplifies this approach. In Sweden, a similar framework is proposed for regulating nitrogen and phosphorus emissions from municipal water treatment plants (EU, 2014). These systems are favoured for their efficiency and flexibility in allocating investments for maximum impact. Yet, within the EU, there lacks a system for purchasing water retention capacity from landowners in a drainage basin. This gap presents an opportunity to explore the concept through the establishment of a marketing organization for aquaculture.

The integration of NBS in flood and drought management necessitates navigating a complex landscape of legal and policy challenges. These challenges span the gamut from legal definitions and court interpretations to conflicting regulatory frameworks and administrative hurdles. The success of NBS implementation hinges on a nuanced understanding of these challenges and the development of innovative policy instruments that can reconcile various stakeholder interests and legal norms.

Water Funds as a tool for basin-scale water management shows another approach to balancing ecological sustainability and economic feasibility. These funds are a pioneering method to using economic incentives to promote environmental stewardship, notably in the field of water resource management. The success stories, such as the Quito Water Fund, show how these approaches may produce win-win situations for both the environment and stakeholders.

However, the effectiveness of Water Funds is dependent on their flexibility to local conditions and the participation of a wide range of stakeholders. The requirement for context-specific strategies, as underlined by Hein, C. et al. (2020) and others, underlines the idea that effective environmental governance necessitates a thorough understanding of local ecological, socioeconomic, and institutional processes.

Additionally, the role of Water Funds in the broader landscape of environmental management strategies is noteworthy. While they present a significant step forward, they should be viewed as one component of a multifaceted approach to sustainable water management. Integrating these funds with other policy tools, technological advancements, and community-based initiatives can enhance their impact and sustainability.

Ultimately, Water Funds represent a promising approach for addressing the complex difficulties of water management in a changing world. They demonstrate how innovative, collaborative techniques can bring various interests together to achieve common goals such as conservation and sustainability. As a result, they give important insights and lessons for policymakers, practitioners, and communities working to manage natural resources in a sustainable and equitable way.

The transformation towards an integrated basin perspective in urban resilience also demands a nuanced understanding of the institutional and policy landscapes. The analysis of existing governance structures, as suggested by Ostrom (2005) and further developed in subsequent research, is fundamental to identifying the complex interplay of actors, norms, and rules in water management. This understanding is crucial for overcoming challenges such as fragmented authority, limited resources, and stakeholder resistance, as highlighted by recent studies (Brown & Farrelly, 2021).

Moreover, the strategic use of policy tools, as discussed by Howlett et al. (2015) and expanded in newer frameworks by Hein, C. et al. (2020), is vital for promoting a basin-based approach. These tools must be evaluated not just for their effectiveness, but also for their efficiency and equity to ensure sustainable, inclusive urban water management.

The proposed business model envisions utilizing the landscape as a resource, enabling landowners to sell water retention services and municipalities to reduce future flood risks. This model is supported by the EU's Flood Risk Assessment and Management Directive (European Commission, 2007), which serves as a key driver in its development and implementation.

Incorporating recent references and case studies, this research presents a comprehensive and practical approach towards flood management, leveraging economic, environmental, and social synergies. Its implications extend beyond mere risk mitigation, offering a blueprint for sustainable and resilient land and water management practices in the face of climate change and urbanization challenges.

4.3. Advancing Landscape Management through Observatories and Multidimensional Assessment

4.3.1. Introduction

The rapid deterioration of the environment during the 20th century, resulting from processes such as urbanisation, agricultural growth, and unsustainable landscape management, played a significant role in the occurrence of climate change, biodiversity decline, wetland loss, and the reduction of ecosystem services. To tackle these concerns, the European Landscape Convention was instituted in the year 2000, with the aim of promoting the preservation of landscapes, raising awareness about them, and encouraging public participation (Council of Europe, 2006). Landscape Observatories

(LOs) exist in various forms, characterised by their organisational structures and degrees of activity. They fulfil multiple roles, including serving as stores of data in the form of landscape atlases, tools for monitoring, platforms for collaboration, and catalysts for innovation. LOs employ either a bottom-up or top-down approach, which entails engaging local groups or formal organisations to facilitate the exchange of knowledge, education, and collaboration between experts and civil society.

As part of the research, investigations have been conducted on the significance of landscape observatories, focusing specifically on the case study of Landscape Observatory Västra Götaland (LOVG) in Sweden. The studies illustrates the effects, difficulties, and insights associated with LOVG by examining the origins and functions of LOs within the framework of current regional development policies, ecosystem-centred management systems, and efforts to mitigate climate change. The case study of LOVG was examined to provide a comprehensive understanding of the functions, bridging roles, and components of LOs, with the aim of facilitating future progress and development. The study spans multiple domains, such as the upcome of landscape organisations, the roles of sustainable landscape management, land utilisation, global practises, and a proposed interdisciplinary model for landscape organisations.

4.3.2. Enhancing Landscape Management and Conservation: The Role of Landscape Observatories in Europe

The primary objective of the Convention was to promote the adoption of policies and strategies by governments at all levels, including municipal, regional, national, and international, with the aim of safeguarding, overseeing, and strategically organising landscapes across Europe. Additionally, it proposes legislative and financial strategies designed to influence "landscape policies" and foster engagement between local and central governing bodies, as well as cooperation in the preservation of landscapes. The Directive mandates member states to e.g., create flood risk management plans that encompass strategies aimed at mitigating the probability and magnitude of flood occurrences. The comprehensive approach encompasses all stages of the flood risk management cycle, encompassing both prevention, which involves avoiding the development of residential and industrial structures in areas prone to flooding, as well as protection, which entails implementing strategies to minimise the occurrence and mitigate the consequences of floods in specific locations, such as the restoration of flood plains and wetlands.

There are different types of landscape observatories and even organisations and institutions with landscape observatory functions such as monitoring of landscapes and maintaining databases. It is important to review international good practices, either directly concerning already existing landscape observatories or landscape observatory functions at different organisations in Europe. Many of these have good practices, which can be adapted and used in a new, universally applicable landscape observatory concept. First, we will analyse already existing, well known landscape observatories and experimental ones followed by some other cases, where some landscape observatory functions are practiced, which may be a good start for the establishment of fully functional landscape observatories in the future.

Additionally, the Landscape Observatory plays a vital role in the ongoing monitoring of changes in landscape evolution, environmental conditions, landscape character, social dynamics, demography, and settlement patterns, utilizing an extensive network of observational points. It also acts as a foundational resource for the scientific and technical study of the Catalan landscape, further underpinning its importance in regional landscape management strategies.

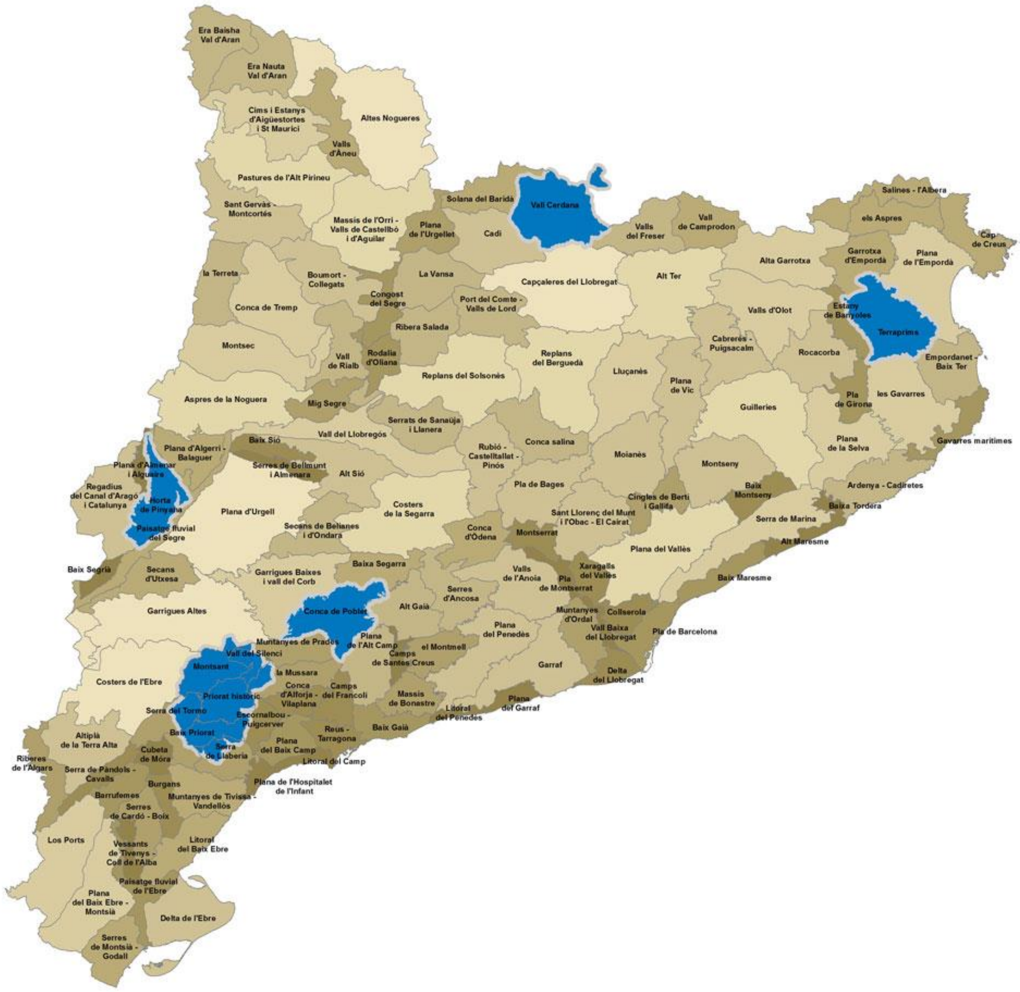

Figure 21. The landscape map of Catalonia. The historical landscapes of outsatanding cultural value are marked with blue colour. Sources: https://www.bbc.com/news/world-europe-20345071 and http://www.catpaisatge.net/pahiscat/eng/estudi.php#!prettyPhoto/0/

The Landscape Observatory of Catalonia stands as one of the most advanced and systematically organized landscape observatories in Europe. Established as a key advisory entity for the Government of Catalonia, it functions as a pivotal platform for communication, education, and information, addressing various landscape-related aspects across Catalan society (Martí, P. S. 2021). Structured as a consortium under the Act for the protection, management, and planning of the Catalan landscape, it was legally formalized on November 30, 2004, with its framework detailed in the Government of Catalonia Official Gazette (Resolution PTO/3386/2004). The primary aims of the observatory are to bolster public awareness and understanding of Catalonia's landscapes and to support the implementation of the European Landscape Convention locally. It serves as a crucial hub, connecting the Government of Catalonia with regional and local authorities, educational institutions, research bodies, NGOs, professional groups, and other societal segments in efforts to manage and conserve the landscape.

It can be concluded that LOs play a pivotal role in promoting sustainable landscape development through functions such as policy implementation, knowledge exchange, and stakeholder collaboration. The proposed adaptable LO concept underscores their significance in tackling contemporary challenges while supporting multiple societal aspects. As societies strive to manage landscapes holistically, LOs emerge as a platform of collaboration, guiding the way toward a harmonious coexistence of natural, cultural, economic, and social dimensions.

In the case of Landscape Observatory Västra Götaland (LOVG), it illustrates a good example of landscape awareness and regional collaboration. This case study, situated in southwestern Sweden, presents an insightful exploration of how landscape observatories can facilitate holistic and integrated approaches to address the complex challenges inherent in sustainable development. Established in 2019 as a two-year pilot project, LOVG exemplifies the potential of harnessing the synergies between public institutions, academia, local municipalities, and civil society to forge a resilient and adaptable framework for landscape management.

The driving force behind LOVG was the need to revitalise the role of the landscape in regional development by fostering a shared understanding among stakeholders. Based on the premise that the landscape contains both natural and cultural history, LOVG set out to build a collaborative platform where varied players could engage in discussion that transcended sectoral barriers. This collaborative spirit was reflected in collaborations with organisations such as the Region of Västra Götaland, the University of Gothenburg, the County Administration Board, and local municipalities. Notably, the observatory prioritised resident feedback, emphasising the need of embracing local perspectives to build a landscape that reflects the values of the community it serves.

LOVG's operational activities were focused on three important case studies, each of which was expressly designed to examine and evaluate collaborative models, competency mapping, and information platforms. The case studies looked at the relationship between urban and rural areas, the conservation of natural and cultural resources, and the identification of historical and contemporary landscape values. The observatory's commitment to documenting the complex character of landscapes and the interaction of ecological, social, and economic aspects was highlighted by this comprehensive strategy. Furthermore, the inclusion of children and adolescents in the debate highlighted the ultimate goal of developing a thorough understanding of the landscape's value in future cohorts.

A distinguishing feature of LOVG's strategy was the use of a transdisciplinary framework to address landscape concerns. Using a triangulation of research methodologies, including stakeholder interviews/questionnaires, expert workshops, and case study analyses, the study broke new ground by combining Earth System Science with the DPSIR (Driving Forces, Pressures, States, Impacts, Responses) framework. This method went beyond traditional disciplinary lines, allowing for a thorough examination of the complex relationships between ecological, economic, social, and cultural factors in the environment. The suggested model demonstrated the potential of this synthesis, encouraging landscape observatories to adopt a dynamic and adaptive perspective that takes into account both natural and human-driven elements.

It is essential to involve a wide variety of stakeholders in addressing landscape issues, and a collaborative platform is likely to produce the desired results. Landscape observatories have proven to be helpful in this regard. Experience from e. g. LOVG in Sweden, as discussed above, also emphasise their visions for the future landscape. Following each point is a brief explanation of how the legal work relates to each priority (Table 9).

Table 9. Identification of Key Topics for the Activity of the Landscape Observatory of VGR.
Source: LOVG 2022, Anders M. Nilsson

Priority	Topic	Legal setting
High	Create a spatial planning platform with broader engagement from public, private and civil society. Increase the accessibility and participation of all residents by encouraging collaboration between natural and cultural heritage organizations and civil society for joint business development and resource utilization	Create an organisation and legal identity at regional level. Facilitation unit of multi-stakeholders' engagement in spatial planning
	Reduce the risk of in silo planning while also ensuring that critical issues in the landscape are managed and coordinated.	Enable cross-border cooperation to address landscape challenges - both regional and municipal level through strategic collaboration between the actors in the cultural environment and the relevant sectors of society
	Inspire new initiatives for sustainable landscape development	Projects established for sustainable land use
	Increase collaboration on landscape issues and strengthen interactions with research and education, and - serve as a knowledge exchange hub for national and international exchange.	New forms of knowledge exchange for sustainable spatial planning
Medium	Increase capacity to meet climate change challenges.	Climate adaptation measurements
	Contribute to children and young people's understanding of the landscape's different values, as well natural and cultural environmental values, as societal values.	Incorporate landscape values in early education
	.	Increase citizens' ability to actively participate in landscape evaluation and management.
Low	Increase the experience value for visitors and tourists by, in collaboration with the hospitality industry, coordinating sustainable natural and cultural heritage experiences and connecting visitor destinations and other cultural events.	

4.3.3. Challenges and Biases in Landscape Management

A critical examination of the European Landscape Convention's and LOs' shortcomings and possible biases brings to light several important issues that illustrate the difficulties in comprehensive landscape management and planning. Firstly, limitations concerning the quantity and quality of data are a common issue for LOs, and this might result in incomplete or incorrect landscape assessments. These restrictions could lead to distorted interpretations of landscape values and bias conclusions.

Another limitation is the lack of standardization in methodologies used by LOs. This can lead to inconsistencies in data collection and analysis, making it difficult to compare findings across different regions or time periods. Additionally, LOs may face challenges in integrating different types of data, such as social, economic, and environmental indicators, which can limit the comprehensive understanding of landscapes.

The European Landscape Convention, while aiming to promote the protection, management, and planning of landscapes, also has its limitations and potential biases. One potential bias is the focus on preserving landscapes that are considered aesthetically pleasing or culturally significant, which may neglect the conservation of less visually appealing or less culturally valued landscapes. This bias can be reinforced by the subjective interpretations of landscapes by LOs.

Furthermore, the Convention's emphasis on stakeholder participation can introduce biases in decision-making processes. The involvement of various stakeholders, such as local communities, interest groups, and authorities, can lead to power imbalances, favouring certain groups over others. This can result in decisions that may not fully consider the interests and needs of all stakeholders, leading to potential biases in landscape management and planning.

To strengthen the arguments presented, it would be beneficial to provide specific examples and methodologies. For instance, examining case studies where LOs have faced data limitations or have shown biases in their assessments would illustrate the practical implications of these issues. Additionally, discussing specific methodologies used by LOs and their potential limitations would provide a more concrete understanding of the challenges they face.

Traditional landscape classification systems, primarily focusing on the physical and environmental impacts of human activities like mining, agriculture, and urban development, often lack sufficient attention to cultural aspects. To address this gap, newer landscape maps and databases have been developed that include a richer cultural dimension.

The ELCA (European Landscape Character Assessment Initiative) concept, introduced by Pedroli et al. in 2013, enhances the cultural sensitivity that was previously missing from landscape assessments. It emphasizes the recognition of unique cultural landscapes through toponyms—names derived from the landscape's perception by people, which are significant both nationally and internationally. These toponyms encapsulate a variety of elements such as language, natural and human-shaped landscape features, agricultural practices, settlement patterns, unique architectural structures, historical events, and ethnic heritage, reflecting the rich, diverse heritage of a place over centuries.

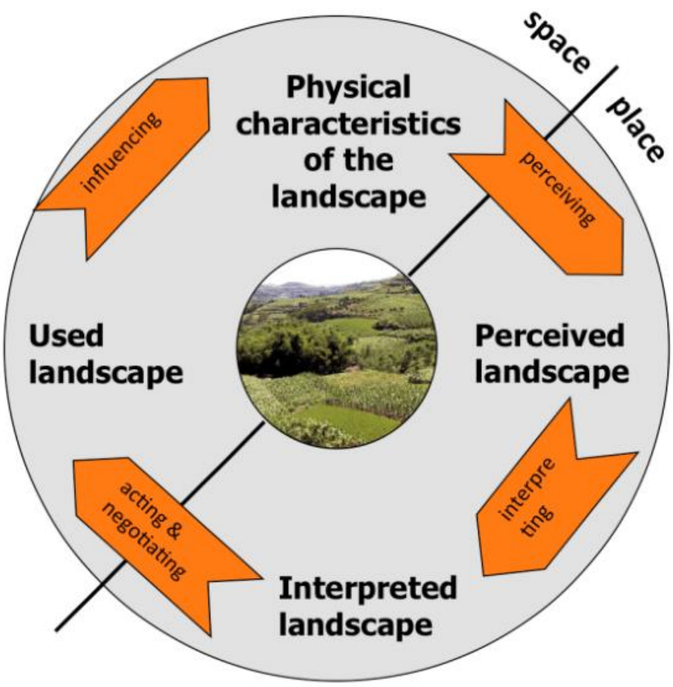

Figure 22. The Space and Place Concept According to Hunziker et al. (2019).

This cultural approach aligns with the broader objectives of sustainability and public participation. It integrates quantitative socio-ecological assessments with qualitative evaluations of cultural values and perceptions by stakeholders, as noted by Marine in 2022. This is reflective of the "space and place" concept proposed by Hunziker et al. in 2007, which has been adopted by the European Landscape Convention in 2019. This concept divides landscape into "space"—the physical attributes like urban structures and natural resources—and "place"—the human perceptions and values associated with the landscape, emphasizing its cultural significance and the experiences it offers.

4.3.4. Enhancing Landscape Management with a Holistic Observational Framework

Concerning the analysis of impacts on ecosystem status there is an interesting approach, which is close to our conception in terms of integrating natural and social factors, this is the holistic DPSCR4 (Drivers–Pressures–Stressors–Condition–Responses) framework, which includes even the environmental stressors (Harwell et al. 2019), a comprehensive conceptual model of the coupled human–ecological system. This holistic model integrates both natural and social factors, allowing for a more comprehensive assessment of risks and the development of targeted remediation strategies at the landscape level. The primary focus of the DPSCR4 framework is on the identification and removal of stressors, facilitating easier and more effective management of ecosystem changes. The framework serves as the basis for developing dynamic landscape observatory models that can adapt to various natural and social environments. These observatories play a crucial role in gathering and synthesizing data to evaluate changes in ecosystems by linking anthropogenic activities and natural factors. This system supports a wide range of functionalities including resource assessment, database management, process formalization, and system dynamics interpretation. It also enhances communication among different stakeholders, aids in decision-making, and promotes educational initiatives tailored to local and regional needs.

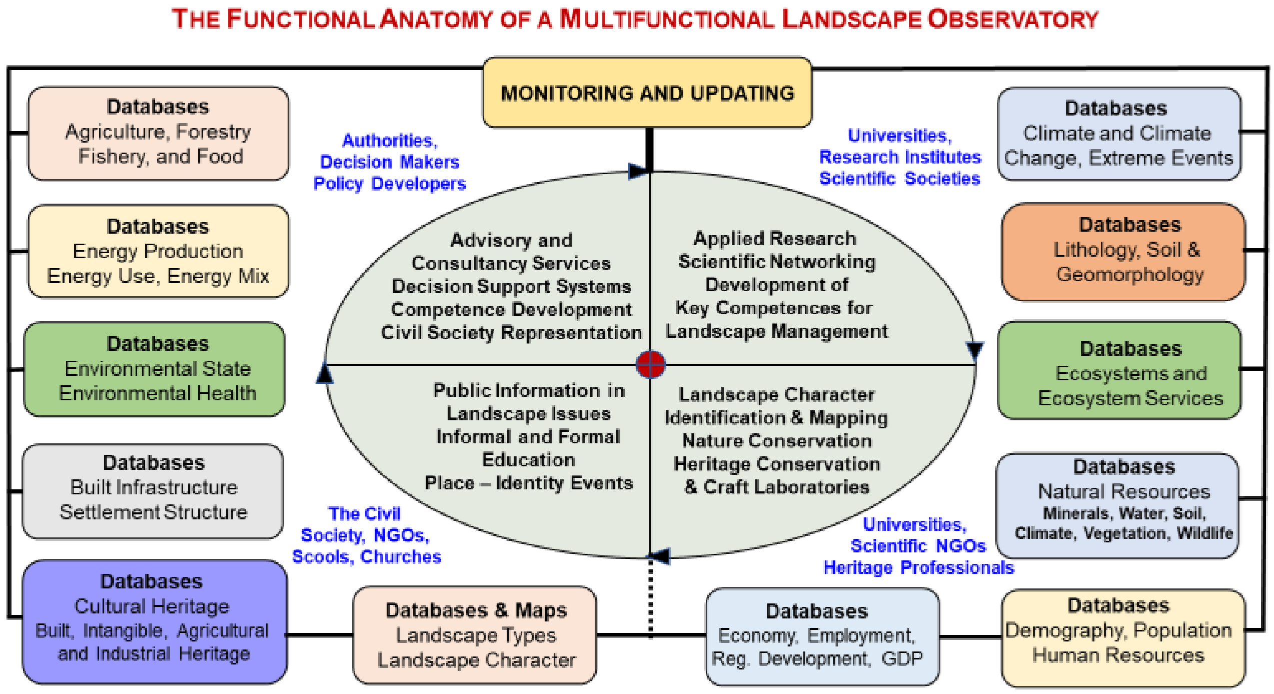

Figure 23. The Conceptual Model – the Functional Anatomy of an Effectively and Efficiently Working Landscape Observatory. In the centre the key functions are maintained from the databases, which supply all information needed for the operation. Obviously, monitoring and research together keep the databases always updated. Source: own design.

Overall, the DPSCR4 framework exemplifies a shift towards integrated landscape management, focusing on the sustainability of natural and cultural resources. It underscores the need for a unified approach in landscape observatories to address the complex interplay of ecological, social, demographic, cultural, and economic factors. This approach aims to foster a holistic understanding of landscapes, encouraging sustainable practices and informed policy-making that reflect both global perspectives and local realities.

This conceptual model shall be a universal mall for the structure and functions of all landscape observatories, adaptable to any natural and social environment, only by adjusting the proportions of the system. Therefore, the model will be able to:

- Assess resources, construct inventories and handle a wide range of databases;
- Formalize and interpret system processes and dynamics;
- Identify linkages of processes across disciplinary boundaries;
- Monitor the changes of ecological, social, demographic, cultural and economic state of the landscape;
- Predict the consequences of changes in the system;
- Identify the connections and scope of the system of interest;
- Acquire and integrate new information into the existing systems;
- Establish efficient communication:
    - Among decision-makers
    - Among scientists and program staff
    - Between scientists and decision-makers
    - With the general public
- Support the decision making of local and regional authorities and government organisations through advisory services and well-established decision support systems and tailored education programmes (competence development – when and where required)
- Establish, expand, and maintain international scientific, innovation and development platform and knowledge bank through active networking in order to intensify knowledge transfer and promote exchange of international good practices;
- Developing formal and informal education programmes adapted to local and regional conditions but emphasizing their global relevance.

4.3.5. Discussion

Landscape observatories (LOs) play a crucial role in promoting sustainable landscape development by implementing policies, facilitating knowledge exchange, and encouraging stakeholder collaboration. LOs, such as the Landscape Observatory Västra Götaland (LOVG) in Sweden, exemplify the potential of collaboration between public institutions, academia, local municipalities, and civil society in managing landscapes holistically.

LOVG's approach was centred around building a shared understanding among stakeholders and embracing local perspectives. The observatory prioritized resident feedback and conducted three case studies to examine the relationship between urban and rural areas, the conservation of natural and cultural resources, and the identification of landscape values. By involving children and adolescents in the discussion, LOVG aimed to develop a comprehensive understanding of the landscape's value for future generations.

LOVG's strategy also involved using a transdisciplinary framework that combined Earth System Science with the DPSIR framework. This approach allowed for a thorough examination of the complex relationships between ecological, economic, social, and cultural factors in the landscape. It encouraged other LOs to adopt a dynamic and adaptive perspective that considers both natural and human-driven elements.

However, there are limitations and challenges that need to be addressed. LOs often face limitations in data quantity and quality, which can lead to incomplete or incorrect landscape assessments. The lack of standardization in methodologies used by LOs also poses challenges, making it difficult to compare findings across regions or time periods. Integrating different types of data, such as social, economic, and environmental indicators, can also be challenging and limit the comprehensive understanding of landscapes.

The European Landscape Convention and LOs themselves may have biases. The focus on preserving aesthetically pleasing or culturally significant landscapes may neglect the conservation of less visually appealing or less culturally valued landscapes. Subjective interpretations of landscapes by LOs can reinforce this bias. Additionally, stakeholder participation in decision-making processes can introduce power imbalances and result in decisions that do not fully consider the interests and needs of all stakeholders. Think of a LO working in a multicultural area, for instance, where different ethnic groups have quite different perspectives of the landscape. The ensuing management methods may privilege the conservation of some landscapes over others, perhaps overlooking regions significant to minority communities, if the observatory's assessments are predominantly based on the cultural values of the majority group. This example could highlight the need for more inclusive data-gathering techniques and show how cultural biases in data collection affect judgements made about landscape management.

Discussions on Landscape Observatories (LOs) can benefit greatly from the inclusion of particular instances and methods, which can improve comprehension and efficacy in landscape management. In-depth case studies provide specific examples of how biases and limits in the data affect landscape management choices, turning intangible problems into concrete difficulties. This method not only helps stakeholders understand the immediate effects of these challenges on their environments, but it also clarifies the intricacies involved.

LOs are better equipped to adopt more robust ways that successfully combine the depth of qualitative insights with the precision of quantitative procedures by examining the advantages and disadvantages of various methodologies. By ensuring that decisions are well-informed and take into account a variety of landscape values and demands, a balanced approach promises more thorough and efficient landscape management.

Moreover, providing specific examples and methodological criticisms is essential for influencing policy. By highlighting areas that require improvement and illustrating the practical implications of present practices, these talks help to steer policy changes and promote more sustainable management techniques.

4.3.6. Conclusion

This chapter addresses the "Hypotheses on Cultural Heritage Conservation and Community Engagement.", which posits that integrating cultural heritage conservation with community engagement enhances the preservation of cultural landscapes and promotes sustainable development.

The research shows how landscape observatories and multidimensional assessments facilitate the management of cultural landscapes by combining conservation efforts with active community involvement. The chapter provides evidence that observatories help document and interpret cultural landscapes while fostering community participation, thereby enhancing conservation effectiveness. By integrating ecological, cultural, and social dimensions, the chapter supports the hypothesis that conservation efforts are more sustainable when they engage local communities. It demonstrates that involving communities not only preserves cultural heritage but also promotes sustainable development and resilience.

Landscape management requires a comprehensive approach, recognizing that all related activities are part of an interconnected system, necessitating a unified response. Initially, the implementation of the European Landscape Convention was often fragmented across different government structures and distributed arbitrarily among various sectors. This approach proved to be inefficient for managing complex ecosystem tasks.

Today, while there are numerous effective practices in landscape management and conservation, a cohesive international solution has yet to be developed. Landscape observatories have been established worldwide, each with distinct systems, structures, and routines, yet sharing the common aim to implement the strategies of the European Landscape Convention. A prime example is the Landscape Observatory of Catalonia, which effectively integrates the conservation of natural and cultural landscape values. However, to broaden the impact globally, a new model that leverages Earth System Sciences and the DPSIR and DPSRC4 frameworks could be beneficial.

Economic and sociological approaches often overshadow the natural complexities of landscapes and ecosystem services at the system level. A proposed dynamic and interactive model for landscape observatories would encompass inventory management, database creation, environmental and socio-economic modelling, ecosystem monitoring, research, education, advisory services, policy development, public information, event organization, and international networking, all as part of a cohesive system.

The ELC's incorporation of the "Space and Place" concept reflects an evolving understanding of landscapes. "Space" relates to tangible characteristics such as urban infrastructure and vegetation patterns, crucial for landscape monitoring and ecological studies. In contrast, "Place" includes intangible values and perceptions associated with landscapes, like aesthetic and spiritual aspects, which contribute to societal well-being.

One crucial role of landscape observatories is to provide advisory services to local and regional authorities and government organizations, ensuring sustainability across all policy areas. This involvement aims to integrate the sustainable management of natural and cultural resources into public awareness and societal values.

Key goals for these observatories include establishing a network of cities with a multi-centered spatial structure, enhancing the support capacity of rural areas, and fostering the development of regions with significant landscape value. Policy objectives should focus on reinforcing nature and landscape protection, preserving biological diversity, and promoting the development based on the cultural, social, and architectural heritage of rural areas, thereby nurturing local traditions and strengthening community identities.

4.4. Technological Innovations in Sustainable Water Management and Conservation Practices

4.4.1. Introduction

Water is an essential resource in all parts of human life, and not the least in agriculture. Crop production would be impossible without water, making it the lifeline of agriculture. The efficient use of water resources in agriculture not only ensures sustainability, but also plays an important role in the preservation of productive farming methods. The importance of water use efficiency in agriculture, its effects on farming, and the cutting-edge technology used to enhance efficiency, particularly in urban and peri-urban regions, is a vast challenge for the future of sustainable agriculture and global food security.

4.4.2. Irrigation and the Protection of Surface Waters and Groundwater Resources

Irrigation is a crucial technique in modern agriculture that is used to increase crop production and guarantee food safety. Nevertheless, the escalation of irrigation has led to a significant issue - the pollution of surface waters and groundwater. Given the crucial importance of water in supporting life and ecosystems, the convergence of agriculture, irrigation, and water pollution presents substantial obstacles that require careful deliberation and proactive remedies (Foley et al., 2005).

Water quality degradation occurs when the runoff from irrigated fields introduces an excessive amount of nutrients, pesticides, and sediment into water bodies. This can lead to eutrophication, algal blooms, and a decline in the overall quality of the water. Consequently, this endangers the existence of aquatic habitats and disturbs the intricate equilibrium of ecosystems (Diaz and Rosenberg, 2008).

Human health risks arise when groundwater becomes contaminated, as it can serve as a drinking water source for communities, hence possibly exposing persons to hazardous compounds such as nitrates and pesticides. Extended exposure can result in detrimental health consequences, highlighting the urgency of addressing water quality as a significant public health issue (Ward et al., 2005).

Loss of biodiversity occurs when surface water as well as ground water is contaminated. Aquatic ecosystems are highly vulnerable to changes in water quality, and pollution caused by agricultural activities can lead to the depletion of fish populations, aquatic vegetation, and other creatures. The decline in biodiversity not only causes disturbances in ecosystems but also has an impact on the means of subsistence for people who rely on these resources (Dudgeon D. et al., 2006; Vörösmarty et al., 2010).

There are several approaches of dealing with these difficulties. For instance, the implementation of precision agriculture techniques can enhance the efficiency of water, fertilisers, and insecticides utilisation. Using technology such as sensors and data analytics, farmers may customise their irrigation methods to suit the individual requirements of crops, hence minimising excessive inputs and decreasing the likelihood of contamination (Zaman Q. U. (2023).

The incorporation of green infrastructure, such as vegetative buffer strips and wetlands, within agricultural landscapes can also serve as natural filters, capturing and reducing the movement of pollutants into water bodies. This strategy aids in safeguarding the quality of water while simultaneously fostering biodiversity (Haddaway, N.R., Brown, C., Eales, J. et al. (2018).

Providing farmers with knowledge about sustainable irrigation practices and encouraging the adoption of optimal strategies can significantly reduce water contamination. Implementing techniques such as crop rotation, cover cropping, and decreased tillage can improve soil health and decrease the reliance on excessive agrochemicals (Zhanguo Bai, et. al., 2018).

Addressing the interconnection between agriculture, irrigation, and water contamination necessitates a comprehensive and cooperative strategy. Through the utilisation of innovative technologies, sustainable practices, and community engagement, we may work towards achieving a state of peaceful coexistence where agricultural productivity is maximised without jeopardising the integrity of our essential water resources.

Consequences of Excessive Irrigation

To maintain human populations, ensure food security, and increase agricultural output worldwide, irrigation techniques have been widely adopted. The unintended repercussions of over-irrigation, however, have become a serious worry, posing a threat to the delicate balance that must be struck between serving the needs of an expanding population and protecting the environment. This phenomenon brings up several related challenges, including soil degradation, water resource depletion, and socioeconomic consequences. It is essential to investigate the effects of excessive irrigation and comprehend its complex effects on ecosystems, agricultural sustainability, and the livelihoods of communities dependent on irrigated agriculture in order to fully address these issues.

A multitude of problems arise from excessive irrigation, which is defined as the overdistribution of water to agricultural fields. Depletion of water resources is one of the main effects, resulting in a fall in water tables and an aquifer overdraft (Miralles et al., 2011). The long-term sustainability of agriculture and the ecosystems that depend on these water reserves are threatened by the increase in irrigation demands, which are especially severe in arid and semi-arid countries.

Furthermore, overwatering for an extended period can cause salinization of the soil, a condition in which deposited salts reduce soil fertility and impede crop growth (Qadir et al., 2014). Salt accumulation in irrigated soils not only endangers agricultural output but also worsens environmental deterioration because saline discharge can contaminate nearby water bodies, endangering aquatic ecosystems and consumers downstream.

Beyond problems with soil and hydrology, the effects also have socioeconomic implications. A cycle of resource reduction and declining returns for farmers can result from excessive irrigation, which can lead to a reliance on non-sustainable water practices (Bhattarai et al., 2016; Wichelns, 2018). Increased climate variability makes agricultural systems more vulnerable, and the livelihoods of populations that depend heavily on irrigated agriculture suffer ever-greater uncertainty.

It is essential to take a comprehensive strategy to mitigating the effects of over-irrigation, incorporating regulatory interventions, technological advancements, and sustainable water management techniques. Through an awareness of the complex network of effects resulting from over-irrigation, stakeholders can work to balance the needs of agriculture with the preservation of the ecological integrity of water resources.

4.4.3. Water Allocation and Integrative Management of Precision Irrigation

Efficient distribution of water resources and comprehensive control of precise irrigation are crucial in tackling water scarcity issues and maximising water utilisation efficiency in agricultural practices. With the increasing global demand for water, especially in areas prone to water scarcity, it is crucial to allocate water resources wisely to ensure sustainable agriculture (Rockström et al., 2009; Wada et al., 2016). Utilising new technologies, precision irrigation presents a significant opportunity to optimise water utilisation and improve crop productivity.

Water allocation schemes include a just allocation of water supplies among different users, while considering the requirements of agriculture, industry, and residents (Hanjra and Qureshi, 2010; Ward et al., 2018). To effectively implement efficient water allocation methods, it is crucial to have a thorough understanding of the specific hydrological conditions in the area, as well as the water needs of different crops. Additionally, it is important to incorporate participatory approaches that involve stakeholders in the decision-making processes.

Precision irrigation utilises technology to customise water distribution according to the precise requirements of crops, hence optimising resource utilisation and reducing wastage (Abdullah, H.M. et.al., (2024). Farmers can utilise advanced sensors, remote sensing, and data analytics to actively monitor real-time information on soil moisture levels, crop health, and weather conditions. This data enables accurate irrigation planning, enabling the timely and focused distribution of water to crops.

The comprehensive administration of precision irrigation extends beyond the technical components, involving the harmonisation of several factors like crop choice, soil administration, and climate concerns (Khose, et.al., 2023). Integrative management approaches encompass the utilisation of cover crops to decrease evaporation, the adoption of conservation tillage to boost soil water retention, and the implementation of agroforestry systems to improve overall water-use efficiency.

Moreover, the incorporation of precise irrigation techniques alongside water-conserving technology, such as the collection of rainwater and the use of drip irrigation, enhances the implementation of a more sustainable approach to water management (Khose, et.al., 2023). These solutions not only preserve water but also mitigate the environmental consequences of agricultural runoff, hence minimising the likelihood of surface water and groundwater contamination.

Water allocation and integrative management of precision irrigation are essential elements of a sustainable strategy to water utilisation in agriculture. Through the integration of fair water distribution strategies, advanced technologies, and comprehensive management approaches, stakeholders may effectively address the challenges posed by water shortage. This approach aims to optimise water usage, enhance agricultural system resilience, and promote efficient water allocation.

4.4.4. Water Saving Technologies in Areas of Water Scarcity.

In areas facing growing shortages of water, it is crucial to implement water-saving technologies to ensure sustainable water management in agriculture. These technologies aim to optimise water usage efficiency, minimise waste, and guarantee the optimal utilisation of scarce water resources. Implementing novel solutions is especially important in arid and semi-arid regions where water scarcity poses a considerable risk to agricultural output and food security.

To promote sustainable agricultural systems, ensuring the continued productivity of crucial food-producing regions, the following water-conserving technologies are useful:

1. Drip Irrigation:

- Drip irrigation is a remarkably efficient technology for conserving water, as it provides water directly to the root zone of crops, thereby reducing evaporation and runoff. This approach enables meticulous regulation of water distribution, ensuring it aligns with the individual requirements of each plant (Hossain S. et.al. (2024). Drip irrigation systems not only help conserve water, but also enhance agricultural yields and improve resource-use efficiency.

2. Collection of Rainwater:

- Rainfall harvesting is an environmentally friendly method that entails the collection and retention of rainfall for agricultural use. This method mitigates reliance on traditional water sources, specifically in regions characterised by erratic precipitation patterns (Ruiz Martínez, Cornejo T., 2022; Ray R.L, et.al., 2022). Through the process of collecting and retaining rainwater, farmers can augment their irrigation requirements during periods of drought, so strengthening their ability to withstand water shortages.

3. Devices for Measuring the Amount of Moisture in the Soil:

- Precision agriculture integrates soil moisture sensors to deliver instantaneous data on soil moisture levels. The provided information allows farmers to enhance their irrigation scheduling, guaranteeing that water is utilised efficiently and exclusively in the required time and location (Bastiaanssen W. G. et al., 2011; Basso B. et al., 2009). Soil moisture sensors aid in water conservation and enhance crop water-use efficiency by preventing excessive irrigation.

4. Aeroponics and Hydroponics:

- Aeroponics and hydroponics are methods of cultivating plants without the need of soil, instead relying on nutrient-rich water solutions. These techniques eradicate the necessity for excessive water consumption linked to conventional soil-based farming (Raviv, et. al., 2019). Aeroponics and hydroponics are cultivation methods that efficiently utilise water by directly supplying nutrients to plant roots in a controlled environment. These techniques are especially well-suited for places with limited water availability.

5. Subsurface Drip Irrigation:

- Subsurface drip irrigation is a method where drip lines are installed below the soil surface. This technique helps to decrease water loss due to evaporation and limits the amount of water that comes into touch with the leaves of plants (Sinobas, L. & Rodriguez, M., 2012). This technology is particularly advantageous in dry locations, since it improves the efficiency of water usage and prevents the accumulation of salt in the soil that is typically caused by surface irrigation systems.

4.4.5. Biodiversity of Agroecosystems and Adjacent Natural Ecosystems and Water Management

The diversity of living organisms in agricultural ecosystems and their connection with nearby natural ecosystems have a significant impact on the development of water management solutions. Agroecosystems, being cultivated landscapes, are closely linked to adjacent natural habitats such as forests, wetlands, and grasslands. Comprehending and utilising the variety of living organisms within and surrounding agricultural ecosystems is essential for attaining sustainable water management methods that effectively balance agricultural output with environmental preservation. These can be summarised as follows:

1. Agroecosystem Biodiversity:

- Agroecosystems that include a wide variety of plant and animal species play a significant role in improving ecosystem services that are essential for water management. Biodiversity enhances soil health, diminishes insect and disease burdens, and enhances nutrient cycling, all of which impact water dynamics in agricultural environments (Tscharntke T. et al., 2012). Diverse plant species in agroecosystems can improve water infiltration, mitigate soil erosion, and enhance overall water retention capacity.

2. Biodiversity in Proximate Natural Ecosystems:

- Riparian zones, which are natural ecosystems adjacent to agroecosystems, play a crucial role in providing essential ecosystem services that impact the quality and availability of water. Riparian vegetation serves as a protective barrier, removing contaminants from agricultural runoff prior to their entry into water bodies (Palmer M. A. et al., 2010). The delicate interplay between natural biodiversity and water management underlines the significance of protecting and repairing nearby ecosystems to enable sustainable agriculture.

3. Study of Ecohydrology and Water Flow:

- Ecohydrology highlights the interdependence between ecological and hydrological systems. Agroecosystems that have a high level of biodiversity play a role in ecohydrological functions, which affect the patterns of water flow, the replenishment of groundwater, and the cycling of nutrients (D'Odorico P. et al., 2010). The existence of various vegetation types, such as cover crops and agroforestry, can alter water availability by affecting evapotranspiration rates and controlling soil moisture dynamics.

4. Conservation Agriculture Methods:

- Conservation agriculture methods, which frequently incorporate varied cropping systems and cover crops, aid in the improvement of biodiversity in agroecosystems. These techniques support the well-being of soil, decrease erosion, and improve the ability of water to penetrate the ground, eventually reducing the effects of water-related problems (Giller et al., 2009; Pittelkow et al., 2015). Integrating cover crops into agricultural practices not only safeguards soil against erosion but also improves water retention by decreasing surface runoff.

5. Holistic Water Resource Management:

- The connection between biodiversity and water management is being increasingly acknowledged, leading to the growing importance of integrated water resource management systems. These approaches examine the impact of various ecosystems on the regulation of water quality, the reduction of sedimentation, and the enhancement of overall watershed health (de Groot R. S. et al., 2010). Executing such programmes requires cooperative endeavours among relevant parties to effectively oversee water resources in a sustainable manner on a large scale.

4.4.6. Discussion

The successful implementation of NBS underscores their effectiveness in enhancing water retention, improving biodiversity, and supporting multifunctional agricultural systems. These solutions are adept at blending ecological restoration with practical water management needs, proving beneficial in both urban and rural settings. Advanced irrigation technologies, including precision irrigation, have shown significant promise in reducing water wastage and improving agricultural productivity. These technologies are crucial in regions facing water scarcity and are instrumental in optimizing water use in agriculture.

Effective stakeholder involvement has been highlighted as a key factor in the successful adoption and implementation of innovative water management practices. Engaging local communities, governments, and international organizations ensures that the solutions are well-suited to local conditions and supported by those who are impacted.

Although NBS and other creative techniques show promising outcomes in certain situations, the problem lies in expanding these solutions across diverse geographic and socio-economic settings. Various factors, including variable climate conditions, economic limitations, and diverse cultural values, can influence the adaptability of these actions. Financial limitations can also impede the extensive implementation of these developments, restricting their influence on a worldwide level. For example, the high initial expenses and continuous upkeep of sophisticated water management technology might be a barrier, especially in underdeveloped areas. Another obstacle is the integration of new technologies with existing systems, which can present technical difficulties that might impede the progress of implementation. Efficient water management frequently depends on accurate data, which may be insufficient in several areas.

Future research should prioritise the promotion of multidisciplinary collaboration that combines the fields of hydrology, ecology, technology, and social sciences. This strategy can effectively tackle the intricate nature of water management concerns in a more comprehensive manner. As technological advancements progress, it is essential to keep up with the rules that regulate water management. Future initiatives should prioritise the revision of regulatory frameworks to facilitate the adoption of innovative technology and processes. Furthermore, given the persistent threats posed by climate change, namely its effects on water resources, it is imperative that future advancements in water management are developed to possess the qualities of resilience and adaptability to accommodate shifting climatic conditions. This involves the creation of systems capable of managing severe weather conditions and fluctuations in water levels. Furthermore, it is essential to enhance public knowledge and education regarding the advantages of implementing sustainable water management practices. Communities that have received education are more inclined to endorse and engage in sustainable activities, thereby enhancing their efficacy.

4.4.7. Conclusion

This chapter relates directly to the "Hypotheses on Mitigation of Climate Change Impacts," which posits that the implementation of innovative water management technologies significantly enhances the resilience of aquatic cultural landscapes against climate change impacts. The research provides empirical evidence and practical examples of how cutting-edge technologies, such as precision irrigation systems, advanced water-saving devices, and real-time monitoring tools, are being employed to manage water resources more efficiently. These technologies are critical in mitigating the adverse effects of climate change by optimizing water use, reducing waste, and ensuring the sustainability of water supplies.

It also includes various case studies showing how these tools work in diverse circumstances. Precision irrigation technologies in agriculture reduce water use while preserving crop yields, while enhanced monitoring tools provide real-time data to better manage water resources. These ideas demonstrate how technical advances can assist NBS to improve aquatic cultural landscape resilience and sustainability. This emphasises the need to integrate these technologies with NBS and traditional water management. Combining technical breakthroughs with NBS can make water management systems more durable and responsive to changing climates, supporting the idea that such integration is necessary to mitigate climate change consequences.

Not only have nature-based solutions been shown to be effective in promoting water retention and improving biodiversity, but they have also been shown to be beneficial in contributing to the development of multifunctional landscapes that strike a balance between the requirements of the environment and the need of humans. These solutions provide an approach to the management of water resources that is resilient and adaptable to a variety of environmental and social circumstances. They exhibit a harmonious integration of human and natural systems.

Nevertheless, there are still several obstacles to overcome in terms of the scalability and economic feasibility of these inventions, particularly in areas that have a limited amount of financial and technological resources. In addition, the adaptability of these solutions across a wide variety of geographical and cultural settings presents a considerable problem, which calls for individualised approaches that take into account the particularities of the local environment. When it comes to the future of sustainable water management, it is imperative that there be a greater emphasis placed on the adaptation of policies and governance that are designed to promote the introduction of innovative technologies. To establish comprehensive plans for water management, it is also essential to take interdisciplinary approaches that include hydrology, ecology, technology, and social sciences. Further, to gather the support and participation of a wider community, it will be vital to raise public awareness and educate people about the advantages of sustainable water management.

It is vital that continued research, policy adaptation, and stakeholder engagement be carried out, even though great improvements have been made in sustainable water management through technological and ecological breakthroughs. When it comes to addressing the challenges of water management in a changing global climate, the integration of these factors will be vital. This will ensure that water resources are managed in a manner that is sustainable, equitable, and resilient for future generations. Through the implementation of this all-encompassing strategy, not only will water systems be improved in terms of their performance and sustainability, but the cultural and ecological integrity of the landscapes that they support will also be preserved.

4.5. Water Management Systems in Agriculture and Urban Agriculture

4.5.1. Introduction

The management of aquatic cultural landscapes represents a pivotal challenge in our contemporary environmental scenario, marked by the accelerating pressures of climate change, rapid urbanization, and unsustainable agricultural and industrial practices. As these landscapes are deeply intertwined with human history, cultural practices, and biodiversity, their sustainable management demands a comprehensive, nuanced approach that respects both their ecological significance and cultural heritage.

This chapter delves into the complex dynamics of aquatic cultural landscapes which are not only ecological assets but also repositories of cultural heritage and centres of human activity. These landscapes, including rivers, lakes, wetlands, and coastal areas, have historically supported human civilization by providing essential resources for agriculture, settlement, and economic activities. However, the sustained health of these landscapes is under threat from a myriad of forces that necessitate an urgent and thoughtful response.

Recognizing the multifaceted challenges faced by these vital ecosystems, this chapter explores the integration of nature-based solutions, innovative water management strategies, and community-engaged conservation practices. It examines how these approaches can be effectively harmonized to foster resilience, promote sustainability, and enhance the liveability of environments intimately connected with water resources.

4.5.2. Sustainable and Climate Resilient Water Usage in Agriculture

It is critical to comprehend the concept of agricultural water usage efficiency. The ratio of agricultural output to the amount of water used for production is referred to as water use efficiency. In simple terms, it measures how efficiently water is used to generate agricultural goods. A high water use efficiency indicates that a substantial amount of agricultural output is produced per unit of water utilised. This is especially important in areas where water is scarce or where agricultural activities have an impact on water availability and water quality.

Multifunctional organic agriculture has evolved as a viable alternative to conventional agricultural practices, emphasising effective water consumption while simultaneously maintaining ecological integrity. This is in response to the issues given by these practices. This method of farming incorporates several ecological processes, with special emphasis on soil health, biodiversity, and water conservation. Using organic agricultural techniques helps to lessen the negative effects that excessive water consumption and contamination have on the environment.

Crop rotations, cover crops, and organic fertilisers are examples of natural processes used in organic farming that improve soil structure and water retention ability (Reganold and Wachter, 2016; Ponisio et al., 2015). Organic agriculture reduces the possibility of contaminating water and enhances the wellbeing of aquatic ecosystems by eschewing synthetic chemicals.

Agroecology is one of the main principles of multifunctional organic agriculture, promoting the harmonious integration of various livestock and crops. By utilising natural processes like the fixation of nitrogen by crop residues, agroecological methods increase water usage efficiency and decrease the demand for synthetic fertilisers (Mäder P. et al., 2002). Furthermore, adding agroforestry components to organic systems promotes water conservation since tree cover increases total water availability and lowers evaporation (Jose, S. 2009).

Moreover, water-smart irrigation techniques like drip irrigation and rainwater collection are frequently highlighted in organic farming (Velasco Muñoz et. al (2019). Particularly in areas with limited water resources, these methods reduce water waste and support sustainable water management in agriculture.

Organic agriculture has more purposes than only conserving water. In order to promote resilience in the face of climate change, it integrates techniques that increase biodiversity, strengthen soil health, and provide ecosystem services (Bengtsson J. et al., 2005; Ponisio et al., 2015). Multifunctional organic agriculture prioritises various ecological elements to support a comprehensive and sustainable food production strategy that places a strong emphasis on water efficiency.

By focusing on agroecology, using water-smart irrigation, and avoiding synthetic inputs, organic farming provides a workable route towards sustainable water use while also enhancing agricultural resilience and environmental health.

4.5.3. Irrigation Methods and Agriculture

In agricultural ecosystems, soil qualities have a major impact on water dynamics and are essential for nutrient cycling and water conservation. One important characteristic of soil is its water-holding capacity, which dictates how much water it can hold for crop usage. It changes according on the structure, organic matter content, and texture of the soil. For example, compared to sandy soils, clay soils can hold more water. In addition, the movement and transformation of nutrients like phosphorus and nitrogen—which are critical for plant growth—are part of the nutrient cycle, which is intimately related to water flow.

The diversity of soil types and conditions in various landscapes is one of the main obstacles to regulating soil qualities for water usage efficiency. The availability of nutrients and irrigation techniques are impacted by this fluctuation. For instance, soil moisture and atmospheric variables interact to influence plant water stress in regions with large vapour pressure deficits (VPD), which in turn affects crop output and water usage efficiency. Zhou et al. (2021) show this interplay and its consequences for irrigation management in the face of climate change.

According to recent research, more comprehension of the dynamics of soil water supply and atmospheric demand is essential for developing sustainable irrigation techniques. In comparison to conventional methods, Zhou et al. (2021) research in Nebraska, USA, showed how effective a plant-centric Sustainable Demand-Demand (SDD) irrigation scheme is at reducing irrigation water use by 24.0% while maintaining crop yields. This scheme considers both soil moisture and VPD. This methodology is consistent with the requirement to consider the intricate relationships among soil characteristics, plant physiology, and climate variables.

The difficulties caused by the differences in soil qualities between different regions are also emphasised. The effectiveness of the SDD irrigation scheme varied depending on the soil type and regional climate; areas with fewer sandy soils and lower VPD shown greater benefits. This suggests that regulating soil qualities for agricultural water usage requires region-specific methodologies.

A sustainable agricultural system requires an understanding of and management of soil qualities in relation to water. Innovative irrigation strategies, like the plant-centric SDD approach, have the potential to significantly increase crop yields and water sustainability because they take into account the dynamic interplay between soil moisture, atmospheric demand, and plant physiology. In order to maximise water consumption and nutrient cycling in agricultural systems, future efforts should concentrate on creating region-specific strategies that take into consideration local soil and climatic circumstances. Sustaining global food security and adjusting to the changing climate depend heavily on ongoing study in this field.

4.5.4. Precision Agriculture in Terms of Water Resources Management

Precision agriculture (PA) is a groundbreaking method for managing water resources in the agricultural sector. With the growing importance of addressing water shortages on a worldwide scale, precision agriculture is expected to play a larger role in promoting sustainable water management. Through the utilisation of cutting-edge technology like GPS, IoT sensors, and data analytics, precision agriculture enables the rigorous surveillance and control of soil and crop conditions, resulting in the optimised utilisation of water resources.

Some of the main technology advancements that are propelling precision agriculture forward include:

- Sensor Technology: Soil moisture sensors, drones, and satellite photography offer up-to-date information on the well-being of crops, the state of the soil, and the requirements for water. This data is essential for executing accurate irrigation methods that effectively minimise water waste.
- Automated Irrigation Systems: These systems utilise sensor data to autonomously regulate the quantity of water supplied to crops in accordance with their real-time requirements, thereby minimising runoff and mitigating evaporation.
- Data Analytics: Sophisticated analytics technologies analyse large quantities of environmental and sensor data to forecast irrigation requirements and enhance water utilisation schedules. Precision agriculture significantly influences water conservation. Research suggests that implementing precision agriculture (PA) techniques can result in a significant decrease in water consumption, up to 30%, without compromising crop productivity, and in some cases, even improving it (Browder et. al., (2019). This is accomplished by administering water with precision at the exact time and location it is required, hence avoiding the conventional method of uniformly irrigating.

Although precision agriculture offers advantages, it encounters various obstacles, such as The initial capital required for acquiring state-of-the-art technology and providing training is substantial. The utilisation of advanced analytics in public administration entails a considerable learning process. Additionally, the establishment of a suitable infrastructure for data transmission and processing is essential, which can pose challenges in remote or rural regions.

The outlook for precision agriculture in water resources management appears optimistic, as technology continues to progress and there is an increasing recognition of its advantages. Further advancements in sensor technology and machine learning have the potential to enhance efficiencies and promote more sustainable water usage in agriculture.

4.5.5. Permaculture in Water Resource Management

Permaculture is a holistic design philosophy that integrates land, resources, people, and the environment through mutually beneficial synergies—imitating the no-waste, closed-loop systems seen in diverse natural ecosystems. Its principles are rooted in the core tenets of care for the earth, care for the people, and fair share. When applied to water resources management, permaculture offers innovative and sustainable strategies that enhance water efficiency and foster environmental stewardship.

Permaculture approaches water management with a focus on conservation, collection, and recycling of water through the following practices. This includes:

- Water Harvesting: Techniques such as swales, keyline design, and rain gardens are utilized to capture and redirect rainfall and runoff to areas where it can be absorbed into the soil, recharging groundwater and providing moisture to plants.
- Contouring and Terracing: Modifying the landscape to create level areas and terraces helps reduce runoff and soil erosion, promoting better water infiltration and retention in agricultural and garden areas.
- Mulching and Soil Health: Permaculture emphasizes the importance of organic mulches and soil-building practices to improve soil structure, increase water retention, and reduce the need for supplemental water through irrigation.

Benefits of permaculture are many. E.g. by maximizing the productive use of rainfall and minimizing runoff, permaculture can significantly reduce the dependence on external water sources, especially in water-scarce regions. Permaculture designs often include a diversity of plant species that create habitats for various wildlife, promoting ecological balance and improving the resilience of the landscape. The emphasis on organic practices and soil preservation also leads to healthier soils that are better able to absorb and retain water, reducing erosion and degradation.

One of the challenges associated with permaculture is the need for a comprehensive knowledge of local ecosystems, climate, and soil conditions in order to effectively execute permaculture designs. This requirement may provide a barrier for individuals who are new to permaculture. Certain permaculture techniques require substantial initial labour and resources, such as building ditches or establishing a food forest. Furthermore, in urban environments, specific permaculture methods may encounter regulatory obstacles or a lack of approval from inhabitants who are unfamiliar with these approaches.

With the increasing global awareness of sustainable practices, permaculture is being acknowledged as a practical approach for conserving water and managing landscapes. Permaculture concepts could be more widely adopted, especially in countries experiencing significant environmental degradation and water scarcity, through the implementation of educational programmes, workshops, and policy efforts.

Permaculture provides a viable framework for achieving sustainable water management by harmonising agriculture and landscaping techniques with ecological principles. The global adoption of this practice is a clear indication of the rising dedication to promoting sustainable development and responsible management of the environment.

4.5.6. Discussion

The integration of sustainable management practices in aquatic cultural landscapes, underscores the critical nature of multifaceted approaches to address the complex interplay of ecological, cultural, and socioeconomic factors inherent in these environments. This discussion reflects on the challenges, methodologies, and collaborative efforts required to foster sustainable and resilient aquatic landscapes amid changing global conditions.

Aquatic cultural landscapes are not only ecological assets but also bear significant cultural and historical importance that necessitates a delicate balance in management strategies. The challenges of urbanization, climate change, and unsustainable agricultural and industrial practices continue to threaten these landscapes, leading to increased water scarcity, pollution, and ecosystem degradation. The complexities of managing these landscapes require a comprehensive understanding that bridges ecological health with cultural heritage and community engagement.

The methodologies explored in this chapter, particularly NBS and Integrated Water Resources Management (IWRM), illustrate innovative approaches to landscape management. NBS, for instance, play a pivotal role in enhancing biodiversity, improving water quality, and reducing the impact of floods, which are increasingly pertinent due to climate variability. IWRM offers a framework for managing water resources in a way that balances social and economic needs while ensuring environmental sustainability.

Effective management of aquatic cultural landscapes is deeply rooted in stakeholder collaboration. Engaging local communities, governments, and experts in the planning and implementation processes ensures that the solutions developed are both inclusive and tailored to specific landscape needs. This collaborative approach not only enhances the practical outcomes but also fosters a sense of ownership and responsibility among local populations, crucial for the sustainable stewardship of these landscapes.

4.5.7. Conclusion

This chapter addresses the "Hypotheses on Integrated Water Resources Management (IWRM)" which suggests that a holistic and integrated approach to water resources management is essential for sustaining agricultural productivity and ensuring the sustainability of water resources in both rural and urban settings.

The study examines agricultural and urban water management systems to use IWRM principles. It shows how merging rural, peri-urban, and urban water management approaches can optimise water consumption, efficiency, and sustainability. The chapter shows IWRM-compliant irrigation, precision agriculture, and water conservation approaches. These methods manage water resources holistically, considering land, water, and ecosystem health. By showing these instances, the chapter proves that IWRM may boost agricultural productivity while protecting water resources. IWRM implementation requires stakeholder collaboration and adaptive management, the chapter notes. It shows how including farmers, local communities, officials, and other stakeholders in water resource planning and management improves resilience and sustainability. The idea is supported by the benefits of coordinated water management.

The examination of water management systems within the contexts of agriculture and urban agriculture, provides essential insights into optimizing water use efficiency and sustainability. These conclusions not only encapsulate the strategies that have been evaluated but also suggest pathways for future development and implementation.

Effective water management in both agricultural and urban agricultural settings hinges on the integration of advanced, holistic management practices. IWRM has been identified as a key framework that supports the sustainable use of water resources by balancing social, economic, and environmental needs. The adoption of IWRM in agriculture and urban contexts helps in optimizing water use, enhancing crop yields, and reducing negative impacts on the environment.

NBS have proven to be valuable in improving water efficiency and addressing environmental challenges in both rural and urban agricultural settings. Techniques such as constructed wetlands for agricultural runoff treatment and green infrastructures in urban farms not only reduce water pollution but also contribute to biodiversity and enhance the aesthetic and recreational value of agricultural landscapes. These practices are crucial for sustainable urban and peri-urban development, promoting ecological health alongside agricultural productivity.

Technological innovations, including precision agriculture and smart irrigation systems, play a pivotal role in enhancing water management. These technologies allow for more precise water application, tailored to the needs of crops, which reduces waste and increases efficiency. In urban agriculture, technologies like hydroponics and aquaponics represent sustainable and space-efficient methods that can significantly cut water usage while boosting food production in limited spaces.

Community involvement and strong policy frameworks are essential for the successful implementation of sustainable water management systems. Engaging local stakeholders in the planning and implementation processes ensures that the solutions developed are relevant and adapted to specific local conditions. Furthermore, supportive policies that encourage the adoption of sustainable practices and technologies are critical for large-scale implementation and success.

There is a continuous need for research into more innovative water management practices that can cater to the varying needs of different agricultural contexts. Future research should focus on developing adaptable, scalable solutions that can be applied in diverse geographical and climatic conditions. Additionally, there is a need to assess the long-term impacts of these management systems on both yields and ecosystems to ensure that they provide sustainable benefits over time.

4.6. Urban Agriculture - Food Systems and Water

4.6.1. Introduction

Agricultural activities in urban areas have the potential to indirectly improve urban water management. This is because green spaces with permeable land surfaces allow rainwater and runoff to drain through the soil, which helps to mitigate the negative impacts of increased volumes of runoff during storms. This is particularly important in cities, where the growing areas of hard-covered surfaces such as streets, roofs, and car parks contribute to the risk of floods and landslides. By investing in urban agriculture and promoting the development of green spaces, cities can minimize the need for costly storm water sewers and drainage systems.

In addition to improving urban water management, the direct use of recovered wastewater for food production in cities can also enhance the efficiency of water use, which is especially important in countries with limited water resources. However, the existing nature of most sewage systems, which combine wastewater with numerous pollutants, poses significant challenges for wastewater re-use. Implementing wastewater recycling and re-use requires substantial investments in separation or treatment technologies, as well as improved organizational capacity. Often, investments in water infrastructure and conservation measures are hampered by issues related to land rights.

A successful case study of wastewater recycling can be seen in Dakar, Senegal. In Dakar, two stations have been established for the filtering of used water, which is then used for irrigation after solid waste is collected and transformed into compost. This recycling system demonstrates the potential for sustainable urban agriculture, even in the face of challenges related to the quality of wastewater. However, it is important to note that recycling wastewater is not without its problems. For instance, in Cairo, the use of untreated sewage water for irrigation has resulted in environmental contamination of soils.

While urban agriculture has the potential to improve food security and livelihoods in urban areas, it also poses risks to water resources. One of the main concerns is the increase in pesticide levels in groundwater due to the use of pesticides in agriculture. In order to mitigate this risk, farmers in Cagayan de Oro, Philippines, have started using organic fertilizers. The local government has also launched an Integrated Pest Management (IPM) program to educate and train farmers on sustainable pest control practices. However, the results so far indicate that only a minority of participants have decreased the level of pesticide application, highlighting the challenges in implementing sustainable agricultural practices.

4.6.2. Urban Living Labs for Sustainable Landscape Management

Living Lab is an applied research and knowledge-transfer concept in which experimentation and co-creation take place in a real environment, where a wide range of stakeholders are involved to transfer knowledge and know-how and implement new and innovative products and services. With Living Lab-based interactive value creation by developing sustainable business models based on circular economy, nature-based solutions, community participation, capacity building and regenerative environmental management the adverse impacts of human activities on the threatened ecosystems of lakes and their hydrographic catchment areas can be reduced or eliminated while the economic and social viability of these regions will be secured.

Regarding lakes and wetlands, there are some famous good practices such as the Lake Superior Living Labs Network, embracing the ecosystems of the world's largest freshwater in North America to identify innovative solutions at the intersection of water, food, land, climate, energy, individual and community well-being, or the multinational ALFA wetlands HORIZON project focusing on peatlands, wetlands, and floodplains across Europe to improve the geospatial knowledge base of wetlands from 10 European countries.

Living Labs for lakes often have a vital function of revitalisation and regeneration of habitats, which have been damaged or eradicated through ecosystem fragmentation and/or pollution or excessive use of water resources such as irrigation, water transport, and regulation of rivers, which are essential as water supply for lakes. Living Labs related to freshwater habitats may be created in many different forms and with several functions such as biodiversity conservation of limnic ecosystems, organic agriculture in coastal areas, soil health, aquaponics, bird sanctuaries and bird watching, fishing, and angling, or ecotourism. It is important to point out the social and eco-political significance of living labs, since one of their key functions is knowledge transfer through community participation with an inherent element of formal and informal education being herewith an indispensable part of lifelong learning for regenerative sustainable development.

The hypothesis suggests that ULLs are not just experimental areas, but essential platforms for practical innovation and problem-solving. These laboratories actively include a vast range of individuals and organisations, such as local communities, government agencies, and researchers, to bring together a wide variety of viewpoints and specialised knowledge. ULLs foster a collaborative atmosphere that facilitates the joint design and experimentation of solutions, hence enhancing the adaptability of urban development to the pressing requirements and ever-changing dynamics of urban environments.

Figure 24. Urban living lab, U-garden project, Gothenburg Sweden, Photo: A. Ternell

ULLs exemplify how integrating stakeholder feedback into the development process can lead to more effective and sustainable urban solutions. By involving stakeholders in every step, from conceptualization to implementation, ULLs ensure that the solutions developed are not only innovative but also grounded in the practical realities and needs of urban populations. This approach significantly reduces the risk of mismatches between designed interventions and their practical utility, fostering greater acceptance and sustainability of implemented solutions.

The dynamic nature of ULLs facilitates the use of real-time data and community feedback, making urban projects more adaptable to changes and unforeseen challenges. This dual approach allows ULLs to function as responsive feedback systems, where the efficacy of strategies and interventions can be continuously assessed and adjusted. This adaptability is crucial in urban settings where socio-economic conditions and environmental factors can change rapidly, requiring quick recalibrations of strategies and plans.

To illustrate the impact of ULLs, this chapter explores several case studies where ULLs have been successfully implemented. These examples highlight how ULLs have led to significant improvements in urban areas, including enhanced environmental sustainability, economic viability, and community well-being. The case studies also demonstrate the practical application of theories discussed in this chapter, showing the real-world impact of stakeholder-engaged, data-informed urban planning.

4.6.3. The Dual Impacts of Agroforestry on Irrigation Practices and Environmental Sustainability

Multifunctional refers to how the same land can provide food and wood products, but also job creation, recreation and be a provider of ecosystem services such as pollination, erosion protection and biodiversity. One example is Agroforestry, incorporating trees and shrubs into agricultural environments. It has a substantial impact on irrigation methods, resulting in a wide range of results, including sustainable resource utilisation and environmental deterioration. It is crucial to have a sophisticated comprehension of both the favourable and unfavourable aspects of combining agroforestry with irrigation to maximise the effectiveness of land management techniques.

Figure 25. The structure of a forest garden as an example of agroforestry and multi-functional sustainable land use. Source, Ternell et.al. 2019

Positive practices in agroforestry aim to optimise water utilisation and improve soil fertility. Silvopastoral or agroforestry systems can enhance water efficiency in irrigated environments by minimising water evaporation, promoting water infiltration, and boosting soil structure (Torralba M. et al., 2016). In addition, properly planned agroforestry systems enhance biodiversity by creating habitats for diverse species, facilitating ecological processes that aid in natural pest management, pollination services, and general resilience of the ecosystem (Nair, P. K. R. et. al, 2021). Agroforestry methods, particularly those that include riparian buffers and filter strips, function as biofilters to reduce the negative effects of agricultural runoff on water quality (Amy Quandt, et.al., 2023). The presence of trees and vegetation in these systems acts as a barrier, effectively capturing sediments, nutrients, and agrochemicals, thereby avoiding their introduction into water bodies.

On the other hand, negative practices may arise in the context of agroforestry. The rise of agribusiness is closely linked to deforestation, which presents a substantial risk to sustainable irrigation techniques. This deforestation leads to soil erosion, the decline of biodiversity, and disturbances in water cycles (Earthday.org, 2024). Inadequate irrigation techniques in agroforestry systems can lead to soil degradation, waterlogging, salinization, and nutrient leaching. Moreover, agrochemicals used in certain agroforestry methods, particularly in intensified agriculture, can negatively impact water quality and ecosystems (IUCN Issue brief (2024). Water contamination can occur when excessive chemical inputs from agroforestry regions are carried away by runoff, which can pose threats to aquatic life and downstream consumers.

Figure 26. Agroforestry, Angereds gård, Gothenburg, U-garden project, Photo: A. Ternell

Ultimately, the outcome of agroforestry combined with irrigation hinges on the techniques utilised. The deliberate incorporation of trees into agricultural landscapes, considering their ability to efficiently use water, boost biodiversity, and improve water quality, can have a beneficial impact on the sustainable management of land. On the other hand, the act of clearing forests, the spread of large-scale agriculture, and the use of unsuitable irrigation methods in agroforestry systems can do harm to the environment and create difficulties for water supplies.

4.6.4. The Critical Role of Water Efficiency in Modern Agriculture

Water efficiency is a critical factor in the quest of sustainable and productive agriculture techniques. Farmers can maximise crop yields within the boundaries of limited water resources by optimising production under water constraints, prudent reduction of water waste, and the deployment of cutting-edge technologies (Langemeyer J. et.al., (2021). The multidimensional benefits of water-efficient agricultural methods include not only economic but also environmental factors, such as lower production costs, increased profitability, and a lower carbon footprint (FAO, 2021).

Considering the current challenges faced by climate change, the importance of adopting effective water management methods becomes even more pronounced, emphasising the crucial significance of such practices in preserving the long-term viability of water resources (IPCC, 2021). The implications of improved water use efficiency touch many aspects of the agricultural realm. It primarily enables farmers to navigate and optimise production in the face of water limits, hence alleviating excessive stress on water supplies (UNEP, 2018). The positive effects extend to environmental sustainability through careful management of water resources, resulting in reduced water body contamination through precision water usage and reduced runoff of agricultural inputs such as fertilisers and pesticides (Langemeyer J. et.al., 2021).

The incorporation of cutting-edge technologies appears as an important aspect in increasing water use efficiency. Modern irrigation systems, precision agriculture techniques that leverage new technologies, and creative crop development approaches all serve as important tools for reducing water waste while simultaneously increasing crop yields (Hatfield and Dold, 2019). Case studies from various geographical regions reveal successful paradigms of water usage efficiency, providing empirical proof of such systems' efficacy (FAO, 2021).

Recognising the growing importance of water usage efficiency, governmental and international organisations have launched programmes that encourage farmers to adopt water-efficient methods, hence contributing significantly to successful outcomes (UNEP, 2018; World Bank, 2021). The significant financial and environmental benefits of implementing water-saving techniques highlight the transformative potential of such actions. Notably, lower production costs, together with lower energy consumption related to water pumping and treatment, not only boost farmers' economic success but also help to reduce the carbon footprint connected with agricultural activities (IPCC, 2021; World Bank, 2021).

Water use efficiency in agriculture is therefore critical because of its numerous benefits to sustainability, profitability, and environmental conservation. As climate change worsens, adopting effective water management strategies becomes not only a wise decision, but an absolute must for ensuring the long-term survival of agricultural water resources. Furthermore, the broadcast of successful case studies and the implementation of incentive programmes by governmental and international entities heighten global recognition of the deep influence and requirement of water use efficiency in modern agriculture.

4.6.5. Discussion

Water-Use Efficiency

The discussion section examines the possibilities of water-efficient agriculture, considering the challenges and potential remedies linked to the implementation of water-efficient practices. This study explores the consequences of climate change on agriculture, with a focus on the significance of comprehending the biophysical and socioeconomic elements that impact crop output and water availability. This study analyses and contrasts the possible advantages, in terms of both economic and ecological aspects, of adopting water-efficient strategies in comparison to traditional methods of irrigation.

The concept of water use efficiency relates to the ratio of agricultural output to the amount of water utilized for production. It enables farmers to optimise production using limited water resources, especially in areas experiencing water scarcity or seasonal fluctuations in water availability. Water usage efficiency helps alleviate the burden on water resources by optimising productivity in the face of limited water availability (Gleick, 2003). Efficient water usage is particularly vital in regions where agriculture significantly depends on irrigation, as it ensures the sustainability of crop yield. Moreover, water use efficiency in agriculture has positive environmental impacts. Cutting-edge technologies play a vital role in enhancing water use efficiency. Modern irrigation systems, such as drip irrigation and precision sprinklers, utilize water more efficiently by delivering it directly to the roots of crops, minimizing wastage (Wada et al., 2016). Precision agriculture techniques, such as remote sensing and data analysis, enable farmers to monitor and manage crops' water needs more accurately, leading to optimal water usage (Gleick, 2003). Additionally, crop improvement methods, including the development of drought-resistant varieties, contribute to maximizing crop yields with limited water resources (Wada et al., 2016). These technological advancements collectively contribute to minimizing water wastage and maximizing agricultural productivity.

Governmental and international institutions have implemented proactive steps to encourage water-efficient practices among farmers in response to the increasing importance of water usage efficiency in the agricultural sector. These initiatives are reflected in programmes that provide incentives for adopting water-efficient techniques. These activities, motivated by a shared dedication to sustainable farming methods, have played a crucial role in promoting positive results through means such as increased awareness, financial assistance, and the facilitation of knowledge sharing (Gleick, 2003). The benefits of using water-efficient practices in agriculture are numerous, including significant economic and environmental gains. More precisely, the decrease in production expenses and the reduced energy usage for water pumping and treatment not only improve the financial feasibility of farming activities but also simultaneously help reduce the environmental impact of the agricultural sector.

However, the adoption of water-efficient solutions in agriculture is not without difficulties, since one of the main obstacles is the widespread influence of climate change on both crop yield and water resources. Climate change causes changes in rainfall patterns and worsens the occurrence and severity of droughts, making water management methods more complex (Wada et al., 2016). The key focus here is to understand the complex interaction between biophysical and social factors that impact both crop productivity and water availability. Efficient planning and management techniques are crucial for adjusting to changing climatic circumstances and implementing wise water-saving measures to protect sustainable water resources.

Urban Agriculture

Urban agriculture can have both positive and negative impacts on urban water management. On one hand, it can indirectly improve water management by promoting permeable land surfaces and reducing the need for costly storm water infrastructure. On the other hand, it can pose risks to water resources, such as pollution from untreated sewage water and pesticide contamination. As urban agriculture continues to expand, it is crucial to implement sustainable practices and invest in water infrastructure and conservation measures to ensure the long-term viability of urban farming.

Urban agriculture presents a unique opportunity for cities to address the challenges of sustainable development, food security, and environmental management. However, there are several implications for urban policies and programs that need to be considered to fully capitalize on the potential benefits of urban agriculture.

One of the key issues is the traditional focus of agricultural policies on short-term profits rather than long-term environmental management of local resources. This focus on profit maximization often neglects the environmental impacts of agricultural activities, leading to unsustainable practices. Urban managers and planners need to shift their mindset and recognize the importance of agriculture in urban areas, even if it generates relatively low yields compared to other sectors.

Furthermore, urban agriculture faces several political restraints that hinder its development (Tuijl E.V. et al. (2018). These include restrictive urban policies, laws, and regulations, mainly due to the illegal status of urban agriculture. Uncertainty about property rights of land also poses a challenge for urban farmers. Additionally, there is a lack of supportive services, such as access to finance and technical assistance, as well as the unfeasible implementation of environmental technologies. Moreover, the lack of organization and representation of urban farmers further hampers their ability to overcome these challenges.

To address these issues, it is crucial to provide urban farmers and consumers with more information and training on environmental risks and sustainable agriculture practices. The engagement of urban populations in food production necessitates a better understanding of techniques such as wastewater treatment and composting. Cities are increasingly using agricultural waste to curb pollution and optimize freshwater usage, making it essential for urban dwellers to be aware of the potential risks and benefits associated with these practices (Reijntjes et al. (1992)).

Disseminating good practices in urban agriculture to farmers and consumers is also vital. Policymakers can play a significant role in supporting farmers and consumers in building up knowledge about the opportunities of urban agriculture for protecting city ecology (Barrs V., 1997). National governments should adopt pesticide reduction targets and promote biological pesticides and fertilizers to reduce environmental risks associated with agriculture. Additionally, governments need to provide funds for information and grant-aid schemes to assist farmers in transitioning to less chemically intensive systems.

However, it is important to note that increasing yields through resource-intensive production methods is not a sustainable solution. Many small-scale farmers in developing countries recognize the depletion of natural resources that accompanies resource-intensive practices. Instead, a focus on making production systems more productive and sustainable is necessary. Development workers need suitable instruments for cooperation with farmers to support them in adopting environmentally friendly farming techniques.

Setting the right conditions for urban agriculture involves developing an urban agriculture plan and policy that recognizes the interrelated nature of food, agriculture, health, and ecology. This requires the establishment of a municipal working group that can deal with food issues from a total system perspective. Collaboration between various departments such as health, planning, engineering, local economic development, water management, and waste management is crucial for the successful integration of urban agriculture into land-use planning systems.

Labelling food to indicate its production methods and origin can also contribute to sustainable approaches to production. Programs like the "BUY BC" campaign in British Columbia, Canada, encourage the purchase of locally-grown food and products, with strict guidelines for production and farm management. Such initiatives enable consumers to make informed food choices that support sustainable practices and contribute to a healthier food system.

Access to capital and credit is essential for starting urban food-production businesses. However, many urban farmers face difficulties in obtaining sufficient funding. Government bodies can play a role in addressing this issue by offering start-up grants or loans for small urban agricultural businesses. Subsidization of inputs, such as municipal compost, can also stimulate projects. These policy interventions can provide favourable conditions for city farmers (Barrs V.1997)

In conclusion, to harness the potential of urban agriculture, cities must develop policies focused on encouraging the productivity of open urban space and integrating the various components necessary to make urban agriculture healthy and sustainable. Urban agriculture can contribute to the availability of healthy, culturally appropriate food, particularly for low-income groups. While local food production cannot fully replace the need for income, it can significantly contribute to adequate and culturally appropriate sources of human nutrition.

Agroforestry

Agroforestry, the practice of integrating trees and shrubs into agricultural environments, presents both positive and negative implications for land management, particularly in the context of irrigation. It is crucial to understand and evaluate these aspects to effectively maximize the benefits and mitigate potential drawbacks of combining agroforestry with irrigation.

Positive practices in agroforestry are geared towards optimizing water utilization and enhancing soil fertility. Silvopastoral or agroforestry systems can play a crucial role in improving water efficiency in irrigated environments. They achieve this by reducing water evaporation, facilitating water infiltration into the soil, and enhancing overall soil structure. These practices not only conserve water but also contribute to soil health and productivity. Additionally, well-planned agroforestry systems foster biodiversity by creating habitats for diverse species. This, in turn, supports ecological processes such as natural pest management, pollination services, and the overall resilience of the ecosystem. Agroforestry systems, particularly those incorporating riparian buffers and filter strips, serve as effective biofilters that help mitigate the negative impacts of agricultural runoff on water quality. Trees and vegetation in these systems act as barriers, capturing sediments, nutrients, and agrochemicals, preventing their release into water bodies.

Negative practices in agroforestry often arise due to deforestation, often linked to agribusiness expansion. This deforestation poses a significant risk to sustainable irrigation techniques, leading to issues such as soil erosion, loss of biodiversity, and disruptions in water cycles. Inadequate irrigation techniques within agroforestry systems can result in soil degradation, waterlogging, salinization, and nutrient leaching, all of which can undermine agricultural productivity and environmental health. The use of agrochemicals in certain agroforestry methods, especially in intensified agriculture, can have adverse effects on water quality and ecosystems. Water contamination can occur when excessive chemical inputs from agroforestry areas are carried away by runoff, posing threats to aquatic life and downstream consumers.

The overall outcome of combining agroforestry with irrigation largely depends on the specific techniques employed. Deliberate and well-planned incorporation of trees into agricultural landscapes, considering their ability to conserve water, enhance biodiversity, and improve water quality, can have a positive impact on sustainable land management. These practices can contribute to long-term environmental resilience and enhanced agricultural productivity. However, when agroforestry is associated with deforestation, large-scale agriculture, and unsuitable irrigation methods, it can harm the environment and create challenges for water supplies. Hence, careful consideration of practices, adherence to sustainable principles, and continuous monitoring are essential for harnessing the full potential of agroforestry in conjunction with irrigation while mitigating its negative impacts. Achieving a balance between agricultural productivity and environmental preservation is crucial for the sustainable future of agroforestry systems.

4.6.6. Conclusion

This chapter addresses the "Hypotheses on Urban Living Labs," which posits that urban living labs enhance sustainable urban development by fostering innovative collaboration between stakeholders and integrating real-time data and community feedback into planning and implementation processes.

The research explores the role of urban agriculture in the context of food systems and water management, demonstrating how urban living labs can be instrumental in these areas. The chapter provides examples of urban agriculture projects that serve as living labs, where new practices and technologies are tested and refined in collaboration with local communities. It further highlights how urban living labs facilitate stakeholder engagement, bringing together residents, researchers, policymakers, and businesses to co-create sustainable solutions. This collaborative approach aligns with the hypothesis by showing how real-time data and community feedback are integrated into urban agriculture initiatives, leading to more responsive and effective solutions.

Water Use Efficiency

Water use efficiency is essential for sustainable and productive agriculture. It enables farmers to achieve higher agricultural output with limited water resources, reduces negative environmental impacts, and contributes to the conservation of natural resources. This article explores the various aspects of water use efficiency in agriculture, including its significance, effects, cutting-edge technologies, case studies, government programs, financial advantages, environmental benefits, and challenges posed by climate change. It is a comprehensive look at the future of water-efficient agriculture and illustrates the difficulties and solutions associated with implementing water-efficient strategies.

The investigation draws on comprehensive data and projections encompassing global water consumption, climate change, and agricultural production dynamics. Region-specific analyses spotlight the impact of water stress on diverse geographical areas, with an emphasis on drylands and tropical/subtropical zones. Additionally, the study scrutinizes the efficacy of water management strategies in enhancing water efficiency and bolstering crop yields.

Projections indicate that global water consumption is expected to increase by 25% by 2050 due to factors such as population growth, industrial expansion, and agricultural development (Gleick, 2003; Wada et al., 2016). This sudden increase, along with less rainfall in some areas, is likely to intensify worldwide water scarcity levels. Climate change serves as an exacerbating element, causing elevated temperatures and modifying rainfall patterns, thereby increasing the pressure on water resources. Dryland regions and rural populations are anticipated to experience a disproportionate amount of hardship, resulting in negative impacts on both agricultural output and economic progress. Under a scenario where things continue as they are, it is estimated that agricultural production will increase by 70%. However, this growth is expected to be 10% lower compared to a scenario where there is no climate change. This is mainly because of water shortages and higher temperatures.

Water management is crucial in mitigating the repercussions of water stress on agricultural production (Falkenmark et al., 2007). It advocates for heightened water efficiency and conservation techniques, particularly in irrigated areas, as crucial measures to fortify crop yields and bridge yield gaps arising from water shortages. Furthermore, the ecological ramifications of water abstraction and the depletion of non-renewable groundwater reserves are considered, emphasizing the imperative for sustainable water management practices. While advancements in land and water management offer potential solutions to alleviate the impact of water shortages, certain regions may confront substantial challenges in meeting ecological flow requirements and ensuring the long-term sustainability of water resources.

Urban Agriculture

The integration of agricultural activities into urban areas holds significant promise for enhancing urban water management and promoting sustainable water use. The creation of green spaces with permeable land surfaces can effectively mitigate the adverse effects of increased stormwater runoff in cities, thereby reducing the need for costly stormwater sewers and drainage systems (Langemeyer J. et.al., (2021). Additionally, the direct utilization of treated wastewater for urban agriculture can contribute to water efficiency, particularly in regions with limited water resources (Brown and Farrelly, 2021).

Nevertheless, challenges persist in the widespread adoption of wastewater recycling and urban agriculture. The quality of wastewater, often containing pollutants, poses a hurdle that requires substantial investments in separation and treatment technologies, as well as organizational capacity improvement (Mara D. et al., 2010). The case study in Dakar, Senegal, provides a successful example of overcoming such challenges, with established stations effectively filtering used water for irrigation after transforming solid waste into compost (Goundo et al., 2016).

Moreover, while urban agriculture holds promise for improving food security and livelihoods in urban areas, it introduces potential risks to water resources. Pesticide use in agriculture poses a threat to groundwater quality, exemplified by elevated pesticide levels in Cagayan de Oro, Philippines (Baldwin A. H. et al., 2021). Initiatives such as the use of organic fertilizers and Integrated Pest Management (IPM) programs aim to address this concern, yet the challenges in implementing sustainable agricultural practices are evident, with only a minority of participants reducing pesticide application (Haque et al., 2017).

The dual potential of urban agriculture to ameliorate water management and enhance food security necessitates a holistic approach. Comprehensive strategies must address challenges related to wastewater quality, promote sustainable agricultural practices, and include community education and engagement to ensure the long-term success and resilience of urban agricultural initiatives.

Lastly, to fully realize the potential of urban agriculture, there needs to be a focus on encouraging the productivity of open urban space, integrating various components to make urban agriculture healthy and sustainable, and addressing bad practices where necessary. Urban agriculture can contribute to the availability of healthy, culturally appropriate food, particularly for low-income urban populations. However, it should be recognized that local food production may never replace the need for a decent income, but it can significantly enhance sources of human nutrition.

Agroforestry

Agroforestry presents a complex array of impacts when coupled with irrigation, demanding a nuanced understanding for effective land management and sustainable resource utilization. Favourable practices in agroforestry, exemplified by silvopastoral systems, hold the potential to optimize water use and bolster soil fertility. These techniques excel in improving water efficiency by curbing evaporation, facilitating water infiltration, and enhancing soil structure. Moreover, they foster biodiversity, promote ecological processes, and function as effective biofilters, safeguarding water quality.

On the other side, negative practices and challenges loom large in the agroforestry-irrigation nexus, particularly in the face of deforestation driven by agribusiness expansion. This phenomenon poses significant risks, including soil erosion, loss of biodiversity, and disruptions in water cycles. Inadequate irrigation methods within agroforestry systems can exacerbate issues such as soil degradation, waterlogging, salinization, and nutrient leaching, as outlined by IUCN Issue brief (2024). Additionally, the use of agrochemicals, especially in intensified agriculture, has raised concerns over water quality and ecosystem health, as observed in studies by Mohotti, A.J. et.al. (2020).

To harness the full potential of agroforestry in conjunction with irrigation while mitigating negative impacts, a balanced approach is imperative. This requires the deliberate selection of techniques that align with sustainable principles, careful monitoring of practices, and the promotion of responsible land management strategies. Achieving this equilibrium between agricultural productivity and environmental preservation is crucial to unlock the promise of agroforestry as a potent tool for addressing resource conservation and food security in a rapidly changing world.

4.7. Existing Policies and their Effectiveness

4.7.1. Introduction

In an era marked by escalating environmental and societal challenges, the scrutiny of existing policies and their efficacy in addressing such issues is crucial. This chapter discuss the policies currently in place to manage environmental sustainability, resource utilization, and social equity. It evaluates the success and shortcomings of these policies, considering their impacts on both local and global scales.

As we navigate through complex issues such as climate change mitigation, resource conservation, and equitable social development, the effectiveness of governmental and institutional policies becomes increasingly pertinent. This chapter aims to uncover the strengths and weaknesses of these policies, offering insights into their practical outcomes and the extent to which they meet their objectives.

By examining case studies and statistical data, this chapter will assess the real-world implications of these policies. It will explore various policy frameworks across different regions and sectors, highlighting innovative approaches and identifying gaps where improvements are necessary. This analysis is crucial for policymakers, stakeholders, and researchers as they seek to enhance the current policy measures or develop new strategies to better address the pressing challenges of our time.

This exploration not only contributes to a deeper understanding of policy effectiveness but also sets the stage for future policy enhancements, ensuring that they are more aligned with sustainable development goals and responsive to the dynamic needs of society and the environment.

4.7.2. Effectiveness of Existing Water Management Policies

The growing challenge of managing water resources sustainably under the pressures of climate change, urbanization, and agricultural demands calls for a critical evaluation of existing policies and their effectiveness. This assessment aims to provide a comprehensive overview of current water management strategies, identifying areas of strength and opportunities for improvement, with a view towards integrating the concrete recommendations outlined previously.

Recent studies and reports indicate that while many regions have adopted policies aimed at conserving water resources and promoting sustainable management practices, the effectiveness of these policies varies significantly. For example, policies promoting grey infrastructure for flood control and water management have shown limitations in adaptability and resilience, particularly in the face of extreme weather events exacerbated by climate change (Ncube, S & Arthur, S, 2021; Bwambale E. et al.2022). These findings underscore the necessity for a paradigm shift towards incorporating Nature-Based Solutions (NBS) and sustainable practices as central components of water management strategies.

Nature-Based Solutions, such as wetland restoration and green infrastructure, have been internationally recognized for their multifaceted benefits, including flood mitigation, biodiversity enhancement, and social well-being improvement (Cohen-Shacham et al., 2016; Costanza R. et al., 2017). However, the adoption of NBS remains limited due to factors such as lack of awareness, insufficient policy support, and financial constraints. This gap highlights the critical need for policymakers and stakeholders to incentivize NBS through financial mechanisms and enhanced policy frameworks, as recommended earlier.

Furthermore, cross-sector partnerships have emerged as a crucial strategy for addressing the complex challenges of water management (Environmental Protection Agency, 2023). Such collaborations can leverage diverse expertise and resources, fostering innovative solutions that are scalable and adaptable to different contexts. Yet, the establishment of effective partnerships often encounters obstacles, including bureaucratic hurdles and misaligned objectives among stakeholders, pointing to the need for policies that facilitate collaboration and shared goals.

Investments in research and development are essential for advancing sustainable water management technologies and practices. Despite this, funding for water-related research remains insufficient in many regions, limiting the development and implementation of innovative solutions (Fletcher et al., 2013; Kayhanian, M. 2019). Policymakers must prioritize and allocate adequate resources towards research and development to catalyze advancements in this field.

Furthermore, educational and outreach initiatives are instrumental in promoting sustainable water management practices. These efforts, essential for enhancing stakeholder understanding and participation, often face limitations in reach and resources. Expanding these programs, as suggested, could markedly facilitate the widespread adoption and effective application of sustainable practices.

Lastly, the efficiency of current water management policies is compromised by the lack of comprehensive vulnerability assessments that accurately reflect the impacts of climate change and urbanization. The existing frameworks often fall short in providing the necessary depth and breadth of analysis, highlighting the critical need for the development of detailed assessment methodologies to guide targeted and proactive water conservation and management strategies.

4.7.3. Enhancing Policy Initiatives for the Adoption of Nature-Based Solutions through Social Marketing

The effectiveness of policy initiatives in promoting the adoption of NBS and multifunctional agriculture hinges not only on informed political decision-making but also on active engagement and value shaping among social actors (Toledano M., 2006). To this end, it is crucial to integrate professional expertise from the field of social marketing to facilitate this process.

As Toledano M. (2006) points out, effective policy creation for NBS entails more than simply alerting politicians about the benefits and technical features of these solutions. It demands a comprehensive approach that takes into account the social factors that impact policy acceptance. The involvement of social marketing specialists is critical in creating and conducting initiatives that successfully communicate the value of NBS to the general public and key stakeholders.

Social marketing plays a critical role in shifting cultural beliefs and behaviours towards more sustainable practices. Social marketing professionals can use focused communication tactics and public engagement campaigns to improve awareness, enhance public support, and build demand for sustainable practices like NBS and multifunctional agriculture. This societal pressure, in turn, persuades government leaders to act and support environmentally friendly legislation. The literature (Rodriguez-Sanchez, C., 2023) discusses various approaches to social marketing:

- Value Shaping: Social marketing experts can craft messages that resonate with the community's values and aspirations, emphasizing the direct benefits of NBS and multifunctional agriculture, such as enhanced community well-being, biodiversity conservation, and economic opportunities. These messages help reshape perceptions and encourage a broader acceptance and adoption of sustainable practices.
- Mobilization of Social Actors: By engaging community leaders, local organizations, and citizens, social marketing campaigns can mobilize these groups to advocate for policy changes. Mobilization involves organizing events, workshops, and public forums where community members can learn about the importance of NBS and participate in discussions on local environmental challenges.

The spread of multifunctional agriculture practices also benefits significantly from the engagement of social actors who can be the practical users of these systems. As farmers and local landowners see the societal support and the policy incentives aligned with multifunctional agriculture, their willingness to adopt these practices increases. Social marketing can highlight successful case studies and provide platforms for knowledge exchange, further promoting the uptake of these practices.

To ensure the successful implementation of these strategies, the following policy recommendations are proposed (Rodriguez-Sanchez, C., 2023):

- Integration of Social Marketing into Policy Development: Policy frameworks should include provisions for social marketing strategies that educate and engage the public in sustainability initiatives.
- Support for Professional Training: Encourage the development of expertise in social marketing within environmental sectors by supporting professional training and development programs.
- Creation of Multi-Stakeholder Platforms: Establish platforms that bring together policymakers, marketers, environmental experts, and community leaders to collaborate on the design and implementation of NBS and multifunctional agriculture initiatives.

4.7.4. Discussion and Future Policy Initiatives

Future water management policies must shift towards comprehensive plans that address the multifaceted issues posed by climate change, while also acknowledging the increased frequency and intensity of extreme weather events and their effects on aquatic environments. As Bridgewater, P., Kim, R.E. (2021) point out, this needs a paradigm change towards creating resilient infrastructure and implementing management approaches capable of minimising the consequences of floods, droughts, and sea level rise. The incorporation of climate change adaptation measures into water management policy is no longer discretionary, but rather required to protect our aquatic ecosystems and the communities that depend on them.

Furthermore, an enhanced cross-sectoral integration is crucial for the sustainable management of water resources. A holistic approach that considers land use, agriculture, urban development, and environmental protection is vital for addressing the complexities of water management. Such an integrated strategy underscores the importance of holistic watershed management and necessitates coordination across various government departments and sectors, ensuring that upstream-downstream interactions are considered in policy formulations.

The role of community participation and local governance in water management cannot be overstated. Encouraging active involvement of communities in decision-making processes and leveraging local knowledge and governance mechanisms can significantly enhance the effectiveness of water management strategies. Policies should, therefore, foster citizen science initiatives and local stewardship programs, creating avenues for communities to contribute meaningfully to the sustainable management of their water resources.

Promoting Nature-Based Solutions (NBS) should be a cornerstone of future water management policies. NBS, including wetland restoration and the integration of green infrastructure, offer a multitude of benefits ranging from biodiversity conservation to improved water quality. Providing incentives for the incorporation of NBS in urban planning and agricultural practices not only aligns with sustainable development goals but also ensures the resilience of water management infrastructures against climate-induced challenges.

To ensure the successful implementation of these policies, strengthening monitoring and compliance mechanisms is imperative. Implementing robust monitoring systems to track changes in policy implementation and water quality, alongside enhancing compliance mechanisms with penalties for non-compliance and rewards for best practices, is crucial for maintaining the integrity and effectiveness of water management policies.

Investment in research and development is essential for pioneering sustainable water management technologies and practices. Supporting public-private partnerships and encouraging innovation in water management can lead to breakthroughs that redefine how we interact with our water resources. Such policies should aim to foster a culture of innovation, bridging the gap between scientific research and practical applications in water management.

Lastly, global collaboration and knowledge sharing play a pivotal role in addressing the shared challenges in aquatic landscape management. Policies that enhance international cooperation and facilitate the exchange of best practices and technological advancements can significantly contribute to global water security. Supporting capacity building in developing countries through knowledge sharing initiatives is vital for ensuring that no community is left behind in the quest for sustainable water management solutions.

4.7.5. Conclusion

This chapter evaluates the current policies related to water management and conservation practices, assessing their effectiveness in promoting sustainable outcomes. It directly relates to the "Hypotheses on Nature-Based Solutions (NBS) and Water Management," which posits that nature-based solutions are essential for effective water management and can provide sustainable alternatives to traditional grey infrastructure.

The study critically explores policies that promote or hinder NBS use in water management. It shows how well present policy frameworks support NBS principles, which emphasise using natural processes and ecosystems to manage water. A number of policies have successfully integrated NBS into water management initiatives. These policies show how NBS improves water retention, flood risk, and quality. These policies demonstrate that NBS are sustainable and resilient alternatives to grey infrastructure by supporting wetlands restoration, green infrastructure, and riparian buffers. The chapter also addresses policy gaps and obstacles to NBS adoption. Policy reforms are needed to integrate NBS into water management practices. Incentives for NBS use, regulatory reform, and stakeholder participation are needed. The chapter emphasises the necessity of strong policy frameworks in NBS implementation by addressing these deficiencies.

Reflecting on the wealth of insights from recent studies, it becomes increasingly clear that the future of water management lies in adaptive, integrated, and participatory approaches. Highlighting the essence of community involvement, Barkdull, J & Harris, P. (2002) underscore the transformative potential of community-led initiatives in steering water management towards sustainability. Complementing this perspective, Green et al. (2023) advocate for a dual approach to tackle emerging contaminants, emphasizing the indispensable role of regulatory measures alongside breakthroughs in scientific research and technological innovation.

Despite the strides made by existing policies in addressing various water resource challenges, there remains a discernible gap between current practices and the evolving demands of sustainable water management. The series of recommendations proposed earlier charts a course for bridging this gap. By incentivizing Nature-Based Solutions (NBS), fostering cross-sector partnerships, refining policy frameworks, bolstering research and development, initiating educational and outreach programs, conducting thorough vulnerability assessments, encouraging community engagement, and implementing robust monitoring and evaluation mechanisms, we can pave the way for a more sustainable, resilient, and efficacious management of water resources.

Climate change, urbanisation, and antiquated management approaches all exacerbate the challenges of achieving sustainable water resource management. However, we may navigate these challenges by coordinated efforts and deliberate interventions. Financial incentives for NBS can catalyse a change towards more environmentally friendly practices in land management, urban design, and agriculture, thereby increasing biodiversity and improving water quality. Cross-sector partnerships can combine the capabilities and resources of multiple stakeholders, resulting in innovative and scalable solutions. An altered policy framework that truly combines NBS and sustainable practices will make these approaches more realistic and vital to water resource management.

Furthermore, investment in research and development is critical for uncovering new knowledge and technologies that can revolutionize water management. Educational and outreach initiatives are vital in building widespread awareness and understanding, empowering stakeholders to contribute actively to water sustainability efforts. Comprehensive vulnerability assessments will ensure that policies are informed and proactive, addressing the specific risks and challenges posed by climate change and urbanization. Finally, engaging local communities in water management decision-making processes and emphasizing the importance of monitoring and evaluating policy outcomes will ensure that strategies remain relevant, effective, and accountable.

4.8. Sustainable Urban Agriculture through Multifunctional Partnerships

4.8.1. Introduction

Climate change presents critical challenges to agriculture and forestry, especially in the context of increasing risks from storm damage, insects, and fungi. Multifunctional sustainable land use, which offers diverse benefits such as food and wood products, job creation, recreation, and ecosystem services like pollination and erosion protection, is emerging as a resilient response to these risks. Urban farming has gained attention for its multiple advantages, including a sense of belonging and food production. This chapter explores the intersection of urban farming with traditional agriculture and forestry in peri-urban areas - the suburbs and outskirts of cities, where opportunities for new, innovative initiatives abound.

4.8.2. Evaluating Business Potential and Sustainable Practices in Urban Agriculture

Multifunctional land use, such as agroforestry, can also be expressed in contrast to monocultures, as shown in Figure 27 The figure is, in simplified terms, visualising the differences between monocultures and agroforestry. Monocultures maximise crop production or forest production.

Whereas agroforestry prioritises both crop and forest production. Most often, the production is not as high as for monocultures. However, several other values can be higher in these systems, such as restoring, preserving, and strengthening habitats and biodiversity, water flow regulation, water quality regulation, carbon sequestration, regional climate and air quality regulation as well as infectious disease mediation.

A comprehensive study was conducted to map green business resources. It revealed a predominant focus on large-scale agricultural monocultures with traditional, low-value products. These practices were not optimally leveraging their proximity to urban markets. Notably, there was a distinct lack of sustainable business models and innovation within the agriculture sector. This indicates a missed opportunity for integrating modern, environmentally conscious practices in these settings.

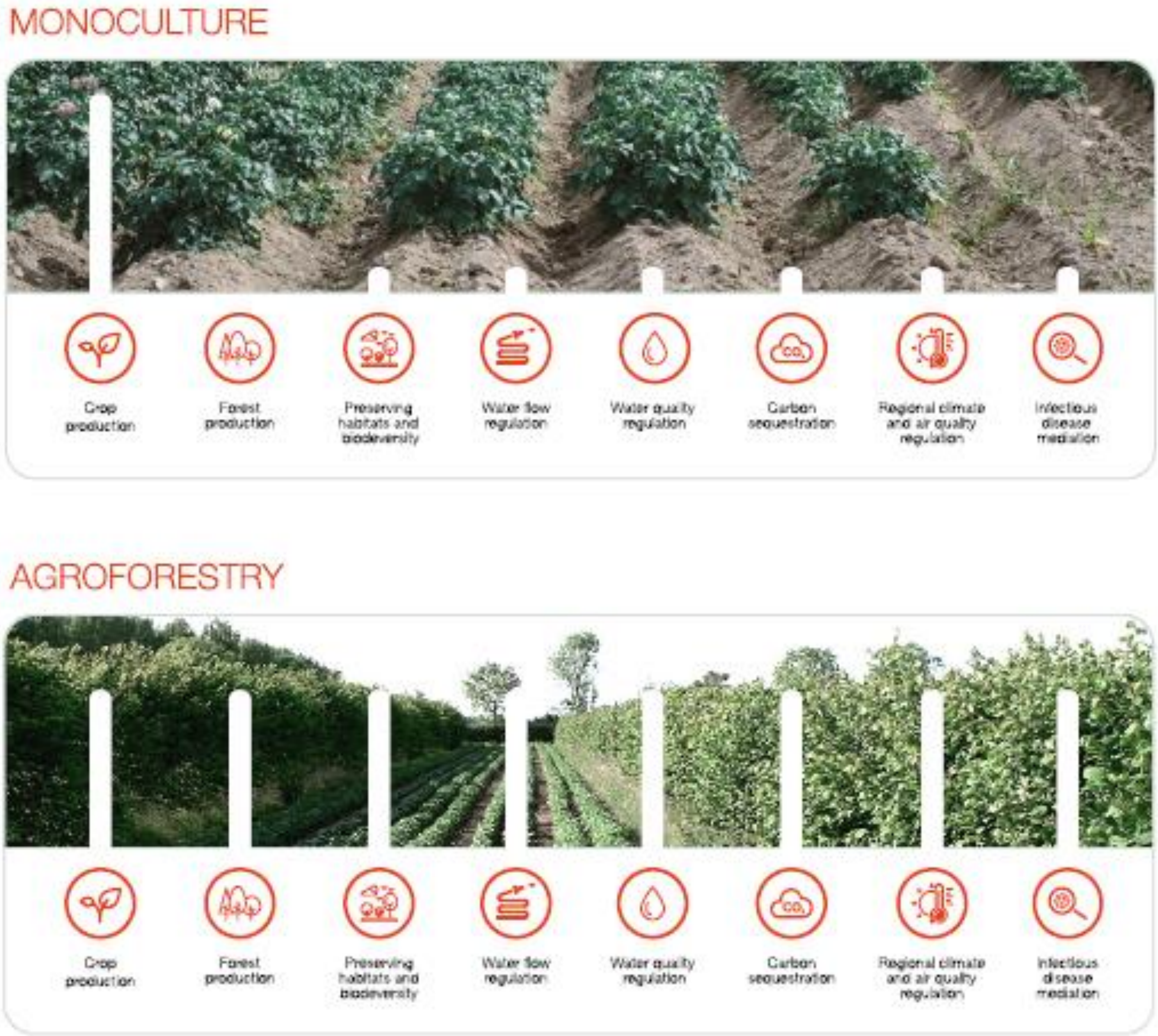

Figure 27. Differences between monocultures and agroforestry, Source: Ternell et.al. 2020

Gothenburg emerged as a frontrunner in urban cultivation, gaining national and international recognition. The Property Management Department played a crucial role in developing methods for urban space cultivation and co-creation. The city's commitment to urban agriculture was exemplified through the Vinnova project 'Stadsbruk' and ‘SATURN project’, which aimed to develop agricultural land for ecological food production and support commercial urban farming initiatives.

4.8.3. Multifunctional Stakeholder Collaboration

Multifunctional stakeholder processes represent a collaborative approach to sustainable development, involving a wide range of participants including local government entities, academic institutions, industries, civil society, and local residents. This method fosters cooperation across different sectors, which is essential for addressing the complex challenges of urban and peri-urban development.

One of the key advantages of this approach is its ability to devise innovative financing models that encourage both public and private sector investment. An example of such a model is the Business Improvement District (BID), which enhances urban areas by pooling resources from property owners and retailers to fund physical enhancements and marketing efforts. This collective investment model minimizes free-rider issues and ensures that improvement efforts are more effective and inclusive.

BENEFITS OF MULTI STAKEHOLDER PROCESSES

- Wider knowledge and exchange of experiences
- Synergy effects
- Better decision making through participation
- Co-financing opportunities
- Sharing economy
- Market benefits

CHALLENGES

- Administrative borders between municipalities, with different agendas, resources and municipality regulations
- Political agendas and objectives
- Different levels of participation
- Parties with different resources
- Different objectives
- Involvement of other sectors can create challenges due to different agendas and funding

LESSONS LEARNT

- Bottom up must meet top down
- Share ownership of the processes at an early stage
- Anchoring in public structures takes time
- Private sector work faster and wants faster results than the public sector
- Goals must be handled as there are conflicts of interest

Figure 28. Benefits, challenges, and lessons learnt on multi-stakeholder processes from Region Västra Götaland/Västarvet LAB190 platform.

Another significant benefit of multifunctional stakeholder processes is the empowerment of small-scale entrepreneurs to invest in green businesses. Typically, individual stakeholders face challenges in driving sustainable development due to limited resources and lack of collaboration. This approach helps bridge the gap between various actors, facilitating the development of a resilient local economy through shared knowledge, distribution channels, and other resources.

These processes also improve decision-making by ensuring that the perspectives of all key stakeholders are considered and integrated throughout the decision-making process. This is achieved through continuous dialogue and consensus-building, which not only leads to more informed and comprehensive decisions but also builds trust among participants.

The participatory nature of this approach engenders a strong sense of ownership among stakeholders. By actively involving them in the decision-making process, stakeholders are more likely to understand and commit to the outcomes, thereby increasing the likelihood of compliance and successful implementation of strategies.

Experience from platforms like the regional cooperation platform LAB190 has demonstrated multiple benefits of multifunctional stakeholder processes. These include synergy effects in physical planning across municipal boundaries and the optimization of resources through shared funding. For instance, in the Stadsbruk project, private entrepreneurs benefit from exchanging knowledge and experiences, which enhances their operational capacities and market reach.

4.8.4. The Role of Urban Agriculture in Urban Metabolism

Since most cities have seriously damaged ecosystems, establishing environmentally, socially, and economically viable forms of organic urban and peri-urban agriculture requires a thorough environmental, social, and economic assessment, a detailed resource audit and land inventories to identify necessary changes in land use, reconstruct or design new ecosystems, develop appropriate infrastructure, support local businesses, and enhance community participation, local and regional sustainability agendas. The environmental economic issues of urban agriculture concern many areas such as:

- Land use and consequences of land use change
- Multifunctional land use and the multifunctionality of agriculture
- Environmental remediation strategies of polluted urban areas
- Ecosystem design, biodiversity, and creation of new habitats
- Soil conservation and remediation
- Groundwater remediation of polluted sites
- Water resources management and wastewater purification
- Urban ecology and assessment of urban ecosystems and their carrying capacity in view of urban evolution and climate change
- Urban agricultural production systems and their economic viability
- The economic viability of low input organic agriculture in urban and peri-urban areas
- Waste management based on reuse and life cycle assessment (lca)
- Renewable energy production and energy mix linked to ecological cycles
- Waste-to-energy strategies
- Restoration or construction of urban-rural ecosystem-continuities and ecotones
- Urban–rural ecological networks for landscape planning
- Co-operative methos of civic involvement in spatial planning
- Innovative development of grey-green and blue-green infrastructures to mitigate the adverse impact of climate change in cities
- Development of local and regional sustainable business models
- Shortening food supply chains through urban agriculture
- Developing new ‘looped’ value chains based on circular economy in urban agriculture

Furthermore, the conversion of natural ecosystems, such as forests, grassland, wetlands into agricultural land is causing deforestation in many places, draining the soil, which will eventually become unsuitable for production and lead to desertification. The long-term economic consequences of such environmental deterioration are obvious. Moreover, by expropriating farmland, we are contributing to the adverse impacts of climate change. About 15 percent of the planet is specifically barren as desert, glacier, or karst land, but this does not matter for indoor production, where vertical farms can produce up to 100 times more per square metre, since they can operate all year round, and farmers can think in three or, rather, four dimensions taking into consideration even the longer time available for cultivation (Andersen, 2022). Thus, by growing on rooftops, in parks, greenhouses and buildings to create economic, social, and ecological sustainability, urban farming has multiple benefits. It can supply the city with locally produced food, which reduces the need for transport and generates economic sustainability for both society and businesses, while teaching people more about food production. In addition, urban farming contributes to ecological sustainability as it can close the city's cycle and create a unique urban metabolism (Fig. 29) that enables the creation of a self-sufficient system. A prerequisite for urban farming to be sustainable is that it uses the nutrients that already exist in the city and does not transport artificial fertilisers and animal manure over long distances (Mendes et al. 2008). Composting food, often by co-fermenting it with sewage sludge, that would otherwise be thrown away, makes it possible to utilise the nutrients available in the city to grow new food, contributing to closing the urban ecological cycle processes.

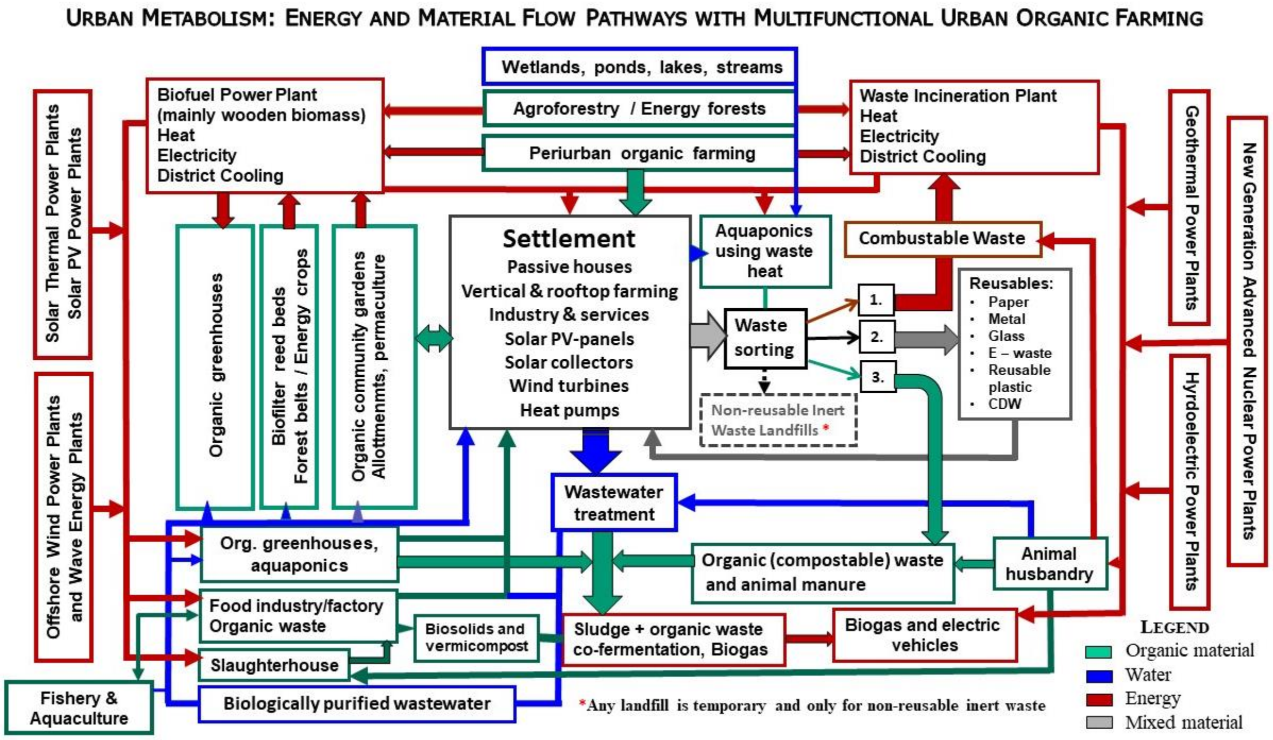

Figure 29. Urban metabolism illustrating the ecological cycle processes and the material and energy flows in green urban ecosystems, with well-developed multifunctional and organic urban and peri-urban agriculture. Important to emphasize the importance of sustainable energy mix and the ecocycle-approach based on the energy-product/service-reuse-zero waste concept. Source: own design.

Several challenges such as high investment costs, development of new technologies, new materials or cultivation methods and high energy consumption are perceived obstacles that can be solved with today's technology and a healthy systems approach. Here an urban metabolism chart is presented, with all the relevant material and energy flows, including the main urban agriculture systems:

1. Community gardens
2. Vertical farming
3. Rooftop farming
4. Aquaponics
5. Indoor Hydroponic Systems
6. Aeroponics
7. Local seed farms
8. Living Gene bank
9. Marine allotments

10. Testbeds
11. Urban agroforestry
12. Temporary rooms in the city
13. Allotments
14. Market gardening

The urban metabolic model established in this research is a unique tool that provides a solid platform for urban planners and policymakers. It helps to fully comprehend the intricate relationships within urban ecosystems, allowing for well-informed choices that support sustainable land utilisation and resilient urban growth. The approach emphasises the need of perceiving cities as living entities that can be intentionally constructed to operate in synergy with the natural environment.

4.8.5. Discussion

Sustainable land use in peri-urban areas, specifically focusing on the Swedish city of Gothenburg, brings to light several key issues that warrant further discussion. These issues include the effectiveness of public-private partnerships (PPPs), the integration of multifunctional land use strategies, and the engagement of diverse stakeholder groups. Each of these elements plays a critical role in the successful implementation of sustainable urban and peri-urban development projects but also presents unique challenges and limitations.

Public-Private Partnerships (PPPs) Effectiveness:
The use of PPPs in developing sustainable land use practices is highlighted as a significant positive development. PPPs can mobilize resources efficiently, leverage private sector expertise, and foster innovation in sustainable practices. However, the effectiveness of these partnerships often hinges on the alignment of goals between public and private entities, which can be challenging to achieve. Differences in timelines, profit motives, and operational approaches can create friction. There is also the risk of prioritizing projects that are profitable in the short term over those that provide long-term sustainability benefits.

Integration of Multifunctional Land Use Strategies
Multifunctional land use is presented as a solution that not only supports agricultural production but also enhances biodiversity and provides recreational opportunities. While these systems are inherently beneficial, their implementation can be complex, requiring detailed planning and management to balance competing land uses effectively. Additionally, the transition from traditional single-use to multifunctional land uses can be met with resistance from stakeholders accustomed to conventional practices. The economic viability of changing land use on a large scale also poses a significant challenge, as initial costs and the uncertainty of returns can deter investment.

Stakeholder Engagement
The engagement of a diverse group of stakeholders is essential for the comprehensive planning and implementation of sustainable land use strategies. This inclusivity ensures that multiple perspectives are considered, leading to more robust and widely accepted solutions. However, effectively managing multi-stakeholder processes can be highly challenging. Conflicting interests, varying levels of influence, and differing visions for development can complicate consensus-building. Furthermore,

ensuring that all voices are heard and valued, particularly those of marginalized communities or smaller enterprises, remains a critical concern.

Future Considerations

Looking forward, the discussion around sustainable land use in peri-urban areas must consider the rapid pace of urbanization and climate change. As urban boundaries expand, peri-urban areas become crucial buffers that provide ecosystem services to urban centres. Planning in these zones must be proactive and anticipatory, incorporating climate resilience into land use planning to manage risks such as flooding, heat islands, and biodiversity loss.

While the multifunctional sustainable land use approach offers significant potential benefits, its successful implementation requires careful consideration of the complexities involved in public-private collaborations, multifunctional land planning, and stakeholder engagement. Future strategies should focus on enhancing the alignment of interests among diverse groups, securing economic viability for long-term sustainability projects, and ensuring that planning processes are inclusive and adaptable to changing environmental and social conditions.

4.8.6. Conclusion

This hypothesis proposes that Urban Living Labs (ULLs) offer a unique platform for testing and implementing sustainable urban development methods like urban agriculture. ULLs enable real-world experimentation and knowledge co-creation involving inhabitants, researchers, government agencies, and enterprises. This chapter proves the hypothesis by showing how Urban Living Labs' multifunctional partnerships advance sustainable urban agriculture. It emphasises the relevance of these labs in experimenting with and adopting novel techniques that improve urban sustainability, supporting the hypothesis' focus on innovation, community participation, and sustainability.

The notion is that these labs improve ecological, social, and economic outcomes by popularising novel urban sustainability techniques. The chapter further discusses how ULL can test innovative agricultural technologies and practices through urban agriculture programmes. It describes how these labs test sustainable urban agricultural methods including vertical farming, hydroponics, and aquaponics with community people and stakeholders. It concludes that these labs are essential for testing and refining different approaches that could be scaled up to improve urban sustainability efforts.

The exploration of multifunctional sustainable land use in peri-urban areas, particularly in the Swedish city of Gothenburg and its surrounding regions, illustrates innovative approaches that integrate public and private efforts to foster sustainable development. These initiatives play a crucial role in creating urban and peri-urban environments that are resilient, capable of adapting to, and mitigating the challenges posed by climate change and urban expansion.

Public-private partnerships (PPPs) are pivotal in this context. Projects like the Business Improvement District (BID) for food production in Gothenburg showcase how collaboration among various stakeholders can lead to effective and sustainable land management. These partnerships facilitate multifunctional land use, integrating agriculture, forestry, and agroforestry to meet economic, biodiversity conservation, and climate resilience objectives simultaneously.

Moreover, the active engagement of diverse stakeholder groups—including government, businesses, and local communities—ensures that multiple perspectives are considered. This enhances the effectiveness and sustainability of development projects by fostering comprehensive planning and implementation strategies that accommodate a wide range of needs and expectations.

However, despite significant progress, challenges such as economic constraints, scalability of projects, and the need for continuous stakeholder engagement persist. Future efforts should focus on expanding these initiatives to more regions, enhancing the integration of technology and innovative practices, and continuing to promote inclusive approaches to stakeholder participation.

For ongoing success, it is crucial to maintain a balance between technological innovation and traditional practices, ensuring that development is sustainable and inclusive. The experiences from Gothenburg provide valuable lessons that can be applied globally, particularly in managing the balance between urban expansion and the preservation of peri-urban and rural landscapes.

5. Conclusions and recommendation

5.1. Conclusion

The comprehensive research on sustainable landscape management underscores the urgent need to integrate Nature-Based Solutions (NBS) into various aspects of urban planning, policy formulation, and stakeholder engagement. This research has provided a framework for understanding and implementing NBS, highlighting the significance of multidisciplinary approaches, continuous education, and stakeholder collaboration.

The research illustrates that the adoption of NBS across diverse geographic and socio-economic contexts can lead to substantial environmental, social, and economic benefits. For instance, the Gothenburg Blue-Green Compensation initiative and the Quito Water Fund exemplify successful integration of NBS in water management, demonstrating significant improvements in water retention, flood mitigation, and biodiversity enhancement. These case studies emphasize the importance of policy support and financial incentives in facilitating the widespread adoption of sustainable practices.

A critical finding from the study is the necessity of cross-sectoral collaborations to address the multifaceted challenges of urban and peri-urban development. The multifunctional stakeholder processes in projects like SATURN and U-Garden reveal the effectiveness of collaborative approaches in fostering innovative solutions and ensuring that initiatives are well-aligned with community needs. These projects also underscore the value of Urban Living Labs (ULLs) as platforms for real-world experimentation and community engagement, essential for the successful implementation of sustainable practices.

Ongoing education and professional training are pivotal in building capacity for sustainable landscape management. The integration of emerging technologies, such as AI and IoT, in environmental monitoring and management can significantly enhance the efficiency and effectiveness of NBS. The educational initiatives highlighted in the study, including workshops and field studies in the Blue-

Green Solutions project, demonstrate the importance of equipping practitioners with the latest knowledge and skills to implement sustainable solutions effectively.

Policy and regulatory support play a crucial role in promoting the use of NBS and sustainable practices. The study advocates for the formulation and enforcement of regulations that facilitate cross-sectoral collaborations and provide incentives for organizations and communities to adopt sustainable solutions. Continuous evaluation of environmental policies is essential to ensure they remain effective and relevant as new challenges and technologies emerge. The examples of strategic planning in the Gothenburg and Tisza Lake projects illustrate the need for comprehensive policy frameworks that support sustainable urban and rural development.

Key Findings:

- Effectiveness of NBS: The research has demonstrated that NBS not only mitigate environmental issues such as flooding, drought, and pollution but also enhance biodiversity and provide economic opportunities through eco-tourism and green jobs. These solutions foster a closer alignment of environmental conservation with economic development, which is critical in persuading stakeholders to adopt sustainable practices.
- Sustainable Urban and Peri-Urban Agricultural Practices: The study has shown that integrating sustainable agricultural practices within urban areas can significantly reduce the ecological footprint of cities. Techniques such as vertical farming and the use of recycled water for irrigation have proven effective in maximizing resource efficiency, which is crucial for sustainable urban expansion.
- Stakeholder Engagement: The development of inclusive stakeholder engagement models has facilitated more effective implementation of environmental projects. These models have led to better project outcomes by ensuring that initiatives are more closely aligned with community values and expectations, thereby increasing local support and participation.
- Policy Impact: The research has influenced policy by providing evidence-based recommendations that are crucial for developing robust frameworks supporting the integration of NBS into landscape management. The policies derived from this research highlight the importance of implementing comprehensive strategies that take into account the requirements of both humans and the environment.
- Educational and Capacity Building: The educational outputs from this research, including workshops and publications, have significantly contributed to increasing the awareness and capacity of practitioners and stakeholders to implement sustainable landscape management practices.

5.2. Recommendations

Based on the research findings, the following recommendations are proposed to enhance the management of aquatic cultural landscapes:

Expand the Application of NBS:

Expanding the application of Nature-Based Solutions (NBS) involves encouraging their broader adoption across various geographic and socio-economic contexts. Governments and international bodies should take the lead in providing both funding and policy support for NBS projects, particularly those that demonstrate potential for scalability and significant environmental, social, and economic benefits. Such support is crucial in ensuring that NBS can be implemented effectively in diverse settings, ultimately leading to enhanced sustainability and resilience.

The research underscores the necessity of integrating NBS with traditional grey infrastructure to address the multifaceted challenges posed by climate change and urbanization. This integration not only offers immediate benefits in terms of flood mitigation and water retention but also fosters long-term environmental sustainability. By embracing NBS, communities can enhance their resilience to climate change impacts, support biodiversity, and improve the quality of life for residents.

For instance, the study highlights the cost-effectiveness of NBS compared to traditional grey infrastructure, noting that integrating NBS can lead to significant savings in long-term infrastructure costs while providing resilient and adaptive solutions to water management. Moreover, the implementation of NBS contributes significantly to biodiversity conservation by providing habitats for various species, thereby enriching the landscape and contributing to human well-being through recreational opportunities and aesthetic enhancements.

Examples such as the Tisza Lake and Little Balaton in Hungary demonstrate the practical application and benefits of integrating sustainable practices in water resource management. This project combined wetland restoration with socio-economic practices, leading to improved water quality, biodiversity, and economic benefits for local communities.

Furthermore, integrating NBS into urban planning and water management policies is a vital step in developing adaptive and resilient infrastructures capable of facing the challenges posed by a changing climate and growing urban populations. The research findings support the hypothesis that NBS are not merely supplementary but are essential strategies for enhancing ecosystem and community resilience.

Integrate Sustainable Practices in Urban Planning:

Urban planners and developers should integrate sustainable agricultural practices and green infrastructures into urban designs, tailoring these practices to the specific environmental and social contexts of urban areas to maximize their effectiveness and acceptance. This integration is crucial as it promotes multifunctional land use that supports agricultural production, enhances biodiversity, and provides recreational opportunities. Multifunctional land use not only balances competing land uses effectively but also addresses the economic viability of transitioning from traditional single-use to multifunctional land uses, which can be challenging due to initial costs and uncertainty of returns.

To support this integration, it is essential to develop and support professional training programs for urban planners and architects that emphasize sustainable design principles and the benefits of integrating agricultural innovations into urban environments. Such training programs should focus on equipping professionals with the knowledge and skills needed to implement sustainable agricultural practices and green infrastructure effectively. These programs can help overcome the resistance from stakeholders accustomed to conventional practices and ensure a smooth transition to more sustainable urban planning approaches.

Moreover, incorporating sustainable agricultural practices into urban planning can significantly reduce the ecological footprint of cities. Techniques such as vertical farming and the use of recycled water for irrigation have proven effective in maximizing resource efficiency, which is crucial for sustainable urban expansion. Additionally, urban agriculture can improve food security and livelihoods in urban areas, particularly for low-income populations, by providing healthy and culturally appropriate food.

Strengthen Stakeholder Collaboration:

To strengthen stakeholder collaboration, developing and implementing frameworks for continuous and structured stakeholder engagement in all phases of landscape management projects is essential. This should include mechanisms for feedback, co-design, and shared governance, ensuring that projects are well-aligned with community needs and values. One notable example from the research is the multi-stakeholder processes in Gothenburg, which involved a collaborative approach to sustainable development by engaging a wide range of participants, including local government entities, academic institutions, industries, civil society, and local residents. This method fostered cooperation across different sectors, crucial for addressing the complex challenges of urban and peri-urban development.

Moreover, the establishment of collaborative platforms such as the Business Improvement District (BID) model in Gothenburg and the SATURN project demonstrates how pooling resources and collaborative efforts can lead to effective and inclusive urban enhancements. These platforms not only enhance urban areas by pooling resources from property owners and retailers to fund physical enhancements and marketing efforts but also support the co-creation of solutions that address local needs and values.

Encouraging and supporting community-led environmental projects by providing technical and financial resources is also vital. This empowerment enables communities to tailor solutions to their specific environmental and socio-economic contexts, ensuring that initiatives are relevant and sustainable. For instance, the SATURN project, which explored how urban farming could be a tool for climate adaptation and mitigation in urban environments, employed comprehensive methodologies to evaluate and compare urban farming models in Gothenburg, Trento, and Birmingham. This project highlighted the importance of stakeholder interviews and workshops in gathering insights and fostering collaborative problem-solving.

The research also emphasized the value of Urban Living Labs (ULLs) as platforms for testing and implementing sustainable urban development methods. ULLs enable real-world experimentation and knowledge co-creation involving inhabitants, researchers, government agencies, and enterprises. These labs play a crucial role in experimenting with and adopting novel techniques that improve urban sustainability, supporting the hypothesis' focus on innovation, community participation, and sustainability.

Policy and Regulatory Support:

Policymakers should formulate and enforce regulations that promote the use of NBS and sustainable practices. These policies should facilitate cross-sectoral collaborations and provide incentives for organizations and communities to adopt sustainable solutions. For example, the project on Business Models for Blue-Green Compensation in Gothenburg has highlighted the potential for upstream NBS to enhance water retention and reduce downstream flooding. This initiative aligns with regional flood plans as stipulated by the EU Floods Directive, showcasing the importance of strategic planning, financial mechanisms, legal and policy support, and stakeholder engagement.

Another notable project is the Quito Water Fund, which has demonstrated cost-effectiveness and multiple co-benefits, including biodiversity enhancement, carbon sequestration, food security, and rural development. The success of this fund underlines the need for policy frameworks that support similar models by providing incentives for upstream landowners to invest in NBS. Such initiatives necessitate a thorough understanding of local variables, including hydrology, ecology, socioeconomics, and institutional frameworks, to build fair and sustainable payment systems.

Implementing mechanisms for the continuous evaluation of environmental policies is also crucial to ensure they remain effective and relevant as new challenges and technologies emerge. The study on Water Funds advocates for an inclusive and open process that fosters confidence and cooperation among varied stakeholders. This includes involving a broad range of stakeholders such as upstream landowners, downstream water users, and local communities to ensure the benefits of NBS are equitably distributed and that all voices are heard in the decision-making process.

Furthermore, cross-sector partnerships have emerged as a crucial strategy for addressing the complex challenges of water management. The Environmental Protection Agency (EPA) emphasizes that such collaborations can leverage diverse expertise and resources, fostering innovative solutions that are scalable and adaptable to different contexts. However, the establishment of effective partnerships often encounters obstacles, including bureaucratic hurdles and misaligned objectives among stakeholders, pointing to the need for policies that facilitate collaboration and shared goals.

To support the adoption of sustainable solutions, policymakers should also prioritize investments in research and development. This funding is essential for advancing sustainable water management technologies and practices. Despite the need, funding for water-related research remains insufficient in many regions, limiting the development and implementation of innovative solutions. For instance, the project on Financial Instruments for Nature-Based Solutions to reduce risks of flooding and drought underscores the importance of legal and policy support to foster the adoption of upstream water retention through NBS. This initiative called for comprehensive reports and field visits to regions like Västra Götaland in Sweden, Tisza Lake, and Lake Balaton in Hungary, and the Netherlands to gather insights and develop effective strategies.

Ongoing Education and Training:

Educational institutions and organizations should continue to provide training and resources to build capacity in sustainable landscape management, focusing particularly on emerging technologies and methods that enhance the efficacy and efficiency of Nature-Based Solutions (NBS). This ongoing education is essential for keeping practitioners up-to-date with the latest advancements in sustainable practices. Projects like the U-Garden and SATURN provide valuable case studies demonstrating the importance of integrating academic research with practical applications. The U-Garden project evaluates multifunctional land use in regional planning strategies through various methodologies including cartographic techniques, stakeholder interviews, and policy analysis. This comprehensive approach ensures that the training provided is both practical and research-driven, addressing the real-world challenges of sustainable urban agriculture.

A significant aspect of ongoing education is the exploration and integration of new technologies. The SATURN project emphasizes the role of innovative technologies such as Geographic Information Systems (GIS) in mapping and analysing urban green spaces. These technologies are crucial for enhancing the effectiveness of NBS by providing accurate data for planning and monitoring. Additionally, the use of Artificial Intelligence (AI) and the Internet of Things (IoT) in environmental monitoring and management is highlighted. These technologies can significantly improve the monitoring of environmental systems, providing real-time data that enhance decision-making processes and the efficiency of NBS.

Urban Living Labs (ULLs) are pivotal in fostering practical innovation and problem-solving through participatory approaches. For instance, the U-Garden project in Gothenburg serves as an Urban Living Lab where stakeholders, including local communities, government agencies, and researchers, collaborate to develop and test sustainable urban agricultural practices. These labs not only facilitate knowledge transfer but also encourage community participation and capacity building, essential for the success of sustainable practices.

Moreover, educational initiatives must also focus on building professional capacity through workshops and structured training programs. The emphasis on professional training is evident in projects like the Blue-Green Solutions for Flooding and Drought, which involved workshops and field studies to collect data and develop viable business models for urban greening. Such initiatives ensure that practitioners are well-equipped with the knowledge and skills needed to implement sustainable solutions effectively.

This research has highlighted the intricate and interconnected nature of environmental, social, and economic systems within aquatic cultural landscapes. This thesis makes a valuable contribution to achieving a sustainable future by adopting a comprehensive and interconnected approach, promoting the harmonious coexistence of human activities and nature. The purpose of the results and recommendations presented here is to provide guidance for future endeavours in landscape management, policy development, and community involvement, with the goal of achieving increased sustainability and resilience.

6. Directions of Future Research

The dissertation titled "An Integrated Approach to Aquatic Cultural Landscape Management: A Cross-Disciplinary Approach" examines the intricacies of maintaining aquatic cultural landscapes in the face of climate change, urbanisation, and unsustainable practices. The thesis emphasises the commitment to the preservation and practical management of water resources within the landscape, considering the changing environment from an evolutionary perspective. The commitment is apparent not only in the thorough investigation of nature-based solutions (NBS) for water retention and their capacity to transform small-scale agricultural systems, but also in the careful analysis of the effects of climate change on water resource management.

While significant progress has been made, several areas warrant further investigation to enhance our understanding and management of these landscapes. Future research should focus on the following key areas:

1. Interdisciplinary Integration

One of the primary gaps identified in the existing literature is the lack of interdisciplinary approaches that integrate ecological, urban planning, and socio-economic perspectives. Effective study of transition zones in aquatic environments requires the synthesis of diverse methodologies—from hydrological modelling to socio-economic analysis—to fully understand the impacts of urbanization on these sensitive ecological areas.

Future Research Directions:

- Develop dynamic models that can accurately simulate ongoing changes in land use, infrastructure development, and their ecological impacts.
- Explore interdisciplinary approaches that combine hydrology, ecology, and socio-economics to address complex urbanization challenges.

2. Dynamic Urbanization Processes

The rapid and often unpredictable nature of urbanization processes complicates the study of these transition zones. There is a need for more dynamic models that can accurately simulate the ongoing changes in land use, infrastructure development, and their ecological impacts.

Future Research Directions:

- Investigate the transient yet impactful nature of urban sprawl and its immediate effects on water quality, habitat disruption, and biodiversity loss in aquatic settings.
- Develop long-term ecological research sites within these transition zones to provide invaluable data on temporal changes and urbanization impacts.

3. Pollution and Hydrological Modifications

Urban runoff and effluents significantly affect water quality and ecosystem health. Additionally, alterations in natural water flow due to urban development—such as the construction of stormwater systems and impervious surfaces—require further exploration to assess their impacts on hydrological regimes and aquatic habitats.

Future Research Directions:

- Conduct detailed studies on how urban runoff and effluents affect water quality and ecosystem health.
- Examine the impacts of hydrological modifications on aquatic habitats, particularly in urban and peri-urban areas.

4. Land Use Practices

There is a lack of comprehensive data linking land use practices in transitional zones to changes in aquatic ecosystems. Future research should focus on how agricultural practices, urban landscaping, and recreational land use contribute to nutrient loading and habitat fragmentation in these zones.

Future Research Directions:

- Investigate the interactions between urbanization, land use practices, pollution, and hydrological modifications in shaping aquatic ecosystems.
- Develop guidelines for sustainable land use practices that minimize nutrient loading and habitat fragmentation.

5. Nature-Based Solutions (NBS)

The dissertation emphasizes the potential of NBS to offer sustainable alternatives to conventional water management methods. However, further research is needed to refine and expand these strategies.

Future Research Directions:

- Optimize NBS to enhance water retention and mitigate flood risks in aquatic cultural landscapes.
- Assess the multifunctional roles of NBS in promoting biodiversity, water quality, and socio-economic benefits.

6. Climate Change Impacts

Understanding the specific challenges posed by climate change to water resource management in aquatic landscapes is crucial. This includes exploring integrated water resources management (IWRM) approaches tailored to improve ecosystem health and sustainability in these landscapes.

Future Research Directions:

- Study the current and future impacts of climate change on water availability and quality in aquatic cultural landscapes.
- Propose adaptive strategies that enhance the resilience of water management systems to climate variability and extremes.

7. Community and Stakeholder Engagement

Effective management of aquatic cultural landscapes requires the engagement of local communities and stakeholders. This involves understanding local perceptions and practices to craft more effective conservation strategies.

Future Research Directions:

- Develop participatory models that involve local communities and stakeholders in conservation and management processes.
- Investigate the socio-economic benefits of preserving cultural heritage through enhanced tourism and local community identity.

7. New Scientific Achievements

This chapter focuses on explaining the key scientific contributions produced in this thesis that are crucial for the advancement of aquatic cultural landscape management. Although these contributions are incorporated throughout the various sections of the thesis, they are specifically mentioned here to highlight their originality and significance.

1. Innovative Integration of Nature-Based Solutions (NBS)

The thesis introduces novel approaches to integrating NBS into traditional water management systems, significantly advancing the practice towards more sustainable and resilient management of aquatic landscapes. The development and application of these solutions have proven crucial in addressing complex challenges such as water scarcity, pollution, and ecosystem degradation, particularly under the pressures of urbanization and climate change.

Contribution:

- Development of a Multifunctional NBS Framework: This research contributes a comprehensive framework that not only enhances biodiversity and water quality but also supports community engagement and cultural heritage preservation. This framework is particularly innovative in its ability to adapt to different geographic and socio-economic contexts, making it a versatile tool for global application.

2. Enhancement of Urban and Peri-Urban Agricultural Practices

Another significant contribution of this thesis is the development of sustainable urban and peri-urban agricultural practices through the implementation of NBS. These practices are designed to optimize water usage and enhance local food systems, which are essential for the sustainability of urban expansions.

Contribution:

- Integration of water-smart agricultural techniques and models: By adapting and innovating water-smart techniques and models within urban farming models, this thesis contributes to the field by providing scalable and sustainable agricultural practices that reduce the ecological footprint of cities.

3. Advancement in Stakeholder Engagement Models

This thesis has developed and refined models for stakeholder engagement that facilitate the collaborative management of aquatic cultural landscapes. These models ensure that various stakeholders, including local communities, governmental bodies, and non-governmental organizations, are actively involved in the decision-making process, leading to more effective and sustainable outcomes.

Contribution:

- Collaborative governance framework: The establishment of a governance framework that incorporates the contributions of diverse stakeholders has been pivotal. This framework not only enhances the implementation of NBS but also ensures that these solutions are culturally and socially acceptable.

4. Policy Development for Sustainable Landscape Management

The contributions to policy development, particularly those that encourage the adoption of NBS and sustainable practices within aquatic landscape management, are notable. These policies are informed by comprehensive research and are designed to foster long-term sustainability and resilience.

Contribution:

- Evidence-Based Policy Recommendations: The thesis offers robust policy recommendations that are supported by extensive empirical research. These recommendations provide a pathway for policymakers to integrate scientific findings into practical, actionable policies that promote sustainable landscape management.

5. Educational Contributions and Capacity Building

Finally, the educational contributions of this thesis should not be overlooked. Through the dissemination of findings and the development of educational materials, this research plays a crucial role in capacity building among practitioners and stakeholders involved in landscape management.

Contribution

- Educational materials and workshops: The creation of educational tools and the conduct of workshops have significantly contributed to building the capacity of stakeholders to implement sustainable practices effectively.

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9. Glossary of Terms

KEY CONCEPTS FOR LANDSCAPE MANAGEMENT

Accessibility. In social contexts**,** accessibility is about how society is designed. An accessible society is designed so that as many people as possible can use and benefit from it. It is about being able to enjoy the physical environment and get around in society. It also means having access to information and communication and being able to use products and services.

Acidification. The introduction of acidic substances into soils and watercourses through, for example, the burning of fossil fuels. Two of the most acidifying gases are nitrogen oxides and sulphur dioxide.

Agenda 21, the Rio Declaration on Environment and Development, and the Statement of principles for the Sustainable Management of Forests were adopted by more than 178 Governments at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, 3 to 14 June 1992**.**

Agenda 2030. The core of the Agenda2030 of the UN's Sustainable Development Goals is that these 17 goals will promote global peace and prosperity by reducing poverty and inequality, improving health and education, stimulating economic growth, tackling climate change, and preserving our oceans and forests.

Agroecosystem. An agroecosystem is a cultivated ecosystem, generally corresponding to the spatial unit of a farm and whose ecosystem functions are valued by humans in the form of agricultural goods and services. It is thus co-produced by nature and humans. Agroecosystems are always integrated in a social, economic and ecological environment, and are part of flows (energy, water) and mechanisms (nutrient cycles, pests and diseases biological control, pollen transfer, etc.). Hence, they are characterized by a structural and dynamic complexity arising from interactions between socio-economic processes (interactions between social and economic factors) and ecological ones (functional links between organisms and their environment) in which they are embedded.

Agroforestry. Agroforestry is the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits. Thus, agroforestry is a combination of agricultural and forestry systems that try to balance various needs: 1) to produce trees for timber and other commercial purposes; 2) to produce a diverse, adequate supply of nutritious foods both to meet global demand and to satisfy the needs of the producers themselves; and 3) to ensure the protection of the natural environment so that it continues to provide resources and environmental services to meet the needs of the present generations and those to come.

Albedo. A measure of a surface's ability to reflect the sun's rays and return the light to space. When the measure is 1.00, it means that 100% is reflected. The albedo of the sea surface is 0.08 while fresh snow has 0.9 (reflects 90%).

Amfori BSCI, Business Social Compliance Initiative. Organisation founded by the International Chamber of Commerce to ensure fair working conditions in the supply chain. Amfori BSCI carries out audits and certifications of suppliers' production facilities that can also be shared with other members of the network.

Aquaculture. Aquaculture, the propagation and husbandry of aquatic plants, animals, and other organisms for commercial, recreational, and scientific purposes. This includes production for supplying other aquaculture operations, for providing food and industrial products, for stocking sport fisheries, for supplying aquatic bait animals, for stocking fee-fishing operations, for providing aquatic organisms for ornamental purposes, and for supplying feedstocks to the pharmaceutical and chemical industries. These activities can occur worldwide.

Aquaculture Stewardship Council - ASC. Reviews (among other things) social aspects of fish and shellfish farms. ASC envisions a world where seafood farming plays a major role in supplying food and supporting local communities across the globe while minimising negative impacts on the environment. Every ASC certified farm and every ASC labelled product gets us closer to achieving this vision and makes a difference to our overall impact.

Aquaponics. Aquaponics is a self-sustaining farming system that allows you to grow edible fish and vegetables at the same time. The name is a combination of two words: aquaculture ('farming of edible fish') and hydroponics ('soil-less, water-based crop production'). It is a new, sustainable production method that can produce large quantities of nutrient-rich food without the use of soil or fertilisers and can produce food without creating large amounts of waste or other pollutants. Another advantage is that it is extremely space-saving.

Aquatic ecosystems. Aquatic ecosystems include oceans, lakes, rivers, streams, estuaries, and wetlands. Within these aquatic ecosystems are living things that depend on the water for survival, such as fish, plants, and microorganisms. These ecosystems are very fragile and can be easily disturbed by pollution.

Bioaccumulation. Bioaccumulation is a process of accumulation of chemicals in an organism that takes place if the rate of intake exceeds the rate of excretion. Chemicals are introduced into the organism through exposure to the abiotic environment (soil, water, air) or as dietary intake (trophic transfer).

Biodiversity. Biodiversity, the variety of life found in a place on Earth or, often, the total variety of life on Earth. A common measure of this variety, called species richness, is the count of species in an area. The idea of biodiversity also encompasses the range of ecological communities that species form. A common approach to quantifying this type of diversity is to record the variety of ecological communities an area may contain.

Biological half-life. The time required, in the absence of further input, for a biological system or compartment to eliminate, by biological processes, half the amount of a substance (e.g., radioactive material) that has entered it.

Biomagnification. Biomagnification is defined as accumulation and transfer of substances via food webs, resulting in an increase of internal concentration in organisms at succeeding levels in the trophic chain.

Bioenergy. Bioenergy is energy produced using biomass (plant or animal material). Energy obtained by burning, fermenting or converting biomass through other processes is called bioenergy. Bioenergy is considered an environmentally friendly energy source because the biomass comes from a renewable source and the carbon dioxide emissions from the process are re-absorbed by the plants during photosynthesis. Bioenergy can take many forms, such as wood chips, pellets, biogas, bioethanol or biodiesel.

Biogeochemical cycles. Any of the natural pathways by which essential elements of living matter are circulated. The term biogeochemical is a contraction that refers to the consideration of the biological, geological, and chemical aspects of each cycle. Elements within biogeochemical cycles flow in various forms from the non-living (abiotic) components of the biosphere to the living (biotic) components and back. Each biogeochemical cycle can be considered as having a reservoir (nutrient) pool - a larger, slow-moving, usually abiotic portion—and an exchange (cycling) pool - a smaller but more-active portion concerned with the rapid exchange between the biotic and abiotic aspects of an ecosystem. Major biogeochemical cycles include the carbon cycle, the nitrogen cycle, the phosphorus cycle, the water cycle, the sulphur cycle, and the cycles of plant nutrients.

Biohazard. A biohazard is a biological substance that's dangerous to people or the environment. Many biohazards are made of bacteria or other microorganisms. Some biohazards are an unintentional side effect of biologists working with or studying toxins or viruses. One common type of biohazard is medical waste - things like used syringes or other tools contaminated with human blood, bacteria, or other microorganisms.

Biological heritage. Biological cultural heritage is nature that tells us about culture. It consists of ecosystems, habitats and species that have arisen, developed or been favoured by human use of the landscape and whose long-term survival depends on or is positively affected by use and management.

Blockchain. A blockchain is a digital register of records linked by cryptography. It records the same set of data in every transaction on the blockchain. In the case of cobalt, it records the origin, weight, size, traceability system and information showing the participant's compliance with the OECD Guidelines for Responsible Mineral Sourcing. The blockchain also ensures that the information cannot be changed without detection.

Blue-green solutions. Blue Green solutions (BGS) is a unique methodology and toolkit that allows developers and planners to adopt 'nature-based solutions' as part of a systematic approach to these problems: for example, by integrating green space, trees and natural drainage into the urban environment. Blue Green Solutions encourages developers to adopt nature-based solutions by focusing on the co-benefits for a wider group of stakeholders.

Bretherton Diagram. The classical depiction of the Earth System and its interactions introduced by Francis Patton Bretherton in the 1980s. The focus is on the interactions between the geosphere and the biosphere, with human forcings represented as an outside force affecting the geosphere-biosphere system.

Brundtland Report. Another name for the report 'Our Common Future' published in 1987 by the World Commission on Environment and Development. The report defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The report also showed a clear link between poverty reduction, gender equality, wealth distribution and environmental protection.

Carbon dioxide emission. Total greenhouse gas (GHG) emissions generated directly and indirectly by an individual, event, organisation, service, place or product. Carbon dioxide emissions are measured in tonnes of carbon dioxide equivalent per year.

Carbon dioxide equivalent (CO_2 e). To compare greenhouse gas emissions according to their global warming potential, we convert other gases into an equivalent amount of carbon dioxide.

Carrying capacity. In ecology, the carrying capacity of a species in an environment is the maximum population size of the species that the environment can sustain indefinitely. The term is also used more generally to refer to the upper limit of habitats, ecosystems, landscapes, waterscapes or seascapes to provide tangible and intangible goods and services (including aesthetic and spiritual services) in a sustainable way.

Climate goals of 1.5 degrees. The Paris Agreement's climate goal is to limit the global temperature increase to 2ºC, preferably 1.5ºC, compared to pre-industrial levels. The path to this long-term goal involves steadily reducing greenhouse gas emissions, with the aim of achieving a climate-neutral world by 2050.

Climate neutrality. Net zero emissions of greenhouse gases. This can be achieved by eliminating greenhouse gas emissions e.g. through carbon offsetting, or completely eliminating them in the product's life cycle, including the use phase and dismantling/scrapping.

Circular economy. The circular economy is about reducing society's resource consumption and associated environmental impacts through the use of multiple circular strategies. In other words, the circular economy is circular thinking at the societal level. The goal, formulated by the EU among others, is a society without waste, which is made possible by, among other things, renewable energy and the manufacture and design of products that can be recycled in their entirety.

Circular materials. We consider materials to be circular when they are produced from waste, recycled material or recycled content, or are designed for easy repair, recycling or reuse.

Code of Conduct. Guidelines on how a company conducts its business from a sustainable perspective. Includes rules on ethics, labour law, social conditions and the environment.

Conference of the Parties (COP), the highest decision-making body of the UNFCCC**.** All countries that have signed the UNFCCC are represented. The COP meets every year to advance international climate action.

Constructed Treatment Wetlands. Because natural wetlands are so effective at removing pollutants from water that flows through them, engineers and scientists construct systems that replicate some of the functions of natural wetlands. These constructed treatment wetlands use natural processes involving wetland vegetation, soils, and their associated microbial life to improve water quality. They are often less expensive to build than traditional stormwater treatment options, have low operating and maintenance expenses, and can handle fluctuating water levels.

Corporate Social Responsibility - CSR: a company's responsibility beyond the strictly economic. Includes ethical, labour, environmental and social aspects.

Cradle to the Grave. An analysis that considers impacts at all stages of the product's life cycle, from the extraction and processing of natural resources to all subsequent phases of manufacturing, transport, product use, recovery and finally scrapping or recycling. This concept is nowadays rather outdated, as it represents a linear economic approach, while the circular economy is based on the Cradle-to-Cradle system.

Cradle-to-Cradle. Cradle-to-Cradle (C2C) is about seeing garbage as an eternal resource and doing the right thing from the beginning. It is about making community and product development function in the same way as a healthy ecological system where all resources are used effectively, and in a cyclical way (as opposed to the current linear system that can be better described as a Cradle-to-Grave system).

Cultural heritage. Cultural heritage includes tangible culture (such as buildings, monuments, landscapes, archival materials, books, works of art and artefacts), intangible culture (such as folklore, traditions, language, and knowledge and skills such as traditional trades and crafts) and natural heritage (including culturally important landscapes and biodiversity). The concept of cultural heritage is often relevant in connection with the protection of indigenous peoples' intellectual property rights. The Act describes what is automatically protected and what can be protected by individual decision. Most cultural monuments from ancient and medieval times (up to 1537) are automatically protected. Since 1972, UNESCO has designated some cultural monuments that it considers to be very important to human history and cultural heritage sites worthy of protection as part of the World Heritage List. The World Heritage List is constantly being updated with new sites.

Cultural heritage conservation. Conservation encompasses all those actions taken toward the long-term preservation and sustainable use of cultural heritage. Activities include examination, documentation, treatment, and preventive care, supported by research and education. Preserving cultural heritage is essential, but it also presents complex challenges. Conservators embrace these challenges with passion, commitment, and dedication.

Cultural landscape. A cultural landscape is a geographic area, with all its cultural and natural resources, the wildlife and domestic animals, natural and artificial ecosystems, the built and intangible heritage therein, continuously shaped by historic and present day evolutionary processes including the adverse or beneficial impacts of human activities, social relations and evolving cultures, which mirror the evolutionary trends of human society.

Dirty Dozen. These were a group of 12 highly persistent and toxic chemicals: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzen, mirex, polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, and toxaphen.

Diversity. In a social context, the concept usually means that everyone, regardless of ethnic background, sexual orientation, gender, age, disability, etc. is given the same opportunities. The aim is to combat discrimination and promote job satisfaction and productivity.

Dow Jones sustainability indices DJSI. The Dow Jones Sustainability Indices (DJSI) are a family of best-in-class benchmarks for investors who have recognized that sustainable business practices are critical to generating long-term shareholder value and who wish to reflect their sustainability convictions in their investment portfolios. The family was launched in 1999 as the first global sustainability benchmark and tracks the stock performance of the world's leading companies in terms of economic, environmental, and social criteria.

Ecomuseum. The ecomuseum is a cultural landscape designed as an open space museum that connects the natural environment and its ecosystem services and the cultural heritage of the landscape into a holistic system, respecting the identity of the place, building heavily on the collaboration and strategic cooperation of local communities to ensure the well-being and development of these communities.

Ecosystem. An ecosystem includes all the living things (plants, animals, and organisms) in a given area, interacting with each other, and with their non-living environments (weather, earth, sun, mineral constituents of soils, climate, atmosphere). Ecosystems are dynamic entities—they are subject to periodic disturbances and are always in the process of recovering from some past disturbance. The tendency of an ecosystem to remain close to its equilibrium state, despite that disturbance, is termed its resistance. The capacity of a system to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks is termed its ecological resilience.

Ecosystem services. Ecosystem services are defined as the direct and indirect contributions of ecosystems to human well-being and have an impact on our survival and quality of life. There are four types of ecosystem services: provisioning, regulating, cultural and supporting services.

Ecosystem Assessment. The Millennium Ecosystem Assessment (MA) was called for by the United Nations Secretary-General Kofi Annan in 2000. Initiated in 2001, the objective of the MA was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being. The MA has involved the work of more than 1,360 experts worldwide. Their findings, contained in five technical volumes and six synthesis reports, provide a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide (such as clean water, food, forest products, flood control, and natural resources) and the options to restore, conserve or enhance the sustainable use of ecosystems.

Ecotone. An ecotone is a transition area between two biological communities, where two communities meet and integrate. It may be narrow or wide, and it may be local (the zone between a field and forest) or regional (the transition between forest and grassland ecosystems).[3] An ecotone may appear on the ground as a gradual blending of the two communities across a broad area, or it may manifest itself as a sharp boundary line.

Earth System Science. Earth System Science (ESS) is a rapidly emerging transdisciplinary endeavour aimed at understanding the structure and functioning of the Earth as a complex adaptive system. The grand challenge for ESS is to achieve a deep integration of biophysical processes and human dynamics to build a truly unified understanding of the Earth System.

Emissions Trading. Emissions trading is a market-based approach to controlling pollution by providing economic incentives for reducing the emissions of pollutants. The concept is also known as cap and trade (CAT) or emissions trading scheme (ETS). One prominent example is carbon emission trading for CO_2 and other greenhouse gases which is a tool for climate change mitigation. Other schemes include sulphur dioxide and other pollutants.

Energy mix. Electricity is normally generated from several different energy sources such as coal, oil, gas, nuclear, hydro, solar, wind and biofuels. A country's 'energy mix' reflects how different energy sources are combined to meet energy needs. This allows us to calculate and compare a country's greenhouse gas emissions.

EU Emission Trading System. The EU ETS is a cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost-effectively. It is the world's first major carbon market and remains the biggest one.

European Landscape Convention. The European Landscape Convention of the Council of Europe promotes the protection, management and planning of the landscapes and organises international co-operation on landscape issues. As a reflection of European identity and diversity, the landscape is our living natural and cultural heritage, be it ordinary or outstanding, urban or rural, on land or in water. The European Landscape Convention - also known as the Florence Convention, - promotes the protection, management and planning of European landscapes and organises European co-operation on landscape issues. The convention was adopted on 20 October 2000 in Florence (Italy) and came into force on 1 March 2004 (ELC, 2000). It is open for signature by member states of the Council of Europe and for accession by the European Community and European non-member states. It is the first international treaty to be exclusively concerned with all dimensions of European landscape.

Forest Stewardship Council (FSC). Promotes (among other things) socially responsible use of the world's forests through a certification system.

Fossil fuels. Natural fuels such as coal, oil and gas that have been formed by living organisms. Fossil fuels are consumed at a much faster rate than they are replenished.

Cradle to gate. An analysis that includes parts of the product life cycle, such as material procurement and production, but excludes the use phase and dismantling/scrapping.

Geoinformatics. Geoinformatics is the science and the technology which develops and uses information science infrastructure to address the problems of Earth sciences such as geography, geodesy, cartography, photogrammetry, GPS, GIS, and related branches of science and engineering.

Geothermal energy: the heat stored in the bedrock. Comes partly from the time when the earth was formed and partly from heat replenished by radioactive decay in the earth's interior. Can be used for heating using a heat pump or - where conditions are favourable - in geothermal power plants or cogeneration plants (e.g. in Iceland).

Global Compact, the UN's initiative to promote responsible and sustainable business. The Global Compact guidelines are summarised in ten principles based on the UN Declaration of Human Rights and the ILO's core conventions on labour rights.

Global Warming. Global warming is the long-term heating of Earth's surface observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere.

Gothenburg Protocol. The Executive Body of the United Nations Economic Commission for Europe (UNECE) adopted the Gothenburg Protocol (GP) on 30 November 1999. The Protocol entered into force on 17 May 2005. The purpose of the document is to mobilize Parties' efforts to control pollution from agricultural sources in the context of the wider nitrogen cycle in an integrated manner harvesting multiple co-benefits of improved nitrogen management. Sustainable nitrogen management provides the foundation to strengthen an emerging “nitrogen circular economy”, reducing nitrogen losses and promoting recovery and reuse. The Guidance demonstrates how actions to control air pollution have co-benefits for climate, water, biodiversity, health and the economy. It identifies 24 principles to help Parties understand and tailor solutions, summarises 76 measures and their performance for abatement of different nitrogen forms and illustrates how to develop packages of measures to improve coherence.

Greenhouse effect. When sunlight hits the Earth, some of the light is reflected back into space and the rest is converted into heat. Greenhouse gases absorb this heat and reflect it to the Earth's surface, thus preventing it from being reflected into space. The result is a steady warming of the planet.

Greenhouse gases (GHG). Gases that contribute to global warming such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6) and freons/CFCs. Greenhouse gases are often quantified as units of mass of CO_2 e, where e denotes equivalent.

Greenhushing. The opposite of greenwashing. When a company deliberately withholds information about its sustainability actions, hoping to avoid scrutiny and criticism. Companies may be reluctant to disclose actions they are taking in the right direction as they do not want to be criticised for not being perfect. As a result, customers and other stakeholders are not informed, educated and inspired by actual progress.

Greenwashing. A deceptive form of marketing that aims to make people believe that an organisation's products, objectives, and policies are more environmentally friendly than they actually are.

Habitat. A habitat is a place where an organism makes its home. A habitat meets all the environmental conditions an organism needs to survive. The main components of a habitat are shelter, water, food, and space. A habitat is said to have a suitable arrangement when it has the correct amount of all of these. Sometimes, a habitat can meet most components of a suitable arrangement, but not all.

Hammarby model. The Hammarby Model: The core of the environmental and infrastructural planning can be summarised in an eco-cycle model. The model for the handling of energy, waste and water is known as the Hammarby Model. It has been developed by Fortum, Stockholm Water Company and the Stockholm Waste Management Administration.

Hazardous materials. A hazardous material is any item or agent (biological, chemical, radiological, and/or physical) that has the ability to cause harm to humans, animals, or the environment. This could be as a result of the material by itself or interaction with other materials.

Heat pump. A heat pump is an energy-efficient device that transfers thermal energy using refrigeration to move heat from a warmer space to a cooler space and vice versa. It extracts heat from its surroundings, such as air, ground, geothermal sources, nearby water, or even waste heat, and amplifies it for transfer to the designated location. It is superior to the traditional fossil fuel-run heating system in terms of efficiency, operating costs, and climate-friendliness.

Human Rights: In the context of sustainability, this refers to a wide range of rights relating to both labour conditions and a company's impact on the society in which it operates. Can include, for example, living wages, education, gender equality, guaranteed schooling for employees' children, etc.

Inclusiveness. Ensuring that all people have equal access to opportunities and resources, especially people who would otherwise be excluded or marginalised, such as people belonging to minority groups and people with physical or mental disabilities.

Integrated Water Resources Management (IWRM) is a comprehensive approach that promotes the coordinated development and management of water, land, and related resources to maximize economic and social welfare while safeguarding vital ecosystems and the environment

Intergovernmental Panel on Climate Change (IPCC), the UN's international climate panel. Draws on thousands of scientists and experts in climate and related scientific fields to assess the magnitude and risks of climate change and what can be done about it. The results are presented in so-called IPCC reports, which are often used in public debate.

Kyoto Protocol. The Kyoto Protocol is an international treaty adopted in 1997 that aimed to reduce the emission of gases that contribute to global warming. The protocol called for reducing the emissions of six greenhouse gases in 41 countries plus the European Union to 5.2 percent below 1990 levels.

Landscape. According to the European Landscape Convention, landscape is an area as perceived by humans and whose character is the result of the influence and interaction of natural and/or human factors.

Life cycle. Successive and interconnected phases of a product system from raw material acquisition, or generation from natural resources to final disposal.

Life Cycle Assessment (LCA): a study that determines the environmental impact of a product. The analysis also includes a framework for measuring the current environmental impact, as well as steps towards a set goal, such as how to make the product more sustainable. Life cycle assessments are often conducted from cradle to grave, meaning that the analysis starts when the raw materials are extracted from nature and ends when the product is treated as waste.

Littoral zone. The littoral zone, also called littoral or nearshore, is the part of a sea, lake, or river that is close to the shore. The littoral zone of lakes is characterized by high diversity of both abiotic (sand, stone) and biotic (vegetation) substrates, forming habitats of varying complexity that change markedly on both spatial and temporal scales. In marine coastal ecology, the littoral zone includes the intertidal zone extending from the high-water mark (which is rarely inundated), to coastal areas that are permanently submerged — known as the foreshore — and the terms are often used interchangeably. However, the geographical meaning of littoral zone extends well beyond the intertidal zone to include all neritic waters within the bounds of continental shelves.

Miljöbalken - the Swedish Environmental Code. The purpose of the Environmental Code is to promote sustainable development. More detailed rules are contained in the regulations of the Environmental Code. Several other laws also contain links to the Environmental Code. The Environmental Code entered into force on 1 January 1999. The purpose of the Environmental Code is to promote sustainable development so that present and future generations can live in a healthy and good environment. Many of the provisions contained in previous environmental legislation have been given wider application under the Environmental Code. The Environmental Code concerns all types of measures, regardless of whether they are part of the individual's daily life or some form of business activity.

Nature-Based Solutions. Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. Nature-based solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services.

Nature conservation. Nature conservation is the care and protection of Earth's natural resources for current and future generations. Earth's natural resources include air, minerals, plants, soil, water, and wildlife. Examples of nature conservation include:

- Restoring and maintaining habitats
- Maintaining species diversity and genes
- Maintaining ecosystems

- Preventing wasteful use of natural resources
- Maintaining environment functions
- Preventing deforestation
- Reducing overfishing

Net zero emissions. Net zero emissions are obtained when the amount of emissions is outweighed by the amount removed from the atmosphere. Net zero emissions can refer to either carbon dioxide or all greenhouse gases.

OECD (Organisation for Economic Cooperation and Development). The Organisation for Economic Cooperation and Development issues detailed recommendations for businesses on how to respect human rights when sourcing and deciding on materials.

Paleoclimatology. Paleoclimatology, the study of past climatic regimes (paleoclimates), has been expanding in scope in recent decades. One reason for this is the light thrown by paleoclimatic studies on the natural variability that exists in the Earth's climate in the context of future, anthropogenically influenced, climate changes. Another is the realization that many of the Earth's sedimentary resources (e.g. coal, hydrocarbons, and other extractable minerals) formed under particular types of climatic regime. Sedimentary facies and paleontological data (paleoclimate proxies) provide evidence of paleoclimates and climate changes. General Circulation Models are currently producing climate reconstructions for the Mesozoic and Cenozoic Eras that are in close agreement with reconstructions based on paleoclimate proxies.

Paris Convention. The Paris Agreement is a legally binding international agreement on climate change that has been signed by almost all nations (197 countries at the time of writing).

Persistent Organic Pollutants (POPs). Persistent organic pollutants (POPs) are toxic chemicals that adversely affect human health and the environment around the world. Because they can be transported by wind and water, most POPs generated in one country can and do affect people and wildlife far from where they are used and released. They persist for long periods of time in the environment and can accumulate and pass from one species to the next through the food chain. POPs include a range of substances that include:

- Intentionally produced chemicals currently or once used in agriculture, disease control, manufacturing, or industrial processes. Examples include PCBs, which have been useful in a variety of industrial applications (e.g., in electrical transformers and large capacitors, as hydraulic and heat exchange fluids, and as additives to paints and lubricants) and DDT, which is still used to control mosquitoes that carry malaria in some parts of the world.
- Unintentionally produced chemicals, such as dioxins, that result from some industrial processes and from combustion (for example, municipal and medical waste incineration and backyard burning of trash).

Plug-in hybrid. A vehicle powered by both a petrol or diesel engine and an electric motor, with a battery that can be charged by the car's generator or via a charging station.

Project Polestar 0. The name of Polestar's (Polestar Electric Cars) ambitious programme that aims to create a climate-neutral car by 2030 by eliminating greenhouse gas emissions throughout the supply chain and production.

Ramsar Convention. The Convention on Wetlands is the intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources. The Convention was adopted in the Iranian city of Ramsar in 1971 and came into force in 1975. Since then, almost 90% of UN member states, from all the world's geographic regions, have acceded to become "Contracting Parties".

Renewable energy is energy from renewable resources that is replenished naturally at the same rate as the energy is consumed. This includes carbon-neutral energy sources such as solar, wind, and hydropower.

Responsible Investment: Investments that take into account or promote sustainable development while providing a good financial return.

Risk materials. A complex concept. Materials such as cobalt, gold, lithium, nickel, mica, tantalum, tin, tungsten, leather and plastic that are associated with a high risk of human rights violations in the supply chain, such as child labour, corruption, etc., or environmental impacts such as ecosystem disruption, greenhouse gas emissions, etc.

Rooftop farming. Rooftop agriculture is the production of fresh vegetables, herbs, fruits, edible flowers and possibly some small animals on rooftops for local consumption. Rooftop agriculture can be good for the buildings, too. For example, plants can help to insulate buildings from extreme temperatures, thereby reducing the amount of energy needed for heat and air conditioning, as well as the pollution produced by the heating and cooling processes. This also lowers the costs to heat or cool the building. Rooftop agriculture can also reduce noise pollution from the city and protect the roof from sun, rain, and wind.

Ruddiman's hypothesis. William Ruddiman is the lead proponent of the Early Anthropocene Hypothesis (2003), which asserts pre-industrial land clearing and agricultural practices caused the release of historically underappreciated amounts of greenhouse gases, transforming the Earth.

Sustainable Development Goals (SDGs). Global Sustainable Development Goals 17 goals with a total of 169 targets that the countries of the world have jointly developed to eradicate extreme poverty, limit global warming and reduce inequalities and injustices in the world. The goals are summarised in Agenda 2030 and are to be achieved by 2030. Replaced the Millennium Development Goals in 2015.

Sustainability. Common term for environment, labour law, social conditions, human rights and anti-corruption. Long-term economy is also included as a criterion. In English, the word sustainability is used for durability. The concept of sustainable development was launched by the UN's Brundtland Commission, which in 1987 defined it as development that: "...meets the needs of the present without compromising the ability of future generations to meet their own needs."

Sustainability reporting. Non-financial report on how the company measures, takes responsibility for and succeeds in its sustainability efforts. It should reflect the company's work on environmental, social and labour issues, respect for human rights, anti-corruption and bribery. The report must also describe the company's policy and the risks that exist in the area of sustainability and how the company manages the risks. GRI, the Global Reporting Initiative, is one of the best known sustainability reporting guidelines and is used by thousands of companies and organisations. ISO 26000 is the international ISO standard for sustainability reporting. SA 8000 is a widely used US-based social responsibility standard. ISO 14001 is the international standard for environmental management. Since January 2017, Sweden has a law on sustainability reporting. Around 1 600 of the largest companies are required to report annually on their sustainability performance.

Sustainability ranking or ESG ranking. A rating of sustainability performance, in particular how organisations address environmental, social and governance risks. The term ESG (environmental, social and governance) ranking is increasingly used. The Dow Jones Sustainability Index (DJSI) is one of the most well-known.

Transparency. Official declaration of our policies, practices, objectives, commitments, successes, failures and real impact on workers, society and the environment. Transparency should be seen as a tool for change rather than an end in itself.

Urban farming. Urban farming occurs when someone living in a city or heavily populated town repurposes their green space to grow food and/or raise smaller animals (think goats, rabbits, chickens, turkeys). Not every urban farm has to be at the owner's house; some urban farmers lease land and work the soil in other backyards, utilize rooftops or even farm indoors using aquaponic or hydroponic systems. Unlike a personal garden, an urban farmer grows to feed the community, sometimes selling it for little or no profit.

Urban - Rural Gradient. Urban-rural gradients are useful tools when examining the influence of human disturbances on ecological, social and coupled systems, yet the most commonly used gradient definitions are based on single broad measures such as housing density or percent forest cover that fail to capture landscape patterns important for conservation. Rural–urban gradients offer an appropriate ecological framework for understanding relevant social issues to sustainability and policy planning.

Vertical farming. Vertical farming is the practice of growing crops in vertically stacked layers. It often incorporates controlled-environment agriculture, which aims to optimize plant growth, and soilless farming techniques such as hydroponics, aquaponics, and aeroponics. This farming method uses Controlled Environment Agriculture (CEA) technology to monitor required humidity, temperature, gases, and light in indoor conditions. For instance, farmers use artificial lighting and metal reflectors to mimic natural sunlight.

Wastewater irrigation. The use of wastewater in agriculture includes the provision of water and nutrients for cultivation and ensuring that cities have sufficient water supply. There are various benefits to using wastewater to irrigate crops or farmland. Benefits of wastewater irrigation:

- High nutrient content: Wastewater is naturally rich in nutrients, which helps to reduce or eliminate the need for costly chemical fertilizers.
- It is environmentally friendly: Using wastewater to irrigate crops or farmland is a sustainable and low-cost way to conserve water and reduce wastage.
- Higher crop production: Farmers can increase their yields by irrigation. This is because they have access to water and are able to plant more crops. Having water available throughout the year allows the growing season to be extended.
- Irrigation allows farmers to plant crops in areas otherwise considered too dry. It acts as an ‘insurance policy’ against drought and seasonal variability.
- Higher quality crops: Water stress can have a dramatic impact on farm produce quality. Higher availability of water eliminates water stress. Therefore, farmers can produce better quality crops and pastures through irrigation.

- Increase the property's value: Irrigated land can support more crops and animal production. This makes it more valuable. It is a common way to increase the property's value.

Wastewater treatment. There are two main levels of wastewater treatment: primary and secondary treatment. In the primary stage, solids are allowed to settle and be removed from wastewater. The secondary stage uses biological processes to further purify wastewater. Sometimes these stages are combined, and in some cases additional treatment such as tertiary treatment and advanced wastewater treatment are used. Primary treatment alone is increasingly unable to meet many communities' water quality standards. As a result, cities and industries normally treat it to a secondary treatment level and in some cases use advanced treatment to remove nutrients and remaining contaminants. Secondary treatment removes the soluble organic matter that escapes primary treatment. Secondary treatment also removes more of the suspended solids, usually by biological processes in which microbes consume the organic impurities as food and then convert them into carbon dioxide, water and energy.

Wetland. Wetlands form a transition (ecotone) between true terrestrial and aquatic habitats. Wetlands can be permanently wet, like peat bogs, or only intermittently wet, like most wetlands that dry up in mid to late summer. They are transitional areas where vegetation development is at some stage of a successional sequence typical of the site. Successional development can be almost untraceably slow (peat bogs) or so rapid that the wetland becomes a terrestrial community almost within years or decades due to the rapid accumulation of organic matter.

Wetland restoration. Restoration should re-establish insofar as possible the ecological integrity of degraded aquatic ecosystems. Ecological integrity refers to the condition of an ecosystem, particularly the structure, composition and natural processes of its biotic communities and physical environment. An ecosystem with integrity is a resilient and self-sustaining natural system able to accommodate stress and change. Its key ecosystem processes, such as nutrient cycles, succession, water levels and flow patterns, and the dynamics of sediment erosion and deposition, are functioning properly within the natural range of variability.

10. Abbreviations

Here is the list of abbreviations and their full names from the document:

BMC - Business Model Canvas

CAP - Agricultural Policy

CAPEX - Capital Expenses

ESS - Earth System Science

GDP - Gross Domestic Product

GGA - Green versus Grey Analysis

LONA - Nature Protection Initiatives

LOVA - Local Water Measures

LRF - Federation of Swedish Farmers

MRV - Measuring, Reporting, and Verification

NA- Negotiated Agreements

NBS - Nature-based Solutions

OPEX - Operational Expenses

PBL - Planning and Building Act

PES - Payment for Ecosystem Services

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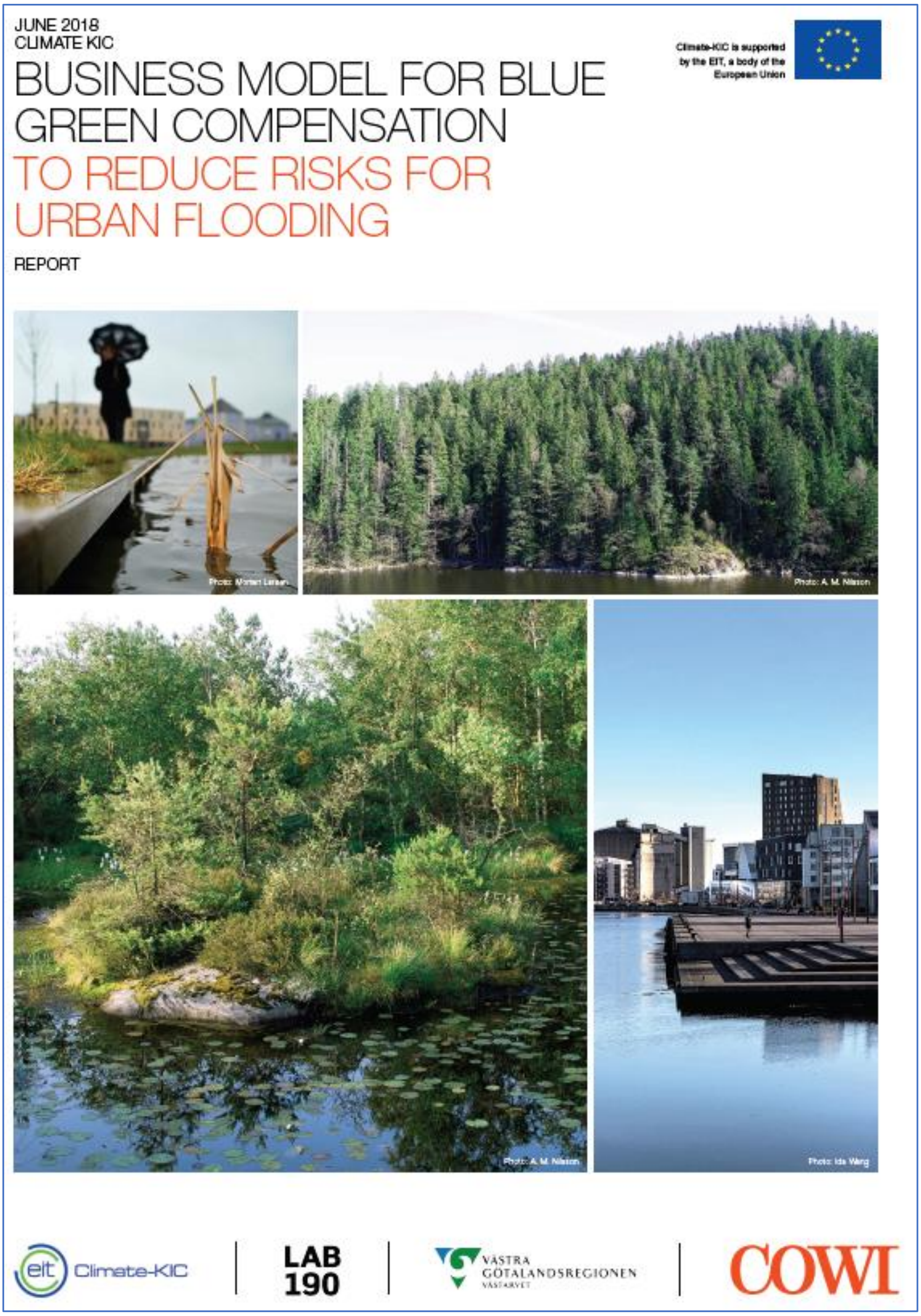
12. Appendix

Executive summaries of research reports, which have been referred to in this dissertation.

BUSINESS MODEL FOR BLUE GREEN COMPENSATION TO REDUCE RISKS FOR URBAN FLOODING

CLIMATE KIC, Gothenburg, June 2018
Authors: Anders M. Nilsson, Anna Ternell, Bodil Elmqvist and Peter Stigson



EXECUTIVE SUMMARY

Climate change will result in more intense precipitation in Sweden, which is expected to have increasingly severe impacts for cities and towns located downstream in catchment areas. If there would be recurring major floods, similar to the 2008 flood event in Gothenburg, what hazards would it present today and in a future scenario of climate change? The aim of this report is to review a financial marketplace as part of a business model for upstream water retention and flood risk management.

The risks in the downstream City of Gothenburg in Sweden are in general perceived to technical control, through the construction of more resilient river and sea defences such as grey infrastructure. Technical solutions are however typically costly and sometimes questionable as some of the flooding could be prevented with the help of more cost-efficient nature-based solutions.

The need to minimize the risks of flooding through increased capacity to retain water in the landscape is widely acknowledged. Landowners, both private and public, can do this, for example, by creating nature-based solutions that also create several other benefits, providing more efficacious solutions. This pre-study proposes a business model where downstream landowners, such as a municipality, compensates or pays upstream landowners to maximize the water retention potential.

Delaying the water upstream through various approaches has several benefits. Added solutions higher up in the landscape may reduce extreme flows downstream. Such measures can be small, simple and cheap, but the effects can be important in terms of other relevant goals in the society. This means that surface runoff and water peaks are reduced with less erosion and less sediment and nutrient movements. Achieving more steady water streams through nature-based solution can provide benefits, such as keeping the groundwater basins well stocked, with the purpose to avoid problems with drought in warmer weather. Increased storage of water in the landscape also benefits biodiversity, water quality, recreation as well as farming and agroforestry activities.

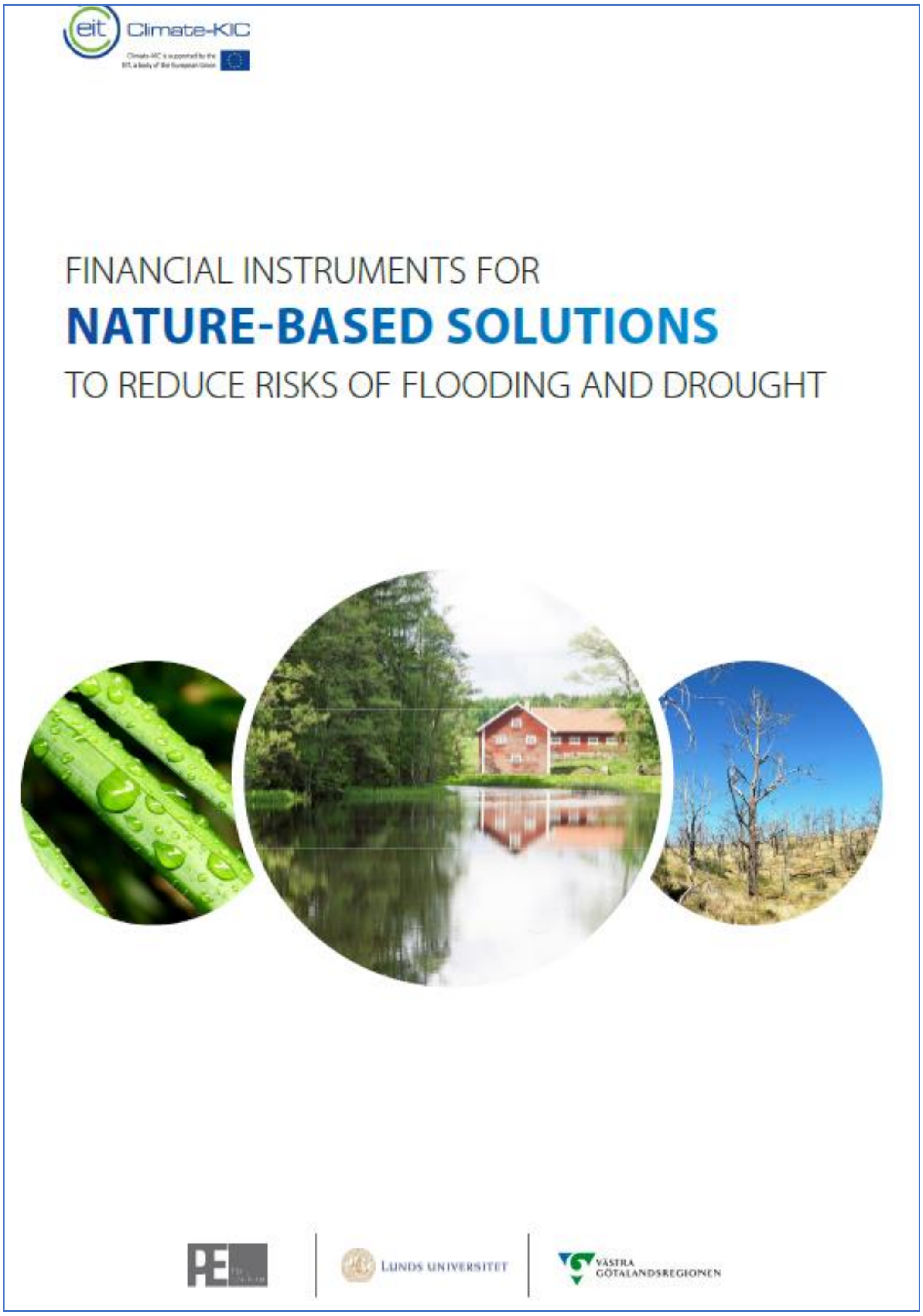
Today there are several ways of being compensated for water retention by applying for national funds. However, none of these comprises the complexity of inter-municipality and multi-stakeholder cooperation and the pre-study therefore investigates the possibilities of developing such a business model through a financial marketplace. We believe such cooperation is of importance since resources spent on grey infrastructure could instead be spent on blue-green solutions upstream.

About ten interviews were carried out with key stakeholders in the project area of the Säveå river catchment reaching the ocean in the city of Gothenburg. They show a great interest in this approach and support a further development. We therefore recommend further studies focusing on the feasibility of implementing the proposed model as well as its applicability in other regional and social contexts.

FINANCIAL INSTRUMENTS FOR NATURE-BASED SOLUTIONS TO REDUCE RISKS OF FLOODING AND DROUGHT

CLIMATE KIC, Malmö, Sweden | 18 December 2019 | Project number: 103409

Authors: Anna Ternell, Peter Stigson, Bodil Elmqvist, Johanna Alkan Olsson and Helena Hanson, Lund University, Anders M. Nilsson, Västra Götalandsregionen/Västarvet



EXECUTIVE SUMMARY

Today's expansion and densification of cities, where more space is being impermeably surfaced by grey infrastructure, means an increased risk of flooding. An urban space with reduced green areas is less resilient to increased temperatures. In dealing with this, research has pointed to the complementarity of NBS in contributing to more resilient and cost-efficient flood and drought management. Nature-based solutions (NBS) do not only serve to reduce risk for flooding and drought, they also provide additional sustainability values, such as strengthening ecosystem services through increased biodiversity and recreation opportunities. In many circumstances, combining this NBS with traditional grey infrastructure can provide next generation solutions that enhance system performance and better protect communities.

The need to minimise the risks of flooding through increased capacity to retain water in the landscape and the need for water access during drought is increasingly emphasized in policy and by regions. These water-related risks can be handled through two main paths: grey infrastructure such as concrete walls, elevated quaysides, and water dikes; or, nature-based solutions (NBS) such as ponds, wetlands and other blue-green measures. Most commonly, measures to address flooding focus on grey infrastructure.

The project aims to encourage more resilient climate adaptation solutions through a policy and institutional development that create a business case in adopting NBS for flood and drought management. This is analysed in a multi-stakeholder setting and highlights new ways of cooperation between private, public and civil stakeholders. The results provide a business model based on downstream landowners (beneficiaries) reimbursing or in other ways compensating upstream landowners (providers) to increase the water retention potential through NBS. The suggestion is a public policy instrument that stimulate financial instruments as a basis for agreements between different landowners – both municipal and private. This is aimed to complement other financial contributions, such as restoring wetlands funded by local water measures (LOVA) granted by the County Administrative Boards.

Challenges to a successful implementation and increased cooperation for NBS are in particular those related to the difficulties in implementing common intermunicipal interventions due to different conditions and priorities of municipalities. Legal barriers can also challenge the viability financial instruments due to the diversity of laws governing water and water activities that in turn give rise to a multitude of legal problems and dilemmas.

A strong input and driver for this financial instrument is derived from The European Landscape Convention and the Directive on the assessment and management of flood. The Convention aims to encourage public authorities to adopt policies and measures at local, regional, national and international level for protecting, managing and planning landscapes throughout Europe. It further proposes legal and financial measures, aimed at shaping ”landscape policies” and promoting interaction between local and central authorities as well as cooperation in protecting landscapes. The Directive requires member states to develop flood risk management plans that include measures to reduce the probability of flooding and its potential consequences. It addresses all phases of the flood risk management cycle including prevention (i.e. preventing damage caused by floods by avoiding construction of houses and industries in present and future flood-prone areas), and protection by taking measures to reduce the likelihood of floods and/or the impact of floods in a specific location (e.g. restoring flood plains and wetlands).

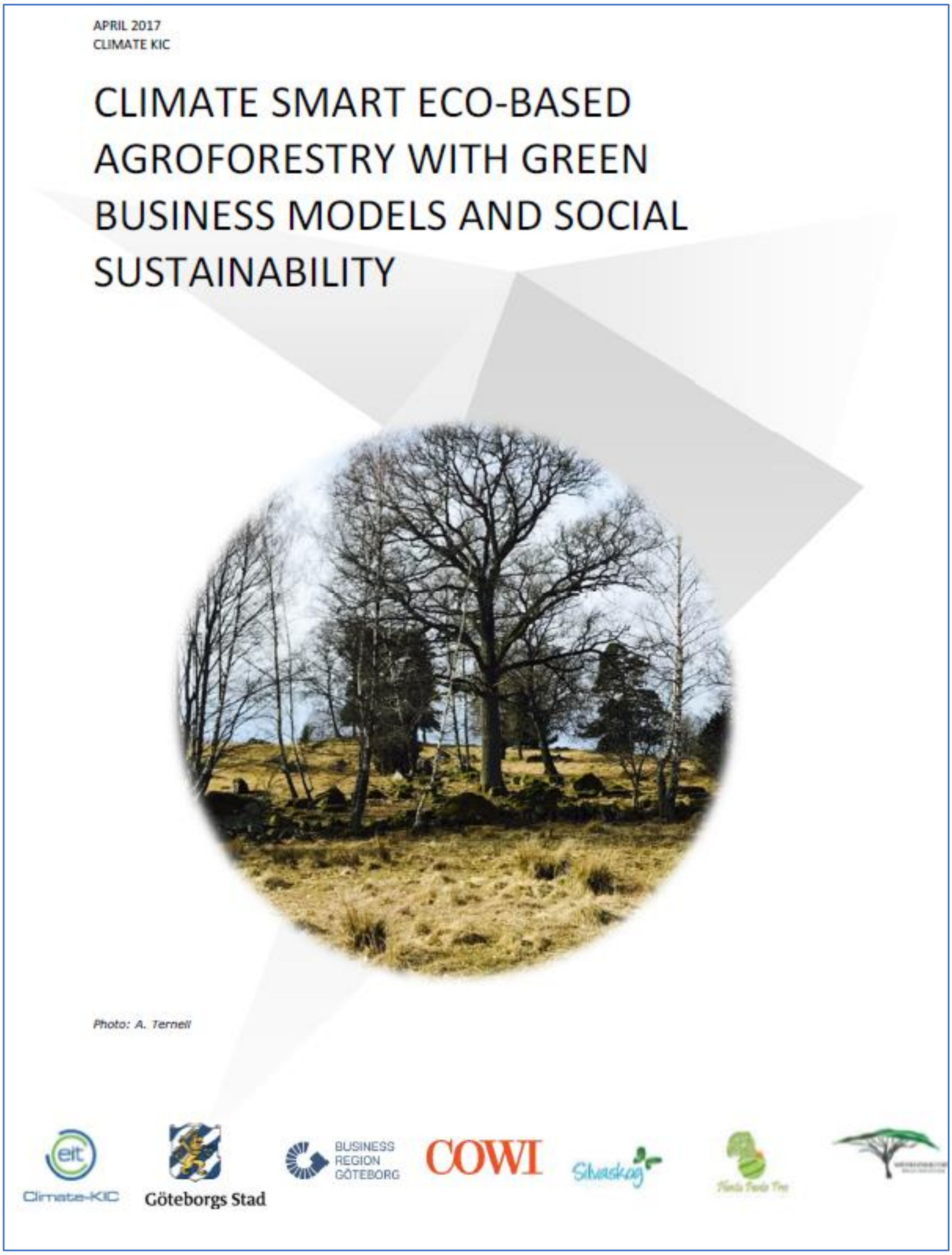
However, NBS is today not implemented on the scale identified as beneficial by relevant stakeholders and in literature. This, arguably, decreases the effectiveness and efficiency of public climate

adaptation policies. The workshops and analyses identify that this is caused by information asymmetries, policy uncertainties as well as cost barriers. The latter highlights the financial systems and a system for monetary transactions from the downstream beneficiary to the upstream provider. The project therefore suggests a new policy initiative aimed to stimulate awareness about, and adoption of NBS.

CLIMATE SMART ECO-BASED AGROFORESTRY WITH GREEN BUSINESS MODELS AND SOCIAL SUSTAINABILITY

CLIMATE KIC, Gothenburg, April 2017

Authors: Anna Ternell, Bodil Elmqvist, Dan Melander, Mikael Karlsson, Sarah Mubiru, Aster Asgedom, Ndi Chesami



EXECUTIVE SUMMARY

In this report we see Agroforestry as a collective name for agricultural and forestry methods that combine farming, cattle, and forestry in different combination to increase economic, ecological and social benefits. This includes the EU, UN and the European Agroforestry Federations (EURAF) definition.

Agroforestry is derived from ecology and is one of the three principal land-use sciences, the other two being agriculture and forestry. Agroforestry differs from the latter two principals by placing an emphasis on integration of and interactions among a combination of elements rather than just focusing on each element individually. Agroforestry can give substantial benefits both economically and environmentally, producing more output and proving to be more sustainable than forestry or agricultural monocultures.

The biological and physical interaction between the crop and the livestock components are manipulated to enhance the agricultural production of the land base. Potential benefits from properly designed and managed agroforestry practices include; increased crop production and economic gain; soil conservation and improved soil quality; sequestration of atmospheric carbon and increased biodiversity.

The City of Gothenburg is a green city with about 70% of the urban areas consisting of green areas. Forests cover more than half of these areas. The majority of the land is owned by the City. They meet challenges with managing the forests to maintain good biodiversity and utilisation of the land. The development of sustainable land use has, by policymakers and practitioners in Gothenburg region, typically focused on sustainable agriculture from isolated (i.e. silo) perspectives. Less attention has been given to a more systematic view on sustainable practices in the forest sector and the agriculture-forest intersection.

The City of Gothenburg is, however, the leading city in Scandinavia in supporting the development of sustainable eco-urban farming in and around the city. Gothenburg is further the first city in Sweden that decided to practice selective forestry for their forests and to forbid clear-cut. Although, agroforestry products are only contributing to the local economy at a very small scale, there is a big potential to develop local economic and social development by integrating new ways of innovative business models. This could partly address the large amount of people in the region that is unemployed, especially among the non-Swedish born.

International aspects of agroforestry related to human rights and social sustainability are acknowledged and this study is therefore highlighting the social innovation by integrating the work of an ecosystem based economic development in urban and rural areas, also by connecting migration and integration. This includes e.g. to integrate co-creative green production and development in beautifying the infrastructure instead of the traditional nature management that is costly and does not involve the people nor develop the biological multitude.

The study is focusing on the growing urban demands for agriculture, urban and peri-urban farming and forestry produce and ecosystem values in a way that create green businesses. Urban and rural areas are no longer separate territories and the emerging ‘peri-urban’ areas are the site of the most dynamic changes. Peri-urban problems and opportunities are best addressed at the level of the rural-urban region, which includes both peri-urban and rural hinterland areas. In many countries around the world1, agroforestry is also related to building local eco-system based economy for eco-justice, human rights, democracy and fair trade. This could be important values in building green ecosystem based infrastructure in a city and peri-urban and rural areas. Agroforestry can in these forms increase co-creative social economy and sustainability, health, psychological well-being, improve aesthetics (in particular in road and industrial areas), property value, and give recreational and educational opportunities as well as job creation. These categories are also compatible with the classified and recognized CICES System as Cultural Ecosystem Services. Eco-system based local tourism is also aspects of Agroforestry.

The climate change challenge to be tackled in this project is to overcome barriers hindering reducing the GHG emissions. There are mainly two ways to tackle GHG emissions: through; a) carbon sequestration from agroforestry and, b) by reducing GHG emissions from transport and production of agricultural crops by encouraging locally produces crops. A new business model can provide local produce which currently is provided by longer distance transport and potentially produced in areas with less stringent climate policy and less focus on optimized
and sustainable land-use.

The current barriers in well-maintained and smart local agroforestry is the lack of coordination and collaboration between stakeholders. To overcome these barriers, collaboration and coordination between stakeholders aiming at managing the land more wisely by introducing agroforestry in the area is crucial. Further public private partnership could be developed to support local businesses. The group of stakeholders specific to this project has a very good dialogue to achieve goals and overcome barriers.

PUBLIC-PRIVATE PARTNERSHIPS FOR MULTIFUNCTIONAL SUSTAINABLE LAND USE IN PERI-URBAN AREAS THE CASE OF THE SWEDISH CITY OF GOTHENBURG AND THE SURROUNDING AREA

CLIMTE KIC, December 2017, Gothenburg

Authors: Anna Ternell, Bodil Elmqvist, Anders M. Nilsson, Region Västra Götaland/Västarvet
Björn Ohlén, Region Västra Götaland/Västarvet

EXECUTIVE SUMMARY

In this paper we illustrate the large potential for continuing to develop public-private partnerships for multifunctional sustainable land use in peri-urban areas in the Swedish City of Gothenburg and the surrounding area based on lessons learnt from ongoing initiatives.

The first aspect, multifunctional land use is a land use system that integrates forestry, agriculture and agroforestry with fruit-bearing trees and shrubs, and animal husbandry. This kind of land use is one way to create resilience and meet climate risks, such as increased risk of damage caused by for example storms, insects and fungi. It also refers to how the land use provides value in terms of for example recreation and job creation. In the City of Gothenburg, the forest policy, states that the clear-cuts are not be practised, instead selective forestry is prioritised referring to a selective harvest of trees with less disturbance to the ecosystem.

››We see the need of land use policies supporting the practice of multifunctional land use such as for example agroforestry and selective forestry. The development of sustainable land use has, by policymakers, civil servants and practitioners, typically focused on land use from isolated perspectives. Less attention has been given to a more systematic view on sustainable practices in the forest sector and the agriculture-forest intersection. ››

Some farmers are focusing on intensive production of high-value added produce, such as special herbs and vegetables for high-end customers as well as basic food stuffs as a way of diversifying agriculture. Such activities can become an important income source for the farmer and optimising the proximity to customers with these needs and should be acknowledged in policy-making.

The second aspect, peri-urban land use, is defined as the area between the urban and rural areas. The peri-urban areas access larger areas of agricultural and forestland compared to urban areas and the peri-urban area can benefit from available work force, infrastructure and urban services, which is not as evident in rural areas.

››A more sustainable development requires more policy attention at the regional level and at the urban-rural interface. Moreover, the potentials for urban and peri-urban land use are both due to the availability of non-built public land and the demand from citizens of the use the land to produce for example food and recreational services.

››Peri-urban agriculture and forestry involve complex interactions of social, economic and environmental aspects in locations that are undergoing rapid change and often with inadequate financial means and political support to respond. Still, there is a large potential to develop the land in close vicinity to the city as well as in the suburbs. Cost savings can be achieved because of, for example, the proximity to the market and less need for transportation and preservation of fresh products.

The third aspect, multi-stakeholder processes, is central for encouraging the development of multifunctional sustainable land use in peri-urban areas. One example in the City of Gothenburg and the surrounding area, is through public-private partnerships, which for example, are supported by the regional platform for sustainable development, LAB190, manged by the Region Västra Götaland. This platform includes four municipalities and has a great potential for fostering multifunctional sustainable land use as it is well integrated in the municipalities, at the level of civil servants and the politicians. One way is to continue to develop the Business Improvement District for sustainable food production, where cooperation between different actors of society is formalised, that is currently (as of December 2017) being established.

A BUSINESS MODEL FOR MULTIFUNCTIONAL SUSTAINABLE LAND USE IN PERI-URBAN AREAS –THE CASE OF GOTHENBURG AND SURROUNDING REGION, SWEDEN

CLIMATE KIC, November 2017, Gothenburg

Anna Ternell and Bodil Elmqvist, Anders M Nilsson, Region Västra Götaland/Västarvet, Björn Ohlén, Region Västra Götaland/ Västarvet, Daniel Stenholm, Chalmer's Technical University, Dag Bergsjö, Chalmer's Technical University

EXECUTIVE SUMMARY

The development of sustainable land use has, by policymakers and practitioners in Sweden typically focused on sustainable agriculture from isolated perspectives. Less attention has been given to a more systematic view on sustainable practices in the forest sector and the agriculture-forest intersection. Further, many projects and initiatives focus on the development of urban areas while peri-urban land have been neglected for many years.

In Gothenburg, peri-urban areas have been treated as reserve land for future exploitation, and few investments are made to strengthen ecosystem services. The potential for the City of Gothenburg is, however, that through its vast land holding, they can control how the urban land area is used. It does not mean there are no conflicts of interest, but to avoid this, the City has categorised the land into medium and long term planning areas. For areas where exploitation is first planned in the long term, the City is strengthening the innovation of green businesses by introducing tenants with new business models to use public land.

If these initiatives should be scalable, more land is required. More land is available in the peri-urban areas and in the neighbouring municipalities. In the neighbouring communities, the strategy for innovation and new users in agriculture and forestry must look different because they do not own much land. We believe that the solution is to release these new players into the unused land where they do not compete with the established businesses.

The most probable type of entity that will deliver the innovation or solution is new ventures and public-private partnerships. Non-project activities and objectives that need to support the successful outcome is the continued dialogue between the City and the Region with the local entrepreneurs and the community. A well-established cooperation platform for this is the LAB190. The platform is a cooperation between four municipalities, including Gothenburg, for sustainable economic and social development.

The proposed business model will build on the tested model of land lease in urban and peri-urban areas and scale up to the larger area and include private and public landowners. This will support the sustainable ecosystem based local management and cultivation of peri-urban areas and enhance the supply of ecosystem services, protect the environment and meet the needs of a growing population. This could benefit the local economy, the biodiversity and the climate resilience and social sustainability. With the close cooperation and participation of the City and The Region and their ongoing activities with local entrepreneurs, the business model has been anchored and validated.

A BUSINESS MODEL FOR MULTIFUNCTIONAL SUSTAINABLE LAND USE IN PERI-URBAN AREAS

SUMMARY

The development of sustainable land use has, by policymakers and practitioners in Sweden typically focused on sustainable agriculture from isolated perspectives. Less attention has been given to a more systematic view on sustainable practices in the forest sector and the agriculture-forest intersection. Further, many projects and initiatives focus on the development of urban areas while peri-urban land have been neglected for many years.

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