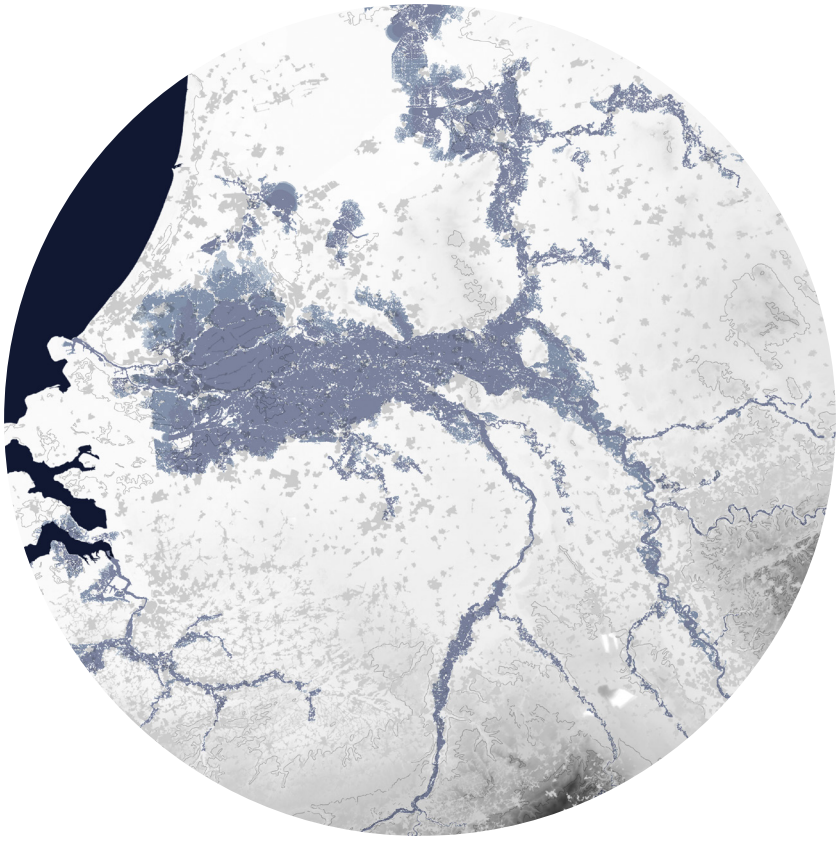


Flooding Resilience Future for the ABC Mega Region

Applying Nature-based solutions as a systematic approach

P5 Report

Minyue Jiang

TU Delft, Faculty of Architecture
November 2022

P5 Report

Flooding Resilience Future for the ABC Mega Region
Applying Nature-based solutions as a systematic approach

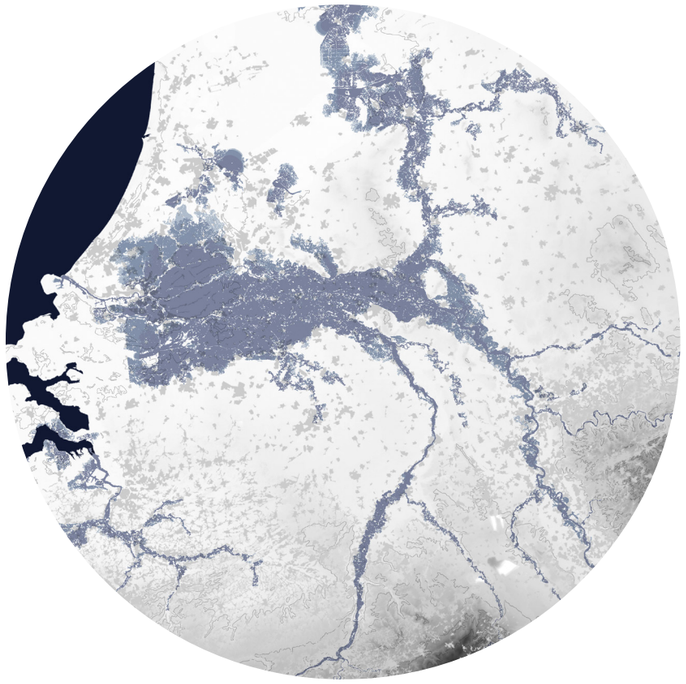
Minyue Jiang
1st mentor, Diego Sepulveda Carmona
2nd mentor, Geert van der Meulen

November, 2022
TU Delft, Faculty of Architecture
MSc Architecture, urbanism and building science (track: urbanism)

Acknowledgment

This graduation project of a year and two months since last September is a treasure for me. I have learnt a lot in the graduation project and gained a lot which I didn't expect.
First of all, I would like to thank my first mentor Diego. Every time I meet with him I feel more motivated. Due to the complexity of the project being beyond my grasp, the project was not completed in time as expected. But Diego never made me doubt that I could finish it or even do better. He always encouraged my every progress and uses his ample academic knowledge and mentoring experience to guide and support me, and restore my confidence, lead me to the right track, and move forward again.
I am also very grateful to my second mentor Geert who graciously and enthusiastically offered to be a part of my project mentor group. He has been a source of inspiration for my project with his interdisciplinary background and perspective. His concise yet perceptive views have always helped me to clarify a lot of my thoughts.
I would also like to thank all my classmates and teachers in the TT studio. They were very helpful and supportive when I had to deal with an unfamiliar subject like the Rhine and delta urbanism. Their hard work and serious attitude also gave me a lot of motivation.
I would like to thank my friends Bowen and Chen for chatting and hanging out with me in the weekend, giving me emotional support and making me feel like family in a foreign country.
I would like to thank my parents in China for their financial support which made it possible for me to come and study and live in the Netherlands. In times of difficulty, although they may not even understand what I am going through, they have always stood behind me unconditionally and made me feel safe to keep on going no matter what.
As I write this, the experiences of the past year and two months are suddenly condensed together and vivid in my mind. It will indeed be one of my most precious memories.

Contents



Abstract

The frequency of flooding events is estimated to increase in the Rhine Basin. Cities are becoming increasingly sensitive to climate change, and urban sprawl and urban population growth are bringing more and more people and areas into the risk. The thesis project is about the flooding resilience future in the lower Rhine River basin. The lack of systematic and scientific spatial planning and flood management tools has resulted in the mega region not having complex flooding issues. In addition, the natural landscape is fragmented by the urban sprawl in the past few years, and the connection of nature landscape and the value of the ecosystems needs to be utilized and demonstrated in future flood management in the face of the new paradigm. In the cross sections and different levels and countries of governance, it is important to investigate the local capacity of adaptation and transformation towards flood resilience. Nature-based solutions are thus chosen as which not only recognize the dynamics of the bio-physical systems but also activate the capacity of local conditions. Nature-based solutions not only enhance the green and blue infrastructure, but also creating added values of social benefits. By investigating the opportunity, suitability, availability and applicability of applying the nature-based solutions, the thesis try to explore a systematic approach to accelerate the transformation towards a flood resilience future in the ABC mega region by the local adaptations.

Source: AP Photo/Michael Probst

Motivation

Before I come to TU Delft to have my master program of urbanism, I have studied architecture for five years in China, and the larger consideration of the whole system which includes not only the buildings and constructions, but also the streets, the cites, the people and the society etc. attracts me a lot. My previously acquired belief was that the reason we design and build is for a better life in the future. But what in exact is a better life? Is it a better living environment, a better standard of live style, or something else that I have been thinking about as an urbanism student?

Any simple theory or principle put into a real-life situation becomes extremely complex, and when multiple factors need to be considered at the same time, it can cause confusion and any subtle decision can lead the future in a very different direction. The discussion of the future of urbanization in the Delta in the face of flood risk is one such complex subject. Under this topic there will be the topics that under discussions frequently, such as the power play of human versus nature, development versus regression, and the micro versus the macro. When it comes to floods, it is evitable of discussing how the forces of nature can backfire and how the relationship between man and nature can be better balanced in the future, so that sustainable urbanization can be achieved and the local and the global can work together. In the Lower Rhine Delta, environmental, climatic, social, economic, policy, the transitional territories of water and land are all included in such a conflicting project. What should and could our urbanist do for a better flood resilience future for the Delta and how to organize the complex system is the thing I want to explore.

CHAPTER 01

INTRODUCTION

In this chapter the basic information of geographical location and general status about the site of this thesis, ABC Mega region, is introduced. As well as explain the research background context of the study, the flooding risk, showing the significance and the urgency of the study.

A crucial issue, flooding risk

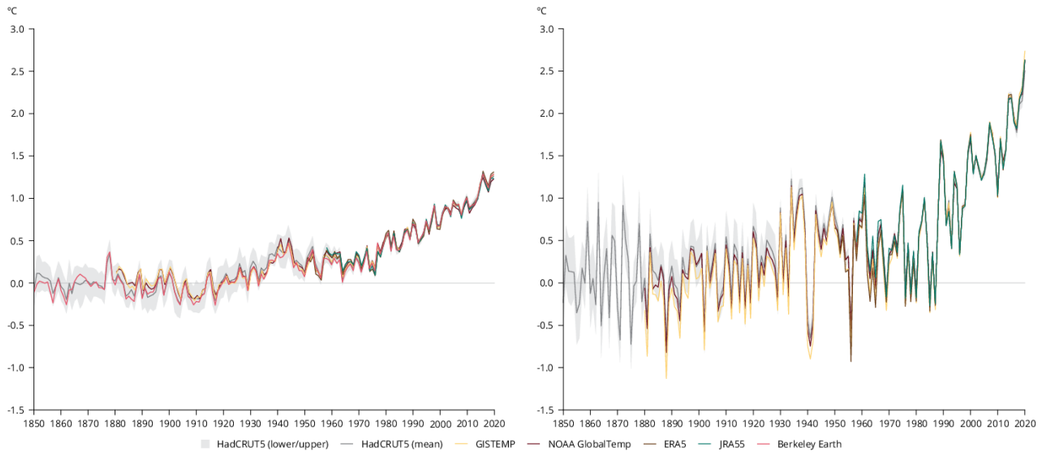


Figure: Global (left) and European land (right) average near-surface temperatures anomalies relative to the pre-industrial period
Source: EEA, 2021

When they consider climate change, scientists predict an intensified global water circulation with respect to magnitude and frequency of extreme precipitation events (Dankers & Feyen, 2008). Mean sea level rise will contribute to projected increases in coastal floods along the European coast. Large changes in flood frequency mean that what is an extreme event today may become the norm by the end of the century in some locations. The frequency of coastal flooding events is estimated to increase by more than a factor of 10 in many European locations, and by a factor of more than 100 or even 1000 in some locations during the 21st century, depending on the emissions scenario.

In the absence of further investments in coastal adaptation, the estimated average annual losses from coastal flooding in the 17 main coastal cities in the EEA member countries could increase from about EUR 1 billion in 2030 to EUR 31 billion in 2100 under the high emissions scenario. The annual number of people exposed to coastal flooding is projected to rise from 102 000 to 1.52-3.65 million over the same time horizon with current flood defence structures.

Cities are becoming increasingly sensitive to climate change, and urban sprawl and urban population growth are bringing more and more people and areas into the risk.

In the context of the challenges posed by climate change, ecological degradation and loss of territoriality, more and more problems are emerging in the progress of human development. In this context, sustainability is particularly important. The earth's carrying capacity is limited and human economic activity must remain within the carrying capacity of resources and the environment.

It is overly optimistic to assume that all environmental problems can be solved automatically in the course of development. Thus, sustainability requires proactive action by people to intervene in the development process. The natural landscape and urban landscape are closely linked and complement each other. Sustainable urban development cannot be allowed to override the nature landscape, otherwise it will be subject to nature's revenge.

Urban area potentially affected by 1m sea level rise

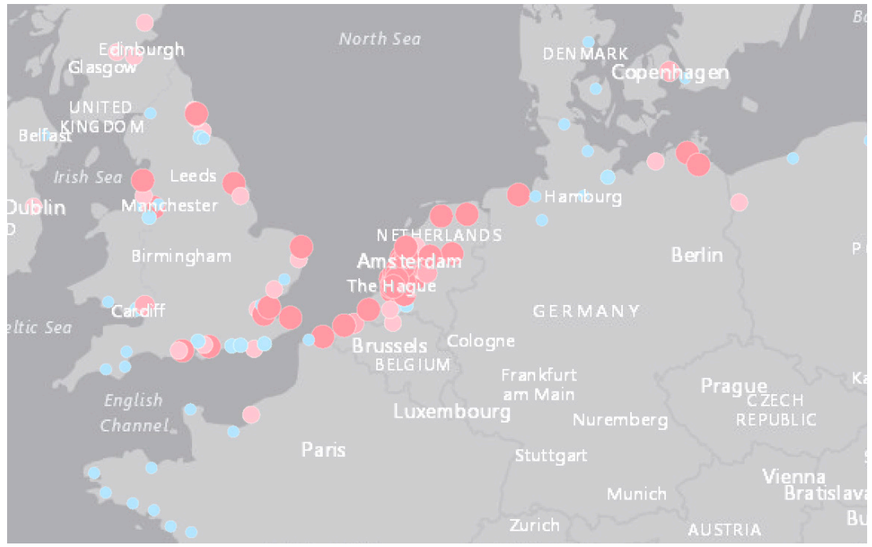


Figure:Urban area potentially affected by 1m sea level rise
Source: Esri, HERE, Garmin, USGS | CReSIS (Centre for Remote Sensing of Ice Sheets) 2018

Urban area potentially exposed to river flooding in 2071-2100 compared with 1961-1990

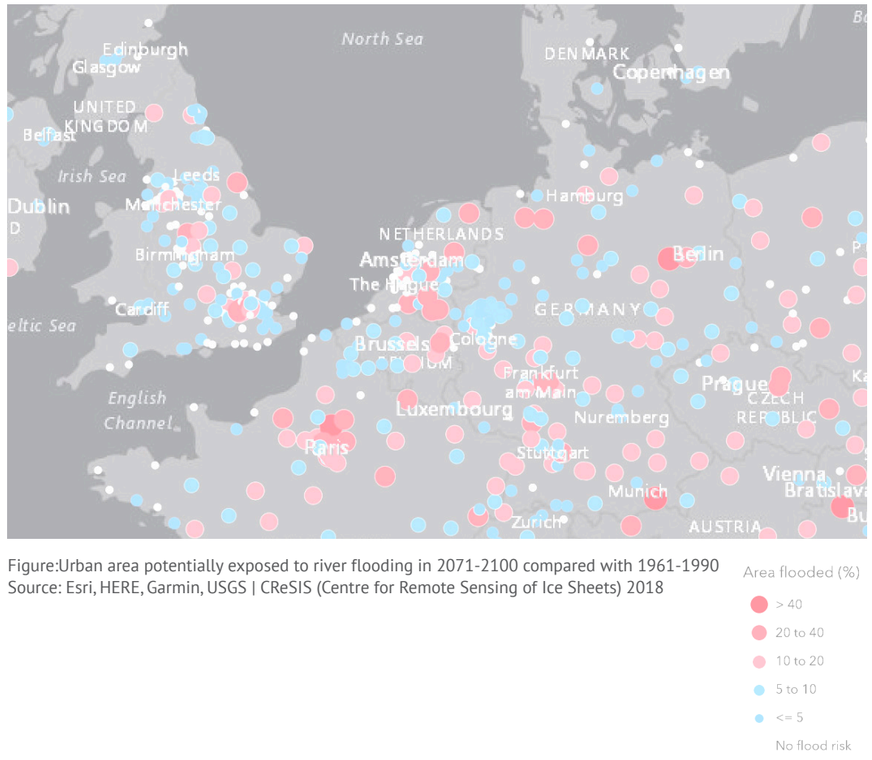


Figure:Urban area potentially exposed to river flooding in 2071-2100 compared with 1961-1990
Source: Esri, HERE, Garmin, USGS | CReSIS (Centre for Remote Sensing of Ice Sheets) 2018

A crucial issue, flooding risk

The ABC Mega region is located in the lower delta of the Rhine. Cities in the ABC mega region are not only at risk of flooding from rivers, but also from coastal flooding due to climate change and sea level rise.

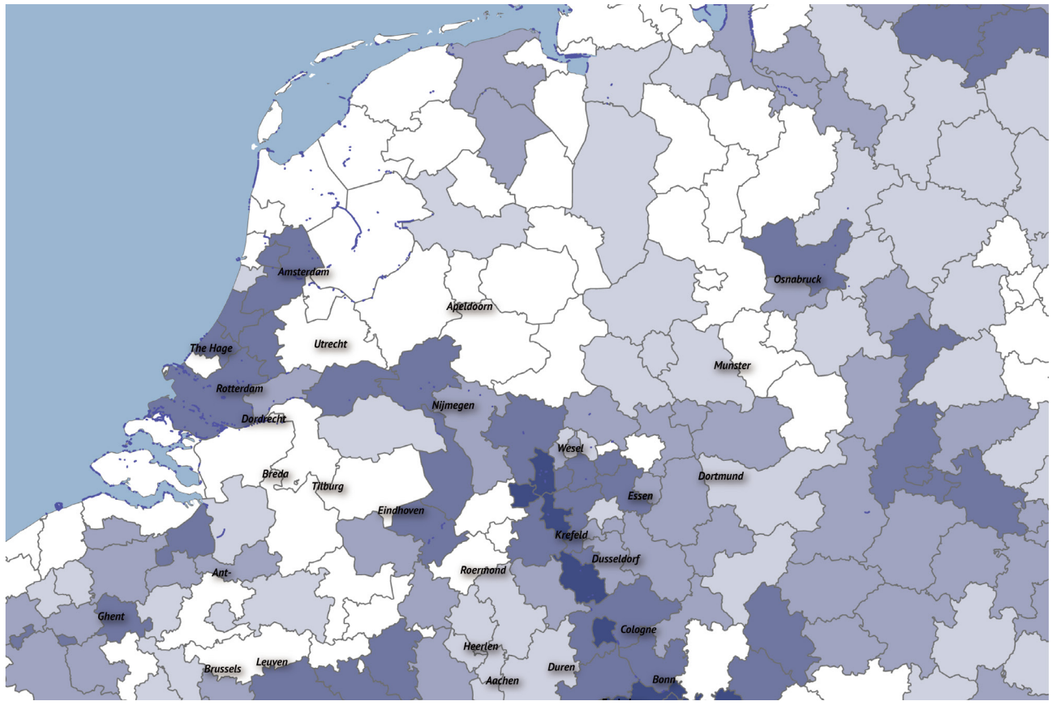


Figure: the river flooding risk ABC Mega region
Illustrate by the author
Source: EEA, 2018

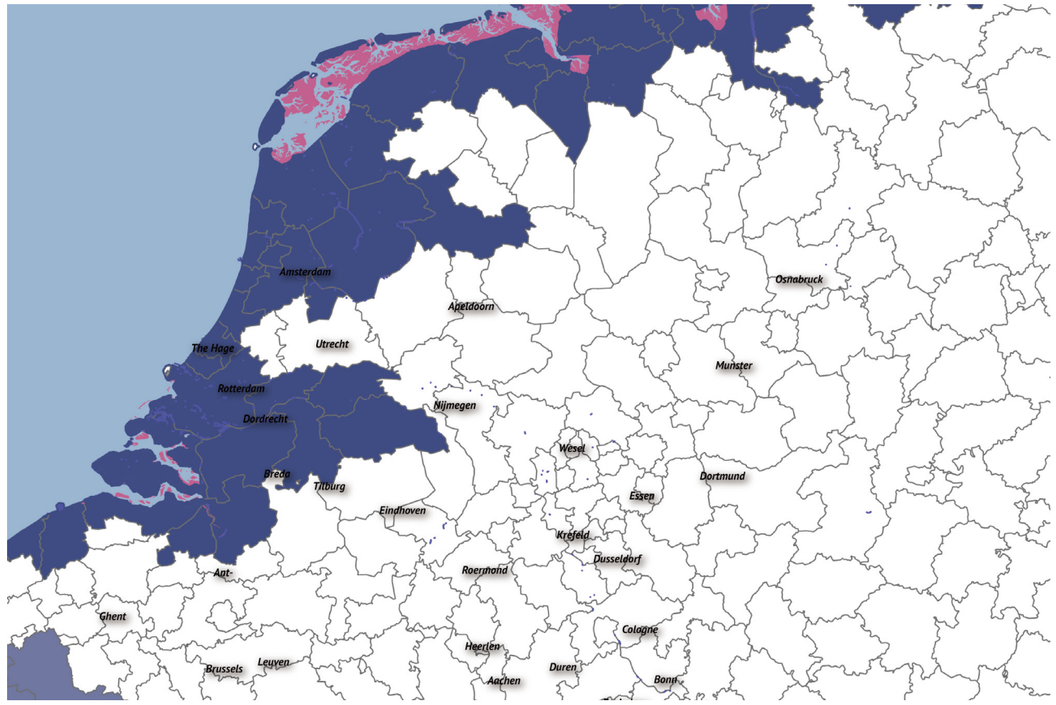


Figure: the costal flooding risk ABC Mega region
Illustrate by the author
Source: EEA, 2018

Thesis Location

Lower Rhine River Basin / ABC (Amsterdam-Bruseel-Cologn) Mega Region

The ABC mega region is located on the lower reaches of the Rhine, which is known as Europe's most important economic development corridor. It has one of the world's most united economic cooperation, but at the same time political, social and developmental divided.

The 'ABC' in ABC mega region refers to Amsterdam, Brussels and Cologne respectively. In other literature it is also referred to as the Am-Brus-Twerp Mega Region.

The mega region, which spans the Netherlands, Belgium and Germany, crossing three national borders, has a complex socio-economic situation. As the mouth of the Rhine is located here, the ABC mega region is also faced with both inland and seaward geographical and environmental conditions.

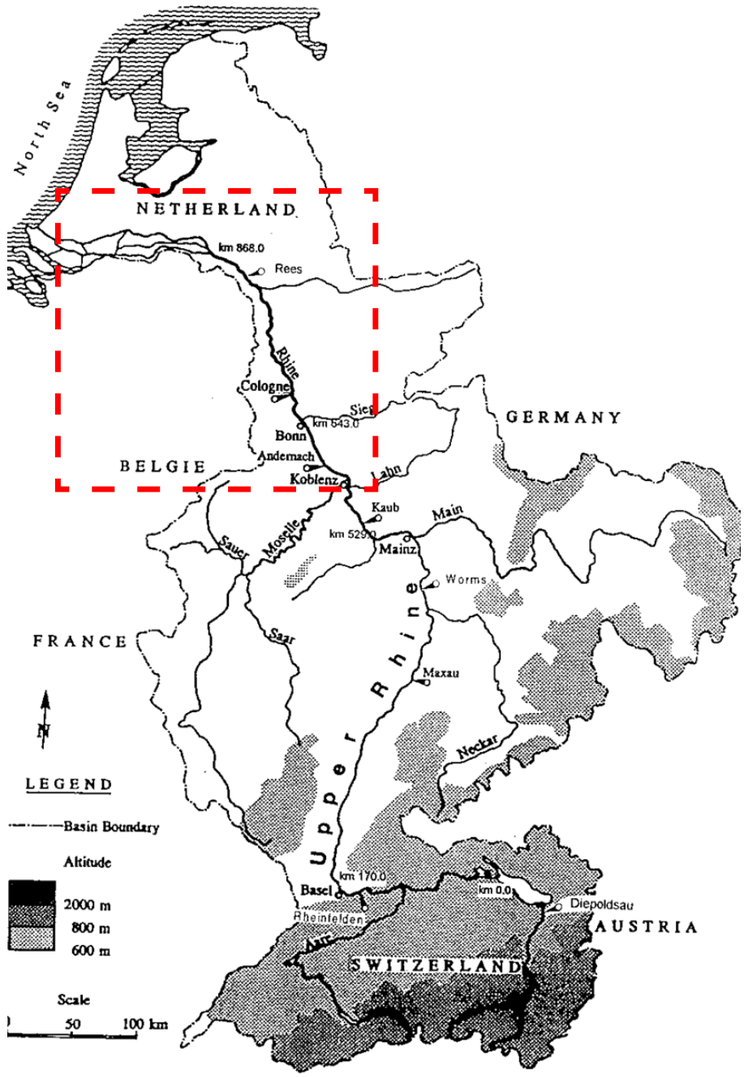


Figure: Rhine river basin
Source: illustrate by Huw C. Davies, 2000

Map of the ABC (Amsterdam-Bruseel-Cologn) Mega Region

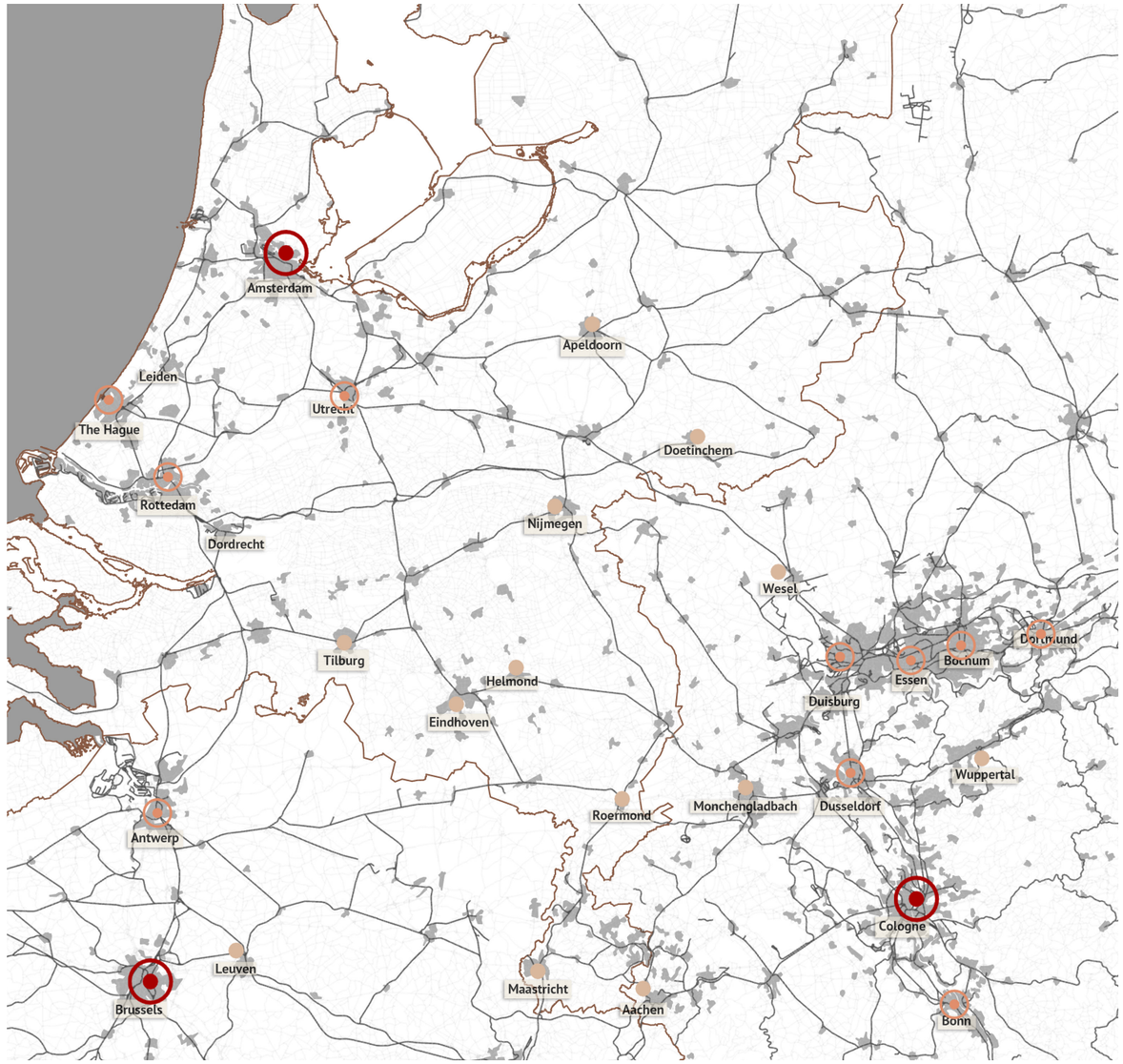


Figure: the ABC Mega region
Illustrate by the author
Source: Openstreetmap, 2018

An integrated network, Mega Region

An integrated network, Mega Region

The process of metropolisation also brings entirely new challenges for planning and governance, including the need for an integrated policy agenda which treats the space such as 'urban', 'suburban', 'rural' or 'natural' as parts of an imprecise geography rather than distinctive physical features (Cardoso R, Meijers E, 2020a).

Because of the less functional and economic characters of the sub-urban areas, in the process of urban planning and design, the potential and importance of these areas are neglected. Especially those green-blue infrastructure which locate in the sub-urban areas have more bio-physical capacity to face the issues of the cities.

The thesis will be approached from the perspective of a mega region. It will not only consider a single city, or a few cities, but a large urban agglomeration and a comprehensive network within it. Consider the rural areas, small towns and villages, small cities and big cities in the mega region as a whole system.

However, the spatial planning and design of the mega region always faces the challenge of the complex situations led by crossing-border governance and diverse cultural and history background. Mega region, as a series of mega-city spanning crossing the national border, has a diverse socio-cultural and historical background, which results in a gap between the communication and implementation of policies and measures. How to keep the alignment of the policies and practice from local to mega region and activate the involvement is crucial for developing a dynamic flood resilience network of the whole mega region is vital.

Many once distinct cities are becoming part of larger, multicentric city-regions, in a process of restructuring and integration of economic activity, spatial forms and institutional settings that has been captured under the concept of 'metropolisation' (Meijers et al., 2014; Cardoso, 2016a). Urban models such as the cores, the forms, the polycentric, the centralisation or scattered are often referred to as defining this framework in terms of spatial relationships. But the Mega region perspective is not just about moving from monocentric to polycentric, it is also about understanding the social, political and economic issues that can be faced. How to work together is therefore key, and how to find and form a systematic integrated flood management network is crucial.

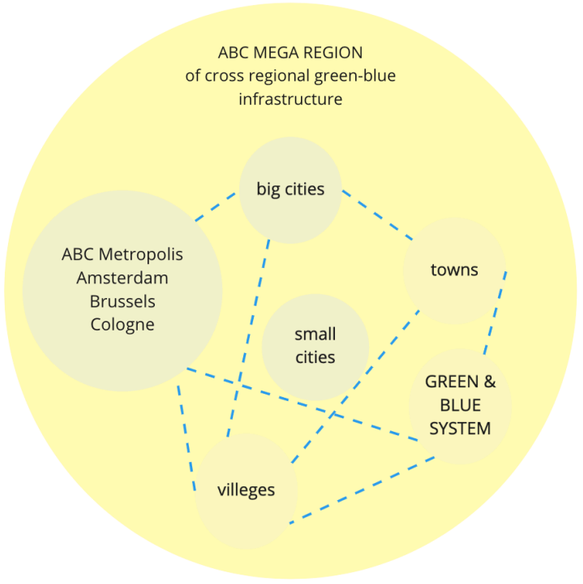


Figure: the mega region
Illustrate by the author

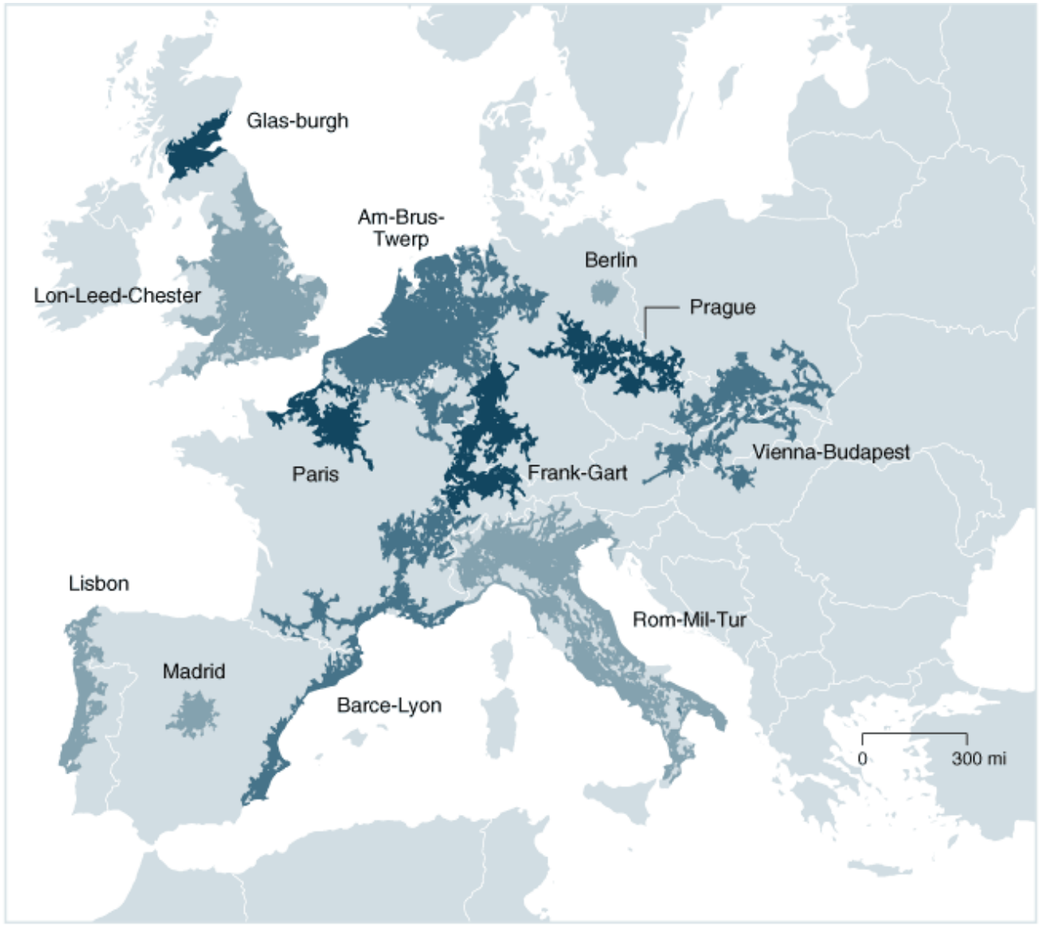


Figure: EU Mega region
Illustrate by Tim Gulden

Territory in between

Territories in Between (TiB)

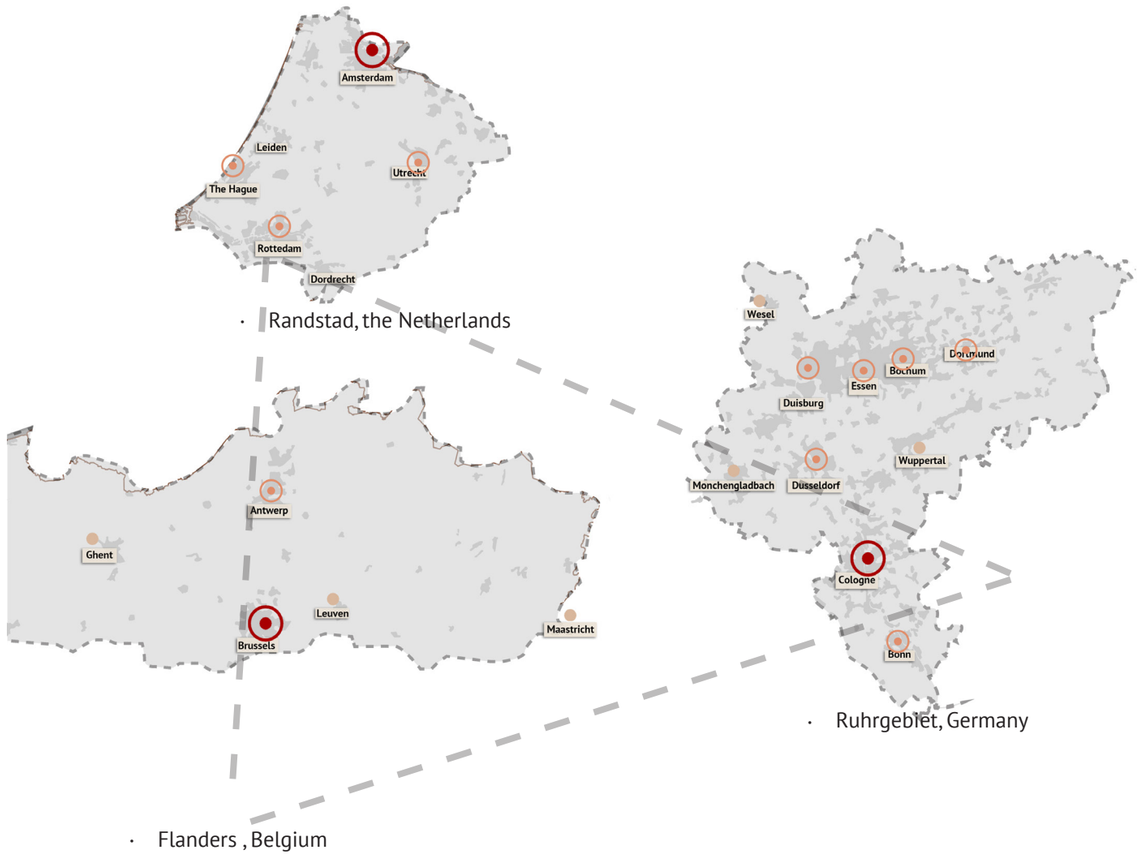
Characters of TiB

- Urban landscape as a large interlocking system
- low-rise dispersed urban development
- high level of functional diversity
- extended networks of infrastructure

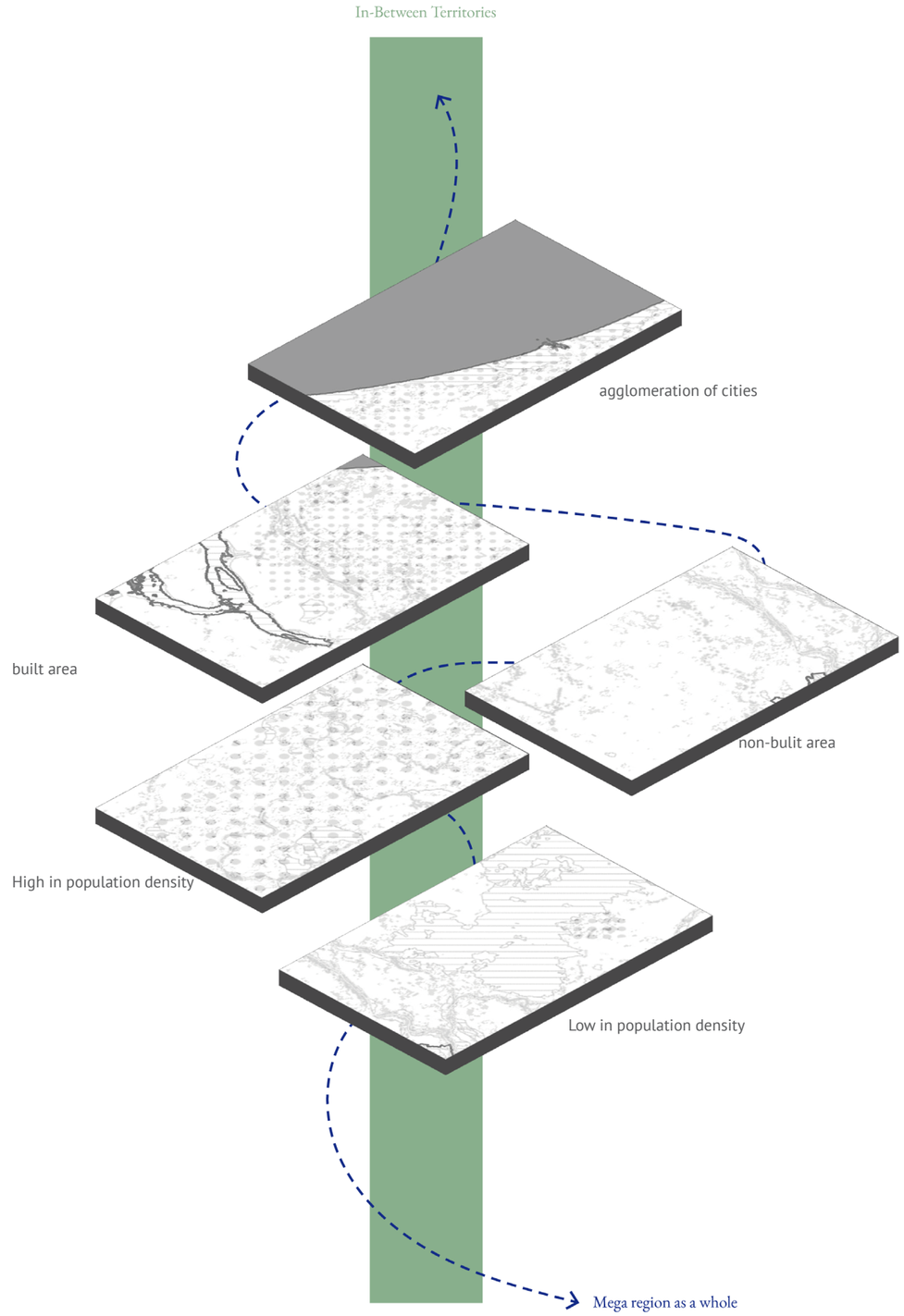
Local: proximate but functionally disconnected

Regional: distant but functionally connected

The Mega region needs to be considered as a whole, not just as a large urban or natural and ecological area, but territories in between need to be given more attention in the future development of flood resilience. It is worth exploring where the future of the Mega region lies and where these nature-based solutions can be used to maximum benefit.



Territories in Between (TiB)



A systematic approach, Nature-Based Solutions (NBS)

Nature-based solutions (NBS) have recently been put for- ward by practitioners (in particular the International Union for Nature Conservation, IUCN) and quickly thereafter by policy (European Commission), referring to the sustainable use of nature in solving societal challenges. In practice, nature-based solutions often make use of green-blue infrastructure to achieve flood control objectives, with additional benefits such as environmental protection, ecological conservation and eco-system enhancement. River landscape is the main subject to be studied in the topic of nature-base solutions of flood management. Nowadays, the borders of river and land are complex and transitional. Several methods regrading to the transitional territories of river and land are the project of Make Space for Water in the UK (Butler & Pidgeon, 2011) and Room for the River in the Netherlands (Neuvel & Van Den Brink, 2009).

It is interesting to explore the potential of nature-based solutions in the flood management. As the green-blue infrastructure is usually a part of nature landscape. It is also important to see how urban planning and design can include the process of using the nature landscape as the infrastructure and how the relationship of the urban landscapes and nature landscapes is settled. For example, making the landscape less connected, facilitating less rainfall to be transformed into runoff and therefore reduce flood risk, droughts and erosion problems (Keesstra, Saskia, et al., 2018). These comprehensive approaches could enhance a series of added value. J. Ran (2016) highlights the necessity of integrating spatial planning with flood-risk management particularly in the Irish and the European context. Spatial planning and flood risk management should be integrated through three dimensions: geographical, policy and institutional. New integrative and synergistic approaches are needed in urban landscape planning design theory and practices that advance stormwater management through the agency of landscape ecology knowledge and livability goals (Bacchin T K, 2014).

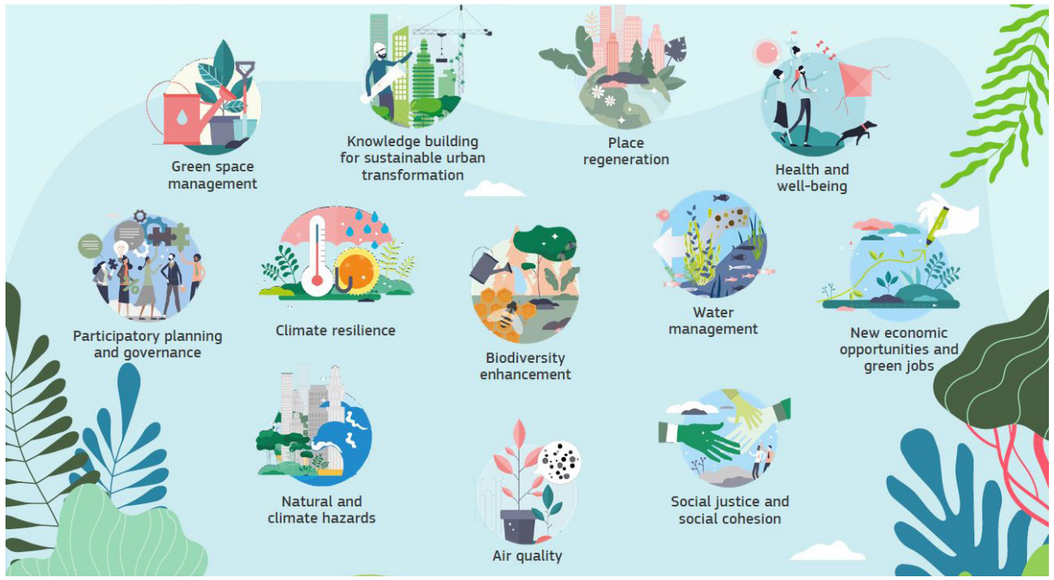


Figure: nature-based solutions
Illustrate by Dumitru, A., 2021

Figure: Deep Forms of Nature-based Solutions: Meishe River Greenway and Fengxiang Park, Haikou, China

A systematic approach, Nature-Based Solutions (NBS)

The traditional approach to flood management is to use water management infrastructure such as dykes and ditches. However, this graduation project focuses on a more ecological and cost-effective approach, namely nature-based solutions. The concept of infrastructure often includes the artificial infrastructure used for mobility transportation, water supply and drainage, energy and power supply, communication and transmission, water conservation and environmental protection, etc., which can be called as grey infrastructure. Infrastructure for water, urban drainage and flood protection has a typical lifetime of 30–200 years and its continuing performance is very sensitive to climate change. The green blue infrastructure could last for a longer period and be resilience to the extreme weather and climate change. To see how infrastructure systems react large-scale flooding, R. Pant (2016) analyze shows how spatial network models inform flood risk management practitioners to identify and compare critical infrastructures risks on flooded and non-flooded land, for prioritizing flood protection investments and improve resilience of cities.

Blue-green infrastructure is currently seen as a way to reduce the negative effects of urbanization (flooding) and to adapt to anticipated climate change (flooding and droughts). Blue-green infrastructure is a possible way to create multifunctional surfaces with environmental and social functions. Apart from stormwater management (sustainable urban drainage systems), it includes greenways and ecological networks, which are important components in the concept of green infra- structure (Demuzere et al., 2014).

Nature-based solutions for flooding

This drawing shows how the nature-based solutions can be work for flood risk management from inland to seaward situations. The introduction of the Nature-based solution allows the ecological value of the space to be emphasized in a higher extend, while having a longer lifespan and more resilience to climate change than the grey infrastructure. Different typologies of strategies they relate and combine with each other to form a systematic performance.

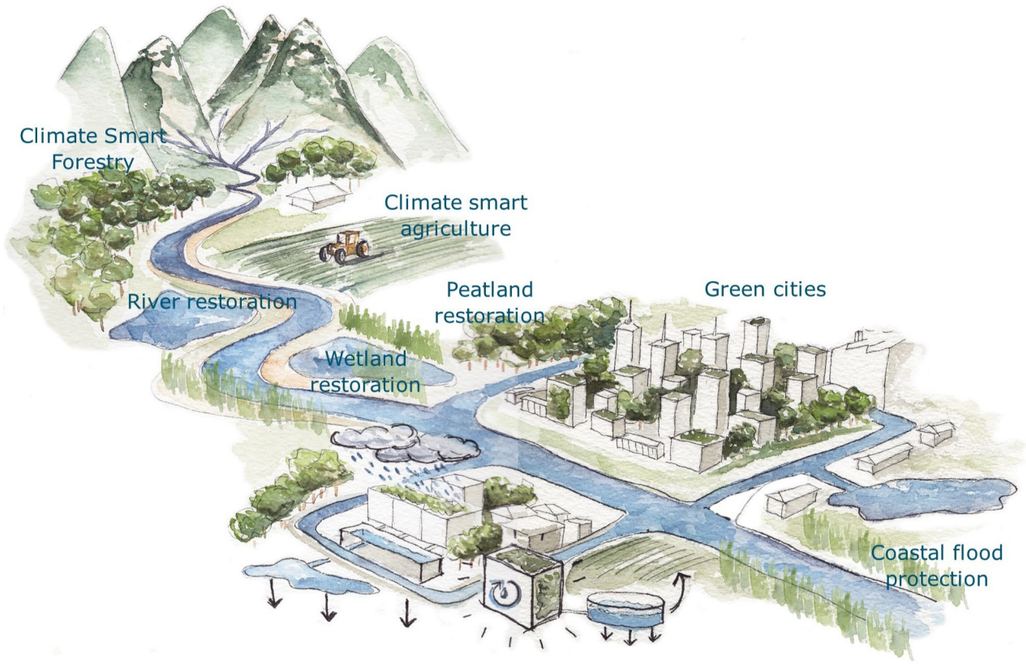


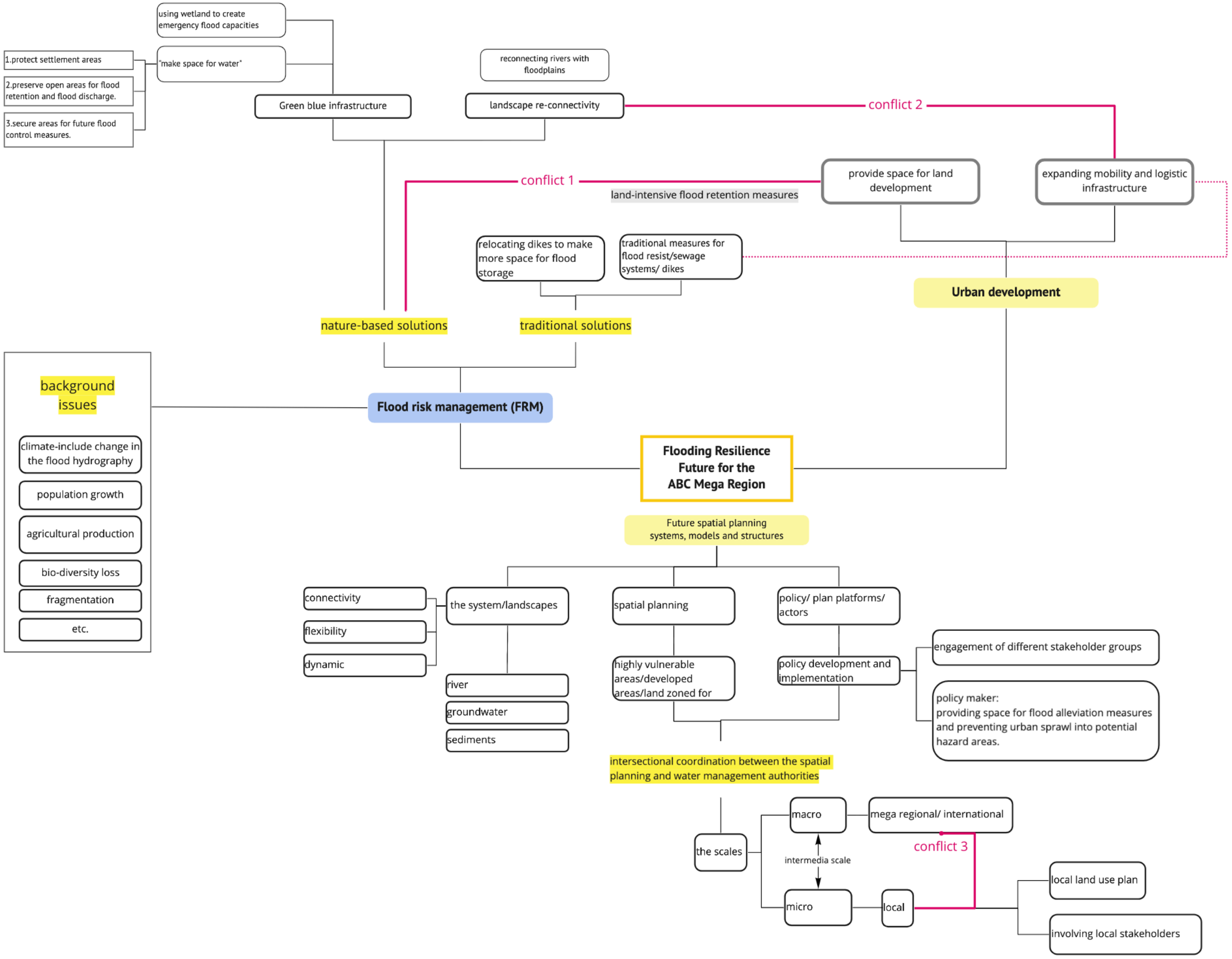
Figure: Nature-Based Solutions are a new focal point in the global effort to deal with climate change
Illustrate by Natasha de Sena, WER

CHAPTER 02

PROBLEMATIZATION

This chapter state the major conflicts for achieving the flood resilience future for the ABC Mega region.
Due to the neglect of the potential of ecosystems and green-blue infrastructure, as well as radical urban sprawl, the delta is at increased risk of flooding. A balance needs to be found between sustainable and resilient flood risk management and urban development in the future.

Problematization



With climate change, sea levels rising and frequent extreme weather events, the flood risk in the Rhine River basin is increasing. The Lower Rhine region is a globally renowned mega region with several mega cities therefore has a large number of inhabitants at risk of flooding. It has the strongest economic cooperation spanning three borders, but due to its political and cultural and historical reasons, the mega region is inevitably fragmented when it comes to issues involving social development and environmental issues, for example, flood management. The lack of systematic and scientific spatial planning and governance tools has resulted in the mega region not having integrated flooding management goals. In addition, the natural landscape is fragmented by the urban sprawl in the past few years, and the connection of nature landscape and the value of the ecosystems needs to be utilized and demonstrated in future flood management in the face of the new paradigm.

Conflict 1: Less spaces for nature

The ABC Mega region, one of the most economically developed regions in the world, has always had a high demand for urban development and expansion. Nature-based solutions, as an eco-system-based approach to flood management, are cheaper and more effective in the long term, but require a very large area of land. The need for urban densification is therefore crucial to balance the already scarce land resources with sustainable approach.

the change in land cover of urban sprawl

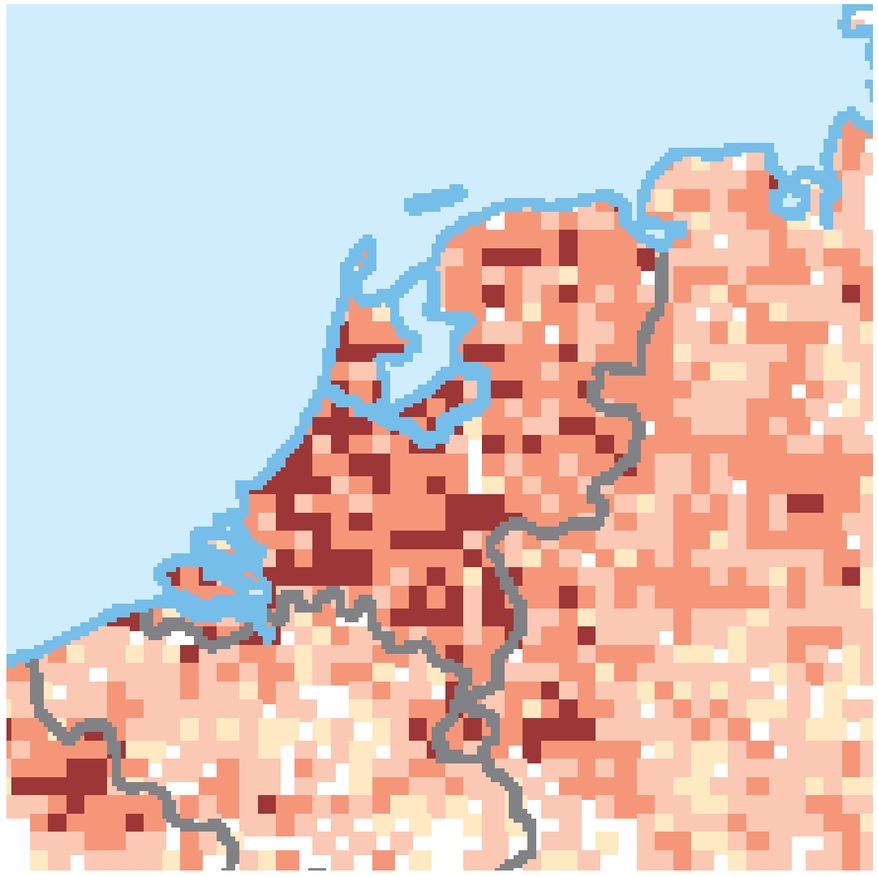


Figure: the change in land cover of urban sprawl
Source: ESRI | European environment agency

Conflict 2: The fragmented landscapes

The map shows how the urban landscapes are scattering the nature landscapes. The connections like green-blue corridors are cut off. And the green-blue patches are shrinking due to the expanding urban areas. The capacity of the nature-based solutions to deal with flooding is thus limited. In the riverine system, the river, as linear eco-systems, is particularly vulnerable to fragmentation, which causing interruption in natural water cycle and water run-offs balance. The wetlands, forests and other green-blue spaces which have the capacity of water retention and water absorption during peak flooding period needs to hence the spatial connection between each other. The total continuity of the dynamic rivers and riparian ecosystems is vital to activate the capacity of the ecological networks.

Fragmentation pressure of urban and transport infrasturcture expansion

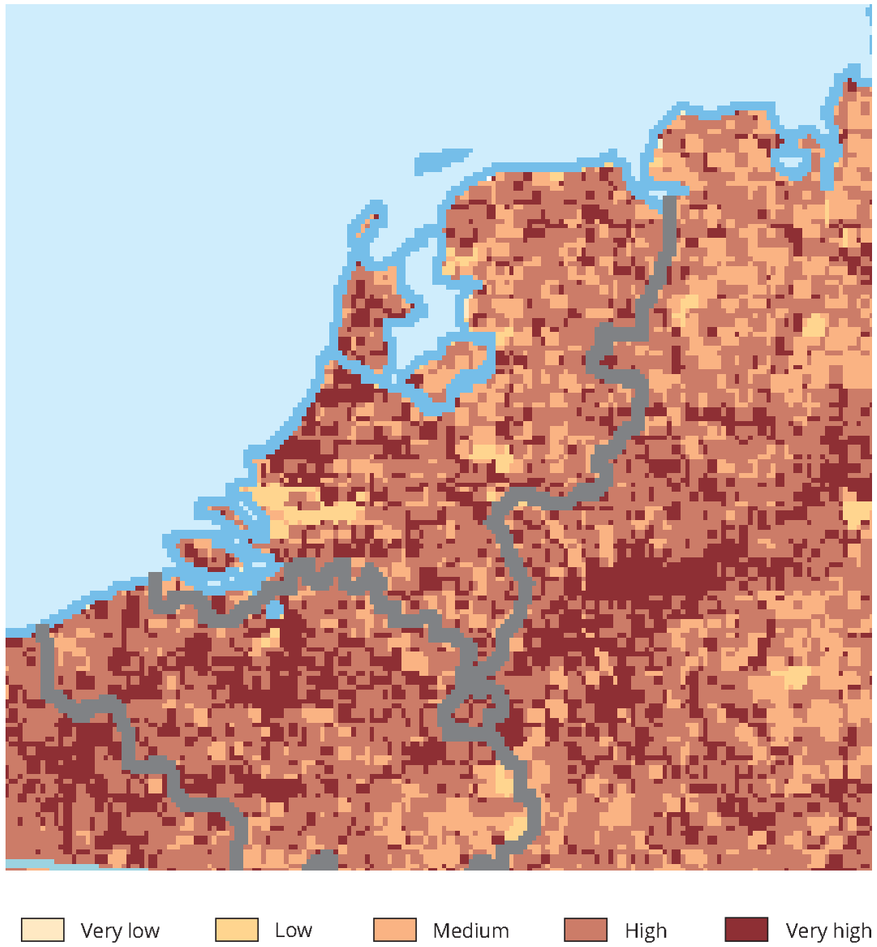


Figure: Fragmentation pressure (number of meshes per 1000km2)of urban and transport infrasturcture expansion
Source: ESRI | European environment agency

Conflict 3: Disconnected policy

The multi-level and crossing border governance cause complex decision making regarding to flood management in the ABC mega region.
The complexity is both in spatial scale and temporal scale.

The Netherlands has high potential of flooding with 26% of land below sea level. Thus, causing the governance of flood management more defense dominant. With lower diversification, the central and regional level water plays dominant role. While the Germany faces the rival flooding most, heavy rains primarily pose a threat to communities in the South and West of Germany (Brasseur, Jacob, &Schuck-Zller, 2017; Climate Service Center,2015; KLIWA, 2006). In Germany the water sector and spatial planning gaining equal importance. The participatory experiences of German federal states are considerably varied since the directive allows for a lot of leeway regarding the establishment of processes (Newig et al.. 2014: Newig, Kochskamper, Challies, & Jager 2016). These difference of facing, interpreting and dealing with flooding risks from inland to seaward causes fragmentation of flood management in the lower Rhine delta. Common integrated goals and approaches of flooding management are necessary in order to maximise benefits without causing misunderstanding and putting each other in danger to both upstream and downstream.

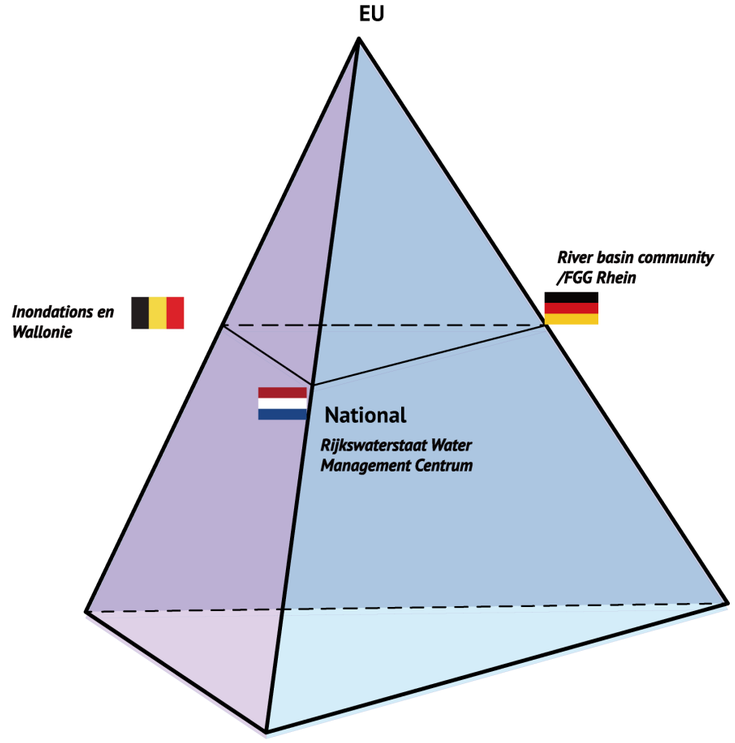
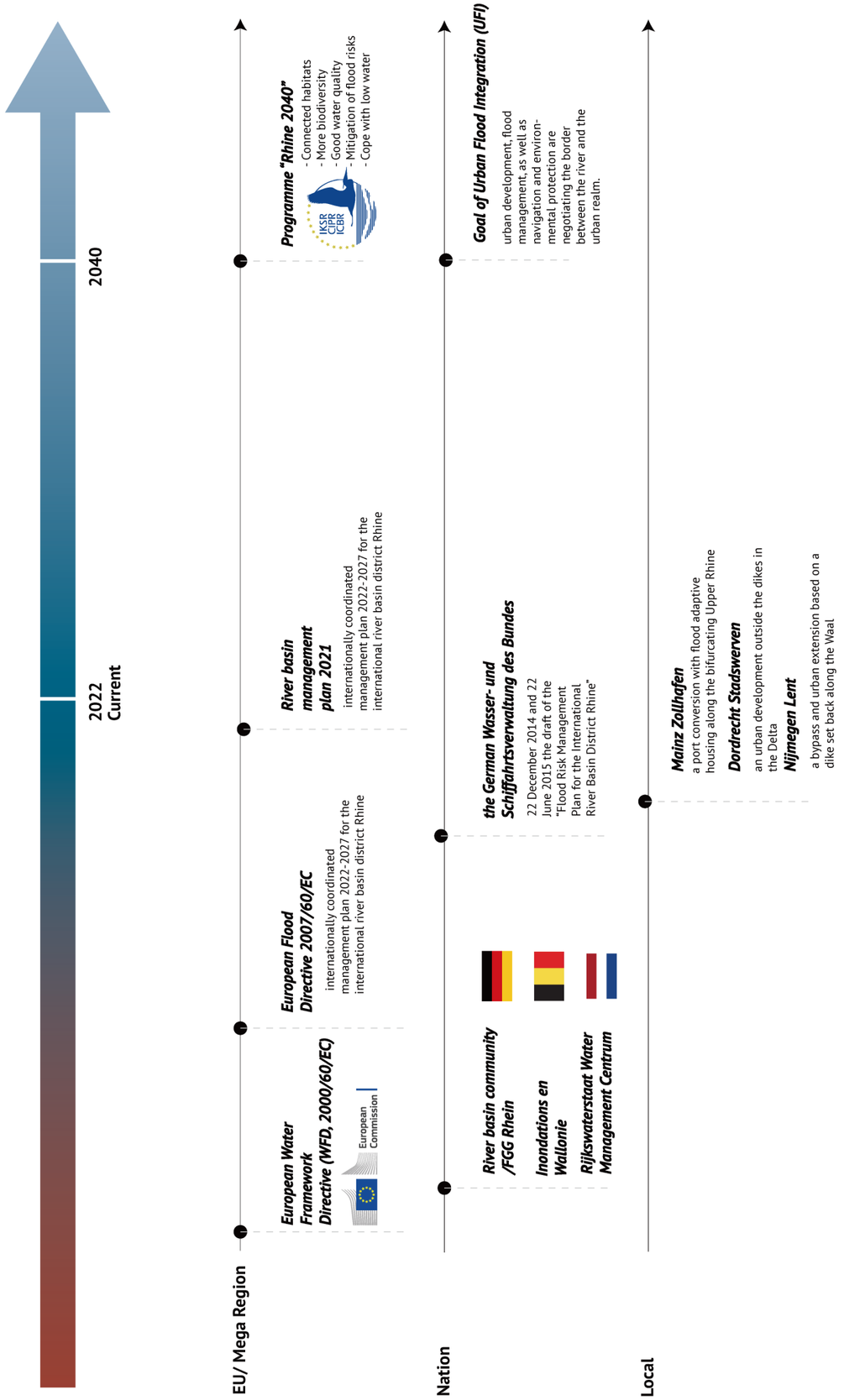


Figure: Fragmented governance and goals of flooding management
Illustrate by the author



Problem statement

In the lower Rhine basin, the ABC MEGA Region is faced with the increasing ***risk of flooding*** *caused by climate changing and extreme weather. The repercussions of over-modifying nature due to the urban sprawl and decay causing the* ***land scarcity and landscape fragmentation,*** *seems to put it in a more dangerous conditions. Crossing border and multi-level governance seems to be difficult to carry out an coherent flood management strategies.*

Spatial planning should be better involved in the process of flood management to ***recognize the dynamics*** *and to* ***activate the capacity of the green and blue infrastructure of flood resilience*** *as well as* ***guide the expasion and form of the cities*** *in the ABC Mega Region.*

METHODOLOGY

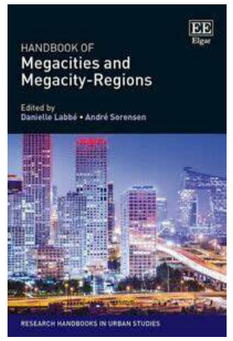
This chapter highlights the main theories used in this thesis, namely nature-based solutions and mega region, as well as other relevant theories that underpin the theoretical framework of the study. It also covers the research questions, aims as well as the conceptual framework and scales used in the study, which clearly explains what the thesis is about and how the thesis is conducted.

Theoretical framework

Mega regional design

There is no longer any meaning to former conceptions of a binary division between "urban and rural," we should see the metropolis, the big and small cities, the villages and rural area as a whole system. (Danielle Labbé, 2020)

The process of metropolisation also brings entirely new challenges for planning and governance, including the need for an integrated policy agenda which treats the space such as 'urban', 'suburban', 'rural' or 'natural' as parts of an imprecise geography rather than distinctive physical features (Cardoso R, Meijers E, 2020a)



Governance of the megacity - regions

(ICPR – International Commission for the Protection of the Rhine)

IKSR
CIPR
ICBR

NBS nature-based solutions

Nature-based solutions (NBS) have recently been put for- ward by practitioners (in particular the International Union for Nature Conservation, IUCN) and quickly thereafter by policy (European Commission), referring to the sustainable use of nature in solving societal challenges.

Green-blue infrastructure and flood risk control

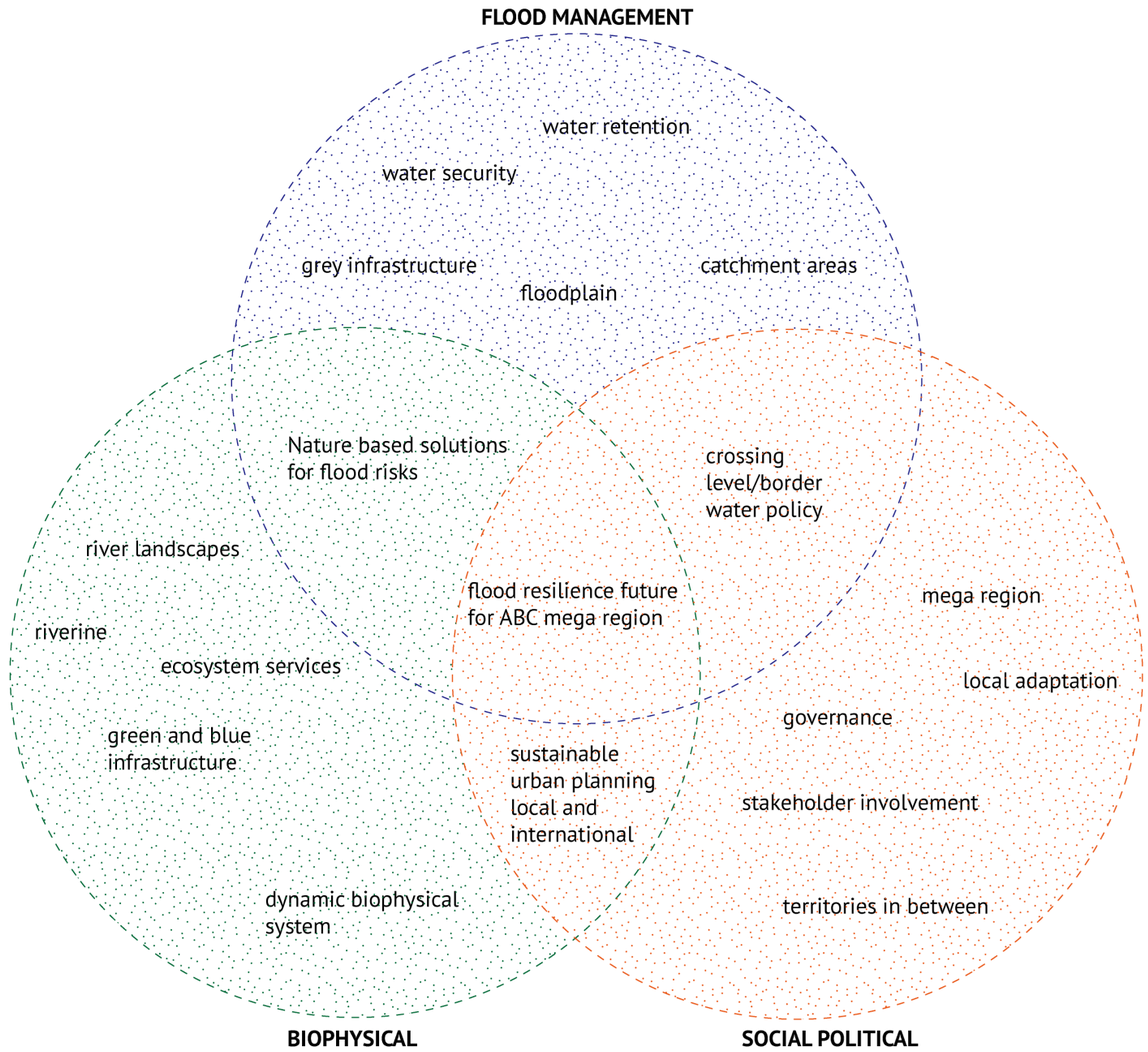
Water Sensitive Urban Design - WSUD (Water Sensitive Cities, 2014)

Blue-green infrastructure is a possible way to create multifunctional surfaces with environmental and social functions. (Demuzere et al., 2014)

Make Space for Water in the UK (Butler & Pidgeon, 2011)

Room for the River in the Netherlands (Neuvel & Van Den Brink, 2009)

Combining Green-Blue-Grey Infrastructure for Flood Mitigation and Enhancement of Co-Benefits



Methods

COGNITION

Literature review:

Summarize and reflect on the previous studies, concepts and theories about the flood management especially aliens with the approach of nature-based solutions or green-blue and grey infrastructure.

Data collection:

Collect the data of flooding information and other systems related to flooding risks, and search for the policy support of applying nature-based solutions for flood management from the level of international (EU) to local.

Visualization:

Using drawings, photography, and other media to form a detailed image of the previous and current conditions about the study areas.

DECONSTRUCTION

Cartography:

Observing: Mapping the information of previous or current conditions which could be reflect on the map about the study area for better presenting and understanding the basic information of the mega region.
The cartography will be developed in the four lines of inquiry, matters, topos, habitats and geopolitics, which present the existing issues and potential for flood resilience future in ABC mega region.

Compare and Conclude:

As flooding risk and flood management are very site specific applied, it is importance to compare different types of flooding risks in the whole mega region from inland to seaward and conclude the commons and differences. Using diagrams to show these kinds of information. Also, using diagrams to compare the difference of the crossing border and multi-level governance and power holders.

Typologies analysis

Using typologies analysis to identify different kinds of nature-based solutions that should be applied according to the related systems of flood risk in local conditions such as land use, soil type, infiltration conditions, functionality of the riverbank and riverbed, etc.

TERRAFORMING

Cartography:

Projecting mapping: Using the data and drawings from the observing mapping and find out the most crucial areas which faces the higher risks or have more potential to be transformed.

Scenarios proposing:

Combing the different levels of risk in the local conditions regarding to the demand of densification or expansion and eco-system enhancement to propose site-based scenarios for the cities in the mega region.

Case study:

By the steps of opportunity, suitability, availability and applicability, using case studies to show how the theories and strategies can work out in the real situation. Choosing local conditions in critical areas as case study to understand how nature-based solutions is chosen and applied, how the local and national or international stakeholders are aligned and involved and how nature and urban landscapes are terraformed. The local transformation would show the value of the complicate adaptive system of the interrelationship between urban and bio-physical system, and support to accelerate the transformation to be expanded in the whole ABC mega region.

Design:

Using spatial planning and design to upscale the local conditions and try to put forward a vision for the new network in the mega region. Spatial design would also show how to transform and improve the spaces for the human well-being. And temporal design would show how to accelerate the transformation of the whole mega region from the local adaptation.

REFLECTION

Reflection:

Reflecting the process and approach of the study to develop a comprehensive research outcome to better understand the dynamics of the complex adaptive system of the interrelationship between urban and bio-physical system. Reflect on the accumulation of the process of urban development and propose for a better and flood resilience future.

Main research questions

How to use Nature-Based Solutions to create a multifunctional and mega-regional network aline with local adapations to collaborate for the integrated goals of flood management of crossing border and multi-level governance in the sight of future urban development in the ABC Region?

Sub-research questions

Flood Management

-- How is the flooding risk in the ABC Mega Region in the future?

-- How is the current flood management elements distributed (waterways, flooding zones, flooding plains, etc.)

Nature-Based Solutions

-- How is the current situation of the green-blue infrastructure and fragmented landscapes in ABC Mega Region?

-- How is the Spatial potential of setting up a green-blue infrastructure network in the region?

-- How to active the green and blue spaces to apply the nature-based solutions?

Mega Regional Planning and Design

-- How is the current form and of metropolitans in the ABC mega region?

-- Where is the crucial areas? (where are the risks? Where are the dis-connectivity of landscapes?)

-- What the configuration and expasion of the form of mega region could be for a flood resilience future?

-- Until what extend can the mega regional development be guided by the projection of the flood management?

Local adaptation

-- How to transform the mega regional core of recognizing flood risk and nature potentialities of green and blue infrastructure in local conditions?

Sectors and Actors

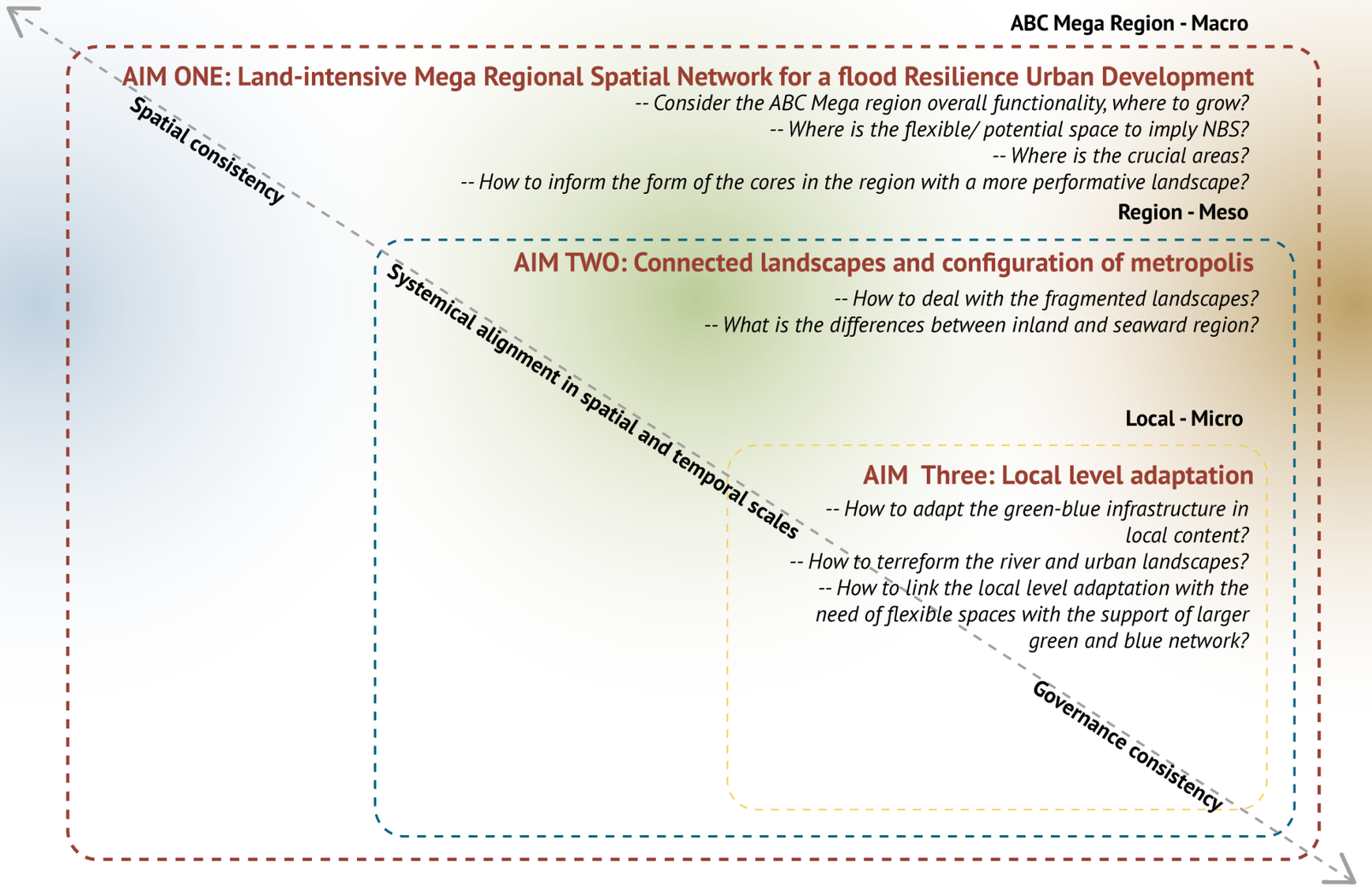
-- How the multi-level polices and governance dealing with the crossing border issues can facilitate systemic integration of nature-based solutions?

-- Is there potential to set up the integrated flood management goals of the crossing border governance?

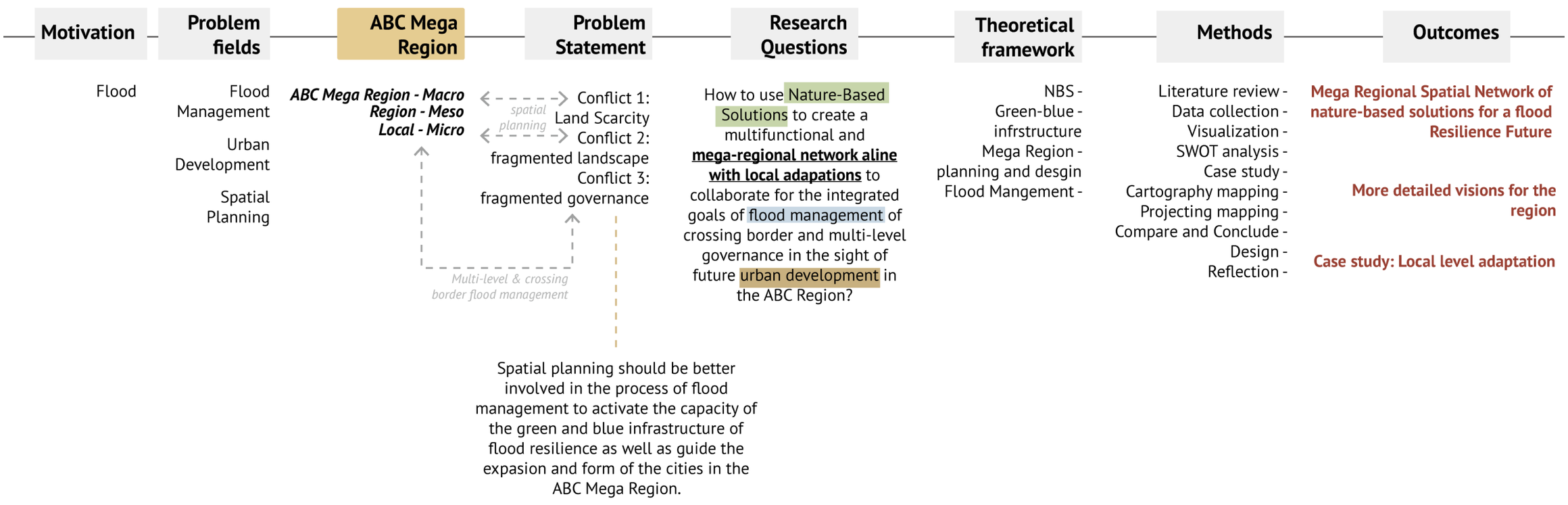
Flood Management

Nature-Based Solutions

Urban Development



Conceptual framework



CHAPTER 04

ASSESSMENT AND PROJECTION

This chapter is divided into two parts. Assessment uses a series of mapping, sections and diagram to show the situation and emergency or chances to transform and projection to indicate the possible measures to solve the problems. The cartography categorized by four lines of inquiry, matters, topos, habitat and geopolitics. Each of inquiry explore series of key element related to the research topic.

Matter

The water systems

Matter, as the starting point of these four inquiries, reflects the effect caused by accumulation and the elements studied in the inquiry, which is water in this project.
There are two river basin located in the ABC mega region, which are the Rhine river basin and the Meuse delta. The map is showing the river streams, flood plains, coastal areas as well as the water transportation element such as ports.Flood risk control measures, such as river embankments, are a system that is currently operating efficiently in the mega region.

The water systems

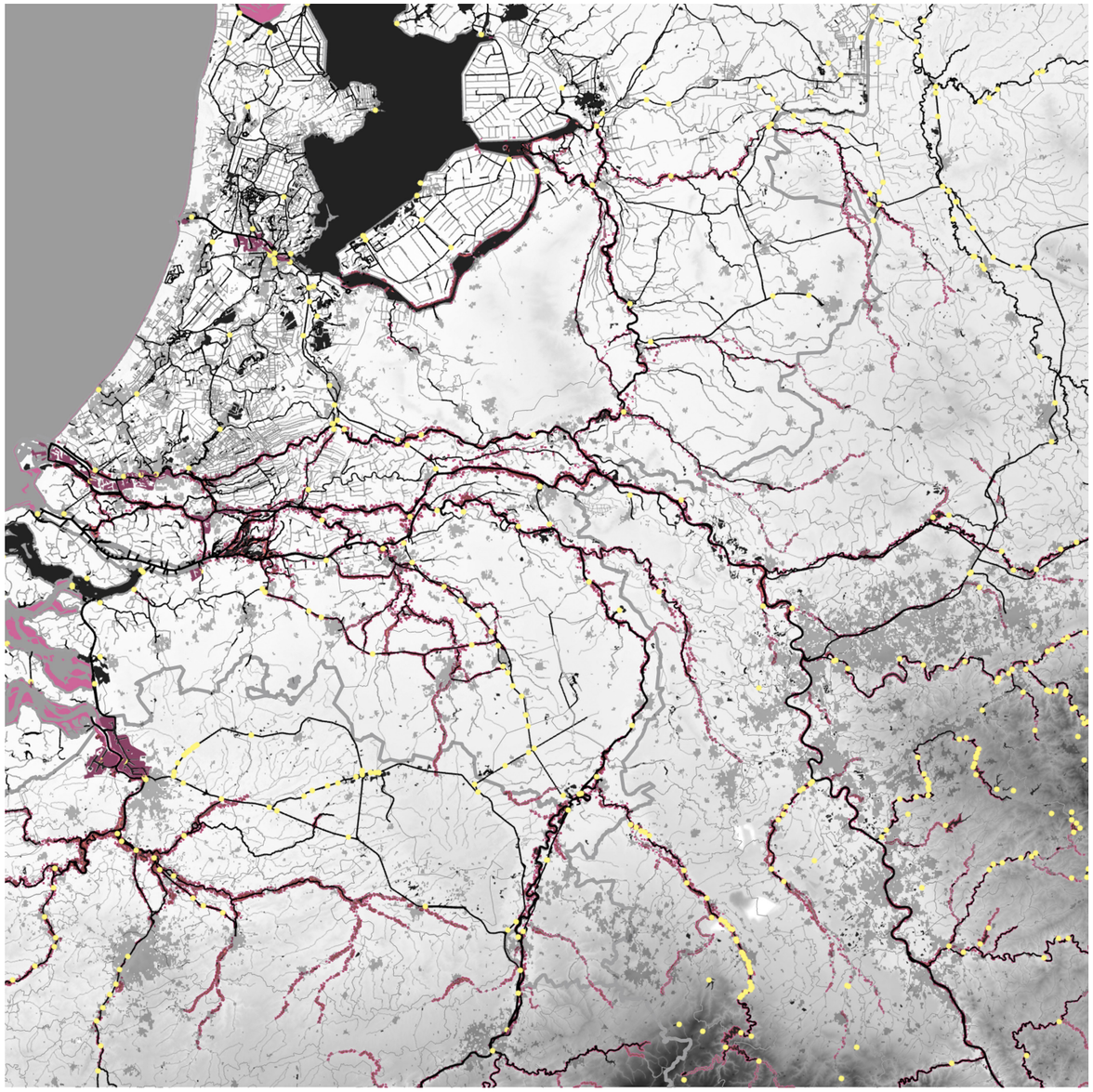


Figure: the water systems
Illustrate by the author
Source: AMBER Consortium, 2020

the flood risks

In order to study and build a flood resilience future for ABC mega region, it is necessary to first understand the water systems and the distribution of flood risks throughout the whole region in the macro scale. Due to the terrain and the rich distribution of the river networks, the Netherlands, located in the lowlands, is exposed to a huge flood crisis. In addition, the red and yellow colours along the river warn of flood risks that require attention.

flood risks in the ABC Mega region

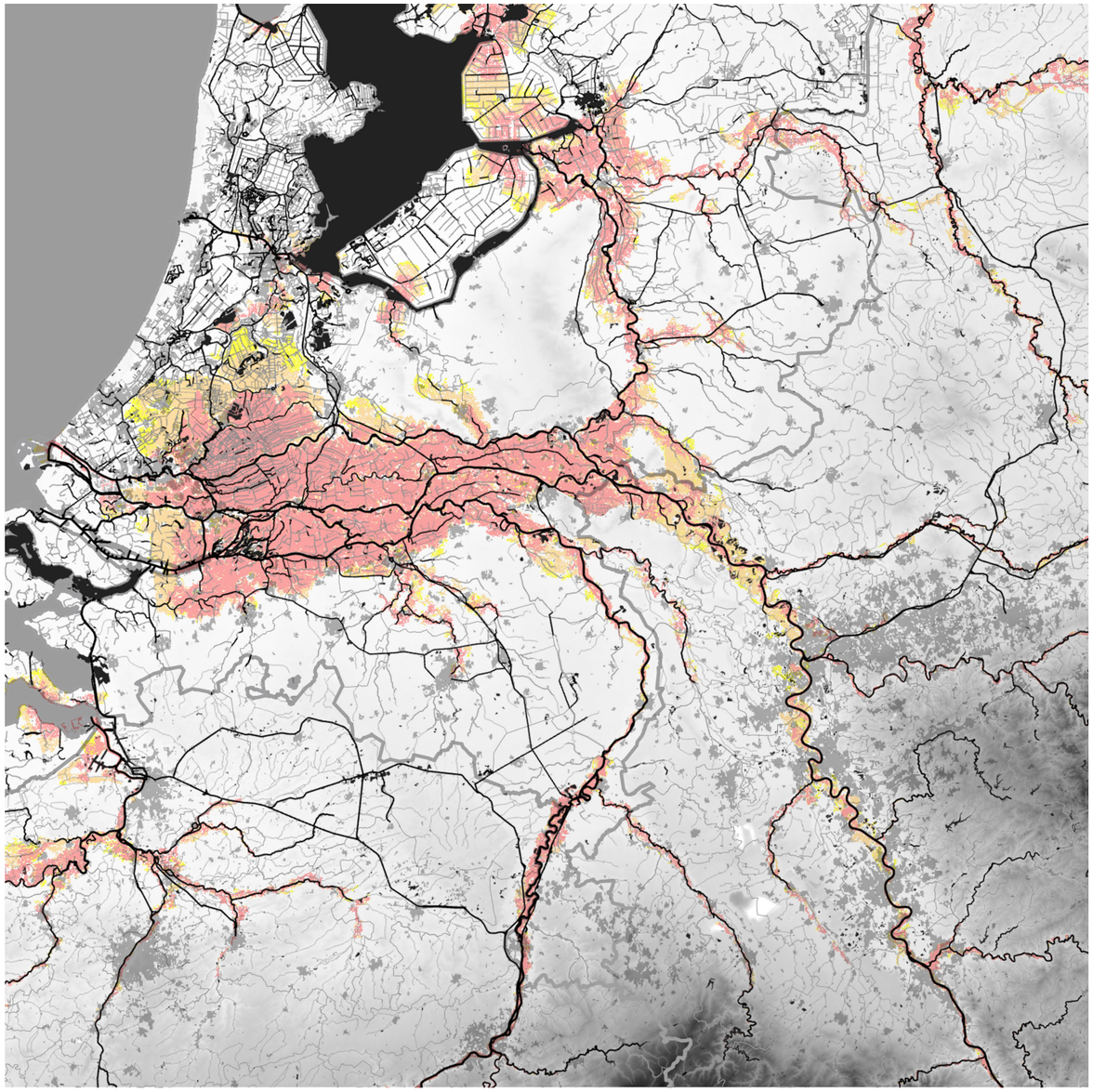


Figure: flood risks in the ABC Mega region
Illustrate by the author
Source: Joint Research Centre (JRC), 2016

Risk of sea level raise

The ABC mega region is located at the mouth of the Rhine basin. Apart from the mountains in the south-eastern part, the overall terrain is basically flat. However, some areas are still below sea level and are therefore at constant risk of flooding due to sea level rise. Some of these areas below sea level are even densely populated metropolitan areas, while others are more rural and natural areas.
At a time when the global climate is changing, sea levels rising and extreme weather events are causing the balance of the global water cycle to be disrupted more frequently. The crisis of solving the flooding problem is already imminent.

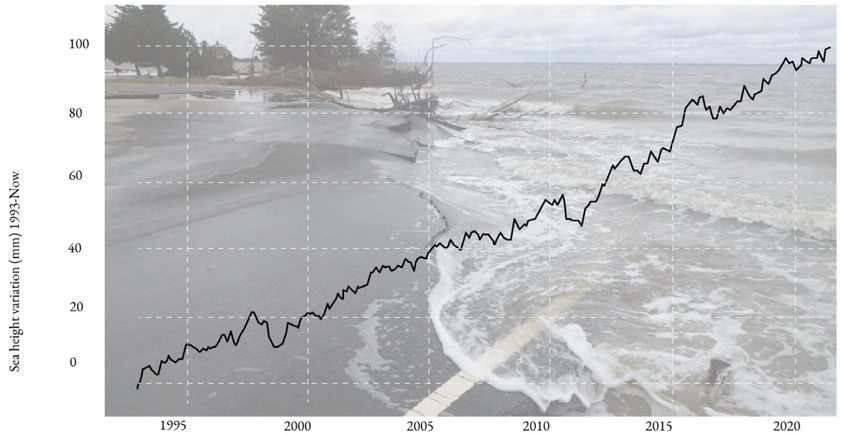


Figure: Sea level raise 1993-now
Illustrate by the author
Source: Climate.gov, 2020

Terrain sections, areas below sea level in ABC Mega region

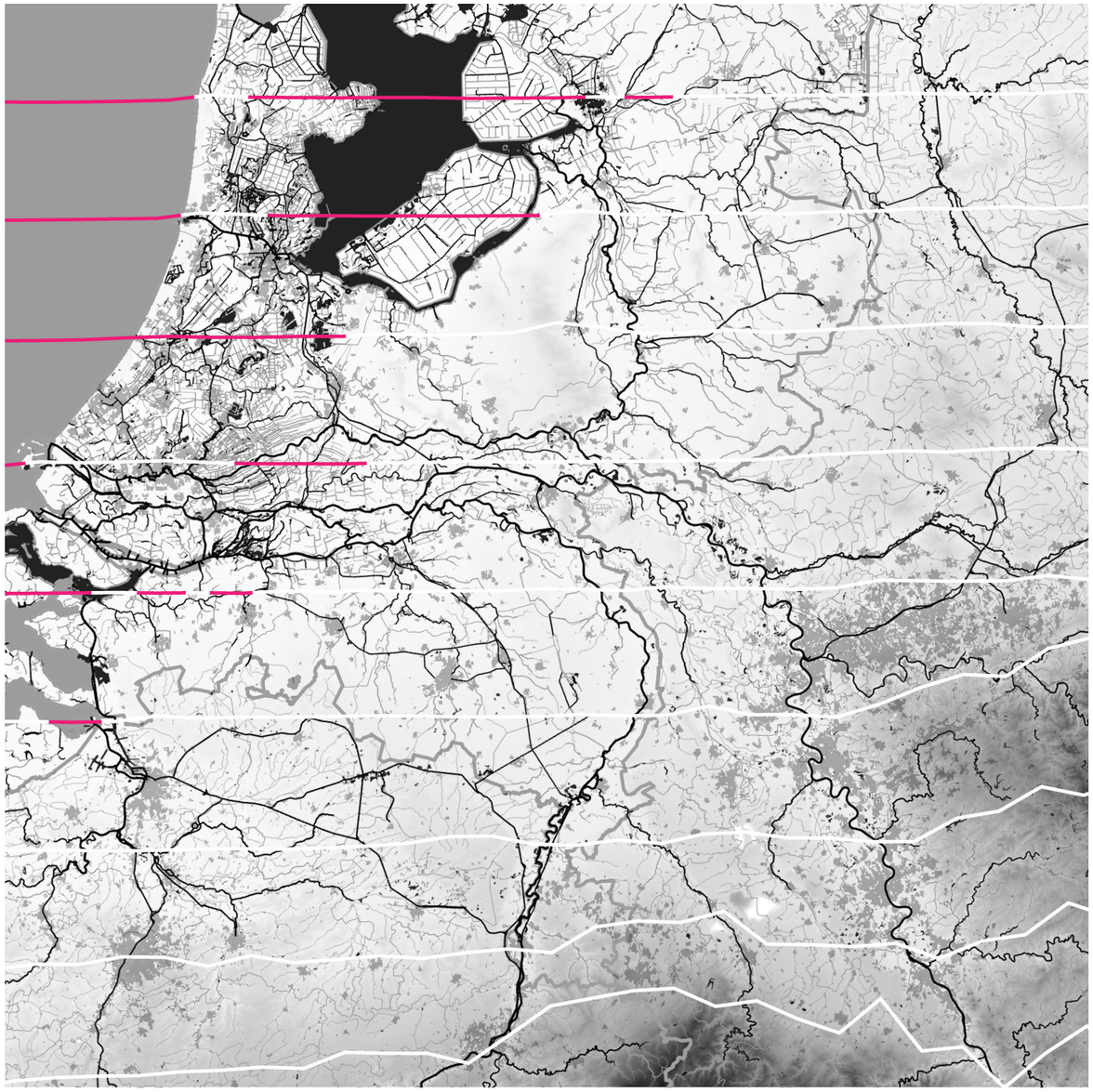
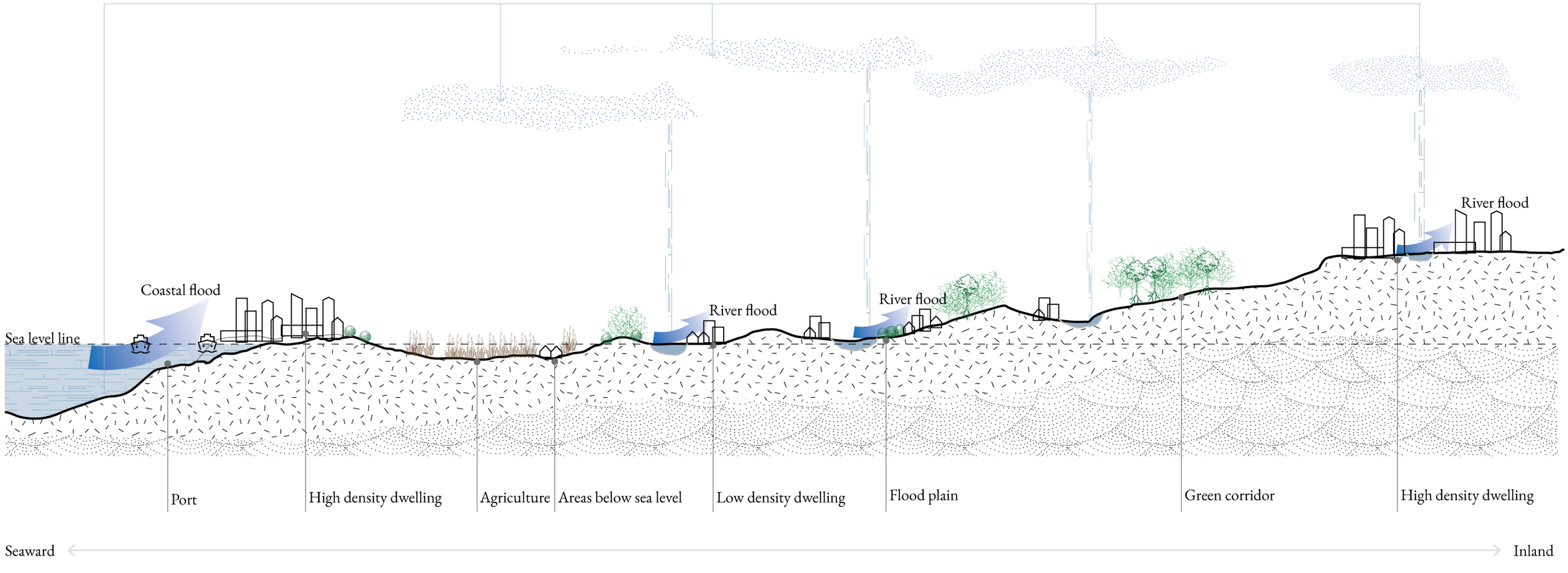


Figure: Terrain sections, areas below sea level in ABC Mega region
Illustrate by the author
Source: DEM,2015

the flood risk: inland and seaward

.The mega region as a whole system is not simply a dichotomy between urban and rural. The profiles show different kinds of flood risks faced by the mega region from inland to seaward, the possible locations of crises, and the potential spaces which might be used to address them.



Topo

Pressure of urban expansion

Topos reflects the series of changes brought about in the process of accumulation to the site itself. These changes are non-biotic. The diagram shows the changes in landcover that have occurred over the last twenty years as a result of urban expansion. The red areas show the space where urban landscapes have replaced the original nature landscapes. In addition to the expansion of areas around large cities, the expansion of small towns in the in-between territory is also noteworthy.

Urban area change 1992-2019

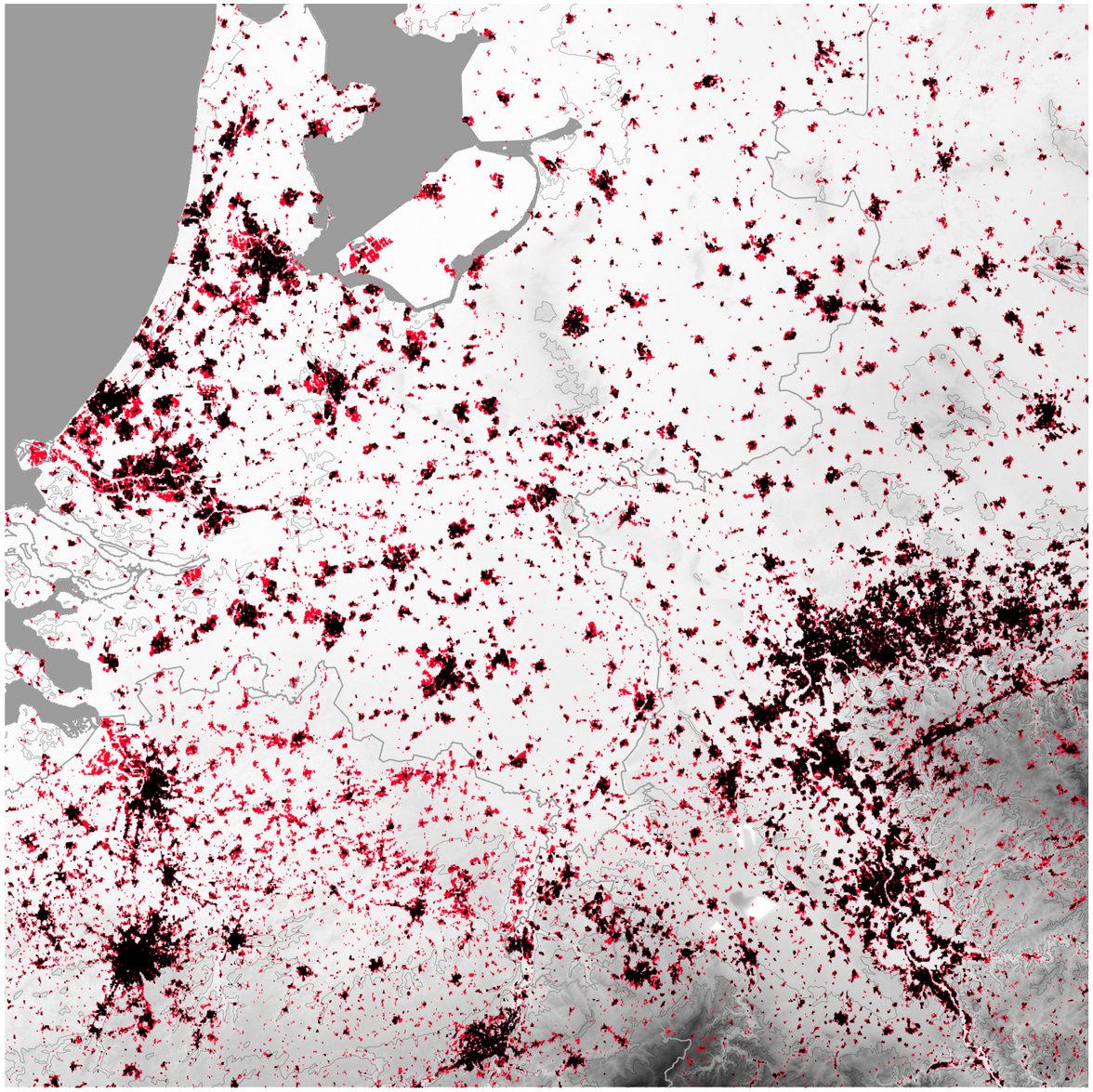


Figure: Urban area change 1992-2019
Illustrate by the author
Source: Corponicus , 2019

the mobility network

The Mobility network shows the level of development and connectivity of the whole city. The ABC mega region is the most economically developed delta and the connectivity between cities is very good.

the mobility network of ABC Mega region

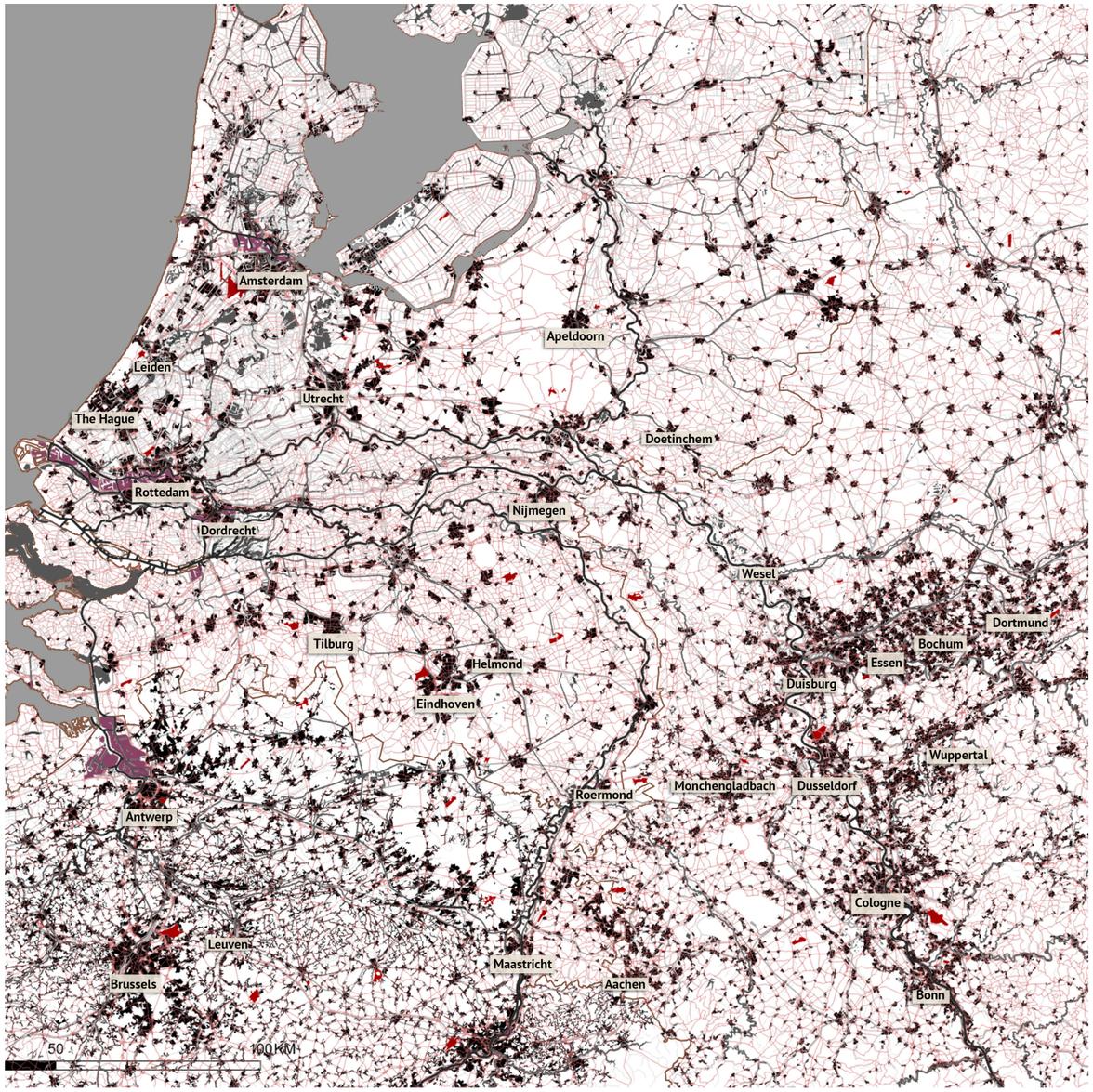


Figure: the mobility network of ABC Mega region
Illustrate by the author
Source: Corponicus , 2019

relationship of cities and river

In the past, the natural conditions on the banks of the rivers were such that people began to gather there and gradually formed cities. Cities were born from water.

Over time, the interrelationship between urban and bio-physical systems especially water in this study has change, just as the transformation of urban landscapes and river landscapes. These different pattern of river and urban landscapes showed on this map reveal different urban forms and spatial relationships. The study of rivers and water is therefore very important for the future configuration of urban agglomerations. Of course, with the city expanding or shrinking, this interrelationship between urban and bio-physical systems are not permanent and constantly changing, so we should see the interrelationship as a dynamic system.

The representitive cities morphology of river landscapes and city landscapes

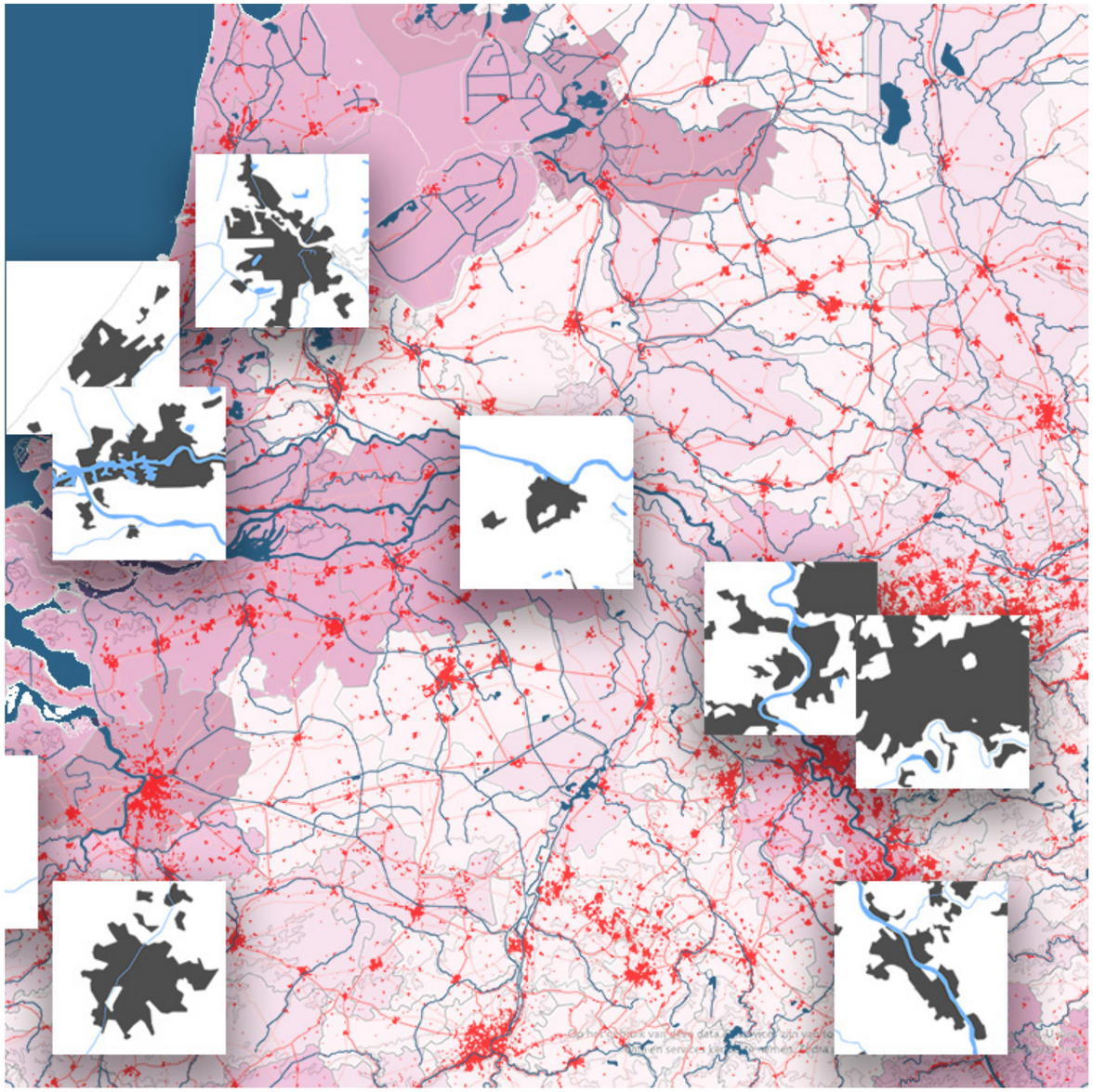
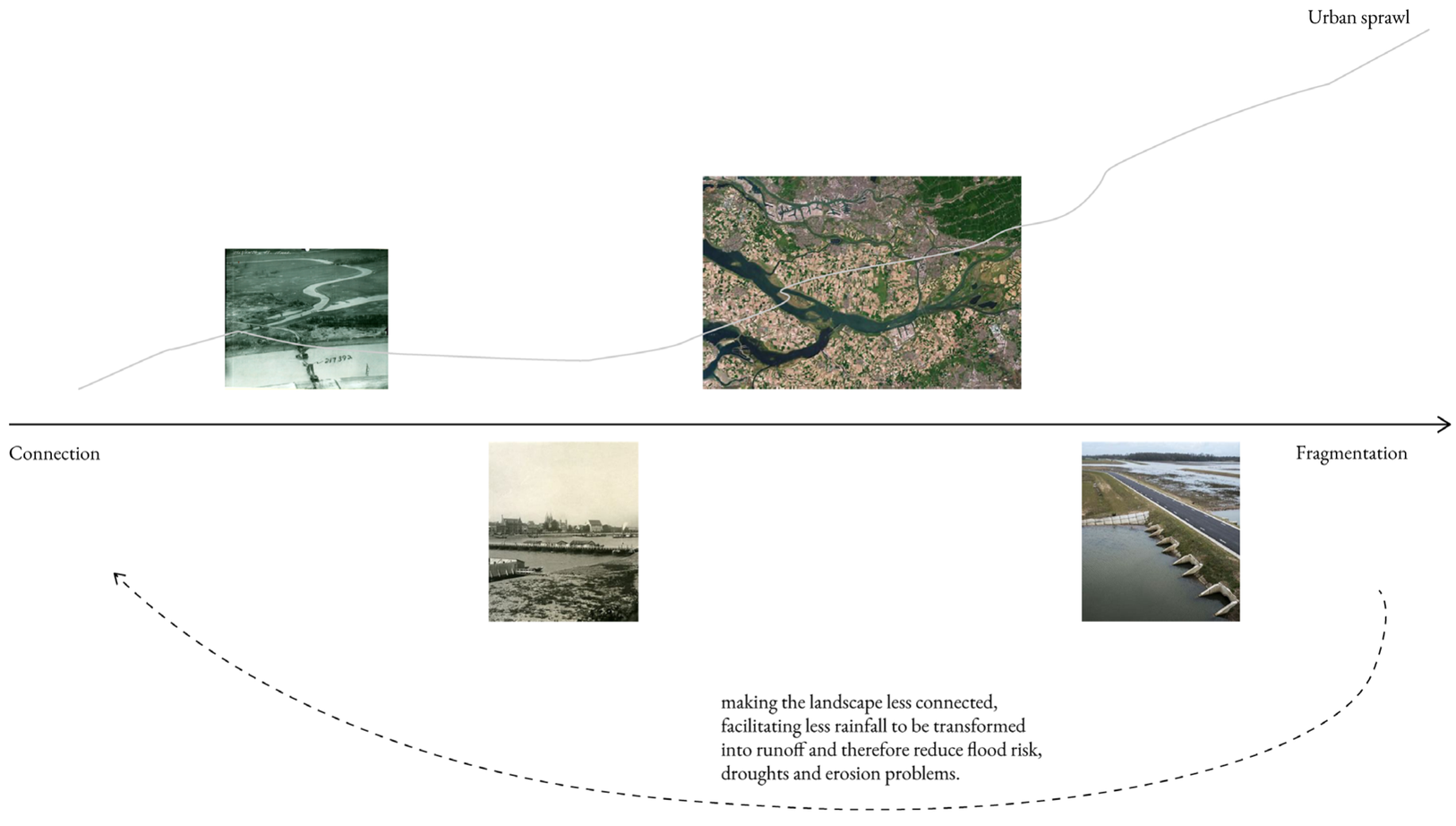


Figure: The representitive cities morphology of river landscapes and city landscapes
Illustrate by the author
Source: Flooding atlas of Rhine River, 2020 and Corponicus , 2019

the fragmented landscapes

Under the objective of flood resilience future for the ABC mega region, the contradiction between nature landscapes and urban landscapes is that the accumulation of development of urban landscapes, including urban and mobility infrastructures, causes a significant increase in the fragmentation of nature landscapes. The connectivity of landscapes influences the risk of flooding to some extent. A new paradigm needs to be set to address and acknowledge the dynamic balance between these two.



Habitats

challenge and opportunities, the changing population

According to the demographic data, there is a need for urban expansion in the ABC mega region due to the growth of the overall population. Within the mega-region, large and small cities are facing different population trends. Some are growing dramatically; others are facing stagnation or decline. ABC mega region as a whole system, the demand of expansion of all cities, including small, medium and large ones, as well as the rural areas, need to be taken into account.

In the face of land scarcity, an analysis of population growth trends can reveal which cities will face greater expansion pressure in the future and which areas have more space. These spaces have the potential to be used to apply nature-based solutions, as a buffer zone for the population pressure areas and to absorb part of the flooding.

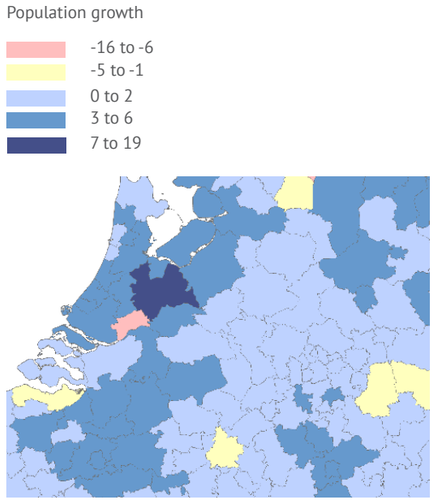


Figure: the population growth rate
Illustrate by the author
Source: NTUS , 2018

Figure: the Increasing population in ABC Mega region
Illustrate by the author
Source: Surostat,2020

Areas of population growth and population decline

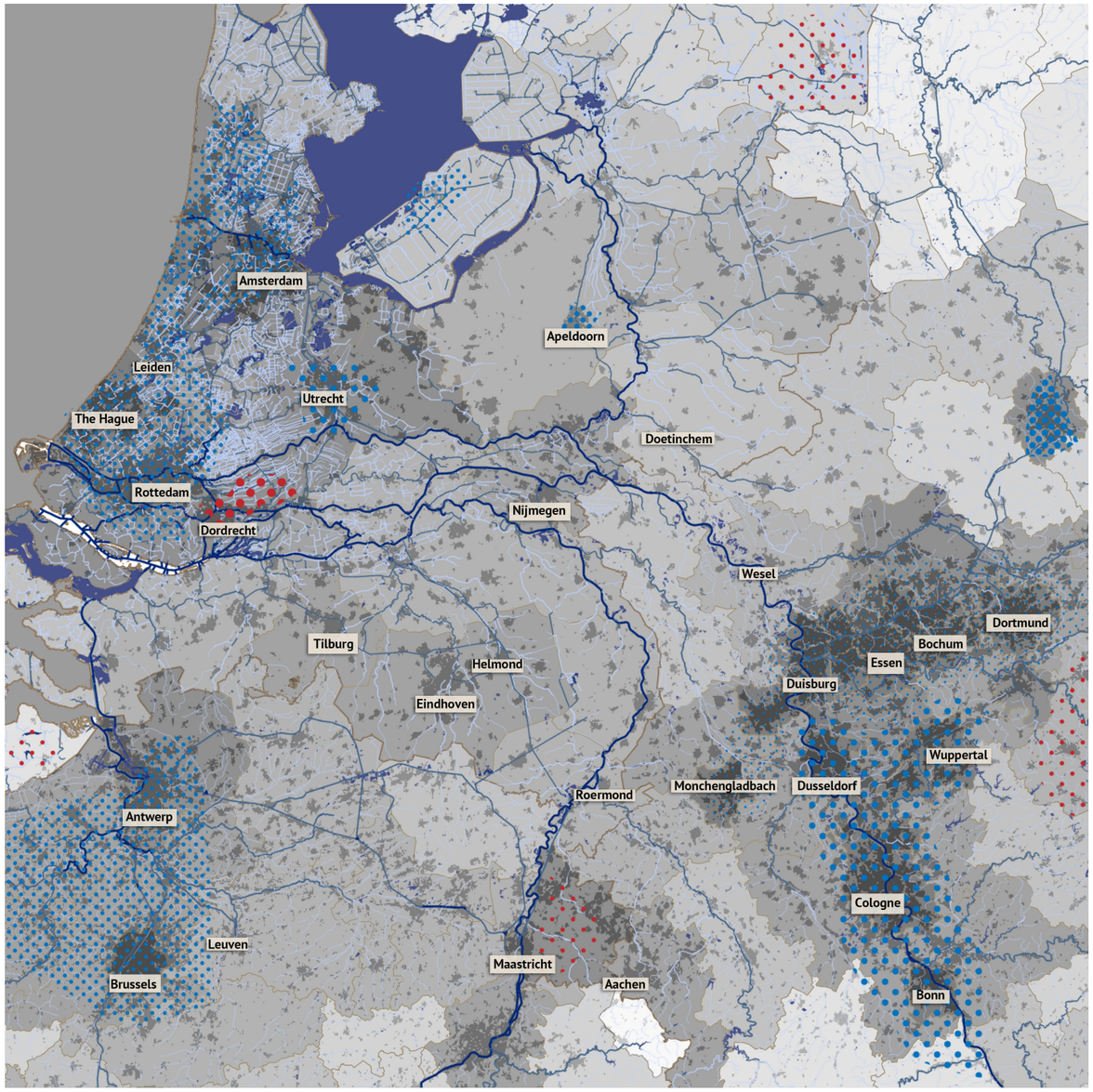


Figure: Areas of population growth and population decline
Illustrate by the author
Source: Source: NTUS , 2018

Geopolitics

Policy support

The study in the line of inquiry of geopolitics takes a more macro and policy perspective, considering the current situation and potential of the elements of study itself and its associated socio-economic and cultural ecological aspects. The various research directions mentioned in the previous inquiries overlap with each other and become the combined information that decision-makers need to grasp in order to build a flood resilience future. The diagram shows the existing ecological protection and flood policies related to the nature-based solution, overlaying these multiple spatial policies from a mega regional planning perspective.

Policy related to flood management and nature landscapes protection

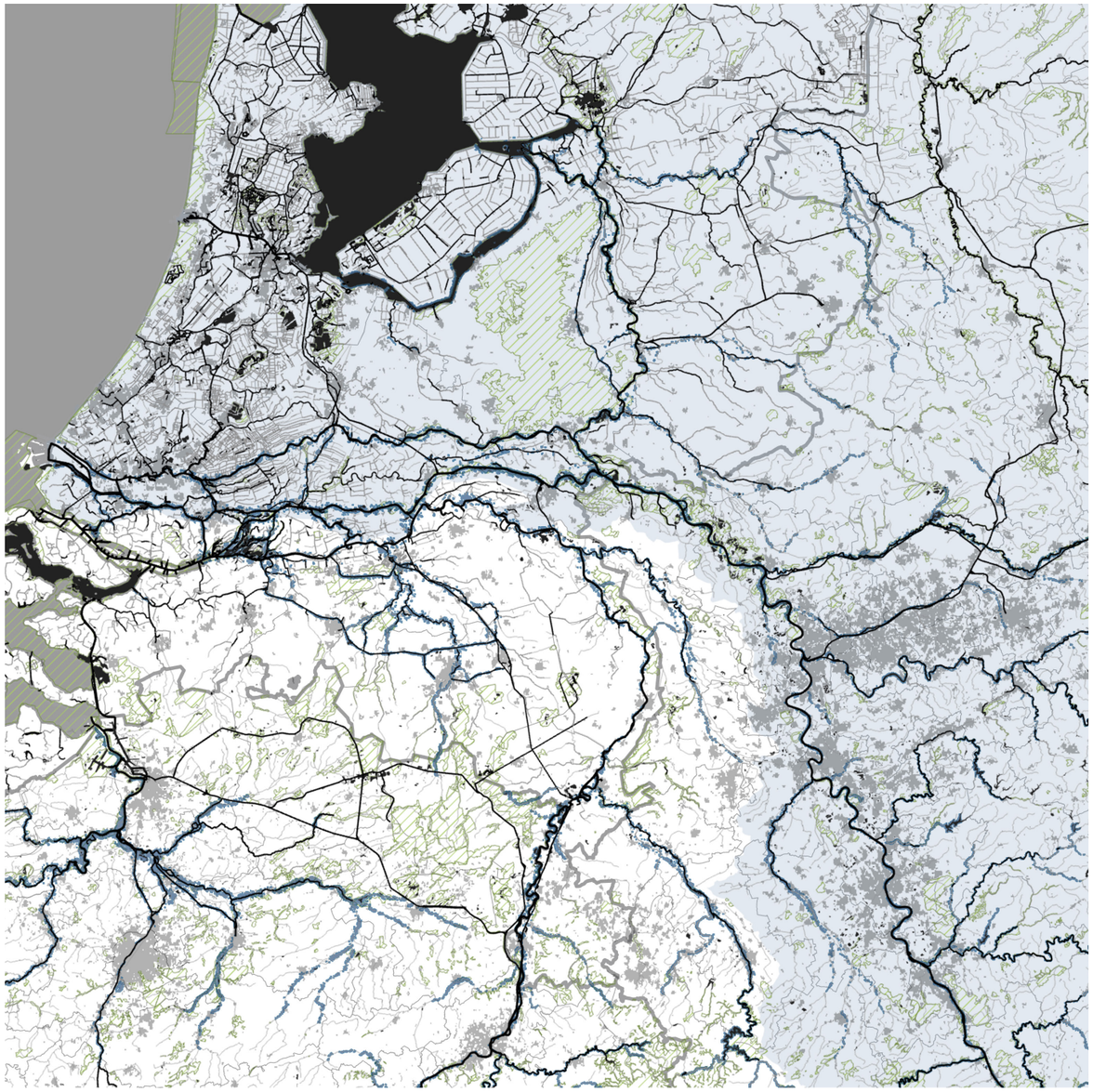


Figure: Policy related to flood management and nature landscapes protection
Illustrate by the author
Source: Copernicus,2017 and Natura 2000

Geopolitics

Complexity of the situatiion

Different countries, different river basins, complex and severe flood risk environments and various policy strategies related to flood control and ecological facility enhancement make the design and implementation of a flood resilience future for the whole region challenging.

Composite mapping

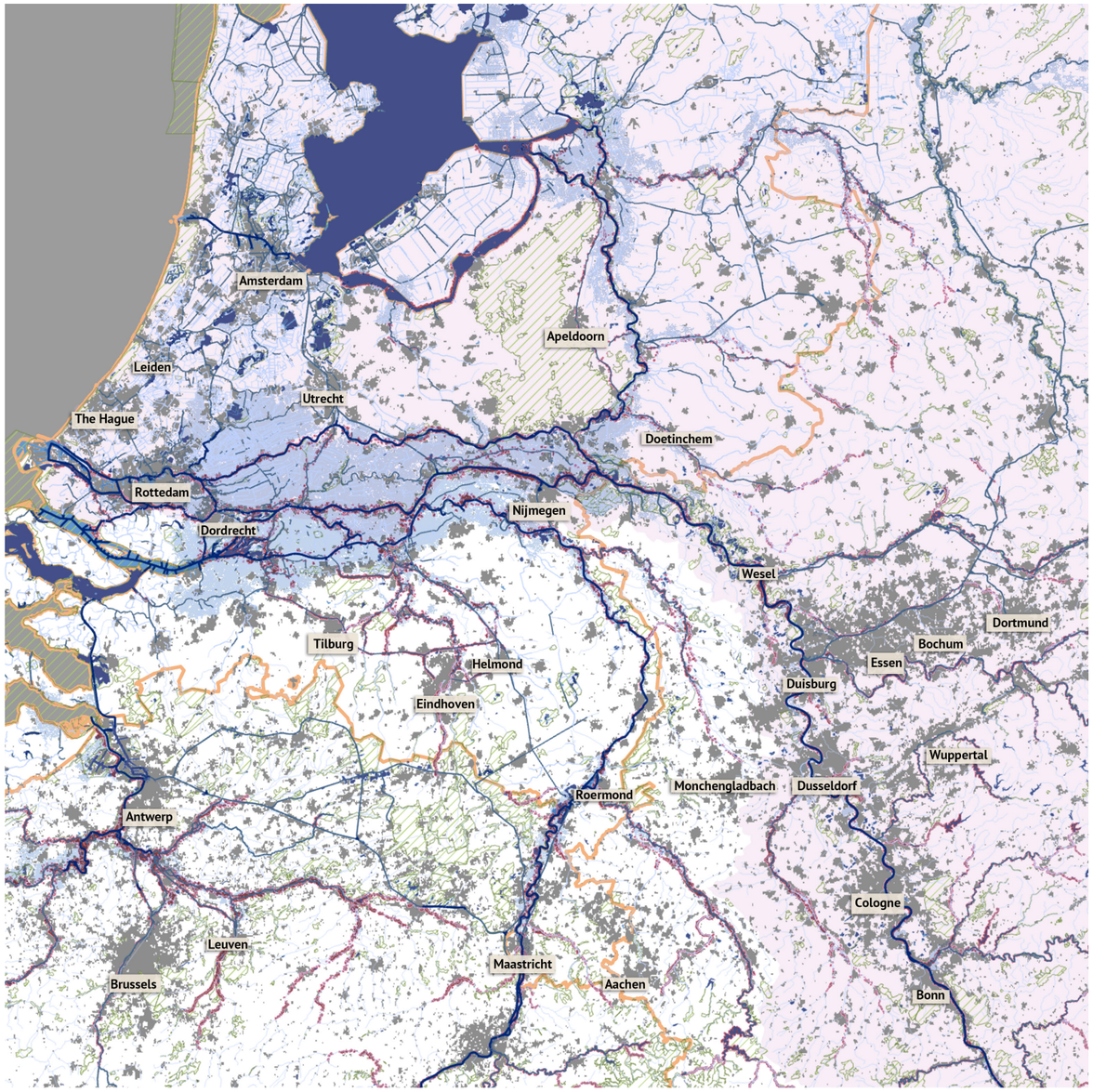


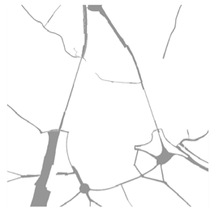
Figure: Composite mapping
Illustrate by the author
Source: Copernicus,2017 and Natura 2000

Projecting

'Water" as solutions

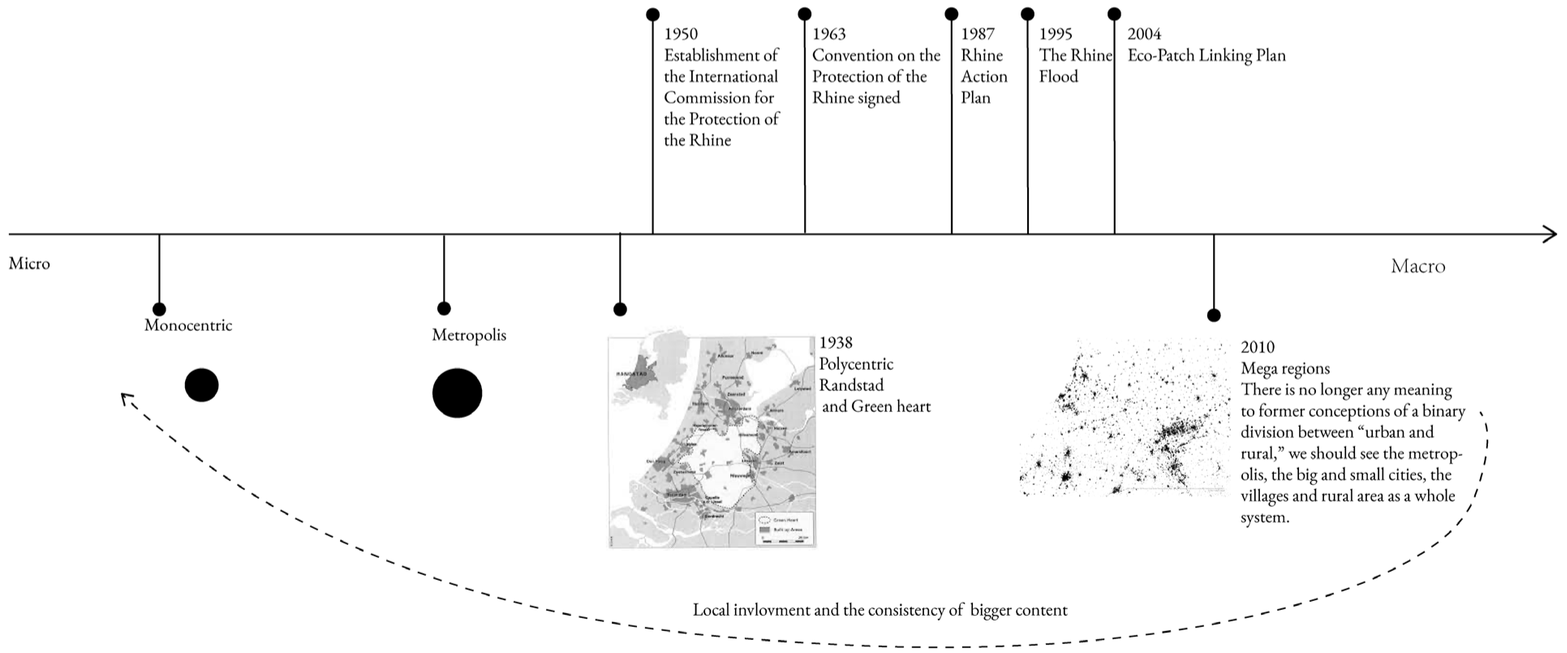
In the past, rivers and waterways were used as a major transport route, influencing the shape of each individual city and transforming the urban landscapes. Nowadays, water connects the entire mega region and is an important factor in the configuration of the future mega region.
With water as the lenses that guide the research, from flood risk management to the future development of the mega region, a holistic approach is required. Water as an element of research significance at both the macro scale and the nano scale is the real backbone that links the whole study.

Water
As the backbone of connection



Infrastructure
As the backbone of connection
Causing the fragmentation of nature environment

Water
Nature based solutions
As the backbone of connection



Projecting

Terreforming the river landscapes

By terraforming the river landscapes, the rigid boundary between cities or territories in between and rivers are removed and replaced by a softer and more organic transition space, applying nature-based solutions for flood risk control.

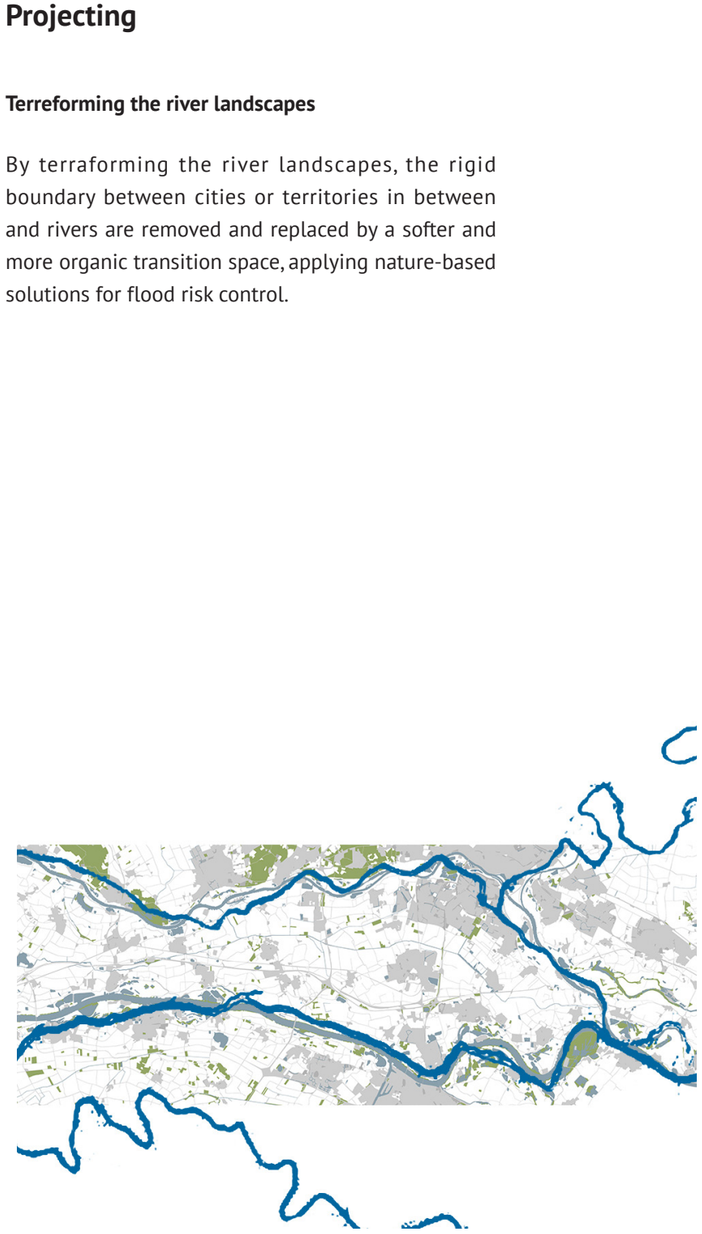
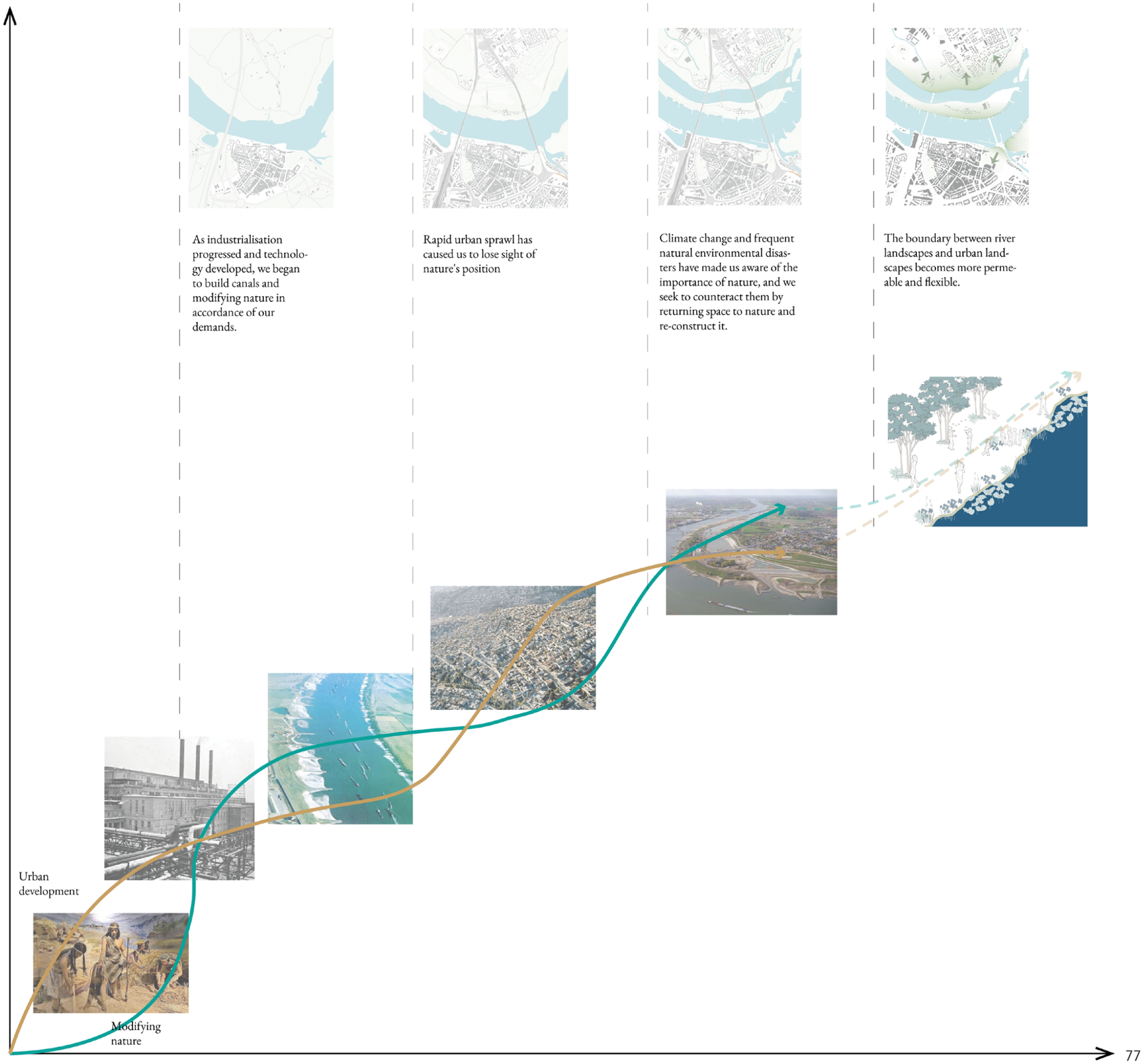


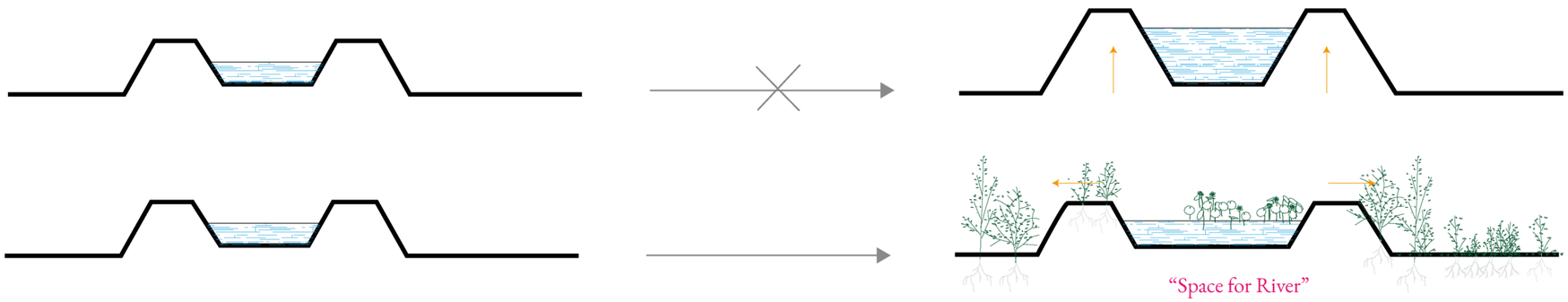
Figure: current and ancient water course
Illustrate by the author
Source: Openstreetmap, 2021

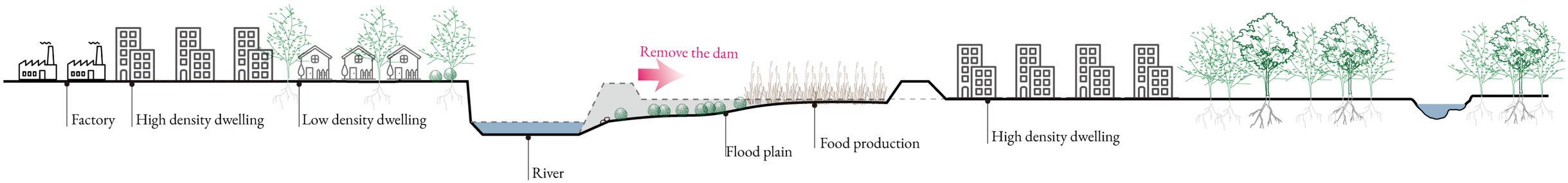


Projecting

“Space for river”

Flood risk control is achieved by increasing the area of the river through 'space for river' and enhancing eco-system services throughout the system associated with the river. The strategy differs from the traditional approach of raising the embankment by maintaining the original embankment height and creating more resilient and versatile riparian spaces.





Projecting

Flood peak season and post disaster season

In the Water Framework Directive and the Floods Directive: actions towards the 'good status' of EU water and to reduce flood risks (EC, 2015a) also mentions measures such as the reconnection of the floodplain to the river, remeandering and the restoration of wetlands to reduce or delay the arrival of flood peaks downstream, while improving water quality and availability, preserving habitats and increasing resilience to climate change.
The diagram shows the different use scenarios of the river and riparian space during the peak season and the pond-disaster season. By diversifying the use of riparian space on a temporal scale, the flexibility, resilience and sustainability of the use of riparian space is achieved.

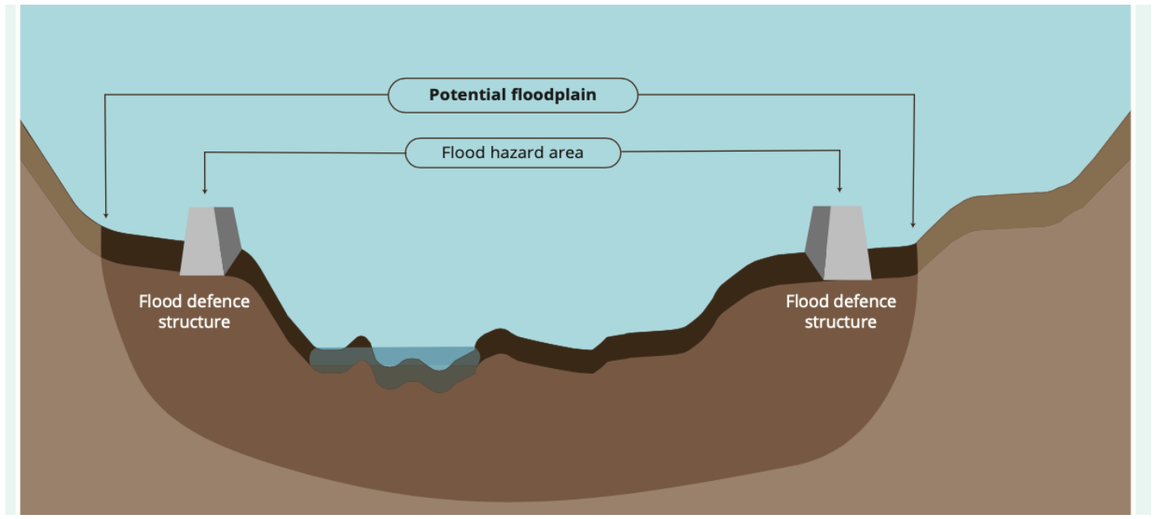
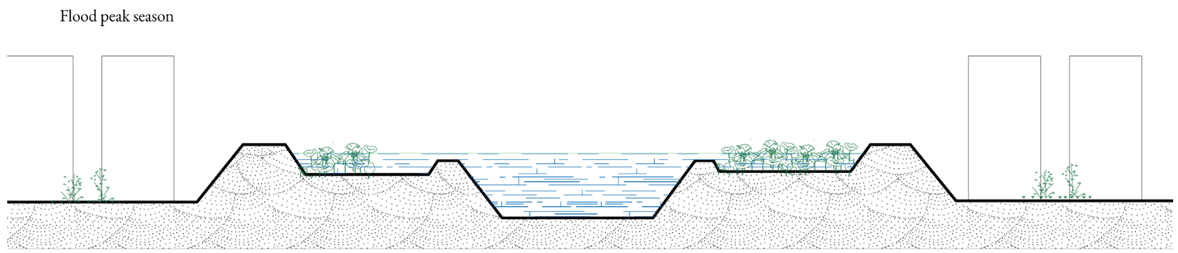


Figure: riparian zone and potential floodplain
Source: EEA, 2019



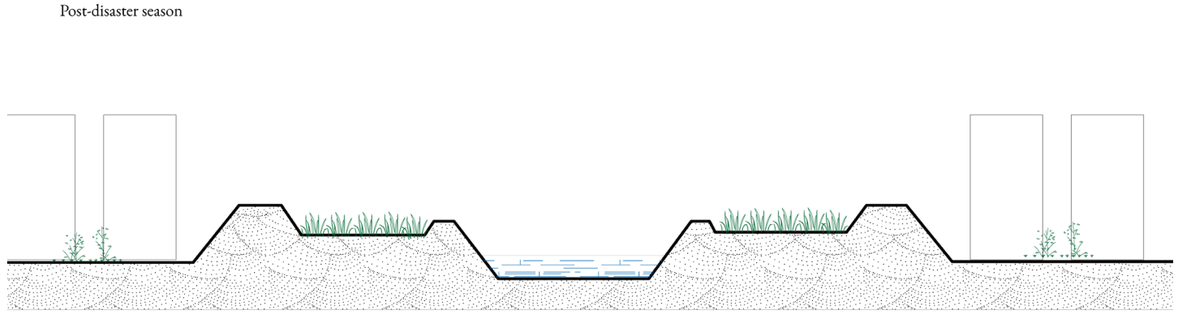
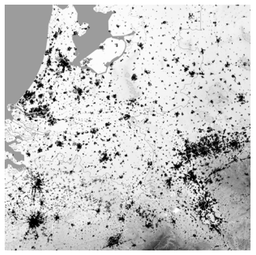


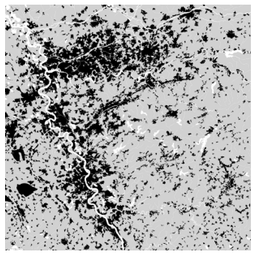
Figure: floodplain in peak season and post disater season
Illustrate by the author

CHAPTER 05

STRATEGY AND DESIGN

In this chapter, the research and design progresses from macro scale to zoom in to nano scale, and the selection and utilisation of nature-based solutions is described through four steps: opportunity, availability, suitability and applicability.





WHY?

OPPORTUNITY

WHICH?

SUITABILITY

WHERE?

AVAILABILITY

HOW?

APPLICABILITY

SCALE UP

IMPLEMENTATION

ABC Mega region

In the lower Rhine River basin, the ABC mega region which consist of Netherlands, Germany and Belgium, is in the world one of the most functionally and economically connected and intertwined mega region. Facing the issue of climate change and flooding risks, the mega region urge to work together.

Nature based solutions

Nature-based solutions (NbS) for flood risk management are strategies or measures that depend on, or mimic, natural system processes to provide flood risk management function, while delivering environmental and other societal co-benefits.

Territories in between

As a widespread urban-rural pattern in the ABC mega region, territory in between areas has a lower population density, i.e. a lower density of flood-affected people, and more open space.

Inland

In the ABC Mega region there is a clear distinction between the upper and lower reaches. In the inland region, there is more undulating terrain and a larger area of forest. The NBS can be taken for example when rivers cross these valleys and forests and therefore have more temporary retention capacity for precipitation above the limit.

Seaward

In the saward area, there is a flatter topography and a wider network of water intertwined with agricultural production plains and settlement plains. Examples of NBS that can be adopted are for example the use of water systems and polder features to give more space to rivers in order to slow down their flow and reduce the impact of floods.

Flooding risks

Projecting mapping: Using the data and drawings from the observing mapping and find out the most crucial areas which faces the higher risks or have more potential to be transformed.

Other related systems

By the steps of opportunity, suitability, availability and applicability, using case studies to show how the theories and strategies can work out in the real situation. Choosing local conditions in critical areas as case study to understand how nature-based solutions is chosen and applied, how the local and national or international stakeholders are aligned and involved and how nature and urban landscapes are terraformed. The local transformation would show the value of the complicate adaptive system of the interrelationship between urban and bio-physical system, and support to accelerate the transformation to be expanded in the whole ABC mega region.

Typologies

Using spatial planning and design to upscale the local conditions and try to put forward a vision for the new network in the mega region. Spatial design would also show how to transform and improve the spaces for the human well-being. And temporal design would show how to accelerate the transformation of the whole mega region from the local adaptation.

Scenarios proposing

Depending on the scenarios of future flooding risks, the water level raise of the river, to form the strategy application.

Case study

By the steps of opportunity, suitability, availability and applicability, using case studies to show how the theories and strategies can work out in the real situation. Choosing local conditions in critical areas as case study to understand how nature-based solutions is chosen and applied.

Scale up

This research process is reproducible and applicable. Test and propose the scale up of Nature-based solutions from an adaptive systemic backbone. Recognize the whole dynamic complexity and form a new mega regional network.

Up to down

Recognizing the new dynamics of the interrelationship between urban and bio-physical systems, the implementation of the Nature-based solutions for flood resilience and future development of the ABC mega region should be aligned from the mega regional scale to local scale.

Opportunity

Where to grow? Where to apply nature-based solutions for flood management?

Where to grow? Where to apply nature-based solutions for flood management?
The analysis of the basic overview of the ABC mega region in the previous section, with all relevant layers overlaid, reveals the opportunities and challenges facing the mega region as a whole. The areas of population growth and low population in the map represent the need for future urban expansion and the availability of remaining spaces in addition to urban expansion. When this population layer is overlaid with the flood risk, a scenario of the future flood resilience of the entire mega region is coming into shape, including where to grow he where to apply nature-based solutions for flood management.
To answer these questions, the complexity of the whole should be revealed. All the systems related to flood resilience future such as flooding risks, land uses, demographic data, green-blue infrastructure, grey infrastructure, policies etc. These layers of different system and the subsystems creates complex interrelationships which are impermanent and dynamic.

Areas to grow or to shrink and the flooding risks

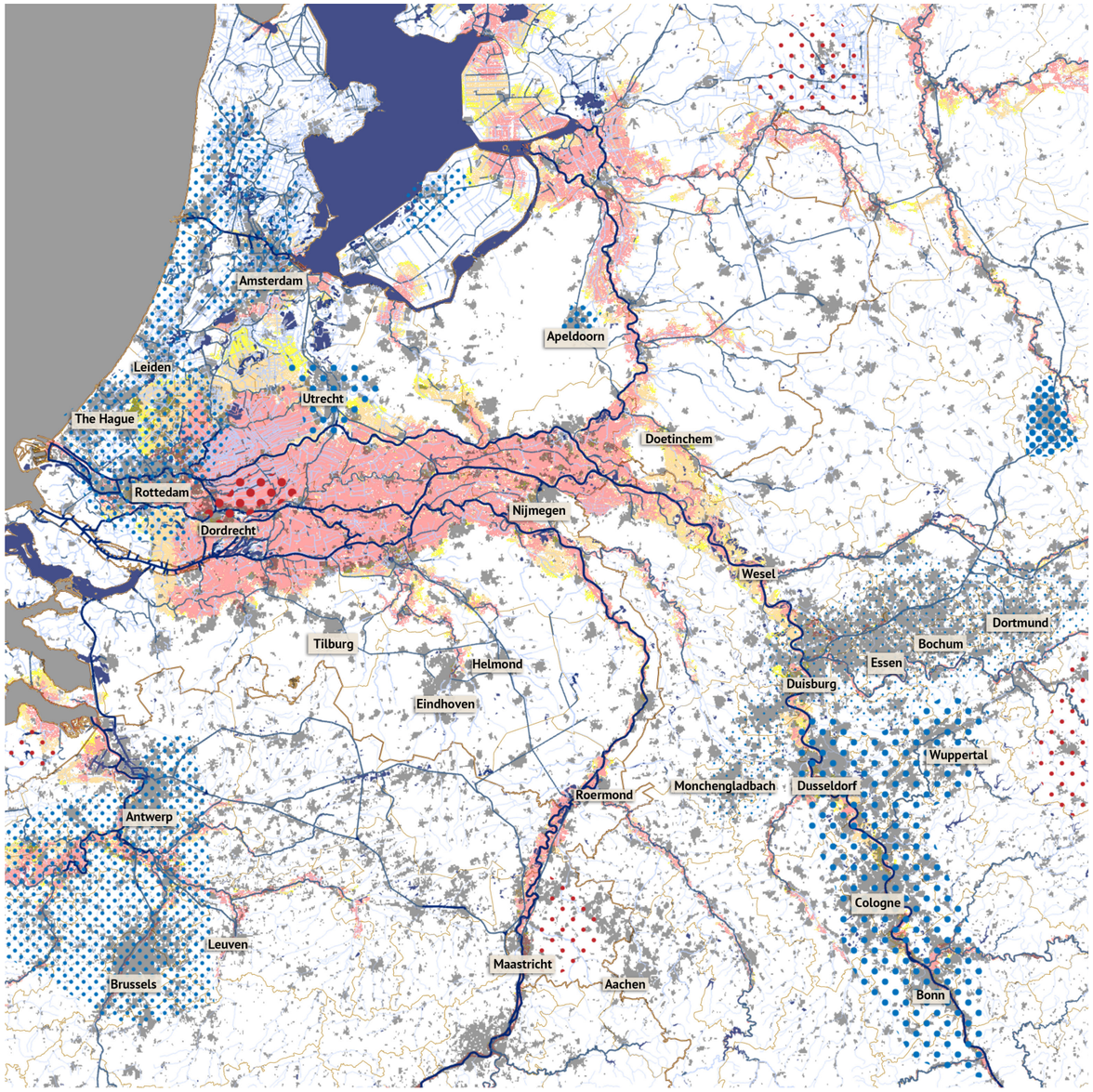


Figure: Areas to grow or to shrink and the flooding risks
Illustrate by the author
Source: Eurostat NTUS , 2018

Opportunity

opportunities

Through the analysis of opportunities and challenges, the map shows the regions with the areas of highest concentration of contradictory problems and the greatest opportunities and potential for solutions in the entire ABC Mega region, which is made up of polycentric urban agglomerations, each with intertwined rural and urban spaces. These three regions are the most populated areas, each in a different country with different spatial patterns due to their inland and seaward geography situation.

potential areas to apply nature-based solutions for flood risks control

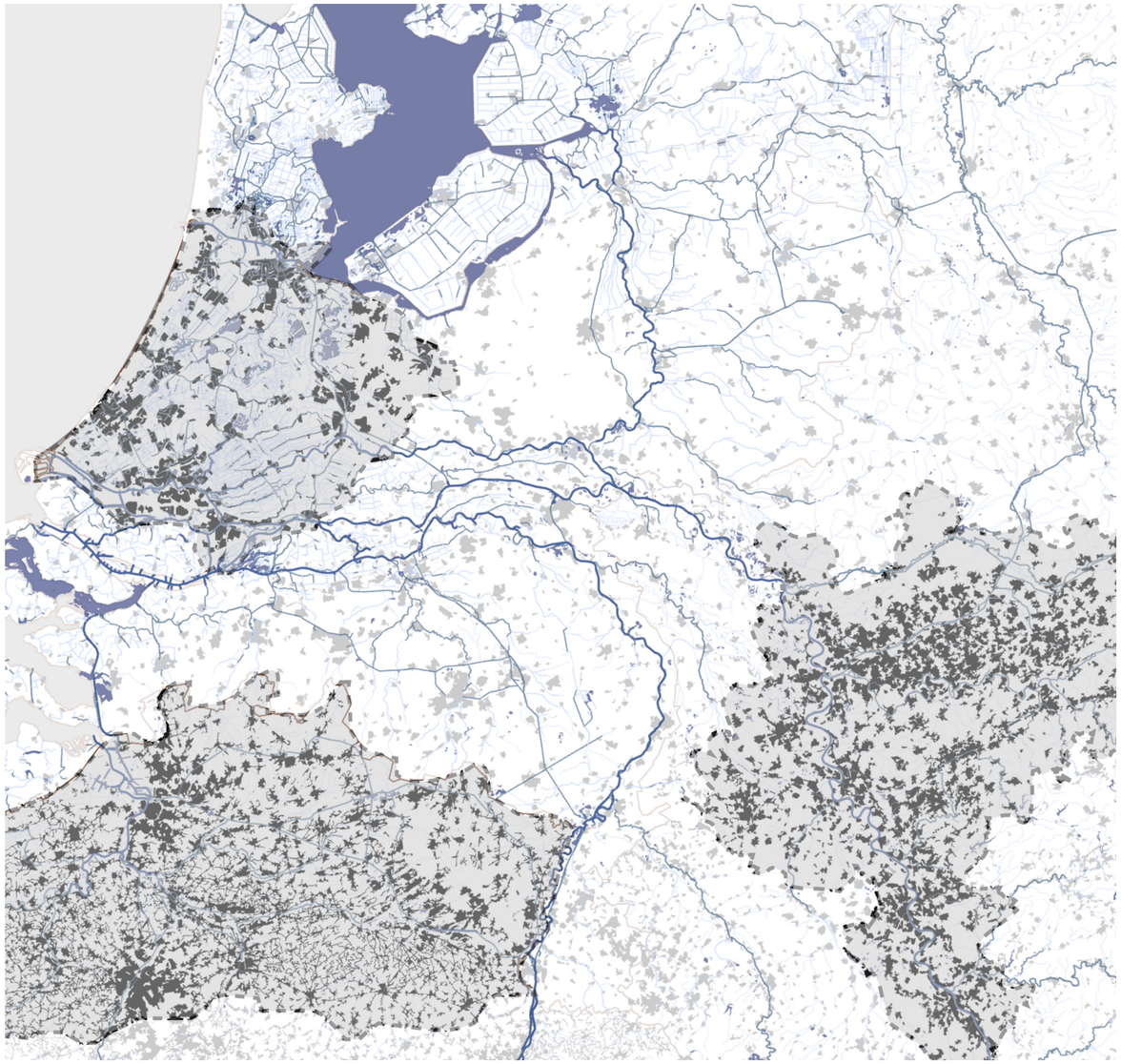


Figure: potential areas to apply nature-based solutions for flood risks control
Illustrate by the author
Source: Copernicus,2017

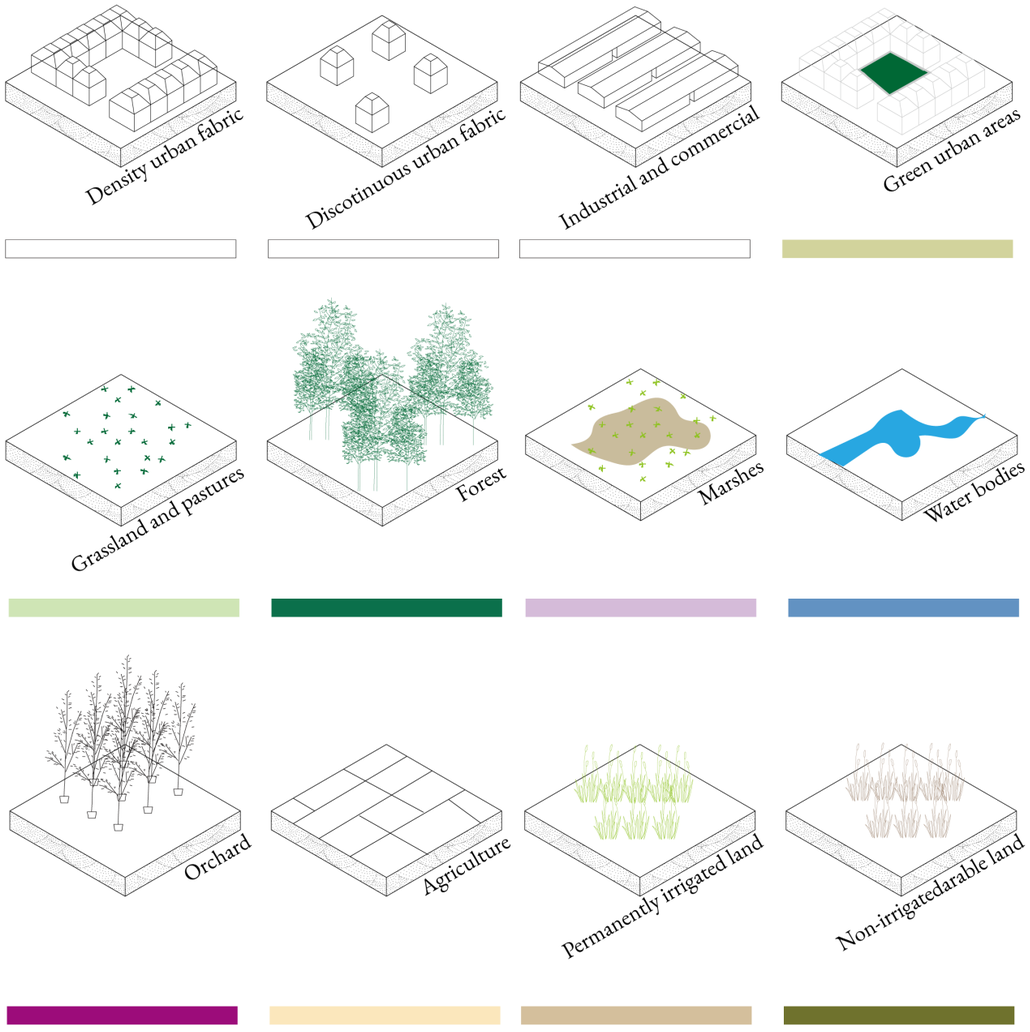
Suitibility

Find the suitable strategy for the design

This mapping classifies and shows the areas in the ABC mega region other than the urbanized area. For example, the central area is more agricultural related and therefore more suitable for agricultural related measures. Similarly, the area to the south-east is more forested and greenfield, and therefore more suitable for strategies related to forests and meadows. The colour scheme of this map corresponds to the typology of the sites described above.

Landcover

Nature-based solutions can be applied to green and blue spaces in the mega region. This thesis classifies the spaces associated with nature-based solutions into the following categories based on the different types of landcover. The colour under each typology corresponds to the colour legend of the mapping below.



Landcover

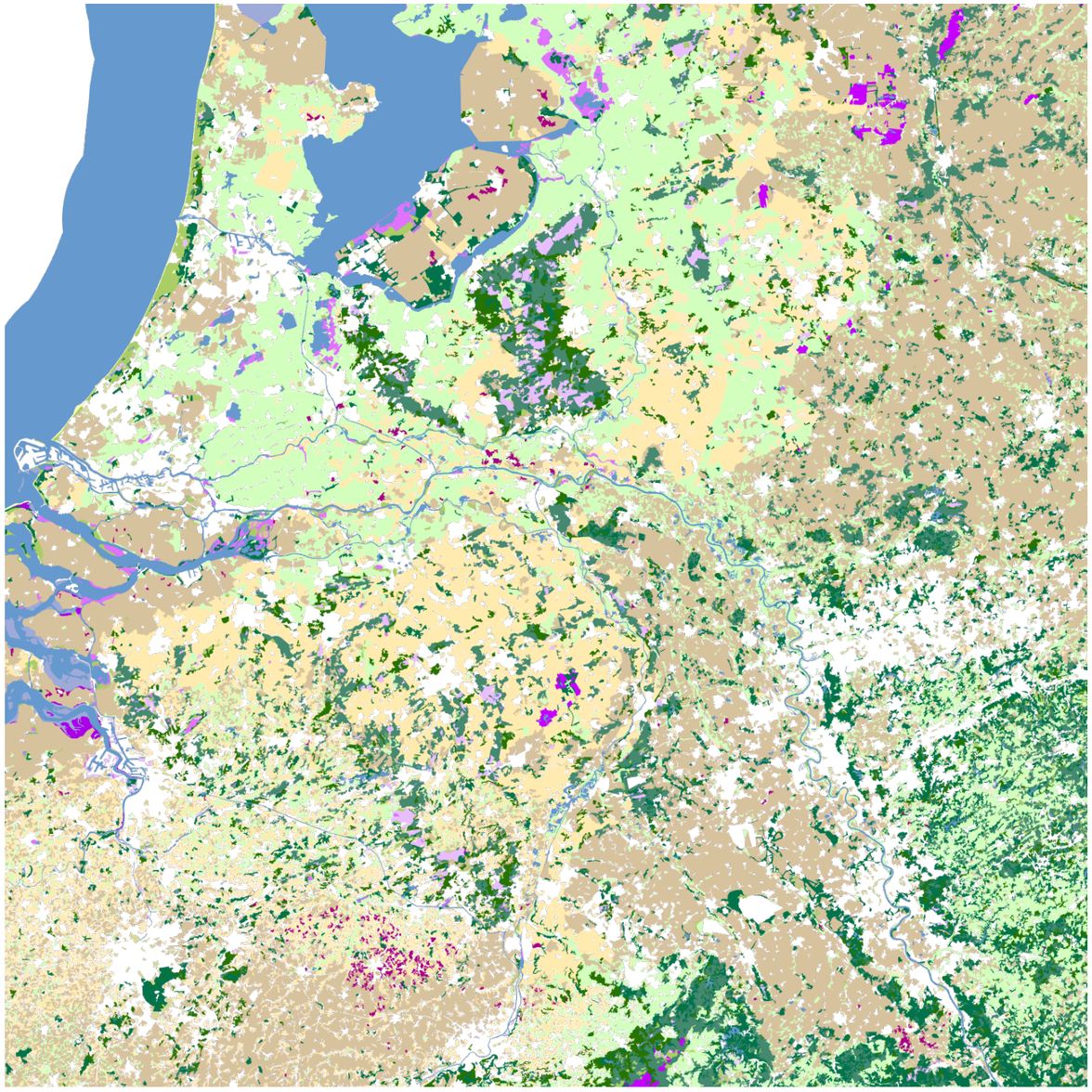
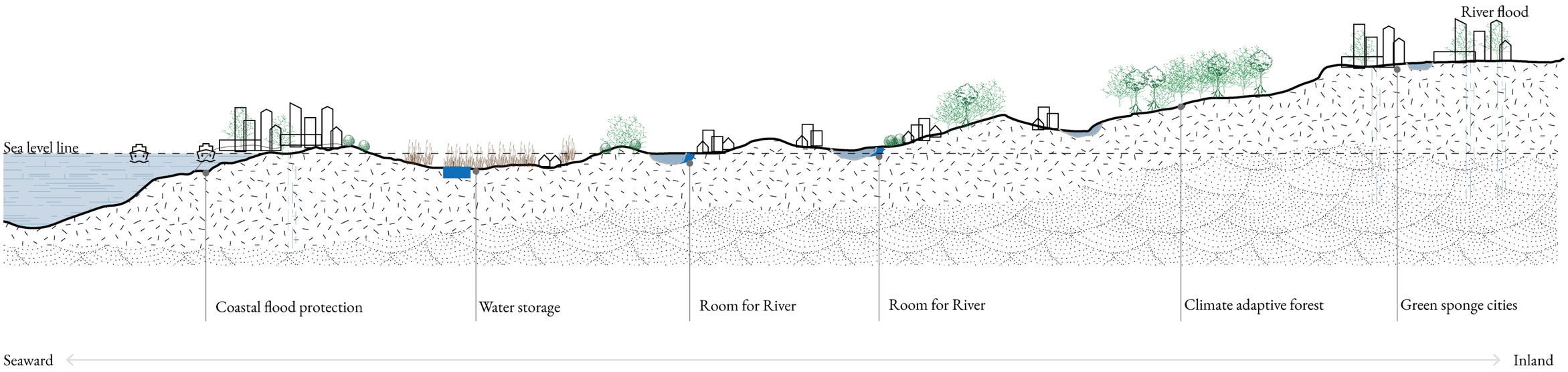


Figure: land cover in the ABC Mega region
Illustrate by the author
Source: Copernicus,2017

Suitibility

Find the suitable strategy for the design

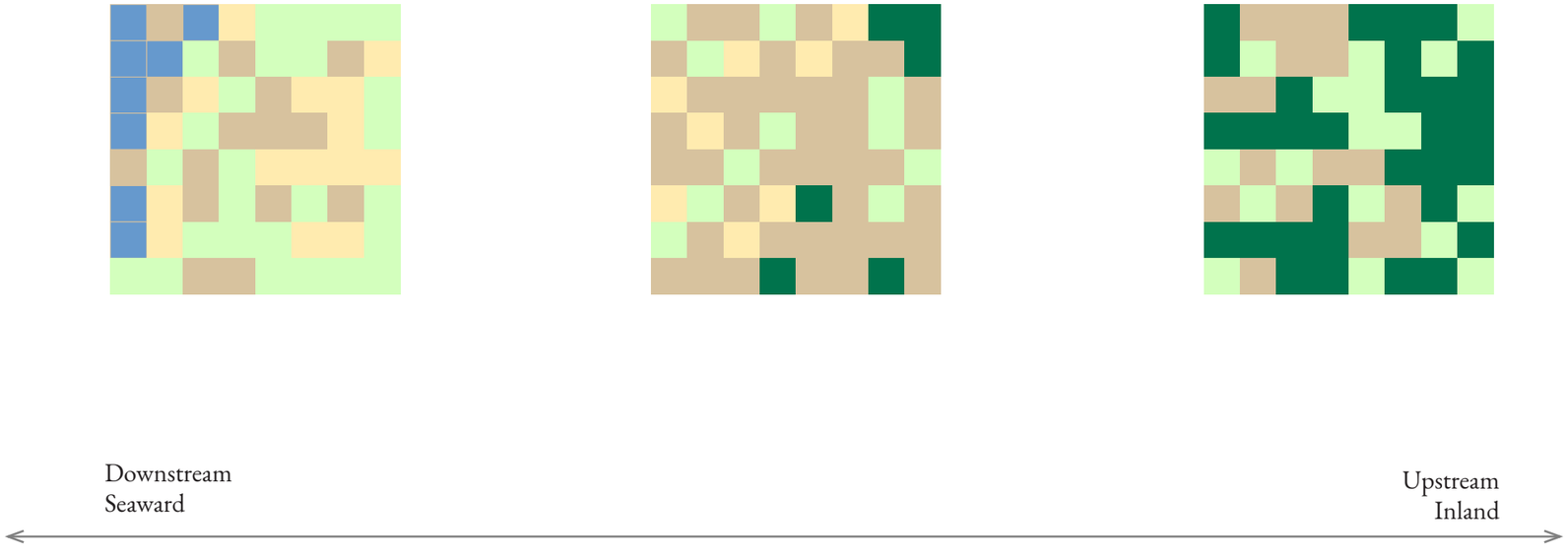
In the ABC Mega region there is a clear distinction between the upper and lower reaches. In the inland region, there is more undulating terrain and a larger area of forest. The NBS can be taken for example when rivers cross these valleys and forests and therefore have more temporary retention capacity for precipitation above the limit. In the seaward area, there is a flatter topography and a wider network of water intertwined with agricultural production plains and settlement plains. Examples of NBS that can be adopted are for example the use of water systems and polder features to give more space to rivers in order to slow down their flow and reduce the impact of floods.



Suitibility

Mosaic study

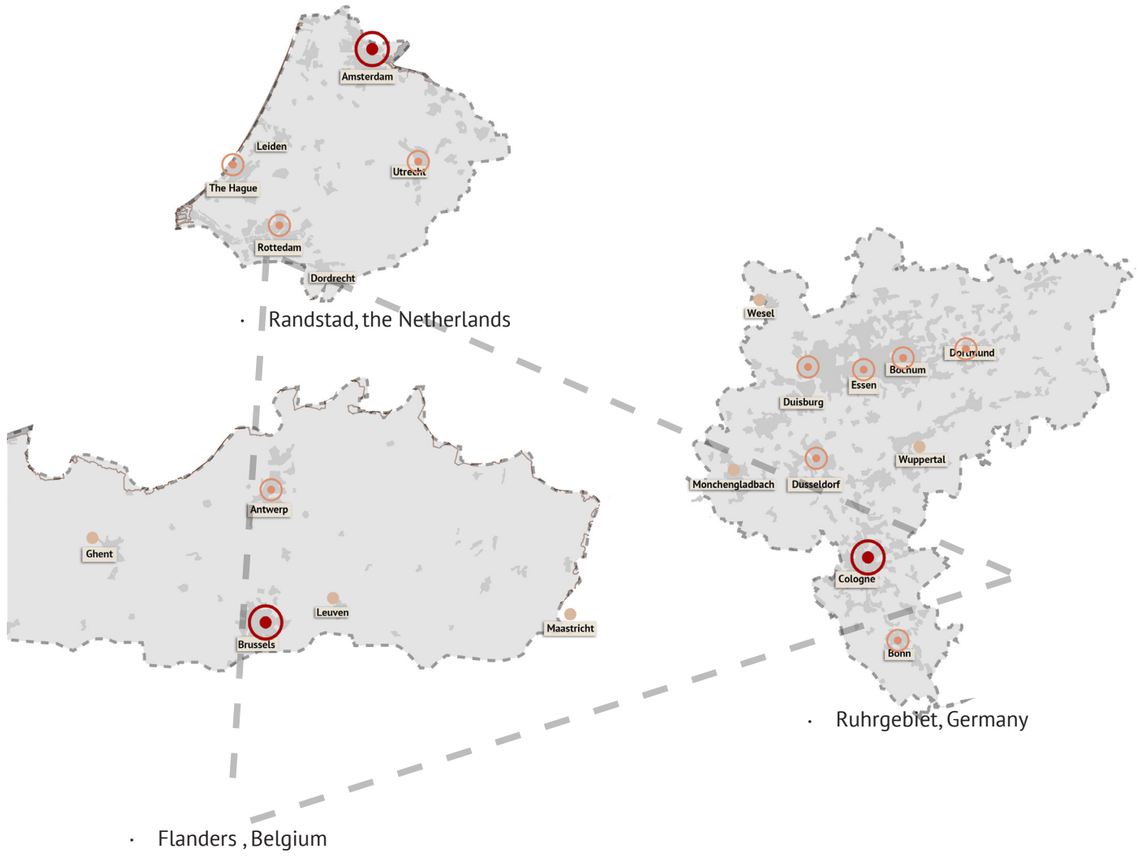
By pixelating the mapping, the spatial characteristics can be more abstractly distilled. From upstream to downstream, this spatial character is reflected in the colourful mosaics. In the ABC Mega region, the downstream in the Netherlands is occupied by more agricultural and grassland and coastal spaces, while the upstream in Germany is occupied by more forests and green spaces. Through this colour abstraction, the inland and seaward regions are able to reflect their respective suitable strategy.



Availability

the Ruhrgebiet Region

The Ruhrgebiet is the most densely populated of the three regions, the most polycentric mega-region and has a lot of territory in between spaces. The urban sprawl has put a lot of pressure on the permeability of the whole region. In the Ruhrgebiet, the Rhine River runs from south to north and passes through many large cities such as Cologne, Düsseldorf and Duisburg.



Permeability of the landcover in Ruhrgebiet

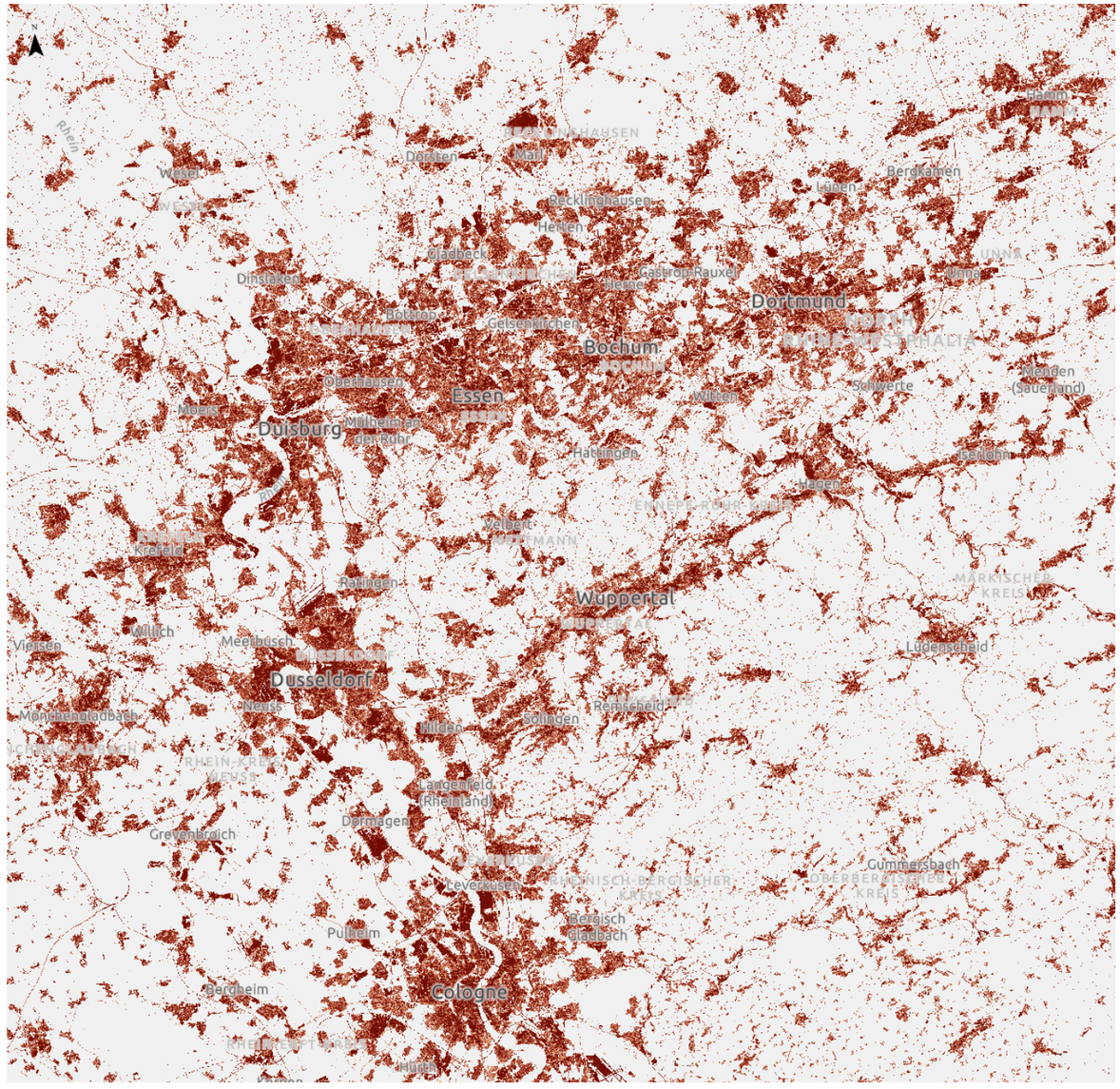


Figure: Permeability of the landcover in Ruhrgebiet
Illustrate by the author
Source: IMD, 2018

Availability

Green corridors alongside the rivers in Ruhrgebiet

The figure shows the green spaces of the Ruhrgebiet, where the green spaces along the Rhine and its tributaries are highlighted to show the interrelationship between water and green space throughout the region, as well as the distribution of the green corridor. Green corridors are important for the connectivity of landscapes. Green corridors are important for the connectivity of the landscapes, and the role of the eco-system can be enhanced.

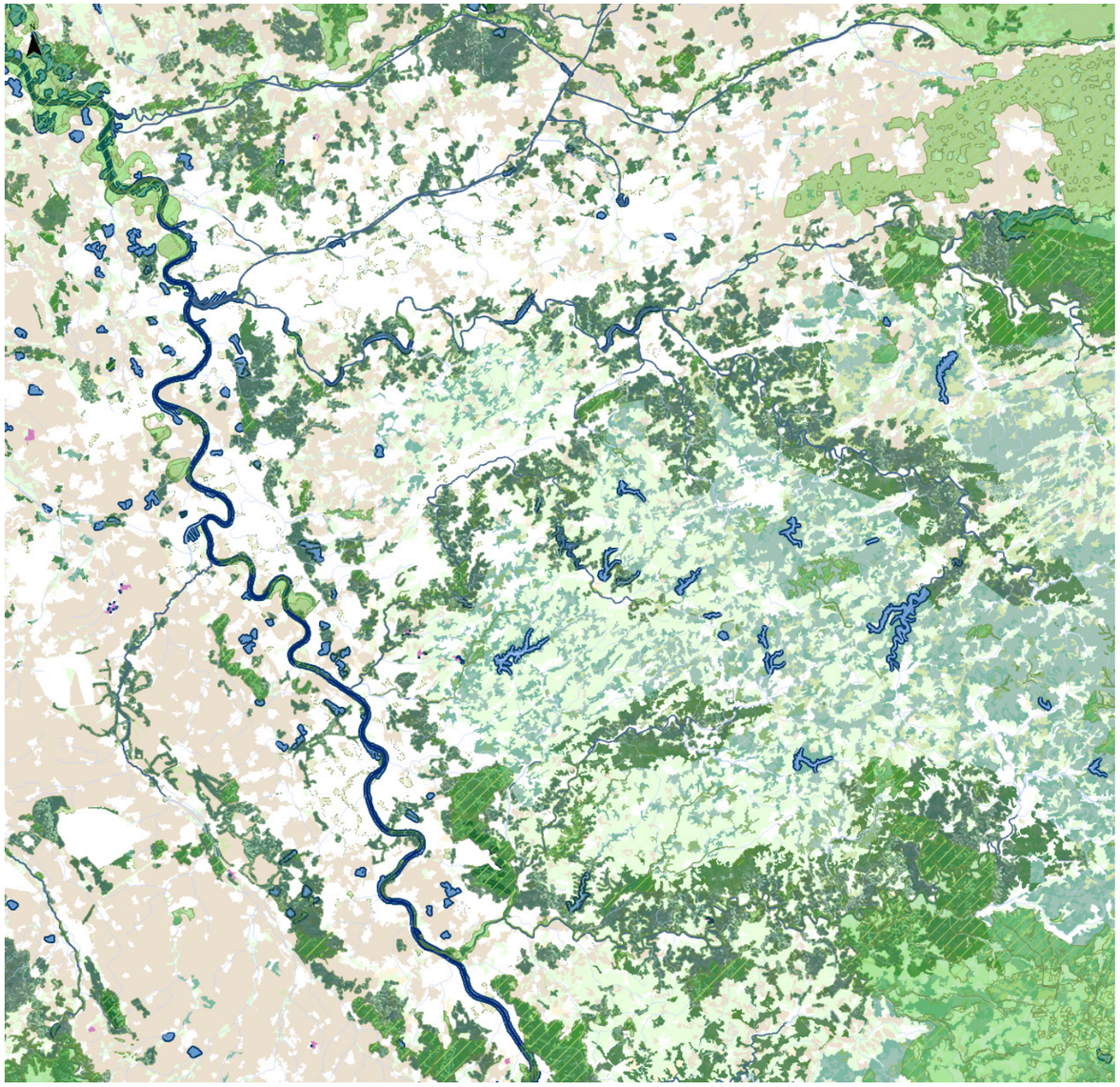


Figure: green corridors alongside the rivers in Ruhrgebiet, Illustrate by the author
Source: Copernicus,2017

Availability

Flood risk area

Ruhrgebiet is located in the inland part of the Rhine in the ABC mega region, where the situation with regard to flood risk is also very serious. The squares on the map are the areas that need to be zoomed in in the next step.

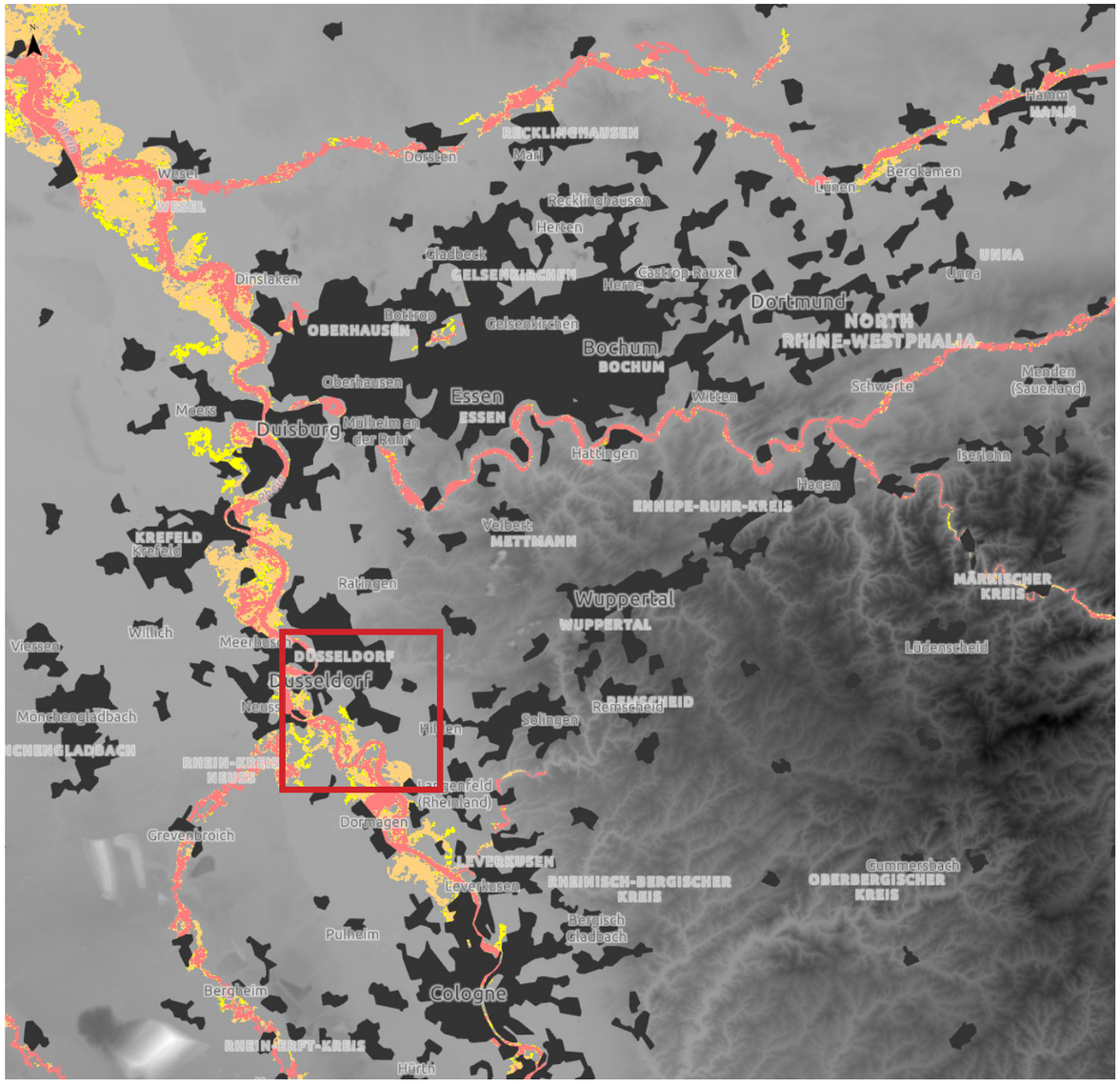
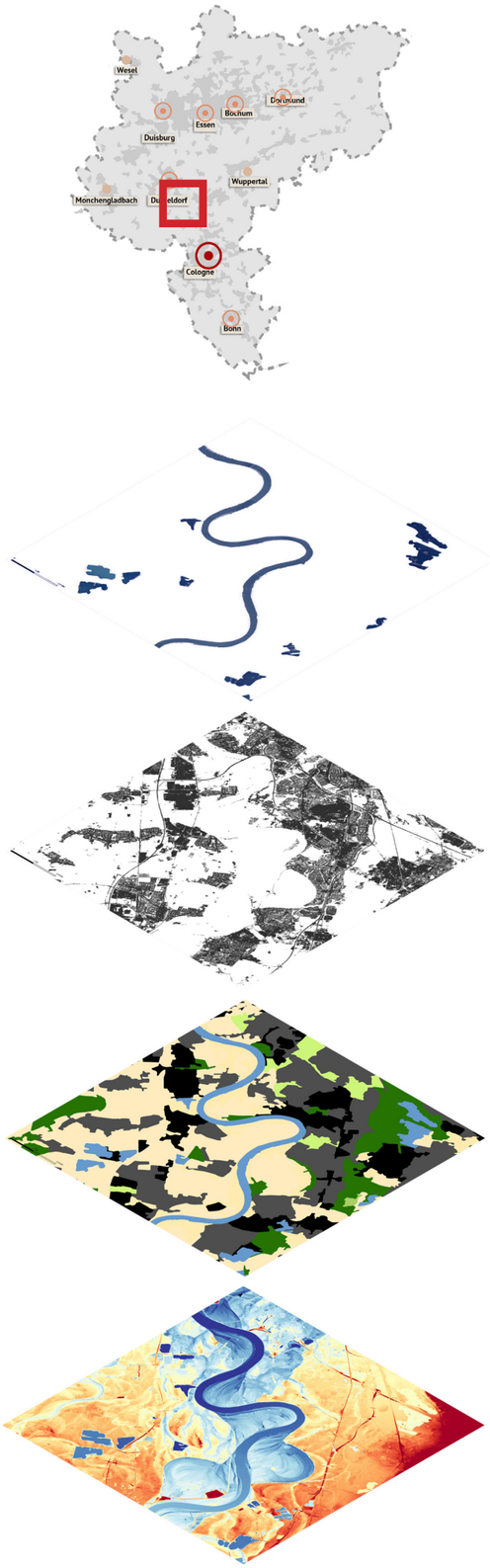


Figure: flood risk area, Illustrate by the author
Source: floodmap EFAS, 2019

Availability

The site

The nano scale site selected for the study of applicability is located on the south side of Dusseldorf and on the north side of Cologne. The site is typically located in a transitional territory space between two big cities. Unlike the big cities, the site is mostly occupied by functions other than urbanized areas. The Rhine river flows from south-east to north-west and the overall topography of the site is flat without great undulations, making it an ideal location for case studies.



Satellite map

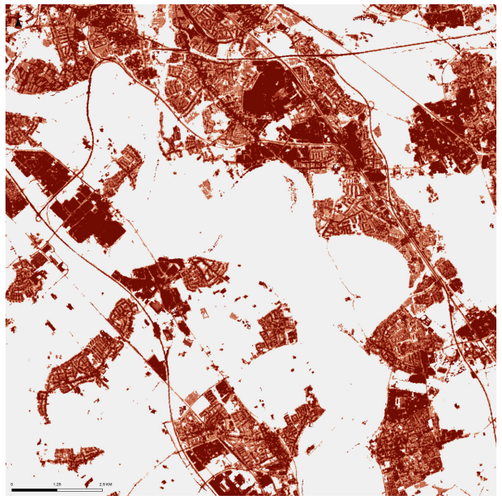
Figure: Satellite map on the site
Source: Googlemap, 2022

0 1.25 2.5 km N

Availability

Permeability of the landcover

The hard surface of urban landscapes prevents the infiltration of water from surface to sub-surface. The occurrence of ponded water in cities is solved by the grey infrastructure of the sewage systems. This artificial approach to the water cycle further increases the risk of flooding. Nature-based solutions approach to flood management looks to the capacity of ecosystems to achieve water retention and sequestration.



Non-permeable

Figure: Permeability of the landcover
Illustrate by the author
Source: IMD, 2018

soil

The various proportions of sand silt and clay in the soil determine the nature and type of soil. Different soil types have different infiltration and absorption capacities for water flow. Most of the river banks on the site are flood plain silt and flood plain sand, which have a good infiltration rate.

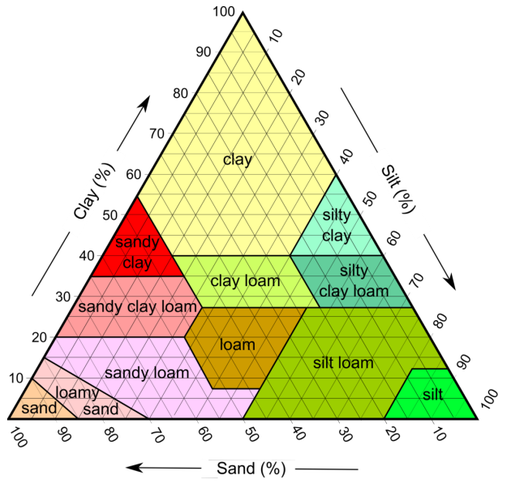


Figure: USDA Soil Texture
Source: Christopher Aragón, 2018

Soil Group	Description	Final Infiltration Rate (mm/h)
A	***Lowest Runoff Potential***. Includes deep sands with very little silt and clay, also deep, rapidly permeable loess.	8 - 12
B	***Moderately Low Runoff Potential***. Mostly sandy soils less deep than A, loess less deep or less aggregated than A, but the group as a whole has above-average infiltration after thorough wetting.	4 - 8
C	***Moderately High Runoff Potential***. Comprises shallow soils and soils containing considerable clay and colloids, though less than those of group D. The group has below-average infiltration after pre-saturation.	1 - 4
D	***Highest Runoff Potential***. Includes mostly clays of high swelling percent, but the group also includes some shallow soils with nearly impermeable sub-horizons near the surface.	0 - 1

Figure: The USDA-NRCS Hydrologic Soil Group Classification
Source: Reynold J. Stone, 2014

Soilmap

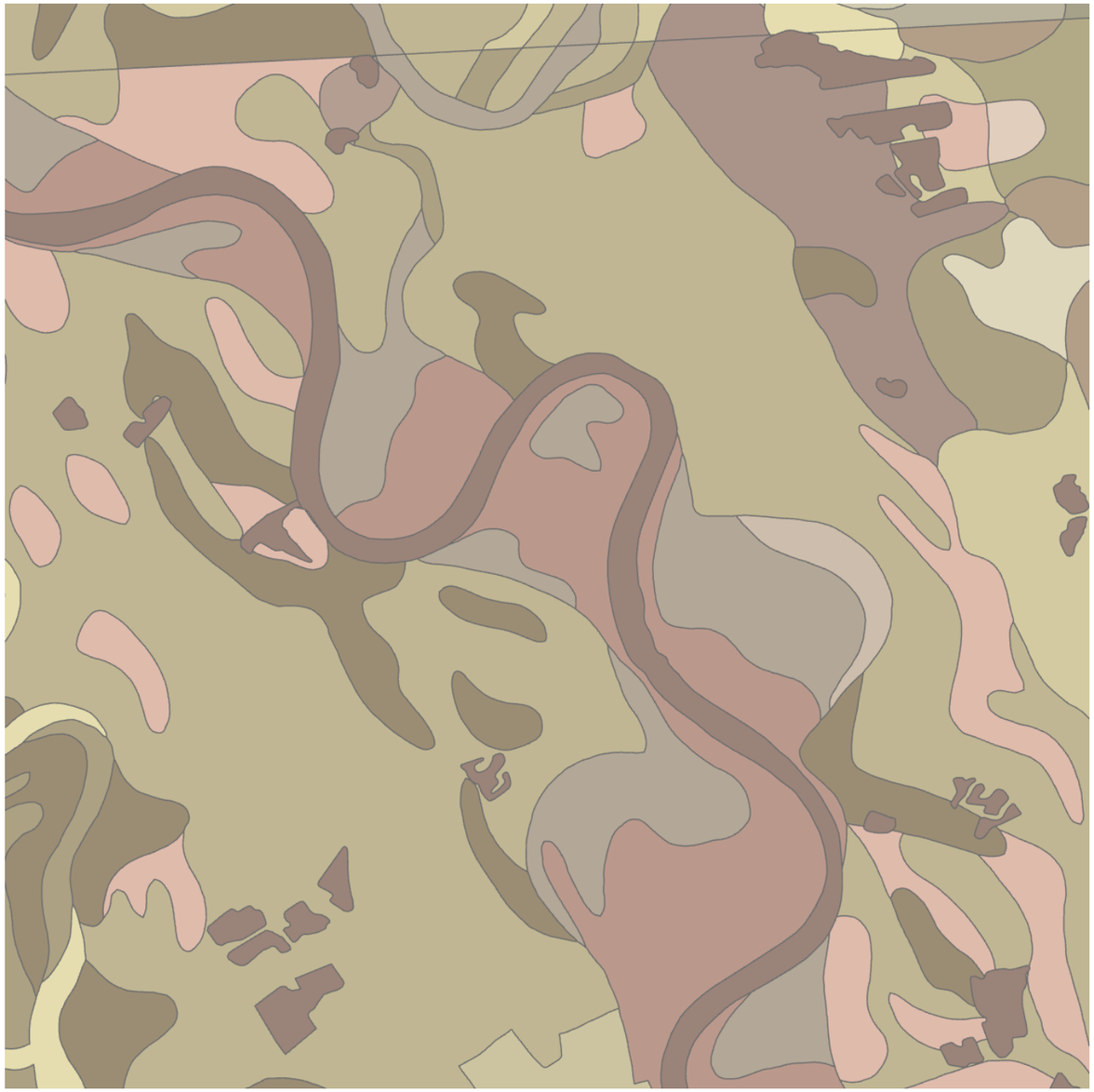
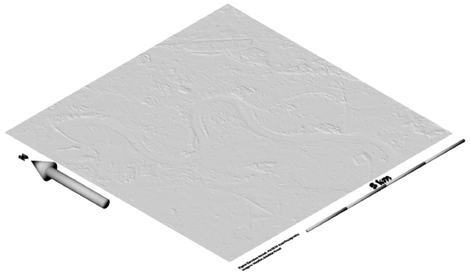


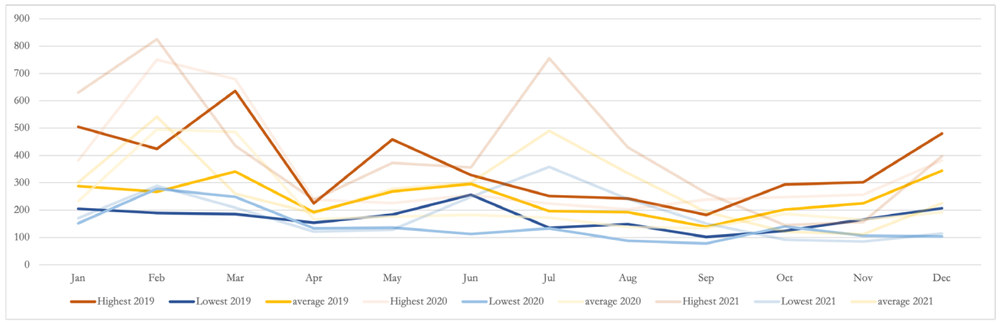
Figure: Soilmap
Illustrate by the author
Source: Regionale Landschaftsbezeichnungen, 2021

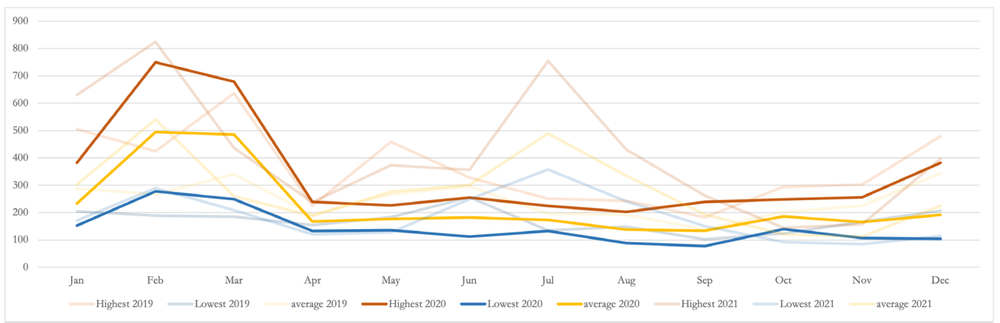
Availability

Terrain and water level

The topography of the base is generally flat, with subtal change in elevation.
The following diagrams show the changes in the water level of the Rhine during the twelve months of the year, as well as the highest and lowest monthly average values. The water level is on average higher in winter than in summer, but in the summer of 2021 it comes to an anomalous maximum. This is a high risk of flooding for a relatively flat river bank topography.







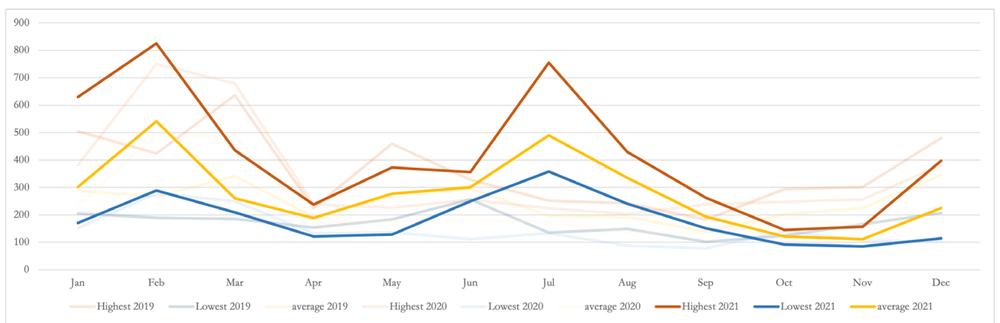
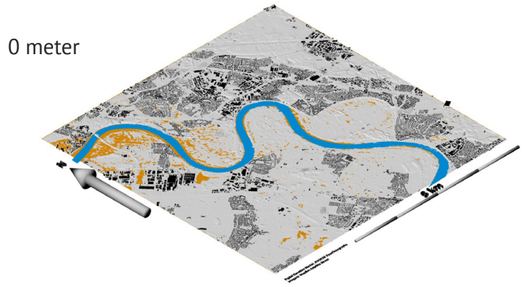
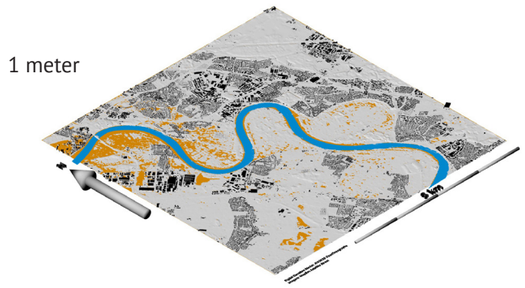


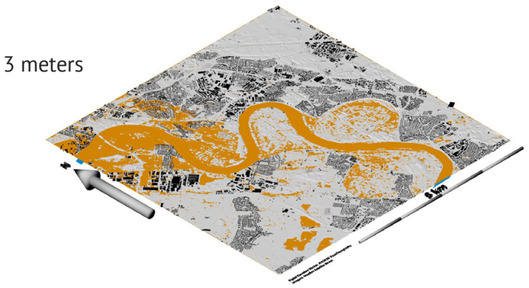
Figure: Rhine waterlevel monthly
Illustrate by the author
Source: OpenDataPortal Düsseldorf, 2022

Terrain and scenarios of water level raising

Predictions are made for areas affected by different levels of water level rise, based on data on topographic height change and water level change.







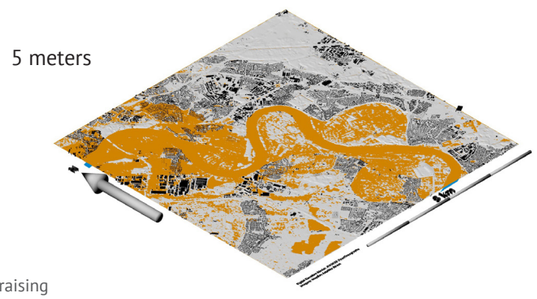


Figure: scenarios of water level raising
Illustrate by the author

Availability

the flood protection system and floodable area

In accordance with the application and approval of the Dike Protection Ordinance, the The Düsseldorf district government has issued an official decree for the special protection of the dykes. This includes all protection systems in the Düsseldorf metropolitan area against flooding from the Rhine.

The Dike Protection Ordinance (DschVO) of 1 September 2020 is currently in force. In this ordinance, protection zones for the dykes are defined and, depending on the respective degree of danger, certain measures or bans and prohibitions need to be approved.

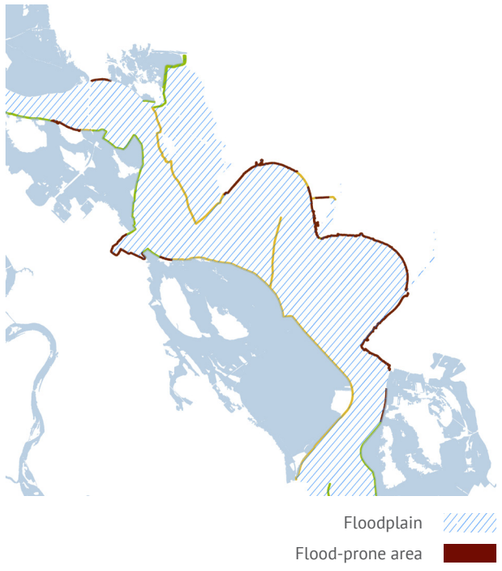


Figure: floodplain and flood-prone area
Illustrate by the author
Source: Bezirksregierung Düsseldorf Sachstand Maßnahmenumsetzung, 2022

status of the flood protection system

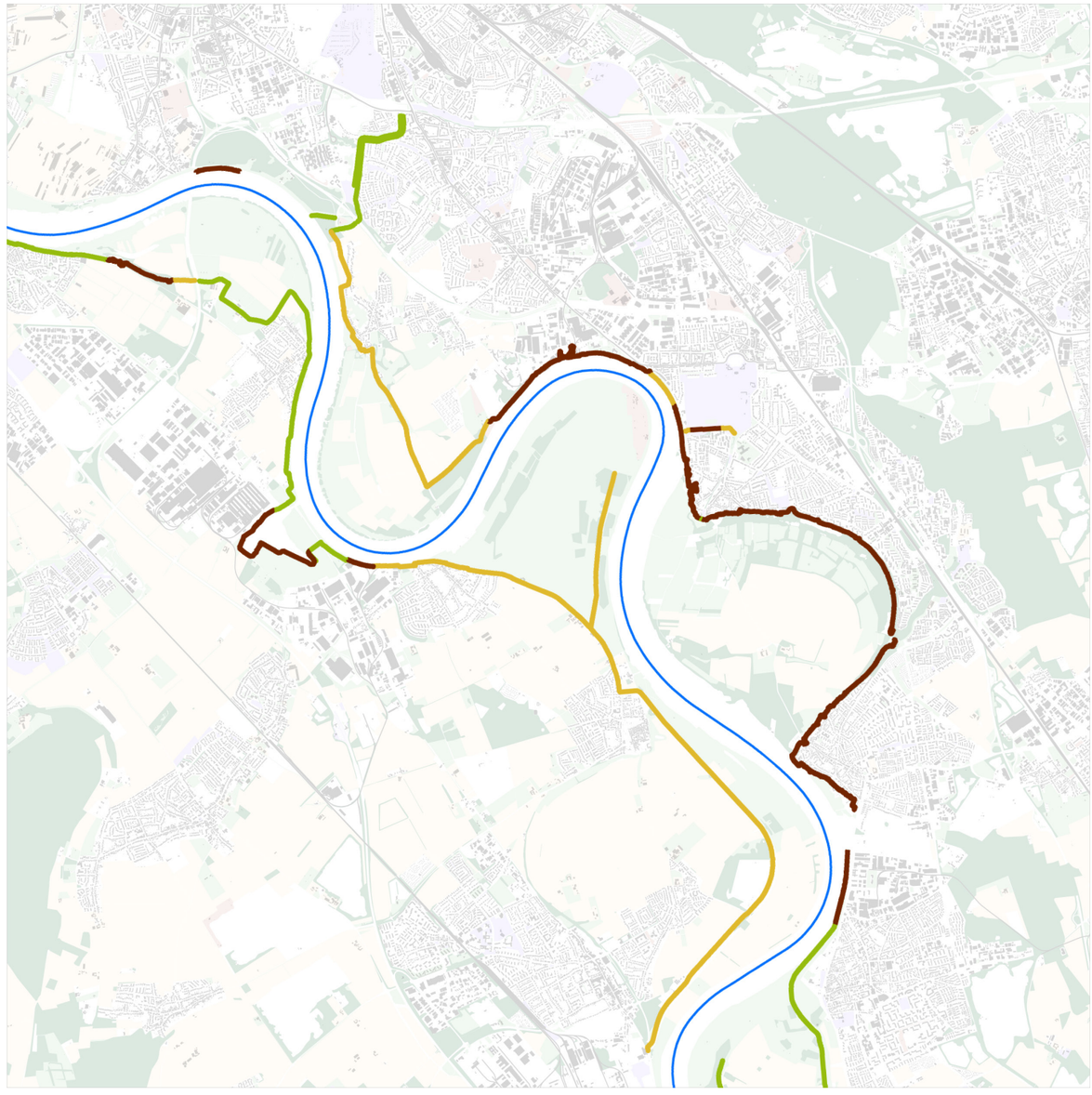


Figure: status of the flood protection system
Illustrate by the author
Source: Bezirksregierung Düsseldorf Sachstand Maßnahmenumsetzung, 2022

Availability

spaces along side the river

The different spatial typologies along the river in the site are observed from the perspective of Google Street View in eye level analysis. The river strings together this series of different spaces.
The differentiated landscape image of the riverlandscape creates a system of diverse and differentiated functions and spatial forms.

1

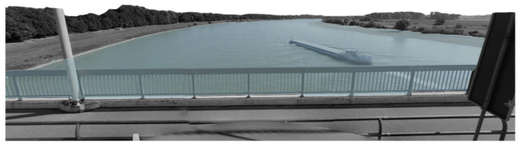
2

3

4

5

6



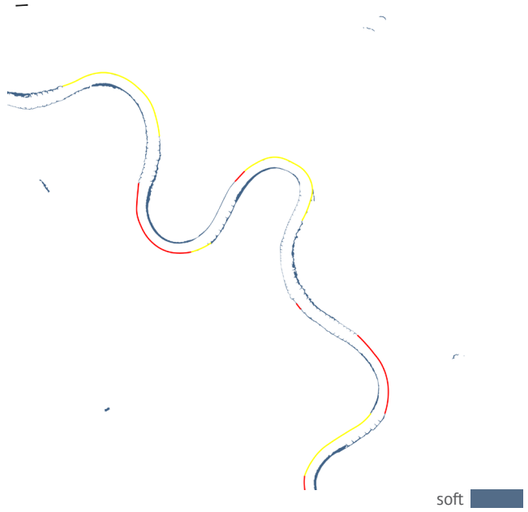


Figure: the spaces alongside the river
Illustrate by the author
Source: Google streetview, 2022

urbanized areas alond side the river(flood risks)

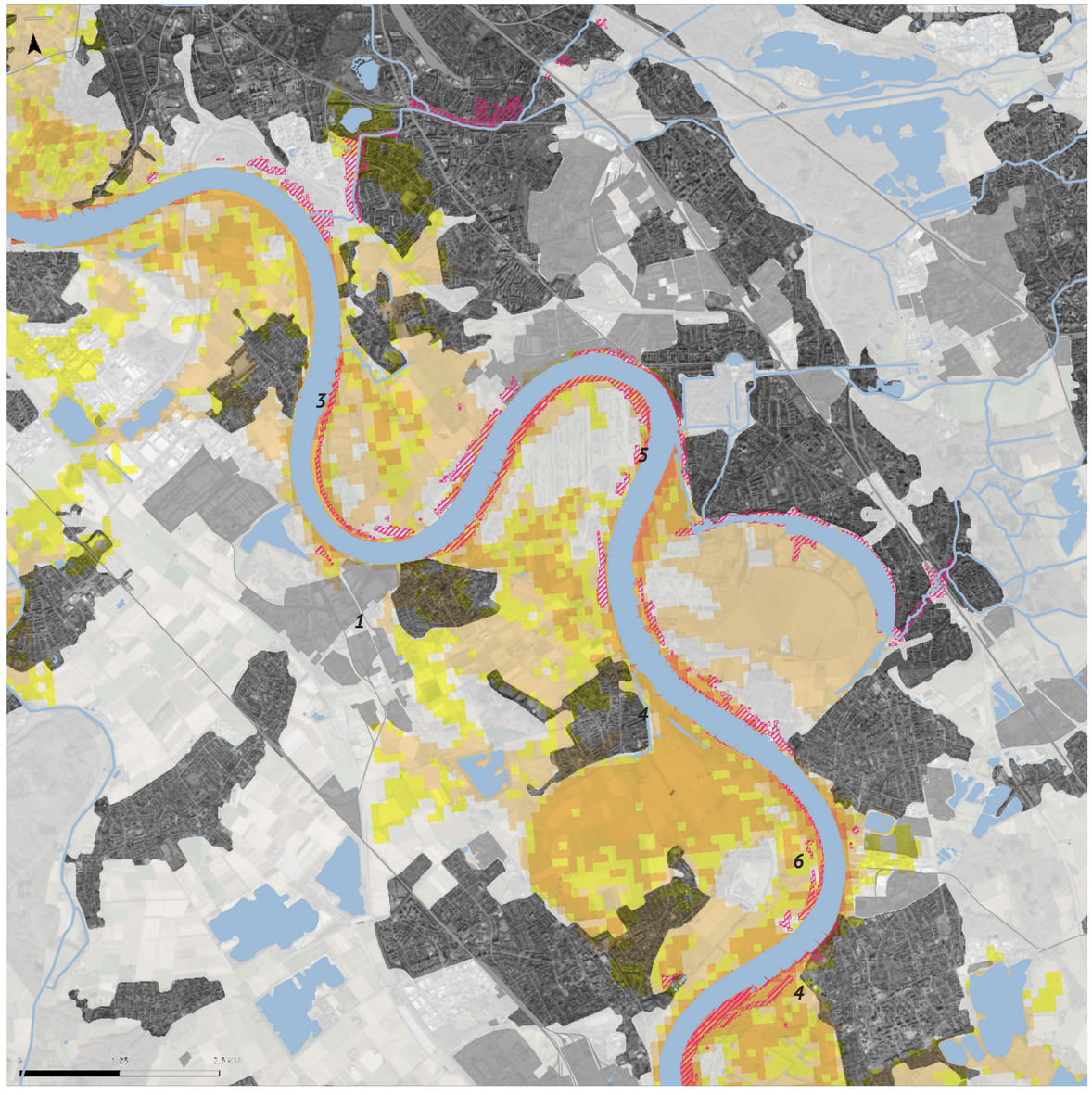
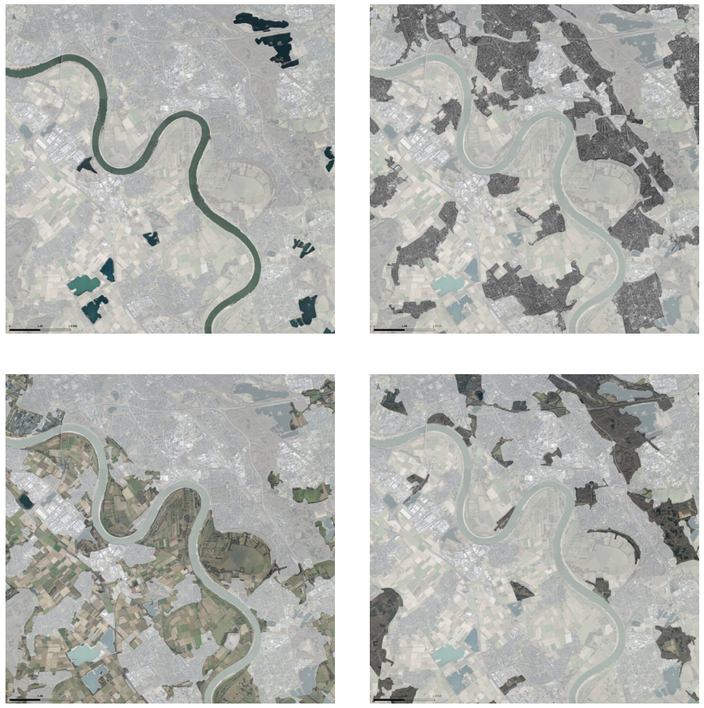


Figure: Functional map alongside the river
Illustrate by the author
Source: floodmap EFAS, 2019 Copernicus,2017

Availability

Functional spaces

The functional areas of the riverbank are mapped in order to correspond to the future strategy of the different typologies.
Satellite maps give the most direct view of the current situation of the site. By extracting the different spatial elements from the satellite map the following diagram can be obtained. It can be seen that nearly half of the area is covered by agricultural land. Agricultural land is also the most distributed type along the river. Urban settlements and industrial areas are scattered along both sides of the river. However, large areas of forest are located away from the river. There is not much interaction between the river and the forest.



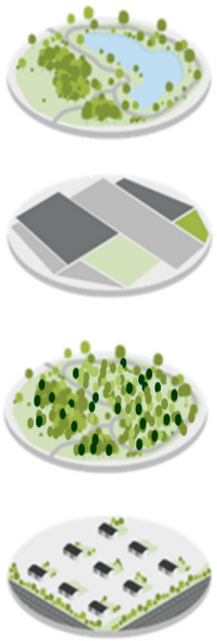


Figure: different spatial element in the satellite map
Illustrate by the author
Source: Googlemap, 2022

Functional map alongside the river

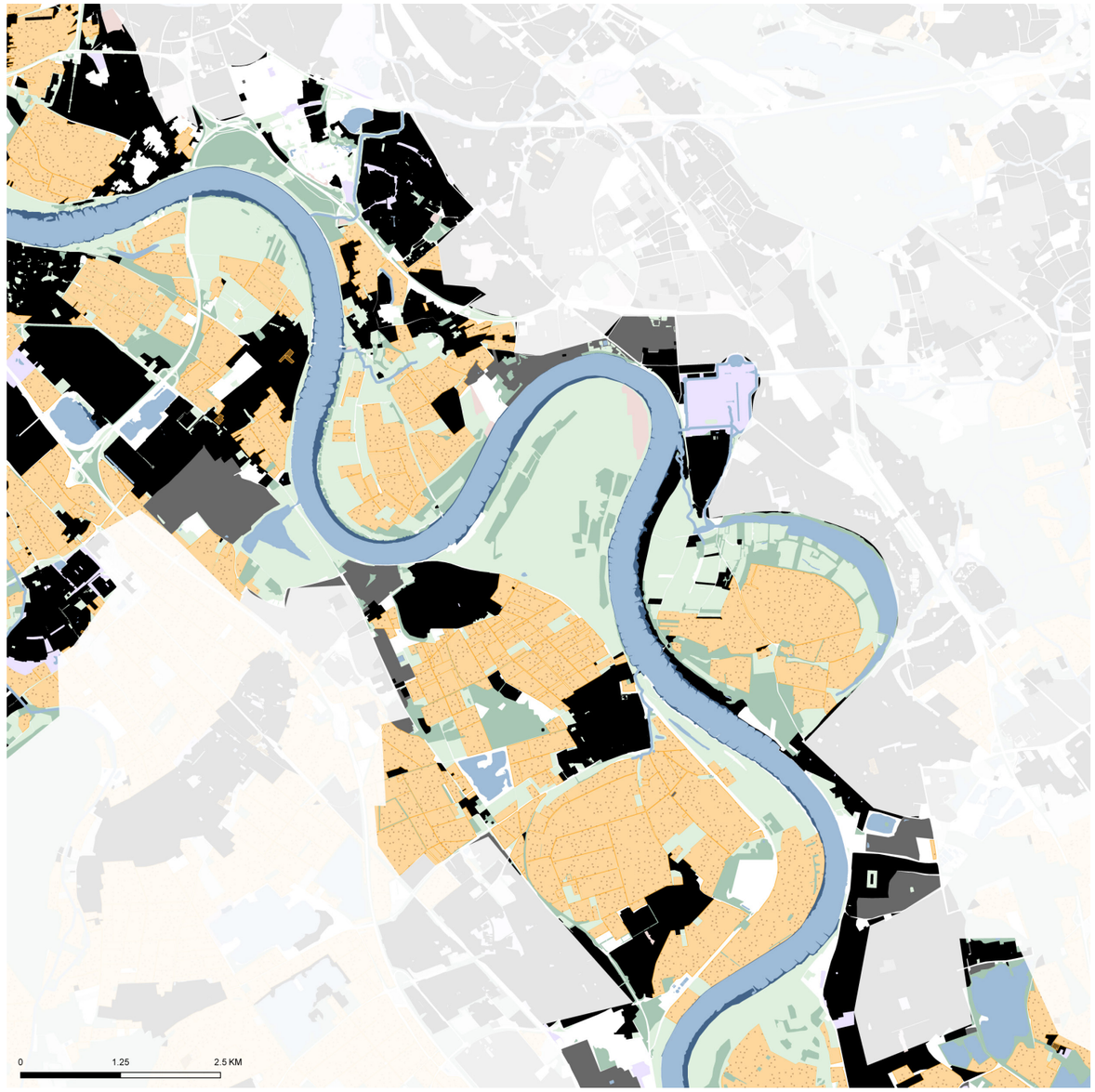
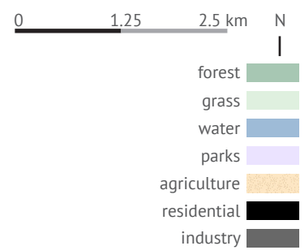


Figure: Functional map alongside the river
Illustrate by the author
Source: Openstreetmap, 2022



Availability

Functional spaces: green spaces

The functional spaces of the site coming from both sides of the Rhine are classified according to the individual systems. Firstly, there are the green areas and the natura 2000 landscape zones that need to be protected. The southern part of Düsseldorf is situated at the foot of the Bergisches Land and offers a beautiful view of the Rhine plain and the terraced landscape of the Bergisches Land. Together, these green spaces and forests create landscape values and a resilient open space system for the city. The high quality of the local green spaces is evident from the fact that a large number of the green spaces and forests in the area are covered by natura 2000.

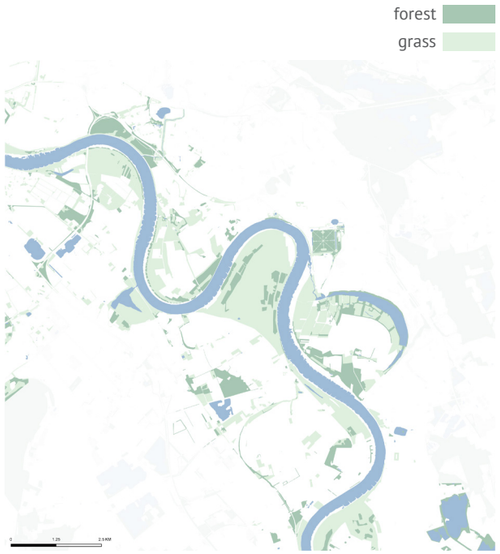


Figure: green spaces
Illustrate by the author
Source: Openstreetmap, 2022

Availability

Natura 2000 and green spaces

Figure: Natura 2000 and green spaces
Illustrate by the author
Source: Openstreetmap, 2022

Availability

Functional spaces: Farmland and agriculture

On the Rhine plain there is a vast productive landscape spread along the river. These farmlands and farm land create an irreplaceable value for local agricultural production. The existing agricultural and entrepreneurial economies reinforce each other, and the production and supply points for agricultural products can be located in close enough proximity to also benefit the environmental and sustainable development of the city. The distribution of the main crops within the region is shown below. As can be seen, the majority of crops are sensitive to flooding. Floods that occur in the floodplain can be harmful to these agricultural crops.

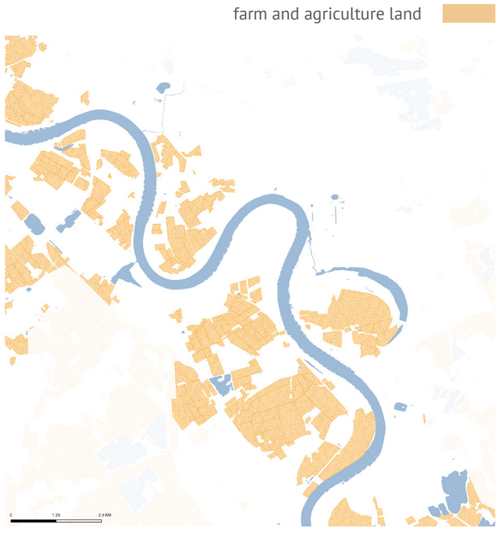


Figure: farmland and agriculture landscapes
Illustrate by the author
Source: Openstreetmap, 2022

Winter rapeseed

Sugar beet

Summer cereals

Sunflowers

Peas

Beans

Maize

Winter wheat
&triticale

Farmland and agriculture landscapes

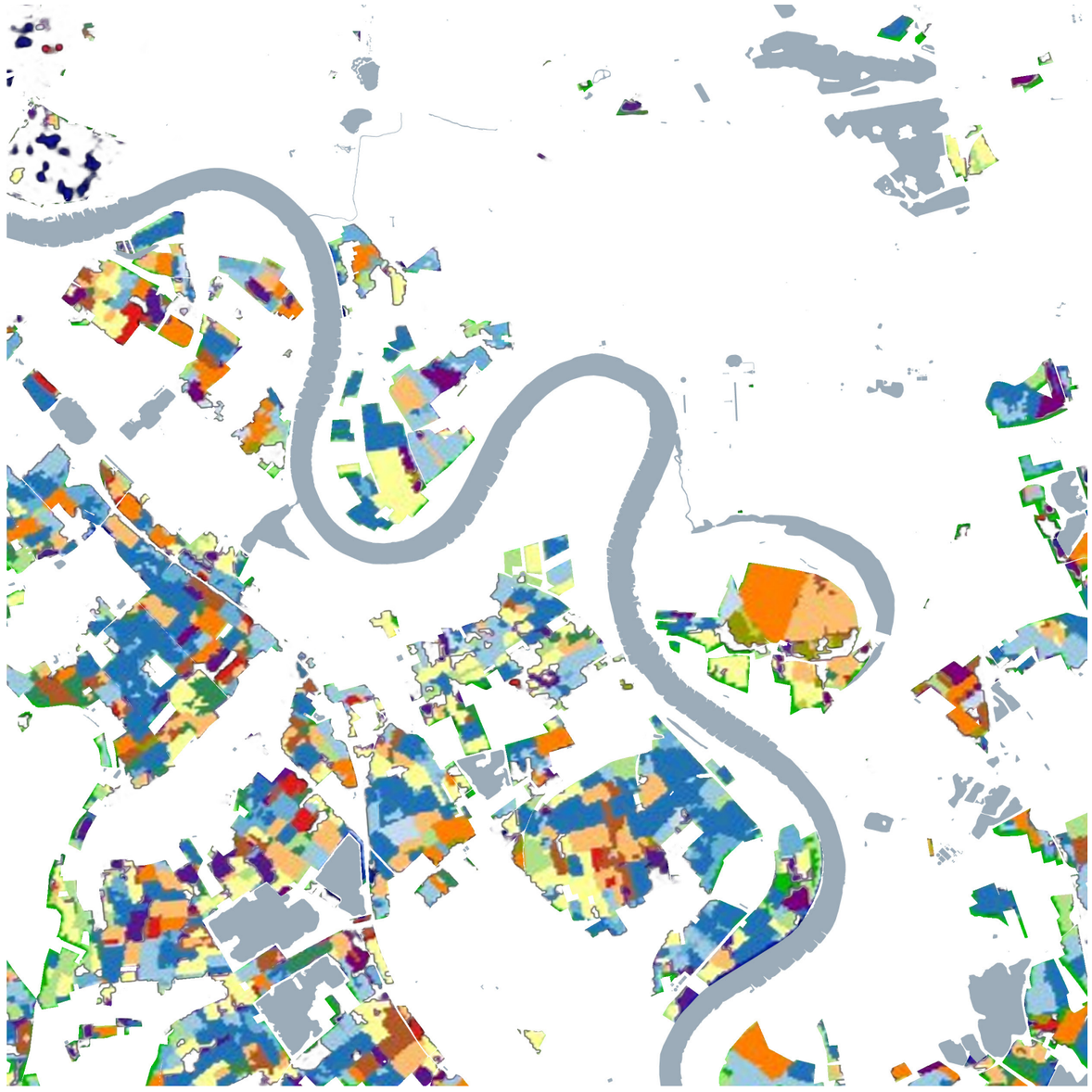


Figure: farmland and agriculture landscapes
Illustrate by the author
Source: Copernicus and Humboldt University Berlin - P.Griffiths, 2016

Availability

Functional spaces: urbanized area and recreation spaces

The industrial sites and docks along the river still show that this is the area located south of Düsseldorf in the Ruhr, once the most famous industrial area. The industrial area of the Ruhr was Germany's main mining and energy producing region, with oil refineries concentrated in the Ruhr and along the Rhine connected by a pipeline system to the North Sea port of Wilhelmshaven and Rotterdam in the Netherlands. To enhance the quality of life in the region, a number of urban parks and recreational areas are located between the industrial and residential areas, including the largest urban park in the Düsseldorf city region, Schloss Benrath, which is located along the river. The urban parks and recreational areas along the river are even more important as a point of integration between water and landscape areas and leisure life.

Figure: Functional map alongside the river
Illustrate by the author
Source: Openstreetmap, 2022

urbanized area and urban parks

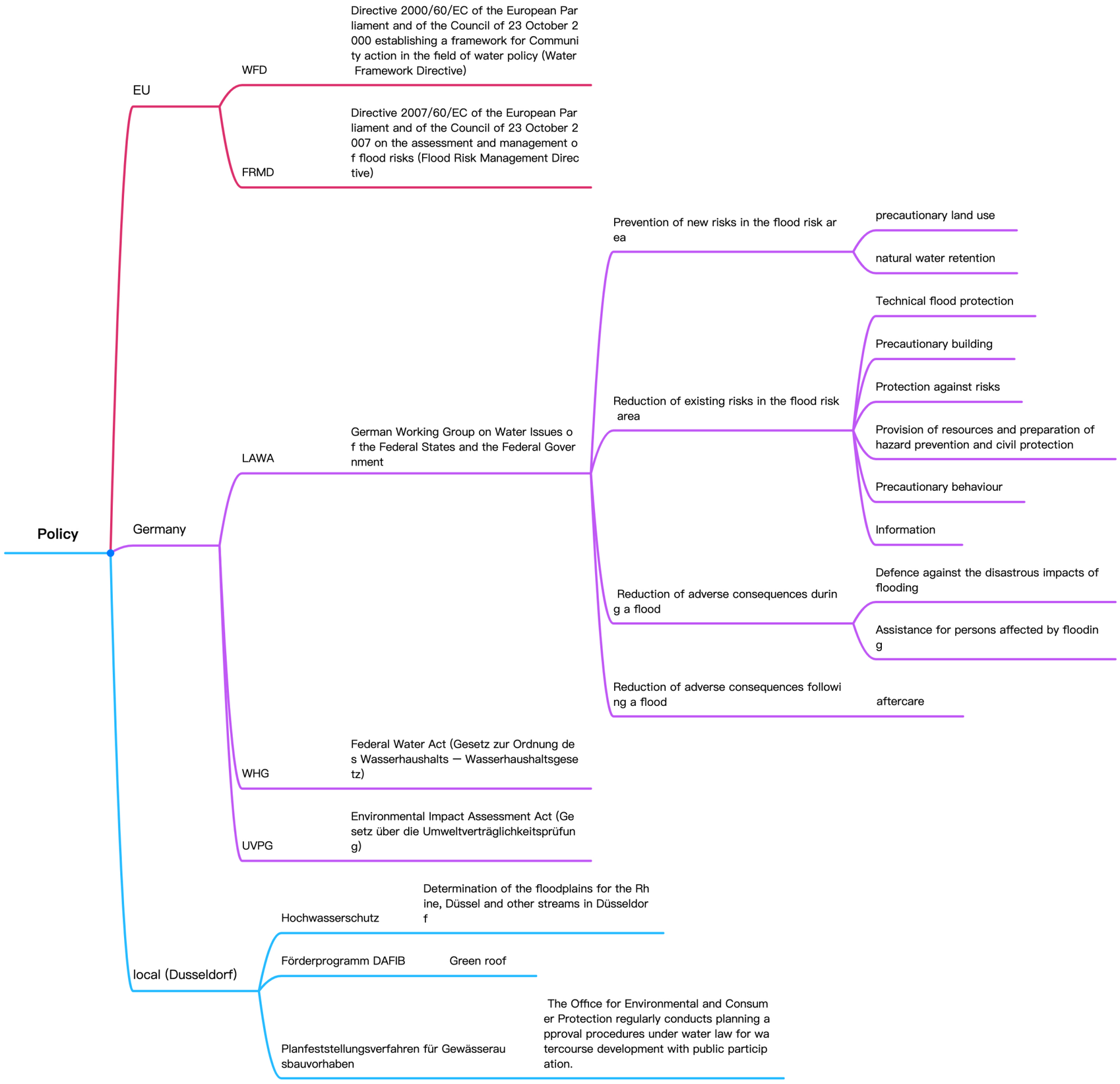
Figure: urbanized area and urban parks
Illustrate by the author
Source: Openstreetmap, 2022

Availability

policy

EU or region-scale policies are more abstract and conceptual for Nature-based solutions, and do not immediately translate into design strategies that can be implemented in the local context. At the same time, local municipality policy and funding support for nature-based solutions is often immature or absent.

Recognizing the new dynamics of the interrelationship between urban and bio-physical systems, the implementation of the Nature-based solutions for flood resilience and future development of the ABC mega region should be aligned from the mega regional scale to local scale. To better institutionalize the governance and support of this dynamic, flexible regimes and tools should be adaptable and aligned through all the crossing level and border.

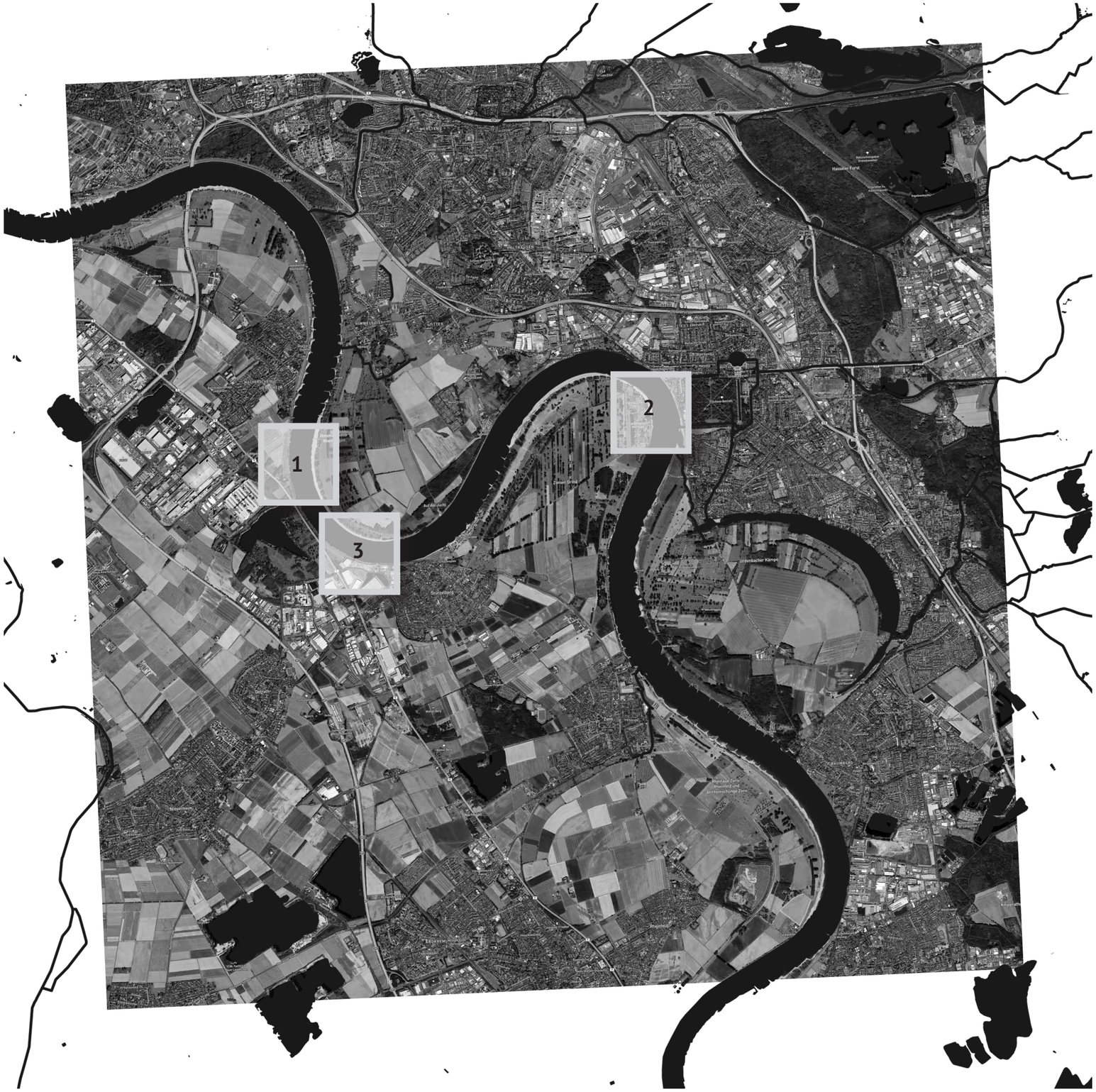


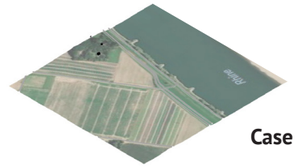
CHAPTER 06

IMPLEMENTATION

In order to clarify that the series of strategies in the above chapters have practical relevance in a realistic scenario. The local site as case study needs to be tested for the design. The local implementation is used to present the concrete implications of these strategies for spatial change.

Location





Case 1

Case 2

Case 3

Source: Googlemap, 2022

Implementation

Find the suitable NBS strategy for the design

The following measures are commonly associated with flood risk management in the above NBS.
Ecological restoration:
1\2\3\4
Forest Landscape restoration:
9\10\11\12
Green Infrastructure:
9\10\11\12\13\17\19\20
Ecosystem-based disaster risk reduction:
5\6\7\8
Climate adaptation services:
13\14\15\16
The diagram shows how flood risk reduction can be achieved through nature-based solutions, each of which can be applied to a specific typology of space.

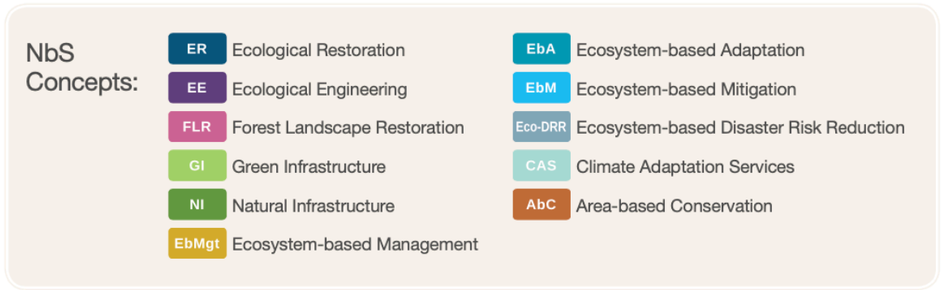
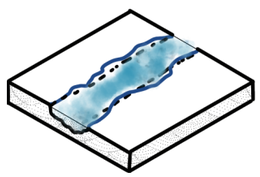
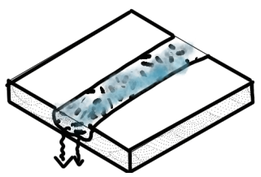


Figure: nbs consepts
Source: IUCN, 2020



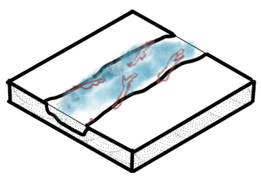
Riverbank softening

1



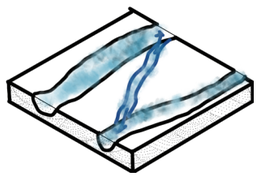
River bed infiltration

2



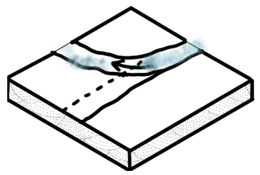
Deadwood and roots runoff control

3



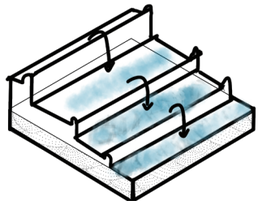
streams connection

4



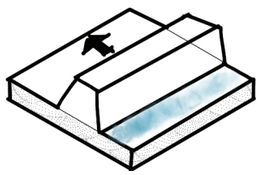
Redirecting

5



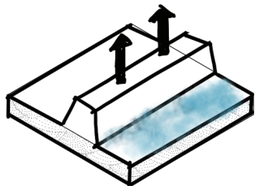
terraces and slopes

6



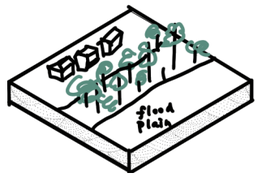
Remove the dam for bigger floodplain

7



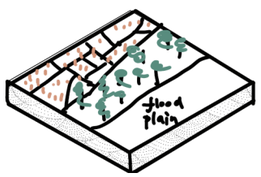
Highten up the dam for bigger floodplain

8



buffer belt for city

9

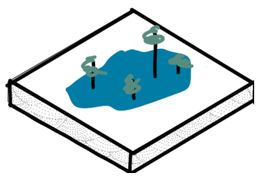


buffer belt for agriculture

10

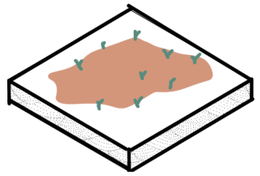
forest restoration

11



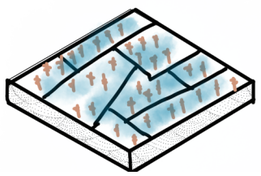
mangrove forest

12



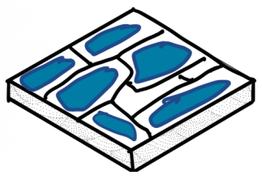
wetland rentention

13



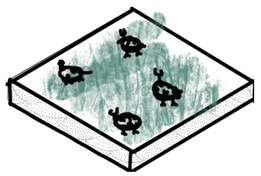
aqua agriculture

14



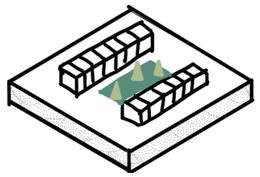
fishing pond with aqua agriculture

15



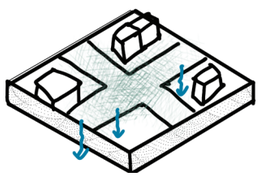
Pastoral in floodplain

16



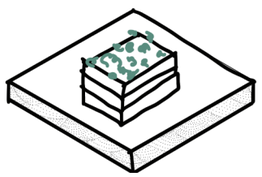
urban farming

17



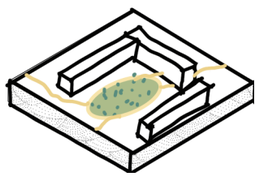
desealing cities

18



green roof

19

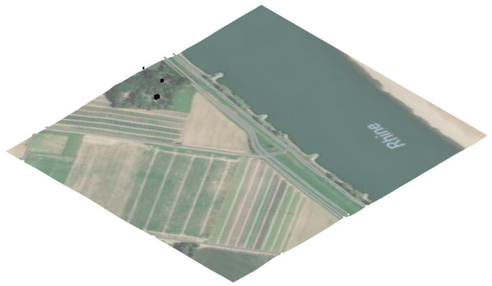


urban parks

20

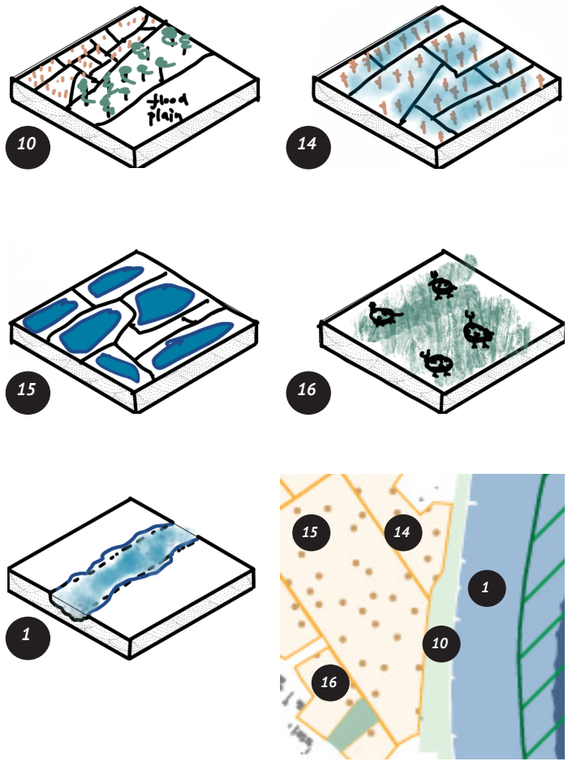
Figure: Typologies of NBS for flood risk management
Illustrate by the author

Case 1

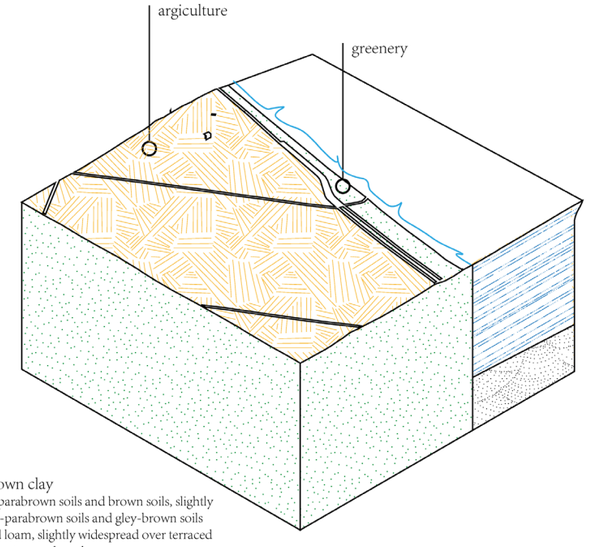


The banks of the river function as agricultural land. The banks have a more natural and softer boundary and are not rigid concrete embankments. As the overall topography does not change much, the river banks are flat and there are no high embankments to block them, so there is a greater potential for flooding on both sides of the river when the water rises. In this intervention, the area is treated as floodable area; the original soil conditions of the river are clay and silty, with poor permeability and absorption, and if the wider nature reserve plant absorption capacity can be applied to improve the soil conditions, this will help to reduce the flood risk. Agricultural land in flood-prone areas can be planted with crops that are adapted to flooding.

Applied NBS

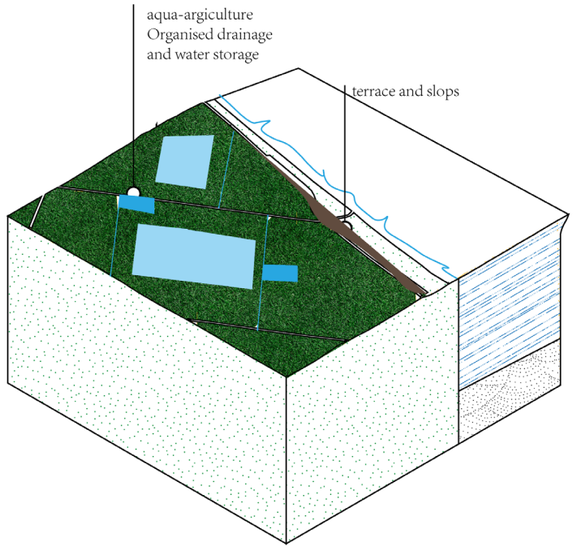


Before



flood soil Brown clay
predominantly parabrown soils and brown soils, slightly widespread gley-parabrown soils and gley-brown soils from high-flood loam, slightly widespread over terraced sand or over deep terraced sand

After



Before

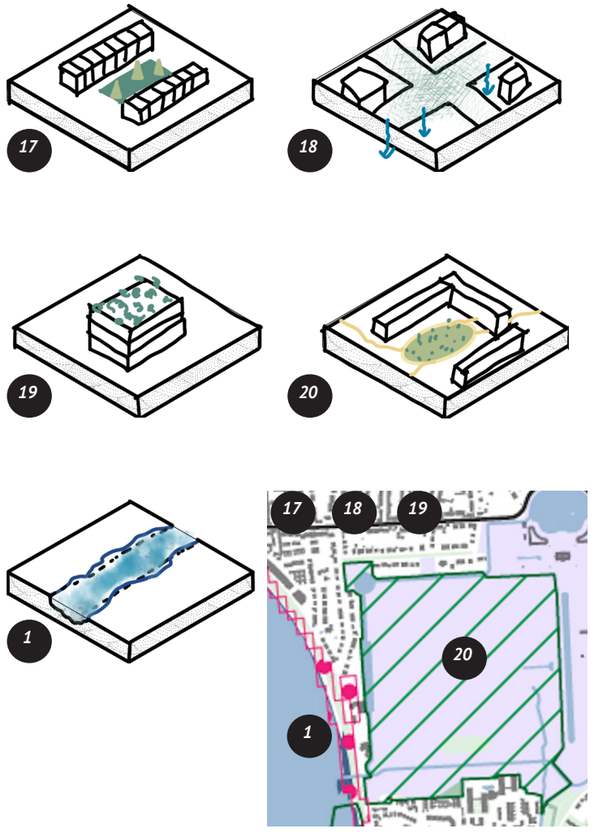
After

Case 1

Case 2

The strategy is to create floodable areas by transforming previously channelized riparian spaces with gently sloping banks that are too rigid, and by planting greenery and paving walkways, these riparian spaces can become an attractive riparian park space. It can work in synergy with the city's parks to serve the city's inhabitants.

Applied NBS



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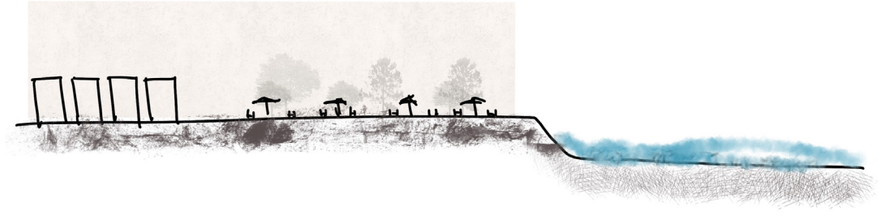

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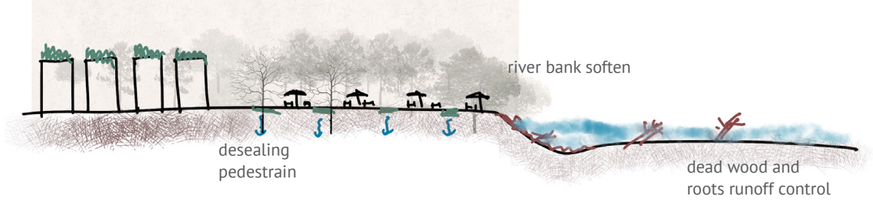

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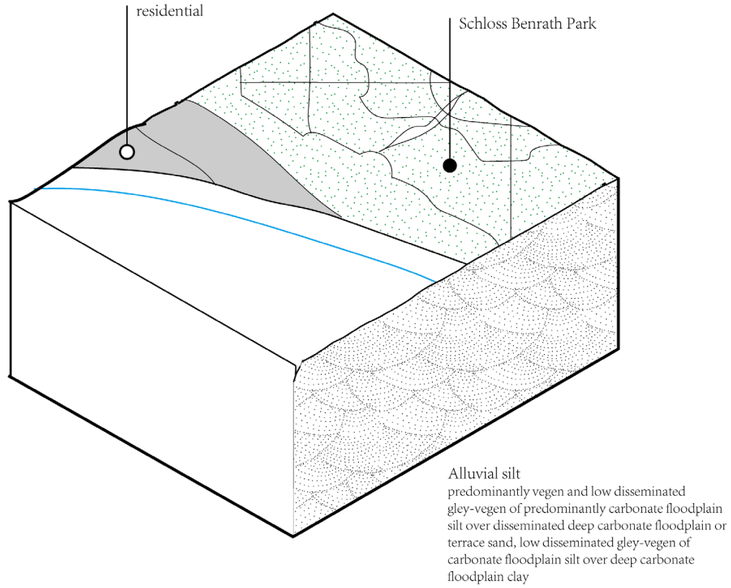

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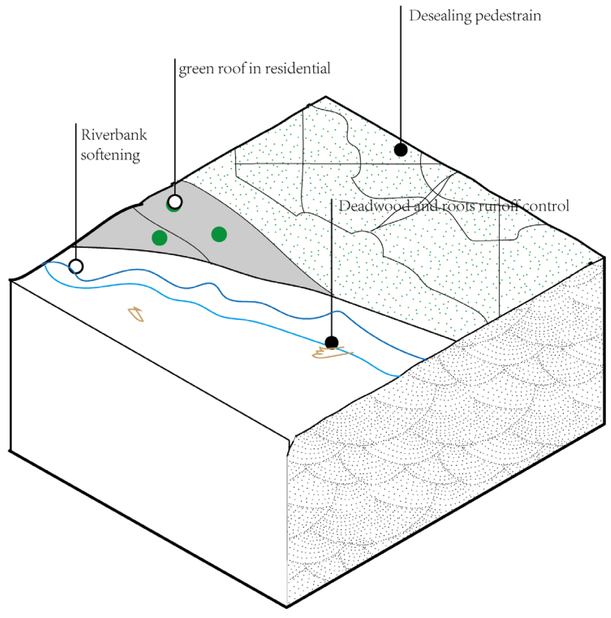
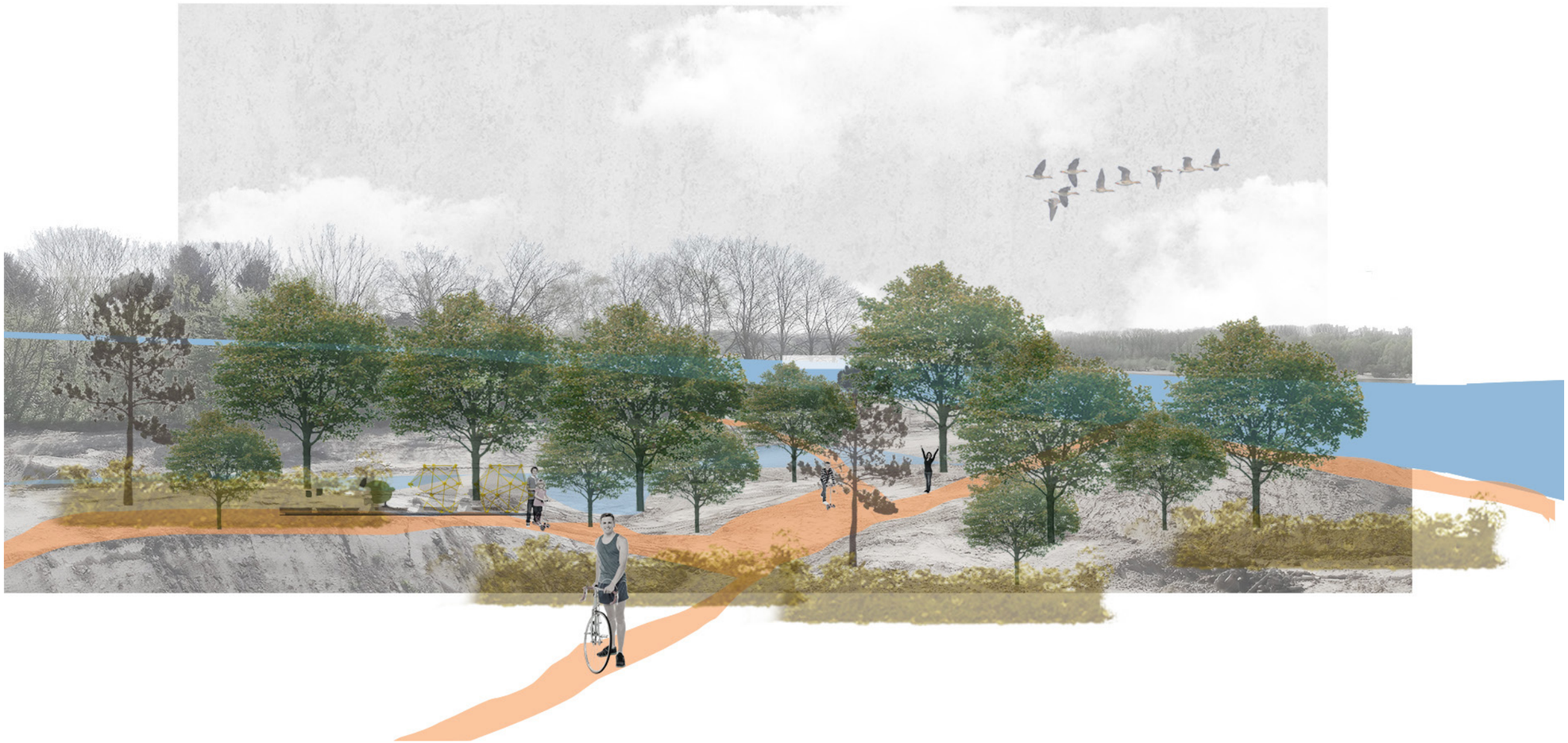
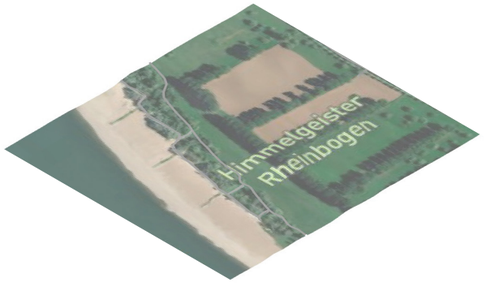


Case 2

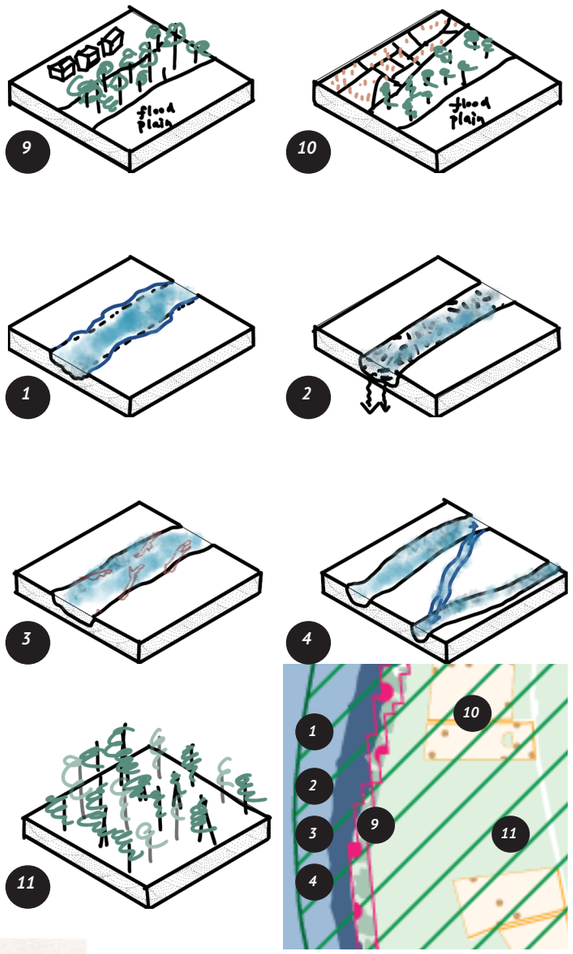


Case 3



These green spaces are located within the natura 2000 reserve along the riverbank. The riparian area acts as a junction between the green-blue ecosystem and in this case the potential of both is recognised and stimulated. Through ecosystem restoration in the NBS, river restoration and green spaces restoration are used to enhance the river's own runoff regulation and infiltration capacity and to increase the green space's ability to retention, absorption and buffering of floods in order to protect the living areas behind the green space and agricultural production areas.

Applied NBS



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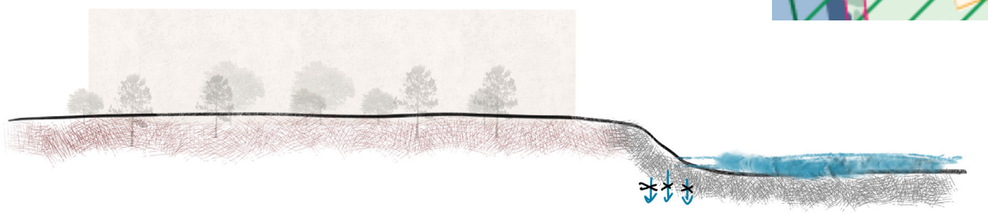

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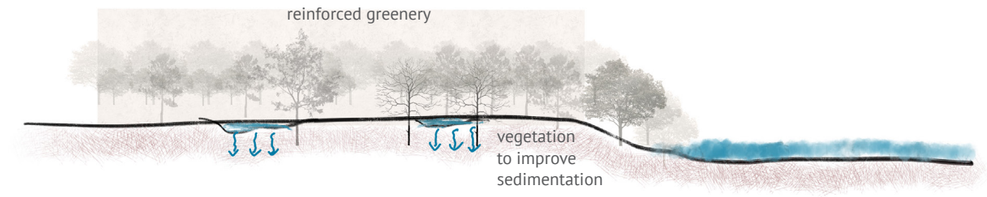
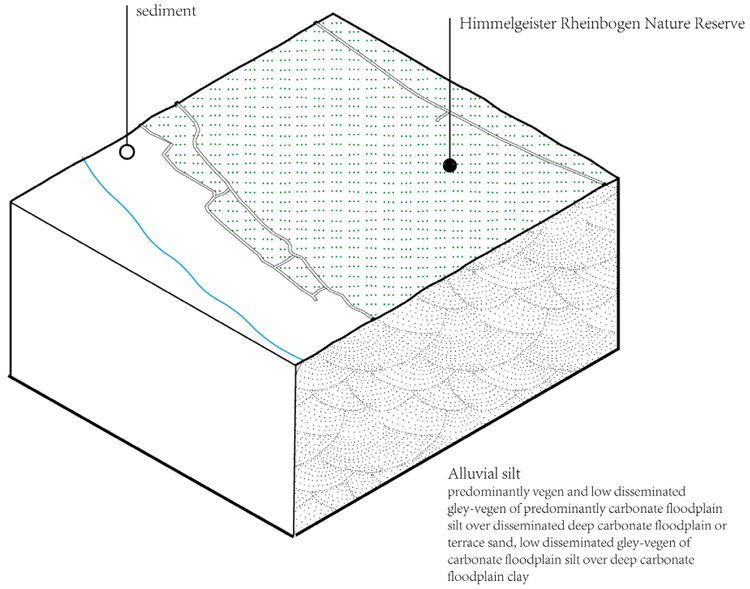
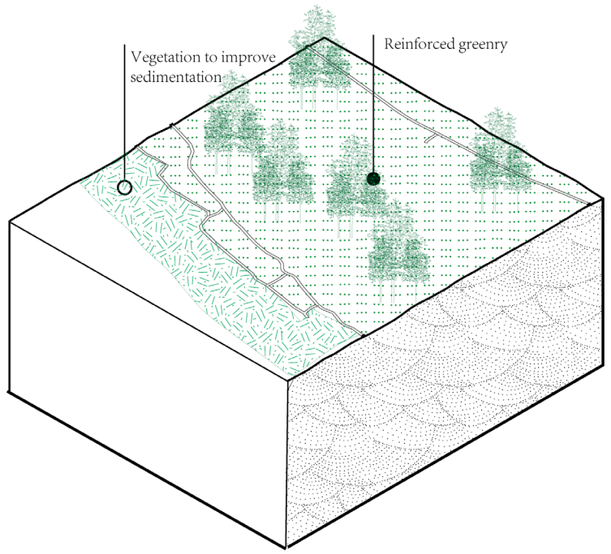


Before



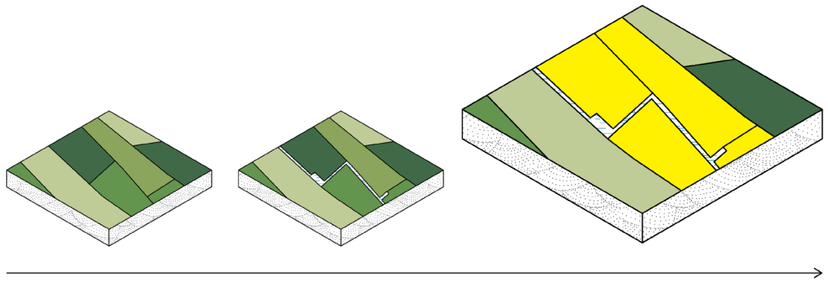
After



Case 3

Implementation

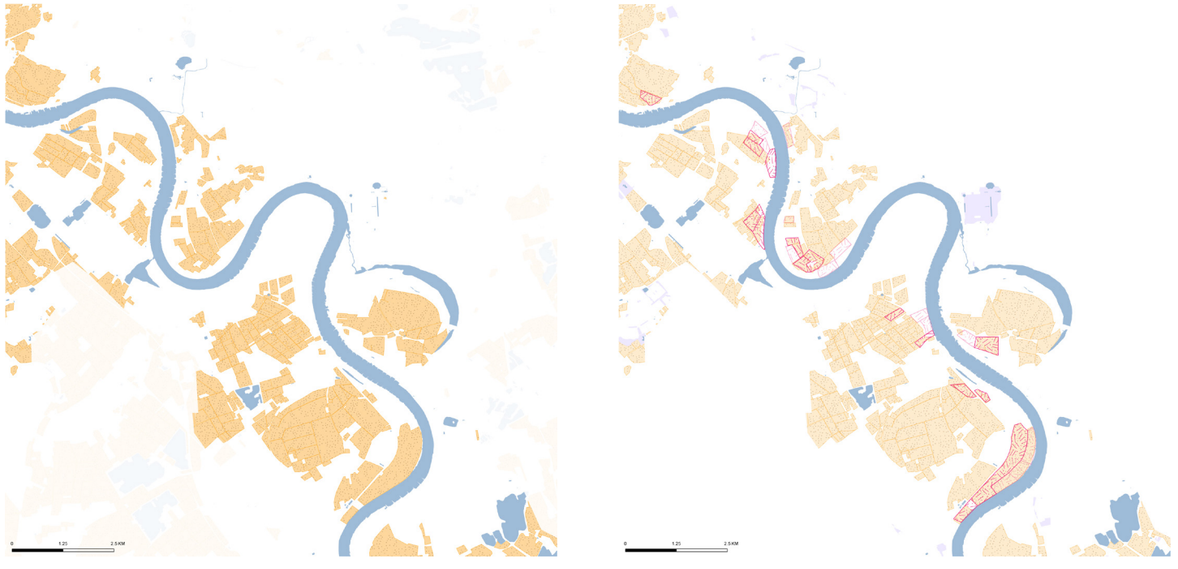
Strategy in agriculture land



original field

A recyclable farming system combining water storage and transport functions

Re-selection of the types of agricultural products to be grown and the implementation of aqua-agriculture



The strategy takes advantage of the fact that agricultural land can use water as part of the production chain, by increasing the number of ditches and streams in the farmland to achieve greater water uptake. At the same time, part of the agricultural land is used to cultivate seasonal crops that can grow and produce during flood post-disaster. This can be used as part of the floodable area in case of flood peak season.

Strategy in agriculture land

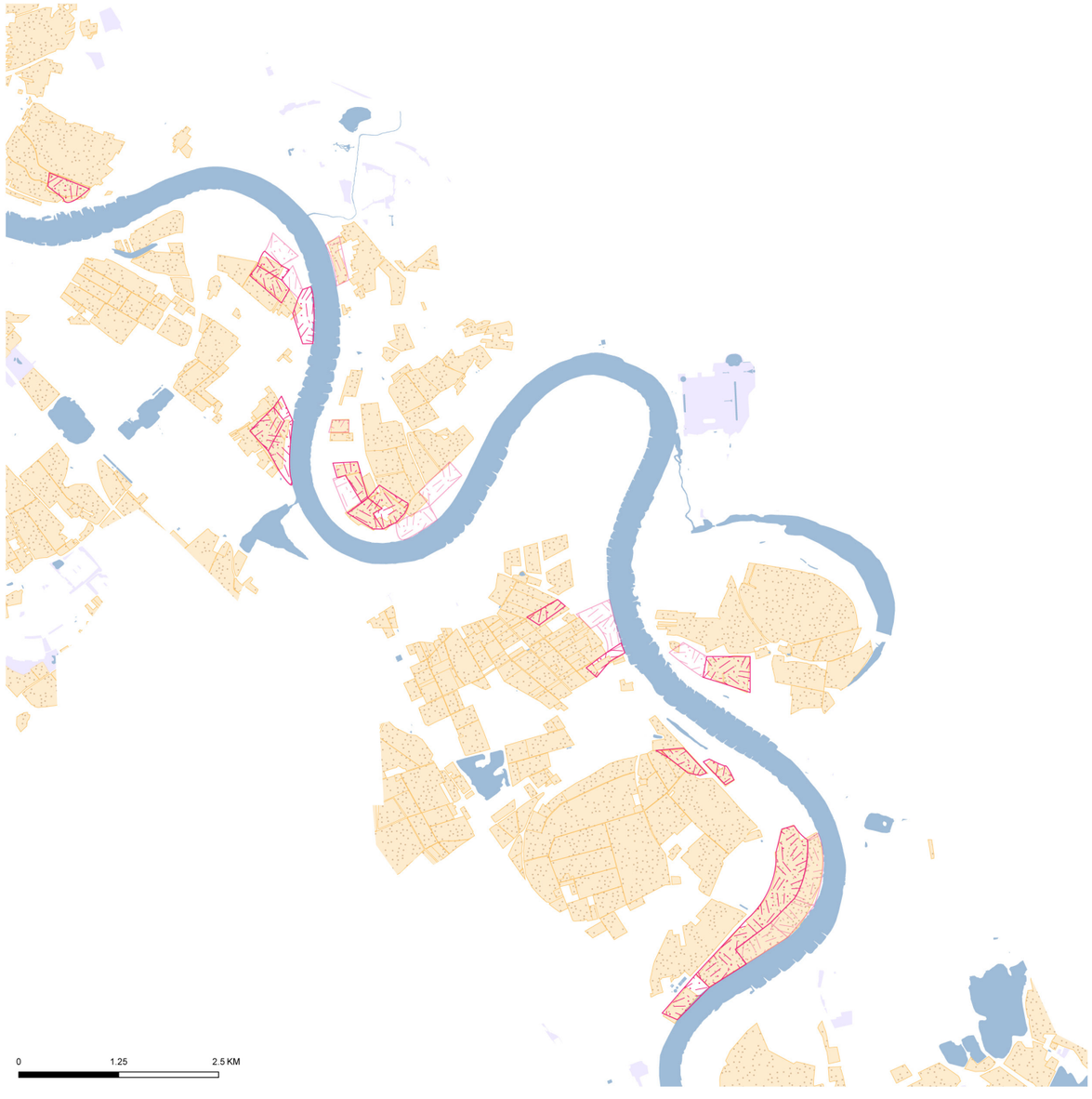
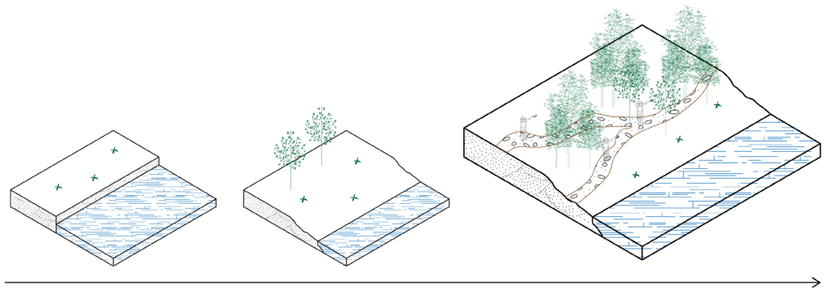


Figure:Strategy in agriculture land
Illustrate by the author
Source: Openstreetmap, 2022

Implementation

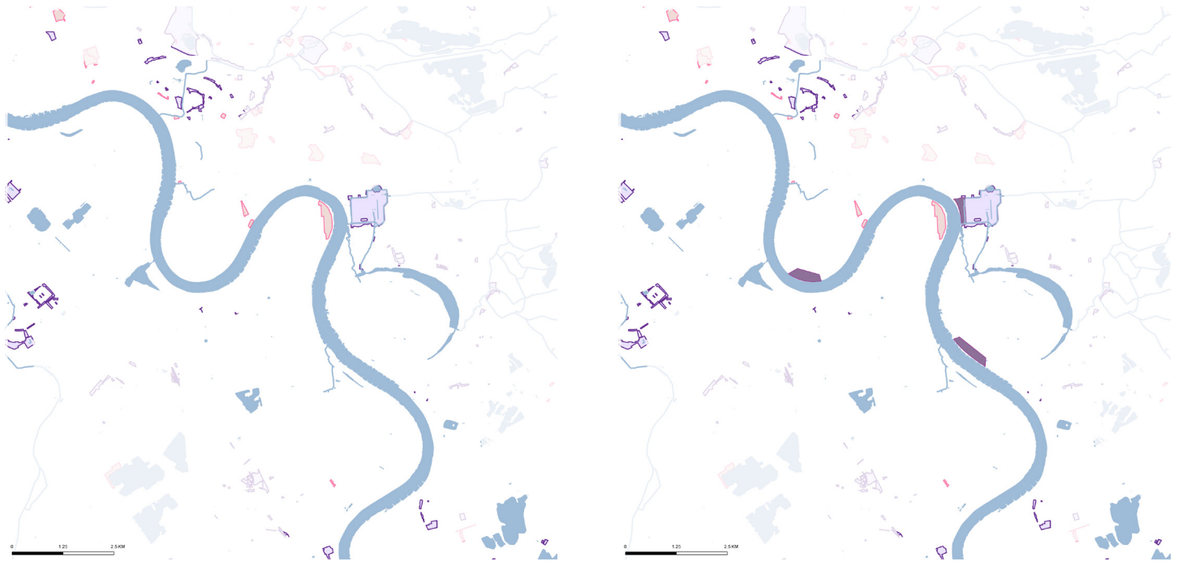
Strategy in urban parks



original channalized rigid river boundary

Gently sloping riverbanks with organic ecological boundary

The riverfront space integrated with the city park provides more recreational space for city dwellers



The strategy is to create floodable areas by transforming previously channelized riparian spaces with gently sloping banks that are too rigid, and by planting greenery and paving walkways, these riparian spaces can become an attractive riparian park space. It can work in synergy with the city's parks to serve the city's inhabitants.

Strategy in urban parks

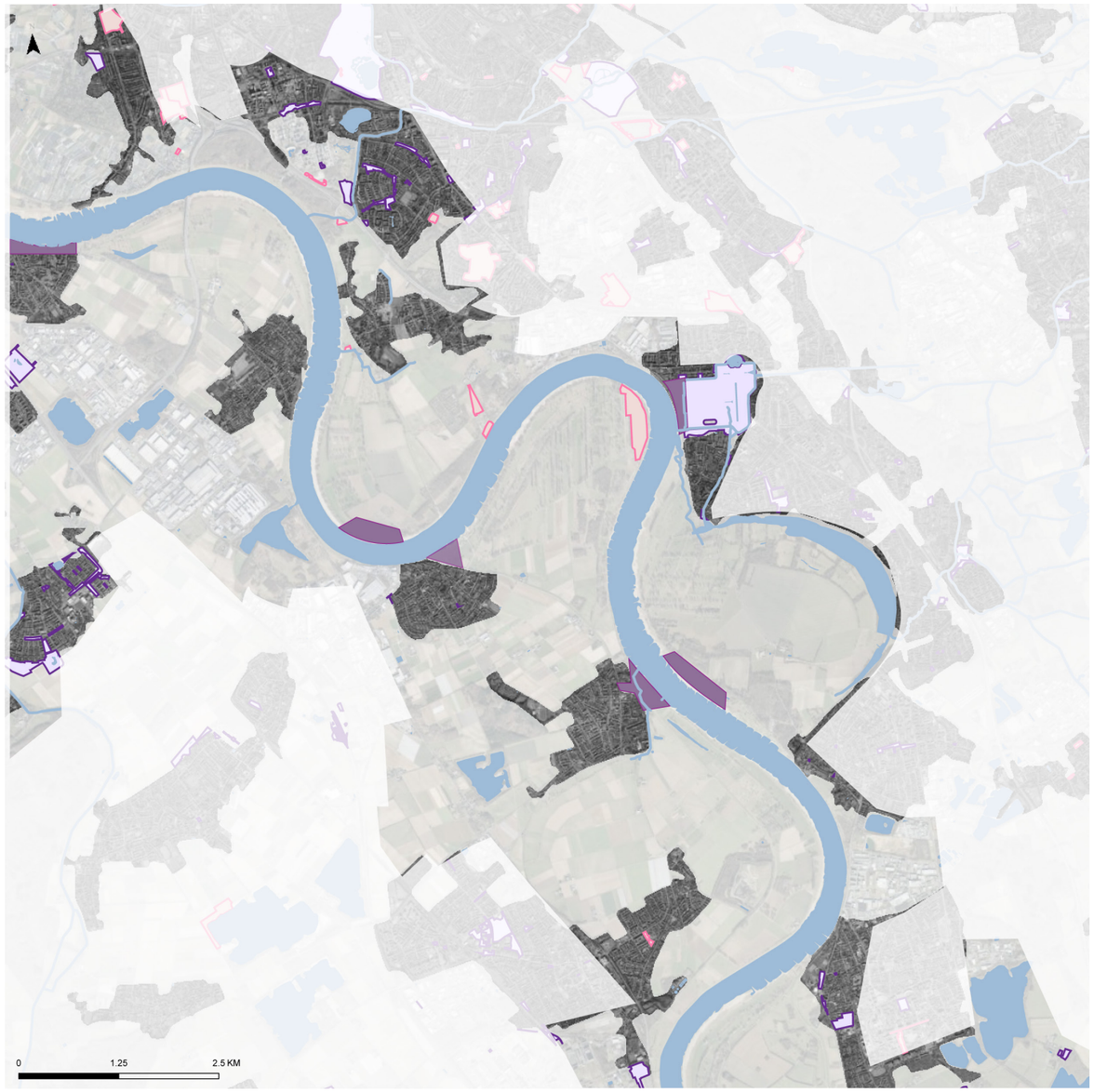
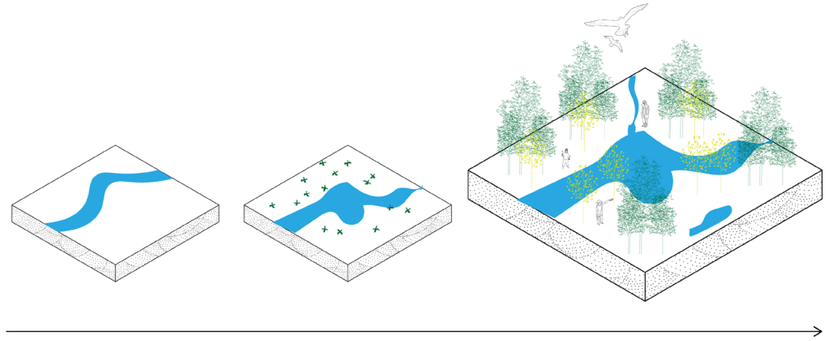


Figure: Strategy in urban parks
Illustrate by the author
Source: Openstreetmap, 2022

Implementation

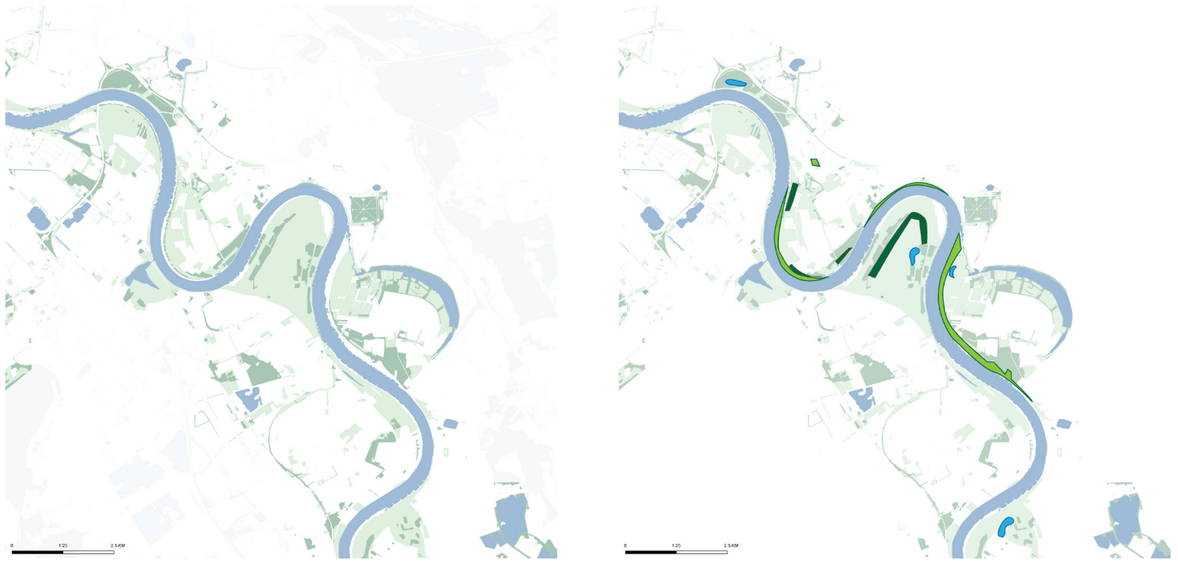
Strategy in green spaces



original riverside

Improving the ecology

Gradually enhanced green-blue infrastructure as the plant grows year by year



The strategy is to enhance the quality of green spaces by, for example, increasing the area of greenery and planting density to bring back the artificiality of green spaces to nature. Trees and grasses may require a certain growth period to achieve the effect.

Strategy in green spaces

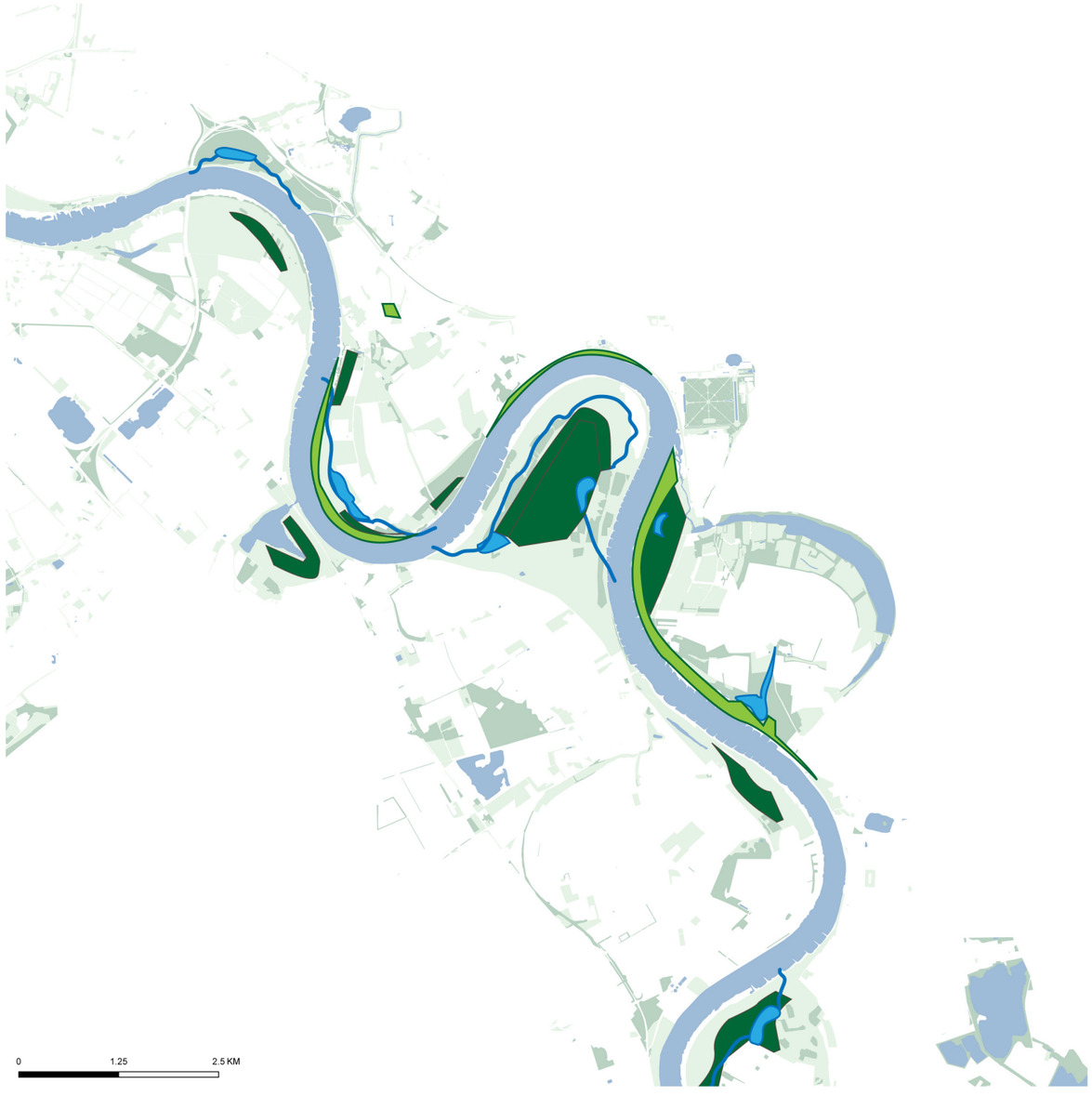


Figure: Strategy in green spaces
Illustrate by the author
Source: Openstreetmap, 2022

Implementation

2030

Nature-based solutions require a certain amount of time to achieve the final effect of flood risk control. The agricultural space along the river is gradually shifting towards a more water-adapted production model. The quality of the riverside green space is also enhanced, with water and green space forming a more organic and rich spatial relationship. These spaces are combined with each other and the city park to provide more public recreational space for local living.

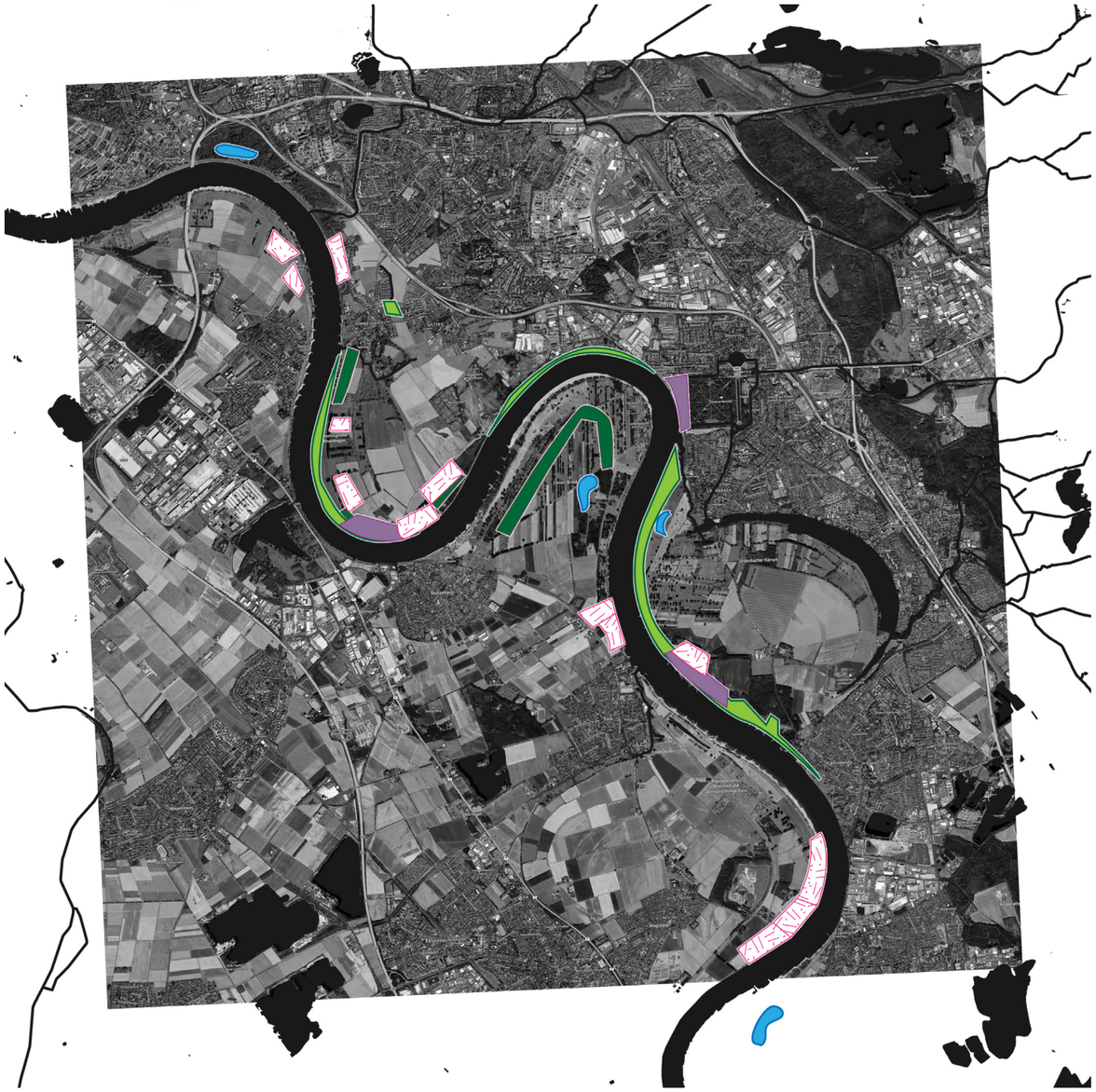


Figure: vision map 2030
Illustrate by the author
Source: Googlemap, 2022

2040

As time progresses and more projects are completed, a more mature and rich multifunctional flood plain system is formed and the eco-system and the various functions of the urban areas reinforce each other to achieve a better flood resilience future.

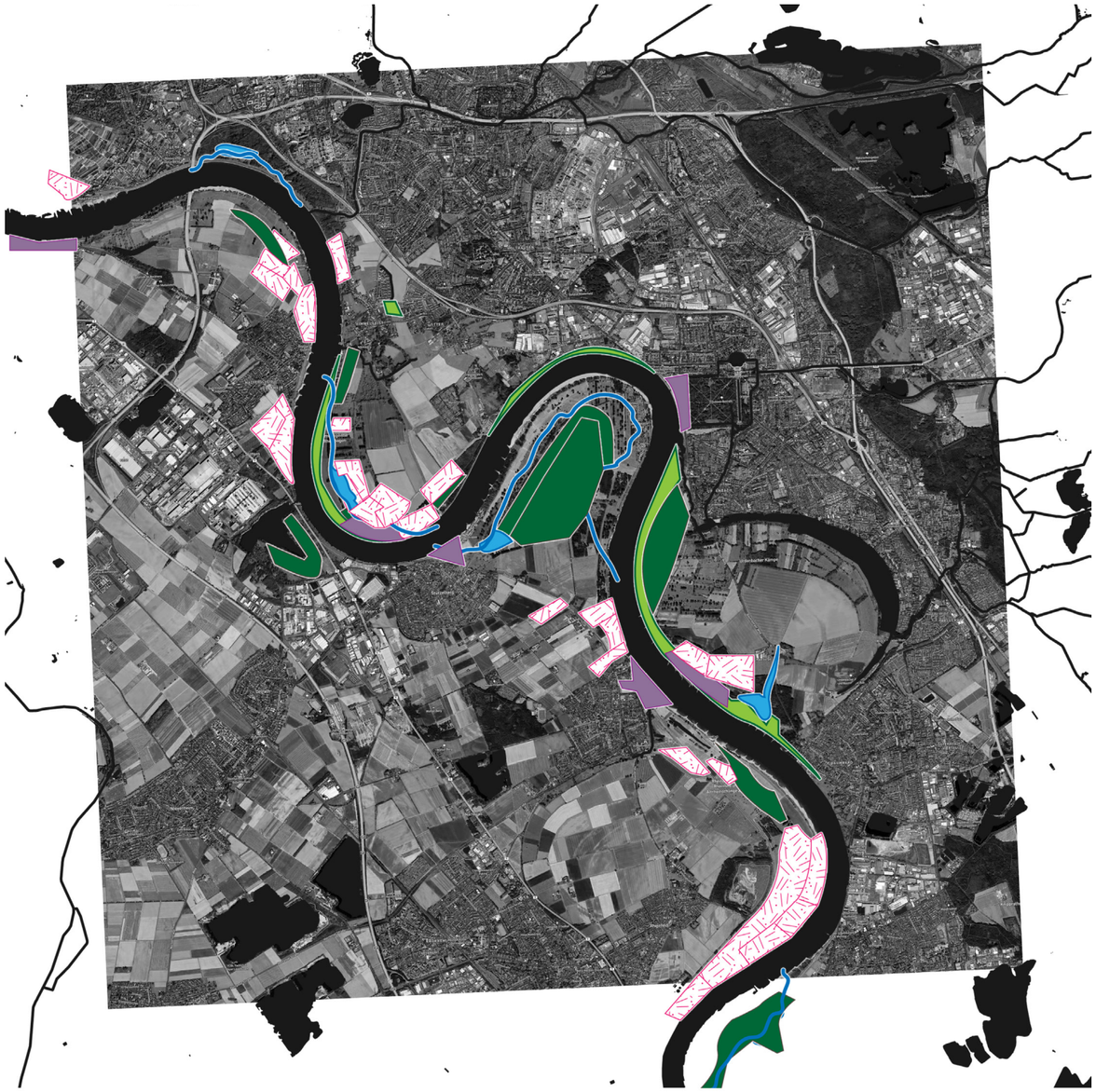
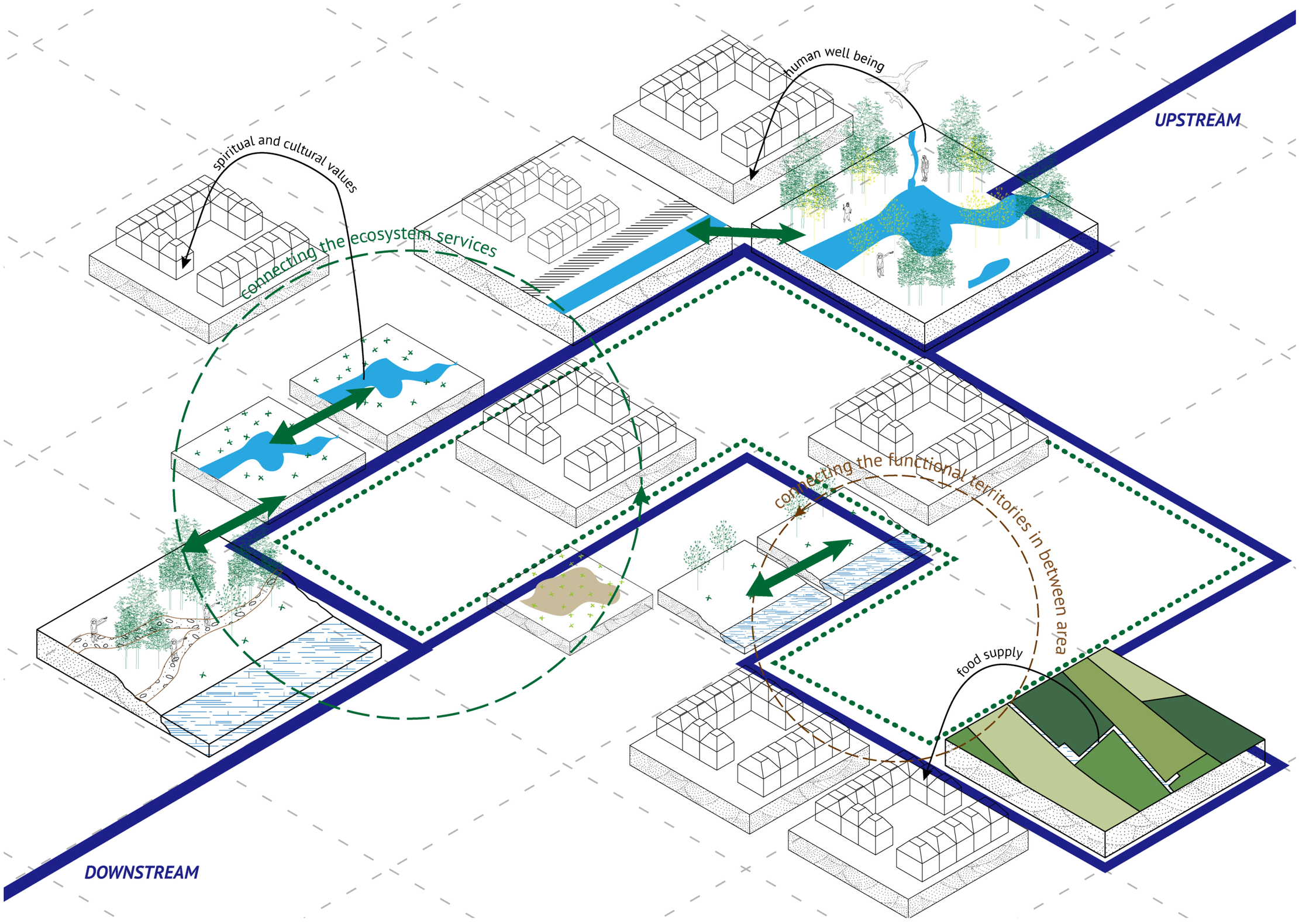


Figure: vision map 2040
Illustrate by the author
Source: Googlemap, 2022

CHAPTER 07

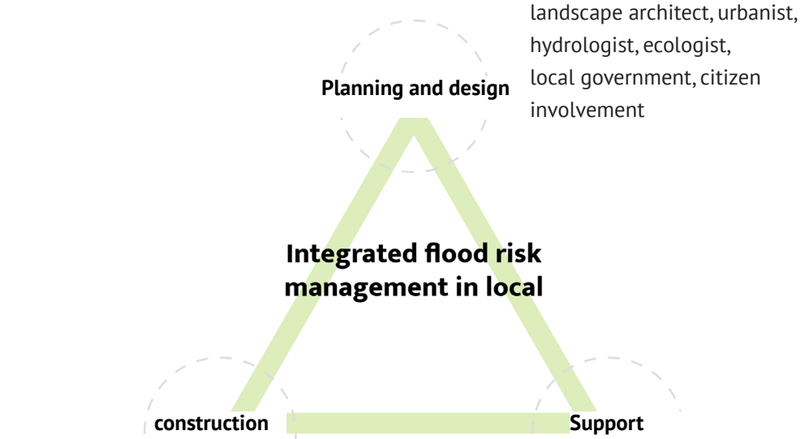
CONCLUSION

Systemical interelations



Stakeholders

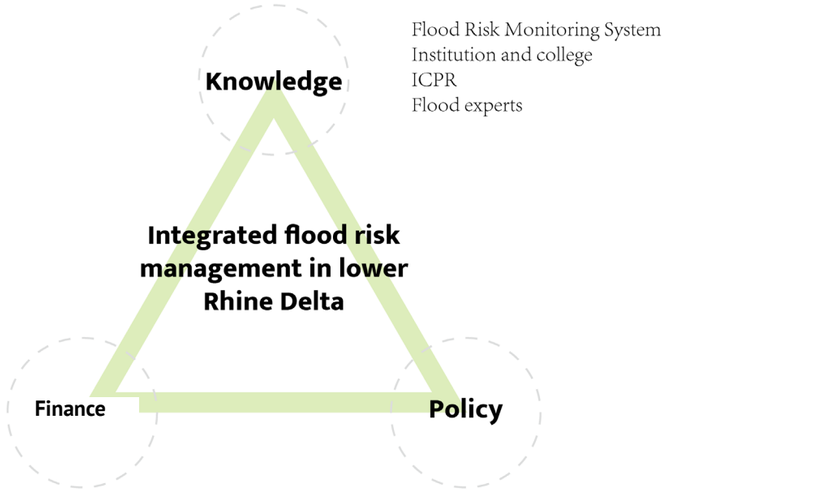
local - execution



Landscape construction companies, farmers, urban park and orchards operators, citizens

Local government funding, local government policies and processes, private landowner land sales or leases, higher level government funding or policy support, eco-friendly NGO organisations

mega regional - cooperation and support

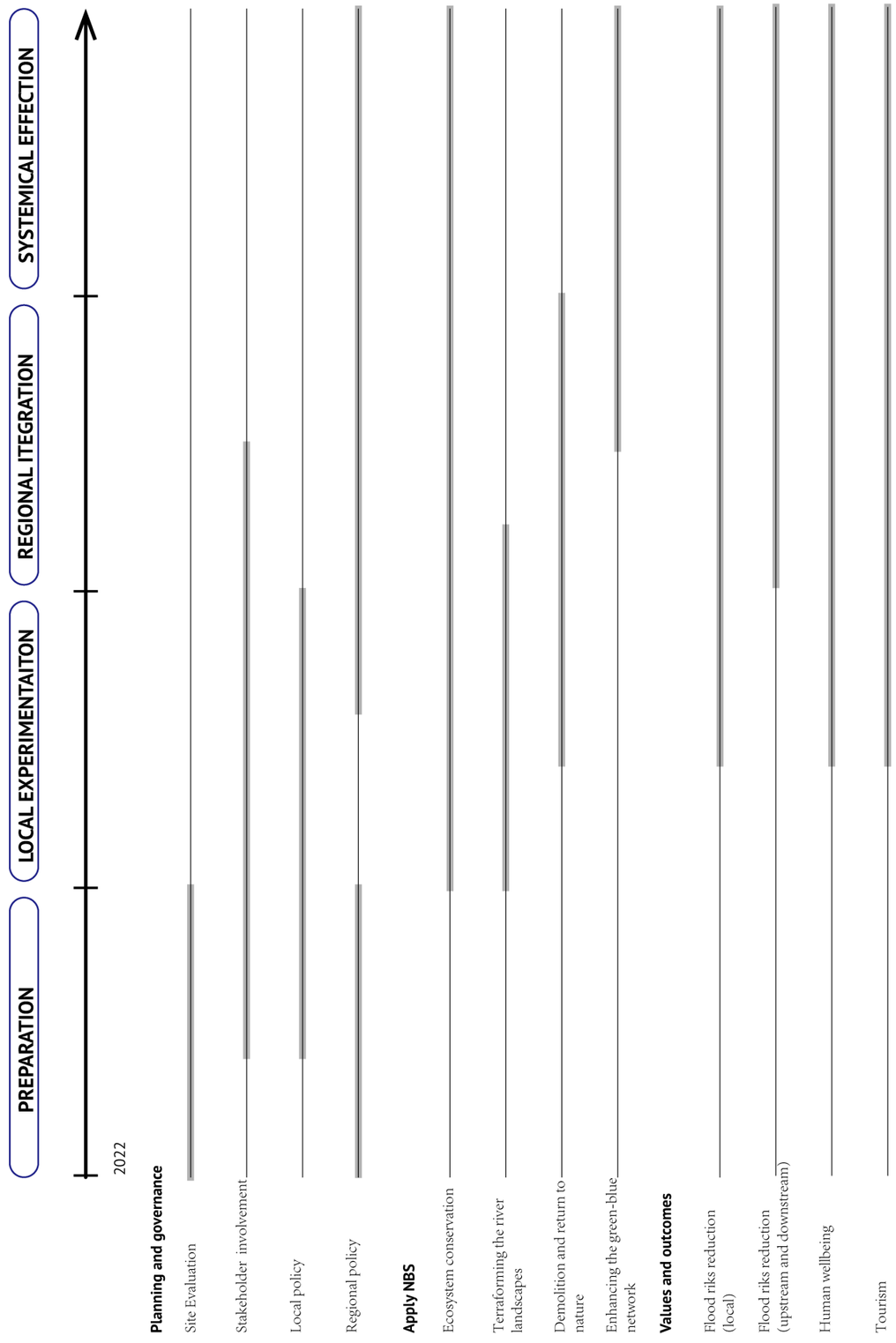


Environmental NGOs
Partners(i.e.GEF, UNDP, UNEP, World Bank, EU, WWF, IUCN, Ramsar Convention)
Government and municipality
Urban Construction Company
Private owner

Policies:
Natura 2000/Flooding Directive
Policy maker:
EU
National Government(i.e. Germany, Netherlands)
Municipality
Citizen envolvement

Schedule

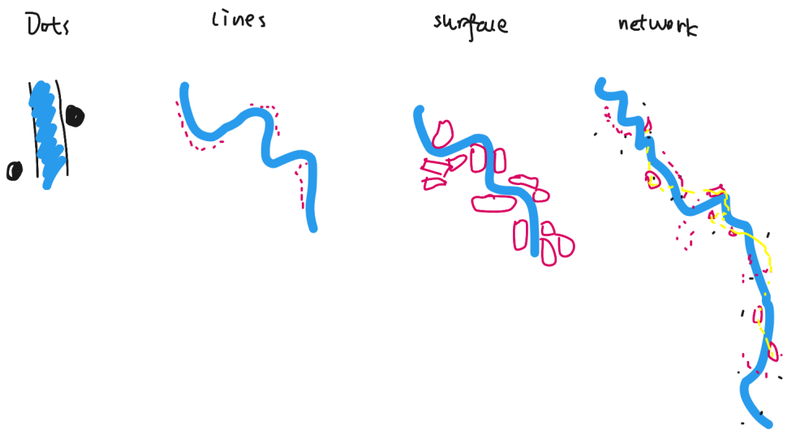
In order to be able to systematically realise the overall transformation from local to mega regional, the plan needs to be integrated on a temporal scale. As a complex system, the redundancy required for the design determines the time and priority of the project. The estimated time and timeline for each local project can be derived from this. It is also important to be aware of the combination of projects and projects to achieve a combined effect on a larger scale. The schedule can be divided into a preparation period, a local project pilot period, a local project development period, a project integration period and a systemic effectiveness period.

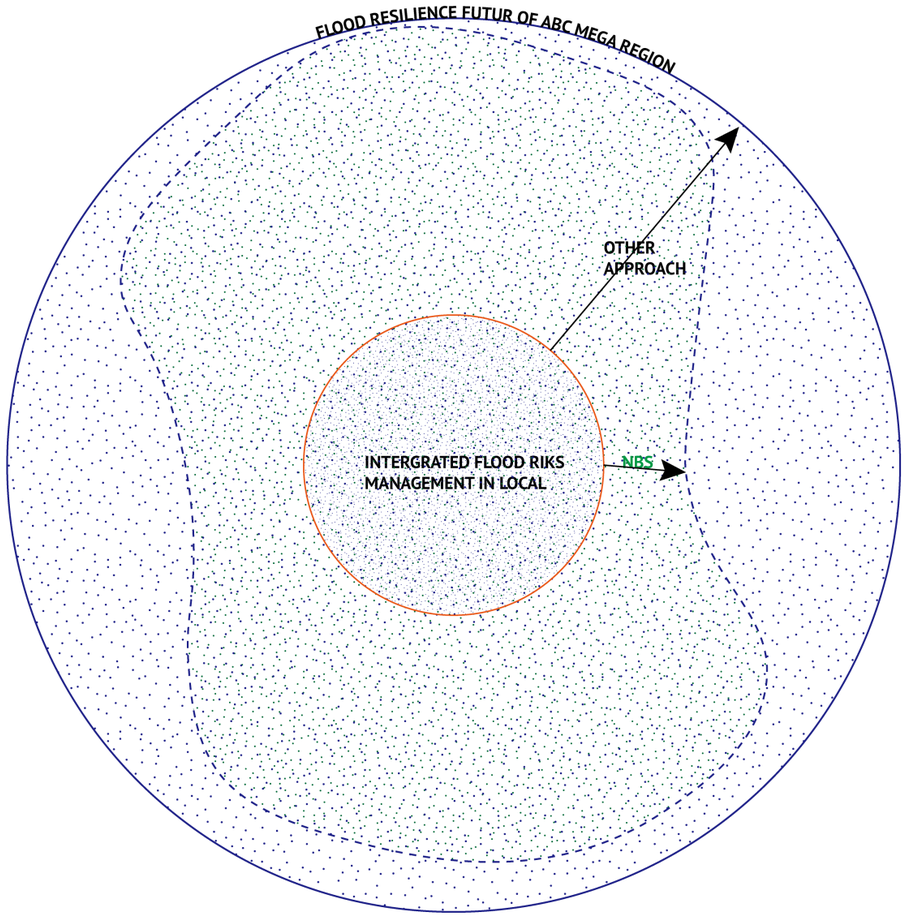


From local to mega region

The big contrast in scale from local to mega region reflects the dialectical unity of the whole and the parts in the process of combination of spatial planning and nature-based solutions for flooding risk management. The overall aim is to achieve a flood resilience future, as well as dynamic and integrated flood risk management for ABC mega
region. The level of redundancy required for the design is determined by the level of integration of actors and flood risks. The different levels of design redundancy will also determine the time required in the transformation and the time point in the whole timeline. This makes the whole ABC mega region not only a multi-functional integrated network at the spatial dimension, but also a more integrated and diverse in temporal dimension. For example, inland and seaward, due to the different levels of risk and natural ecological conditions, the four-step approach of opportunity, suitability, availability, and applicability in this thesis allows for the selection and adoption of the most appropriate integrated measures.

Furthermore, the time of transformation across the mega region will be shorten up by all of the local adaptive projects. By using NBS, the local action enhanced eco system services and revealing potentialities to shorten up the transformability needed in constant alignment with the larger mega regional scale policies and planning.





From local to mega region

Water/ blue infrastructure
Flooding risks
Green infrastructure
Landscapes
the policy boundary
the trend and potential

Water/ blue infrastructure
Flooding risks
Green corridors and patches
Spaces for expansion
Urban and sub-urban areas

Water/ blue infrastructure
Flooding risks and flood plain
Green corridors and patches
Urban landscapes
Landuse and landprice
Population growth
Production and economic
City functions

Water/ blue infrastructure
Flooding risks and flood plain
green spaces
River landscapes
Local interventions and design
Local involvment
Plotting

Mega regional | Regional | City | Local

Nature based solutions for flood risk management

2022

Current

2040

Programme "Rhine 2040"

- Connected habitats
- More biodiversity
- Good water quality
- Mitigation of flood risks
- Cope with low water

Goal of Urban Flood Integration (UFI)

urban development, flood management, as well as navigation and environmental protection are negotiating the border between the river and the urban realm.

2100

Flood resilience future

Urban spaces configurations and development

Mega regional

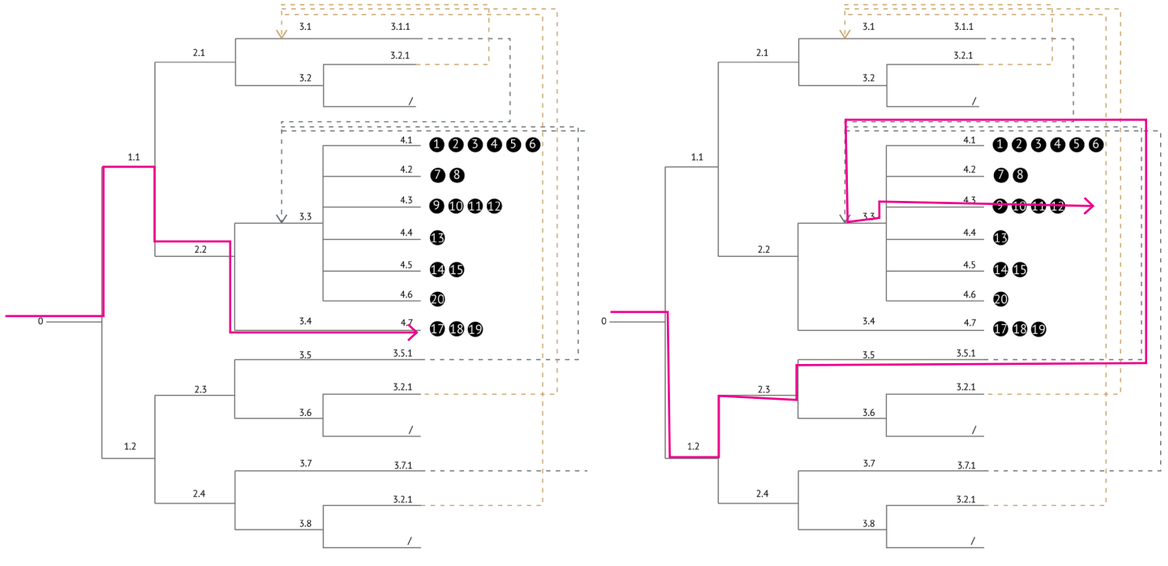
Regional

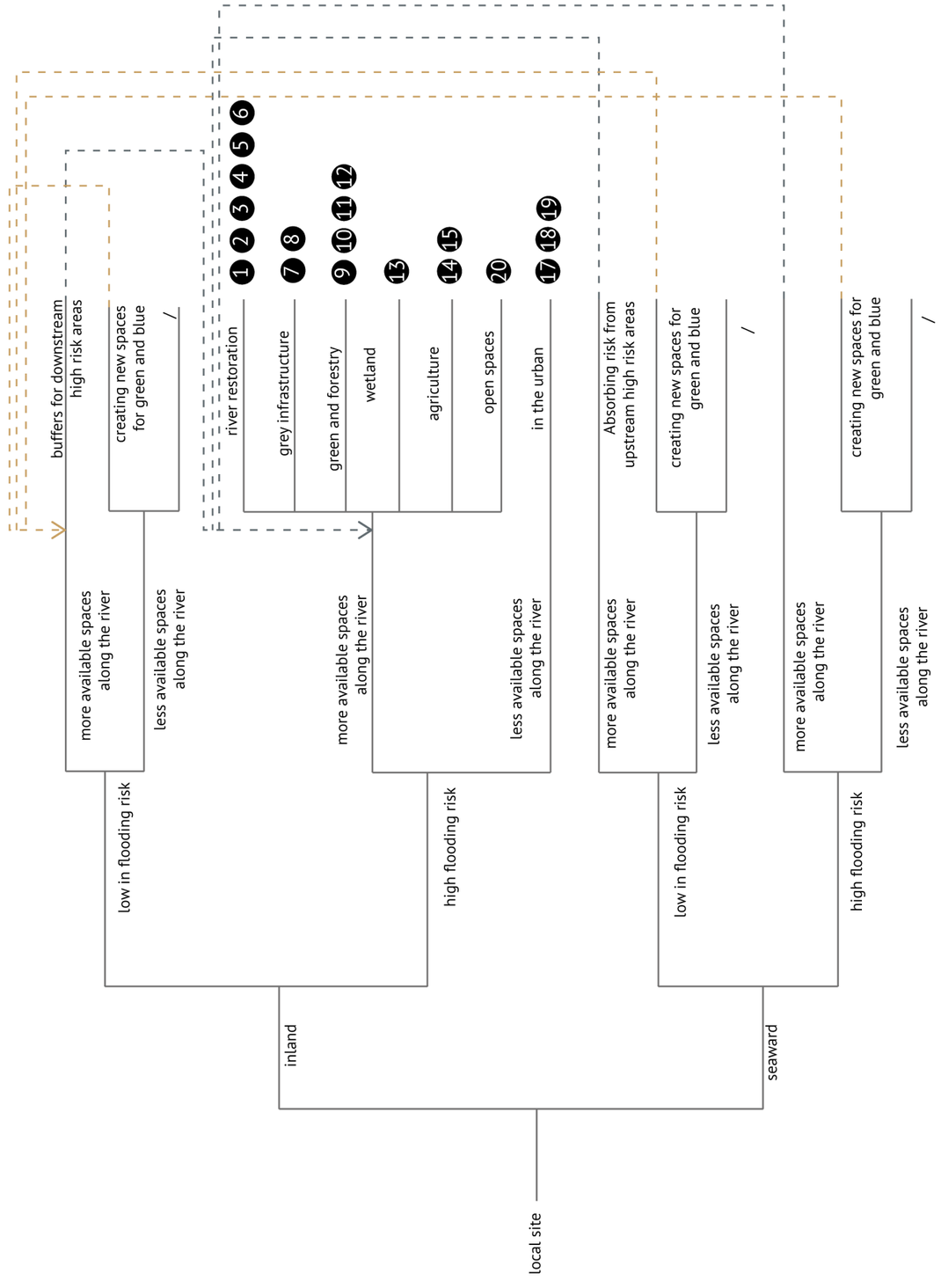
City

Local

From mega region to local

In the above-mentioned chapter, the measures and proposals taken for a specific local condition in the ABC Mega region, a rural area in the south of Düsseldorf, explore and demonstrate how the most appropriate nature-based solutions can be selected for flood risk management, but also to demonstrate the spatial design effects it brings. However, in real life application scenarios, due to the different geographical locations and other underlying conditions within the different ABC mega regions, as well as the dynamically changing ecology and urban development needs, there should be a dynamic system that can demonstrate the dynamism and adaptability of nature-based solutions. The flowchart below shows how any small change in input values such as site conditions, site function, flood risk, will correspond to different measures and solutions. Although the flow chart does not take into account all scenarios and conditions, it still demonstrates a degree of system dynamics and complexity. Flood risk as an upstream and downstream factor can influence each other rather than causing harm to each other. At the same time other added values such as the functional network of the agricultural industry also flow dynamically throughout the system.



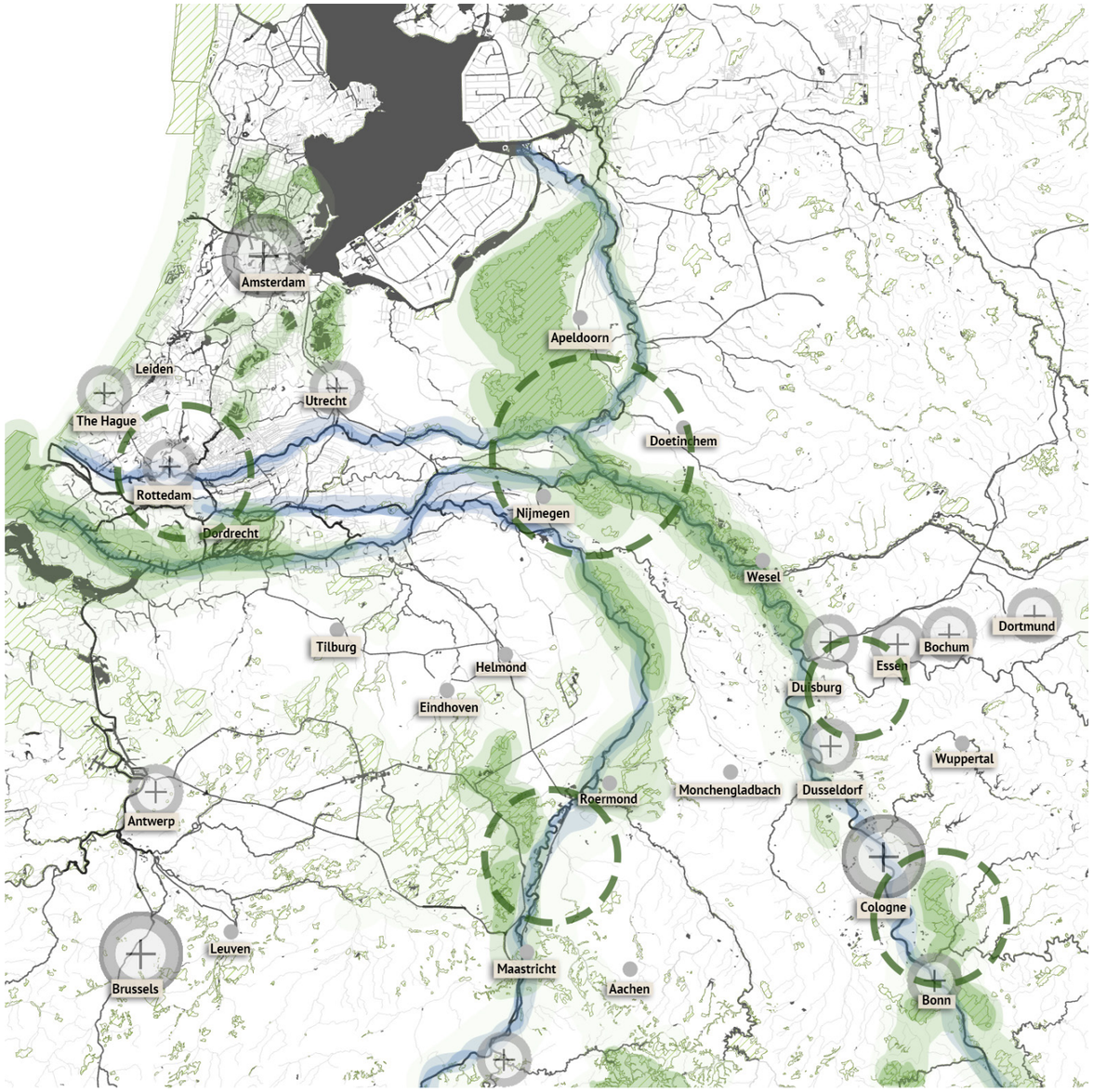


Thesis positioning

In the face of increasing frequency of extreme weather and climate change, planning and designing for flood resilience cannot be delayed. In this thesis by concluding the characteristics of the European urban sprawl and rural-urban pattern, i.e. the typical territory in between features, that perhaps nature-based solutions are a very promising way to address flooding resilience in the ABC mega region. In recent years, there has been a popular trend in research on how nature-based solutions can be used to solve flooding issues. There is also a growing number of collaborative projects on flood risk management and river space conservation in Europe. For example, the SEE River project in South East Europe, which aims at developing a joint approach for integrative management of international river corridors in South East Europe, uses the toolkit approach, a joint approach developed for the Drava River Corridor to improve the transboundary and cross-sectoral cooperation. Project WaReLa uses a geographic information system (GIS) to identify hotspots of run-off creation in order to implement their targeted measures for retaining water and reducing flood peaks. Whether it is more about policy and regulation for cross-border cooperation on river issues or the integration of spatial planning and water retention to address flooding, both are aspects that need to be promoted in practical implementation. In this thesis, the two aspects are promoted simultaneously.

In this thesis, a systematic strategy of Nature based solutions for flood risk management is explored through a specific selected location, the ABC mega region in lower Rhine Basin. The possibilities and importance of combining spatial planning and nature-based solutions for flood risk control are emphasized as well as a spatially visualized vision maps. A step-by-step exploration of why? which? where? and how? to apply the NBS is presented by the order of opportunity, suitability, availability, and applicability. The thesis mainly focus on the territory of river landscapes, proposing expansion of the floodplain by enabling a set of eco system services as integrated performative network. Using texted cases in local conditions, a series of strategies implementing NBS for flood risk management is presented. The flood risk management link local level to a bigger scale system as river corridors. Also measure and assess flooding issues from local to larger scales to understand the supply, demand and problem solving potential and thinking across the system. Calls for greater use of NBS to address and respond to possible future flood risk, giving more scope for river landscapes to expand. A call for the creation of these resilient, dynamic, ecosystem-valued river spaces.

Vision maps



CHAPTER 08

REFLECTION

Reflection

Aspect 1: the relationship between research and design.

In this project, it is very difficult to define whether the design drives the research, or the research drives the design. These two steps are alternating with each other.

There are much theoretical research that have to be done to make this project work, such as the theory of nature based solutions, transitional territories, urban and river landscapes, green and blue infrastructure, mega region, crossing border politics, water management and spatial planning. In addition, in this project, in order to design a flood resilience future for the ABC Mega region, it was necessary to first research and understand the elements and the whole systems which are involved in the project. From subsurface, to surface, to atmosphere, the current state of the various elements and their relationships with each other are worth researching. For example, the impact of green and blue infrastructure on the water cycle and flooding mitigation, the changes and impacts on river landscapes as a result of over-artificialization due to urbanization, etc. On the basis of the research of current situation and problems, the existing theories on sustainable development and flood management are examined, and some theoretical frameworks or models such as nature-based solutions and territories in between are compiled and applied to the project, and then translate to real projection.

The project requires not only a projection in the strategic sense of planning, but also, as a design-led work. The design that corresponds to the strategies, not only in terms of abstract summaries in diagrams, but also in terms of visualized drawings such as mappings and sections are required. As a project that spans various scales, from macro scale to nano scale, the final outcome of each scale needs to show visually. This is the design context in which the project is being undertaken, and although the resolution and depth of the strategy is different at different scales, it is a complete sequence. Among the macro scale, the meso scale and the nano scale, research is the essential step to drive and connect, ultimately form the project.

Aspect 2: the relationship between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS).

Graduation topic: Flood resilience future for ABC Mega region

Studio topic: Transitional territories “Inland, Seaward. The form of time and the politics of spaces”

Master track: Urbanism

My graduation project is about the flooding resilience future in the lower Rhine River basin, I need to investigate the river stream from inland to seaward to understand the flooding and other related issues. The studio topic of transitional territories 2021-2022 is 'inland and seaward' fits this topic very well. With a group of students who are interested in studying the areas of Rhine River Basin, I am able to collect and communicate with them on the same subject with different angles and entry points. In this studio, with the help of crossing disciplinary experts such as mentors from sector of spatial planning and water management, I can develop my ideas more comprehensively.

Besides, the studio is also investigating the ‘form of time and the politics of spaces. Which fit with my topic which is about the terraforming of river landscapes from mage regional scale to local scales. The impact of the process of urbanization which has formed and will forming the river landscapes, should be considered in the future projection for a flood resilience urban development. And also, the crossing border and multiple scales politics also determine the direction of the future space terraforming.

As an urbanism student, the courses which I took in the first year of my master track is helpful, especially the research and design studio of the spatial strategies for the global metropolis. The topic is in a larger scale which would involve not only the spatial issues, but also political, social, and environmental issues. As an urbanism student, being able to see the world by my graduation project in a more systematical way is what I benefit a lot in my master program. The position I put in myself in the project as a urbanist, so I not only trying to solve the flooding issue as a water management engineers, but also how should we guide the future urban development under this circumstance.

The master program MSc AUBS provide me with a team of experts and theories and knowledges. The interdisciplinary communication also inspires me in the project.

Aspect 3: Elaboration on research method and approach chosen by the student in relation to the graduation studio methodical line of inquiry, reflecting thereby upon the scientific relevance of the work.

In this graduation studio, the themes of accumulation and clearance are set up to help me move from researching on the current situation, to interpreting it, and to looking at possible future projections. The four lines of inquiries matters, topos, habitats, and geopolitics are able to cover a wide range of possible topics in the project. As my project is more ecological and ecosystem oriented, focusing on this one aspect of research and observation may lead to an overly one-sided interpretation of the project and a lack of consideration and exploration of other designed systems. These lines of inquiry in studio help me not limit the research to a specific level or theme of the thesis but encourages me to think at all levels and perspectives. In particular, the themes of habitats and geopolitics allowed me to think deeply about the societies and people involved behind the projects, and the conflicting or unifying policy systems between the various layers. Accumulation is an analysis of the impact and pressure of urbanization on various geographical, ecological, social and political systems. In the way of doing the inquiries, it is a reflection on the process of urbanization, which should guide the future of urbanization and urban planning. It will also lead me to move more quickly from the status quo stage to the next step in the design process.

Aspect 4: Elaboration on the relationship between the graduation project and the wider social, professional and scientific framework, touching upon the transferability of the project results.

The societal relevance of the graduation work:

The thesis is going to work a flooding resilience network in the ABC mega region for the future. Flooding, as we all know, has impact on the social aspects and causes the vulnerable groups to suffer and hinder development at all aspects of the society. The crossing border and crossing hierarchy of policy is also one of the societal aspect of this project.

This thesis not only mentions traditional technical solutions but also makes use of nature-based solutions, to achieve a flooding resilience and sustainable development of the mega region as well as other societal goals besides flood risk mitigation, such as enhancing the diversity and quality of people's lives by creating multifunctional flooding plains. Managing flood risk is a social responsibility for all the social groups, whether government, municipalities, or local involvement. Because the ABC mega region, as a mega-city spanning three countries, has a diverse socio-cultural and historical background, which results in a gap between the communication and implementation of policies and measures. Flooding as a natural process always causing societal challenge to human and to find a balanced way to live with it, the governance from Rhine River basin to local municipality has carried out lots of related policies. One of the research questions of this thesis is to seek common ground while preserving societal differences.

The professional relevance of the graduation work:

As an urbanism student, what I have studied mostly about is the city spaces. However, in this thesis, the crucial study areas are usually the spaces between urban landscapes and nature landscapes. These rural areas should not be the blank spaces in the spatial planning and design as we need to look at issues holistically rather than dichotomizing them. In my thesis, the mentioned nature-based solutions are attempts to solve social, ecological and other complex problems with less costly and more environmentally friendly measures. The environmental challenge should not only be seen as an issue to be solved, but also as an entry point for research and problem solving. As urbanist, we need to take a shaper view of the relationship between man and nature, from where we can ask for resources to where we can find solutions. In the past, perhaps we have over-transformed nature in the construction of our cities, and this is something we need to reflect on. But more importantly, we always need to deal with the relationship between urban development and environmental balance in the process of planning and designing.

The scientific relevance of the graduation work:

In this thesis, I investigate the relationship between spatial planning, governance, and flood management. The concept of nature-based solutions is getting more popular and green-blue infrastructure is also be seen as a great potential to solve the issue related to the eco-system and environmental challenge. However, there is a missing gap between these overall concepts and actual local practice because these solutions should always be site specific and evolves a lot of participants. It is also interesting to see how the multi-level and crossing border influence would play a role in the flooding resilience future in the mega region. Understanding the different contexts faced by individual cities in the mega regions, why and how to propose flood management strategies adapted to their future development needs and obtaining a spatially and policy coherent network of these objectives and strategies across the mega region is key to the whole graduation project.

Referring to the transferability of the project outcomes, the final design study explores a systematic approach to planning and decision making from the regional to the local scales for dealing with potential future flood risk with the tools of nature-based solutions. Although the final case study is site-specific, the whole process from strategy selection to design and implementation can be generalized and repetitive. In the future, when other sites or areas within the ABC Mega region need to adopt nature-based solutions to address flood risk, the process mentioned in the thesis can be used to help carry out the process of evaluate the opportunities, suitability, availabilities, and applicability of the nature-based solutions to implement the overall strategy and the specific site-based spatial design. The thesis calls for the involvement and support from all of the stakeholders in the world to see the potential of nature-based solutions and to formulate a network of cooperation and a dynamic ecosystem.

Aspect 5: Discuss the ethical issues and dilemmas you may have encountered in (i) doing the research, (ii, if applicable) elaborating the design and (iii) potential applications of the results in practice.

This study is huge in terms of the geographical scale of the research. The site of the study spans three countries so in the process of gathering research materials, different databases need to be applied for searching and this language barrier may cause defects in research consistency and understanding. As the topic of the thesis is flood risk control, which involves a variety of specialisms such as hydraulic engineering and water management in addition to the discipline of urbanism, the benefits of flood risk control cannot be quantified in the graduation project and therefore the results of the study are more of a systematic strategy of how to consider the subject of flooding in the field of spatial planning.

In terms of future perspectives on the vision of ABC mega region, the thesis focuses on the balance and dynamic flood risk control through nature-based solutions for flood risk control from inland to seaward. The application of nature based solutions would take a lot of spaces. This may therefore limit regional urban expansion to a certain extent. And also the effect might be unpredictable and influence the upstream or downstream. The unpredictable nature of flooding can lead to areas being exposed to a higher flood risk. And because the benefits of the project cannot be quantified, the implementation of flood risk control policies as a public strategy on private land may encounter some resistance in terms of economic investment and require some administrative provisions or legal basis.

CHAPTER 09

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