Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

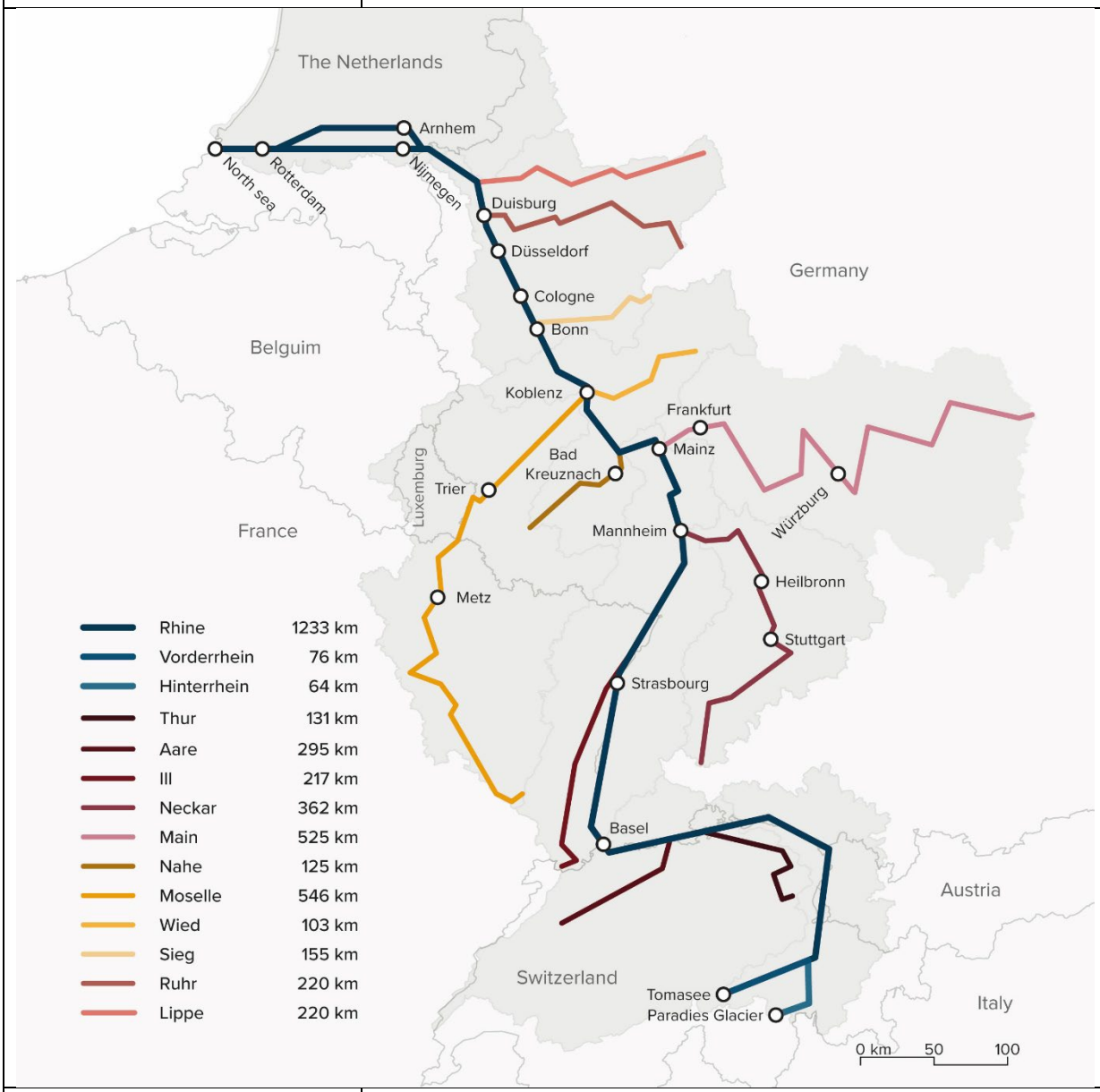
Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Anna van den Berg
Student number	5438888

Studio		
Name / Theme	Metropolitan Ecologies of Place	
Main mentor	Ir. K.P.M. (Kristel) Aalbers	Environmental Technology & Design
Second mentor	Dr. ir. C. (Claudiu) Forgaci	Urban Design
Argumentation of choice of the studio	I first and foremost chose the studio Metropolitan Ecologies of Place because of the approach the studio takes. I was intrigued by systemic thinking as a skillset to further develop after encountering this during Q3. I was interested in applying this research to a river system like the Rhine. To create a result that supports human and ecological well-being fits with my research about keeping the Rhine vibrant and functional in times of drought. Working on the topic of drought, the studio's research-informed design approach fitted well. By designing metropolitan environments from an ecological perspective and using a combination of methods from different scientific disciplines combined with a creative design process I wanted to tackle the drought problems.	

Graduation project	
Title of the graduation project	Every drop counts – How to keep the Rhine vibrant and functional in times of drought
Goal	
Location:	River the Rhine, Switzerland, Germany, The Netherlands



The posed problem,	

During the summer half-year, drought has become a more apparent problem. Natural climate variability causes some summers to have more drought periods than others. Due to this the streamflow of the Rhine can become dangerously low. This has a big impact on many functions and ecosystems that are dependent on this streamflow. Since the Rhine accounts for two-thirds of all inland waterway transports across Europe (Trouw, 2022), Europe experiences economic consequences when the streamflow gets low. Goods can no longer be shipped, but also industries and agriculture along the Rhine are dependent on this water supply. More importantly, the Rhine also serves as a source of clean drinking water. During droughts, this comes under pressure.

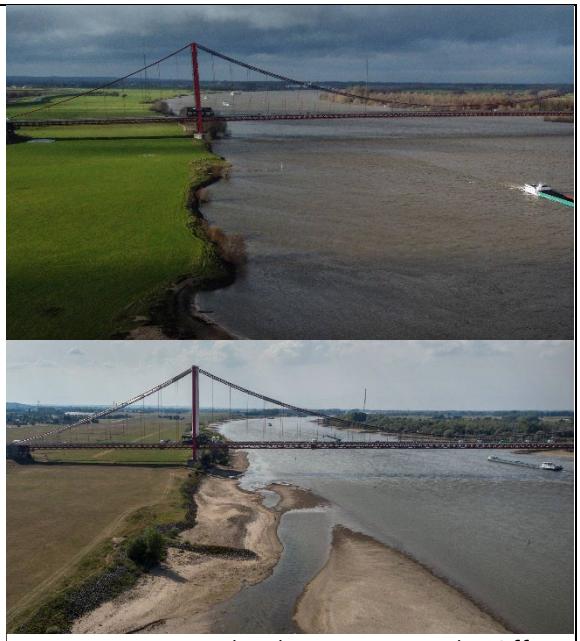
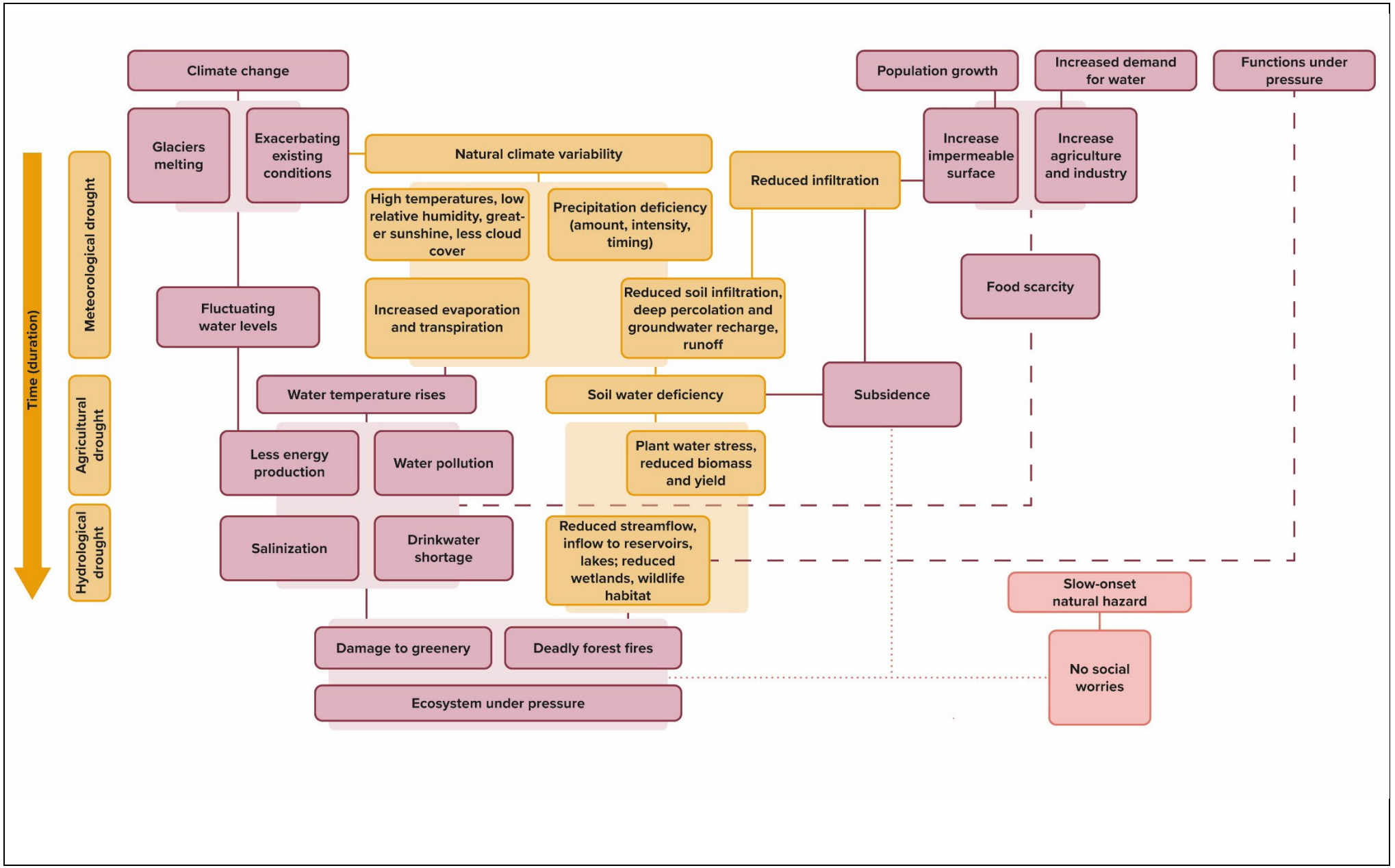


Figure 1 Low water levels near Emmerich. (Offern, 2022)

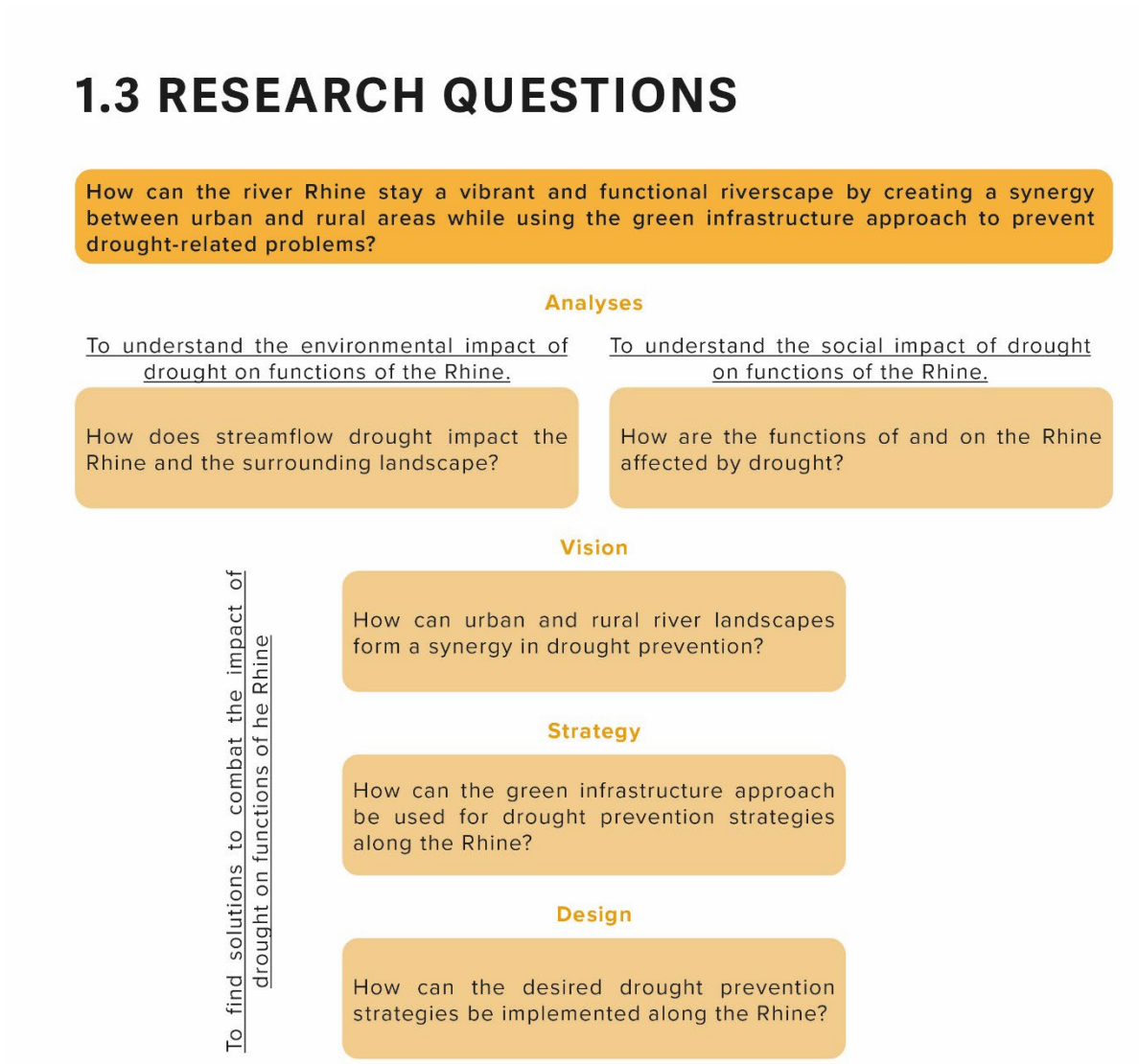
With growing urbanization, industries and agriculture along the Rhine the pressure on the drinking water supply grows. But the chances of more periods of drought are also increasing. Due to climate change, the source of the Rhine slowly moves from glacier and snow meltwater, to completely rainwater based. This causes water levels to fluctuate throughout the year, and dry summers can become up to two times more likely. Problems like salinization, water pollution, shortage of clean water, subsidence, damage to ecosystems and the rise of water temperatures will only become more apparent in the future. The functions of and on the Rhine are under threat due to drought and this will only increase in the coming decades.

*full problem statement in the report

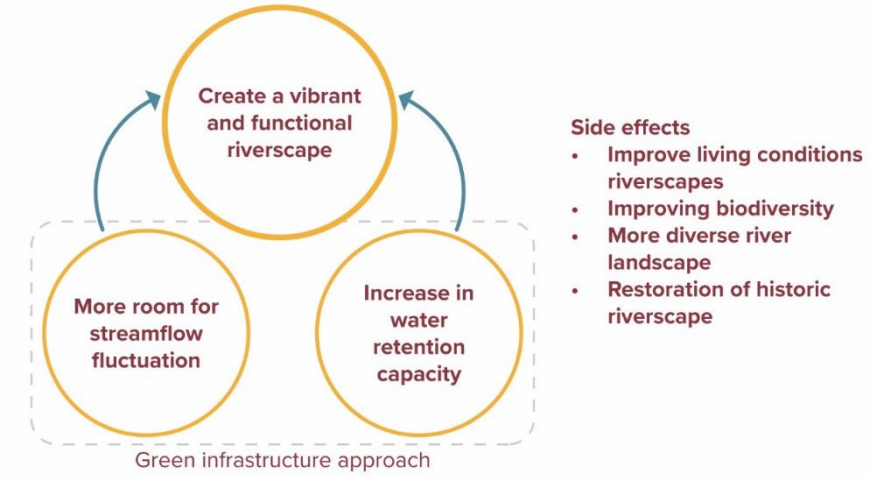
Figure 2 Glaciers melting between 2006 and 2018 Source (Huss & GLAMOS, 2018)

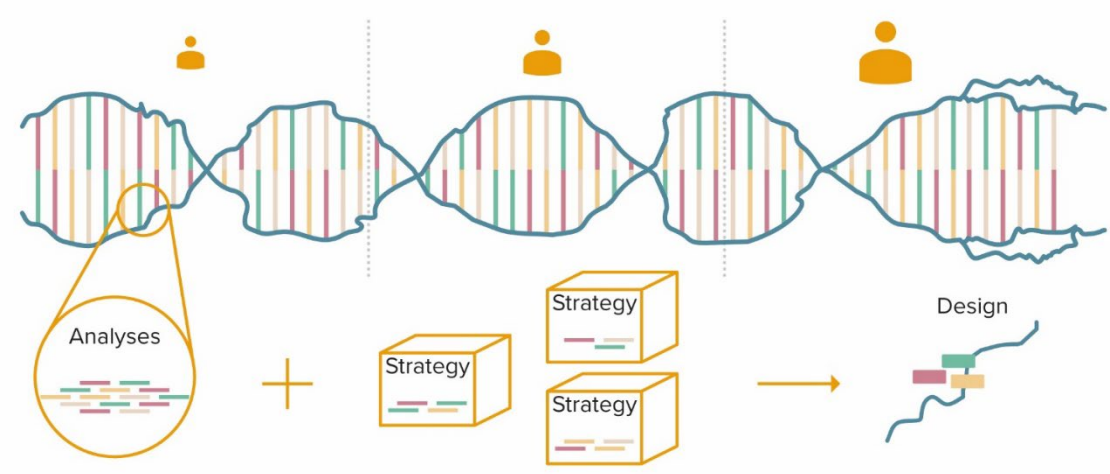

Climate change
Population growth
Increased demand for water
Functions under pressure
Glaciers melting
Exacerbating existing conditions
Natural climate variability
Increase impermeable surface
Increase agriculture and industry
Reduced infiltration
High temperatures, low relative humidity, greater sunshine, less cloud cover
Precipitation deficiency (amount, intensity, timing)
Food scarcity
Fluctuating water levels
Increased evaporation and transpiration
Reduced soil infiltration, deep percolation and groundwater recharge, runoff
Water temperature rises
Soil water deficiency
Subsidence
Less energy production
Water pollution
Plant water stress, reduced biomass and yield
Salinization
Drinkwater shortage
Reduced streamflow, inflow to reservoirs, lakes; reduced wetlands, wildlife habitat
Slow-onset natural hazard
Damage to greenery
Deadly forest fires
No social worries
Ecosystem under pressure
Time (duration)
Meteorological drought
Agricultural drought
Hydrological drought

research questions and	



design assignment in which these result.	To keep the Rhine a vibrant and functional river landscape. Analyses that describe the streamflow of the Rhine and the impact of climate change on the streamflow, functions and landscape surrounding the Rhine. A vision for the Rhine, showing the synergy between river landscapes and large-scale drought prevention measurements. Strategy with a green infrastructure approach to creating drought prevention measurements for river landscapes. Test the strategy on two design locations.





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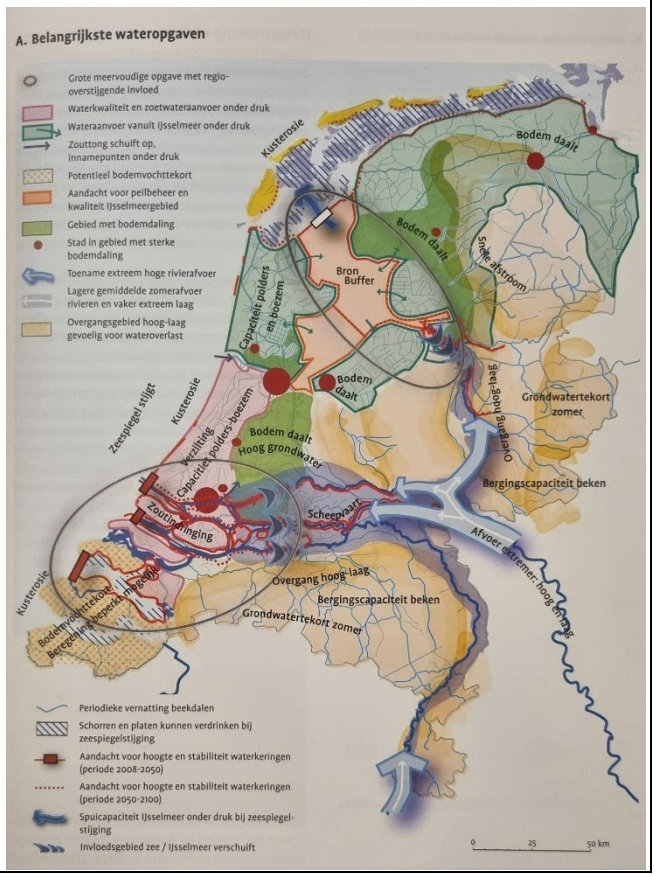
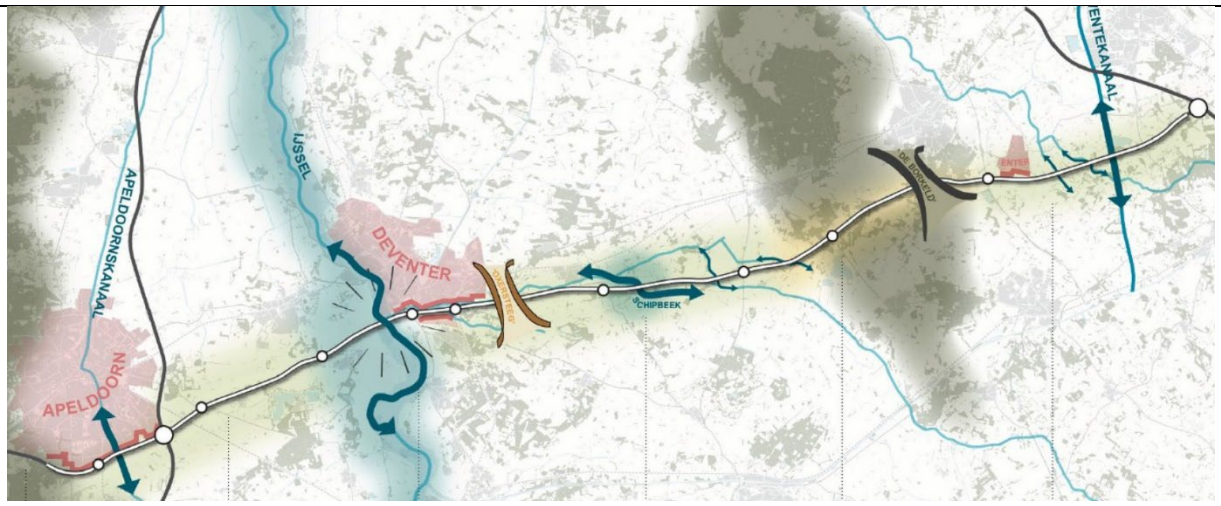
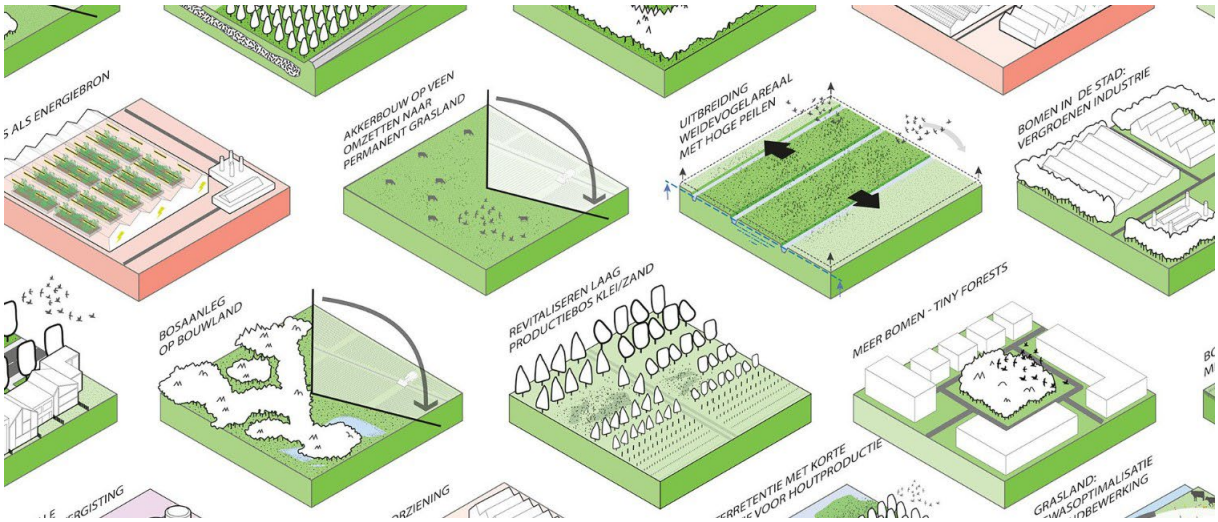
Example for potentials map, outcome after all analyses. First to determine leverage points, then problems and opportunities. After that, the TWOS method will be used and a potentials map with similar information to this will be produced.

Figure 3 (Noordhoff Atlasproducties, 2010, p. 43)





^ Example for large-scale vision on Rhine level
Figure 4 (H+N+S+, 2019)



^ Example for strategy Figure 5 (H+N+S+, 2018)

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Example for strategy Figure 6 (Wang, 2022)

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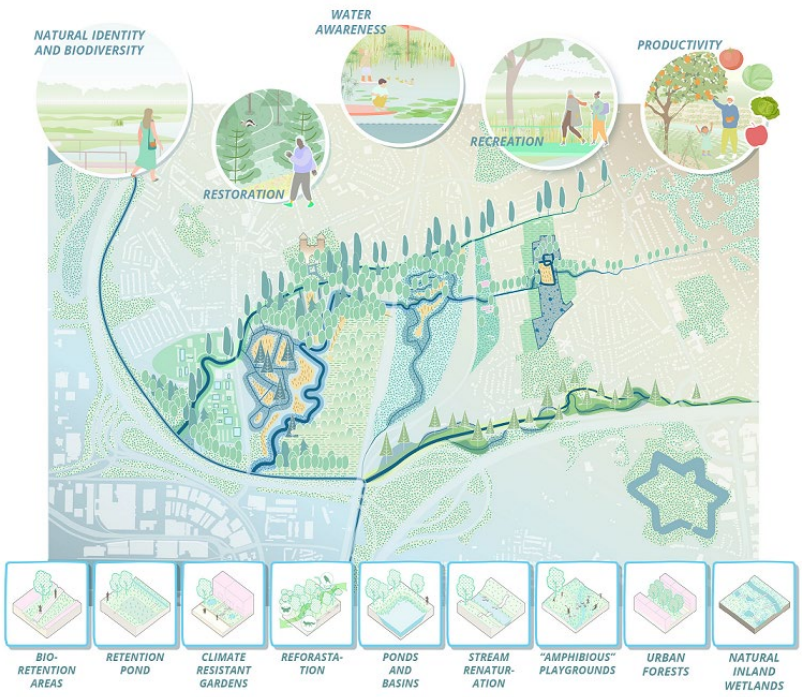
Example for strategy implementation into the design

Figure 7 (Felixx, 2023)



Process

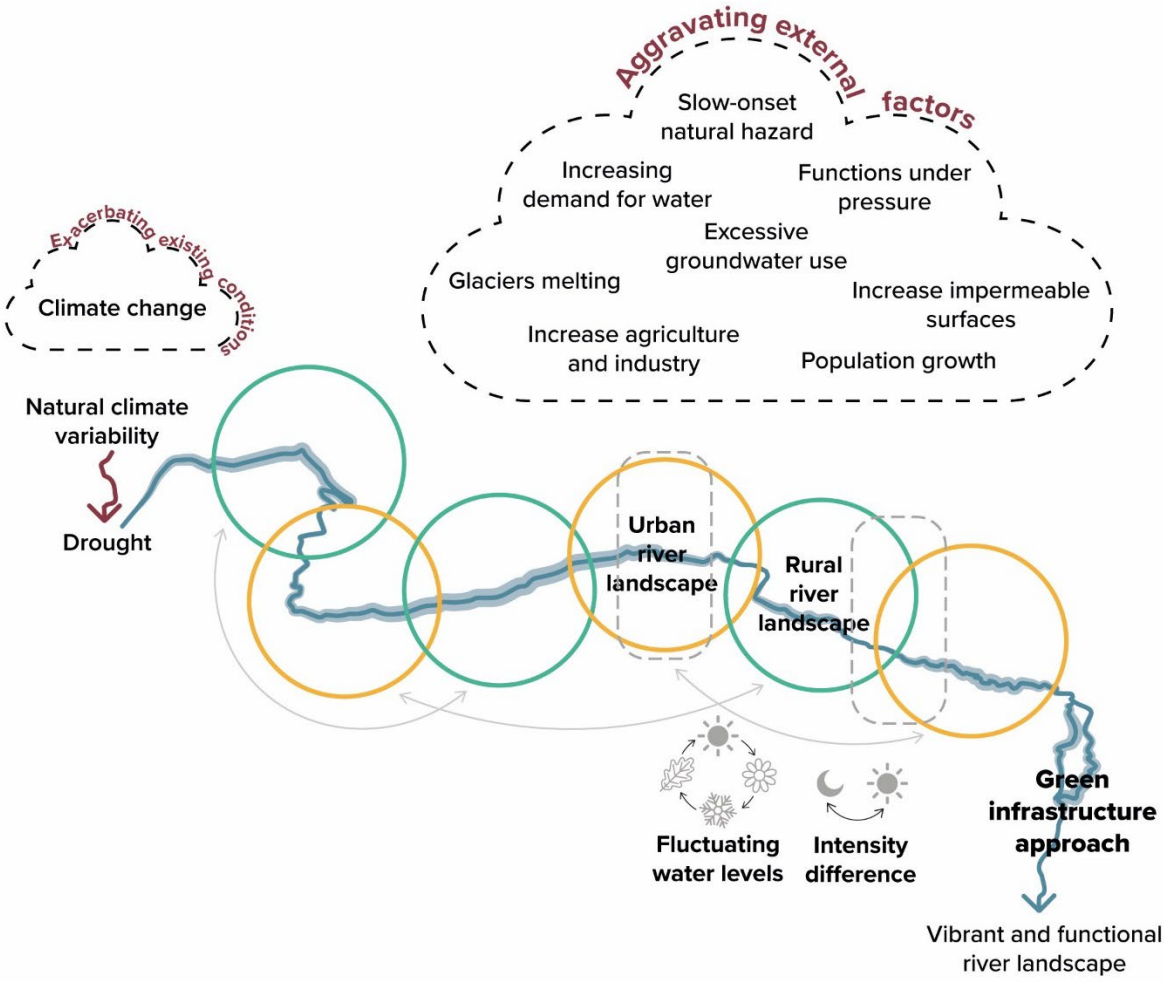
Method description

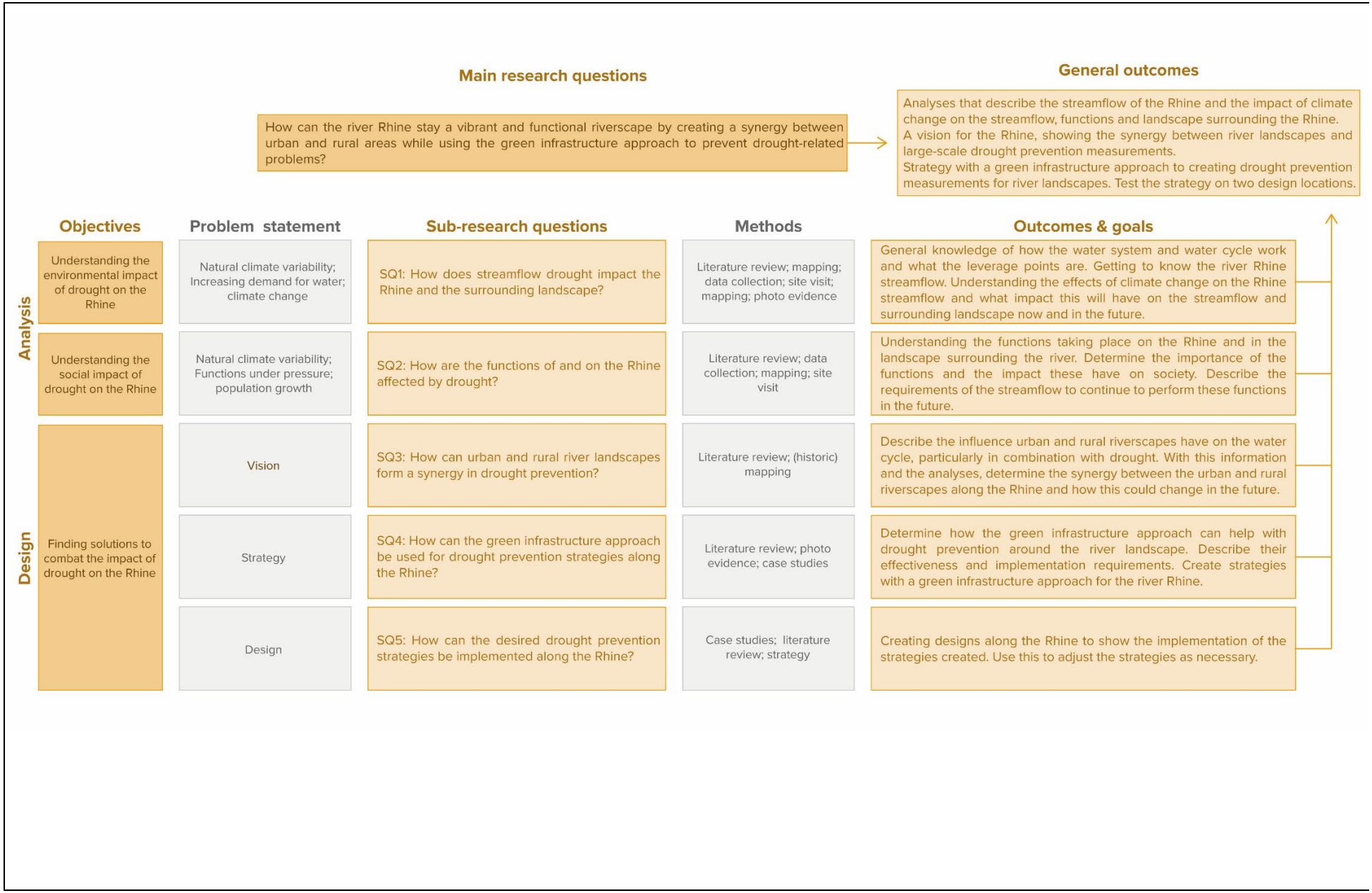
World Meteorological Organization (2006) defines drought as '*an insidious natural hazard characterized by lower than expected or lower than normal precipitation that, when extended over a season or longer period, is insufficient to meet the demands of human activities and the environment'.*
The variability in climate is what is the main instigator of drought occurrences. Natural differences in a climate occur between different years, causing some years to have periods of drought. This is a natural occurrence. But climate change is exacerbating the probability of an extreme weather event, like drought. The water levels in the river are fluctuating due to natural climate variability, but with climate change, the flux in the water levels will become more extreme.
Besides climate change, several aggravating external factors can be determined that have an impact on the water level of the Rhine, as shown in the conceptual framework.

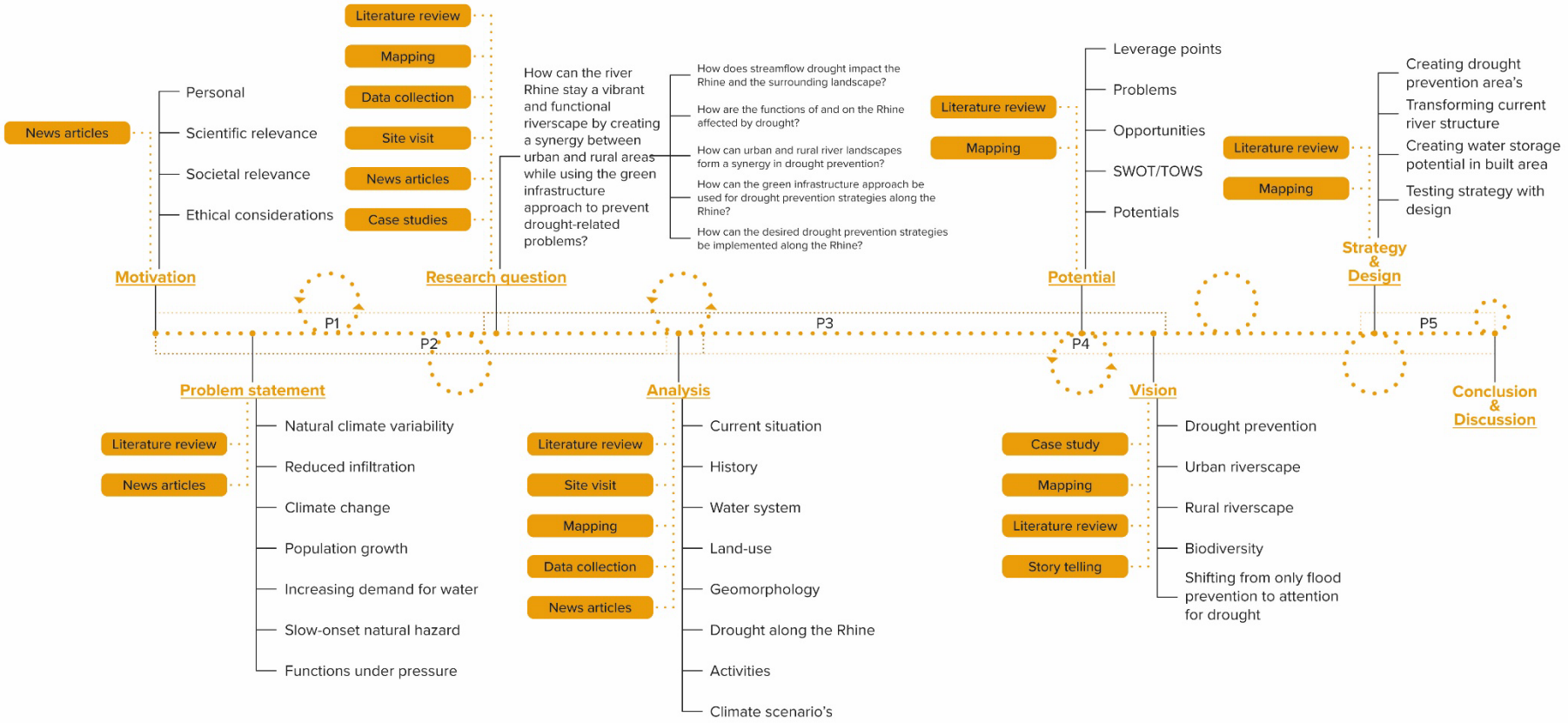
For this project, the river landscape of the Rhine will be taken as its main research area. A river landscape, or riverscape, is defined by Stanford et al. (2017) as '*an expansive view of a stream or river and its catchment, including natural and cultural attributes and interactions'.* Within this riverscape of the Rhine, two types of areas will be used, rural and urban. Rural areas will be defined by their natural characteristics as found in Pizzoli and Gong (2007). This is done at the hand of land cover profiles (arable, forest, etc.), topographic roughness (mountain, hill, plain) and climate. They define rural as an area that should be mainly covered by agricultural land, forest and natural areas. This includes disadvantaged areas for human activities like mountains and extreme climate conditions. In this definition, the natural environment is significantly different for human opportunities and behaviour, between rural and urban areas. With this definition based on the natural characteristics a distinction between the two areas can be made, but there will still be overlaps, where the two areas meet.

Finally, the solutions are introduced in the conceptual framework, a green infrastructure-based approach to decrease the impact of drought, which will lead to a vibrant and functional river landscape.
The European Commission (2013, p. 3) defines Green infrastructure (GI) as '*a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are*

concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings'. When using GI in spatial planning, the approach will cross ecological and political boundaries. The GI approach *'looks for connections between different elements of nature in the geophysical area, between nature and people's quality of life, across ecological and political boundaries, and across policy sectors'*(ESPON EGTC, 2020, p. 18).
The cross-border approach of green infrastructure fits with the study case of the Rhine. Looking for those connections between nature and people's quality of life is the purpose of creating a vibrant and functional riverscape along the Rhine. With the decline of nature in Europe using a green infrastructure approach to decrease the impact of drought will have an impact on the living conditions of the people around the Rhine. The strategy with a green infrastructure approach will be applied to two design locations, marked with grey dotted lines in the conceptual framework. One of these locations will be an urban area, as this will be a complicated location where the strategy has to be tested. The second location will be the area where urban and rural meet, this will have some interesting implications that will be investigated during the design phase.




Main research questions
How can the river Rhine stay a vibrant and functional riverscape by creating a synergy between urban and rural areas while using the green infrastructure approach to prevent drought-related problems?
General outcomes
Analyses that describe the streamflow of the Rhine and the impact of climate change on the streamflow, functions and landscape surrounding the Rhine.
A vision for the Rhine, showing the synergy between river landscapes and large-scale drought prevention measurements.
Strategy with a green infrastructure approach to creating drought prevention measurements for river landscapes. Test the strategy on two design locations.
Objectives
Problem statement
Sub-research questions
Methods
Outcomes & goals
Analysis
Design
Understanding the environmental impact of drought on the Rhine
Natural climate variability; Increasing demand for water; climate change
SQ1: How does streamflow drought impact the Rhine and the surrounding landscape?
Literature review; mapping; data collection; site visit; mapping; photo evidence
General knowledge of how the water system and water cycle work and what the leverage points are. Getting to know the river Rhine streamflow. Understanding the effects of climate change on the Rhine streamflow and what impact this will have on the streamflow and surrounding landscape now and in the future.
Understanding the social impact of drought on the Rhine
Natural climate variability; Functions under pressure; population growth
SQ2: How are the functions of and on the Rhine affected by drought?
Literature review; data collection; mapping; site visit
Understanding the functions taking place on the Rhine and in the landscape surrounding the river. Determine the importance of the functions and the impact these have on society. Describe the requirements of the streamflow to continue to perform these functions in the future.
Finding solutions to combat the impact of drought on the Rhine
Vision
SQ3: How can urban and rural river landscapes form a synergy in drought prevention?
Literature review; (historic) mapping
Describe the influence urban and rural riverscapes have on the water cycle, particularly in combination with drought. With this information and the analyses, determine the synergy between the urban and rural riverscapes along the Rhine and how this could change in the future.
Strategy
SQ4: How can the green infrastructure approach be used for drought prevention strategies along the Rhine?
Literature review; photo evidence; case studies
Determine how the green infrastructure approach can help with drought prevention around the river landscape. Describe their effectiveness and implementation requirements. Create strategies with a green infrastructure approach for the river Rhine.
Design
SQ5: How can the desired drought prevention strategies be implemented along the Rhine?
Case studies; literature review; strategy
Creating designs along the Rhine to show the implementation of the strategies created. Use this to adjust the strategies as necessary.


Literature review
Mapping
Data collection
Site visit
News articles
Case studies
News articles
Personal
Scientific relevance
Societal relevance
Ethical considerations
How can the river Rhine stay a vibrant and functional riverscape by creating a synergy between urban and rural areas while using the green infrastructure approach to prevent drought-related problems?
How does streamflow drought impact the Rhine and the surrounding landscape?
How are the functions of and on the Rhine affected by drought?
How can urban and rural river landscapes form a synergy in drought prevention?
How can the green infrastructure approach be used for drought prevention strategies along the Rhine?
How can the desired drought prevention strategies be implemented along the Rhine?
Literature review
Mapping
Leverage points
Problems
Opportunities
SWOT/TOWS
Potentials
Literature review
Mapping
Creating drought prevention area's
Transforming current river structure
Creating water storage potential in built area
Testing strategy with design
Motivation
Research question
Potential
Strategy & Design
P1
P2
P3
P4
P5
Problem statement
Analysis
Vision
Conclusion & Discussion
Literature review
News articles
Natural climate variability
Reduced infiltration
Climate change
Population growth
Increasing demand for water
Slow-onset natural hazard
Functions under pressure
Literature review
Site visit
Mapping
Data collection
News articles
Current situation
History
Water system
Land-use
Geomorphology
Drought along the Rhine
Activities
Climate scenario's
Case study
Mapping
Literature review
Story telling
Drought prevention
Urban riverscape
Rural riverscape
Biodiversity
Shifting from only flood prevention to attention for drought

Objectives, outcomes & goals
For this thesis, the research is separated into three objectives as shown in the research approach. (1) understanding the environmental impact of drought on the Rhine, (2) understanding the social impact of drought on the Rhine, and (3) finding solutions to combat the impact of drought on the Rhine. The first objective focuses on the increasing demand for water and the impact climate change will have on this. The streamflow of the Rhine will be affected and the environmental impact this has on the functionality of the Rhine will be explored. The outcome of this objective is an understanding of the water cycle and the leverage points. Also understanding the streamflow of the Rhine and the impact climate change will have on this and the impact this will have on the surrounding riverscape and the impact the surrounding riverscape might have on the streamflow of the Rhine.

The second objective focuses on the social impact drought will have on the riverscape. The functions connected to the Rhine will be explored and assessed. The requirements for the streamflow will be determined for each of the functions. These requirements can be used to test the proposed strategic interventions later on.

The third objective focuses on the proposed solutions. This objective aim is to find a synergy between the different riverscapes, determine the strategic interventions that can take place with a green infrastructure base, and implement the interventions to design locations along the Rhine to test their functionality.
The final result should be a vibrant and functional Rhine riverscape.

Systemic design
Systemic thinking is a combination of Design thinking and systems thinking. Combining these interdisciplinary fields, open up more possibilities for understanding complex systems. With Systemic thinking, a design process should include phases of divergence and convergence. This process can start even when the intended outcome is not clear. But Systemic thinking is not a process in itself, it is a way to understand dynamic complexity and to generate innovation and value creation(Ryan, 2016; Wandl, 2022).

Next to phases of divergence and convergence, a design process with systemic thinking should be an iterative process that is continuously improving upon itself. Systemic thinking helps with discussing concrete actions by using the following multiple steps. The steps are; (1) research stakeholders (network); (2) Define the system, problems and challenges should be defined and the amount should be limited; (3) Map the system, common needs between stakeholders should be described. They should be addressed before individual needs; (4) Choose leverage points, leverage points are described further on in this chapter; (5) Ideate solutions; (6) Prototype solutions; (7) Test; (8) Evaluate results.
When following these steps, spatial quality will be part of the discussion early on to avoid complications during the implementation phase (Wandl, 2022).

Leverage points
Leverage points are described by Meadows (1999) as '*places within a complex system where a small shift in one thing can produce big changes in everything.'* By determining the leverage points in a complex system we know where to intervene, they are points of power. There is no quick or easy way to determine the leverage points in a complex system. Meadows composed a list;
Places to intervene in a System (increasing order of effectiveness):

12. Constants, parameters, numbers (such as subsidies, taxes, standards)
11. The sizes of buffers and other stabilizing stocks, relative to their flows.
10. The structure of material stocks and flows (such as transport networks, population age structures)
9. The lengths of delays, relative to the rate of the system change

8. The strength of negative feedback loops, relative to the impacts they are trying to correct against
7. The gain around driving positive feedback loops
6. The structure of information flows (who does and does not have access to what kinds of information)
5. The rules of the system (such as incentives, punishments, constraints)
4. The power to add, change, evolve, or self-organize system structure
3. The goals of the system
2. The mindset or paradigm out of which the system – its goals, structures, rules, delays, parameters – arises
1. The power to transcend paradigms

To relate these leverage point to intervene the system first has to be unravelled. In chapter 3.1 the leverage points found during the analysis phase will be examined and the theory of Meadows will help to unravel the leverage points by using the places to intervene in a system (Meadows, 1999).

For this thesis, the Rhine is seen as a complex system. This research sees the functions that depend on the Rhine as stakeholders, they will be a guide to developing solutions. During the analysis phase, mapping the system, leverage points will be identified. These leverages point will help to identify and develop the proper solutions. The solutions or strategies will be implemented into a design to test them after which these can be evaluated.

From analyses to strategy

The route this research will take is shown in the method of approach. The research starts with analysis, to explore, understand and interpreting the streamflow of the Rhine, the functions surrounding the Rhine and on the Rhine itself, and the geomorphology of the Rhine. Lastly, the changes in the streamflow and the functions due to climate change will be explored.

The analysis for the Rhine will result in different building blocks per area of the Rhine, like in a DNA string. All building blocks along the Rhine built up the identity of the Rhine. These building blocks will be brought back into the strategy and can then be compared to the analysis. The type of building blocks suitable for a certain strategy will help determine which will be suitable for a design for a particular location along the Rhine. This way the different areas of the Rhine can be categorized and the strategies can be matched during the design phase.

Between the chapter analysis and strategy lies the subchapter potentials. This subchapter will help to determine the vision and design locations. First, an overview of the leverage points will be made. Secondly, a map with the problems the Rhine faces in terms of staying a vibrant and functional river landscape will be combined into one map. This map will determine the points along the Rhine with the most risk of no longer being functional. A second map, the opportunities map, shows areas that have high potential in harbouring potential drought prevention measures.

The next step is using the TOWS analysis based on Weihrich (1982). TOWS stands for Threats, Opportunities, Weaknesses and Strengths. To use this analysis first these different factors need to be determined. Threats and weaknesses can be identified through the problem map. The opportunities and weaknesses can be found in the opportunities map. A TOWS analysis shows the relationships between these different factors. The opportunities with strengths will be identified, threats will be prevented with strengths, opportunities will be used to minimise weaknesses, and potential pitfalls where threats and weaknesses meet will be minimized (Weihrich, 1982). By going through these steps pitfalls and potentials can be identified. These potentials will be shown in the last map and be the foundation for the vision on a regional scale.

Literature and general practical preference

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* Official reference list in the report

Reflection

1. What is the relation 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: Every drop counts; How to keep the Rhine vibrant and functional in times of drought. Studio topic: Metropolitan ecologies of place.
The project focuses on keeping the Rhine vibrant and functional in times of drought by looking at ways to implement large-scale drought prevention measures with a green infrastructure approach. The studio MEP works with spatial design to react to four key challenges: biodiversity restoration, climate adaptation, energy transition and resource scarcity. My project falls mostly into the first two categories and also touches upon resource scarcity. Next to that, the studio focuses mostly on large-scale projects with a complex system. The Rhine fits perfectly in this category and thus this creates a link between my project and the graduation studio. The link with the master track (urbanism) is found in the context of this project. At first glance, this project looks more water-based, but the project takes the Rhine and the drought as a starting point for the interference in the activities and areas around the rhine. This project aims to keep those functions, including urban life, industry, agriculture, and recreation. Everything has to do with creating a liveable and enjoyable urban environment and robust city life. Urbanism goes further into other fields than just cities, like environmental questions, sustainability, climate adaptation, and social-ecological emergencies. The design part of this project will focus on the implementation of drought prevention measurements in an urban locations and a location where urban and rural meet. This also is what connects this project to the master programme MSc AUBS.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

This project aims to create a river landscape that is resilient in times of streamflow drought. The social relevance of this project is to improve living-, economic-, and recreational conditions during periods of drought and to ensure there is less of an impact on society during periods of drought. Low water levels during streamflow drought can have a big impact on functions on and around the Rhine. By creating a design strategy that will create a more drought-resistant riverscape, the impact on society will be reduced and living conditions will be improved.

The scientific relevance of this thesis is about the knowledge gap that exists between urbanism and drought as a climate adaptation strategy. Drought has not been as much explored as other climate adaptation strategies, especially in Europe. For the Rhine specifically, most climate adaptation designs are focused on flood prevention. With this research, there is an attempt to close this gap and make sure that climate adaptation strategies will also account for drought.
Next to that, this strategy tries to apply to all parts of the Rhine and even be adaptable to rivers with similar conditions.

My personal scientific relevance for this research is part of the fact that I have never experienced working with this large research location. With working on the Rhine the research location expands to multiple countries and a river as a basis for research. During my studies, I have never attempted to work with this before. It is a challenge to expand my way of researching and making analyses. Working with data outside of the Netherlands is also partly new. By working on the Rhine I am expanding my horizon and closing a bit of my knowledge gap in the field of urbanism.
Next to that, I haven't had much experience working on drought-related climate adaptation strategies. By shifting my focus to this I gain a lot of knowledge in a new field of interest.