Nature-based Solutions for Territorial Resilience.
Flood Adaptation along Adige River, Verona.

POLITECNICO DI TORINO

Master's degree programme
TERRITORIAL, URBAN AND LANDSCAPE-ENVIRONMENTAL PLANNING
Curriculum: Urban and Regional Planning
Academic Year 2023/2024

Nature- Based Solutions for Territorial Resilience. Flood Adaptation Along Adige River, Verona (Italy)

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December 2024

ABSTRACT

This thesis is based on exploring Nature-Based Solutions (NBS) as the best solution to reduce flood risks caused by climate change along the Adige River in Verona, Italy. It illustrates that urban development cause of the growing vulnerability of urban areas to unpredictable and unusual weather phenomena and examines how NBS can improve flood protection and strengthen territorial resilience through urban planning. The study identifies high flood-risk areas along Adige river that it is a part of Verona's historic center by using Qgis tool for risk analysis. In this reaserch NBS, such as urban forests, natural wetlands, floodplain restoration, river re-naturalization, and slope management, used to adapt flood risk based on urban needs and opportunities.

These solutions help collect floodwaters, improve biodiversity, and create recreational spaces, reduce runoff and prevent soil erosion. This research supports sustainable urban planning by proposing NBS strategies that enhance flood resilience, ecological sustainability, and public well-being. The thesis provides a model for integrating NBS into flood adaptation planning, helping Verona move toward climate adaptability and stronger territorial resilience.

This thesis was developed as part of an internship with the Comune di Verona. The work was supervised by Professor Ombretta Caldarice from the Politecnico di Torino, a member of the Interdepartmental Centre R3C - Responsible Risk Resilience Centre, and co-supervised by Professor Francesco Musco from the Università Iuav di Venezia, President of the Center for International Study and Research on Climate Change (CSRCC).

Acknowledgments

I want to thank my **professor Omberta Caldarice**, for her help and support me during my research. She gave me advice and guidance that helped me finish my thesis.

I also thank the Urban Planning Office of the Comune di Verona team: **Dr. Ernesto Caneva, Ing. Matteo Baccara, and Ing. Roberto Carollo.** They supported me with important resources, knowledge, and experience about Verona, which were very helpful for my thesis.

I want to thank **my Love**, **Reza**, for his support and love, which made this journey beautiful, and my **parents** for their encouragement during this time.

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CHAPTER 01

INTRODUCTION

In Chapter 1, the project's objectives were established, key research questions were formulated, and the expected results were outlined. This foundation establishes precise success criteria and acts as the investigation's guiding framework.

1-1.INTRODUCTION

Indeed, climate change is posing serious problems for cities around the world. Floods, droughts, sinking ground, and heat waves are examples of extreme weather phenomena that are becoming more frequent and worrisome. A significant concern among these issues is the increase of severe floods linked to climate change.

To address these issues, urban planners are turning to Nature-Based Solutions (NBS). These strategies harness nature to adapt to climate change, providing a natural safety net for communities facing such challenges. This thesis proposal's primary objective is to use NBS to adaptation flood issues along the Adige River in Verona. The Adige River is particularly important for this study because of its proximity to Verona's historic center and the presence of nearby buildings. The potential for floods to ruin landmarks and historic structures highlights the urgency of taking preventative action. Changes in the river's behavior caused by factors like melting ice and harsh weather patterns emphasize the need for preventive steps to avert disasters.

In recent years, Urban planners are using Nature-Based Solutions (NBS) to solve these problems. As a natural safety net for communities dealing with such issues, these tactics use nature to adapt to climate change. The main goal of this thesis proposal is to employ NBS to alleviate flood problems along Verona's Adige River. Because of its closeness to Verona's historic core and the existence of surrounding structures, the Adige River is very significant for this study. The possibility that floods could destroy historic buildings and landmarks emphasizes how urgent it is to put precautionary measures in place. The necessity for preventive measures to avert disasters is further highlighted by changes in the river's behavior brought on by elements like melting ice and extreme weather patterns.

Questions

1.What are nature-based solutions, and how do they adaption climate change hazards in urban areas?

2.Which nature-based solutions are most effective in improving flood adaptation and enhancing territorial resilience?

3.How can Nature-Based Solutions support urban design and planning for flood adaptation along the Adige River?

Objectives

- Identifying criteria for Nature-Based Solutions to answer climate change challenges, with a particular focus on Flood adaptation.

- Analysis using natural based criteria to identify high flood risk areas along the Adige River in Verona.

- Exploring and evaluating the effectiveness of various natural solutions in effecting on flood adaptation and territorial resilience along the Adige River.

- Reaching out Urban design and planning principles based on natural solutions to adaptation flood risks through territorial resilience along the Adige River.

These goals aim to give practical ideas to improve flood resilience along the Adige River by combining territorial resilience and natural solutions.

Results and Findings

This reaserach emphasizes the effect of natural elements on flood adaptation. As it is clear that flood occure in areas with fewer nature elemalnts. The study demonstrates how these elements can improve resilience in vulnerable areas along Adige river by reducing flood risk. It also illustrates how NBS into urban planning & design can improve territorial resilience for flood adaptation along Adige River in Verona.

Challenges

Lack of Data:
The lack of data in the field of climate change, as a dynamic and new topic as well as urban planning, make it difficult to collect data.

Time Constraints:
Lack of time for the thesis, as a university exercise with real-world needs, is difficult due to the time and the broadness of the topic.

Dynamic Urban Environment:
Finding Sustainable solutions, especially nature- based solutions, is difficult as the city is dynamic and change over time, so our predictions may contain errors.

THEORETICAL FRAMEWORK

- Literature Review
- Case Studies Analysis
- Existing Solutions

The output of Section one is the identification of Nature-Based Solutions for flood adaptation in urban areas.

SITE ANALYSIS (Verona,Adige River)

- Analysis of Existing large-scale & city scale planning for climate change and flood adaptation in Verona
- Analysis of Verona City
- Analysis of the Adige River

The output of Section 2 is the understanding and analysis of the current situation in Verona and along the Adige River, as well as identifying the flood challenges in verona.

PLANNING AND DESIGN

- Design & planing
- Design & planning Principles

The output of the final step is the proposal of local design solutions based on Nature-Based Solutions (NBS) for flood adaptation, focusing on territorial resilience. This will be developed through a strong combination of the theoretical foundations of NBS and the analysis of Verona and the Adige River.

CHAPTER 02

THEORETICAL FRAMEWORK

Chapter 2, introduces the concept of territorial resilience to flood adaptation based on a literature review in this field and shows how cities can address these challenges using nature-based solutions. The outcome of this chapter identifies the best nature-based solutions for addressing flood challenges in cities with rivers. This chapter provides key solutions, bridging the theoretical and practical aspects of the thesis. It serves as a connection and guideline for the subsequent chapters.

2-1.INTRODUCTION

Climate change is a significant threat to urban areas worldwide, exacerbating river flooding and challenging traditional urban planning (Nordin von Platen, 2018; Dharmarathne, 2024). This threat comes from the complex relationship between climate change and rapid urbanization, altering natural hydrological processes and reducing permeable surfaces in cities (Skrydstrup, 2022). Over a decade, flood hazards affected half of the global population exposed to natural hazards (Nordin von Platen, 2018).

In response to these challenges, there is growing recognition of the importance of NBS in improving urban resilience to flooding (Egegård, 2024). NBS uses natural features and ecosystem services to mitigate and adapt to flood risks, offering sustainable alternatives to conventional engineering approaches (Horizon, 2020). The concept of resilience territory has emerged as a holistic framework for flood adaptation, emphasizing the Connectivity of ecological, social, and infrastructural systems within urban landscapes (Mariano, 2022). However, the implementation of NBS and resilience territory in urban settings presents unique challenges (Gaisie, 2023). Traditional urban planning practices often Select traditional engineering strategies, which may not adequately address the multifaceted impacts of climate change on urban flood risk. (Nilubon, 2024). Furthermore, the complex and dynamic nature of urban systems requires interdisciplinary approaches that consider ecological, social, and economic dimensions of flood resilience (Dharmarathne, 2024).

Nature-based solutions offer promising measures for protecting ecosystems and addressing societal challenges, including climate change mitigation and adaptation (Hori, 2023). Urbanization exacerbates flood risks, with cities facing increased vulnerability due to landscape transformations (Dharmarathne, 2024). Climate change-caused hazards, such as floods, challenge urban resilience, affecting various city components, including ecological-environmental, settlement, and infrastructure and services systems (Mariano, 2022).

In conclusion, embracing NBS and resilience territory offers sustainable paths toward urban flood resilience amidst climate challenges.

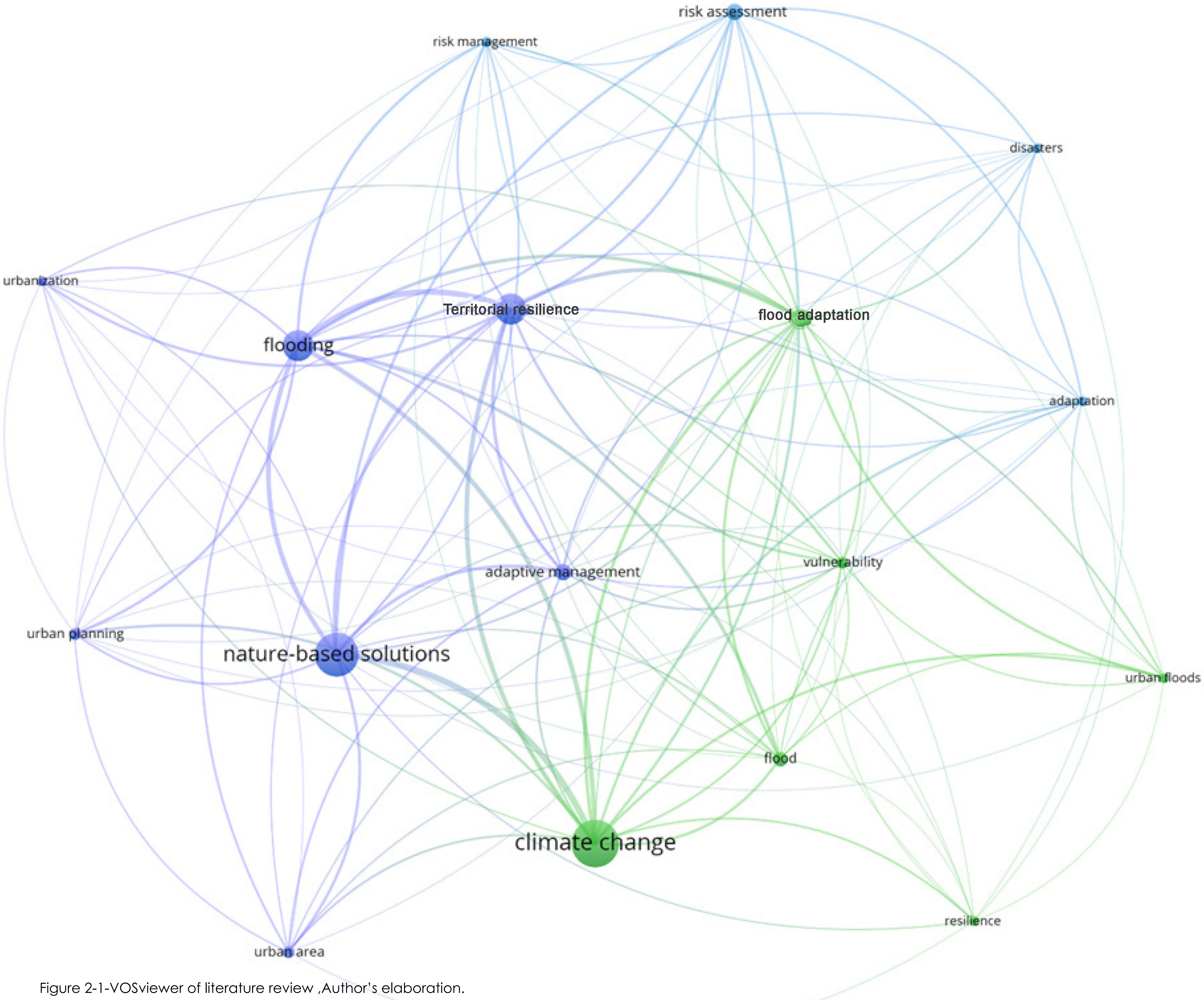


Figure 2-1-VOSviewer of literature review ,Author's elaboration.

The following VOSviewer-generated visualization shows where important terms appear in the dataset. With each term displayed as a node sized proportionate to its frequency, this occurrence metric illustrates the frequency of particular terms. (Bukar, 2023) With climate change as the main issue and nature-based solutions (NBS) and flood adaptation as important subtopics, this analysis of the literature review in this thesis identifies two major clusters.

According to the diagram, the first emphasis is on natural-based solutions as a crucial component of territorial resilience in response to the difficulties posed by climate change, with a particular focus on flood adaptation along riverbanks. This section of the thesis is devoted to providing definitions for important words like:

- NBS
- Territorial Resilience
- Flood
- Flood adaptation

establishing a strong framework to continue this chapter.

2-2 SUSTAINABLE DEVELOPMENT GOALS

The research outlined in this thesis is aligned with several Sustainable Development Goals (SDGs) and their associated targets. Specifically, the research aims to address SDGs 11 (Sustainable Cities and Communities), 13 (Climate Action), 15 (Life on Land), and 6 (Clean Water and Sanitation). Tasks 11.b and 13.1 within these SDGs are particularly relevant, focusing on disaster risk reduction and increasing climate change resilience and adaptive capacity. (Egegård, 2024; Tyllianakis, 2022) Additionally, target 15.1 from SDG 15, concerning the conservation and sustainable use of terrestrial ecosystems, and target 6.6 from SDG 6, aiming to protect and restore water-related ecosystems, are also associated with this research.

"LIFE ON LAND

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss."

Target 15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements. (Source: European Commission)

"CLEAN WATER AND SANITATION

Ensure availability and sustainable management of water and sanitation for all. "

Target 6.6 by 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
(Source: European Comission)

"SUSTAINABLE CITIES AND COMMUNITIES

Make cities and human settlements inclusive, safe, resilient and sustainable."

Target 11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels.

Target 11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations. (Source: European Comission)

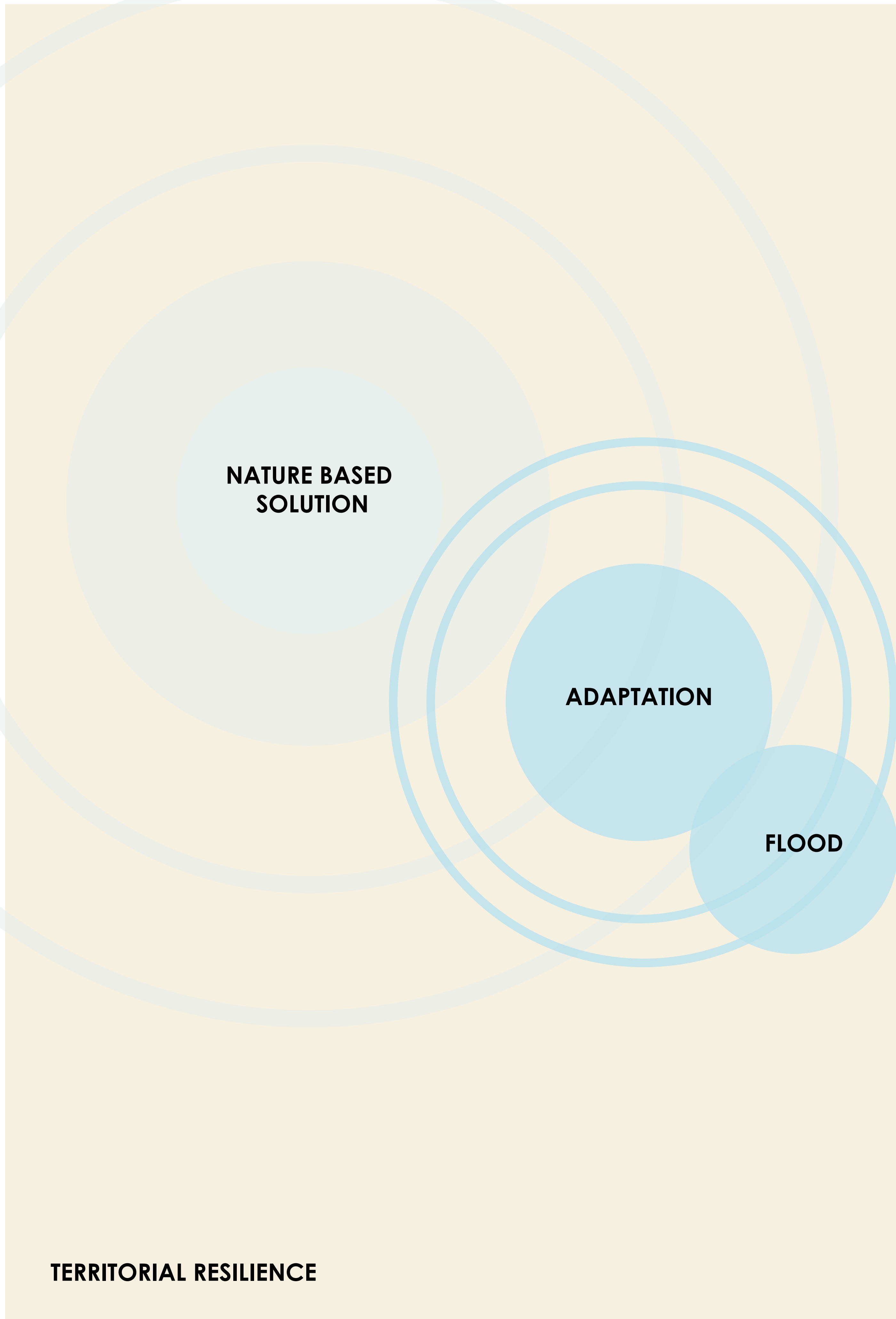
"CLIMATE ACTION

Take urgent action to combat climate change and its impacts."

Target 13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries. (Source: European Comission)

2-3.THEORETICAL FRAMEWORK

Territorial resilience contains a wide range of strategies and measures aimed at building resilience within a geographical area, and NBS are essential to achieving these goals. Flood adaptation, which often involves the implementation of NbS like green infrastructure and ecosystem-based approaches to manage flood risks, is a specific aspect of NBS within the broader context of territorial resilience. So, in summary, NbS are a part of territorial resilience, and flood adaptation is a part of NBS.



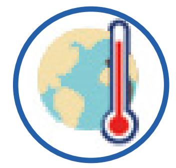
2-3-1. NATURE BASED SOLUTIONS (NBS)

Figure 2-2-Defining Nature based solution (IUCN, 2020)

Nature-Based Solutions (NBS): Developing into Crucial Approaches to Worldwide Sustainability

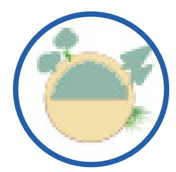
NBS became well-known as efficient tools for disaster risk reduction, climate change adaptation, mitigation, and attaining sustainable development goals after being first acknowledged in international accords like the Paris Agreement and policy frameworks like the European Green Deal (Tyllianakis, 2022). At the 2019 United Nations Climate Summit, their linkage with the Sustainable Development Goals of the UN was reaffirmed, underscoring their ability to address global issues (IUCN, 2020). Furthermore, NBS was endorsed in important reports like the IPBES Global Biodiversity Assessment Report and the IPCC's Special Report on Global Warming of 1.5°C, confirming their significance in tackling ecological and societal issues on a global basis (de Coninck et al., 2018; IPCC, 2019; IPBES, 2019a).

Definition of Nature Based Solutions





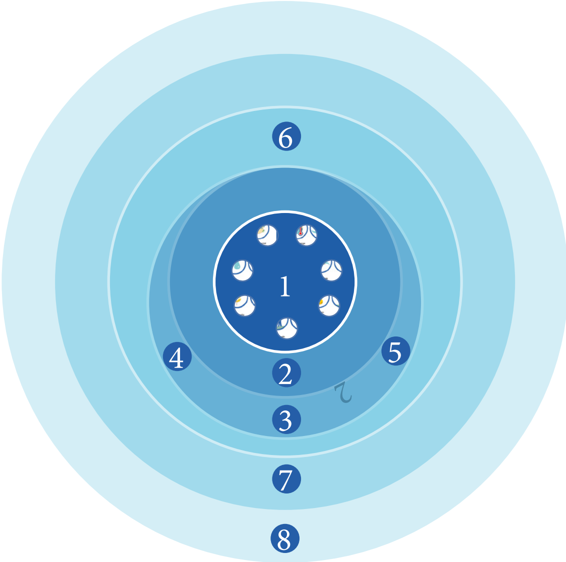




Nature-Based Solutions offer a comprehensive strategy for resolving city issues by incorporating ecosystem-based tactics that capitalize on nature's innate advantages. In order to effectively address urgent problems like the effects of climate change, natural disasters, and urbanization pressures, NBS, as defined by the International Union for Conservation of Nature (IUCN), include a variety of conservation strategies like Ecosystem-based Adaptation (EbA) and Ecosystem-based Disaster Risk Reduction (Eco-DRR) (IUCN, 2020).
These nature-inspired and nature-backed solutions seek to improve sustainability, increase resilience, and offer social, economic, and environmental advantages (Randrup, 2020).
The natural benefits the multifunctionality of ecosystems to mitigate risks, improve well-being, and foster biodiversity, thereby contributing to a greener and more sustainable future (Babí Almenar et al., 2021; Horizon, 2020). Through locally adapted, resource-efficient, and systemic interventions, NBS bring diverse natural features and processes into cities, landscapes, and seascapes, addressing challenges like climate change, urban heat islands, flooding, and impaired health and well-being (Kalantari, 2023; Randrup, 2020). By providing cost-effective solutions that simultaneously enhance environmental quality, support human livelihoods, and build resilience, NBS emerge as a vital framework for achieving sustainable development goals at local, national, and global scales (Tyllianakis, 2022; Nordin von Platen, 2018). NBS acts as an umbrella for development by using natural elements. (Egegård, 2024)

Nature Based Solutions Criteria

This thesis as a guideline define brilliant criteria for using NBS. Each criteria provide a framework to understand the role of NBS in urban context to answer challenges And support sustainable city and development goals.



NBS Criteria		Description
1	**Social challenges**	NBS should consider social challenges such as urbanization, climate change and natural disasters.
2	**Design based on scale**	The implementation and design of NBS should be based on the context and scale, such as city, neighborhood, region and so on.
3	**Biodiversity improvement**	NBS can help to improve and protect biodiversity by protecting natural habitats and their functions.
4	**Economic feasibility**	Cost effecive: NBS should demonstrate cost-effectiveness compared to grey infrastructre, highlighting the long term benefits of nature- based solutions.
5	**Inclusive governmance**	Creating a sense of engagement in the project for locals, stakeholders, communities and governing bodies is essential.
6	**Balance trade-offs**	Ballancing between primary goals such as flood mitigation and climate adaptation with social, economic and environmental benefits are esssential.
7	**Adaptive management**	NBS management should remain flexible to adapt to changing environmental conditions.
8	**Sustainability & adaption**	NBS should enter into city planning by considering policies on different aspects.

Table 2-1. Criteria of NBS(Horizon, 2020)

Nature Based Solutions Goals

For desired results, such as a lower risk of disaster, better human well-being, and socially inclusive green growth, nature-based solutions make advantage of the characteristics and complex system processes of nature, such as its capacity to store carbon and control water flow. (Horizon, 2020)

GOAL 1.0

Increasing sustainalbe urbanization

Sustainable urban development and nature-based solutions improve urban environments by supporting economic growth, Increasing climate resilience, and improving public health through green spaces.

GOAL 2.0

Restoring harmed Ecosystems

Restoration efforts improve resilience to risks like sea level rise, storms, floods, and landslides.

GOAL 3.0

Developing Climate Change Adaptation and Mitigation

Restoration efforts improve resilience to risks like sea level rise, storms, floods, and landslides.

GOAL 4.0

Improving Risk Management and Resilience

Improving climate adaptation and mitigation by reducing hazards, pollution and carbon emissions.
Existing green spaces, walls, and roofs provide green infrastructure that the city can benefit.
Improving the quality and quantity of water, preventing floods and droughts.

Nature-Based Solutions and Cities

NBS is a comprehensive method of urban planning that acknowledges the interdependence of human societies and natural ecosystems. Its goal is to build cities that are not only resilient to environmental shocks but also sustainable, inclusive, and supportive of human well-being. Combining natural solutions into urban planning has ecological and financial advantages. Health, social cohesiveness, and community support are all Improved by access to green spaces and high-quality landscapes. (Horizon, 2020)

Main Advantages of Nature-Based Solutions (NBS)

Sustainable Systematic and Integrative Approach

- **Multi-functional Benefits:** NBS combine economic potential, biodiversity preservation, pollution mitigation, carbon storage and leisure activities (Horizon, 2020).
- **Long-term Benefits:** Unlike unsustainable methods that provide short-term gains but long-term negative effects, benefits of NBS appear over time (Simelton, 2021).

Resource Efficient

- **Cost-effectiveness:** : NBS offer a long-term, cost-effective approach to environmental management by using natural elements, compared to grey solutions, are more affordable.(Skrydstrup, 2022)
- **Efficient Use of Natural Resources:** NBS make effective use of natural resources and processes, which lowers air and water pollution, the urban heat island effect, and improves human well-being (Bernello, 2022)

Long-term Cost-efficient

- **Economic Advantages:** By protecting against flooding, increasing flood storage, and improving ecosystem services like carbon mitigation and climate change adaption, NBS offer long-term cost savings. (Horizon, 2020).
- **Habitat Creation:** In order to improve biodiversity and ecosystem health, They offer solutions like creating habitats and replacing for environmental losses. (Nordin von Platen, 2018)

Benefits of Nature-Based Solutions

Drawing from a variety of academic sources, this section highlights the many advantages of nature-based solutions (NBS). The primary benefits of NBS are The four primary benefits include co-benefits, resource efficiency, long-term cost efficiency, and a sustainable, systematic, and integrated strategy. (Nordin von Platen, 2018)

Co-benefits

- **Improved Biodiversity:** By preserving and improving plant cover, which sustains a variety of ecosystems, NBS play a major role in biodiversity conservation. (Kabisch, 2016; Egegård, 2024)
- **Climate Change Mitigation and Adaptation:** Reducing various hazards (such as floods , droughts and ...) (Horizon, 2020)
- **Social and Economic Co-benefits:** NBS provide social and economic co-benefits by improving habitat quality, lowering the cost of artificial infrastructure, encouraging community involvement, generating employment in the green industry, and enhancing health and leisure activities. (Ruangpan et al., 2021; Giachino et al., 2022)
- **Resilient and Liveable Cities:** NBS help to build resilient cities by addressing urban challenges such as flood risk, air quality, and heat stress, improving overall quality of life. (Mah, 2023)

Benefits of Nature-Based Solution

Nature-based solutions offer a special opportunity to enhance well-being and strengthen community cohesion. Particular attention must be paid to the involvement of society and individuals in restoration and other nature-based solutions, with the aim of re-connecting people with nature, raising awareness of societal benefits, and creating a public demand for healthy natural environments. (Horizon, 2020)

Diadvantages of Nature-Based Solutions

- **Needing more time for implementation than grey solutions**

- Implementation time is long:
As in NBS trees are used, it takes a lot of time to show NBS benefits in comparison with grey infrastructure. (Simelton, 2021).

- **Skilled workforce:** Combining NBS into urban development takes a lot of time and requires expert expertise. (Egegård, 2024)

- **Space Consuming**

- Space Requirements: The implementation of NBS need more physical space compared to standard gray solutions. (Skrydstrup, 2022; Horizon, 2020, Nilubon, 2024; Zandersen, 2021)

Operational Challenges

- **- Economical Challenges:** This approach is new, and bringing it into urban planning and city development is very challenging due to budget and financial limitations.(Egegård, 2024).

- Lack of documents: As NBS is a new approach, lack of many real world examples and essential documents can be seen. (Simelton, 2021).

- **Making Environmental Injustice**

- Policy and Implementation Gaps: The lack of climate change policies and implementation challenges lead to inconsistent actions, making injustices in natural capital. (Nilubon, 2024)
- Misleading Initiatives: In some NBS projects, ignoring the needs of people and biodiversity can lead to negative outcomes. (Simelton, 2021)

2-3-2. RESILIENCE

Definition and Importance

Urban resilience refers to the capacity of urban systems to respond to shocks by preventing, adapting, or responding to them by making innovation solution, ensuring the functionality of cities between disturbances (Mannucci, 2022). This concept is an important goal for cities, especially facing climate change, as it provides insights into the management of complex socio-ecological systems (Folke, 2006; Pickett, Cadenasso, & McGrath, 2013).

The lack of funding and policy tools can make it difficult to implement climate adaptation strategies (Nilubon, 2024; Egegård, 2024). Although in recent years, benefits of ecosystems in recognized, without any structure is difficult also to inter traditional urban planning method. (Egegård, 2024) Despite these challenges, it is clear that incorporating NBS into urban planning brings many benefits. (Bernello, 2022; Horizon, 2020) This change allows cities to become places for implementing resilience strategies. It helps cities adapt to change, stay current and respond to problems at any time. (Sara Meerow, 2016) In one word making cities sustainalbe.

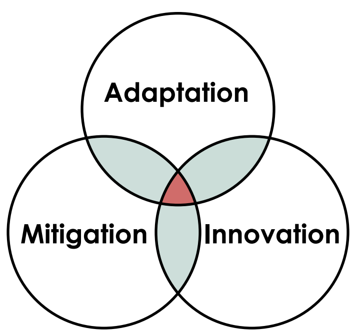


Figure 2-3 - Resilience phases (SaraMeerow, 2016)

PHASE 1

Mitigation: This phase focuses on mitigate risk.

PHASE 2

Adaptation: For reducing damage this phase bring fast action to answer risk for reduction damage.

PHASE 3

Innovation: by learning from disaster build situation to answer risk and challenges in the best way. (Bhoite, 2023)

Resilience Phases

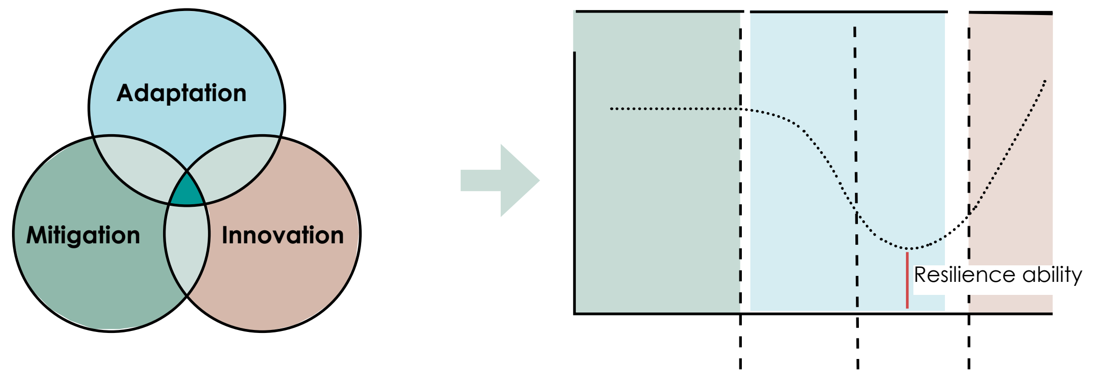


Figure 2-4 - Resilience phases(Istanabi, 2019)

Conceptual framework of city resilience

Social Dimention

Making and improving social networks to support people before, during, and after disasters.

Spatial Dimention

Analyzing vulnerability and resilience from spatial perspective.
Recognizing the relationship between resilience and context, location, spatial arrangement, and spatial attractions.
Using technical standards to built environment performance in response to hazards.

Environmental Dimentions

Creating a combination between environmental controling and prediction capability.
Adopting to increase risks.
Manage of risks, improving resilience and reducing vulnerability.

Figure 2-5 - Conceptual Framework of city resilience (Ferhat Bejtullahu, 2017)

Resilience and Cities

Addressing the vulnerabilities brought on by climate change, earthquakes, diseases, and other hazards is crucial because over half of the world's population lives in cities (Mannucci, 2022). In order to address particular vulnerabilities, climate-resilient urban Needs shifting from unrealistic analysis and broad statements.(Gaisie, 2023).

Territorial resilience

Territorial resilience refers to a system's capacity to respond to changes while keeping essential functions of system, by recognizing vulnerabilities cause making decisions that adapt socio-ecological and technological systems (SETSs) to these changes. (Brunetta, 2019)

Socio-Ecological and Technological Systems (SETS)

SETS is a framework for answering these challenges caused from climate change in recent years that helps in the implementation of NBS in territories. This framework combines ecological elements with socio-technical elements to answer these challenges. Unlike traditional methods, it is dynamic, adapting to context, time, and different situations. (Brunetta, 2019)

Vulnerability and Resilience

Vulnerability refers to the extent of weaknesses in a system when facing challenges. Resilience, on the other hand, is the system's ability to recover, adapt, and continue performing important tasks after disruptions. Meaning that, when a system has high vulnerability and low resilience, it is unable to respond to threats efficiently. (Brunetta, 2019).
Urban planning plays a key role in building city resilience. The recent approach, compared to traditional methods, is better because it combines engineering risk management with historical and multidisciplinary perspectives to address both immediate vulnerabilities and long-term resilience (Brunetta, 2019).

Implementation of Resilience

Urban planning is responsible for improving territorial resilience by identifying and fixing system weaknesses to respond efficiently to risks. Implementing resilience requires both societal and governance.
Social and Institutional Learning: Encouraging learning and adaptability
Territorial governance: To support adaptability Improving structure of governance. (Brunetta, 2019).

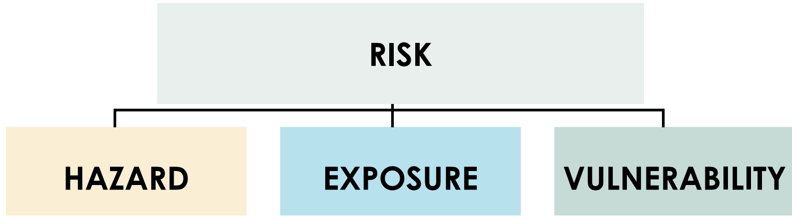
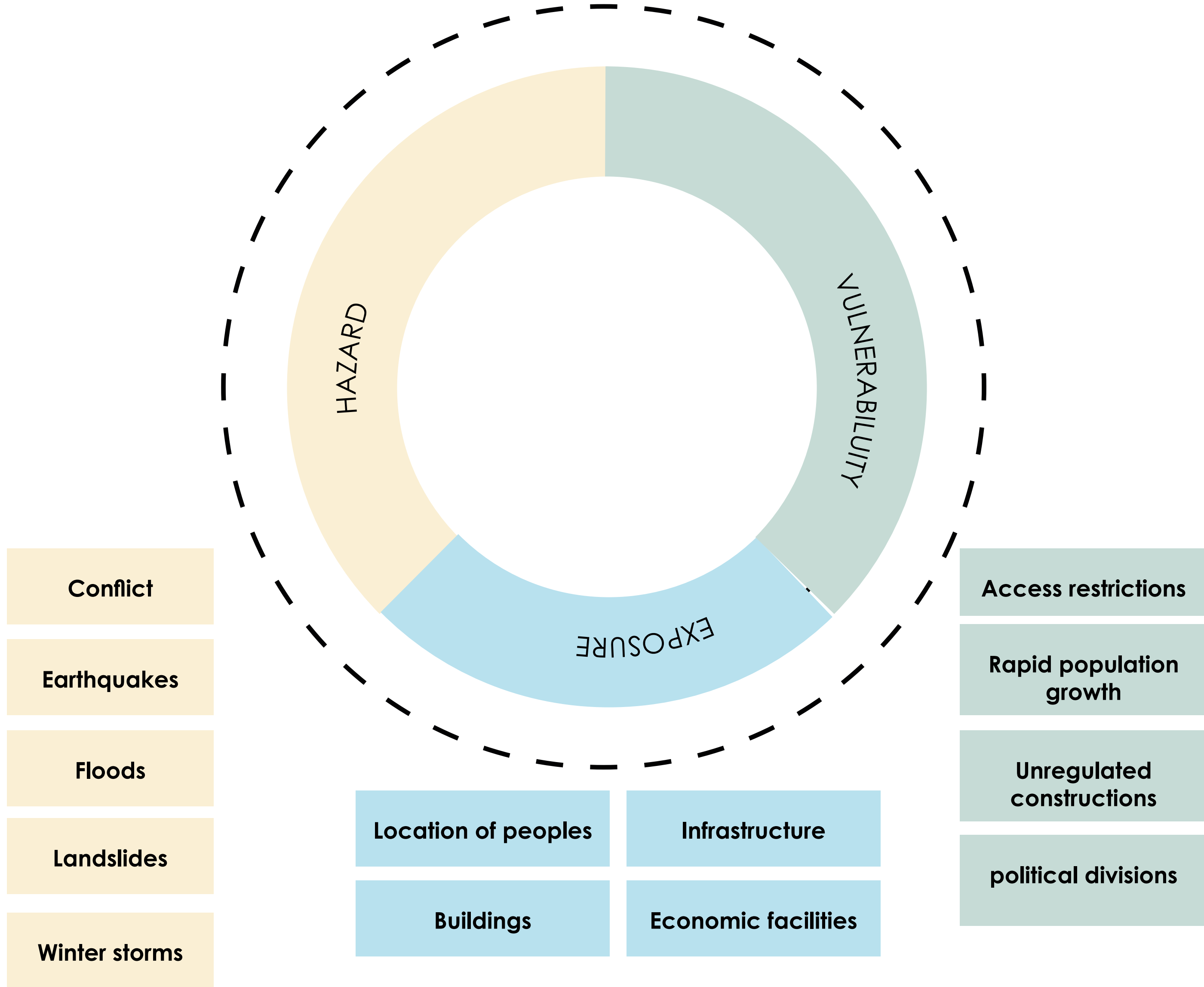


Figure 2-6-Risk Analysis (Peng, 2024)



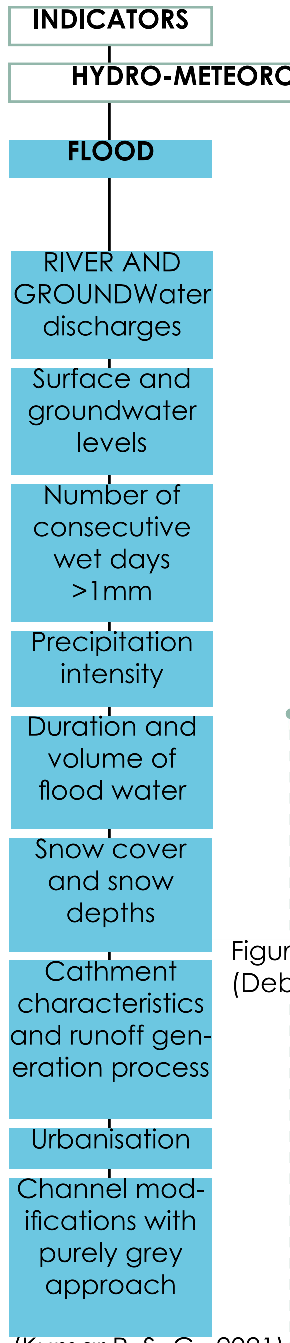
Urban systems can better prepare for and adapt to climate-related difficulties by supporting the SETS paradigm and emphasis on resilience. This will ensure that communities are resilient, creative, and able to adjust to future uncertainties and changes. It can Help cities to make more resilience for answer challenges. (Brunetta, 2019)

2-3-3. FLOOD

Definition and Importance

Since flooding seriously damages infrastructure, property, and human life, it can consider The most common and destructive natural disaster in the world. (Egegård, 2024) 50% of all people affected by natural hazards were harmed by floods between 2002 and 2012. (Nordin von Platen, 2018)
Geographical conditions, inadequate sanitation infrastructure, climate change-Increased to extreme rainfall events, rapid urbanization, and natural factors like vegetation and soil characteristics are some of the many factors that contribute to floods, which are widespread and destructive natural phenomena (Gaisie, 2023; Bernello, 2022; Egegård, 2024).
These elements have an impact on landscapes' ability to control and modify to flooding. For example, marshes in rainy regions have a tendency to overflow, while low, level places and landscape depressions can store more water than sloped locations. Flood dynamics are greatly influenced by soil properties including porosity and hydraulic conductivity, and vegetation preservation can slow down flow (Nordin von Platen, 2018).
Based on these descriptions, urban areas—particularly those along riverbanks—are more vulnerable to flooding. Strategic changes are necessary to improve climate resilience since urban infrastructure is at the forefront of the effects of climate change (Dharmarathne, 2024). In order to reduce hazards and enhance spatial quality, flood adaption strategies are being entered into urban planning more and more (Nilubon, 2024). Nature-based solution is one of these strategies for adaptation, but unfortunately it doesn't widely used in flood risk , despite their potential (Lallemant, 2021).
While the primary focus of flood adaptation along the Adige River revolves around fluvial floods, it's crucial to acknowledge and comprehend the implications of other flood types. These flood typologies indirectly influence flood risk and adaptation measures along riverbanks, highlighting the critical need for a comprehensive and inclusive approach to flood adaptation customized to urban planning and design aspects. Such strategies aid cities in adapting to flood disasters by addressing their root causes and increasing the resilience of urban areas to future flood events.

This chart illustrates four categories of natural hazards: fire, meteorological/ climatological, hydrological/geological, and environmental. It shows both single and multi-hazard events and their effects in a single location.



(Kumar P. S.-C., 2021)

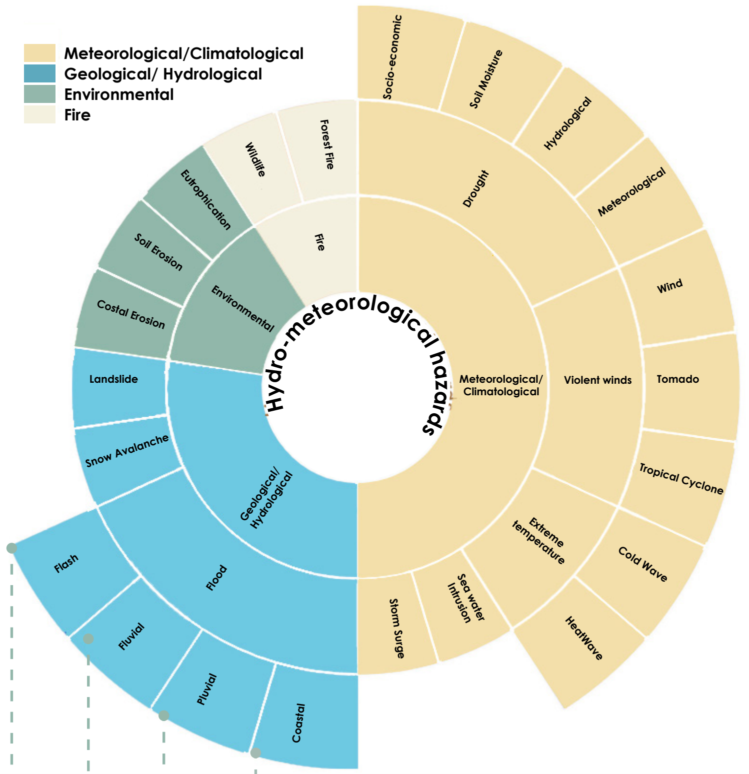


Figure 2-7-Classification of hydro-meteorological hazards (Nordin von Platen, 2018) (Debele, 2023)

Coastal floods, Coastal floods, caused by rising sea levels and storm waves, are more threatening to low-lying coastal areas near river mouths. (Toledo, 2024)

Pluvial floods,
This type of flood results from heavy rainfall that the capacity of urban drainage systems are not sufficient. It occurs more frequently in developed areas that there is lack of adequate stormwater management infrastructure. (Nordin von Platen, 2018)

Fluvial floods,
This type of flood occurs more frequesntly along rivers, often because of heavy rain or melting snow that cause incresing river flow. This type of flood especially occure near riverbank. (Zandersen, 2021)

Flash floods, This type of flood occurs suddenly and without warming, it impacts cities without sufficient drainage systems. These systems are not able to handle the volume of water of flood. (Kabisch, 2016)

2-3-4. Adaptation

Two interrelated strategies that are essential for tackling the problems caused by climate change are adaptation and mitigation. The main goal of mitigation is to lower greenhouse gas emissions, especially carbon dioxide, from a variety of sources, including industry, land use, transportation, and energy generation. Mitigation techniques try to reduce the amount of greenhouse gases released into the atmosphere by addressing the underlying causes of climate change. This will slow down the rate of global warming and the effects that come with it (Caldarice, 2021). On the other hand, adaptation entails making adjustments to the resource shortage, extreme occurrences, and shifting environmental conditions brought on by climate change. Strategies for adaptation are intended to deal with the effects that are already happening or are anticipated to happen in the future, as opposed to mitigation, which attempts to address the causes of climate change. Rising temperatures, changed precipitation patterns, sea level rise, an increase in the frequency of extreme weather events, and other effects of global warming are all included in these impacts (Caldarice, 2021). Adaptation is especially urgent in Europe, where a number of climate hazards necessitate prompt action.

More frequent and extreme weather events pose significant threats to Europe's ecosystems, food security, public health, and infrastructure. While coastal flood risks have been relatively well managed, rising sea levels and shifting storm patterns still present challenges to people, infrastructure, and economic activities. Southern Europe faces substantial risks from heatwaves and droughts, which jeopardize energy production, transmission, and demand. Residential buildings also need to be adapted to withstand increasing heat levels. Addressing these challenges requires proactive measures and significant investments in resilient infrastructure and innovative adaptation strategies (Agency, 2024).

Moreover, adaptation to climate change requires a paradigm shift from defensive actions against natural hazards to integrated management of natural resources. This holistic approach combines defensive measures with adaptive management to build resilience against the multifaceted impacts of climate change (Kalantari, 2023).

By combining mitigation and adaptation strategies, societies can create a more sustainable and resilient future amid climate change. While mitigation tackles the root causes, adaptation equips communities to handle its unavoidable effects. Through collaboration, we can reduce climate change severity and bolster our ability to adapt, fostering a more resilient and sustainable world for generations to come.

Flood Adaptation

Flood adaptation is an approach to addressing flooding by redesigning urban landscapes, public spaces and building in each city related to context. (Nilubon, 2024) This approach uses all city resources, including architecture, landscape and urban design to benefit local communities and increase climate resilience in cities. (Nilubon, 2024) In recent years, it has become clear that urban infrastructre, including urban flooding systems, is vulnerable to climate change. it is necessary to plan adaptations for bulding, infrastructure and other urban elements to respond to the challenges that cause climate change. This adaptation requires shifting to natural resources that respond to natural events in better way, as they are designed naturally to handle such occurrences. Considering effective adaptation strategies with innovative solutions a new policy approach to address new challenges posed by climate change, particulary in the context of flooding in this research. (Kalantari, 2023) (Young, 2019)(Nilubon, 2024; Dharmarathne, 2024). (Zandersen, 2021), necessitating urgent actions (Toledo, 2024; Horizon, 2020).

Features of flood that can affect by NBS , Decrease by NBS

- Peak Flow Control
- Volume Control
- Flood Risk within the Development

(Anne-Marie McLaughlin, 2018)

Adaptation Vs Mitigation

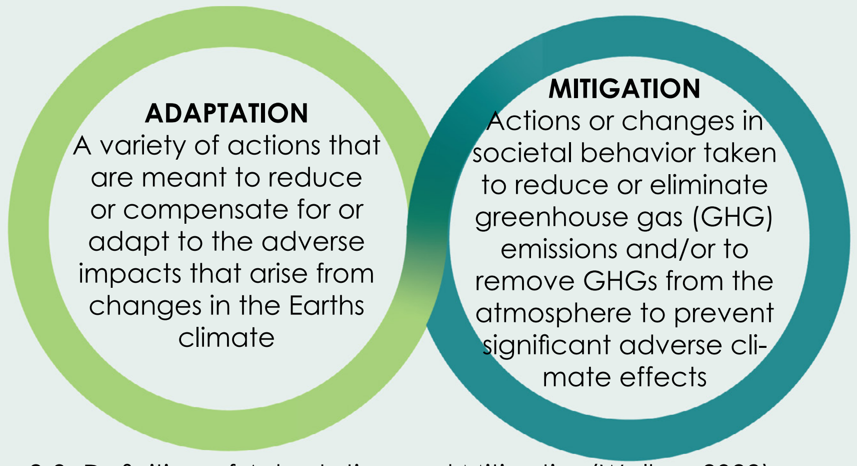


Figure 2-8- Definition of Adaptation and Mitigation(Walker, 2022)

Grey & Green infrastructures

In addressing urban flooding, two main strategies emerge: grey infrastructure and green infrastructure.

Grey Infrastructure:
All traditional infrastructure that is based on engineering to solve flood risk, called Grey infrastructure. (Bernello, 2022) This kind of solution is more expensive and needs a lot of energy. (Lallemant, 2021) Not only this kind of solutions can not solve environmnetal challenges, but also can casue damage to environmental places. (The Nature Conservancy,2013; Nordin von Platen, 2018)

Green Infrastructure:
Green infrastructure, on the other hand, uses methods like Nature-based Solutions and Sustainable Drainage Systems to incorporate natural processes into flood management. (Bernello, 2022) By reducing and storing runoff, these systems—such as green-blue infrastructures—avoid floods and frequently have additional ecological advantages. (Bernello, 2022)

Emphasis on Natural Infrastructure:
NBS supporters for addressing natural challenges, especially floods in this context emphasise on NBS insted of Grey infrastructre. (Nordin von Platen, 2018) Benefits of NBS are: reduceing negative ecological impacts and cost, more sustainalbe and eco-friendly. (Lallemant, 2021)
In field of Urban flood resilience, More focuses are on green and natural infrastructure to get environmental benefits. (Nilubon, 2024)

Roads, Sewer/Water Pipelines

Cenatralized treatment
Collects and channels runoff
High impact

Detention Ponds and Holding Tanks

Slow release into sewer system Volume peak rate reduction

Networks of Wetlands / Floodplain Restoration

Allow infiltration
Evaporation
Transpiration
Enhanced water quality
Reduced erosion/ sedi-mentation
Restoration
Minimal impact

Adaptation

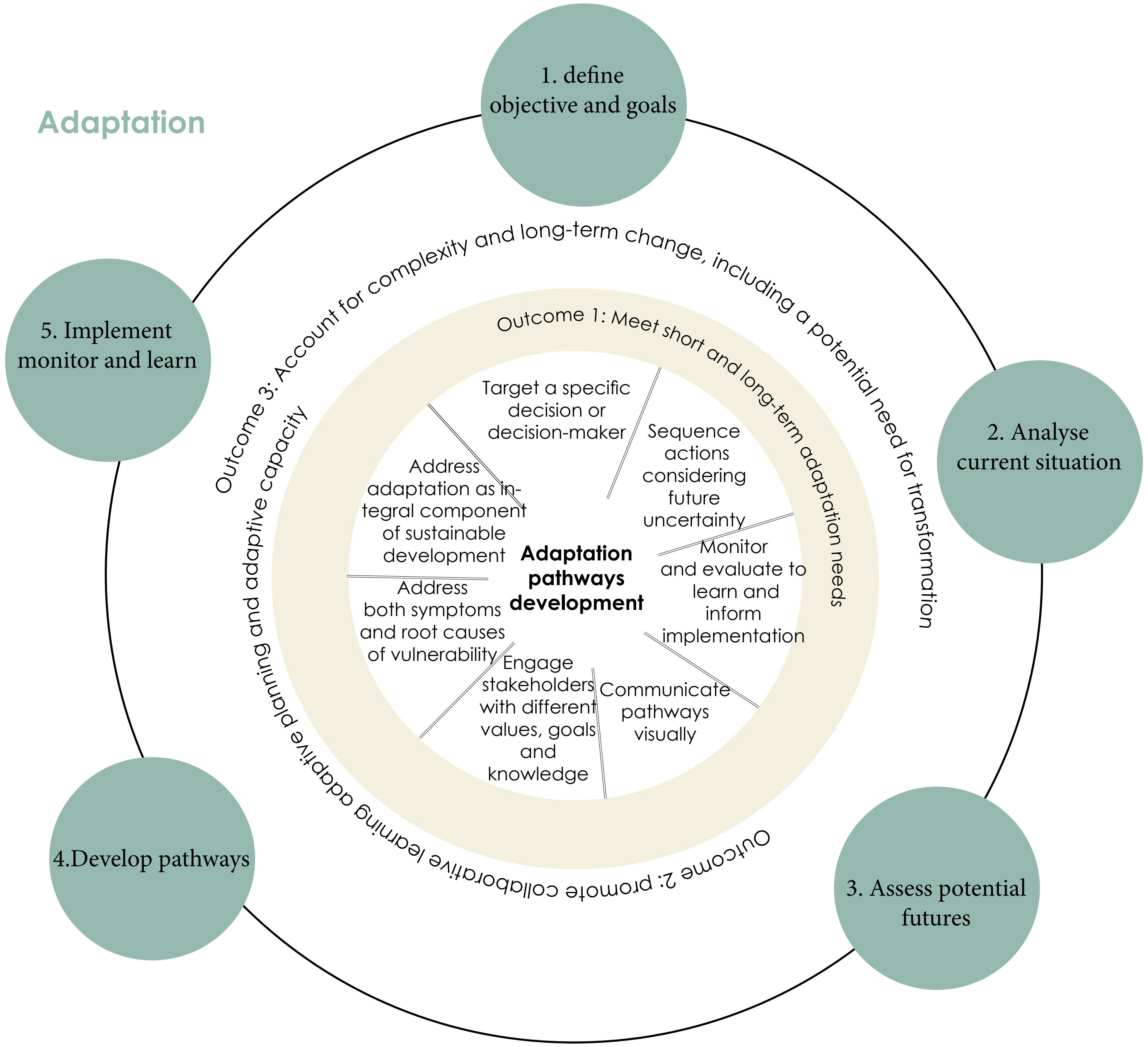


Figure 2-9- Five stage approach to adaptation pathways planning (adapted from Serrao-Neumann, 2015.) (Saskia E. Werners, 2021)

Adaptation pathway

The adaptation plan approach is a tool of planning that helps urban planners and designers to deal with flood adaptation. This is a road map to help planners to consider short- medium and long actions and making a making teamwork working between stakeholders to create policies for flood adaptation. Also consider budget and time to address climate risks over times. (Nilubon, 2024)

2-3-5. NATURE BASED SOLUTION FOR FLOOD ADAPTATION

Is the NBSs suitable at this location?

Identifying NBS and considering suitable approach for this context New solutions or modifying existing ones.

INTRODUCTION

Cities globally are grappling with resilience challenges as climate risks intersect with urbanization, biodiversity loss, poverty, and increasing socioeconomic inequality. Climate change is exacerbating natural hazards such as extreme precipitation and flooding, causing significant economic and social disruptions. As urbanization continues, particularly in high-risk and unplanned settlements, the vulnerability of urban populations to climate impacts grows. Traditionally, resilience efforts have relied on gray infrastructure—engineered structures like reservoirs and drainage systems. However, these solutions may not always be cost-effective or sustainable.

NBS is the most approach to help cities to solve challenges come from climate change as floods and heat islands.making well combination between NBS and existing grey infrastructures can be more beneficial.. This approach not only make environmental more resilience, but also improve human health, more recreational areas by existing green spaces for people to enjoy.

NBS can address challenges come from climate change and the difficulties of urban resilience as cities continue to grow. As a result, NBS help to create safer and more livable urban environments.

NBS APPROACH
Provide NBS for Resilience in the Urban Context by Using an Integrated Systems Approach

This thesis offers a combined approach between green and grey infrastructure to deal with floods and heat islands risk in the city. NBS not only help to deal with challenges that come from climate change, but also improving urban life for communities. Making cities beautiful and resilient and improving biodiversity and promoting culture. The most important point for success of NBS approach in cities is providing community coordination with planning.

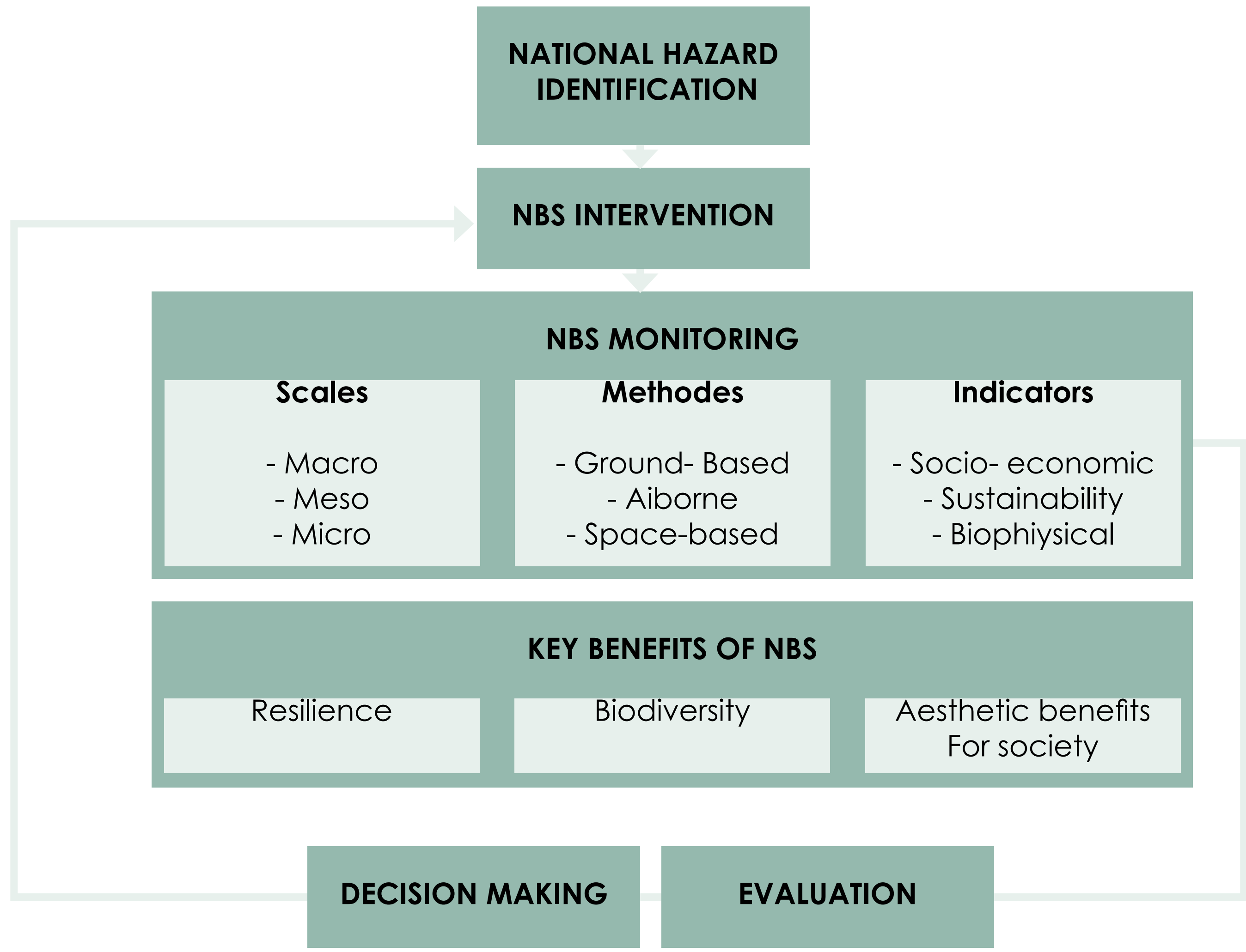
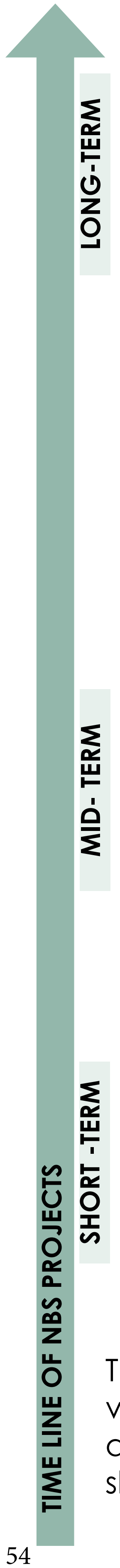


Figure 2-10- Process of NBS in solving national Hazard (Kumar P. S.-C., 2021)



NBS FOR FLOOD ADAPTATION

In this thesis, nature-based solutions are used as a method for flood adaptation. To reduce flood risks by considering sustainability and societal benefits, by inspiration ecosystem strategies. (Mah, 2023) In recent years, changes in climate and urban development have made NBS an effective approach to addressing flood risks .(Lallemant, 2021)
The goal in this section is to investigate which kinds of NBS are most capable of adapting to urban flooding. These systems are especially well-suited for urban settings, where they can be integrated with current infrastructure to adapt flooding and offer other advantages.
To sum up, NBS provides strategies to flood adaptation, lowering the risk of flooding and improving urban resilience and livability through multipurpose, sustainable tactics.

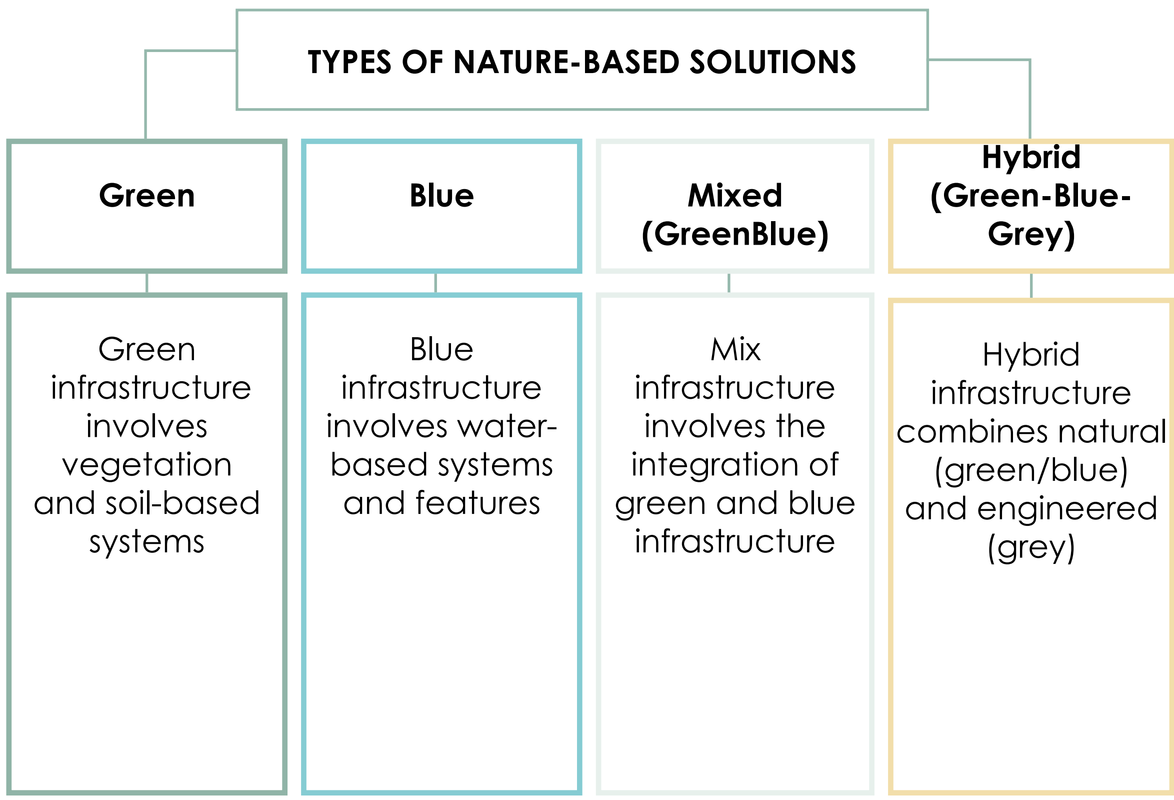


Figure 2-11- Types of natural based solutions in urban context (Debele, 2023)

This method guarantees that a single solution can provide benefits at various points over time by allowing designers, urban planners, and decision-makers to examine a range of adaptation measures over short, medium, and long periods (Nilubon, 2024).

NBS APPROACH
Hierarchy of approaches under the nature-based solutions

NBS strategies are ordered based on their importance. First is preservation, which focuses on maintaining existing ecosystems. Next is improvement and restoration, which involves sustainable management and the restoration of ecosystems, as well as the development of green infrastructure. The final step is the development of new NBS.

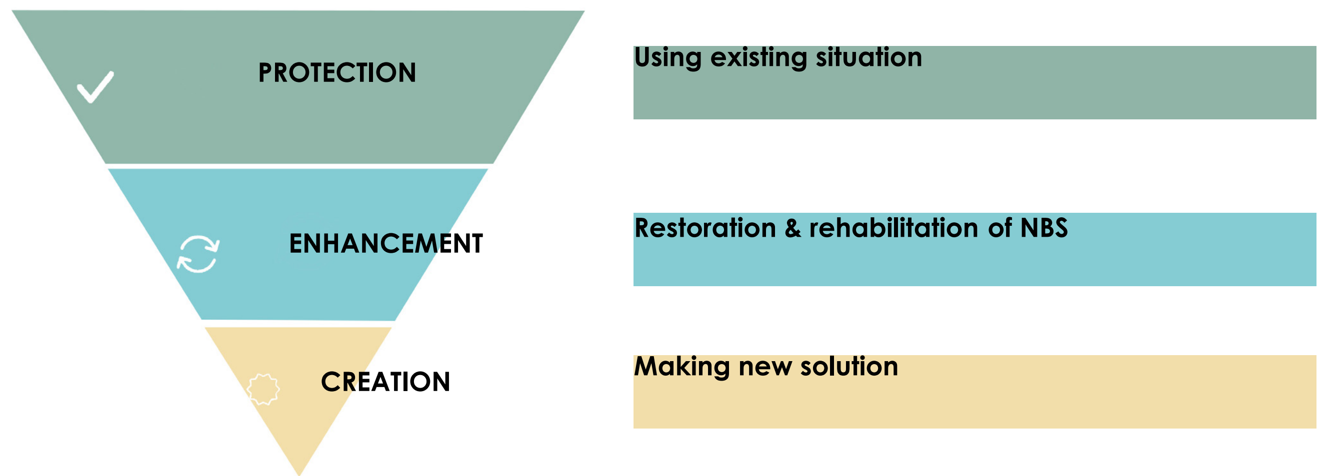


Figure 2-12- A hierarchy of approaches under the nature-based solutions umbrella (Bank, 2021)

NBS APPROACH	DETAILS	
PROTECTION	Objective	Sustain benefits and biodiversity by safeguarding existing ecosystems.
	Methods	Include wetlands, grasslands, floodplains, urban forests, and mangroves in zoning plans and Take steps to prevent damage and invasion.
	Scale	Crucial at strategic levels, such as city-wide planning, to secure and maintain the functional and biodiversity values of natural infrastructure.
ENHANCEMENT	Objective	Improve the performance, functionality, and benefits of Destructed ecosystems.
	Methods	Implement restoration and rehabilitation projects such as reforestation, stream and wetland restoration, and enhancement of urban green spaces and corridors.
	Scale	Related to all scales, such as the neighborhood, city, and river basin levels, where certain ecosystems might be improved. (e.g., restoring floodplains and urban parks)
CREATION	Objective	Mitigate & adapt impacts and strengthen urban resilience by introducing new NBS.
	Methods	Develop new green infrastructure such as bioretention spaces, artificial wetlands, vegetated facades, and green roofs, which also provide additional community benefits.
	Scale	Suitable at the project and neighborhood levels, where particular new NBS (such installing green roofs in urban structures) can be created and put into practice to meet the needs of urban resilience.

Table 2-2- Detailed of NBS approaches (Bank, 2021)

2-3-6. SELECTING NBS FOR FLOOD ADAPTATION (Based on literature review)

Going forward, based on the literature review analysis, this study identifies which solutions are beneficial for flood adaptation. The analysis focuses on specific tactics that can effectively address three crucial elements essential for flood adaptation: wave energy reduction, soil strengthening, and erosion management.

Figure 2-13. Three Pivotal Factors Critical for Flood Adaptation (Simelton, 2021)

The following all nature-based solutions categorizes, based on the NBS categories: Green, Blue, Hybrid, and Mixed.

Type of NBS for flood adaptation		Flood Adaptation		REF.
Green infrastructure	Urban Parks	Absorb and store rainwater	🔴 🔵 🟢	(Debele, 2023) (Kumar P. S.-C., 2021) (Lallemant, 2021) (Mannucci, 2022)
	Flood parks	Temporarily store floodwater	🔴 🔵 🟢	(Mannucci, 2022) (Dharmarathne, 2024) (Lallemant, 2021)
	Heritage Parks	Absorb and store rainwater	🔴 🔵 🟢	(Debele, 2023)
	Green Strips and Plains Grass Cover	Absorb rainfall, reduce runoff	🔴 🔵 🟢	(Debele, 2023) (Su, 2024)
	Trees and Shrubs	Intercept rainfall, reduce runoff	🔴 🔵 🟢	(Debele, 2023) (Koutsovili, 2023) (Shrestha, 2021)
	Forest Orchard and Agroforestry	Reduce surface runoff	🔴 🔵 🟢	(Debele, 2023)
	Hedges/Shrubs/Green Fences	Slow runoff, absorb water	🔴 🔵 🟢	(Debele, 2023)
	Street Trees	Intercept rainfall, reduce runoff	🔵 🟢	(Debele, 2023)
	Forest Protection and Reforestation	Regulate water flow	🔴 🔵 🟢	(Debele, 2023) (Kalantari, 2023) (Lallemant, 2021) (Mah, 2023)
	Optimized Forest Management	Regulate water flow	🔴 🔵 🟢	(Debele, 2023)
	Garden that serves vegetables	Absorb rainfall, reduce runoff	🔴 🔵 🟢	(Shrestha, 2021)
	Grassland	Absorb rainfall, reduce runoff	🔴 🔵 🟢	(Mah, 2023) (Zandersen, 2021)
	Soakaways	Allow stormwater infiltration	🔴 🔵	(Bernello, 2022)
	Riparian vegetation	Slow down floodwaters	🔴 🔵 🟢	(Lallemant, 2021)
	Green wall	Absorb rainfall, reduce runoff	🔴 🔵 🟢	(Kabisch, 2016)
	Vegetated Swales (Wadi)	Absorb and convey stormwater	🔴 🔵 🟢	(Shrestha, 2021) (Su, 2024) (Mannucci, 2022)

Type of NBS for flood adaptation		Flood Adaptation		REF.
Blue infrastructure	Ponds and Wetlands	Collecting Extra Water During Flood, Natural flood Storage to decrease flood risk	🔴 🔵 🟢	(Debele, 2023)(Kumar P. S.-C., 2021) (Salata, 2021) (Shrestha, 2021) (Mah, 2023) (Nordin von Platen, 2018) (Lallemant, 2021) (Horizon, 2020) (Mah, 2023) (Nilubon, 2024)
	Wetland soils	It is a natural sponges to absorbe water during flood	🔴 🟢	(Kumar P. S.-C., 2021)
	Floodable area	Allow controlled flooding, reducing the impact on built infrastructure and communities.	🟢	(Mannucci, 2022)
	Rivers	Reducing and mitigation flood.	🔴 🟢	(Debele, 2023)
	Lakes	It is a natural container to collect water during floods.	🟢	(Debele, 2023)
	Groundwater Protection	Protecting of groundwater as an answer in emergency situations of lacking water such as droughts.	🟢	(Debele, 2023)
	Making more Space for the River	Providing more space for rivers.	🔴 🟢 🟢	(Debele, 2023)
	mountain water container	For controlling water flow and flood constructing water containers.		(Koutsovili, 2023)
Hybrid Solutions	Bioswales	Redirect stormwater runoff, preventing flooding in urban areas.	🟢	(Debele, 2023)
	Rain Gardens	storage of rainwater	🔴 🔵	(Debele, 2023) (Su, 2024)(Mannucci, 2022)
	Rain harvesting	storage of rainwater	🔴 🔵	(Bernello, 2022)
	Green Roofs	Capture rain water in bulding in neighborhood scales	🔴 🔵	(Bernello, 2022) (Kabisch, 2016) (Shrestha, 2021) (Debele, 2023) (Kumar P. S.-C., 2021) Mannucci, 2022)
	Permeable Surface Channels	Allow stormwater to infiltrate into the ground, reducing surface runoff.	🔴 🔵	(Bernello, 2022) (Shrestha, 2021) (Mannucci, 2022)
	Live Pole Drains	Manage stormwater runoff while providing habitat for vegetation.	🔴 🔵	Debele, 2023)
	Live Cribwalls and Ground Anchors	Stabilize slopes and prevent erosion, incorporating vegetation for additional stabilization.	🔴 🔵	Debele, 2023)
	Green parking	Utilize permeable surfaces or vegetated areas to reduce runoff and manage stormwater.	🔴 🔵	(Su, 2024)

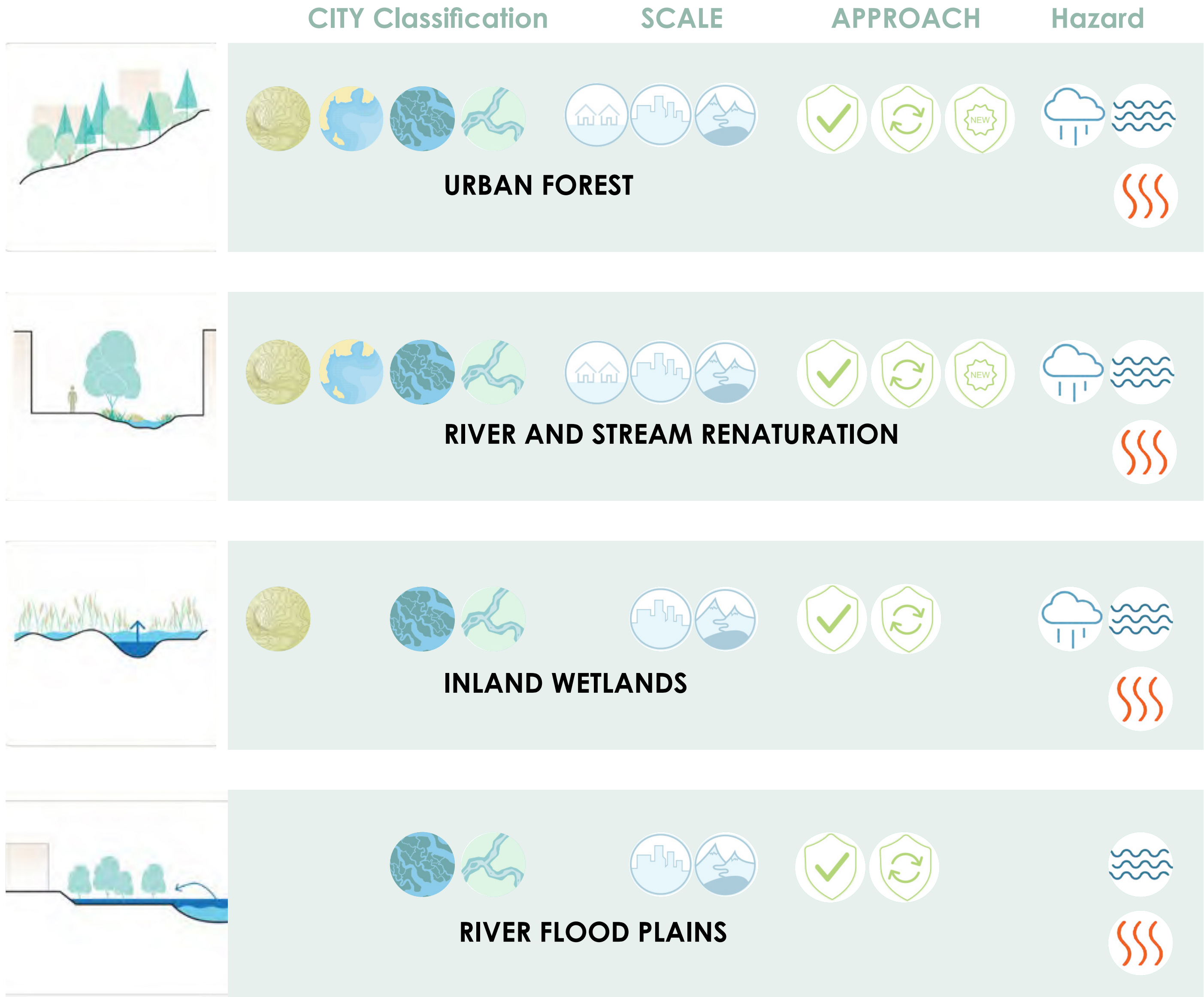
Type of NBS for flood adaptation	Flood Adaptation	REF.
Mixed Solutions		

Table 2-3- Details of Types of Nature-Based Solutions for flood adaptation in an Urban Context, Author's elaboration.

As Shown in the table, all the NBS listed are based on literature review from various authors. Also, this table presents the solutions that are suitable for flood adaptation. In the following, as a conclusion, these solutions are merged and categorized as guidelines for the practical part. In the following chapters most beneficial and relevant solutions to context and research will be selected for implementation.

2-4. CONCLUSIONS

In conclusion, the literature review and analysis of case studies have highlighted the diversity of NBS for urban flood adaptation, categorizing them into 14 distinct categories. Among these, urban forests, river and stream renaturation, natural inland wetlands, and river floodplains stand out as direct solutions for flood adaptation, offering immediate benefits in terms of flood adaptation and ecosystem resilience. Other solutions, while not directly aimed at flood adaptation, provide valuable insights and ideas that can be integrated into broader flood management strategies. These findings underscore the versatility and efficacy of NbS, reinforcing their potential to enhance urban resilience against flooding through both direct and indirect applications.



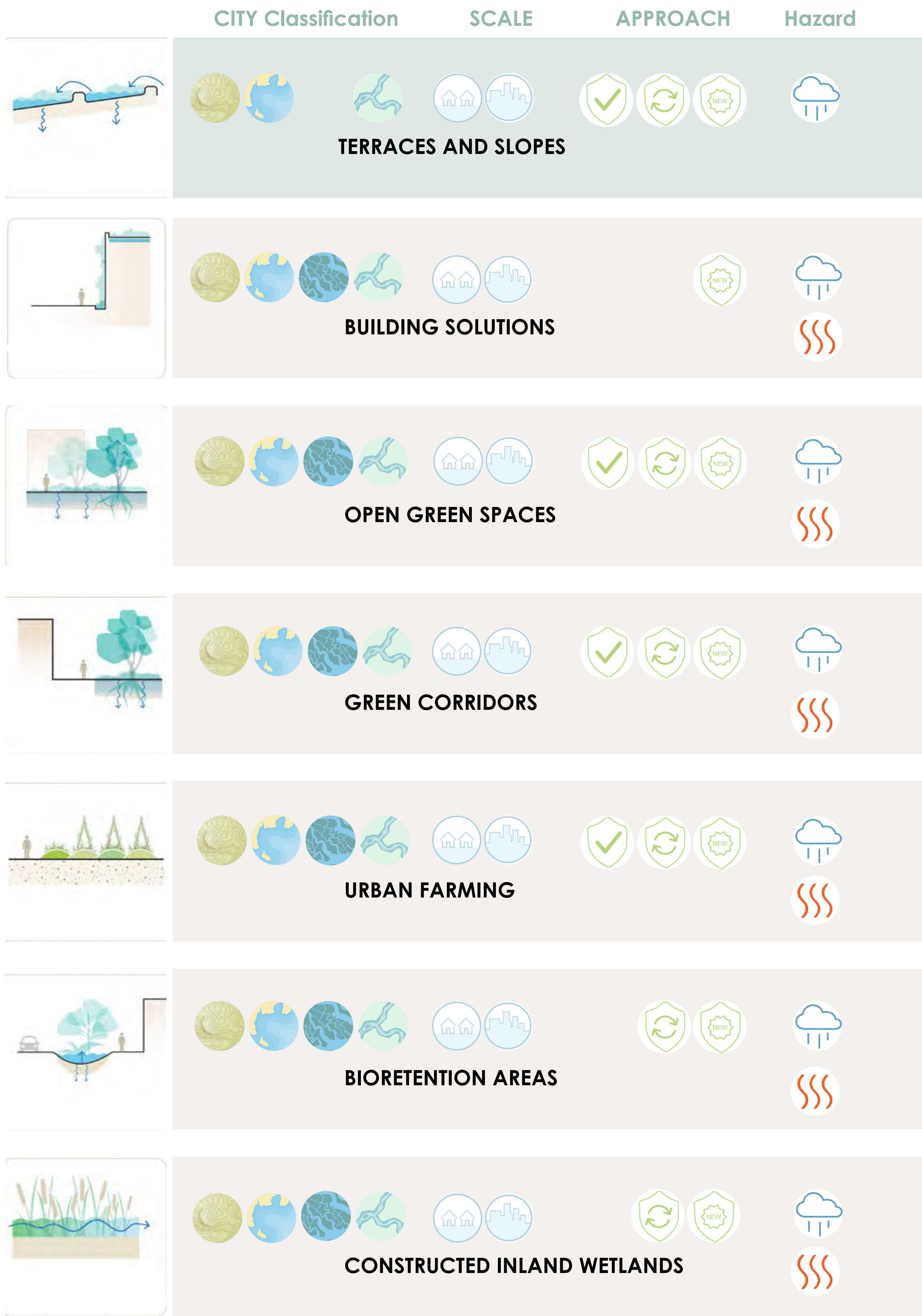
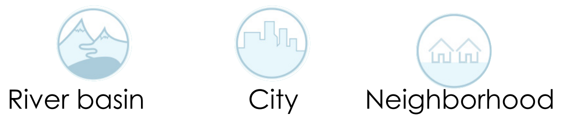


Table 2-4- NBSs for urban flood adaptation Author's elaboration. (Vallejo,2024)

LEGEND

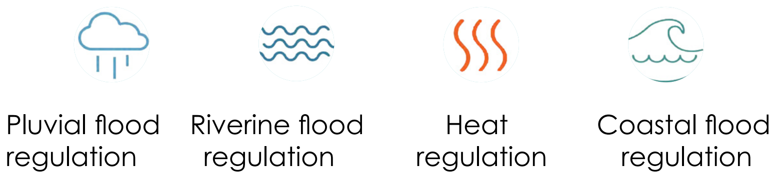
City classification – position of the city into the river basin

Scale



Approach

Type of Hazard



After a thorough theoretical analysis and examination of the case study, key nature-based solutions have been identified to enhance flood adaptation in response to flood as a climate change impacts near the river. Primary strategies include **urban forests, river and stream renaturation, inland wetlands, floodplain restoration, and the stabilization of slopes and terraces**. In addition to these flood-specific measures, other general nature-based solutions at the neighborhood and design scale—such as **green corridors, open green spaces, and building adaptations**—are effective tools for mitigating climate change effects. Although not exclusively designed for flood adaptation, these solutions help reduce urban heat, enhance biodiversity, and increase overall climate resilience, indirectly contributing to flood adaptation. Together, these approaches provide a comprehensive strategy for strengthening territorial resilience in flood-prone urban areas.

CHAPTER 03

CASE STUDIES

Chapter 3 analyzes case studies to provide real-world examples and evidence of using NBS in different environments. This chapter is a key part of this research as it highlights important lessons and best practices to guide practical approaches in later chapters.

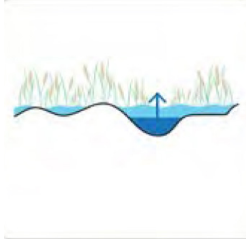
3.CASE STUDIES

3-1.INTRODUCTION TO CASE STUDIES

The NATURVATION project has created an atlas of different nature-based solutions from cities around the world. Two filters are used to highlight projects: nature-based solutions for river-related challenges and climate adaptation efforts. The image below shows projects from around the world in this field. These filters help focus on projects that are most relevant to the topic of this thesis. (Mariano, 2022)

Figure 3-1- Nature-based solutions for river for climate change adaptation from European cities and beyond (Urban nature atlas , 2022)

3-2. SELECTING NBS FOR FLOOD ADAPTATION (Based on Case studies)



INLAND WETLANDS

	Location	Name of Project	Type of NBSs for flood adaptation	REF.
	Nijmegen (Netherlands)	Room for the river (Waal River-Nijmegen project)	- Making more space for water the relocation of the dike 350 meters inland, the digging of a Backup channel in the floodplain enabling the creation of a new island.	(Horizon, 2020) (Lee, 2018)

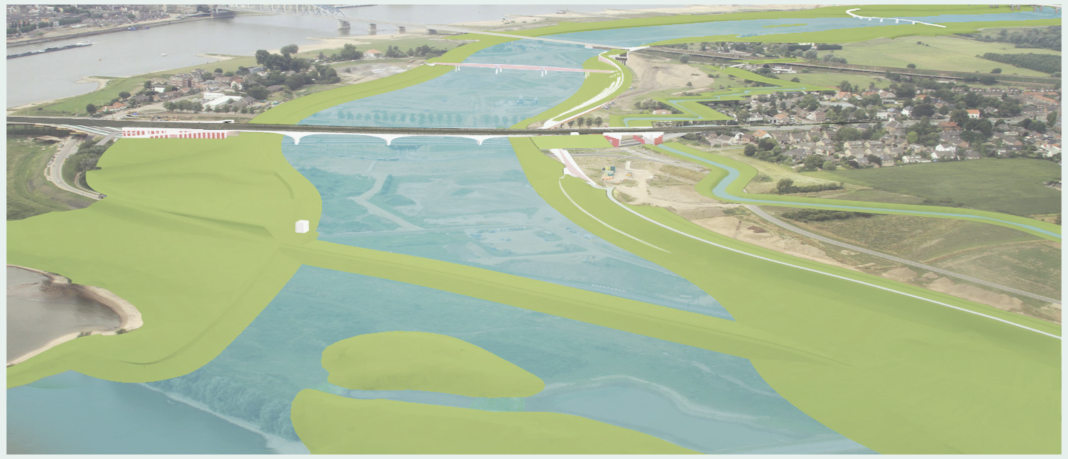


Figure 3-2- Room for the river -Waal River-Nijmegen project (Lee, 2018)

	Location	Name of Project	Type of NBSs for flood adaptation	REF.
	Jutland peninsula (Denmark)	Sigma Plan (The Kalkense Meersen Cluster)	- Wetlands with a variety of grasslands, flower meadows, reed beds and open water.	(Horizon, 2020)

Figure 3-3- Sigma Plan -The Kalkense Meersen Cluster (Horizon, 2020)

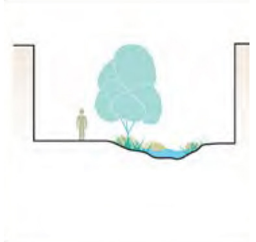
URBAN FOREST

	Location	Name of Project	Type of NBS for flood adaptation	REF.
	Bremen (Germany)	Beach Park in Bremen	- Large urban parks or forests - Rivers/streams/canals/Wetlands - Permeable pavement with a sandy surface installed alongside the river.	(Kumar, 2020)

Figure 3-4- Beach Park in Bremen (Kumar, 2020)

	Location	Name of Project	Type of NBS for flood adaptation	REF.
	Doncaster (United Kingdom)	Inspiring Water Action in Torne (IWAIT)	- Large urban parks or forests - Rivers/streams/canals/estuaries	(Smith, 2021)

Figure 3-5- Inspiring Water Action in Torne (IWAIT) (Smith, 2021)



RIVER AND STREAM RENATURATION

	Location	Name of Project	Type of NBS for flood adaptation	REF.
	Bishan (Singapore)	Bishan-Ang Mo Kio	-River Naturalization -Floodplain Design -Vegetated Riverbanks	(ASLA PROFESSIONAL AWARDS, 2016)

Figure 3-6- Bishan-Ang Mo Kio (ASLA PROFESSIONAL AWARDS, 2016)

	Location	Name of Project	Type of NBS for flood adaptation	REF.
	Bangladesh	Brahmaputra River Basin	- Artificially coral reefs - Protecting and restoring forests - Wetlands - Mangroves	(Smith, 2021)

Figure 3-7- Brahmaputra River Basin (Smith, 2021)

TERRACES AND SLOPES

	Location	Name of Project	Type of NBS for flood adaptation	REF.
	Hamburg (Germany)	Flooding city	- Altering the topography of the site itself, by creating « teras » or artificial hills designed to raise buildings between 8 m and 8.50 m above level of water	(Mariano, 2022)

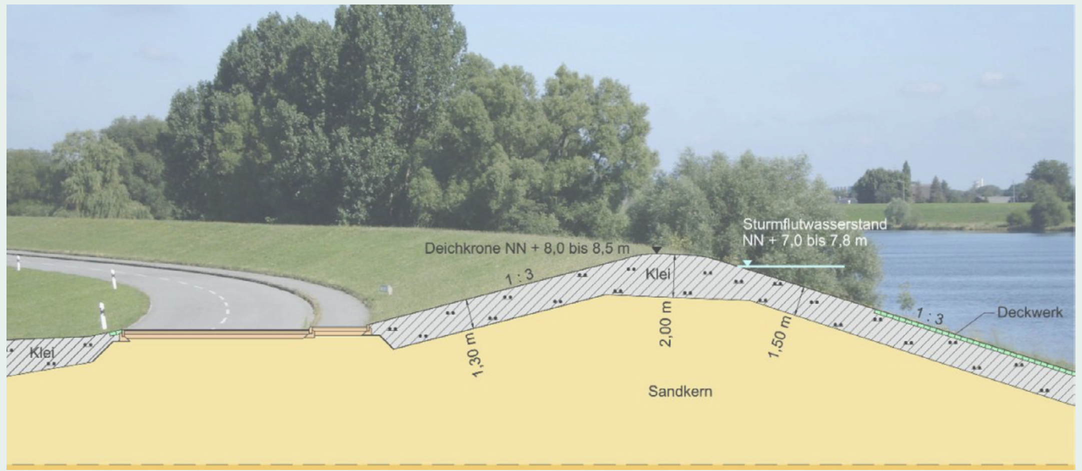
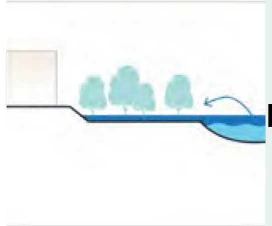


Figure 3-8- Flooding city (Mariano, 2022)

	Location	Name of Project	Type of NBS for flood adaptation	REF.
	New York	Hunt point lifeline	- Defence and adaptation Prevailing system: -infrastructure and Service System - Artificial hills to raise buildings above sea level	(Mariano, 2022)

Figure 3-9- Hunt point lifeline (Mariano, 2022)



RIVER FLOOD PLAINS

	Location	Name of Project	Type of NBS for flood adaptation	REF.
	Arhus (Denmark)	Aarhus River Project	-Pocket parks/neighbourhood green spaces -Green corridors and green belts -Lakes/ponds -Rivers/streams/canals/estuaries -Green areas for water management -Sustainable urban draining systems	(NATURVATION,2024)

Figure 3-10- Aarhus River Project(NATURVATION,2024)

	Location	Name of Project	Type of NBS for flood adaptation	REF.
	Singapore	(Bishan-Ang Mo Kio Park) Singapore in green plan	-Wetlands - Sustainable Drainage Systems - River Parks (rain gardens, vegetated bioswales for flood regulation, recreation, biodiversity support) (Singapore has maximised urban green space along the river banks)	(Cui, 2021)

Figure 3-11- Singapore in green (Cui, 2021)

This section examines case studies in detail that incorporate a combination of nature-based solutions, each contributing with relatively equal value, to support flood adaptation.

- Vinh River Rehabilitation Project (updated May2024)

The Vinh River rehabilitation and upgrade project in Vinh City, Vietnam, supported by the World Bank, stands as a significant project in urban infrastructure development and resilience improvement. This Project includes a series of actions to address flooding as an environmental issue in this area. Some of these solutions involve developing green public spaces along the river and improving the flood control system. These NBS cause environmental quality, urban beauty and above of all, flood control along the river. This case study shows territorial resilience for flood adaptation and serves as a valuable lesson in this field for worldwide.

Vinh, Vietnam	
City Population	226000
Duration	2023-2029
Implementation Status	Ongoing
Scale	Meso-scale: Regional, metropolitan and urban level
Project area	820000 m2
Type of area	Agricultural, Residental, Central Business District, City center
Nature- based solution	**Key Challenges**
Blue infrastructure • Lakes/ponds • Rivers/Streams/Canals/Estuaries Gray infrastructure featuring greens • Riverbank/Lakeside greens	• Climate action for adaptation, resilience, and mitigation (SDG 13) o Climate change adaptation • Green space, habitats and biodiversity (SDG 15) o Green spaces creation and/or management • Water management (SDG 6) o Flood protection
Focus	
Creation of new green areas, Management of rivers and other blue areas	
Climate-focused activity: climate change adaptation	
• Implement measures that prevent/manage desertification, soil erosion and landslides. • Implement sustainable urban drainage infrastructure (e.g. to make space for water). • Renaturalization of rivers and other water bodies.	
Objectives	
• minimize urban flooding and landslides, improve riverbank land quality, and enhance the city's resilience to climate change. • enhancing climate resilience by building public green spaces and riverbank areas in the city. • Foster sustainable urban development and climate adaptation to drive socio-economic growth in Vinh city and Nghe an province. • enhancing Vinh City's infrastructure, resilience, and climate adaptation by upgrading the Vinh river drainage systems. • Improving environmental conditions and quality of life by upgrading the Vinh River and wastewater collection and treatment system.	
Main beneficiaries	
Local government/Municipality Citizens or community groups	

Table 3-1- Details of Vinh River Rehabilitation Project (Urban nature atlas , 2022)

Implementation activities

1. From late 2022 to early 2023, the Vinh River rehabilitation and upgrade project got underway.
2. The project's third component is to improve a 11.4-kilometer section of the Vinh River from where it joins the Ke Gai River to the Ben Thuy sluice gate.
3. To increse water quality, Component 3 activities include dredging, slope protection, embankment repair, and wastewater intercept construction.
4. In addition, the project intends to create 20 hectares of green public areas alongside the river, including market connections, heritage bridges, and an ecological community.
5. In addition, a 53-hectare new regulation lake called Hung Hoa 2 would be built, encircled by another 70-hectare green public area.

Impacts & Monitoring		
Environmental Impacts	Economic Impacts	Socio-cultural impacts
• Water management and blue area o Improved water quality o Increased protection against flooding • Green spaces and blue o Increased green space area. o Reduced biodiversity loss	• Increased property prices	• Social justice and cohesion o Fair distribution of social, environmental and economic of the NBS project.

Table 3-2- Impacts & Monitoring of Vinh River Rehabilitation Project (Urban nature atlas , 2022)

Analysis of Case Studies

By examining the implementation processes, challenges, and outcomes of these projects, The aim is to uncover best practices and innovative approaches to nature-based flood adaptation. This thorough analysis will provide a robust framework for developing a tailored, effective flood adaptation strategy for the thesis, drawing on the successes and lessons learned from similar contexts.

By analyzing these case studies, a key finding across all projects focused on designing open spaces along rivers in cities worldwide to allow water flow. This was not only important for flood adaptation but also emphasized creating green, wide spaces along rivers as public areas. These spaces serve multiple purposes, such as engaging communities with the city through activities like education, entertainment, tourism, and more.

- Aarhus River Project (Last updated: October 2021)

The project refers to the recovery of the Aarhus River, which was piped in the 1930s for hygiene reasons and road infrastructures. In 1989, the river was resurfaced to restore its presence in the city. This river now plays a vital role as a green and blue corridor in the city center, helping to both environmental and social. Finally, as a key element of this project, flood adaptation were implemented between 2006 and 2013 to reduce flood risk.

Arhus, Denmark	
City Population	308508
Duration	2005-2013
Implementation Status	Completed
Scale	Meso-scale: Regional, metropolitan and urban level Micro-scale: District/neighbourhood level Sub-microscale: Street scale (including buildings)
Project area	Unknown
Type of area	Other
Natural- based solution	**Key Challenges**
Parks and urban forests • Pocket parks/neighbourhood green spaces • Green corridors and green belts Blue infrastructure • Lakes/ponds • Rivers/streams/canals/estuaries • Coastlines Green areas for water management • Sustainable urban draining systems • Others	• Climate action for adaptation, resilience, and mitigation (SDG 13) o Climate change adaptation • Water management (SDG 6) o Flood protection. • Green space, habitats, and biodiversity (SDG 15) o Green spaces creation and/or management • Social justice, cohesion, and equity (SDG 10) o Social interaction • Health and well-being (SDG3) o Enabling physical activity o Creation of opportunities for relaxation and recreation • Economic development and employment (SDG8) o Economic development: service sectors o Real estate development o Employment/ job creation
Focus	
Management of rivers and other blue areas, Other	
Climate-focused activities	
Climate change adaptation: • Implement sustainable urban drainage infrastructure (e.g. to make space for water)	
Objectives	
• Restoring the river to improve water quality and hygiene in receiving waters, supporting recreational use of Lake Brabrand, the Aarhus River, and the Port of Aarhus. Solutions are tailored to expected climate change scenarios. • Implementing flood prevention measures, including "time and space for water" strategies such as separate sewers, construction of large rainwater ponds, and reservoir lakes. • Creating waterfront spaces to foster lively and engaging activities. • Rebuilding Mølleparken and establishing connections to green and recreational areas near the river. • Developing a large pumping and locking system to enhance flood protection for Aarhus Midtby against sea floods.	
Main beneficiaries	
Local government/Municipality Citizens or community groups	

Table 3-3- Details of Aarhus River Project(Urban nature atlas , 2022)

Implementation activities

Establishment of two meadow lakes (100 ha and 115 ha) upstream to mitigate agricultural nitrogen and phosphorus runoff into the Bay of Aarhus.

1. Using of the river as a green and blue corridor Crossing the city center.
2. Rebuilding Mølleparken and developing waterfront spaces to stimulate economic activity.
3. Adaptation of planned solutions to anticipated climate change scenarios.
4. Creation of approximately 23,000 m2 of new waterfront spaces, equivalent to four football fields.
5. Implementation of eight large basins, mostly underground, for temporary rainwater and wastewater collection during heavy rainfall, with a total capacity of 50,350 m3.
6. Closure of many sewers, redirecting pipes to new basins or treatment plants.
7. Enhancement of wastewater treatment at Viby and Åby Wastewater Treatment Plants.
8. Expansion of capacity at Viby and Åby Wastewater Treatment Plants.
9. Establishment of a large pumping and locking system to enhance flood protection for Aarhus Midtby against sea floods.
10. Implementation of an IT solution integrating rain radar and overall control of the wastewater system, including basins, sewer systems, and treatment plants.
11. Provision of notifications in case of exceeding requirements for bathing water quality.

Impacts & Monitoring		
Environmental Impacts	Economic Impacts	Socio-cultural impacts
• Climate, energy and emissions o Strengthened capacity to address climate hazards/natural disasters • Water management and blue areas o Improved water quality o Increased stormwater management o Improved stormwater management o Enhanced protection and restoration of freshwater ecosystem • Green space and habitat o Increased conservation or restoration of ecosystem o Increased ecological connectivity across regeneration sites and scales • Other	• Increased property prices • Simulate development in deprived areas • Attraction of business and investment • Generation of income from NBS	• Social justice and cohesion o Increased opportunities for social interaction • Education o Increased support for education and scientific research

Table 3-4- Impacts & Monitoring of Aarhus River Project(Urban nature atlas , 2022)

- Beach Park in Bremen (Last updated November 2021)

This Project, developed by local government with EU and Federal funding, Aims to present a model for urban flood protection that focuses on integrating the city with flood management, rather than seprating them. Insted of insolating water, the project brings it into the urban environment by expanding green public spaces along the river and planting greenery. This solution transforms the riverbank into a space not only suitable for answering flood but also making it a better place for the community.

Bremen, Germany	
City Population	356227
Duration	2017-2019
Implementation Status	Completed
Scale	Micro-scale: District/neighbourhood level Sub-microscale: Street scale (including buildings)
Project area	22000 m2
Type of area	Other
Nature - based solution	**Key Challenges**
Parks and urban forests • Large urban parks or forests Blue infrastructure • Rivers/streams/canals/estuaries	• Climate action for adaptation, resilience, and mitigation (SDG 13) o Climate change adaptation • Water management (SDG 6) o Flood protection. • Green space, habitats and biodiversity (SDG 15) o Green spaces creation and/or management • Regeneration, land-use and urban development o Promotion of naturalistic urban landscape design • Health and well-being (SDG3) o Enabling physical activity o Creation of opportunities for relaxation and recreation • Economic development and employment (SDG8) o Real estate development • Cultural heritage and culture diversity o Protection of historic and culture landscape/ infrastructure
Focus	
Creation of new green areas, Management of rivers and other blue areas	
Climate-focused activities	
Climate change adaptation: • Implement sustainable urban drainage infrastructure (e.g. to make space for water) • Renaturalization of rivers and other water bodies	
Objectives	
• Developing the green and beach area as part of flood protection system refurbishment, enhancing recreational space and highlighting the historical significance of the Bremen port. • Creating a new city attraction to address space deficiencies in the adjacent Gröpelingen district, stimulating development in neighboring areas of Bremer West. • Establishing a model project for urban flood protection, demonstrating the integration of city and water, while providing new water and shore experiences. • Implementing an urban hinge project, utilizing the recreation center to foster closer ties between Bremen and Überseestadt Gröpelingen and Walle.	
Main beneficiaries	
Citizens or community groups	

facilities opened in May 2019.

Table 3-5- Details of Beach Park in Bremen Project(Urban nature atlas , 2022)

Implementation activities

1. Appling "rinsing dikes" along the new water edge, which are filled with sand until reaching the final level.
2. Installing a deck of building blocks in front of the rinsing dikes on the water side.
3. Expanding the public space at the beach by depositing additional sand.
4. Redesigning the beach area.
5. Planting greenery.
6. Ensuring barrier-free access to the waterfront in the lower beach area.
7. Constructing new connections to Nearby streets and squares.
8. Build new play facilities.

Impacts & Monitoring		
Environmental Impacts	Economic Impacts	Socio-cultural impacts
• Climate, energy and emissions o Strengthened capacity to address climate hazards/natural disasters • Water management and blue areas o Increased protection against flooding • Green space and habitat o Increased green space area	• Stimulate development in deprived areas	• Social justice and cohesion o Increased opportunities for social interaction o Improved access to urban green space • Health and wellbeing o Gain in activities for recreation and exercise. • Cultural heritage and sense of place o Protection of historic and cultural landscape/ infrastructure

Table 3-6- Impacts & Monitoring of Beach Park in Bremen Project(Urban nature atlas , 2022)

Figure 3-12- Beach Park in Bremen (Urban nature atlas , 2022)

- Iloilo River Esplanade (Last updated: June 2022)

This project is recognized as the largest linear park in the Philippines, designed by architect Paulo Alcazaren. It includes a wide range of plants and was created to address biodiversity, reduce carbon, and provide flood adaptation. Not only does the project achieves these environmental goals, but it also serves as a vibrant space for tourists and local communities. Originally, it was a simple dike built for flood control; However, it has since been transformed into an attractive public space in the city that also plays a key role in flood management.

Bremen, Germany	
City Population	447992
Duration	2010-2020
Implementation Status	Completed
Scale	Micro-scale: District/neighbourhood level
Project area	Unknown
Type of area	Other
Nature - based solution	**Key Challenges**
Blue infrastructure • Rivers/streams/canals/estuaries • Mangroves Grey infrastructure featuring greens • Riverbank/ lakeside greens	• Climate action for adaptation, resilience, and mitigation (SDG 13) o Climate change adaptation o Climate change mitigation • Green space, habitats and biodiversity (SDG 15) o Habitat and biodiversity restoration o Habitat and biodiversity conservation o Green spaces creation and/or management • Regeneration, landuse and urban development o Promotion of naturalistic urban landscape design • Water management (SDG 6) o Flood protection • Economic development and employment (SDG8) o Real estate development o Tourism support
Focus	
Creation of new green areas, Management of rivers and other blue areas, Monitoring of habitats and/or biodiversity	
Climate-focused activities	
Climate change adaptation: • Implement sustainable urban drainage infrastructure (e.g. to make space for water) • Renaturalization of rivers and other water bodies Climate change mitigation: • Increase green urban nature for carbon storage (wetlands, tree cover)	
Objectives	
1. To capture and store carbon by mangrove plantation alongside the Iloilo River. 2. To provide an improved flood protection system to the city of Iloilo. 3. To create new habitats and protect the existing ones. 4. To enhance species enrichment, especially native biodiversity. 5. To create an eco-tourism hub for the city.	
Main beneficiaries	
Local government/Municipality Citizens or community groups	

Table 3-7- Details of Beach Park in BIloilo River Esplanadenade (nature atlas , 2022)

Implementation activities

This area has been changed from a dike road for flood adaptation to a eco-tourism hub and an educational center for community, to flood adaptation. Trees, are used in both side of riverbank including flowering and ornamental varieties and also Mangroves introduced as a part of this project. Additionally, as other activites is Eco-trails were created for communities to enjoy and engage with the environment.

Impacts & Monitoring		
Environmental Impacts	Economic Impacts	Socio-cultural impacts
• Climate, energy and emissions o Strengthened capacity to address climate hazards/natural disasters o Enhanced carbon sequestration • Water management and blue areas o Increased protection against flooding o Enhanced protection and restoration of freshwater protection and restoration of freshwater ecosystem • Green space and habitat o Increased green space area o Increased conservation or restoration ecosystem o Reduced biodiversity loss o Increased number of species present	• Increase of jobs • More sustainable tourism • Increased property prices • Attraction of business and investment	• Safety o Improved community safety to climate-related hazards o Decreased crime rates. • Social justice and cohesion Improved access to urban green space o Increased opportunities for social interaction. • Health and wellbeing o Gain in activities for recreation and exercise • Culture heritage and sense of place o Improvement in peoples connection to nature • Education o Increased support for education and scientific research o Increase awareness of NBS and their benefits

Table 3-8- Impacts & Monitoring of Beach Park in BIloilo River Esplanadenade (nature atlas , 2022)

Figure 3-13 - Iloilo River Esplanade (Urban nature atlas , 2022)

3-2.Detailed Design of Nature-Based Solutions for Flood Adaptation

After understanding NBS for flood adaptation, this section focuses on the implementation details of each solution, which can help in the design process.

URBAN FOREST

Forests, including urban forests Consisting of woodlands and all trees in urban area to protect rivers and reduce flooding by intercepting rainfall and increasing water infiltration.

-Function

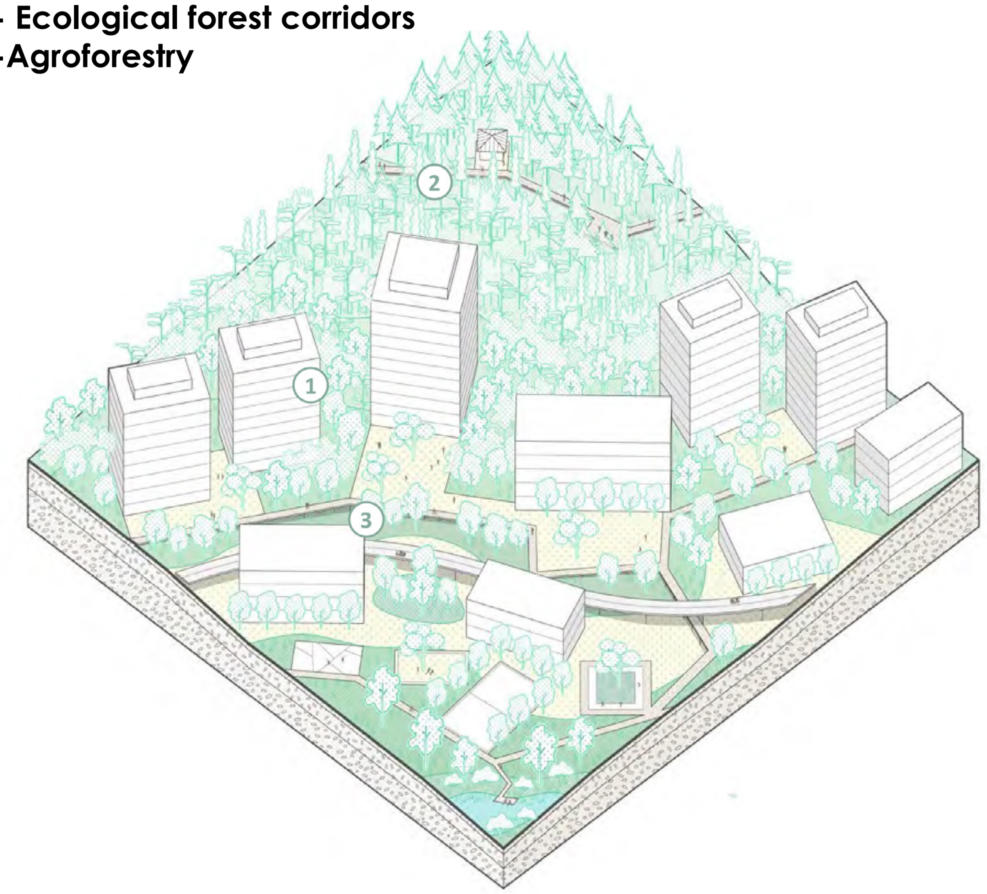
Urban forests can more efficient to collect water from flood instead of paved surface. Forests can increase infiltration capacities to store water by tree roots and also by evaporation. stuidies shows more forest restoration, more infiltration capacity.

-Benefits

Existing forests and trees in cities help protect against floods, especially along rivers. They can reduce flood heights and speeds, slow down rapid runoff, and offer many other benefits. For example, they improve air quality and temperature, reduce pollution, and provide green spaces for urban planning. These spaces can be used for community activities, tourism, and connecting people with nature. Overall, they create better living environments for healthier and happier communities.

VISUALIZATION OF URBAN FORESTS IN THE URBAN CONTEXT

- **Phytoremediation forest**
- **Ecological forest corridors**
- **Agroforestry**



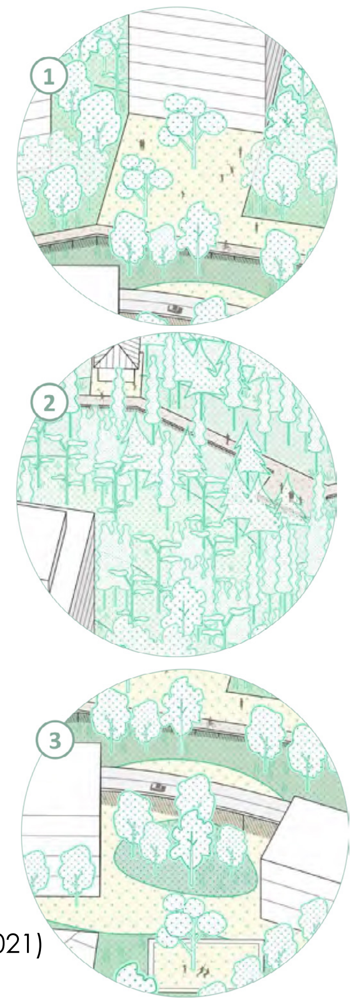


Figure 3-14 - VISUALIZATION OF URBAN FORESTS IN THE URBAN CONTEXT(Nielsen,2021)

SUITABILITY CONSIDERATIONS		
	Factors	**Description**
TECHNICAL	Slope	Variations in soil humidity, the velocity of stormwater drainage, and the rate of soil erosion are all caused by slopes.
TECHNICAL	Site evaluation and preparation	Site preparation for forest restoration may involve weed suppression, soil cultivation and fertilization, improving soil structure and composition, and establishing fast-growing nurse crops before planting preferred species.
TECHNICAL	Species selection	choosing suitable tree species for specific sites, and preferring local species, all to support a strategic planting and growing plan.
TECHNICAL	Species combination	Providing a mix of species that simulate forest, providing resilience and productivity more effectively
URBAN	Planting	For sustainability in creating urban forests, it is necessary to consider pre-planting conditions such as planting policies in urban areas.
URBAN	Land use	Use of land Reforestation of degraded natural forest regions such as : alluvial sites, rivers, steep slopes susceptible to landslides and soil erosion also, unproductive agricultural sites, and no longer viable industrial wood plantations are all suitable land uses for urban forests.
URBAN	Area	Small to extra-large

Table 3-9- Technical & Urban consideration for Urban forest (Zhou, K , 2024)

TERRACES AND SLOPES

Terraces provide safe areas for entertainment and other activities while stabilizing areas impacted by landslides and flooding. Wattle fences and vegetated gabions are two effective types of terraces for stabilizing slopes.

1.**Wattle fences**, made from wooden posts and woven shoots, reduce storm impact and support vegetation.
2.**Vegetated gabions**, steel mesh baskets filled with stones and earth, protect slopes from stormwater and foster plant growth through their porous structure.
3. **Living smiles,** A living grin is a naturally occurring, permeable barrier composed of pliable plant fragments that are intended to drain

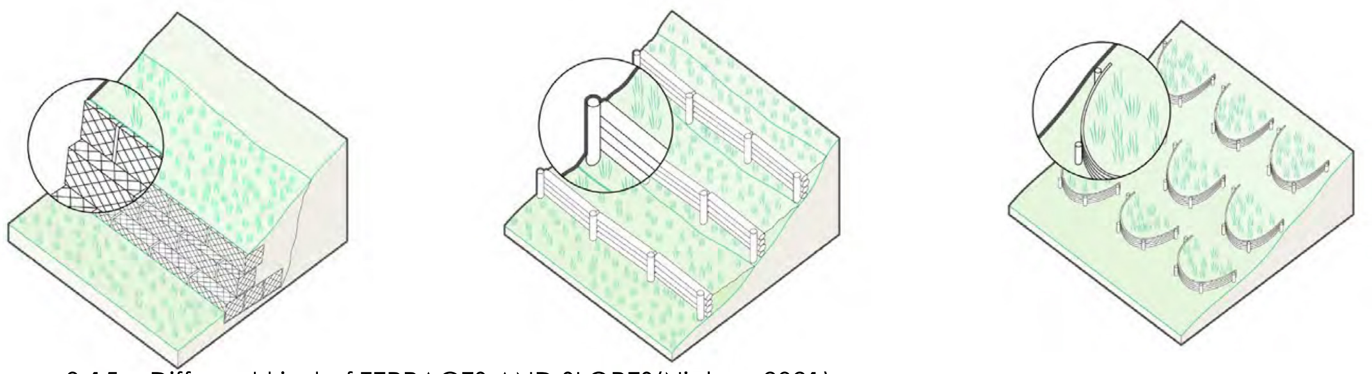


Figure 3-15 - Different kind of TERRACES AND SLOPES(Nielsen,2021)

-Function
Terraces can effectively control erosion, store floodwater, and prevent landslides. Research in Veneto, Italy, has shown that this approach increased the floodwater storage capacity by 50%.

-Benefits
Terraces help reduce the risk of floods, as well as landslides, erosion, and other related issues.

SUITABILITY CONSIDERATIONS		
	Factors	**Description**
TECHNICAL	Slope	Terraces are typically constructed on slopes up to 50%.
	Dimentions	The size of a terrace depends on how it is used. In humid tropical areas, the recommended maximum length is 100 meters. The width can range from 2.5 to 5 meters or 3.5 to 8 meters, depending on its purpose.
URBAN	Land use	Peri-urban green spaces, agricultural regions, slopes, and green spaces are all appropriate land uses for terraces.
	Urban density	Urban areas with low to medium densities can benefit from terrace construction.
	Area	Terraces are nature-based solutions generally applied on a medium to large scale.

Table 3-10- Technical & Urban consideration for Terraces and slops (Zhou, K , 2024)

VISUALIZATION OF TERRACES AND SLOPES IN THE URBAN CONTEXT

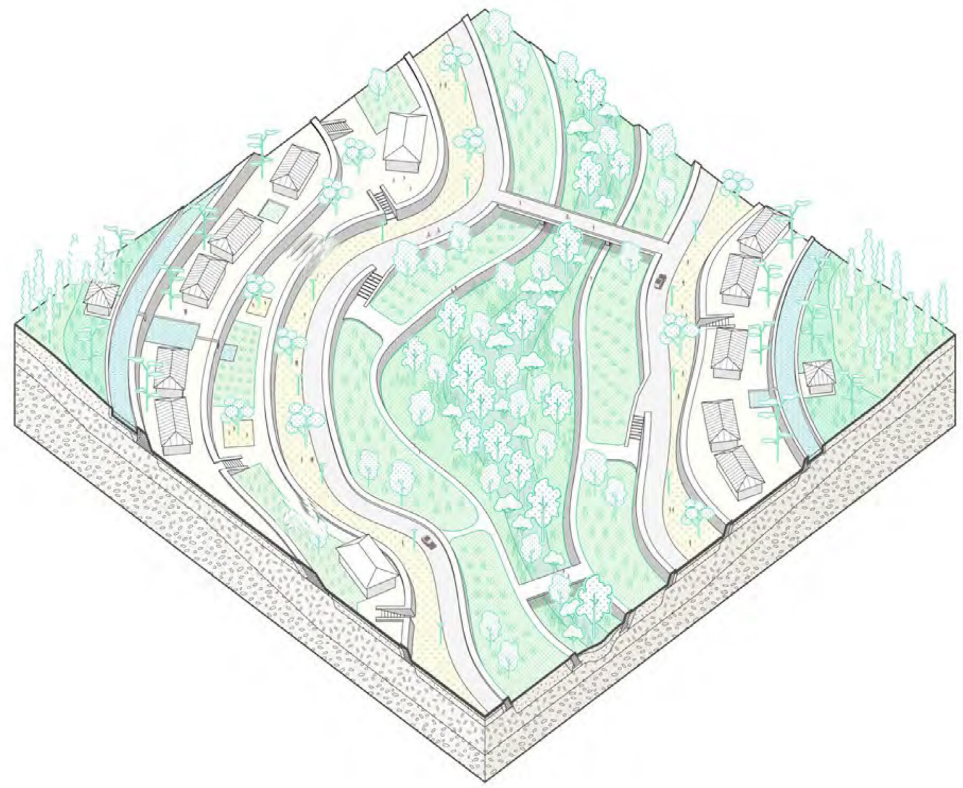


Figure 3-16 - VISUALIZATION OF TERRACES AND SLOPES IN THE URBAN CONTEXT(Nielsen,2021)

RIVER AND STREAM RENATURATION

Renaturating rivers with nature-based solutions can decrease floods and restore natural river dynamics.

-Function

This solution slows down river flow, helping water absorb into the ground. Winding river paths, naturally existing in Verona as a case study, and plant-covered riverbanks reduce water speed, which helps protect against flooding. Also, when combined with other nature-based solutions, this approach can significantly reduce flood risk.

-Benefits

This approach can reduce flood height and speed by restoring rivers to their natural flow, which helps decrease the overall impact of flooding. So, it can also protect infrastructure and buildings from flood risks.

SPECIAL TECHNIQUES FOR THIS APPROACH

Restoring riverbanks: Restoring riverbanks is a method that helps reduce flood risk. It involves reshaping the river to return to its natural form, creating habitats for aquatic species, managing water flow, and integrating these efforts with the city's cultural and social needs by building public spaces for various functions.

Bioengineering techniques

Bioengineering techniques help restore a river's natural path and connect it to its surroundings. Also, it involves fixing riverbanks using plants, rocks, and natural materials. This technique creates a natural space that promotes healthy living for communities and provides a place for recreation.

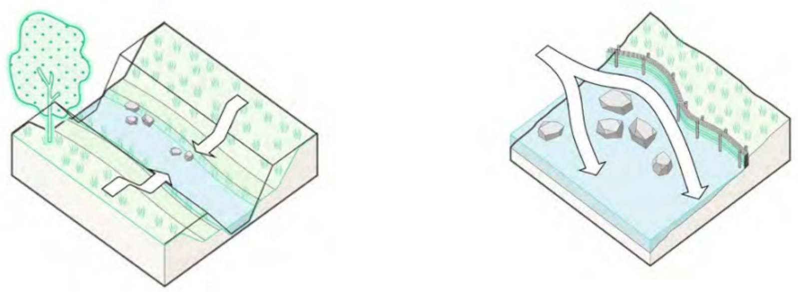


Figure 3-17 - Different kind of River and Stream renaturation (Nielsen, 2021)

SUITABILITY CONSIDERATIONS		
	Factors	**Description**
ENVIRONMENTAL	Hydrology	It is important to understand water flow and the river's ability to handle high water levels for Controlling floods and stabilizing the river.
ENVIRONMENTAL	Soil	Implementing this technique requires examining the soil characteristics in these areas. The soil must support plant roots, sustain plants during droughts, and resist erosion.
TECHNICAL	Slope	Riverbanks and floodplain slopes should help store floodwater, support river habitats, and remain stable.
TECHNICAL	Planting and growing strategy	Native plants should be chosen for river and stream restoration to strengthen and protect riverbanks, and reduce soil erosion. The best trees are those that can survive in wet conditions, provide shade, improve wildlife habitats, and offer shelter for animals. When selecting plants, it's important to consider the water and soil conditions in different areas.
TECHNICAL	Natural fabrics	In this technique, erosion control can be used with natural materials like stones, wood logs to protect the riverbed and banks and control water flow.
TECHNICAL	Land use	Considering multifunctional use in this area, such as recreation, can help make the project more successful.
URBAN	Integrated urban planning	The construction or restoration of green spaces and public parks, water management, and eco-conservation should all include river and stream renaturation.

Table 3-11- Technical & Urban consideration for River and stream renaturation (Zhou, K, 2024)

NATURAL INLAND WETLANDS

Wetlands act as natural sponges in the city, by collecting extra water, they can reduce flood risk.

-Function
Wetlands function as sponges, controlling floods by storing runoff and slowing down the flow of water. Wetlands help conserve water, provide homes for species, and enhance biodiversity. Additionally, storing water supports the area during dry periods by improving the water supply.

-Benefits
The first benefit of wetlands is capturing and storing runoff, which adaptation flood, improves water quality and supports biodiversity. Additionally, they serve as vital carbon reservoirs, helping to mitigate climate change. These benefits also boost the economy by promoting urban sustainability through environmental preservation and attracting communities and tourists with recreational opportunities.

VISUALIZATION OF NATURAL INLAND WETLANDS IN THE URBAN CONTEXT

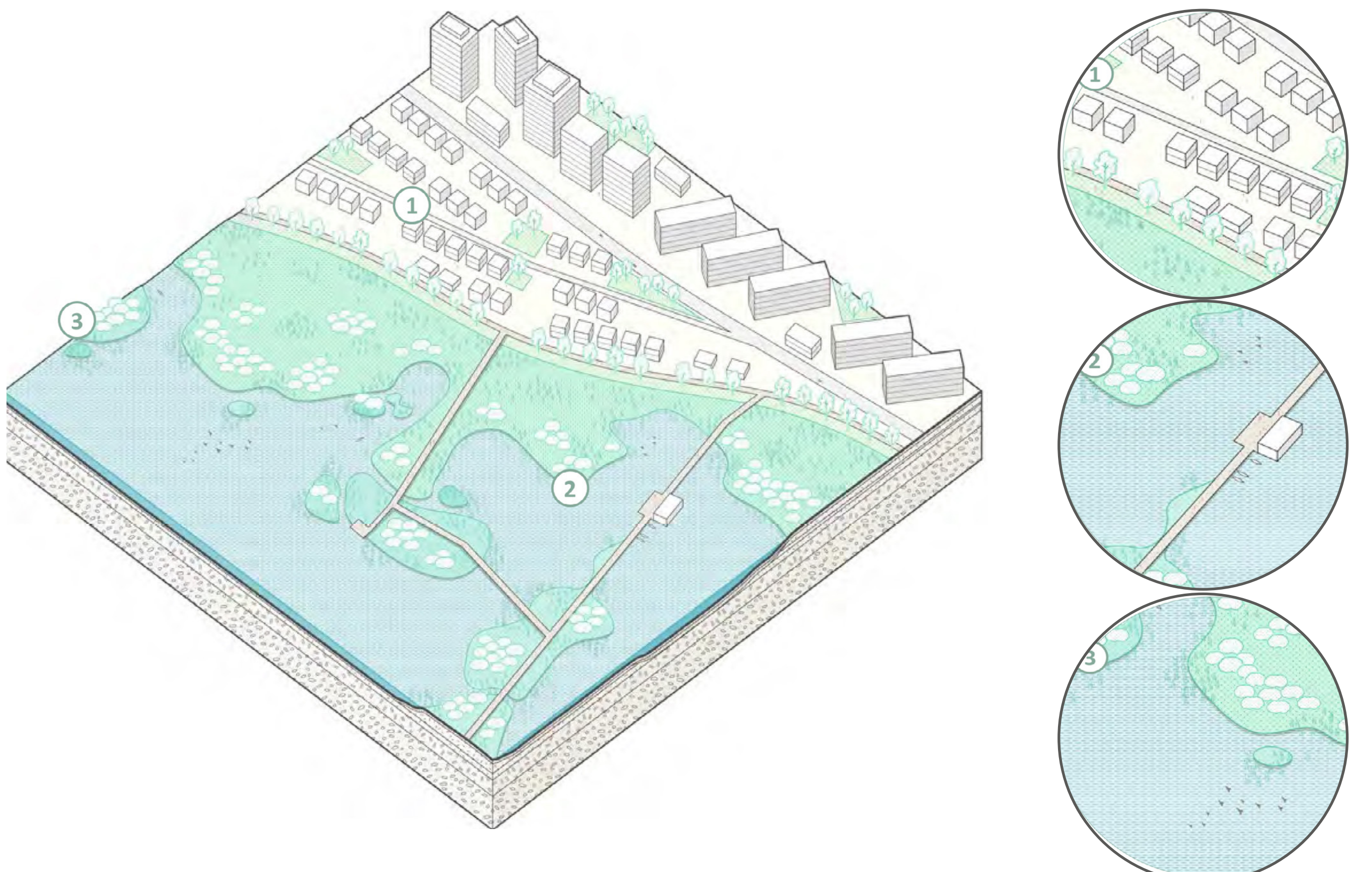


Figure 3-18 - VISUALIZATION OF NATURAL INLAND WETLANDS IN THE URBAN CONTEXT(Nielsen, 2021)

SUITABILITY CONSIDERATIONS		
	Factors	**Description**
TECHNICAL	Planting and growing strategy	Native plants are the best options, whenever possible, for using for wetland.
TECHNICAL	Hybrid infrastructure	Grey infrastructure can be used to restore and improve key wetland functions when they are badly damaged. These artificial structures are often needed to prevent erosion by increased runoff. However, floods can damage these structures, so their design should carefully consider the pros and cons of different options.
URBAN	Urban density	For wetland restoration and improve sustainable urban density, The location of existing wetlands is important, which is usually low to medium.
URBAN	Area	Extra-large to medium. A common natural solution that is usually used at the city or river basin to adapt flood is wetland that it needs space for implementation.
URBAN	Integrated urban planning	Wetland restoration can be used as a public parks, green space development, or environmental conservation programs.
URBAN	Land use	Nature, green spaces, and aquatic regions are good land uses for inland wetland restoration.

Table 3-12- Technical & Urban consideration for NATURAL INLAND WETLANDS (Zhou, K, 2024)

Wetlands are areas where water and land meet, meaning that they are part of both water and land ecosystem. Their main functions are reducing flood impacts and pollution.

Natural wetlands offer the best opportunity to connect communities with nature. With educational facilities and spaces, people can learn more about nature-based solutions and the environment.

Wetlands can offer recreational activities like boating and kayaking. Additionally, the variety of habitats adds beauty and makes the area more attractive.

RIVER FLOODPLAINS

As cities grew, traditional flood control methods couldn't address this challenge. To respond to climate change, cities have recently used the "Room for the River" approach. This approach gives rivers more space to handle water flow and rising water levels. Not only, it helps reduce flood risks,But also improve biodiversity, and create recreational spaces for communities.

-Function
Riverine floodplain restoration help to store water and decrease speed of water.

-Benefits
It provides benefits such as storing water, cooling area, maintanance biodiversity, improving water quality and reducing pollution. It also creates natural and entertaimnet spaces in the environment, providing fresh air for communities.

VISUALIZATION OF RIVER FLOODPLAINS IN THE URBAN CONTEXT

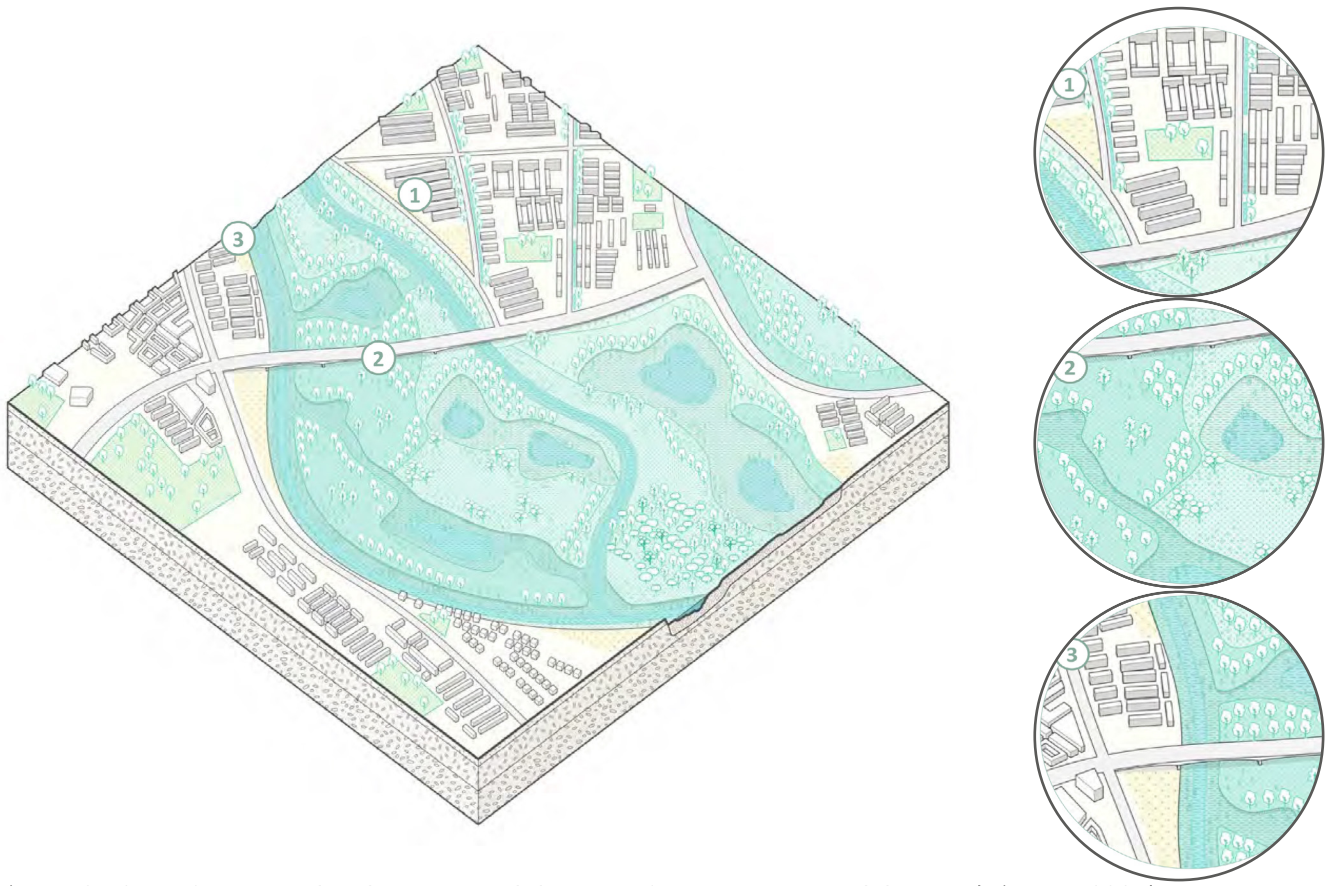


Figure 3-19 - VISUALIZATION OF RIVER FLOODPLAINS IN THE URBAN CONTEXT(Nielsen, 2021)

SUITABILITY CONSIDERATIONS		
	Factors	**Description**
TECHNICAL	Slope	Slope and shape can affect Floodplain water storage. Meaning that shallow slopes helping to more water.
	Floodplain profile	Floodplain rehabilitation in urban areas often involves restoring natural processes while also reducing flood risks
	Dimensions	The original floodplain should be preserved, with added buffer space for future climate adaptations.
	Riverbank	In this approach by using suitable vegetation can reshape and protect riverbanks to prevent erosion and support natural habitats.
	Planting and growing strategy	Planting native plants, like trees, shrubs, and grasses can be help to reduce regular flooding and wet soils.
URBAN	Urban density	Low to medium urban densities are ideal for river floodplains
	Area	River floodplains can be from large city-scale areas to smaller ones connected to rivers and streams
	Integrated urban planning	River floodplains are an important part of the city's structure, play key role as open spaces.
	Land use	These areas experience floods periodically, so they should be protected from development, allowing only appropriate activities to take place.

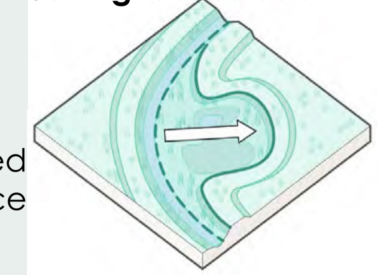
Table 3-13- Technical & Urban consideration for RIVER FLOODPLAINS (Zhou, K ,2024)

Floodplains can help collect polluted runoff, capture sediment, and reduce pollution risks.

Connection of rivers and floodplains can reduce flood risk and help to protect wildlife habitats

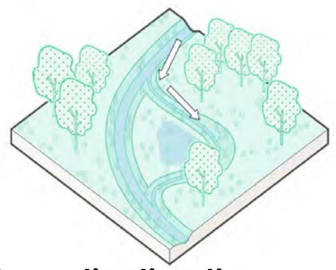
Rehabilitated floodplains along rivers can improve the landscape, So can bring a wide range of economic and social opportunities for cities.

Setting levees back



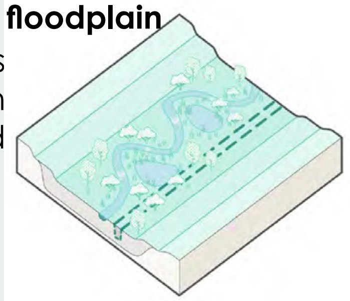
Setting levees back or creating new stream channels expands floodplain area, lowers flood levels, and enhances habitats for ecological and recreational uses.

River bypass or Oxbow



An oxbow is a former river curved filled by floods or groundwater, with structures sometimes added to manage water flow.

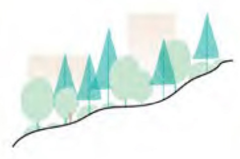
Re-activating the floodplain



Re-activating the floodplain such as creating channel newly and filling the old channel.

3-3.CONCLUSION

After conducting a thorough literature review and analyzing relevant case studies, we have formulated a set of guidelines for implementing nature-based solutions aimed at enhancing territorial resilience and flood adaptation along the Adige River. The findings of this study are essential for creating resilient, environmentally sound, and sustainable plans to adjust to flood hazards and shifting environmental condition.
The literature study emphasized how different nature-based solutions (NBS) can effectively manage flood risks and foster ecological resilience. Practical insights into the effective implementation of these ideas were offered by case studies from comparable river systems and geographical areas. After combining this data, we have determined that there are four primary types of interventions: Wetlands and River Floodplains, Urban Forest, River and Stream, and Renaturation/Natural Inland. A variety of tactics that can be applied at various scales (River Basin, City, Neighborhood) and throughout various time periods (Short-Term, Mid-Term, Long-Term) are included in each area.



URBAN FOREST

LONG-TERM

- Developing large urban parks or forests at the city and river basin scales.

MID-TERM

- Creating pocket parks/neighborhood green spaces at the neighborhood and city scales.
- Developing green corridors and green belts at the city scale.

SHORT -TERM

-Implementing tree planting and green spaces at neighborhood and city scales.
- Establishing stormwater controls like retention ponds at the neighborhood scale.

RIVER AND STREAM RENATURATIO

LONG-TERM

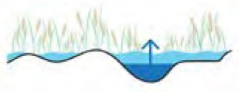
- Creating sustainable urban drainage systems at the city and river basin scales.
- Developing river parks (rain gardens, vegetated bioswales) for flood regulation, recreation, and biodiversity support at the city and river basin scales.

MID-TERM

- Restoring urban rivers and installing green roofs at the neighborhood and city scales.
- Implementing permeable pavement with a sandy surface installed alongside the river at the neighborhood scale.

SHORT -TERM

- Installing green roofs at the city and neighborhood scales.
- Establishing stormwater controls like retention ponds at the neighborhood scale.



NATURAL INLAND WETLANDS

LONG-TERM

Unsealing areas and land-use changes at the neighborhood scale.
Implementing defense and adaptation measures, such as artificial hills to raise buildings above sea level at the neighborhood and city scales.

MID-TERM

- Re-naturation of embankments at the neighborhood and city scales.
- Deleting all artificial elements along the river bank at both scale of neighborhood and city.

SHORT -TERM

-Implementing tree planting and green spaces at neighborhood and city scales.
- Establishing stormwater controls like retention ponds at the neighborhood scale.

RIVER FLOODPLAINS

LONG-TERM

- Relocating the dike 350 meters inland, digging an ancillary channel in the floodplain, and creating a new island at the city and river basin scales.
- Implementing large-scale wetland restoration, such as creating wetlands with a variety of grasslands, flower meadows, reed beds, and open water at the river basin scale.

MID-TERM

- Re-activating floodplains at the neighborhood and city scales.
- Green support of decentralized storage areas in the marshland at the neighborhood and city scales.

SHORT -TERM

- Creating small scale wetlands at the neighborhood scale.
- Developing linked retention ponds with open drainage channels at the neighborhood scale.

CHAPTER 04

Case study analysis & Pilot Implementation in Verona

An extensive case study analysis and pilot deployment in Verona are the main topics of Chapter 4. Verona is introduced in this chapter, and a thorough flood risk analysis is carried out, with a focus on finding high-risk sites along the Adige River. In order to improve flood resilience, a design approach based on nature-based solutions is suggested for the high-risk areas that have been identified. In order to create resilient urban planning that is suited to Verona's particular environmental and geographic circumstances, this chapter connects theoretical understanding with real-world implementation.

4.Case study analysis & Pilot Implementation in Verona

Process

1 Analysis of the Case study (Verona and Adige river)
Such as : Geographical, Demographical, historical and so one.

2 Review and analysis of all planning in the larger scale of Verona and Adige River.

3 Collecting and analyzing flood data in Verona, consist of historical and hydrological factors,

Using QGIS and data sources for flood risk assessment along the Adige riverbank.

4 In high risk area in riverbank, improving flood adaptation by offering NBS.

5 Setting strategy for implementation and collaboration with stakeholders and communities.

Tracking live situation to adjust policies and strategies to answer flood risk

4-1. Introduction to Verona

4-1-1.GEOGRAPHIC LOCATION

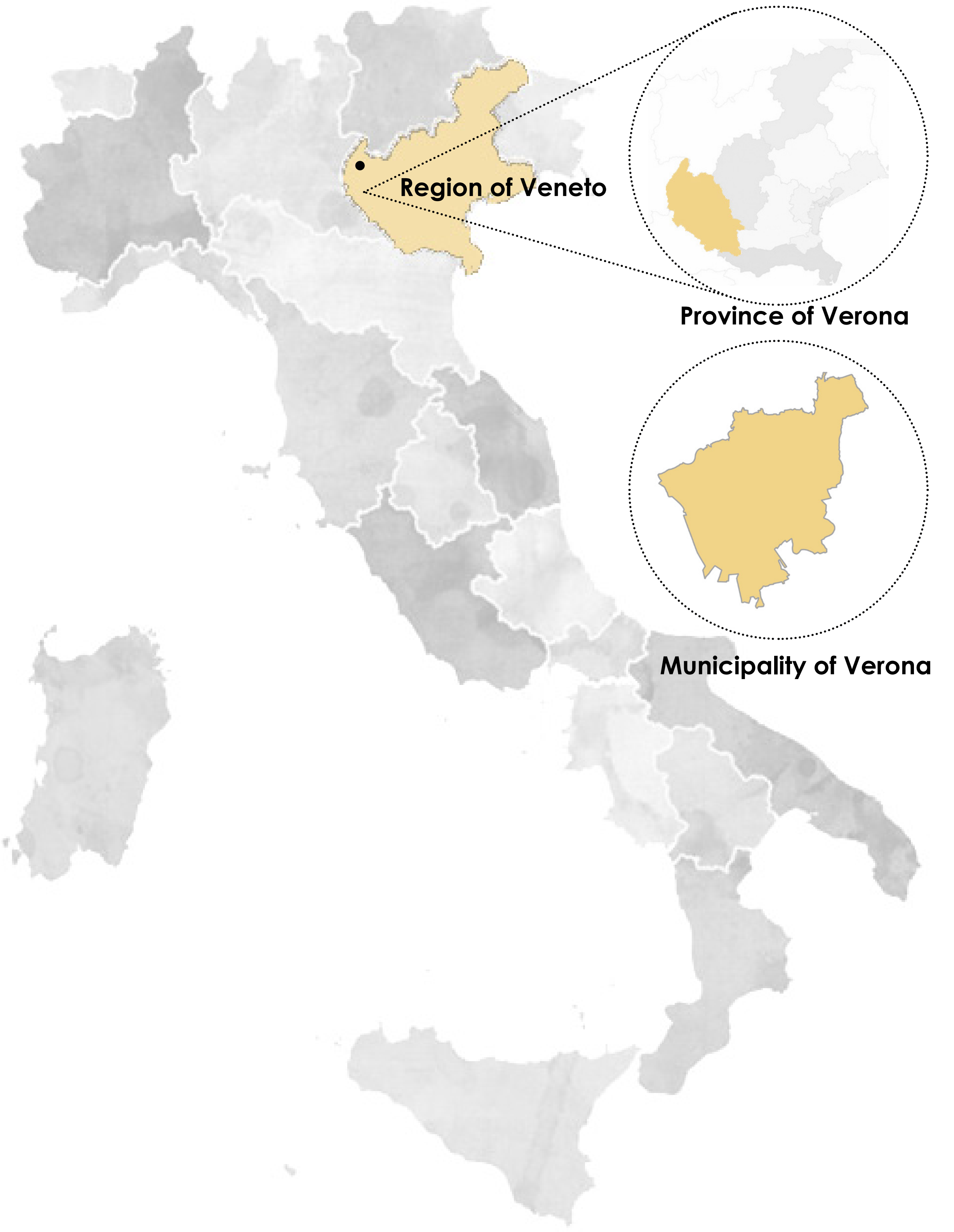


Figure 4-1. Location of Verona in italy

4-1-2.Verona: A City of History and Culture

Verona located in the northern region (Veneto) of Italy, it is a rich city in history, culture, and romance. Known primarily as the setting for Shakespeare's iconic play "Romeo and Juliet" (Boitani, 2009), Verona offers much more than literary fame. It is a city known for its mix of ancient Roman architecture, medieval buildings, and Renaissance art, making it a unique and compelling destination for scholars, Tourists and residents (Claridge, 2010; Christie, 2006). The city's preseverd historical era such as Roman that backed to the 1st century AD. (Claridge, 2010). The region of Verona is Veneto. Main city structure of Verona is strategically positioned with combining Adige river(Atkinson, 2016). Moreover, The main structure of city is a combination between historical periods such as Roman, medieval, and Renaissance that effect on streets, squares, and buildings. (Moseley & Sugg, 2009)

The largest city municipality in the region and in northeastern Italy is Verona, which is one of the seven provincial capitals in the area. Seventeen hundred and thirty-one people live in the 1,426 km2 (550.58 sq mi) Verona metropolitan area. Due to its cultural heritage, yearly fairs and performances, and the opera season in the Arena, an old Roman amphitheater, it is one of the most popular tourist sites in Northern Italy.

DEMOGRAPHIC ANALYSIS

	Popolazione al 1st Gennaio					
Territorio	2019	2020	2021	2022	2023	2024
Veneto	4884590	4879133	4869830	4847745	4849553	4851972
Verona	922857	924742	927810	924024	925656	927231

Table 4-1- DEMOGRAPHIC ANALYSIS of Verona -Refrence: Verona Population Statistics/ Istat (Istituto Nazionale di Statistica)

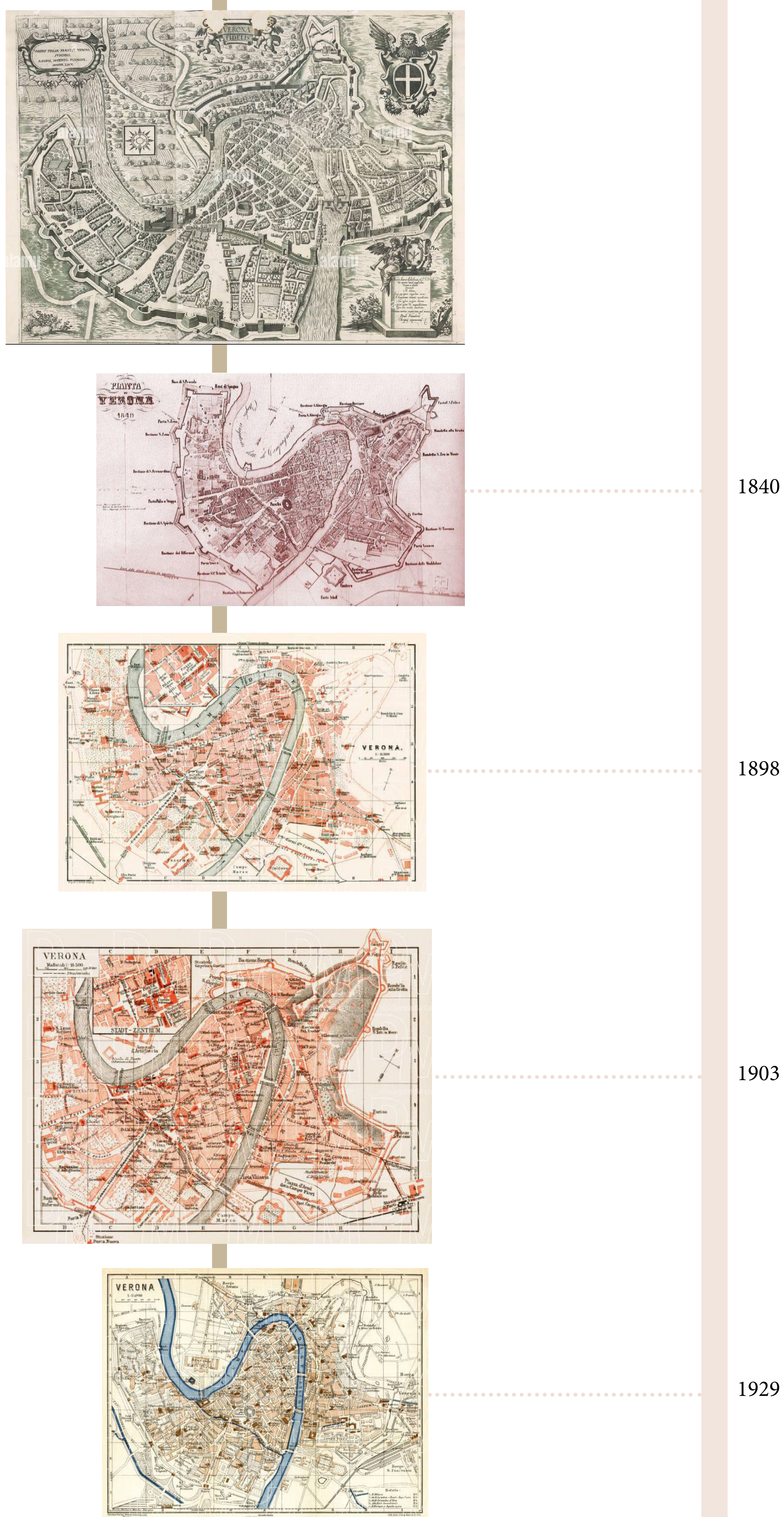


Figure 4-2. Historical Timeline(Andreotti-Giuliana,1993)

4-1-3.Verona: A River city

The Adige River, which runs through the center of Verona, is what makes it a city with a river. The history, growth, and cultural character of Verona have been significantly influenced by the Adige, the second-longest river in Italy (Atkinson, 2016). Verona has historically profited from the Adige as a natural resource, a commerce route, and a defensive barrier due to its advantageous location along the river's banks. The Adige River has shaped the structure of Verona, with its bridges and landmarks in riverbank has been defined the unique identity for Verona. (Claridge, 2010)

Historically, the Adige River has played a strategic role in both the economic and cultural development of Verona, this river helping to shape Verona into one of the most economically significant cities in northern Italy. (Moseley & Sugg, 2009). The river also helped to the city's defense, serving as a natural barrier against Attackers during medieval times. Today, the Adige remains an integral part of Verona's identity, adding to its natural beauty and playing a role in the city's cultural and recreational life. The river not only reflects Verona's rich past but also continues to shape its future as a vibrant and picturesque city. (Christie, 2006)

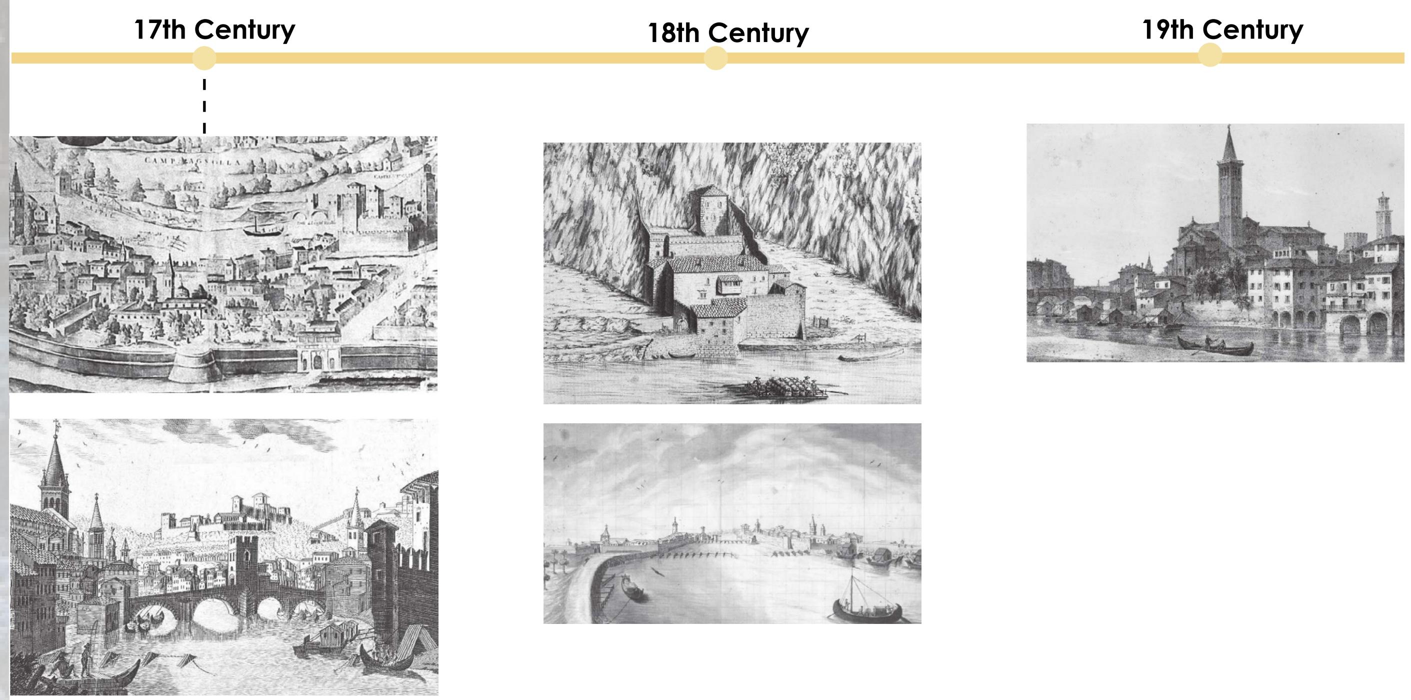


Figure 4-3. Adige River Through History: A Timeless Journey (Wiel 1902)

Figure 4-4. City classification – position of the city into the river basin (Nielsen, 2021)

4-1-4. Weather, Climate Change in Verona

Yearly Temperature Change - Verona

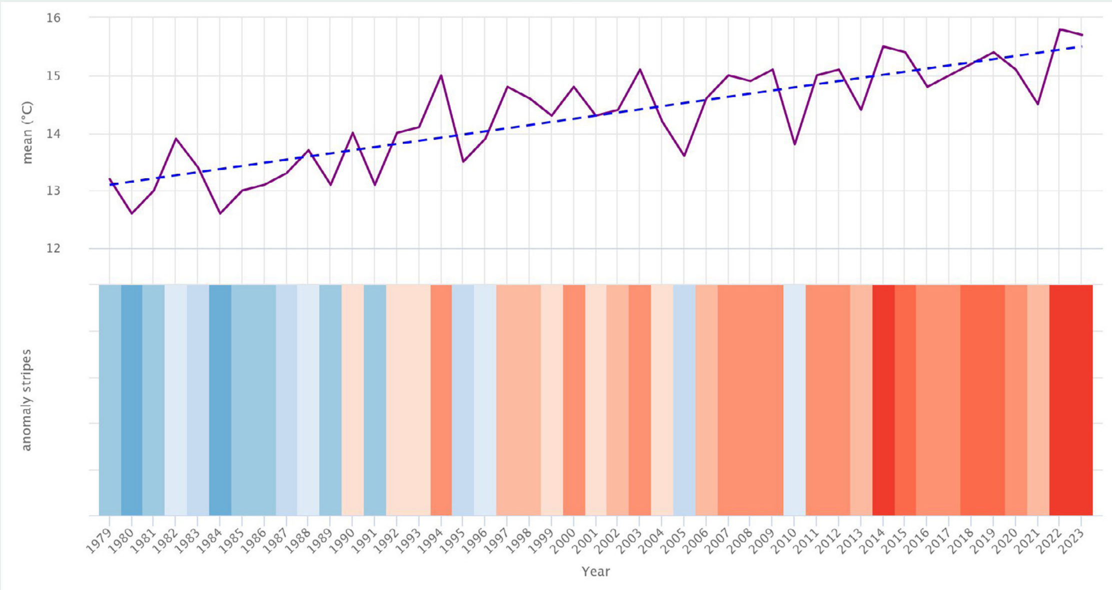


Figure 4-5.Mean yearly temperature trend and anomaly (1979-2023) / Climate Change plan of Verona)

The graph illustrates Verona's mean annual temperature trend, with a dashed blue line showing the impact of climate change. An upward trend indicates warming. Warming stripes below show each year's average temperature, with blue for cooler years and red for warmer ones.

Yearly Precipitation Change - Verona

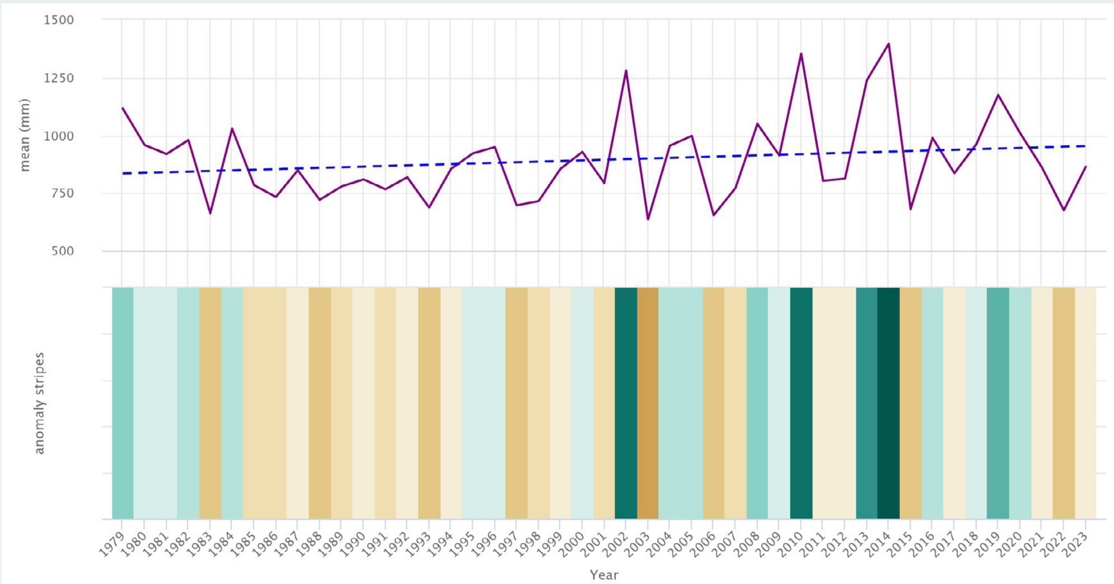


Figure 4-6.Mean yearly precipitation, trend and anomaly (1979-2023) / Climate Change plan of Verona

The top graph displays Verona's mean total precipitation trend, with a dashed blue line indicating climate change effects. An upward trend suggests increasing precipitation. The stripes below show annual precipitation, with green for wetter years and brown for drier years.

Monthly Anomalies of Temperature and Precipitation Climate Change Verona

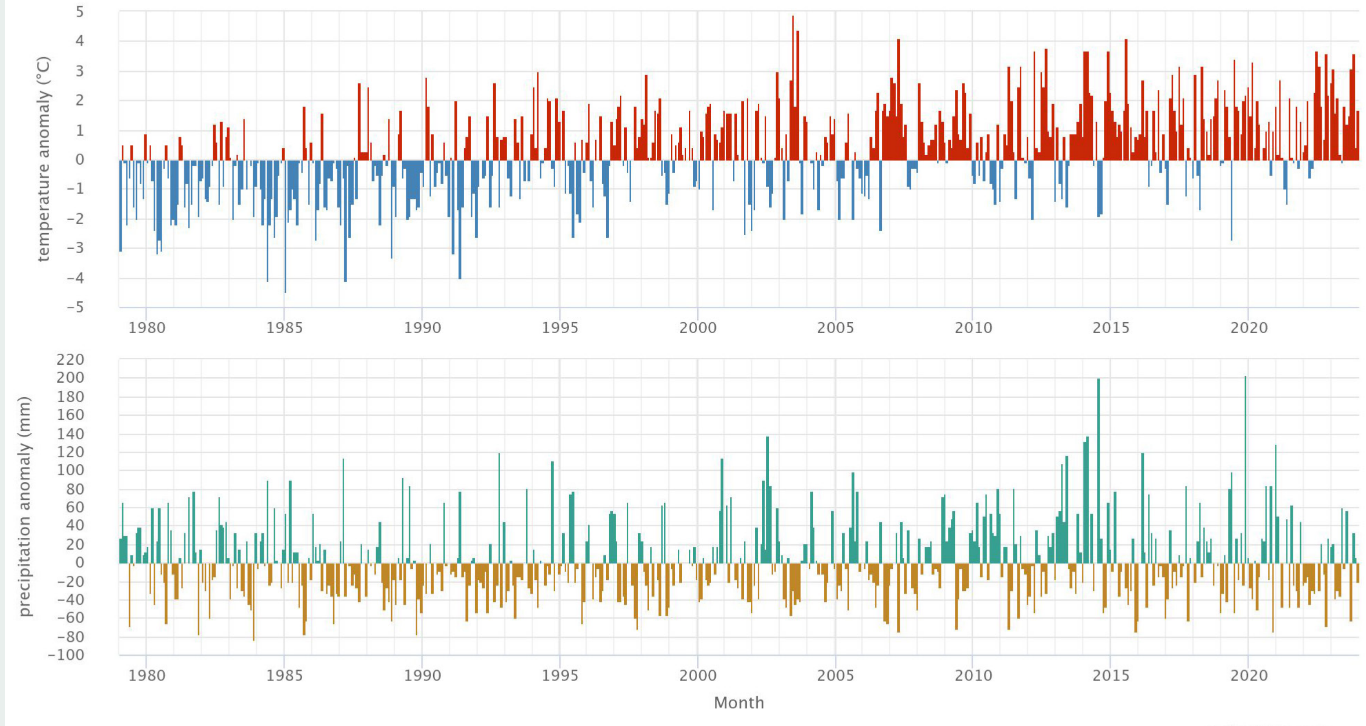
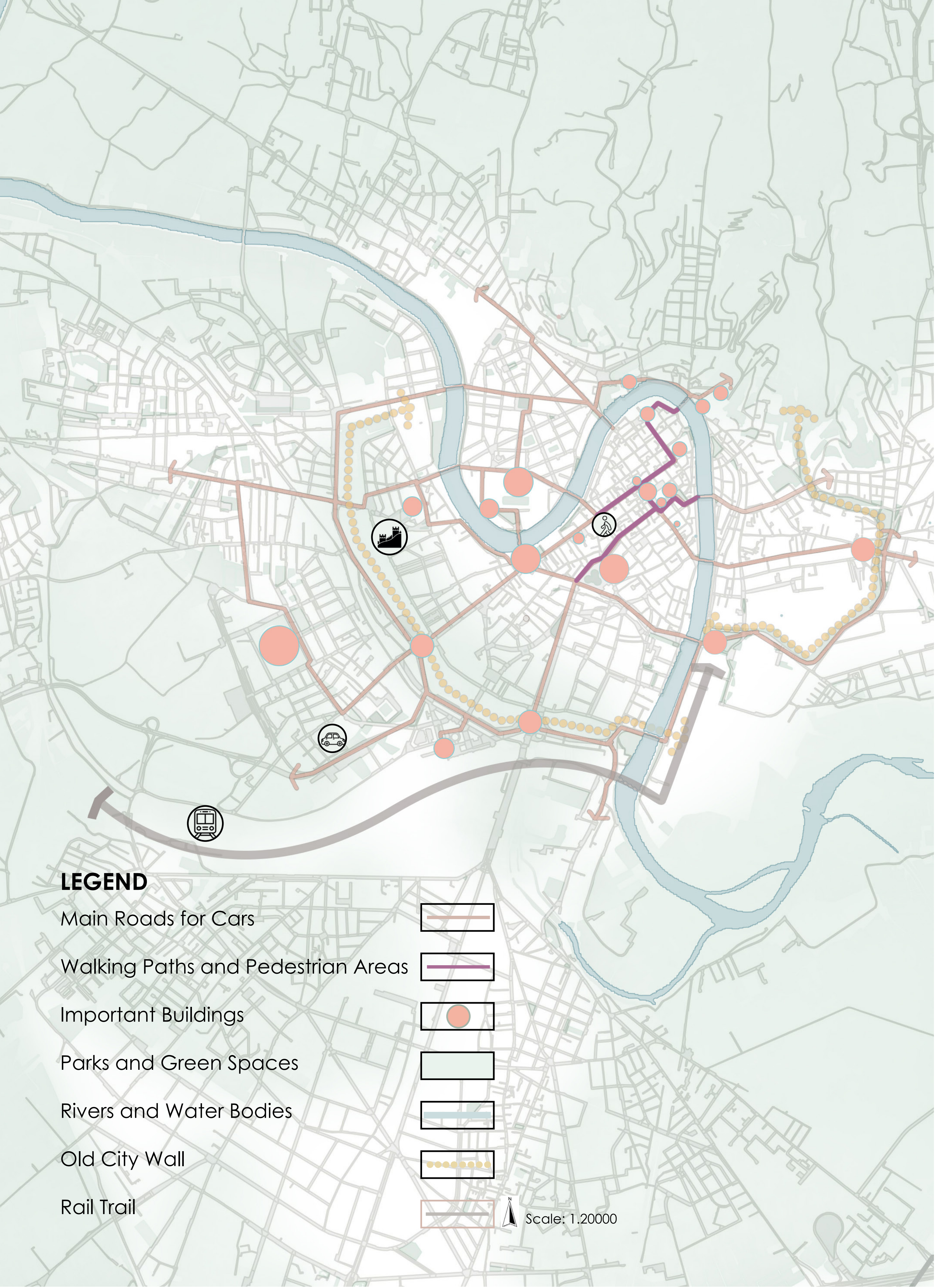


Figure 4-7. Monthly anomalles for temprature and perticipation (1979-2024) / Climate Change plan of Verona

The top graph displays Verona's monthly temperature variations since 1979, showing how much warmer or cooler each month was in relation to the average for 1980–2010. Global warming was reflected in the overall rise in warmer months, with red months being warmer and blue months being colder. Monthly precipitation variations are displayed in the lower graph, which indicates whether each month was wetter (green) or drier (brown) than the average during 1980–2010.

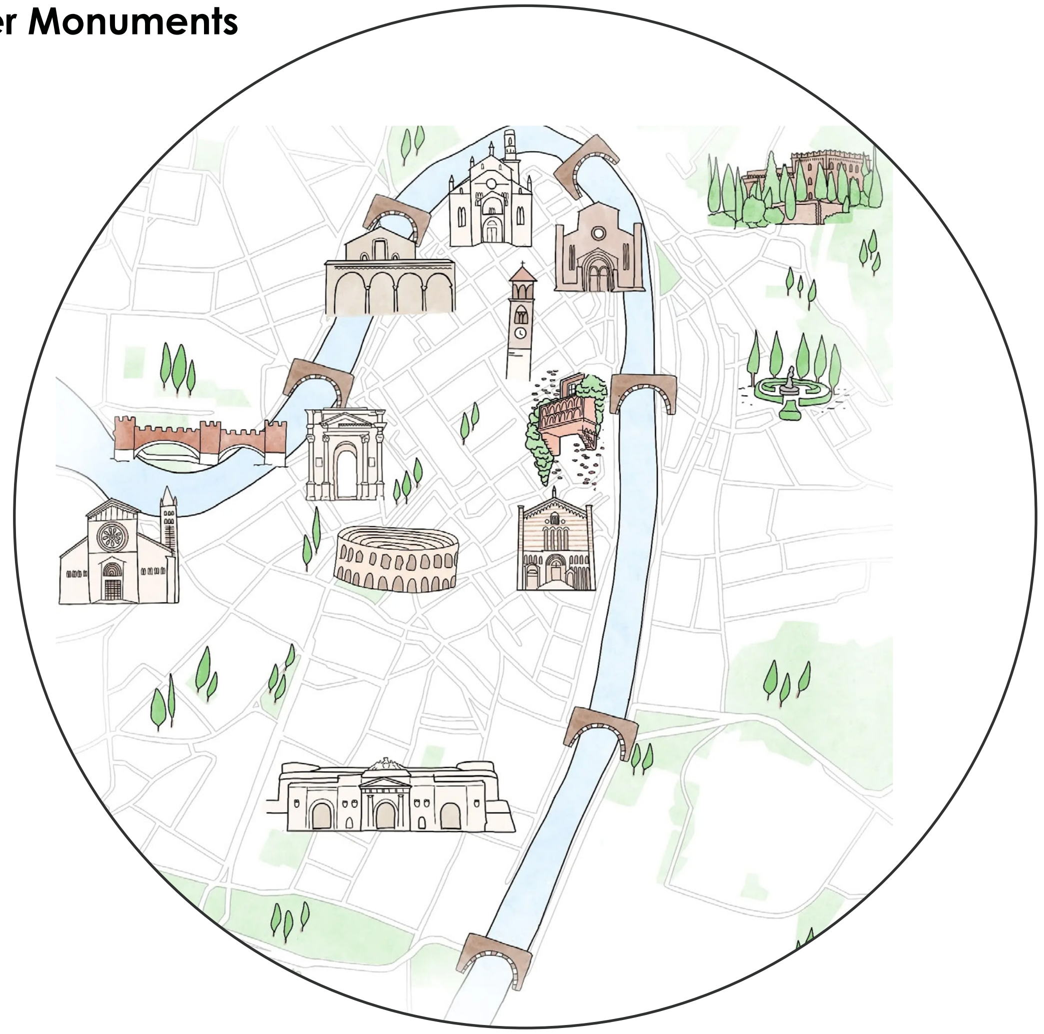
Meteorological data shows that due to climate change, Verona is experiencing more Strong and unpredictable rainfall. This change has brought additional pressure on the city's infrastructure, increasing flood risks. Historically, Verona has faced severe flooding events that damaged infrastructure and historical structures, often caused by the Adige River's overflow from heavy rainfall or rapid snowmelt from the Alps. To protect the city from future flood risks, immediate implementation of flood adaptation measures is essential.

Historical City Center Structure

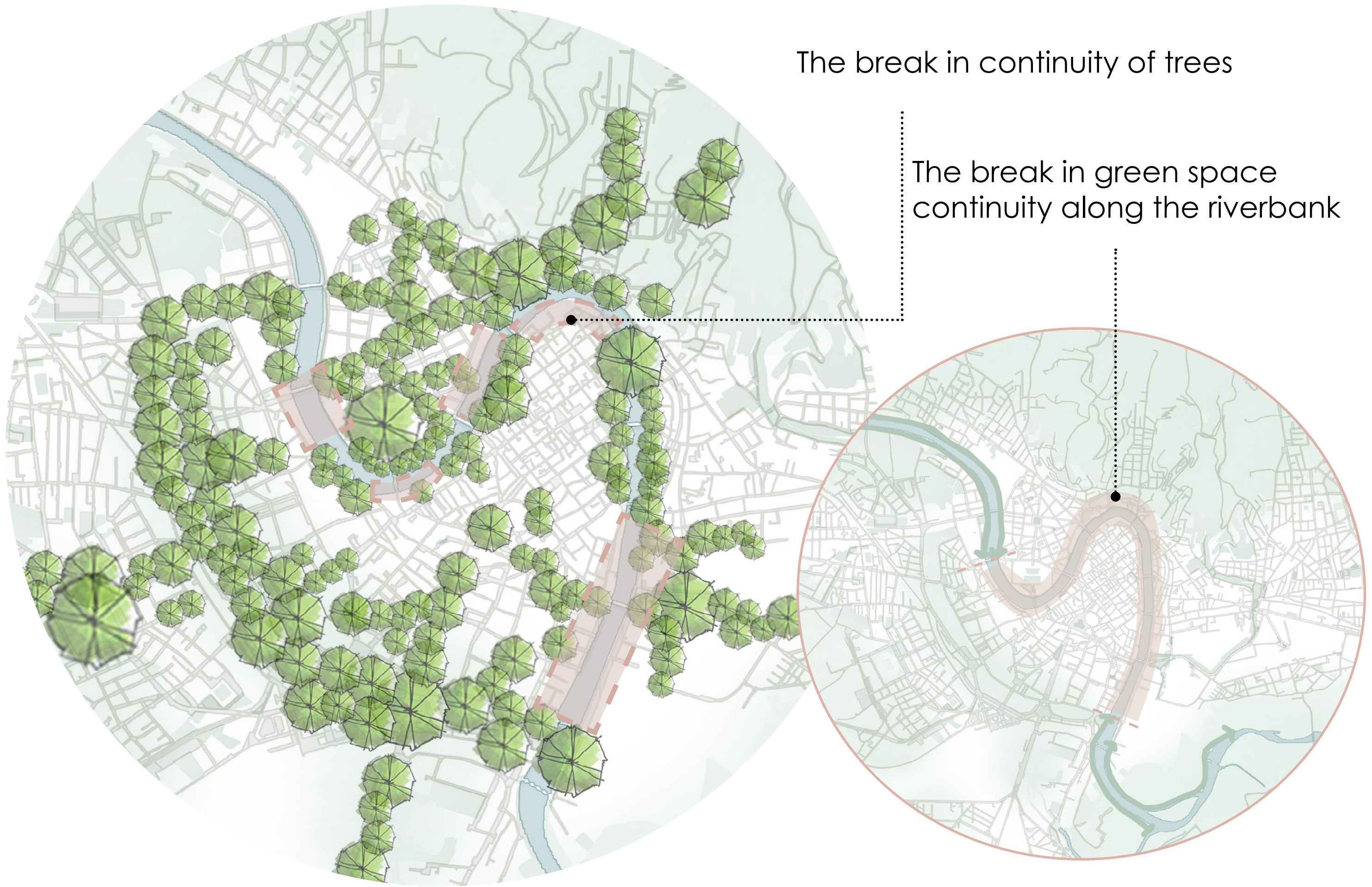


Historical City Center Monuments

Historical Buildings



City Center Environmental Characteristics



4-2.Introduction to the Adige River in Verona

4-2-1.Geographical Context

The Adige, the second-longest river in Italy and the third largest by catchment area, originates in the Upper Val Venosta at an altitude of 1,550 meters above sea level. After flowing for 409 km through South Tyrol, Trentino, and Veneto, it Flows into the Adriatic Sea. The Adige River basin covers about 12,100 km² and includes a small part of Switzerland. It flows from Lake Resia to the Adriatic Sea, with Significant branches like the Isarco, Noce, and Avisio. The basin features significant hydrological infrastructure, including the Montecatini-Biffis canal for hydroelectric power and the Adige-Garda tunnel for flood management. There are 31 artificial reservoirs with a total capacity of 571 million m³. As flooding is a major issue.

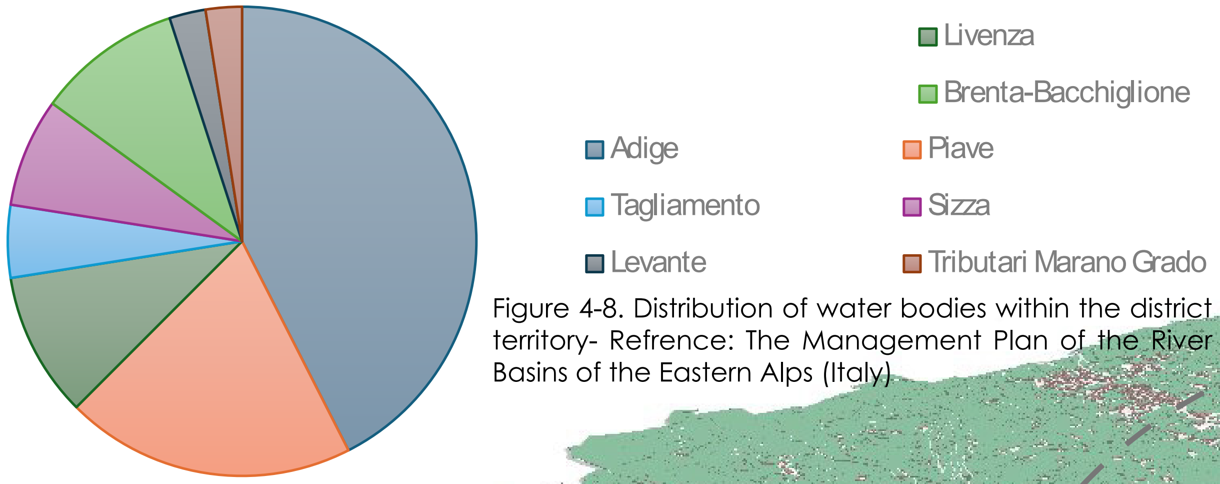
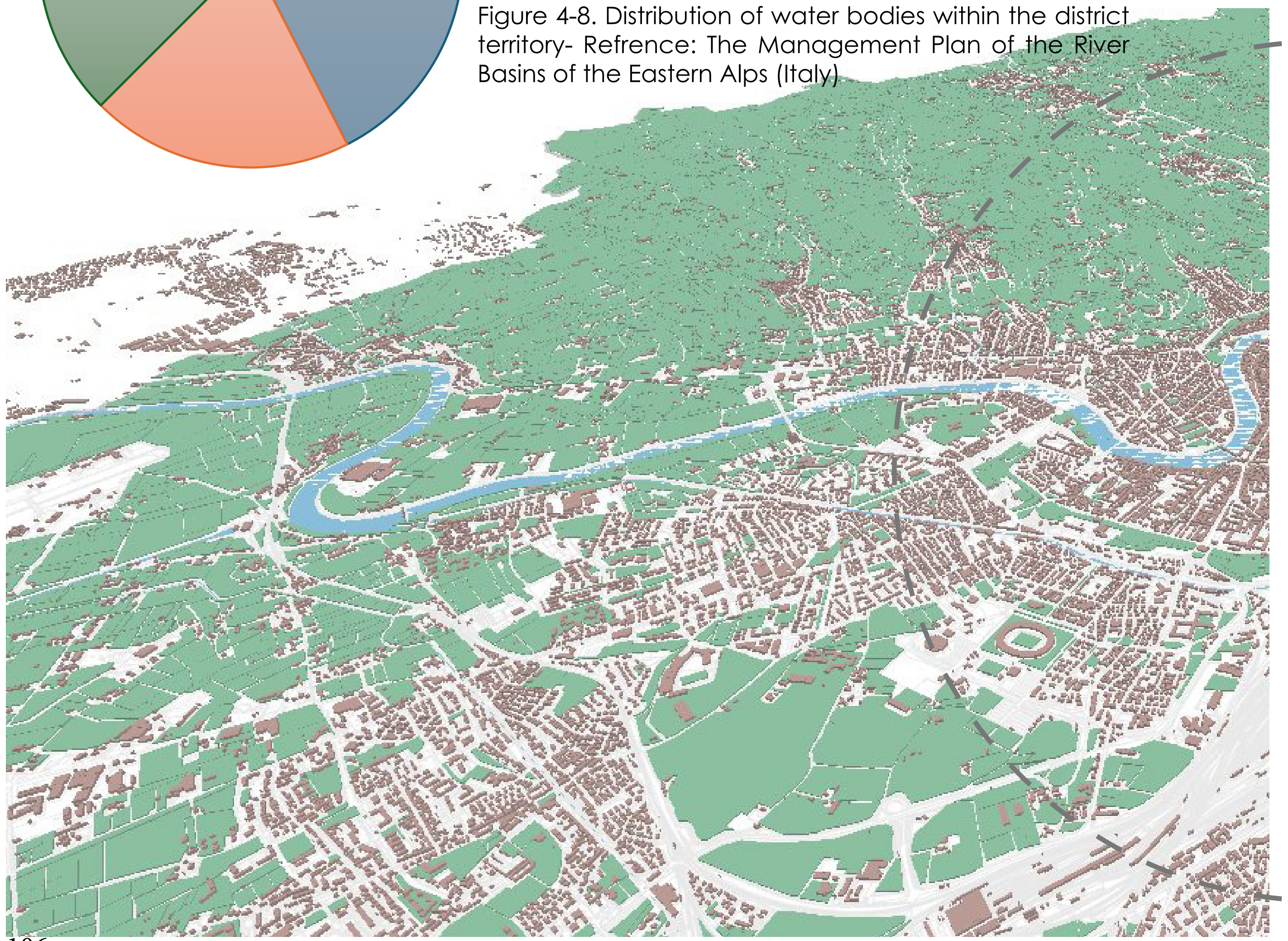


Figure 4-8. Distribution of water bodies within the district territory- Refrence: The Management Plan of the River Basins of the Eastern Alps (Italy)



The Adige River, "croce e delizia" – cross and delight – of the Veronese, Adige river is the river that Veronese love to watch it so much but they fear the river on heavy rain days.

Sections of the Adige River in Verona

Figure 4-9. current situation of the Adige River in Verona

This page provides an overview of the current situation of the Adige River in Verona, focusing on several key aspects. It highlights the condition of the riverbanks, illustrating both natural and reinforced areas. The images also showcase the river's relationship with the city, illustrating how urban areas and infrastructure interact with the river. Additionally, the layout includes visual evidence of flood prevention measures and infrastructure, such as embankments and barriers, which have been implemented to reduce flood risks and protect the city.

4-2-2.Historical Floods of Verona: Impact of the Adige River

the Adige, a symbol of Verona, remains a “cross and delight”

Verona has a well connection with the Adige, but based on previous floods, bringing both fear and dependency for the city. The serious flood that occurred in 1882 in Verona was a key time for changing the attitude towards the Adige River, changing how Verona managed the river. Some solutions considered for the city to adapt to floods included restoring land, conserving forests, and controlling the river. To prevent future flooding, the city built high walls along the river. This event also created a closer connection between the city and nature, leading to new ways of planning the city and thinking about the environment. This event also provided an opportunity to make a connection between city planning and the environment. Since 1882, Verona has worked hard to protect itself, but until now, the Adige is a symbol of both life and danger. The river supports the city, but the communities don’t forget that nature has unpredictable power.

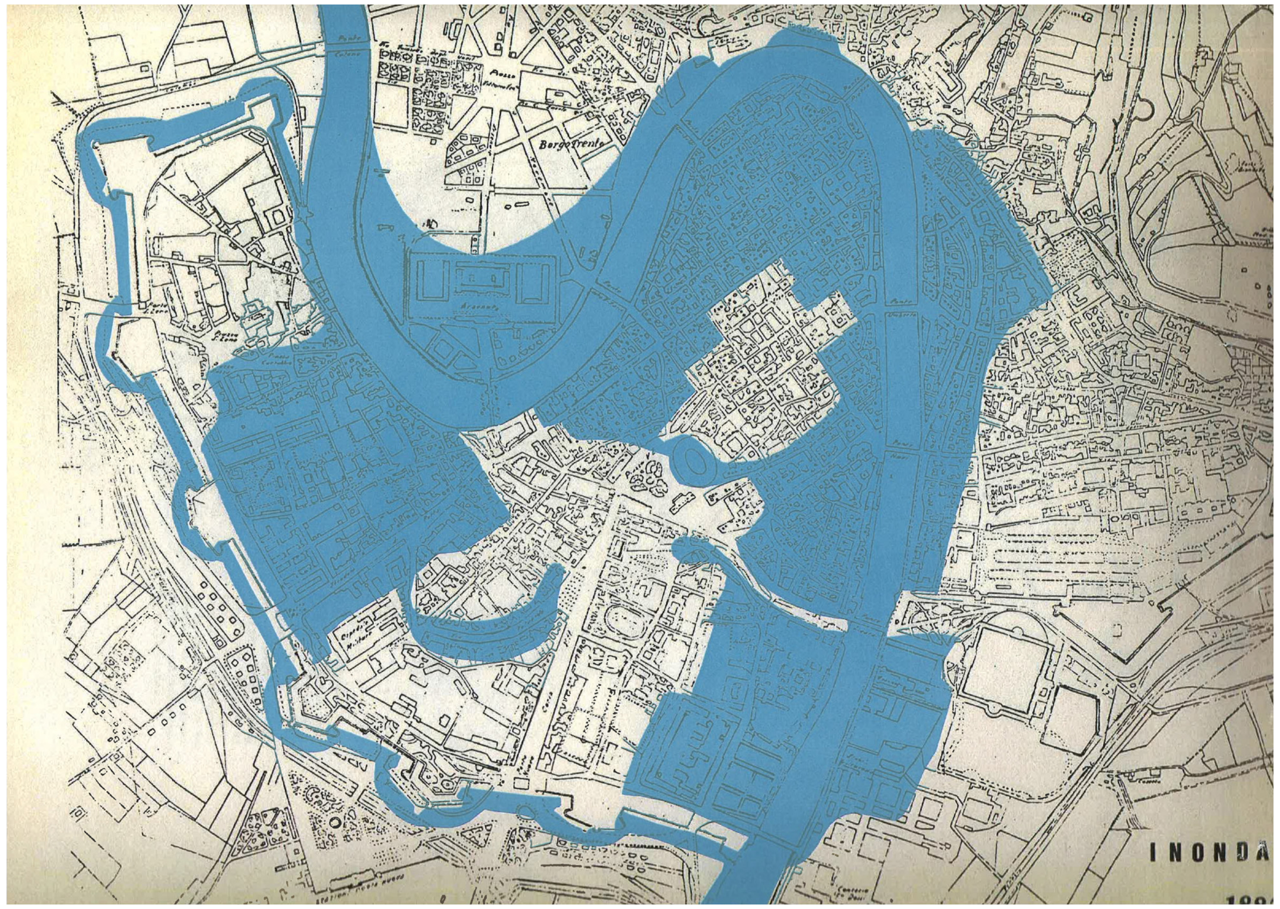
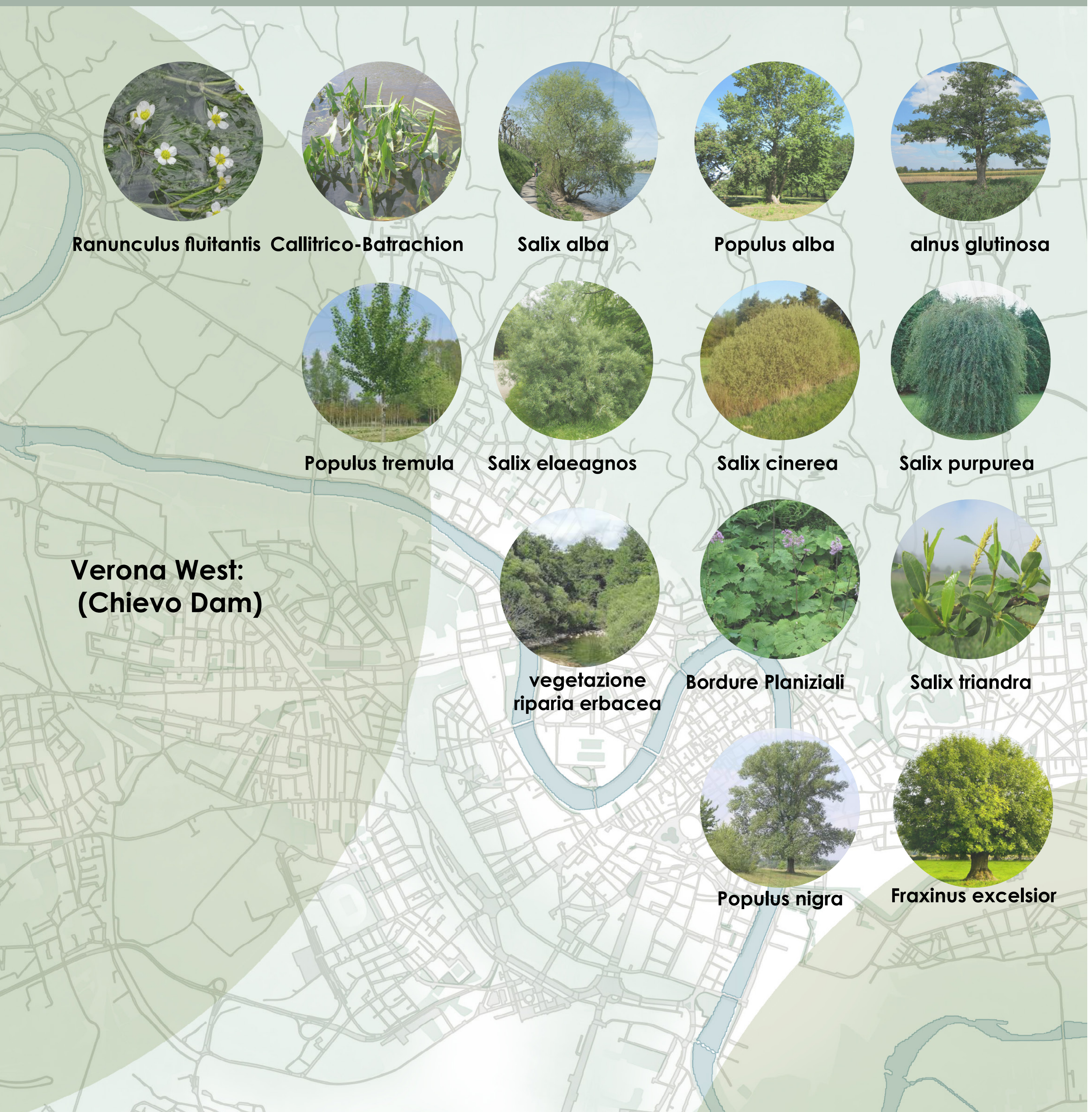


Figure 4-10. Flood in Verona 1882- Refrence: Comune di Verona

Despite these advantages that were brought after flood in 1882 for city , still heavy rainfall is caused the overflow of Adige, that increse flood risk especially for Adige riverbank and some areas such as: Vicolo Mustacchi, Via Prato Santo, Piazza del Porto in Parona, Via XX Settembre, and Lungadige Porta Vittoria.

Figure 4-11. mpact of the 2023 Adige River Fluvial Flood on Verona- Refrence: Google



Salix alba (white willow) and Populus nigra (black poplar) are predominant in small spaces, such as in the basal area of the embankment slope, in contact with the water. Associated with them are Alnus glutinosa (black alder) and, somtimes, Populus alba (white poplar), Populus tremula (aspen), and other willows (Salix elaeagnos, S. cinerea, S. purpurea) in the riparian and floodplain areas nearby. In some areas, on the sands near the water, Salix triandra (almond willow) has a significant presence.

Locations and Important Protected Features (Habitats and Species)

As previously mentioned in the “Descriptive Framework of SIC Areas Part II,” along the course of the Adige River, there are two SICs (Sites of Community Importance) within the Municipality of Verona, specifically covering their terminal and initial sections, respectively:

upstream: IT3210043 – Adige River between Belluno Veronese and Verona West (Chievo Dam),
downstream: IT3210042 – Adige River between Verona East (Santa Caterina Dam) and Badia Polesine.
The two SICs extend:

the first, for 4.7 km on the left bank and 6 km on the right bank;
the second, for 9.5 km on the left bank and 6.8 km on the right bank.
Table 1 lists the habitats and species of fish fauna and birdlife that require special protection according to Directives 79/409 and 92/43 EEC.

Code and description of the habitats and species listed in the standard form

SIC IT3210043		SIC IT3210042	
Codice	Descrizione	Codice	Descrizione
	Habitat		Habitat
3260	Fiumi di pianura e di montagna con vegetazione a Ranunculus fluitantis e Callitrico-Batrachion	3260	Fiumi di pianura e di montagna con vegetazione a Ranunculus fluitans e Callitrico-Batrachion
92A0	Foreste di Salix alba e Populus alba	92A0	Foreste di Salix alba e Populus alba
91E0	Foreste alluvionali di Alnus glutinosa e Fraxinus excelsior	91E0	Foreste alluvionali di Alnus glutinosa e Fraxinus excelsior
6430	Bordure Planiziarie montane ed alpine di megaforbie	6430	Bordure Planiziarie montane ed alpine di megaforbie
3220	Fiumi alpini con vegetazione riparia erbacea	3220	Fiumi alpini con vegetazione riparia erbacea
	Ittiofauna	1095	Ittiofauna
1097	Lethenteron zanadreai	1097	Lethenteron zanadreai
1107	Salmo marmoratus	1107	Salmo marmoratus
	Avifauna		Avifauna
A029	Ardea purpurea	A029	Ardea purpurea
A229	Alcedo atthis	A229	Alcedo atthis
A022	Ixobrychus minutes	A022	Ixobrychus minutes
A166	Tringa glareola	A166	Tringa glareola
A026	Egretta garzetta	A026	Egretta garzetta
A027	Egretta alba	A027	Egretta alba

Table 4-2. Code and description of the habitats and species listed in the standard form - Refrence: QUADRO DESCRITTIVO DEL SISTEMA AMBIENTALE, COMUNE DI VERONA CENTRO DI RESPONSABILITA' AMBIENTE, Marzo 2007

4-3-1.CLIMATE CHANGE PLANNING for Verona

CLIMATE CHANGE PLANNING RELATION TO HYDRAULIC RISK in Verona
The Flood Risk Management Plan

PGRA 2015-2021 — PGRA 2021-2027

Eastern Alps District Basin Authority

Autorità di bacino distrettuale delle Alpi Orientali

The Flood Risk Management Plan (FRM) that is for the Eastern Alps District, is a document for assessment and management of flood. This document focus on flood mitigation and adaptation strategies. For being update with dynamic situation, Every 6 years is revised to get better strategies to deal with challenges in this field. This collaborative approach is mandated by Legislative Decree 49/2010, which implements the Flood Directive. This documen is for the Eastern Alps District.

Following the last changes, the Eastern Alps District now covers an area of 34,566 km². It includes territories from the following regions:

Alto Adige	Trentino	Veneto	Friuli Venezia Giulia
21,3%	13,1%	43,0%	22,6%

The District is divided into the following basins, which constitute Units of Measurement (UoM) for compliance with the Flood Directive (FD).

euUOMCode	euUOMName	AREA (km2)
ITN001	Adige	12016,8
ITN003	Brenta-Bacchiglione	5720,1
ITN004	Isonzo	1097,1
ITN006	Livenza	2215,9
ITN007	Piave	4021,7
ITN009	Tagliamento	2743,4
ITR051	Regionale Veneto	3736,0
ITR061	Regionale Friuli Venezia Giulia	2156,0
ITI017	Lemene	859,3

Table 4-3. Flood Directive (FD)of Eastern Alps District-Source: Eastern Alps District Basin Authority

Essential Actions

1. Correction of Municipal building policies
2. Decreasing Hydraulic vulnerability.
3. Urban Forestation
4. Providing a legal framework of Resilience in cities
5. Continuous Monitoring of climate change
6. Large decrease in paved area

ACTIONS

1. Adding new policies and modern standards related to climate resilience and flood adaptation for city and buildings.

2. Supporting infiltration, lamination, and sustainable drainage of rainwater.
Actions may include updating the Water Plan or guidelines for sustainable urban drainage.
Creating green, blue, and grey infrastructure.
Acting on the minor hydrographic network.
Creating controlled floodable areas.
Developing a maintenance and cleaning plan for secondary channels.

3. Revisioning of the Civil Protection Plan: Update the plan to enhance preparedness and response strategies for emergencies and natural disasters.

4. Increasing natural area in the city by creating new forests in city and pri-city.
Planting trees in public spaces in the city such as: streets and squares.
Developing green roofs and green spaces in bulding scale.
Focusing on are that they to exposure of heat waves and water runoff.

5. Defining new role in the municipal administration for implementing this plan in an accepted way.

6. Tracking key weather and climate variables to consider better decision and strategies.

7. Implementing actions to improve water management and reduce heat impacts in large paved areas.(changing from impermable to permable area)

General objective

Reduction of the negative consequences of floods on human health	• Households reporting irregularities in water supply • Number of hospitals located in flood-prone areas • Number of schools located in flood-prone areas • Residents in flood-prone areas
Reduction of the negative consequences of floods on the environment	• Area under protection in the district (terrestrial protected areas, marine protected areas, Natura 2000 network, wetlands) • Natura 2000 sites with a management plan for protected areas and adopted conservation measures • Number of landfills located in flood-prone areas • Impermeable surface area in flood-prone areas
Reduction of the negative consequences of floods on cultural heritage	• Sites of cultural and architectural heritage in flood-prone areas • Archaeological sites in flood-prone areas • Landscape assets in flood-prone areas
Reduction of the negative consequences of floods on economic activities	• Roads and railways in flood-prone areas • Activities in flood-prone areas, including industrial, commercial, and agricultural activities

Due to annual population growth as charts shown, more people are being exposed to flood risks and vulnerabilities in these areas. Therefore, reducing urban risks, such as flooding, has become important.

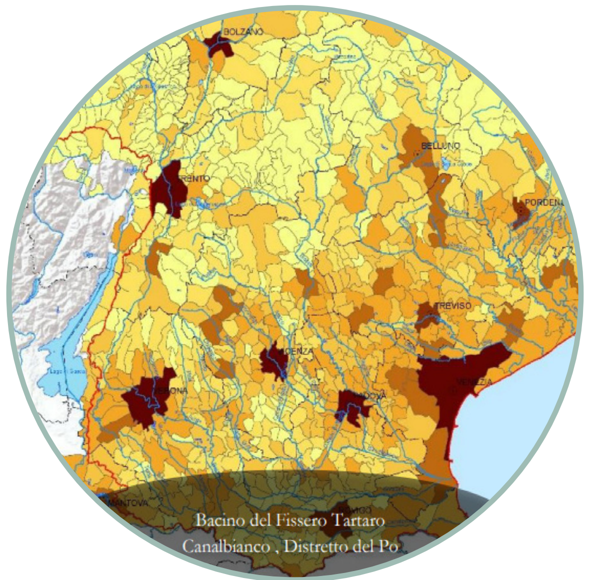


Figure 4-12. Resident population in the Eastern Alps district-Refrence: The Flood Risk Management Plan of Verona

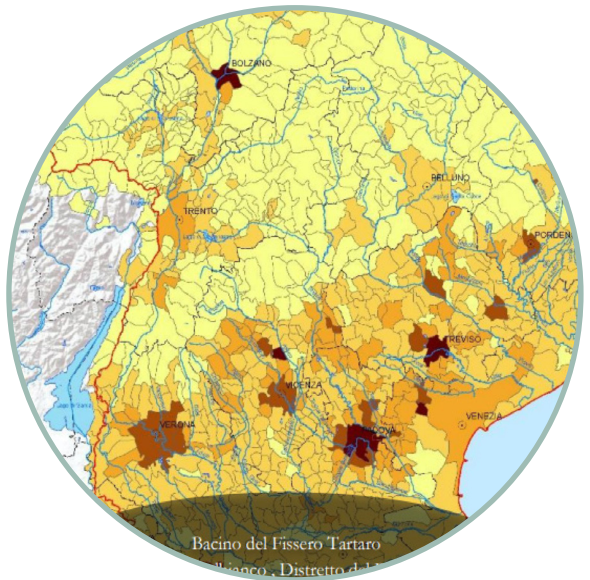


Figure 4-13. Population Density: The Flood Risk Management Plan of Verona

	census 1971	census 1981	census 1991	census 2001	census 2011
Adige e Drava	1.134	1.184	1.205	1.265	1.373

Table 4-3. Trends in the resident population within the basins that make up the Eastern Alps hydrographic district- Refrence: The Flood Risk Management Plan of Verona

Climate Change Modeling for the Eastern Alps Basin:

Main Finding

warming

5°C over the 21st century

Climate models project a significant warming of about 5°C over the 21st century for the Eastern Alps Basin.

Seasonal Shifts

decrease in average spring and summer

Increasing autumn precipitation intensity and decrease in average spring and summer runoff. This results in earlier snowmelt and reduced summer runoff.

Hydrological Changes

runoff is projected to decrease slightly.

Higher precipitation and temperatures cause an increase in average monthly winter runoff impacting snow characteristic. In other hands, total annual runoff is decreased.

Risk

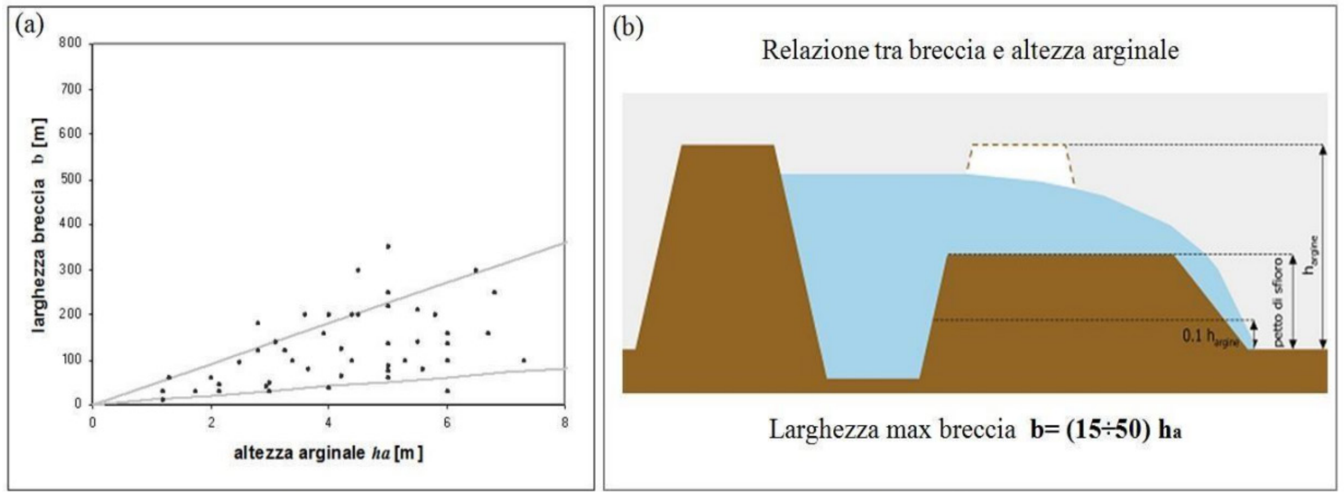
modest rise in extreme flood events

Future projections indicate a modest rise in extreme flood events by the end of the century.

The Flood Risk Management Plan

Prediction

The expected changes in climate are likely to worsen hydraulic risk in the Albania Eastern Alps district Rivers water leveled increase is projected up to at least 30 cm. Such as increase threatens also over fifteen thousand square kilometers of land being protected by thousands of km of embankments. This system of embankments, stretching for several thousand kilometers with a total volume of more than three hundred million cubic meters, is at risk of collapse under extreme floods, such as a once in a century event.



a) Breach Width vs. Embankment Height on the Countryside Side.
b) Schematic Representation of the Embankment Breach and Empirical Relationship Between Breach Width and Embankment Height Measured on the Countryside Side.

Introduction to Flood Risk Management Plan Analysis

Within the context of the Water Flood Management Plan, the classification of Hydraulic hazards is one of the best practices in flood risk analysis.

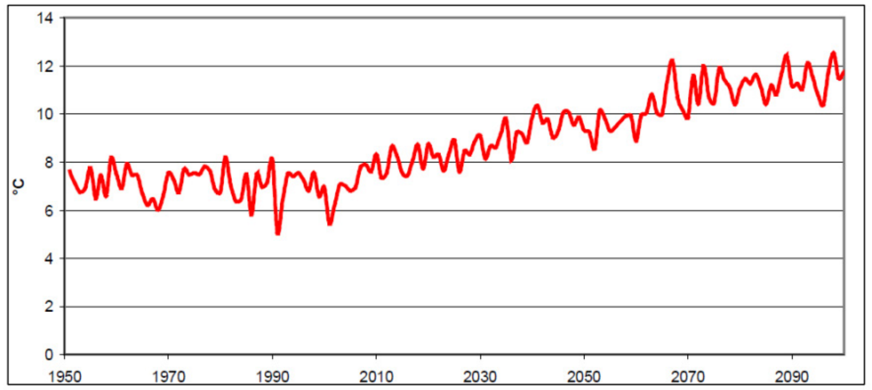


Figure 4-14. Simulation of average annual ground temperatures over the district area (IPCC A1B scenario)-Refrence: The Flood Risk Management Plan of Verona

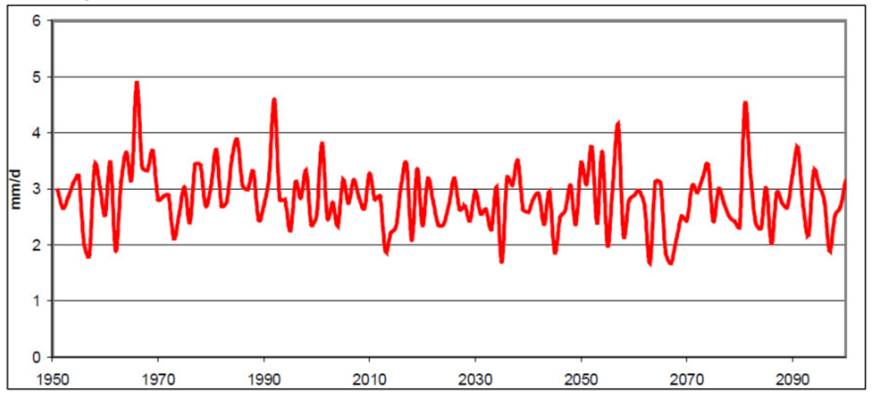


Figure 4-15. Simulation of average daily precipitation on an annual scale over the district area (IPCC A1B scenario)-Refrence: The Flood Risk Management Plan of Verona

There are Three main categoriesrelated to flood challenges that are included in this classification related to beyond river. For flood analysis in river areas, they are mapped based on the maximum natural flow based on their shape, which includes typical, natural flooding events. These areas are usually not included in risk evaluations for serious events because flooding is a natural occurrence. However, it is important to implement protective measures to improve safety against flooding and reduce the risk along riverbanks and edges.

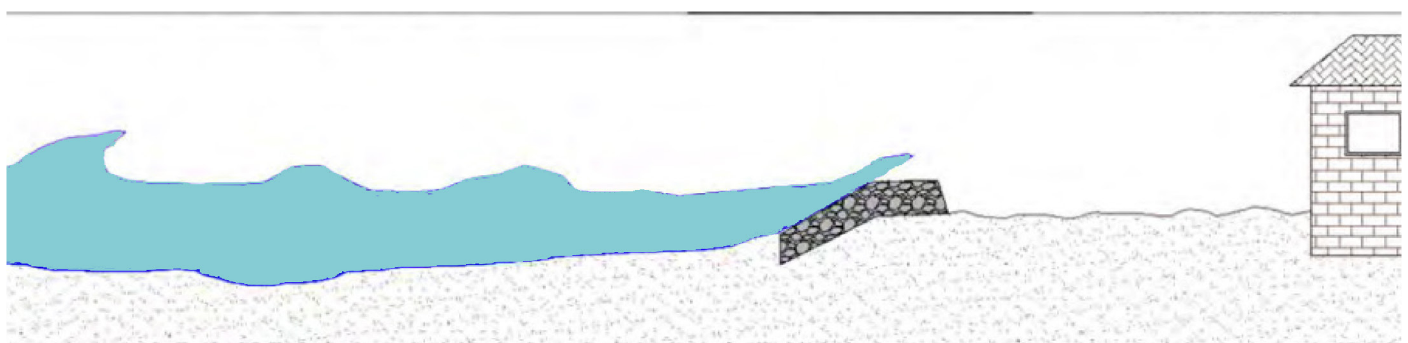


Figure 4-16. Diagram with study sequence-Refrence: The Flood Risk Management Plan of Verona

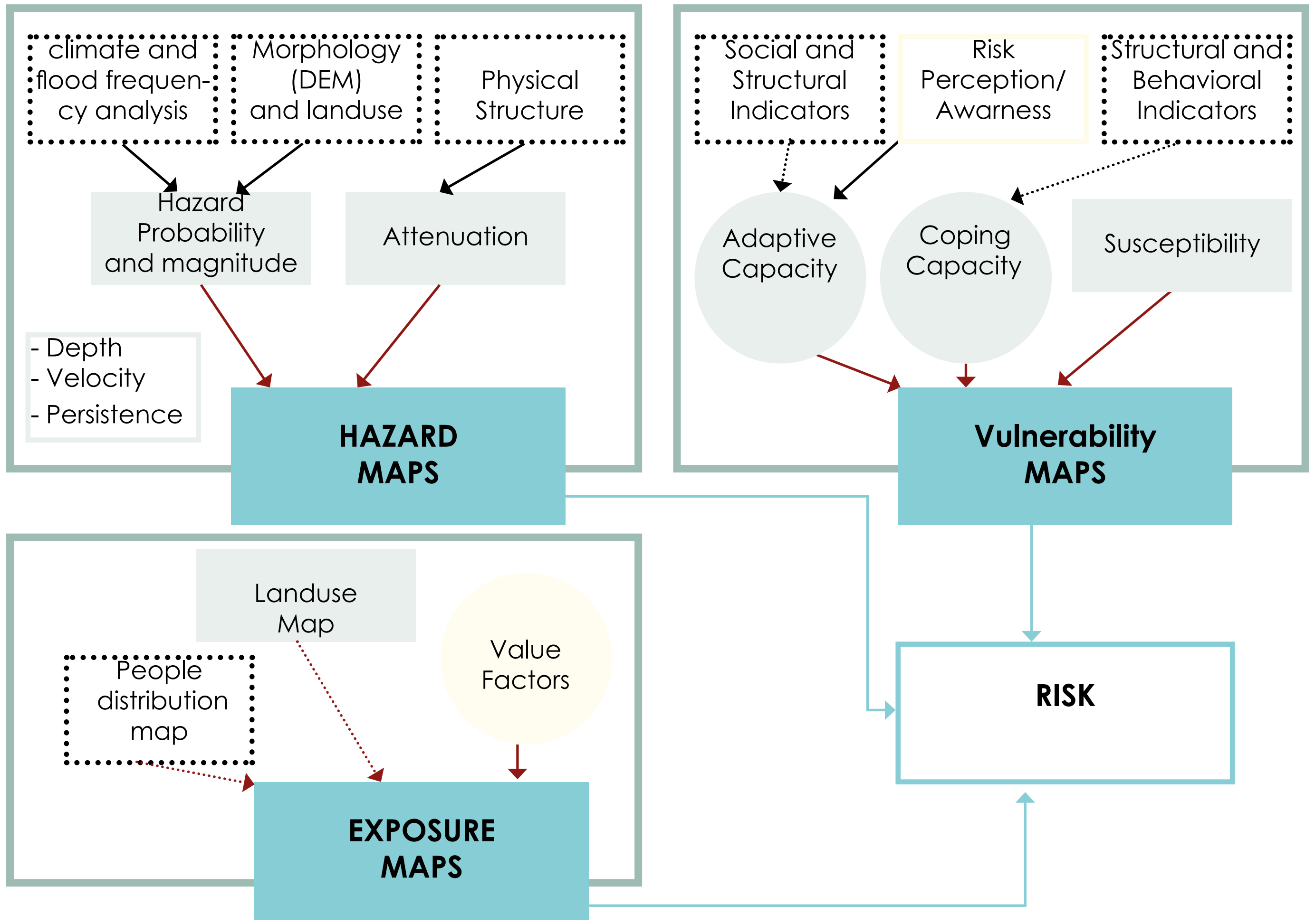
Flood Risk Analysis in Flood Management Plan

The Flood Management Plan analyzes flood risk based on hazard, vulnerability, and exposure for the Eastern Alps District, In the following, is focused on Flood risk model based on three factors.

Hazard Analysis
Historical Data: Gathering reliable historical data of previous flood events.
Hydrological Studies: Employing hydrological models to better explain rainfall and runoff processes.
Flood Mapping: Preparing flood maps indicating areas that are prone to flooding, the extent and depth for each flood in the return period of interest, 10-year specific, 50-year or 100-year floods and so on.

Exposure Analysis
Analysing Population Data, Infrastructure and Assets and Land Use that will exposure Flood risk.

Vulnerability Analysis
Building Vulnerability, Socioeconomic Factors that will vulnerable in flood event.



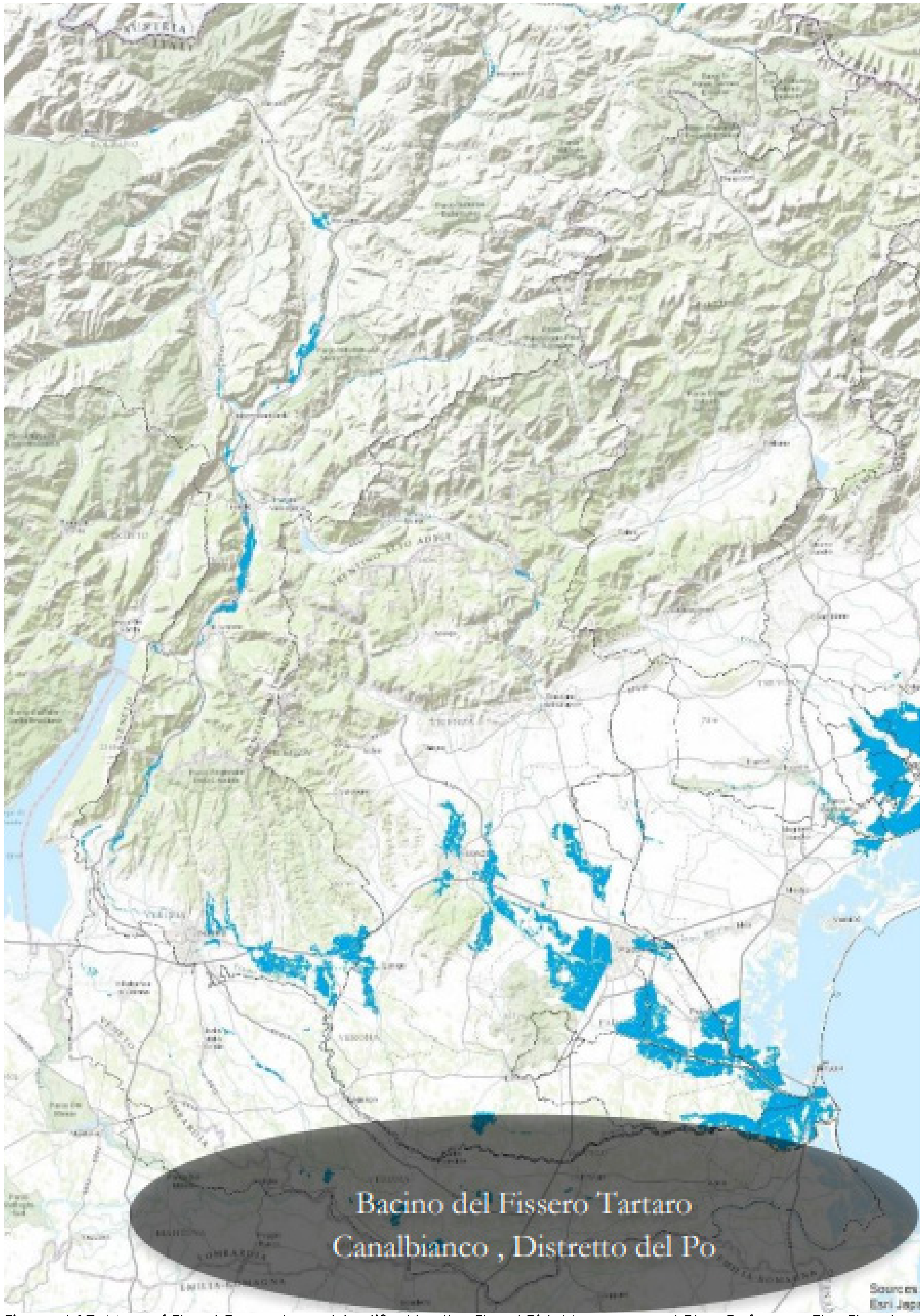


Figure 4-17. Map of Flood-Prone Areas Identified by the Flood Risk Management Plan-Refrence: The Flood Risk Management Plan of Verona

4-3-2. CLIMATE CHANGE PLANNING (Verona)

CLIMATE CHANGE PLANNING RELATION TO HYDRAULIC RISK in Verona
Veneto ADAPT Project is in the Padano-Veneta plain

Veneto ADAPT

This is a regional planning for veneto that involves creating regional adaptation standards and a multi-level governance approach. As The central Veneto Region has in risk of flood due to climate change this plan focus on these area in risk of flooding such as :Verona, Vicenza, Padua, Treviso, and Belluno. The Veneto ADAPT is answer to these challenges.

AIMS

This project focuses on hydro-geological hazards. The main aim of this project is increasing climate change adaptation. Introduce solution for reducing the impact of climate change and organize some plan such as climate action plans. This project offers NBS as the main approach to answer these challenges that cause of climate change phenomena.

In the Municipality of Vicenza, The SECAP focuses on managing hydraulic risks that in this project is introduces such solutions for increasing resilience to reduce flood risk. These solutions are improving flood barriers, and using green infrastructure .

VENETO REGION

1714 kmq
Flooding sensitive areas

1565 kmq
Urban areas Sensitive to heat Waves and Heat islands

Step 1

MAPPING

- Mapping of climate change adaptation issues.
- Mapping of the best samples as adaptation to climate change in regional scale.
- Introducing adaptation strategy at regional level.

Step 2

IMPLAMANTATION

- Planning for cities that are resilient
- Using Veneto ADAPT methodology and structure as an adaptation plan
- Using best adaptation strategy for climate change in the pilot areas.

Step 3

Monitoring of the results and impacts

- Definition of indicators for analysis Vulnerability, resilience in Veneto as a reference.
- Definition of Urban adaptation measures for development SECAPs. as a reference.

Step 4

Communication and networking

- Publishing based on managers of project
- Networking with other projects and experiences at European level.
- Publishing result of Veneto ADAPT Guidelines.
- Presenting results in national and international events.
- Making connections between other projects in Europe level.

Comune di Vicenza

In the Municipality of Vicenza, the SECAP focuses on managing hydraulic risks due to significant flooding in recent years. The city has implemented measures like reinforcing flood defenses, improving urban drainage, and installing green infrastructure to reduce flood impacts and enhance resilience. These actions serve as a model for other cities in the Veneto region, such as Verona, which could copy these strategies to manage similar hydraulic risks and improve resilience across the region.

ACTIONS

- Building a large park: making Larg park in place of Dal Molin civil airport as a green space to collect floodwater through the functions of trees.
- Decreasing flood risk by storage of water in ponds and flood field.
- Improving water collection planting trees and shrubs and forests. for this reason, 1,330 mature trees and more than 17,000 other trees and forest shrubs are being planted.
- Restoration of river natural water flow to reduce flooding by absorbing floodwater.
- Reconstruction of historical places according to attention of environmental advantages.

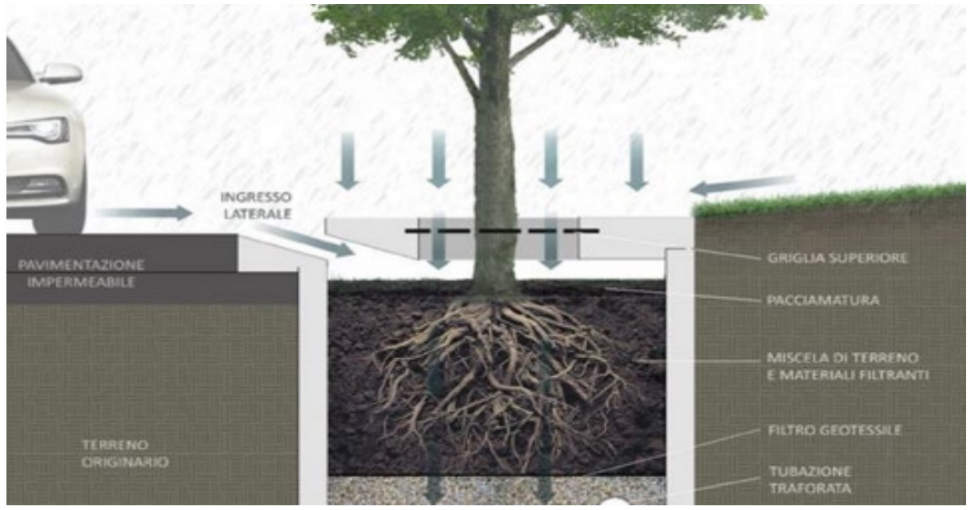
Città di Treviso

To address Hydrolic risk, the municipality of Treviso has set up territorial adaptation programs. This approach creates a multifunctional network within the city for decreasing flood water volume.

ACTIONS

- Improvement of the Hydrographic Network
- Maintenance of Canals and Ditches
- Construction of Reservoirs
- Rainwater Harvesting Measures
- The "Canale delle Convertite" has been hydraulically requalified.

Facing Hydraulic concerns through creative and multipurpose solutions, the Unione dei Comuni del Medio Brenta has defined some projects for improving environmental Sustainability and water management.



Collecting, Cleaning, and Purifying Rainwater: Setting up systems to gather, filter, and clean rainwater to improve water quality and reduce runoff. Creation of Basins:

Planting of Trees

Updating the Water Plan

Guidance for Urban Planning

4-3-1. CLIMATE CHANGE PLANNING (Verona)

CLIMATE CHANGE PLANNING RELATION TO HYDRAULIC RISK in Verona
Verona Energy and Climate Action Plan

PAESC Verona
Piano d' Azione per l' Energia Sostenibile e il Clima

The Sustainable Energy and Climate Action Plan (SECAP) for the city of Verona was approved by the City Council with resolution no. 75 of 16 December 2021 .
Its approval follows the joining to the Covenant of Mayors for Sustainable Energy and Climate , which took place in 2018, with which the Administration committed to pursuing the policy of energy saving and adaptation to the effects of climate change on its territory, to achieve a 40% reduction in CO_2 emissions into the atmosphere by 2030.

Regarding the territory of the Municipality of Verona, the following climatic hazards have been analyzed:

Extreme heat
Extreme cold
Extreme precipitation
Floods (overflowing of rivers or watercourses beyond their normal boundaries or accumulation of water on normally dry surfaces)
Drought (an unusually long period of dry weather causing severe hydrological imbalance)
Storms (atmospheric disturbances with strong winds and rain, snow, or other precipitation accompanied by thunder and lightning)
Landslides (downward movement of material such as soil, rock, or debris)
Wildfires
Biological hazards (vector-borne insects)

Figure 4-18. The Adige basin-Refrence: Verona Energy and Climate Action Plan

4-3-1. CLIMATE CHANGE PLANNING (Verona)

CLIMATE CHANGE PLANNING RELATED TO ECOLOGY in Verona

Verona, despite its recognition as a green city and being the first biophilic city in the world from Italy, currently lacks a specific urban planning framework that effectively incorporates nature-based solutions to address the challenges cause by natural climate change vulnerabilities. Italy has made progress in promoting NBS to improve urban resilience as part of a larger European landscape that is becoming more and more focused on sustainability. Verona hasn't yet developed a coherent strategy that include these fixes into its urban planning techniques. Nevertheless, In an effort to improve urban sustainability, Verona has placed a greater emphasis on natural planning projects in recent years. Nature-based solutions are aims to be included into urban development through the implementation of the new Territorial Planning Scheme (PAT). The èVRgreen project also encourages green infrastructure to lessen the ecological impact of the city èVRgreen project to map the city ecosystem's health.

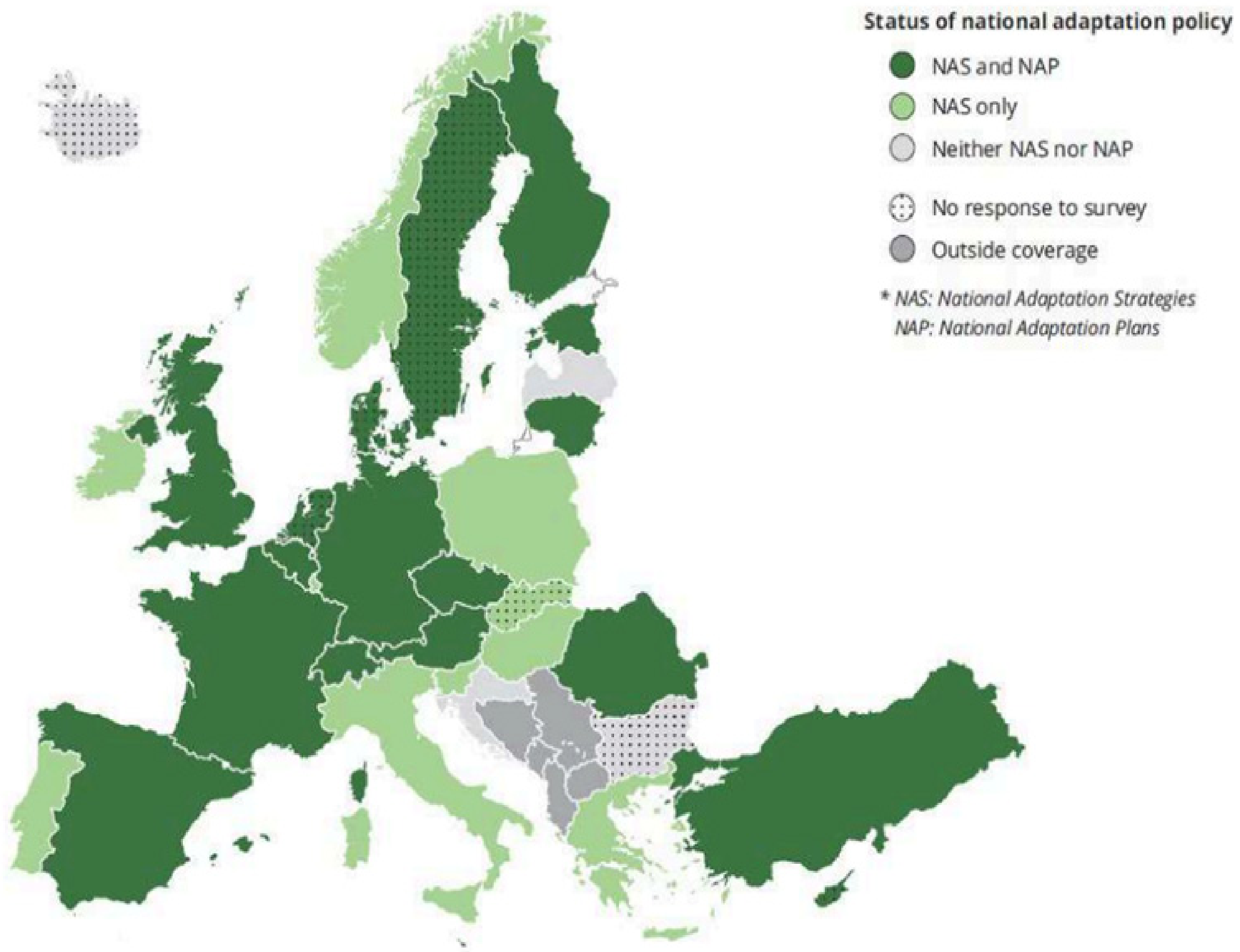


Figure 4-19. State of National Adaptation Policies in Europe- Source "Natural Climate Change Vulnerability and Risk Assessment in Europe" (2018)

2023

èVRgreen project

èVRgreen project to map the health of the city ecosystem

The University of Verona, the Municipality of Verona, and the University of Padua collaborate on the èVRgreen project, which is supported by Fondazione Cariverona and supported by the University of Verona. The project's goal is to map a number of indicators that will show important environmental challenges and give a quick overview of the city's ecosystem. For the administration to carry out successful plans and initiatives, this mapping is an essential tool. In order to provide a healthier urban environment for present and future generations, it focuses on locating new public and private spaces for green space creation, especially in areas most impacted by the heat island effect and poor air quality.

2024

Territorial Planning Scheme (PAT)

With an emphasis on the creation of green areas, water management, soil health, and community improvement, Verona is becoming a greener city. The development of a Renewed network of green and blue infrastructures is part of the city's strategic vision, which is in line with the Nature Restoration Law, new European legislation, the Nature-positive Cities initiative, and the sustainability objectives of the UN.
The current Territorial Planning Scheme (PAT) highlights the deficiency of green spaces, especially large urban parks, as a major concern. About 8% of people do not have access to green places within 15 minutes of walking, 26% within 5 minutes, and 43% within 10 minutes.. This issue is especially prevalent in the southern areas, the industrial zone in the west, and various residential neighborhoods.
To address these challenges, increasing tree cover is essential for improving air quality and mitigating the effects of climate change by creating cooling islands.

Main aim of Verona and the new PAT is transfering to a ecological model for cities that consider nature as avital element and infrastructure. this plan is for future over the next 10-15 years ahead of verona and consider farawework of: ecological-environmental, historical-cultural, and infrastructural. The ecological-environmental framework emphasize on green and blue infrastructre for planning for new Verona.

4-4.FLOOD RISK ANALYSIS OF ADIGE RIVER IN VERONA

Flood Risk Analysis in Flood Management Plan

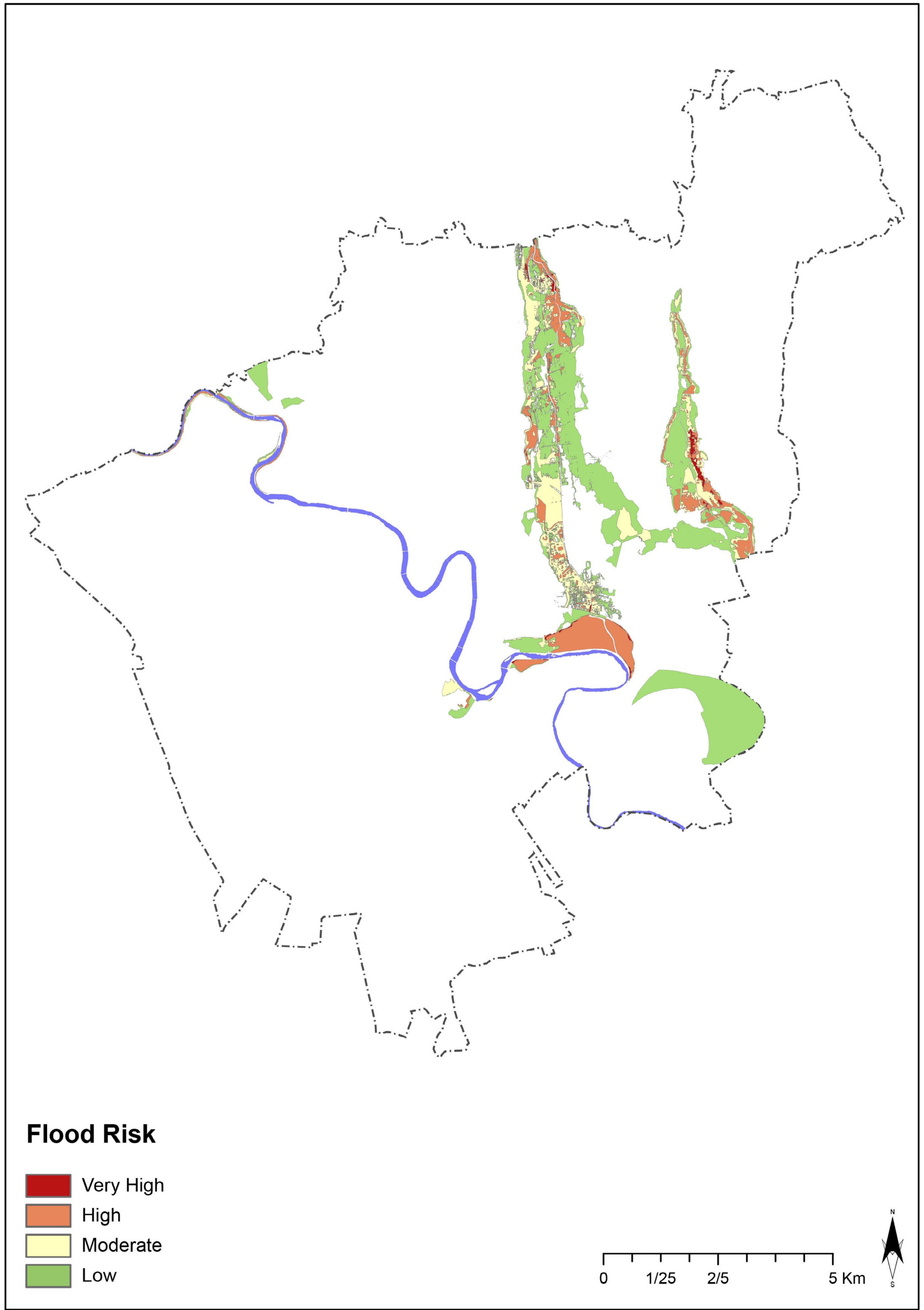
As mentioned earlier in this research, Verona is a historic city surrounded by the Adige River. Therefore, it is essential to analyze flood risk and identify high-risk areas within the city. Although Verona is not listed as a high-risk area on the regional scale, the city's proximity to the river and the historical significance of many structures and neighborhoods raise serious concerns.

This section focuses on analyzing flood risk in the Adige River based on the technical information provided in the Flood Management Plan for Verona. The key factors considered are hazards and vulnerable areas that contribute to flood risk. While the Flood Management Plan analyzes flood risk at a regional scale.

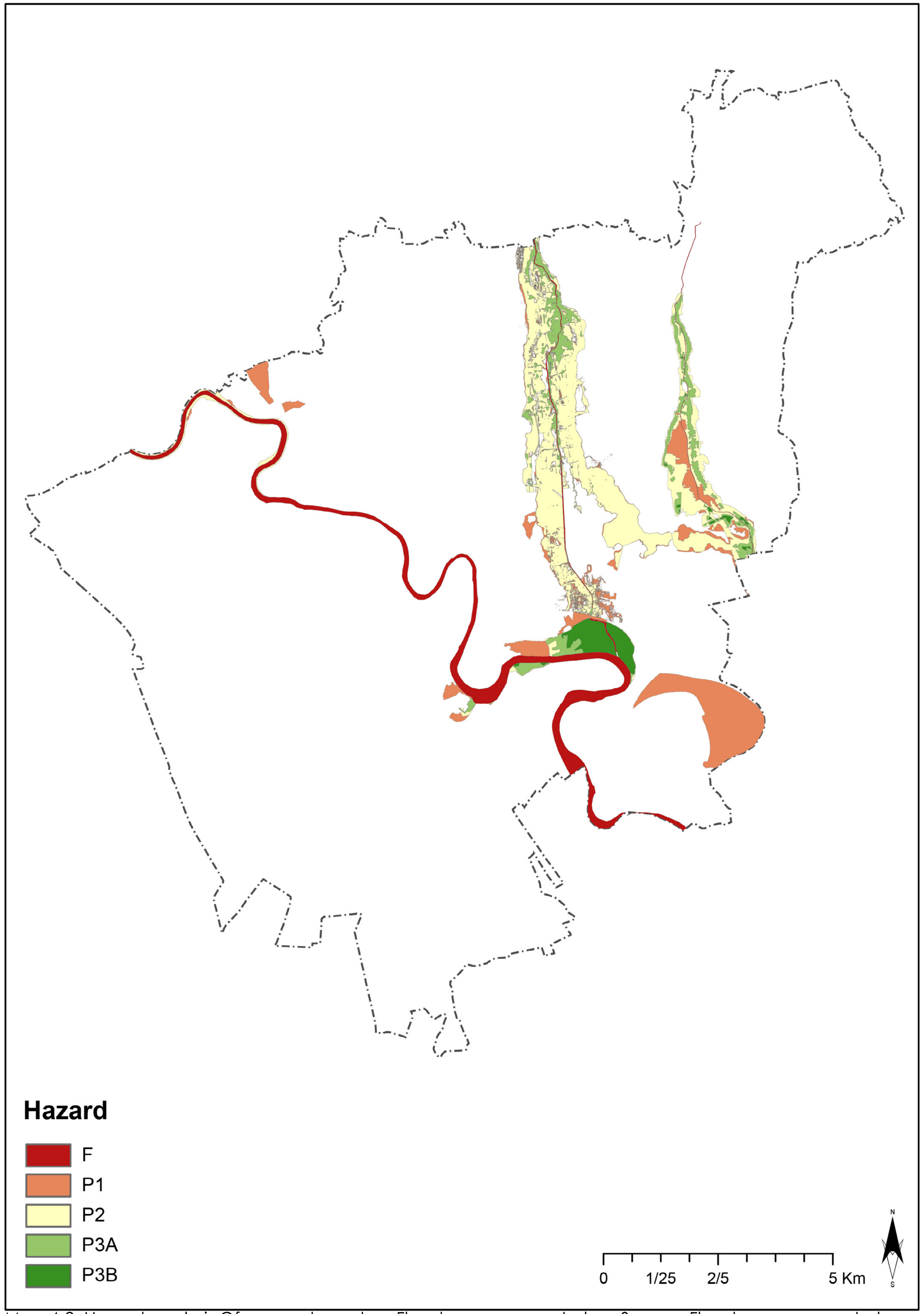
Additionally, it is important to note that this plan operates on a larger scale, considering the entire Alpine region and considering multiple cities and regions together. This more general viewpoint might ignore certain weaknesses that are essential to Verona's urban setting. Determining extra criteria that address the particular vulnerabilities associated with urban development is therefore crucial. We can perform a more comprehensive analysis that more precisely captures Verona's unique features and better provides the city for any obstacles related to its interaction with refining these criteria.

Hazard Analysis in Flood Management Plan

The Hazard Analysis for Verona comes from Verona Flood Risk Management Plan. This analysis is based on historical data of previous floods.(such as 10-year, 50-year, and 100-year floods). Additionally, the bahavious of the Adige river has been modeled for Fluvial flooding in different senarios. Based on these efferts, a comprehensive map has been created to show areas that are at risk of flooding in Verona.



Map 4-1. Flood Risk analysis Of verona based on Flood management plan -Source. Flood management plan

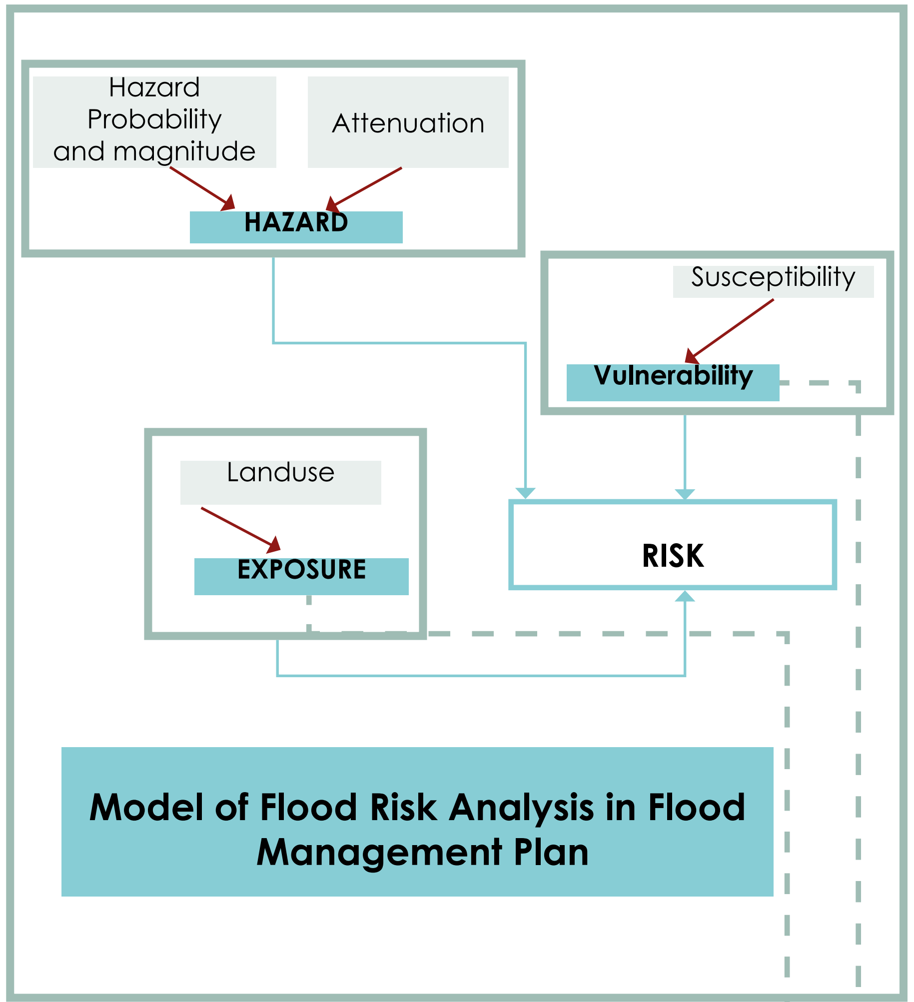


Map 4-2. Hazard analysis Of verona based on Flood management plan -Source. Flood management plan

Weaknesses of Flood management in scale of city (Verona):

Lack of Urban scale Indicators:

The primary weakness is that the focus is on a regional scale, ignoring urban-scale criteria that affect the city management plan in Verona. For a more accurate analysis at the urban level, additional indicators related to vulnerability in Verona are necessary. These criteria should consider the specific situation of Verona, particularly the location of the Adige River in close relationship with historical core of the city.



Modeling Flood Risk in Verona: A Comprehensive Framework for Evaluating Vulnerability and Exposure

Criterias for Flood Risk Analysis in Verona

Criteria	
Closeness to the Adige River Closeness to Infrastructure	**EXPOSURE**
Important Historical sites Permeable and Impermeable Areas Building Density Green Spaces Elevation and Slope Accessing to Emergency Services.	**VULNERABILITY**

Vulnerability = sensitivity − adaptive capacity

Vx = (Sensitivity − Adaptive Capacity) × Hy (2)

Vx: Vulnerability to Impact,

Hy: Hazard Scenario

Risk = Hazard × Vulnerability × Exposure

(Maragno, 2021)

Methodology: Hierarchical Multi-criteria Analysis (HMA)

Step 1 Defining the Objective

Assess the overall urban vulnerability and exposureto floods

Step 2 Identifying Criteria

Proximity to the Adige River
Infrastructure Proximity.

Historical Significance
Permeable/Impermeable Areas
Building Density
Green Spaces
Elevation and Slope
Access to Emergency Services.

Step 3 Hierarchical Structure

Social-Cultural Factors

Valuable historical monuments from the perspective of tourists and residents

Physical Factors

Proximity to Riverbank
Building Density
Infrastructure Proximity

Environmental Factors

Permeable/Impermeable Areas
Green Spaces
Elevation and Slope

Step 4 Assigning Weights to Criteria

To determine the weights for each criterion in assessing flood vulnerability, we employed a pairwise comparison method based on Saaty's 9-point scale. This systematic approach involved evaluating each criterion against others to ascertain their relative importance. The process unfolded as follows:

Pairwise Comparisons Expert Judgment Matrix Construction
Weight Calculation Normalization

Proximity to the Adige River 0.30
Historical Significance 0.25
Permeable/Impermeable Areas 0.15
Green Spaces 0.15
Building Density 0.10
Infrastructure Proximity 0.03
Elevation and Slope 0.01
Access to Emergency Services 0.01

Step 5 Data collection

Step 6 Drawing map of flood

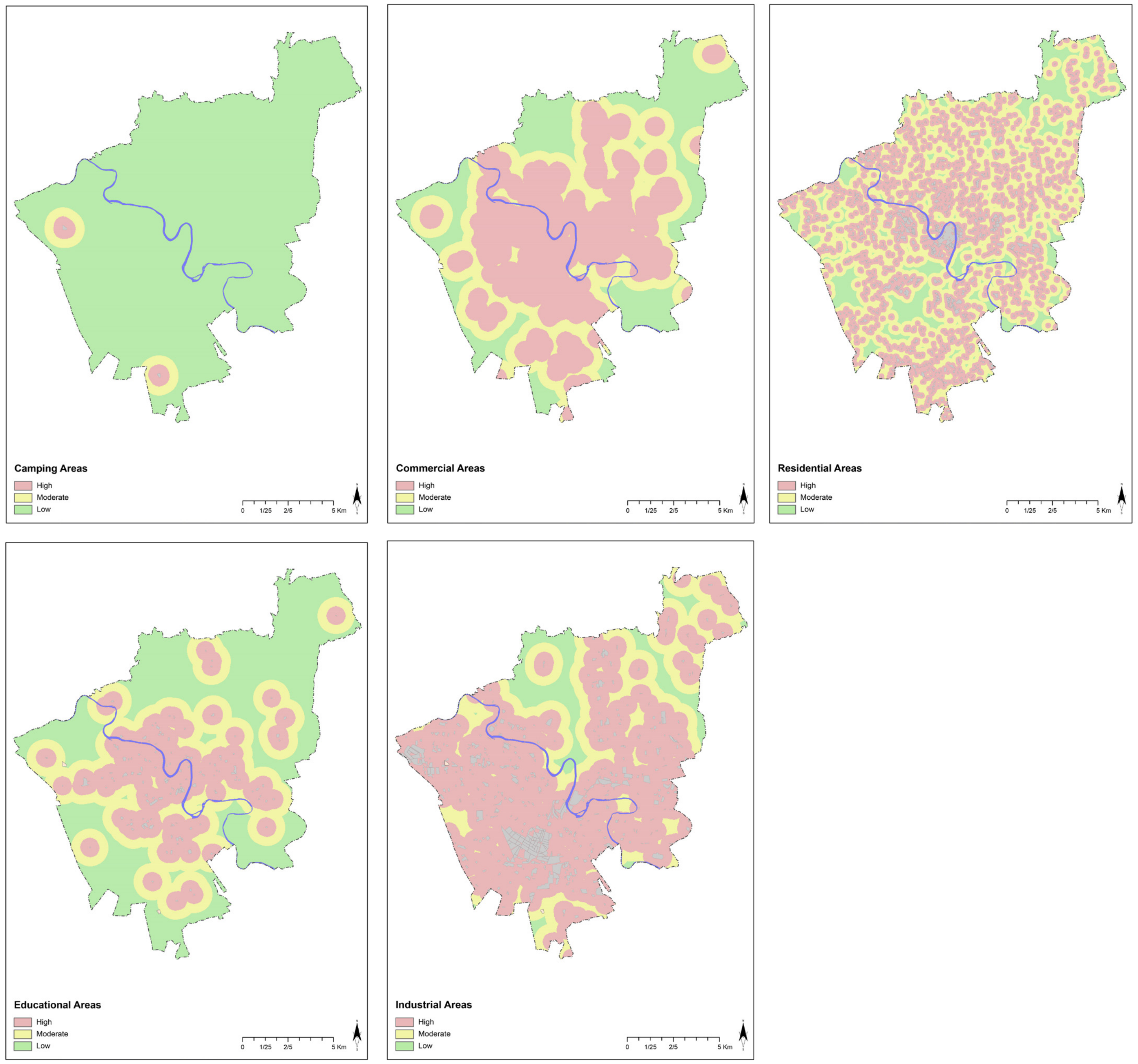
After extractions the scores of criteria based on HMA method, in the next step by Usign Qgis as an analysis tool to make maps of vulnerability for flood. This document is as a visual documents for planner and stakeholder. Helping them to identify high flood risk area and bring solution to solve these issues.

Justification of Criteria: (Exposure analysis)

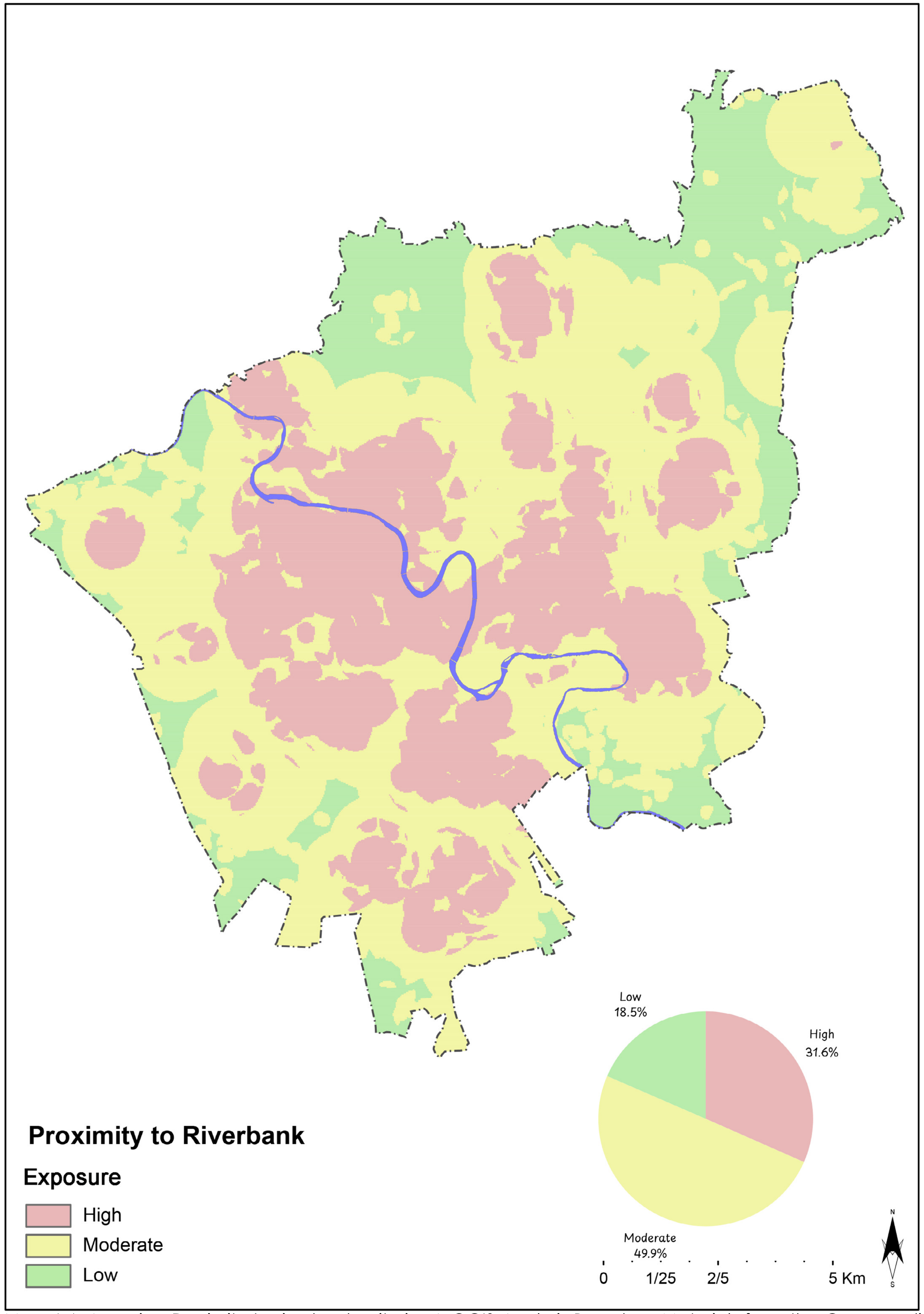
Proximity to Riverbank: This criterion is essential in assessing flood vulnerability, particularly for areas near to the Adige River. Land uses such as commercial and industrial sites, schools, tourist camping facilities, and residential neighborhoods are particularly vulnerable. These areas often have significant populations and assets, making them susceptible to flooding. The literature indicates that closeness to water bodies increases the risk of flood, thus justifying its high weighting.

Criteria 1: Proximity of Urban Areas to the Riverbank

•Subcriteria: Residential, Commercial, Industrial, Hospital, School, Camping area



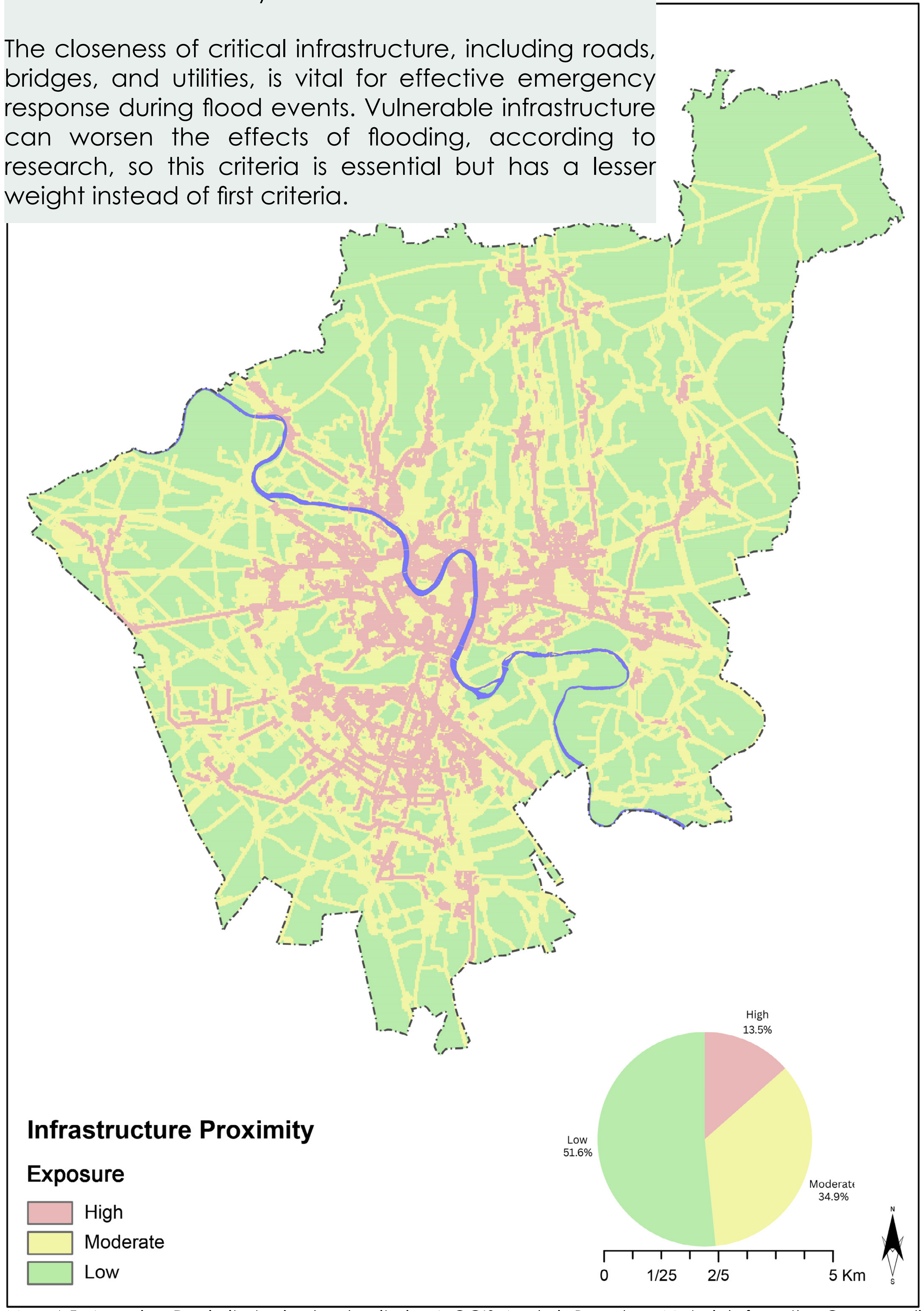
Map 4-3. Assessing Vulnerable Land Use Near Riverbanks: A QGIS Analysis Based on Materials from the Comune di Verona



Map 4-4. Assessing Proximity to riverbank criteria: A QGIS Analysis Based on Materials from the Comune di Verona

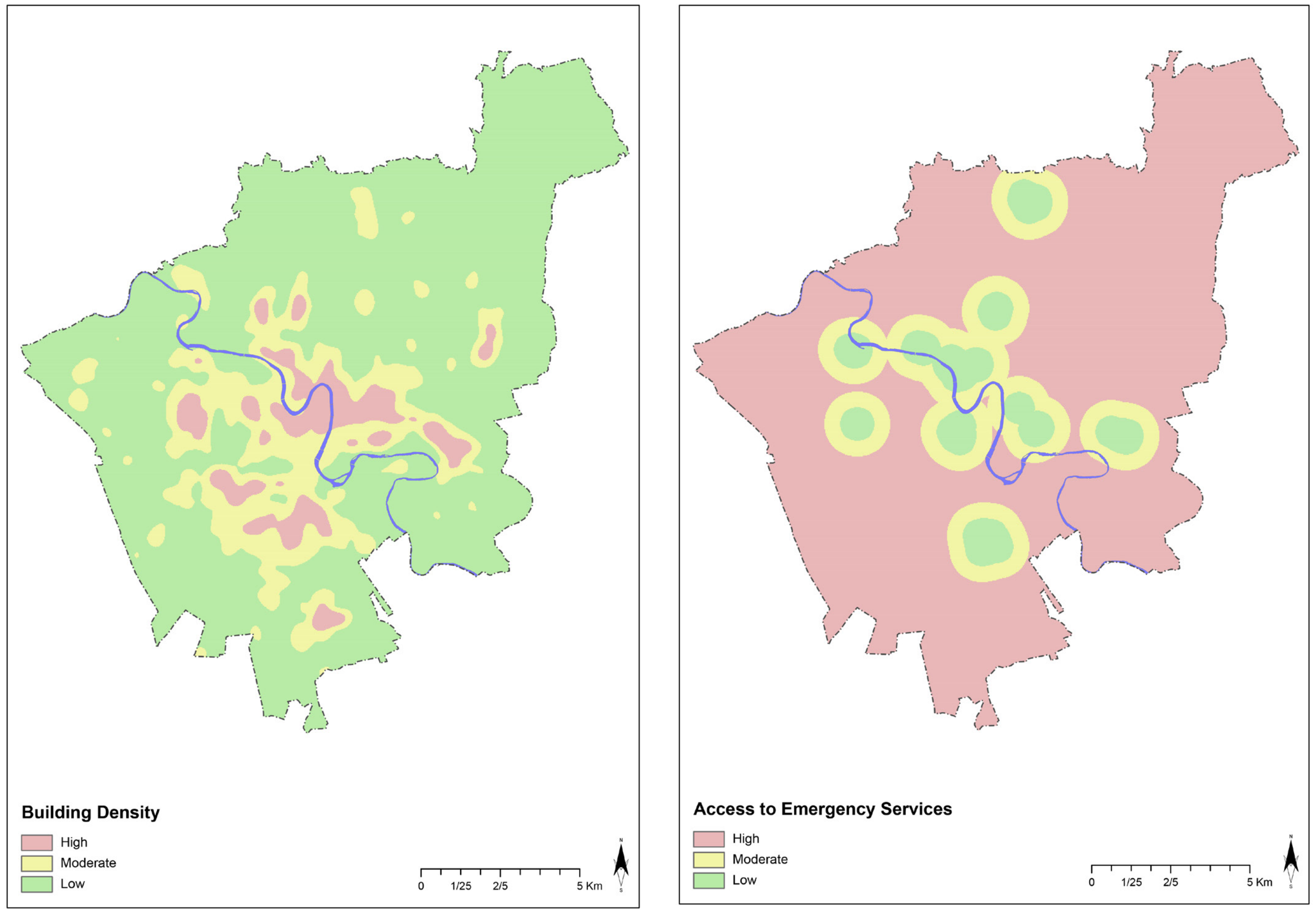
Infrastructure Proximity:

The closeness of critical infrastructure, including roads, bridges, and utilities, is vital for effective emergency response during flood events. Vulnerable infrastructure can worsen the effects of flooding, according to research, so this criteria is essential but has a lesser weight instead of first criteria.



Map 4-5. Assessing Proximity to riverbank criteria: A QGIS Analysis Based on Materials from the Comune di Verona

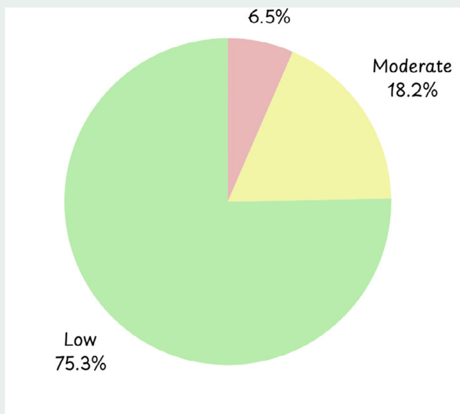
Justification of Criteria: (Vulnerability analysis)



Map 4-6 &4-7. Building density and access to emergesncy services criterias: A QGIS Analysis Based on Materials from the Comune di Verona

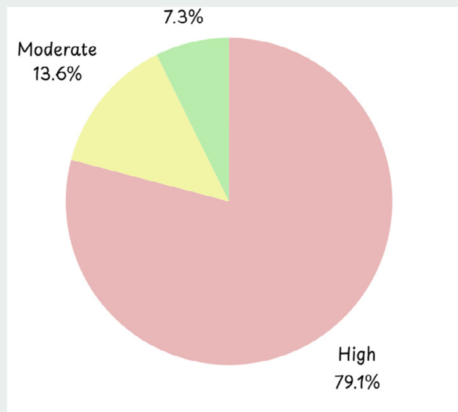
Building Density:

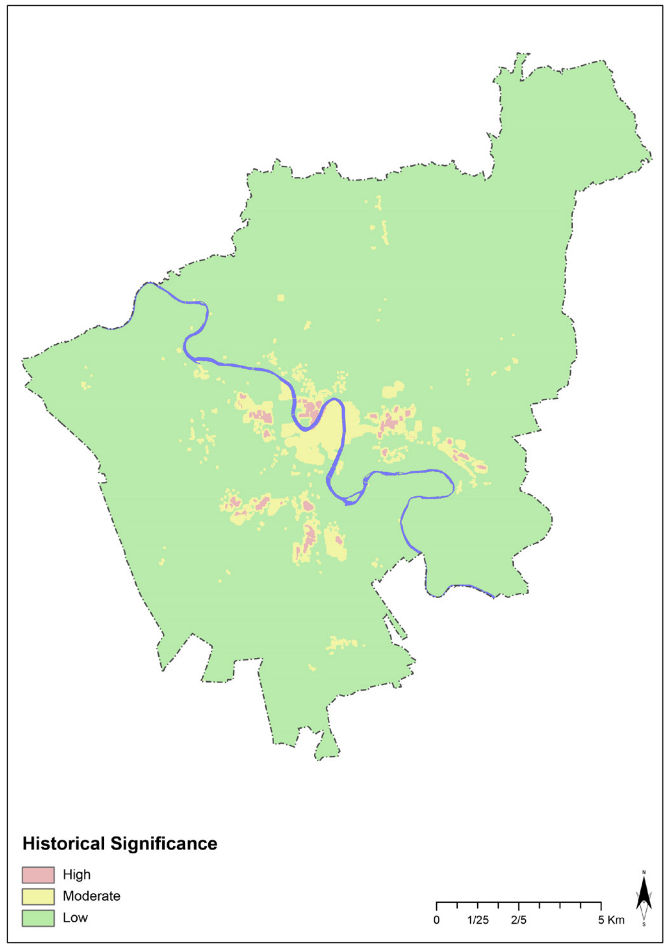
From side of Vulnerability during a flood, higher building density exposures more population and property at the risk of flooding. In these areas, some problem occurs during flood time such as: difficulty to access emergency services and evacuation of building and area. So for Vulnerability analysis this factors is important.

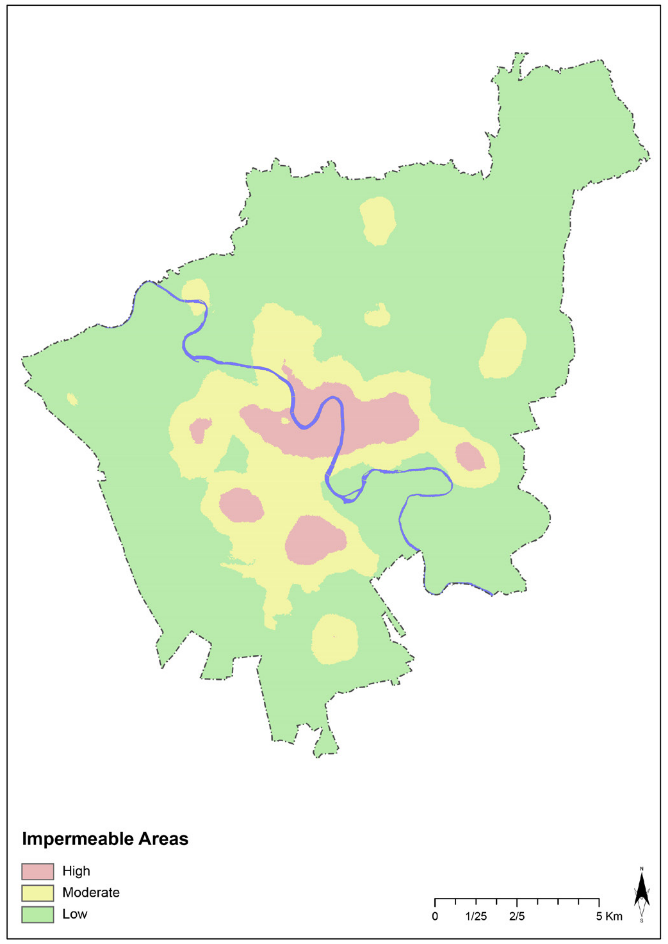


Access to Emergency Services in an emergency Situation:

Another important criteria that is important to analysis vulnerability for places that more vulnerable in face of flood risk is accessing to emergency services. This criteria shows difficulty to access to emergency services in emergency situations. This criteria shows problem to access help in danger.



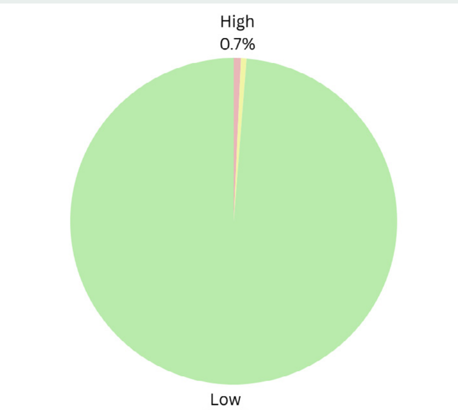




Map 4-8 &4-9. Historical Significance and Permeable and impermeable criterias: A QGIS Analysis Based on Materials from the Comune di Verona

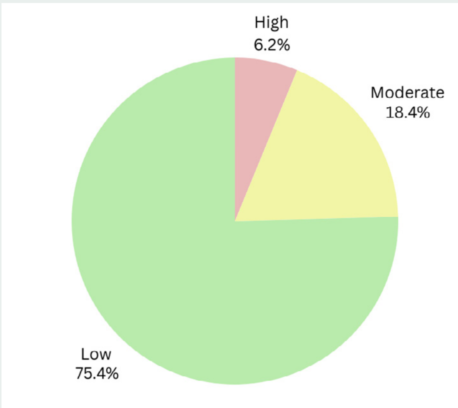
Historical Significance:

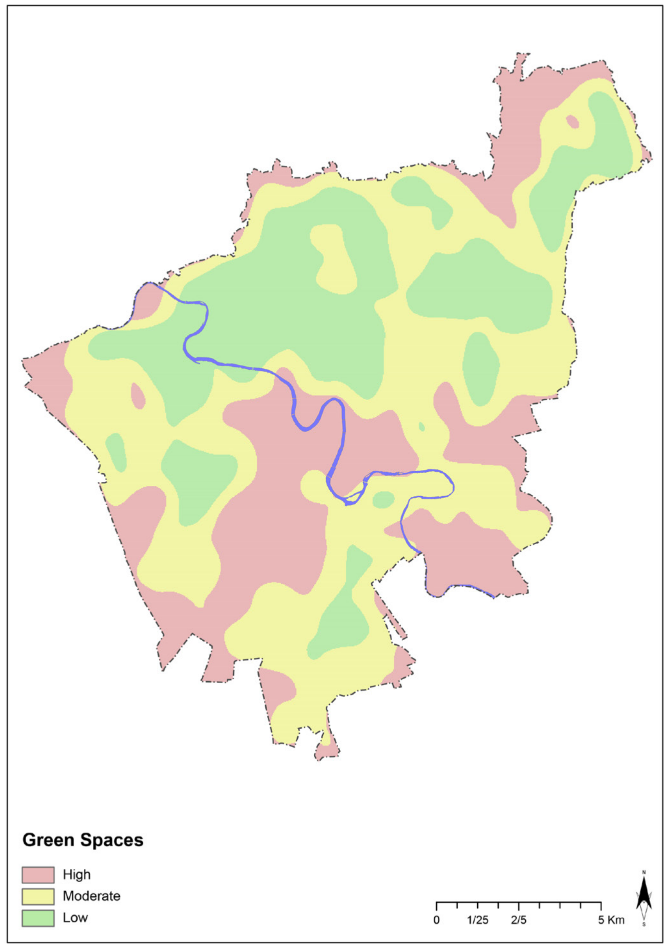
Since Verona is a historic city with numerous buildings of historical significance, it is essential to protect them from natural challenges such as floods. Maintaining these structures is vital for cultural and economic stability, especially in the tourism industry. They are highly vulnerable to flooding risks.

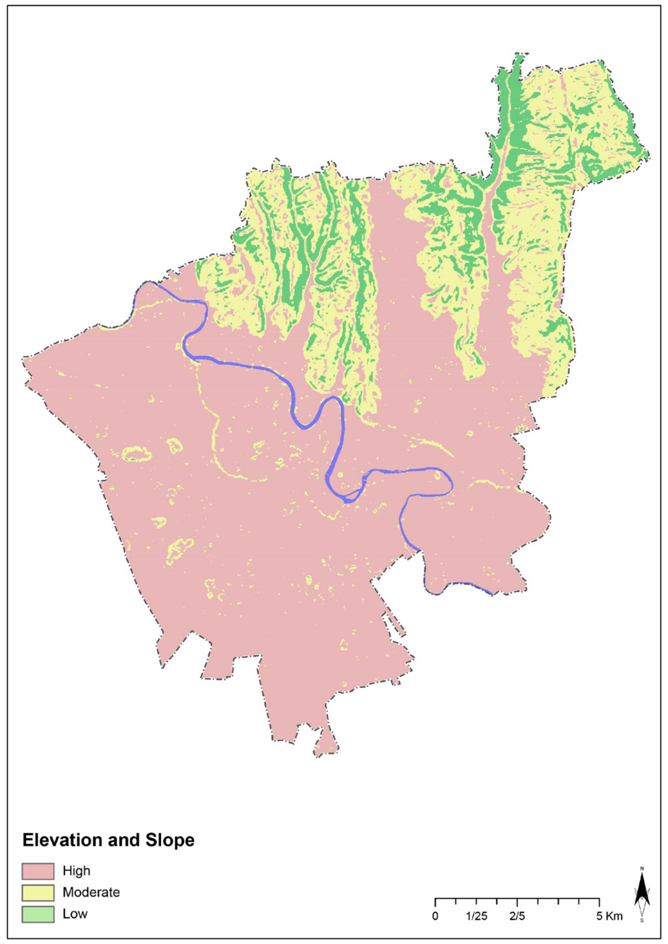


Permeable/Impermeable Areas:

This criteria related to paved areas that are recognized as impermeable surfaces that increase runoff can bring a higher risk of flooding. The importance of criteria is based on hydraulic response to flood risk.



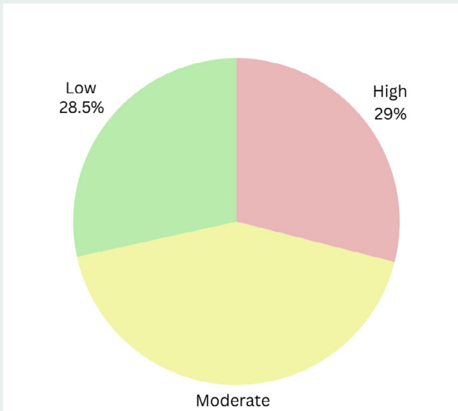




Map 410 &4-11. Historical Significance and Permeable and impermeable criterias: A QGIS Analysis Based on Materials from the Comune di Verona

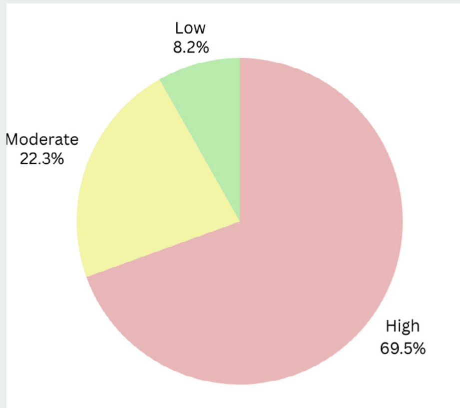
Green Spaces:

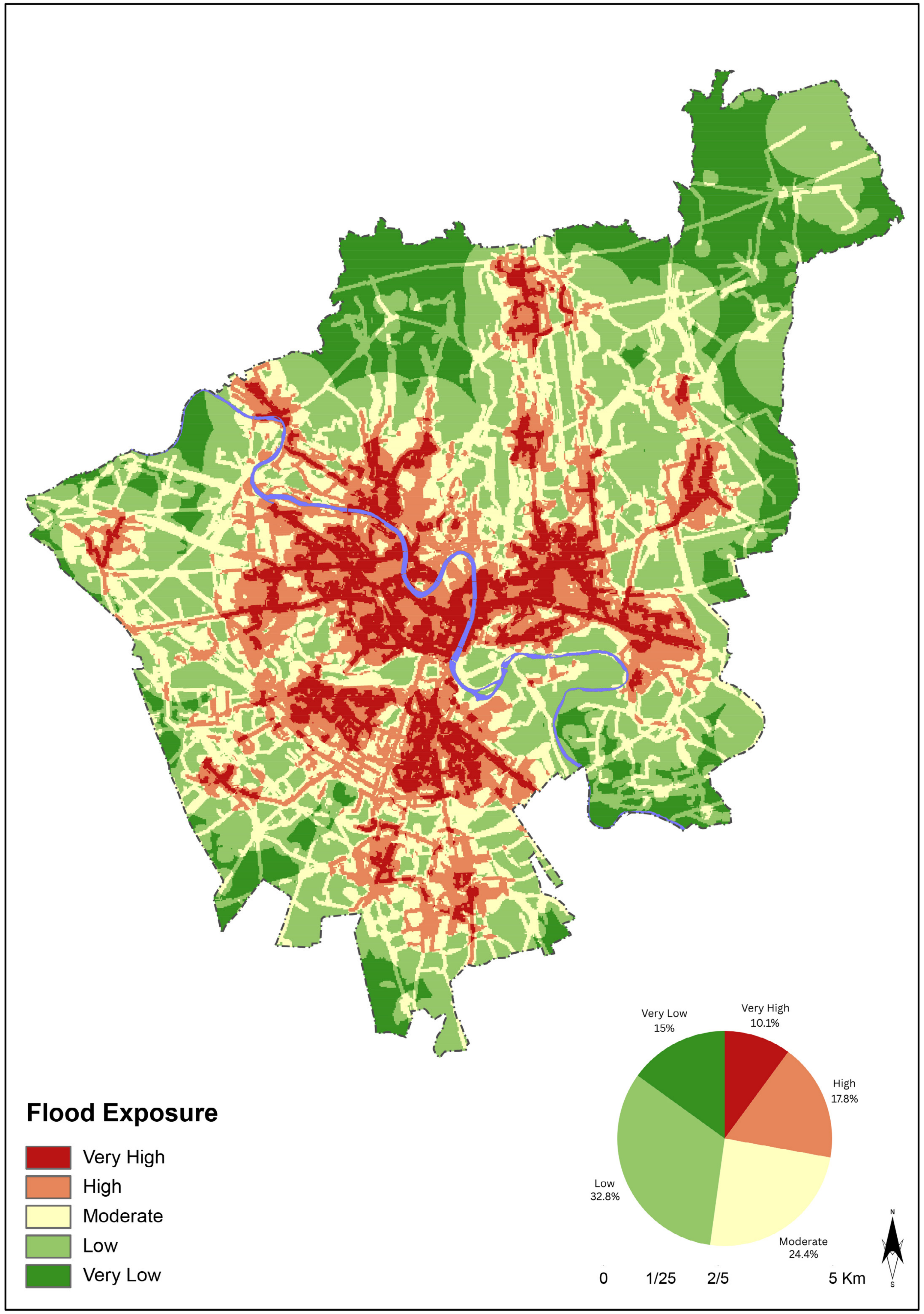
Green spaces can mitigate flood risks because vegetation causing store water and decreases the speed of moving water so have lower vulnerability levels.



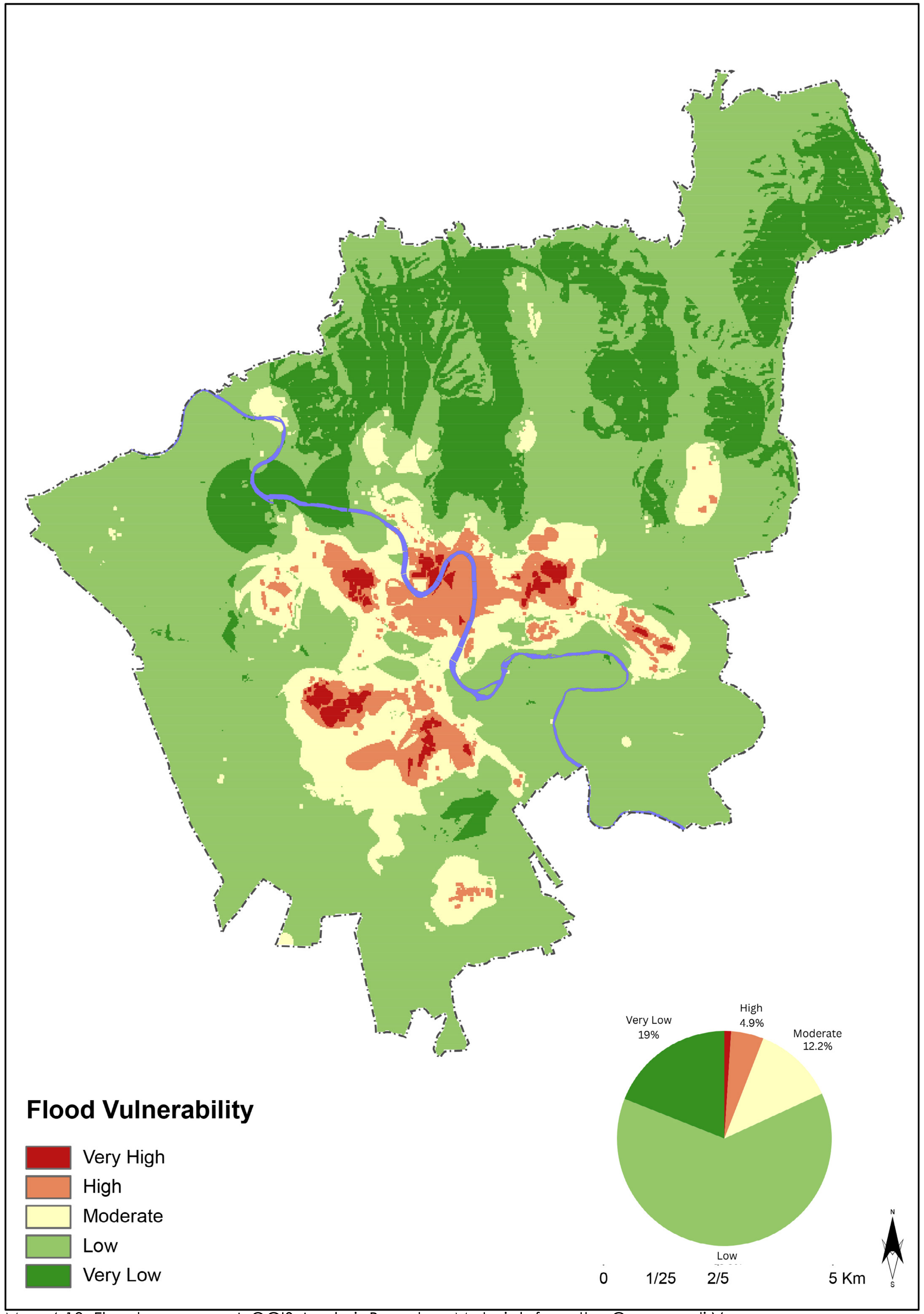
Elevation and Slope:

Elevation and slop help to control of runoff, Meaning that lower elevations is in higher risk.

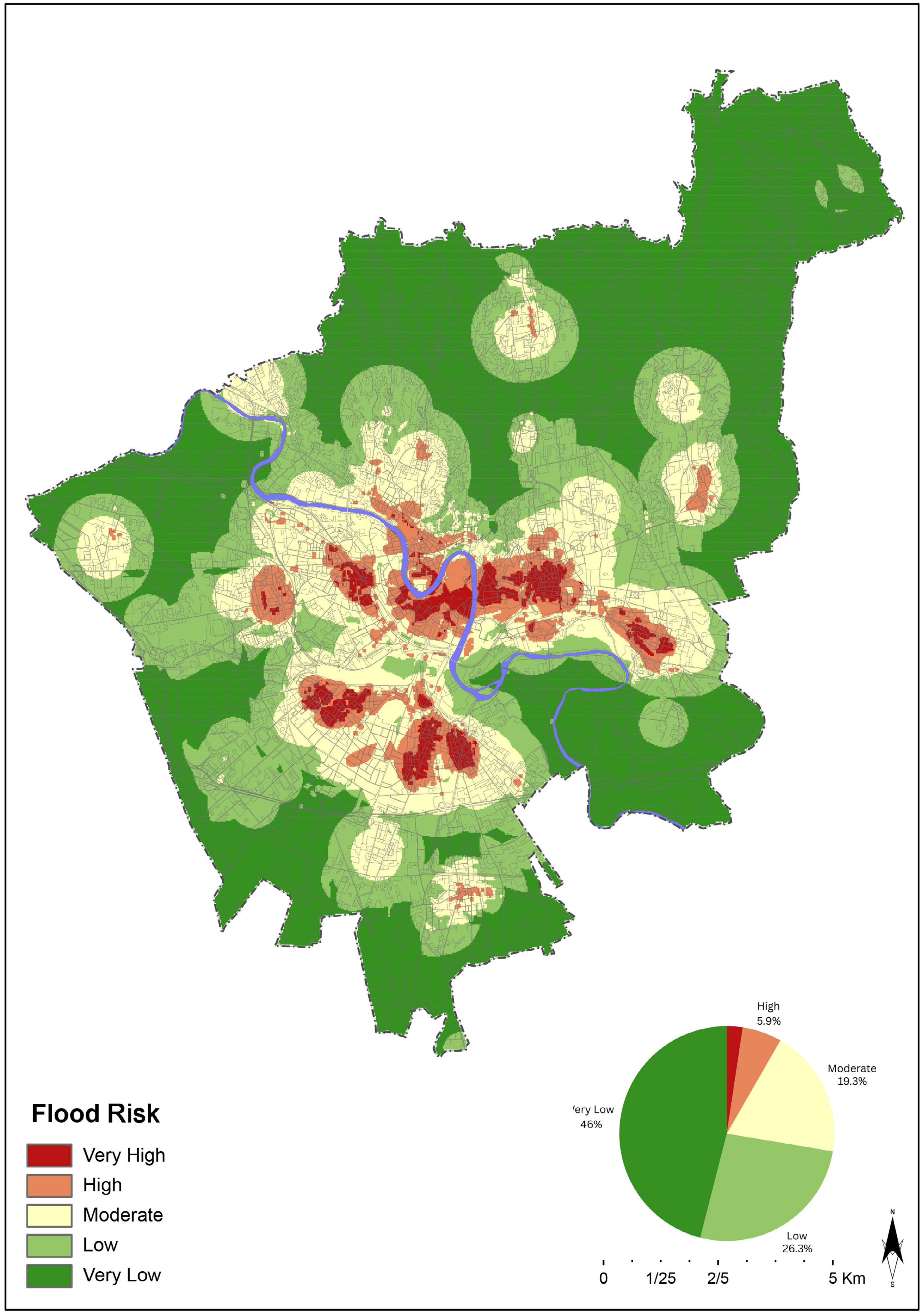




Map 4-12. Flood exposure: A QGIS Analysis Based on Materials from the Comune di Verona



Map 4-13. Flood exposure: A QGIS Analysis Based on Materials from the Comune di Verona



Map 4-14. Flood risk analysis: A QGIS Analysis Based on Materials from the Comune di Verona

Map 4-15. Landuse: A QGIS Analysis Based on Materials from the Comune di Verona

Land Use

Transport and Infrastructure
- Civil Airports for Sports and Recreation
- Parking Areas
- Public, Military, and Private Services (Not Transport-related)
- Large Cargo Handling and Sorting Facilities

Commercial and Industrial Areas
- Commercial Activities and Related Spaces
- Industrial Activities and Related Spaces
- Active Extraction Areas
- Inactive Extraction Areas
- Agricultural-Industrial Complexes

Natural Environments
- Wet River Environments
- Bushland
- Sparse Vegetation Areas
- Forests of Broadleaf Trees
- Fruit Gardens

Urban Areas
- Mixed-Use City Center with Very Dense Urban Fabric
- Residential Complexes Including Green Areas

Recreational Areas
- Sports Areas (Football, Athletics, Tennis, etc.)
- Camps and Tourist Facilities like Bungalows

Waste Management and Unused Areas
- Abandoned Areas
- Deposits of Waste in the Open and Car Cemeteries
- Landfills and Deposits from Mines,

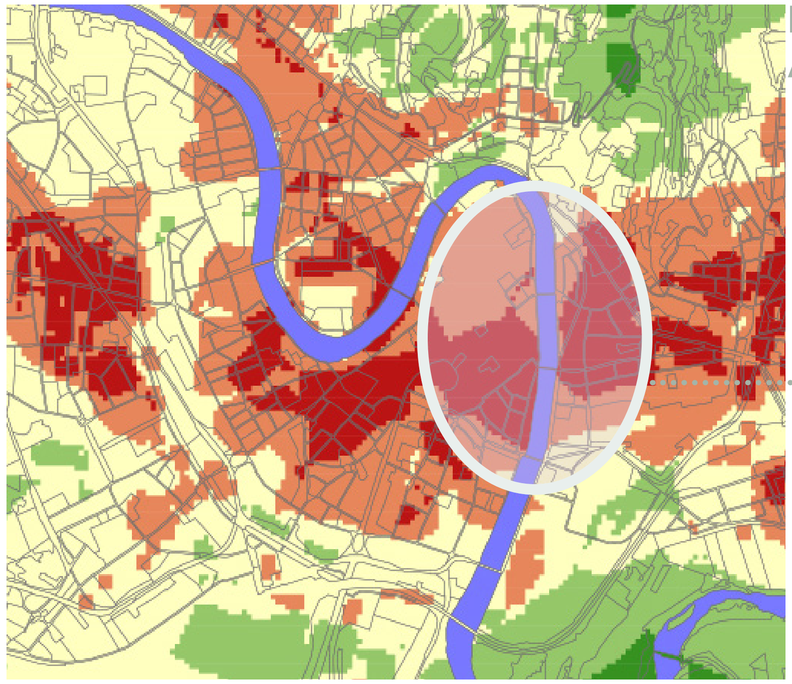
Water Bodies and Wetlands
- Rivers, Streams, and Ditches
- Canals and Waterways
- Water Bodies with Mainly Non-Production Uses

Transformation and Construction Areas
- Transformation Areas
- Construction and Excavation Sites

Environmental Protection Areas
- Green Areas Associated with Transport Infrastructure
- Private Green Areas

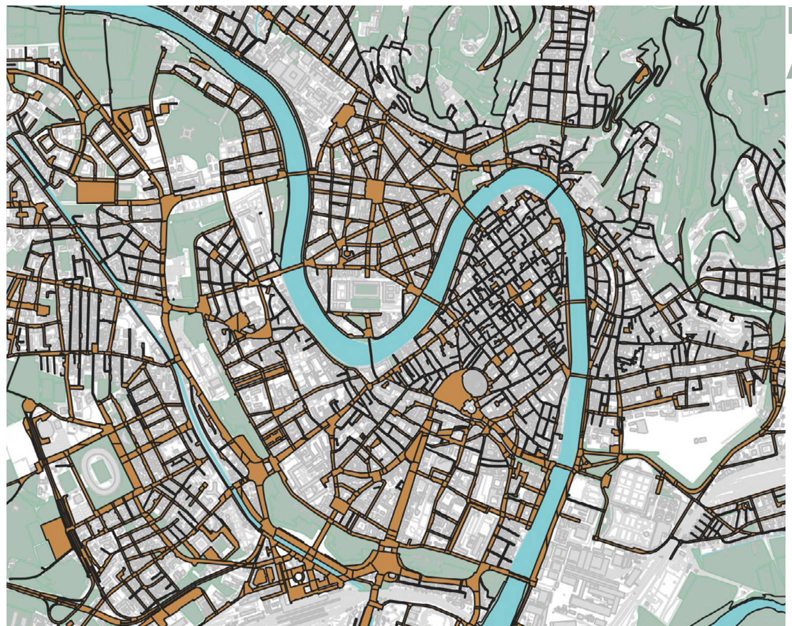
Cemeteries
- Non-Vegetated Cemeteries
- Vegetated Cemeteries

Technological Infrastructure
- Water Supply Infrastructure, Coastal and River Defenses, Breakwaters, Dams
- Technological Infrastructure for Public Utilities: Waste Disposal, Incinerators, and Water Treatment Plants



FLOOD RISK
Alongside of the Adige river

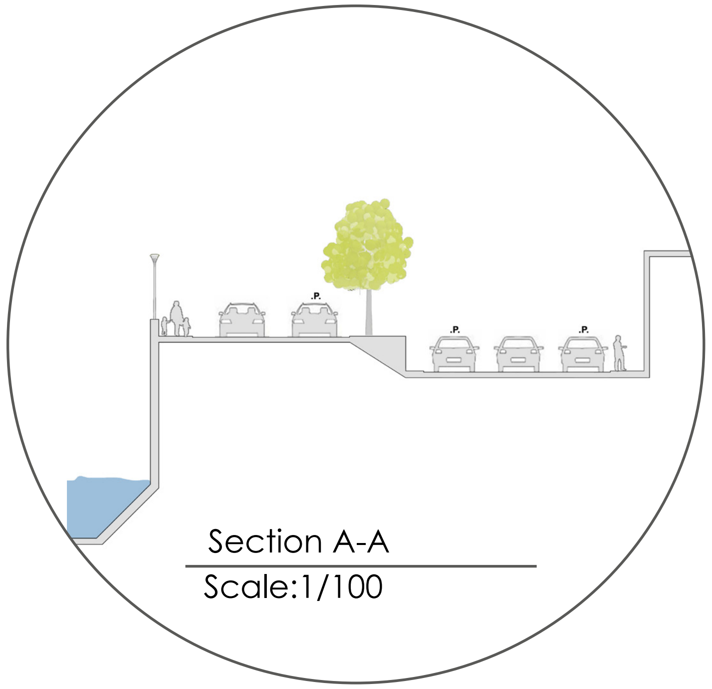
LAND USE
Alongside of the Adige river

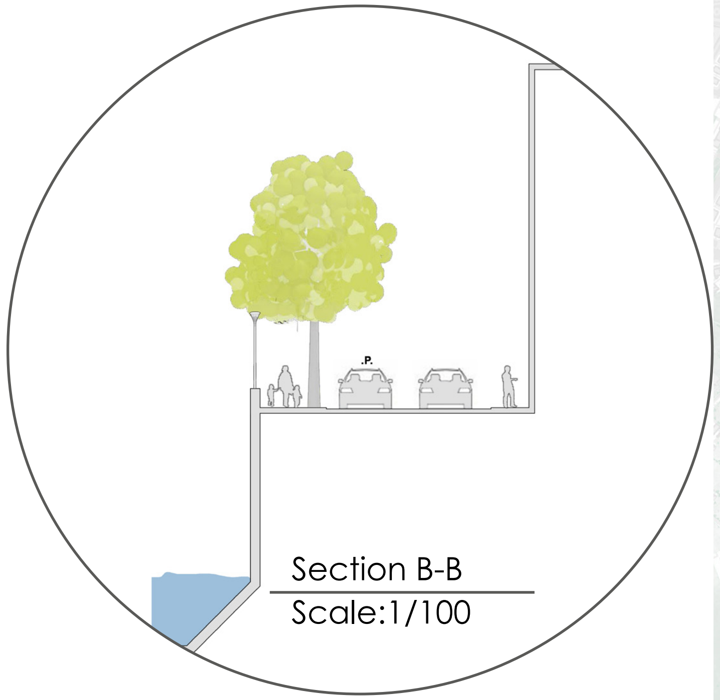


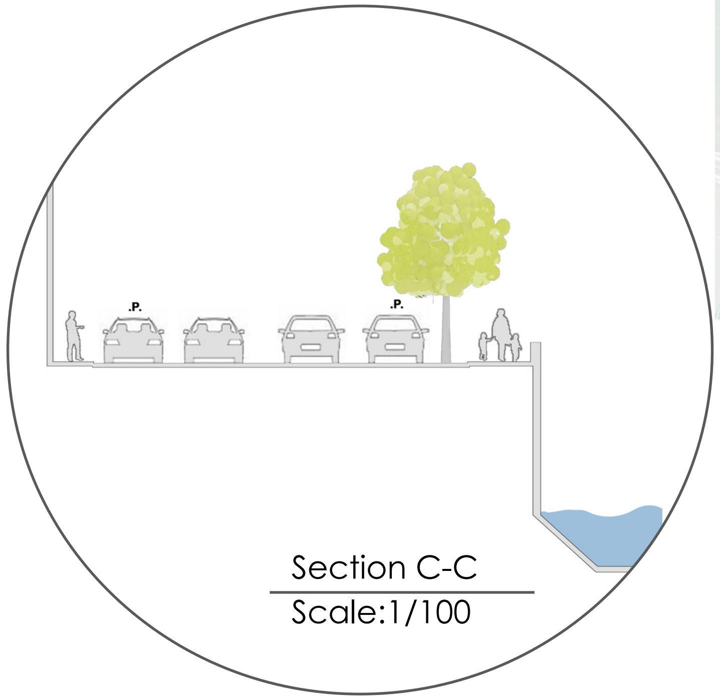
ROAD NETWORK
Alongside of the Adige river

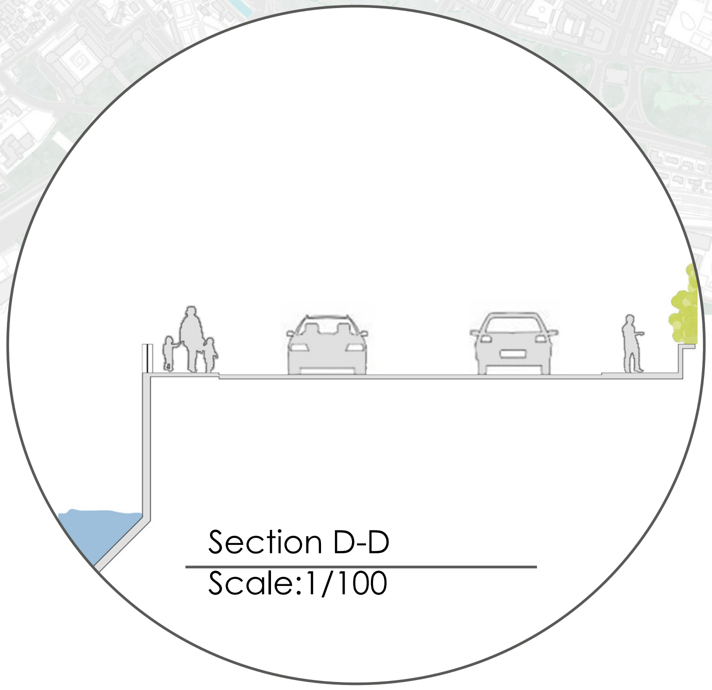
Map 4-16. Maps of Verona (Flood risk, Landuse and Road network): A QGIS Analysis Based on Materials from the Comune di Verona

Current State of the Design Area (Sections)









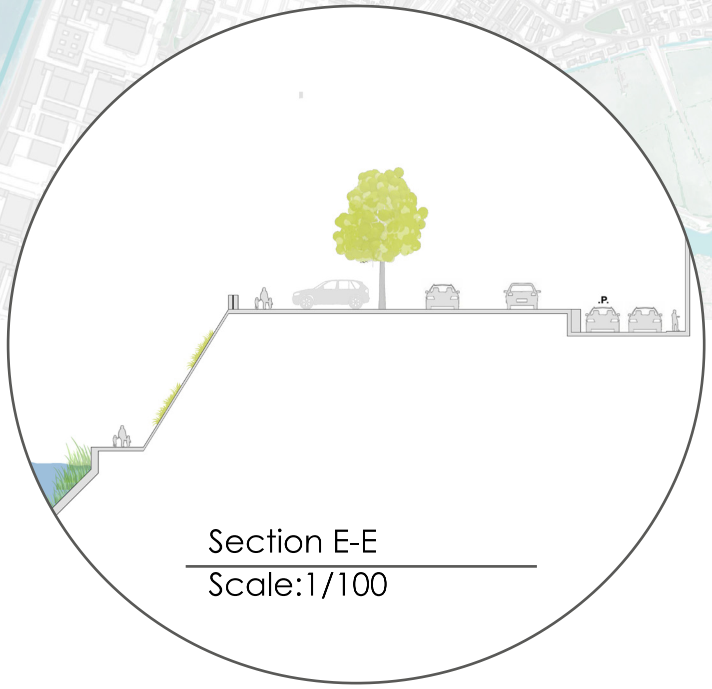


Figure 4-20. Current situation from PonteAleardo Aleardi to Ponte delle Navi- Source. Google earth

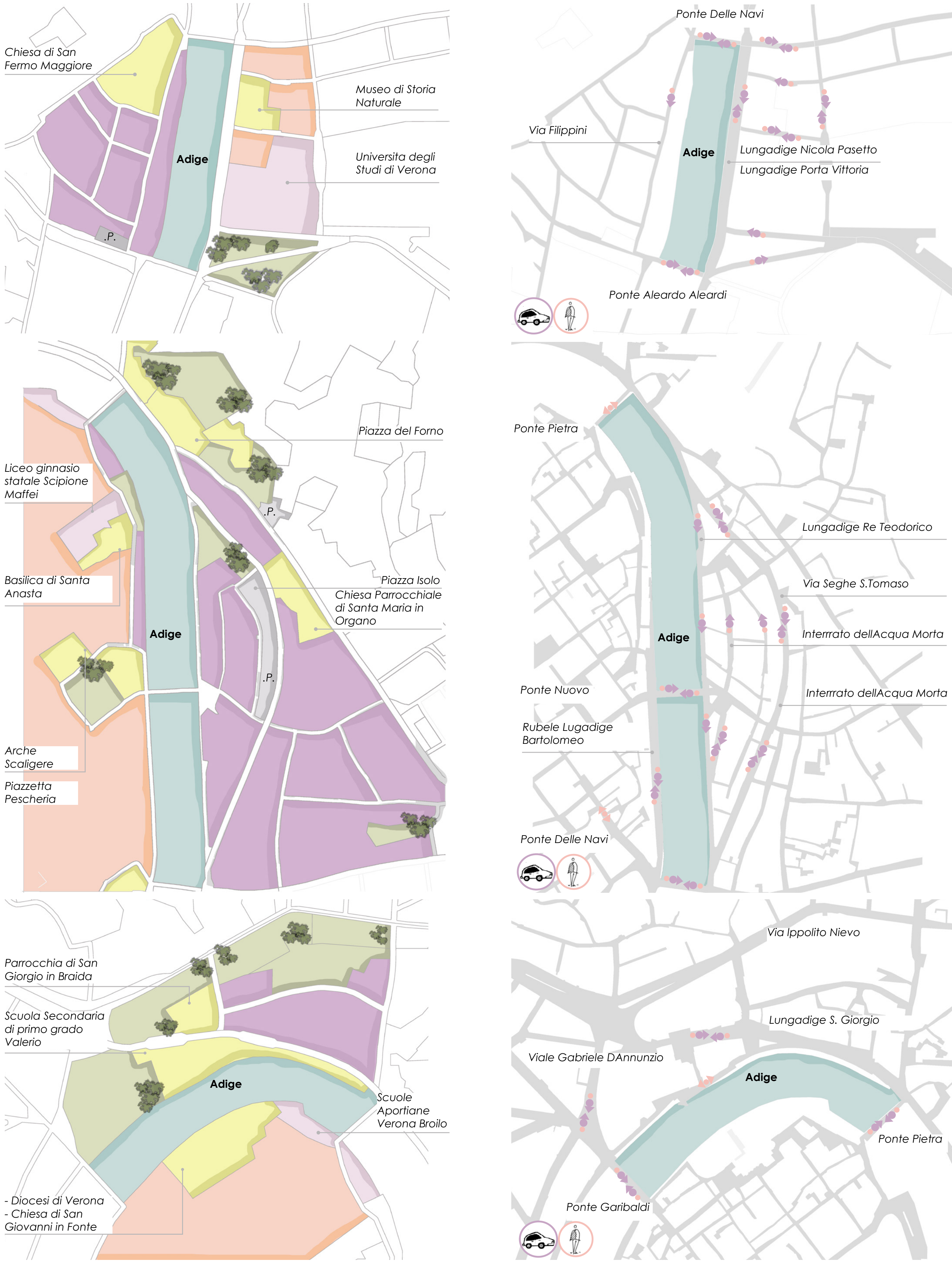
Figure 4-21. Current situation from Ponte delle Navi to Ponte Nuovo- Source. Google earth

Figure 4-22. Current situation from Ponte Nuovo to Ponte Pietra- Source. Google earth

Current State of the Design Area (Maps)

Lnaduse

Road network



Map 4-17 & 4-18. Landuse and road network of design area

4-5.Design Based on Nature based solution

ALTERNATIVE 1 : Emphasize on Ecological Elements for Flood Adaptation (Nature for Resilience)

Perspective:
This design focuses only on reaching to territorial resilience through nature-based solutions with minimizing human interventions.

Aim:
Reducing fluvial flooding in Verona by using Nature solutions.

Objective Urban Forest

Increasing urban forest along the river to reduce runoff for flood risk reduction.

Actions

- Planting native tree species of Verona near Riverbank
- Considering green corridors to Connect all Green areas together

Objective: River and Stream Renaturation

Restoring the natural hydrological functions of rivers and streams that feed into the Adige to slow down water flow and reduce the risk of fluvial flooding.

Actions

- Removing or modifying artificial embankments and infrastructure along the Adige

Objective Natural Inland Wetlands

Considering wetlands in low-lying areas around Adige river to collect flood water

Actions

- Considering new wetland areas in the best location near the River
- Protecting and managing existing wetlands of Verona which are located in the south of Verona
- Considering areas near to the ancient walls of Verona, as buffer zones to gather additional water from the river.

Objective River Floodplains

Expanding and restoring the Adige River's floodplains to absorb and distribute excess floodwater, protecting the urban core of Verona from river flooding.

Actions

- **Restoring historical floodplains** of the Adige River by converting agricultural land along the riverbanks outside Verona into floodplain areas where water can naturally spread and be stored during high-flow events.
- **Creating multifunctional floodplain parks** near Verona's city center, which can flood during extreme river events while being used for recreation and ecological purposes during dry periods.

Objective Terraces and Slopes Alongside the River

Using terraces and slope along riverbank for decreasing flood

Actions

- Designing terraced along the riverbanks to slow down floodwaters during heavy rain events.
- Increasing length of terraces and slope techniques along the banks of the Adige River and consider more spaces for this reason.

ALTERNATIVE 1 :Ecological Flood Adaptation (Nature for Resilience)

City wall as a Inland wetland

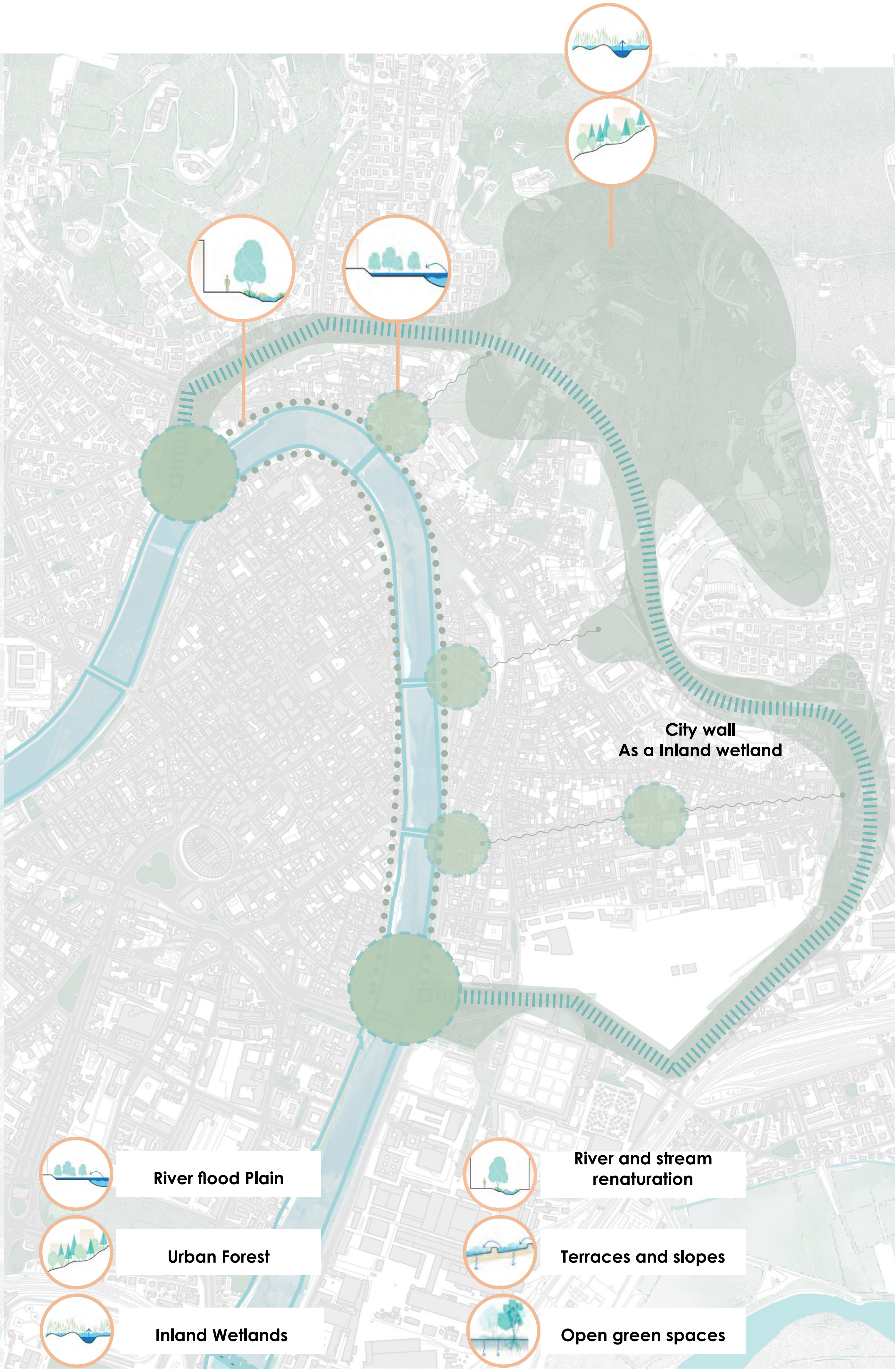
It is necessary to place a protective barrier near the wall to prevent water erosion and damage to the historical wall.

S T R E N G T H

Consider connecting forest that surrounds design area with green corridors and urban forests to enhance green connectivity, biodiversity, and flood adaptation by collecting water through dense tree coverage.

W E A K N E S S E S

- It is not possible to create these spaces in this area because all the buildings have historical value.
- There is no public spaces or community involvement to connect nature with people. Without people's role in maintenance, it will be destroyed quickly.



ALTERNATIVE 2 :Flood Adaptation by well combination between Nature elements and Urban Functionality

Perspective:
This design combines nature-based solutions with urban activities to create a more integrated approach to flood adaptation. It balances ecological restoration with urban development. It is a well combination between natural and human systems to create a resilient, multifunctional urban environment.

Objective Urban Forest

Combining urban forestry with city and creating green spaces that mitigate runoff.

Actions

- Considering parks with full of plants and trees to collect flood water along Adige river and providing recreational space for Veronese and tourists.
- Using green wall and roof as a vertical forest to reduce water runoff.
- Expanding tree planting along roads and pathways to improve water infiltration and mitigateing the impact of extreme weather.

Objective: River and Stream Renaturation

Recreating streams and river to improve city landscape and flood adaptation.

Actions

- Deleting artificial elements of Adige river to allow river overflow in specific areas.
- Designing public spaces along the riverbank to collect floodwater and while also providing areas for community.

Objective Natural Inland Wetlands

Using wetland as a solution to decrease flood risk in urban areas and provide a well-combination between of NBS solution and urban life.

Actions

- Considering an Urban wetland park near the Adieg River for responsibility during flood while providing public spaces for the presence of residents.
- Allocation of lands near the Historical wall of Verona for creating wetland to collect water during Fluvial flood.

Objective River Floodplains

Considering floodplain with urban functionality.

Actions

- Considering floodplains areas around Adige river for managing flood, while using these areas for farming, recreation, cultural and tourism events during other times.
- Designing some urban infrastructure such as: walkway and sport facilities in at level of above river, these areas can stay without damage of flood and prevent movement to the city.
- Considering policies related to land use such as parks and green areas alongside river.

Objective Terraces and Slopes Alongside the River

Well-Combination of terraces and slope with community needs along riverbank to decrease flood risk.

Actions

- Reducing flood risk by designing urban terraces along riverbank that also offer spaces for citizens to sit, walk, and enjoy.

ALTERNATIVE 2 :Hybrid Flood Adaptation: Balancing Nature and Urban Functionality for resilience

Historical-Touristic Zone: Scenic

Eco-Friendly Shops with Plant and Tree Souvenirs for Remembrance Planting

These environmentally friendly stores offer native and local plants of Verona that flourish in the park's ecosystem. Tourists can as a souvenir buy them and plant. For example: when they will come back to Verona another day in the future, they can find their trees in Remembrance Planting Area, with their name.

Green Spaces for Rest and Reflection

Photography Points with Scenic River and Sea Views

Historical Walks and Eco-Tours

Residential Zone: Quiet

Quiet Riverfront Parks

Children's sand playground

Terraced Seating Along the River

Walking Trails with Observation Points and Sitting Areas Near the River

Educational Zone: Interactive and Active

Terraced Seating Along the River

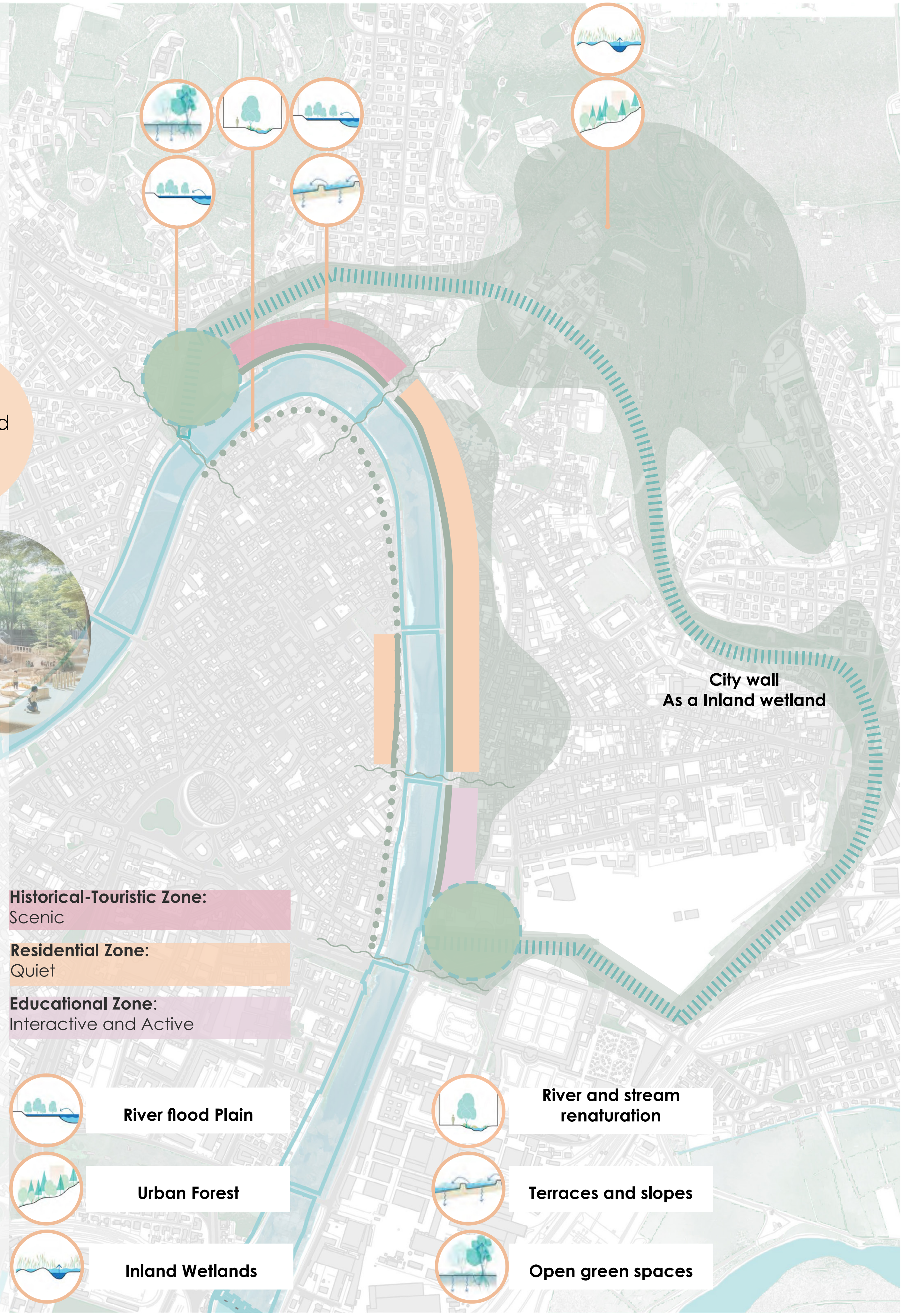
A tiered seating area built along the riverbank, where students and visitors can sit and observe the river's natural flow and the surrounding landscape.

Riverbank Walking Trail with Learning Stations

A way along river to show local green species and explain role of them for flood reduction.

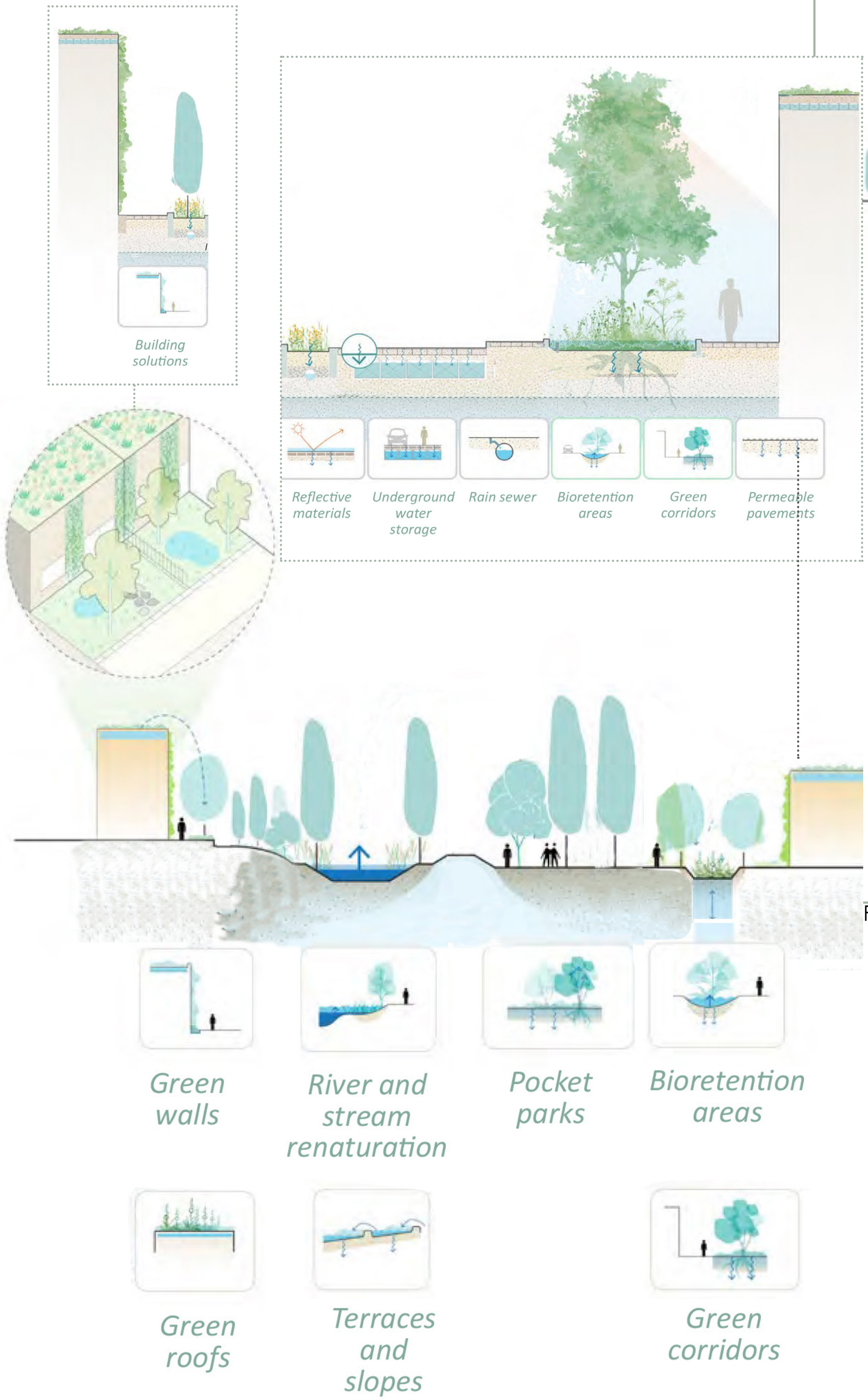
Nature-Based Solution Exhibit Garden

Each section includes native plants of Verona that used for flood adaptation in this project with all useful information of these plants.



4-5.Design Based on Nature based solution

Schematic section of NBS at the Neighborhood scale



Schematic section of NBS at the city scale

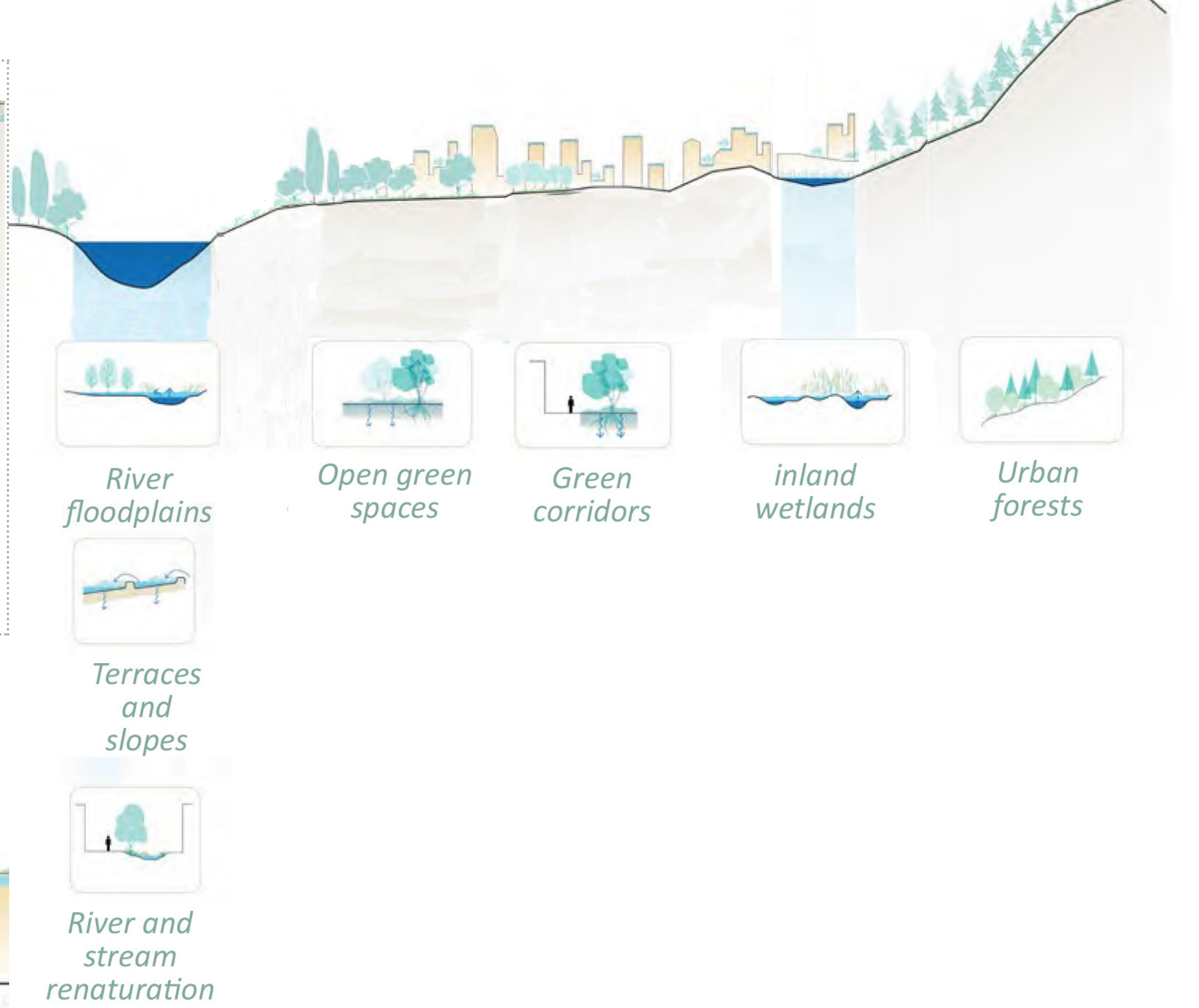
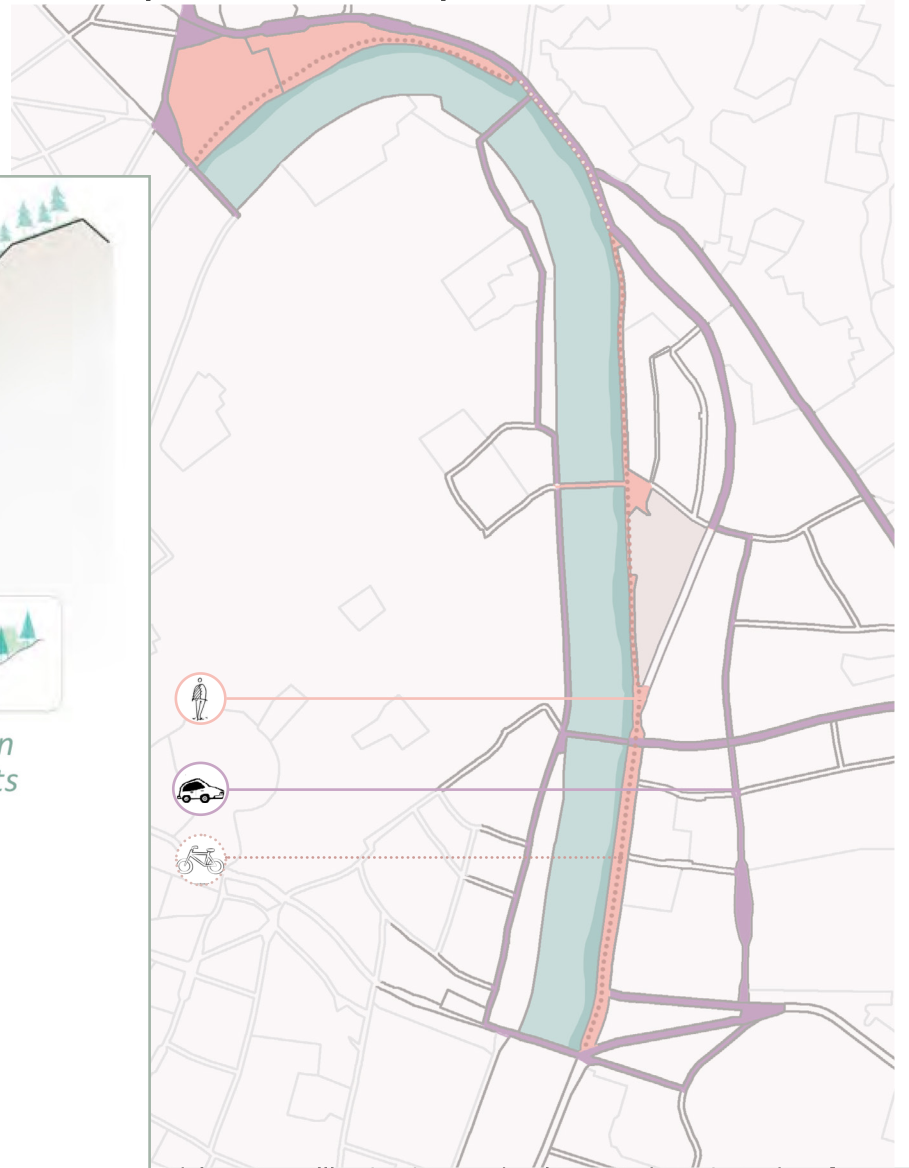


Figure 4-23. Sections of NBS for flood adaptation along Adige river

Mobility Network: Car, Bicycle, and Pedestrian Paths



This map illustrates a balanced network of car, bicycle, and pedestrian routes along the Adige River, designed to support accessibility while preserving space for nature-based solutions.

4-6. CONCLUSION

In conclusion, This chapter was started with information about Verona, including its geography, climate change challenges, history, and other key aspects, to give a full understanding of the city and the role of the Adige River in Verona. Verona is a historic city with especial cultural and architectural heritage that shaped by the Adige River as a main element of the city. However, flooding has become a serious challenge for Verona, especially as the city increasingly faces the impacts of climate change.

To analyze vulnerable areas at risk of flooding, criterias were selected based on experience, interviews with city officials, and literature reviews that by using Hierarchical Multi-Criteria Analysis (HMA) each criterias got a score. The analysis that Used Gis tool highlighted high-risk areas, such as the riverbank near the city center, specifically between Ponte Aleardo Aleardi and Via Ponte Pietra that is consider as a place for designing to adaptaion flood.

Nature-based solutions were identified as effective strategies to deal with these flood risks. These include urban forests, inland wetlands, river floodplains, terraces, slopes alongside the river, and river and stream renaturation. By using these solution not only help to adapt flood. but also improving the ecological and aesthetic value of the riverbanks. Additionally, they can create recreational spaces for people and preserve Verona's historic identity.

CHAPTER 05

CONCLUSION

Chapter 5, is a summary of this thesis. This chapter refers to answer the questions from Chapter 1 and introduces the outcomes, results, findings, and challenges of the research. The answers are supported by pictures of designing to provide a clearer understanding.

5-1. THESIS CONCLUSION

This thesis is a study on the new challenges cities have faced in recent years due to climate change. The research shows that nature-based solutions can help cities adapt to floods. These solutions not only reduce flood risks but also brings healthy living for communities and make cities more livable. The following section will present solutions for adapting to floods and improving territorial resilience.

Questions

1.What are nature-based solutions, and how do they adaption climate change hazards in urban areas?
2.Which nature-based solutions are most effective in improving flood adaptation and enhancing territorial resilience?
3.How can Nature-Based Solutions support urban design and planning for flood adaptation along the Adige River?

Results and Findings

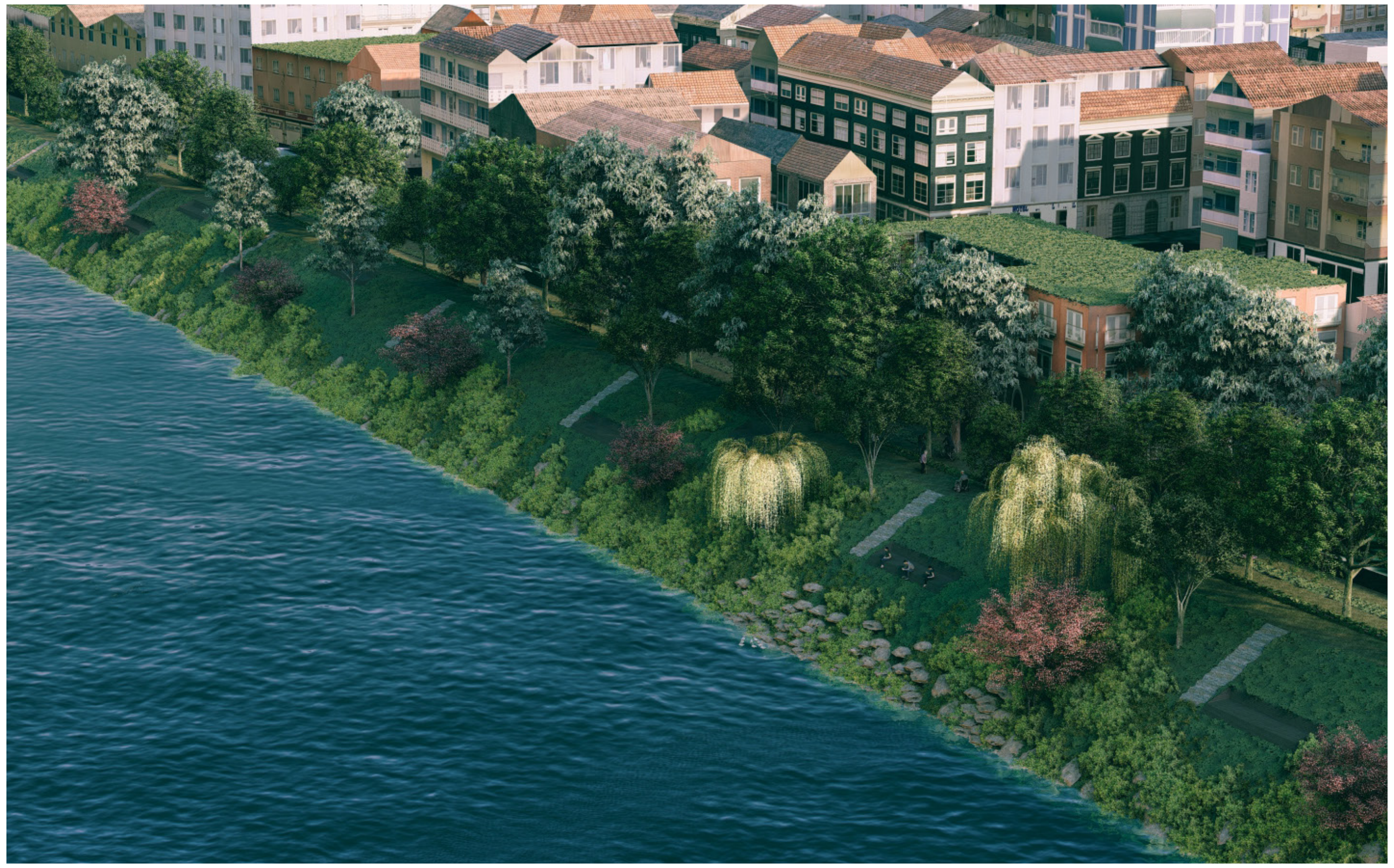
This reaserach emphasizes the effect of natural elements on flood adaptation. As it is clear that flood occure in areas with fewer nature elemalnts. The study demonstrates how these elements can improve resilience in vulnerable areas along Adige river by reducing flood risk. It also illustrates how NBS into urban planning & design can improve territorial resilience for flood adaptation along Adige River in Verona.

Nature-Based Techniques for Flood Adaptation Along the Adige River

River flood Plain	**River and stream renaturation**
Urban Forest	**Terraces and slopes**
Inland Wetlands	**Open green spaces**

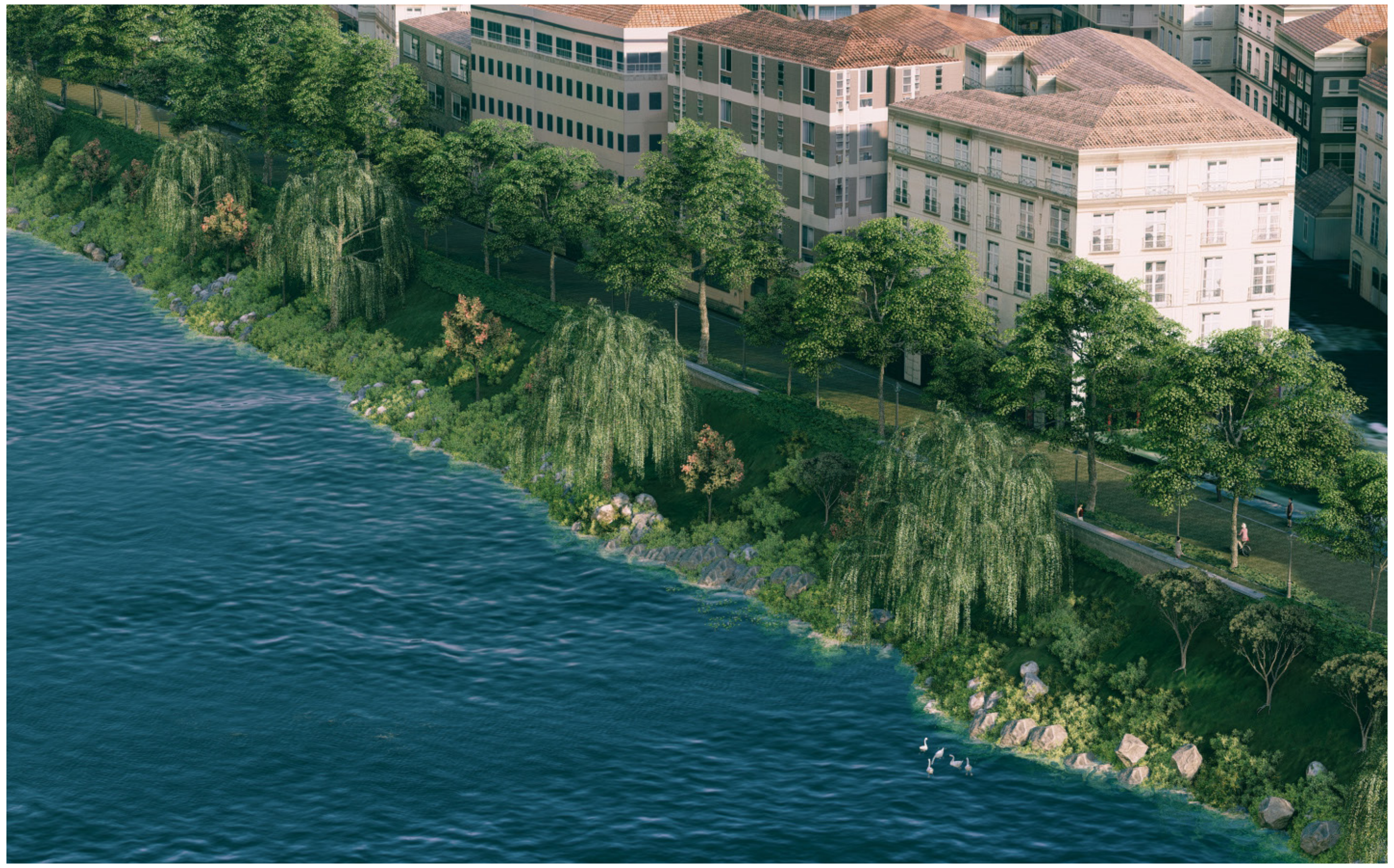
5-2. HOW THIS THESIS ADDRESSE THESE CHALLENGES

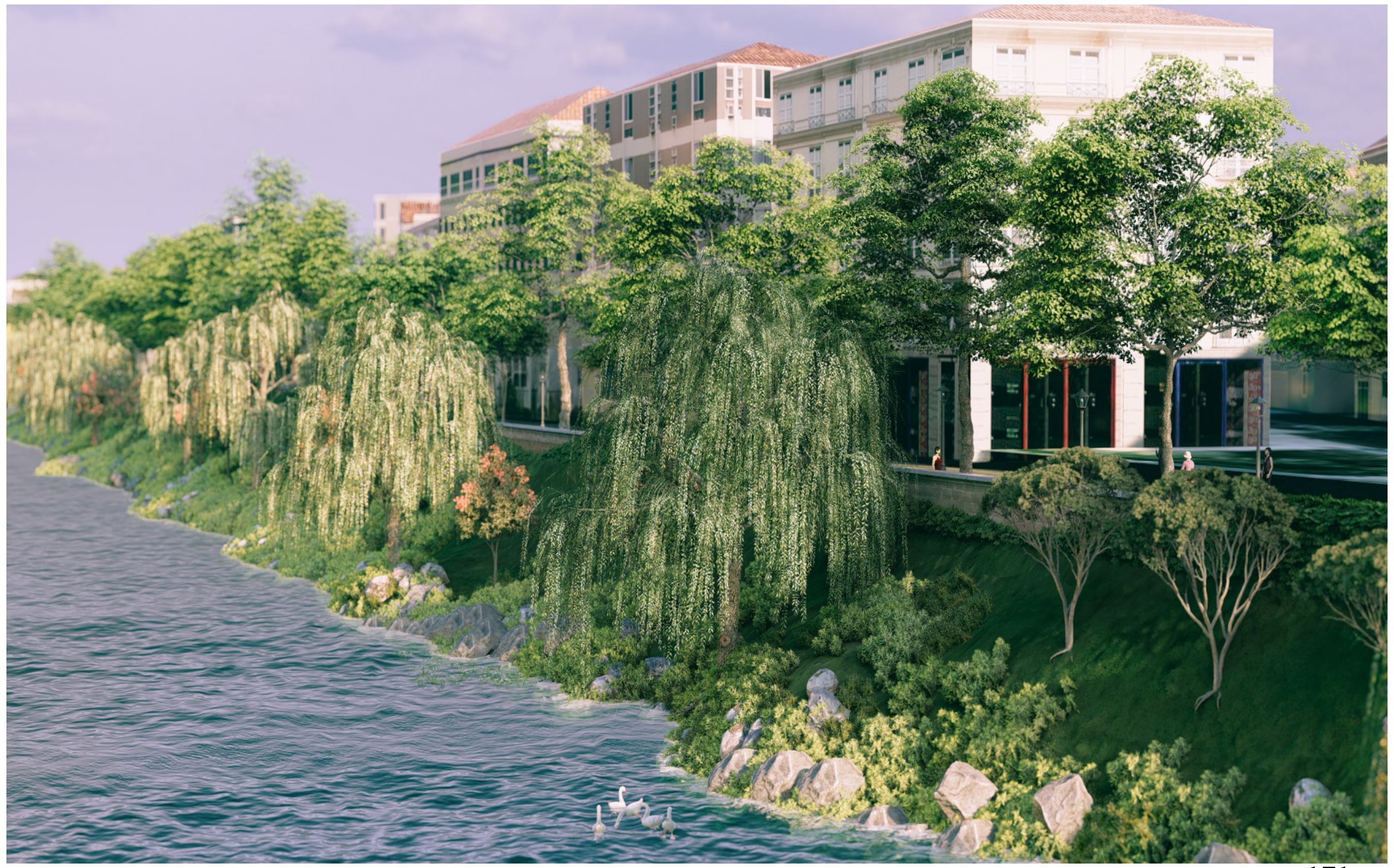
Educational Zone (From Ponte AleardoAleardi to Ponte delle Navi)



Educational Zone (From Ponte AleardoAleardi to Ponte delle Navi)

Residential Zone (From Ponte delle Navi to Ponte Nuovo)



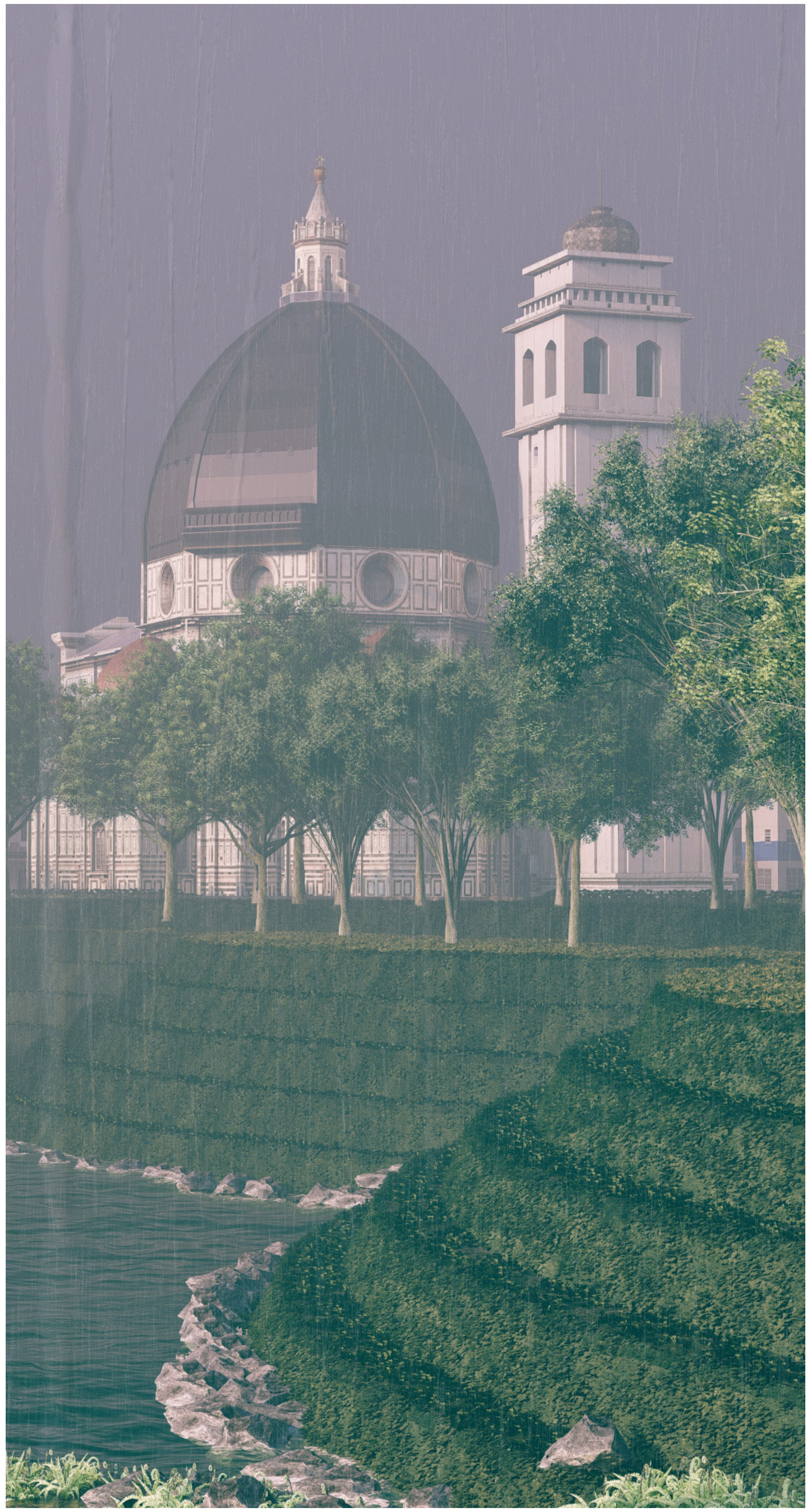


Residential Zone (From Ponte delle Navi to Ponte Nuovo)

Residential Zone (From Ponte delle Navi to Ponte Nuovo)

Historical-Touristic Zone (From Ponte Nuovo to Ponte Pietra)

Historical-Touristic Zone (From Ponte Nuovo to Ponte Pietra)



Internship in Urban planning office of Comune di Verona

This thesis is based on my internship at the Comune di Verona in the urban planning office, where I worked on urban planning, analyzing Verona's natural conditions, and studying climate change in the city. An important topic that led me to choose this thesis is that Verona is the only city in Italy with a biophilic city designation in the world. During my internship, I participated in meetings both inside and outside the Comune, including discussions with representatives from Venice, Padua, and Verona universities. Based on these experiences, I chose this topic to address the main challenges Verona is facing.

Outcomes of the reaserch

As an outcome, I am currently working on a book chapter titled Nature-based Solutions (NbS) Practices in Terms of Energy Management in the Built Environment, in collaboration with Amir Gholipour, PhD, from LEAF – Linking Landscape, Environment, Agriculture, and Food, School of Agriculture (ISA), University of Lisbon, Tapada da Ajuda, Lisbon, Portugal; Corentin Juin, PhD, from i3-CRG, École polytechnique, CNRS, Institut Polytechnique de Paris, France; Marcio Yukihiro Kohatsu, Postdoc, from Programa de Pós-graduação em Engenharia Hidráulica e Saneamento (SHS), Escola de Engenharia da Universidade de São Paulo (EESC-USP), Brazil; and Jalal Azimi, PhD, from the Department of Economics, Management, Industrial Engineering and Tourism (DEGEIT), University of Aveiro, Aveiro, Portugal.

ESSENTIAL REFERENCES

1.Liao, Kuo-Wei, John Thedy, and Chun-Che Tai. "Fluvial flood adaptation using nature-based solutions: A comprehensive and effective assessment of hydro-meteorological risks." Science of The Total Environment 912 (2024): 169329. https://doi.org/10.1016/j.scitotenv.2023.169329

2.Spyrou, Christos, Michael Loupis, Nikos Charizopoulos, Ilektra Apostolidou, Angeliki Mentzafou, George Varlas, Anastasios Papadopoulos et al. "Evaluating nature-based solution for flood reduction in spercheios river basin under current and future climate conditions." Sustainability 13, no. 7 (2021): 3885. https://doi.org/10.3390/su13073885

3.Skrydstrup, Julie, Roland Löwe, Ida Bülow Gregersen, Mark Koetse, Jeroen CJH Aerts, Marleen de Ruiter, and Karsten Arnbjerg-Nielsen. "Assessing the recreational value of small-scale nature-based solutions when planning urban flood adaptation." Journal of Environmental Management 320 (2022): 115724. https://doi.org/10.1016/j.jenvman.2022.115724

4.Gaisie, Eric, and Patrick Brandful Cobbinah. "Planning for context-based climate adaptation: Flood management inquiry in Accra." Environmental Science & Policy 141 (2023): 97-108. https://doi.org/10.1016/j.envsci.2023.01.002

6.Lallemant, David, Perrine Hamel, Mariano Balbi, Tian Ning Lim, Rafael Schmitt, and Shelly Win. "Nature-based solutions for flood risk reduction: A probabilistic modeling framework." One Earth 4, no. 9 (2021): 1310-1321. https://doi.org/10.1016/j.oneear.2021.08.010

7.Bernello, Giacomo, Elena Mondino, and Lucia Bortolini. "People's perception of nature-based solutions for flood mitigation: the case of Veneto Region (Italy)." Sustainability 14, no. 8 (2022): 4621. https://doi.org/10.3390/su14084621

8.Egegård, Colin Hultgren, Maja Lindborg, Åsa Gren, Lars Marcus, Meta Berghauser Pont, and Johan Colding. "Climate Proofing Cities by Navigating Nature-Based Solutions in a Multi-Scale, Social–Ecological Urban Planning Context: A Case Study of Flood Protection in the City of Gothenburg, Sweden." Land 13, no. 2 (2024): 143. https://doi.org/10.3390/land13020143

9.Nilubon, Polpat, and Naim Laeni. "Re-thinking new possibilities for urban climate resilience planning in Bangkok: Introducing adaptation pathways through a multidisciplinary design workshop." Environmental Science & Policy 154 (2024): 103711. https://doi.org/10.1016/j.envsci.2024.103711

10.Dharmarathne, Gangani, A. O. Waduge, Madhusha Bogahawaththa, Upaka Rathnayake, and D. P. P. Meddage. "Adapting Cities to the Surge: A Comprehensive Review of Climate-Induced Urban Flooding." Results in Engineering (2024): 102123. https://doi.org/10.1016/j.rineng.2024.102123

ESSENTIAL REFERENCES

11.Toledo, Ignacio, José Ignacio Pagán, Isabel López, Luis Aragonés, and Jorge Olcina. "Nature-based solutions on the coast in face of climate change: The case of Benidorm (Spain)." Urban Climate 53 (2024): 101816. https://doi.org/10.1016/j.uclim.2024.101816

12.Smith, A. C., T. Tasnim, H. Md Irfanullah, B. Turner, A. Chausson, and N. Seddon. "Nature-based solutions in Bangladesh: evidence of effectiveness for addressing climate change and other sustainable development goals." Frontiers in Environmental Science 9 (2021): 737659. https://doi.org/10.3389/fenvs.2021.737659

13.Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities, Final Report of the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities' (full version) (2022).
10.2777/765301
https://www.researchgate.net/publication/297032348_Towards_an_EU_research_and_innovation_policy_agenda_for_nature-based_solutions_re-naturing_cities_Final_report_of_the_Horizon_2020_expert_group_on_'Nature-based_solutions_and_re-naturing_cities'

14.Zandersen, Marianne, Jakob Stoktoft Oddershede, Anders Branth Pedersen, Helle Ørsted Nielsen, and Mette Termansen. "Nature based solutions for climate adaptation-paying farmers for flood control." Ecological Economics 179 (2021): 106705. https://doi:10.1016/j.ecolecon.2020.106705

15.Randrup, Thomas B., Arjen Buijs, Cecil C. Konijnendijk, and Tom Wild. "Moving beyond the nature-based solutions discourse: introducing nature-based thinking." Urban Ecosystems 23 (2020): 919-926. https://doi.org/10.1007/s11252-020-00964-w

16.Kabisch, Nadja, Niki Frantzeskaki, Stephan Pauleit, Sandra Naumann, McKenna Davis, Martina Artmann, Dagmar Haase et al. "Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action." Ecology and society 21, no. 2 (2016).
http://dx.doi.org/10.5751/ES-08373-210239

17.Simelton, Elisabeth, Jeremy Carew-Reid, Miguel Coulier, Beau Damen, John Howell, Chloe Pottinger-Glass, Hung Viet Tran, and Marlies Van Der Meiren. "NBS framework for agricultural landscapes." Frontiers in Environmental Science 9 (2021): 678367. https://doi.org/10.3389/fenvs.2021.678367

18.Nordin von Platen, Hanna, and Matilda Gustafsson. "Nature-based solutions for flood risk reduction, contamination control and climate change adaption." Thesis of KTH university (2018). file:///D:/Documents/italy/thesis/material%20verona%20climate%20change/flood%20adaptation%20based%20on%20natural%20solution/thesis(18).pdf

19.U. Ronchi, Silvia, and Andrea Arcidiacono. "Adopting an ecosystem services-based approach for flood resilient strategies: the case of Rocinha Favela (Brazil)." Sustainability 11, no. 1 (2018): 4. https://doi.org/10.3390/su11010004

20.Salata, Stefano, Silvia Ronchi, Carolina Giaimo, Andrea Arcidiacono, and Giulio Gabriele Pantaloni. "Performance-based planning to reduce flooding vulnerability insights from the case of Turin (North-West Italy)." Sustainability 13, no. 10 (2021): 5697 https://doi.org/10.3390/su13105697

21.Kumar, Prashant, Sisay E. Debele, Jeetendra Sahani, Nidhi Rawat, Belen Marti-Cardona, Silvia Maria Alfieri, Bidroha Basu et al. "An overview of monitoring methods for assessing the performance of nature-based solutions against natural hazards." Earth-Science Reviews 217 (2021): 103603.
https://doi.org/10.1016/j.earscirev.2021.103603

22.Han, Sungju, and Christian Kuhlicke. "Barriers and drivers for mainstreaming nature-based solutions for flood risks: The case of South Korea." International Journal of Disaster Risk Science 12 (2021): 661-672. https://doi.org/10.1007/s13753-021-00372-4

23.Sahani, Jeetendra, Prashant Kumar, Sisay Debele, Christos Spyrou, Michael Loupis, Leonardo Aragão, Federico Porcù, Mohammad Aminur Rahman Shah, and Silvana Di Sabatino. "Hydro-meteorological risk assessment methods and management by nature-based solutions." Science of the Total Environment 696 (2019): 133936. https://doi.org/10.1016/j.scitotenv.2019.133936

24.Frantzeskaki, Niki, Timon McPhearson, Marcus J. Collier, Dave Kendal, Harriet Bulkeley, Adina Dumitru, Claire Walsh et al. "Nature-based solutions for urban climate change adaptation: linking science, policy, and practice communities for evidence-based decision-making." BioScience 69, no. 6 (2019): 455-466.

25.Cui, Mengmeng, Filipa Ferreira, Tze Kwan Fung, and José Saldanha Matos. "Tale of two cities: How nature-based solutions help create adaptive and resilient urban water management practices in singapore and lisbon." Sustainability 13, no. 18 (2021): 10427. https://doi.org/10.3390/su131810427

26.Basu, Arunima Sarkar, Francesco Pilla, Srikanta Sannigrahi, Rémi Gengembre, Antoine Guilland, and Bidroha Basu. "Theoretical framework to assess green roof performance in mitigating urban flooding as a potential nature-based solution." Sustainability 13, no. 23 (2021): 13231. https://doi.org/10.3390/su132313231

27.Mayor, Beatriz, Pedro Zorrilla-Miras, Philippe Le Coent, Thomas Biffin, Kieran Dartée, Karina Peña, Nina Graveline et al. "Natural assurance schemes canvas: A framework to develop business models for nature-based solutions aimed at disaster risk reduction." Sustainability 13, no. 3 (2021): 1291. https://doi.org/10.3390/su13031291

28.Debele, Sisay E., Prashant Kumar, Jeetendra Sahani, Belen Marti-Cardona, Slobodan B. Mickovski, Laura S. Leo, Federico Porcù et al. "Nature-based solutions for hydro-meteorological hazards: Revised concepts, classification schemes and databases." Environmental Research 179 (2019): 108799. https://doi.org/10.1016/j.envres.2019.108799

ESSENTIAL REFERENCES

29.Lee, Kumjin, Heseong Chun, and Jongsub Song. "New strategies for resilient planning in response to climate change for urban development." Procedia engineering 212 (2018): 840-846.

30.Mabrouk, Mahmoud, Haoying Han, Chao Fan, Karim I. Abdrabo, Guoqiang Shen, Mohamed Saber, Sameh A. Kantoush, and Tetsuya Sumi. "Assessing the effectiveness of nature-based solutions-strengthened urban planning mechanisms in forming flood-resilient cities." Journal of Environmental Management 344 (2023): 118260. https://doi.org/10.1016/j.jenvman.2023.118260

31.Young, Andrea Ferraz, José Antonio Marengo, Juliano Oliveira Martins Coelho, Graziela Balda Scofield, Camila Cristina de Oliveira Silva, and Carla Correa Prieto. "The role of nature-based solutions in disaster risk reduction: the decision maker's perspectives on urban resilience in São Paulo state." International Journal of Disaster Risk Reduction 39 (2019) . https://doi.org/10.1016/j.ijdrr.2019.101219

32.Matos Silva, Maria, and João Pedro Costa. "Urban floods and climate change adaptation: The potential of public space design when accommodating natural processes." Water 10, no. 2 (2018): 180. https://doi.org/10.3390/w10020180

33.Bush, Judy, and Andréanne Doyon. "Building urban resilience with nature-based solutions: How can urban planning contribute?." Cities 95 (2019): 102483. https://doi.org/10.1016/j.cities.2019.102483

34. Bukar, Umar Ali, Md Shohel Sayeed, Siti Fatimah Abdul Razak, Sumendra Yogarayan, Oluwatosin Ahmed Amodu, and Raja Azlina Raja Mahmood. "A method for analyzing text using VOSviewer." MethodsX 11 (2023): 102339.
https://doi.org/10.1016/j.mex.2023.102339

35. Peng, Lu, Yifei Wang, Liang Yang, Matthias Garchagen, and Xiangzheng Deng. "A comparative analysis on flood risk assessment and management performances between Beijing and Munich." Environmental Impact Assessment Review 104 (2024): 107319.
https://doi.org/10.1016/j.eiar.2023.107319
(Peng, 2024)

36. Brunetta, Grazia, Rosario Ceravolo, Carlo Alberto Barbieri, Alberto Borghini, Francesca de Carlo, Alfredo Mela, Silvia Beltramo et al. "Territorial resilience: Toward a proactive meaning for spatial planning." Sustainability 11, no. 8 (2019): 2286.
(Grazia Brunetta, 2019)

37. Brunetta, Grazia, and Ombretta Caldarice. "Spatial resilience in planning: meanings, challenges, and perspectives for urban transition." Sustainable Cities and Communities (2020): 628-640.

38. Wiel Alethea, The story of Verona, 1902.

ESSENTIAL REFERENCES

39. Ferreira, Carla SS, Zahra Kalantari, Thomas Hartmann, and Paulo Pereira, eds. Nature-Based Solutions for Flood Mitigation: Environmental and Socio-Economic Aspects. Vol. 107. Springer Nature, 2022.

40. Zhou, K., Kong, F., Yin, H. et al. Urban flood risk management needs nature-based solutions: a coupled social-ecological system perspective. npj Urban Sustain 4, 25 (2024).

41.Andreotti, Giuliana. “Adige= Etsch: il fiume, gli uomini, la storia.” IN ALTO 75, no. 3 (1993): 266-268.