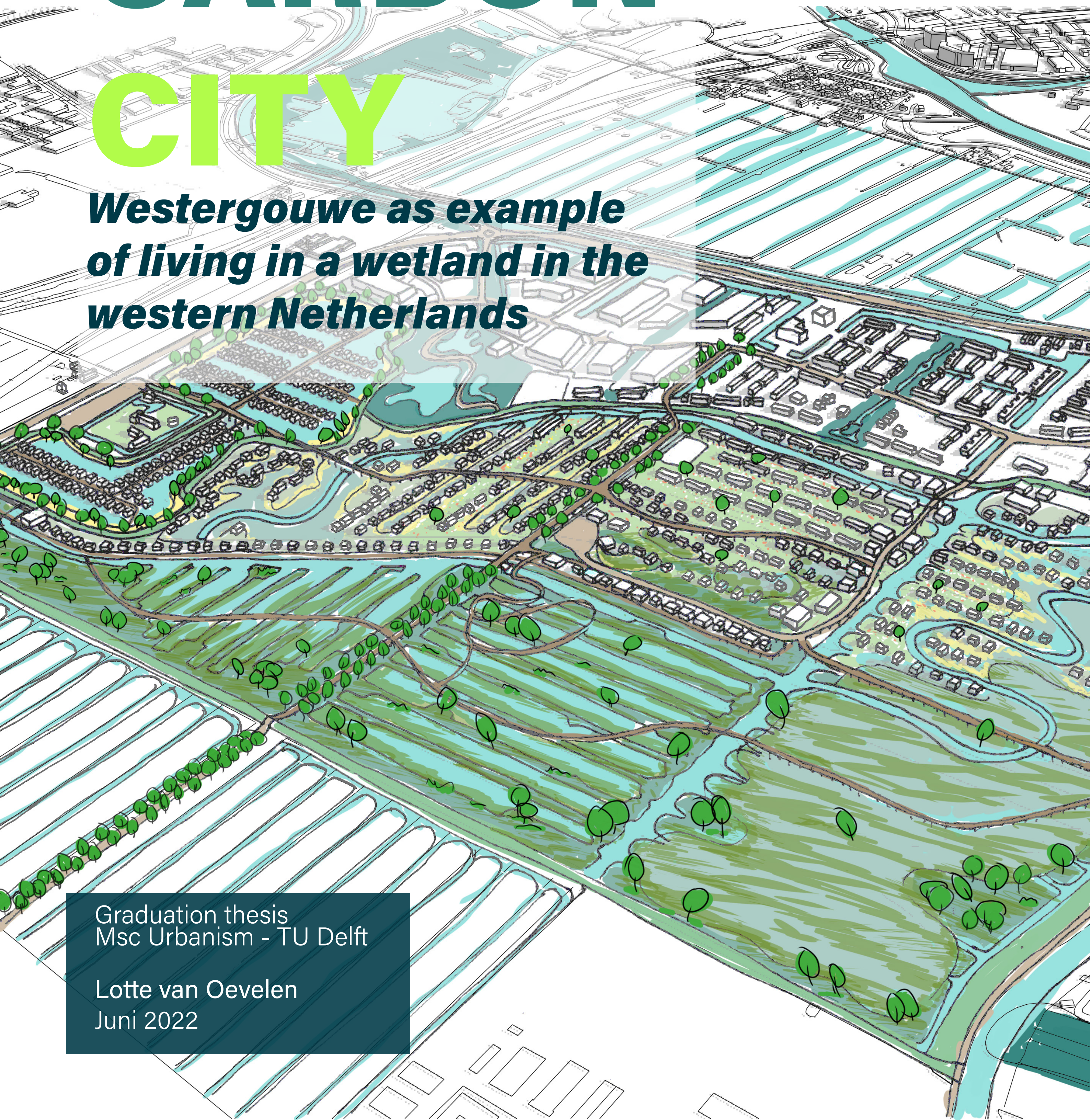
(RE) CARBON CITY

Westergouwe as example of living in a wetland in the western Netherlands



Graduation thesis
Msc Urbanism - TU Delft

Lotte van Oevelen
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THESIS PROJECT
(RE)CARBON CITY
Westergouwe as example of living in a wetland in the western Netherlands

Master thesis project
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ABSTRACT

As the climate is changing, the need to mitigate and adapt to the climate is getting more urgent every day. One of the biggest causes of global warming is the greenhouse gas carbon dioxide. Simultaneously, we are destroying one of our biggest carbon sinks; our peat soil. Peat soil in the Netherlands is destroyed by the Dutch polder system and the way the Dutch are building on top of the peat layer. This results in oxidation, which results in a release of carbon dioxide. Fortunately, there is a solution to preserving the peat soil and even regrowth. By rewetting the peat layer, the anaerobic conditions needed to maintain the peat are created. This calls for a different type of built environment in order to prevent the loss of our carbon sink.
The study location of this project is Westergouwe in Gouda, which is designated for the building of housing and the soil contains our beloved peat soil. To still gratify the big housing need, a design is made of the neighborhood Westergouwe combining the urban environment with the goals of preserving and growing peat, in an ecologically responsible way. This project answers questions through literature research like: How can carbon be stored in the soil, vegetation, and in the urban environment? How can you build on peat soil without destroying it? And what is the urban ecosystem? Also, an analysis using mapping, expert interviews, and literature research is done of the polder system surrounding Westergouwe, of other environmental problems, and of suitable biotopes within this vision. After the design, is looked at how this design could be implemented in phases and which stakeholders would be involved. This type of design requires long-term planning. Throughout the process, the involvement of local and national governments is key to realizing this design. To transfer the knowledge maintained in this project, a pattern language is made and a method is abstracted. This project is not only applicable to Westergouwe, it could be relevant for a lot of places where peat is present in the soil. But not only that, because of the finiteness of the polder system, this type of design could be relevant for the whole of the western Netherlands.
The author hopes that more research is done to continue the project's search for a landscape-based urban environment that mitigates and adapts to the climate and that this project is used as a framework for further research.

Image made by author

PREFACE

This report is made in the graduation period of urbanism as a second part of the graduation period after the booklet was made for Staatsbosbeheer; as an analysis of the Groene metropool vision (Cobben et al., 2022). As the Groene Metropool vision, this project explores the collision of two worlds: the natural landscape and the urban living environment. With this collision, a lot of challenges arise, but these two worlds do not have to be opposites to each other. As current views on nature and city are changing, the qualities and potentials become more apparent. This project tries to bridge these two while facing the current carbon crisis. I hope that this project inspires urban planners and designers to understand the challenges and more importantly the potential and qualities of combining the urban environment and the natural environment.

I am grateful for all the guidance of my mentors, Remon Rooij and Nico Tillie, and other professors, Frits van Loon, Sjef Jansen, Kristel Aalbers, and Gabriel Geluk, that gave me advice throughout the project. I also want to thank my fellow students as they have given me extra inspiration when I was stuck in the process and as they shared my enthusiasm along the way. It was a pleasure to work with you all on this project.

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H1. INTRODUCING

CONTENT H1.

1.1 MOTIVATION

1.1.1 CO_2 and climate change

The earth is heating up. In figure 1.1.1 you can see the land and ocean percentiles for 2020 (NOAA a., 2021). You can see that most of the map is colored red, and thus is warmer than average. The Netherlands is colored the darkest shade of red which means that 2020 shared with 2014 (11.7°C) has been the hottest year since national records started in 1901. 2020 will be the fifth year in a row that national averages have been above normal.
Scientists have found that global warming is dominantly caused by the greenhouse effect (Dunn et al., 2021). This effect is the warming of the earth that happens when the atmosphere releases less heat from the earth to space than it receives from the sun (NASA b., 2021). This is caused by greenhouse gases which block the heat from escaping the atmosphere. In particular carbon dioxide (CO_2), methane (CH4), nitrous oxide (N2O), and water vapor (H20) have a big role in the greenhouse effect. Of which CO_2 has the biggest contribution to global emissions (65%) (Bhattacharyya et al., 2021).

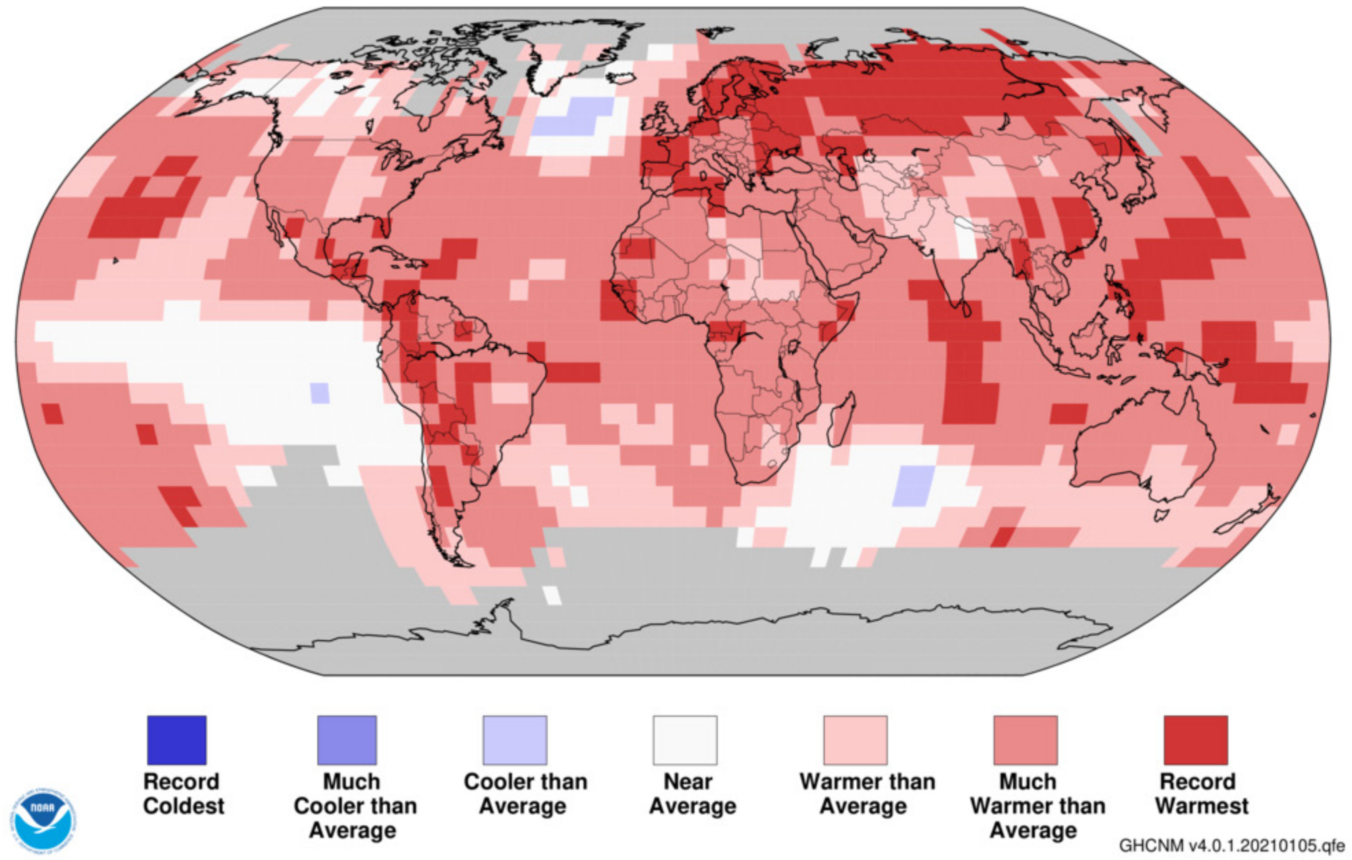
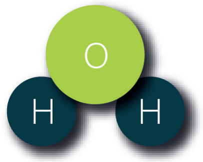
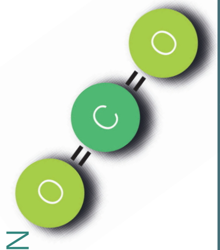
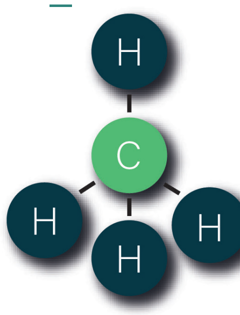


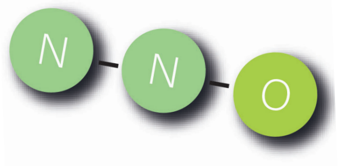
Figure 1.1.1: January-December 2020 Blended Land and Sea Surface Temperature Percentiles.
From "ncdc.noaa.gov" By NOAA National Centers for Environmental Information, 2020 (https://www.ncdc.noaa.gov/monitoring-content/sotc/global/map-percentile-mntp/map-percentile-mntp-202001-202012.png)



- *Water vapour (H2O): This gas is the most abundant of the four gases on earth. Water vapor increases as the planet warms and forms clouds and precipitation. This greenhouse gas is the only gas of the four that responds physically or chemically to changes in temperature. This makes it an indicator (NASA b., 2021).*
- *Carbon dioxide (CO_2): Carbon dioxide is released into the air by natural processes like respiration and active volcanoes, as well as by human activity like deforestation, land-use changes, and fossil fuel combustion. This gas is the biggest contributor to climate change (NASA b.,2021).*
- *Methane (CH4): Methane is in comparison to CO_2 on a molecule level a much more active greenhouse gas, But is much less present in the atmosphere. Decomposition of wastes, farming, particularly rice farming, and animal digestion and manure handling linked with domestic cattle are sources of the gas (NASA b., 2021)*
- *Nitrous oxide (N2O): This gas is released by soil cultivation activities, including the use of fertilizers in agriculture, fossil fuel burning, nitric acid generation, and biomass burning (NASA b.,2021).*





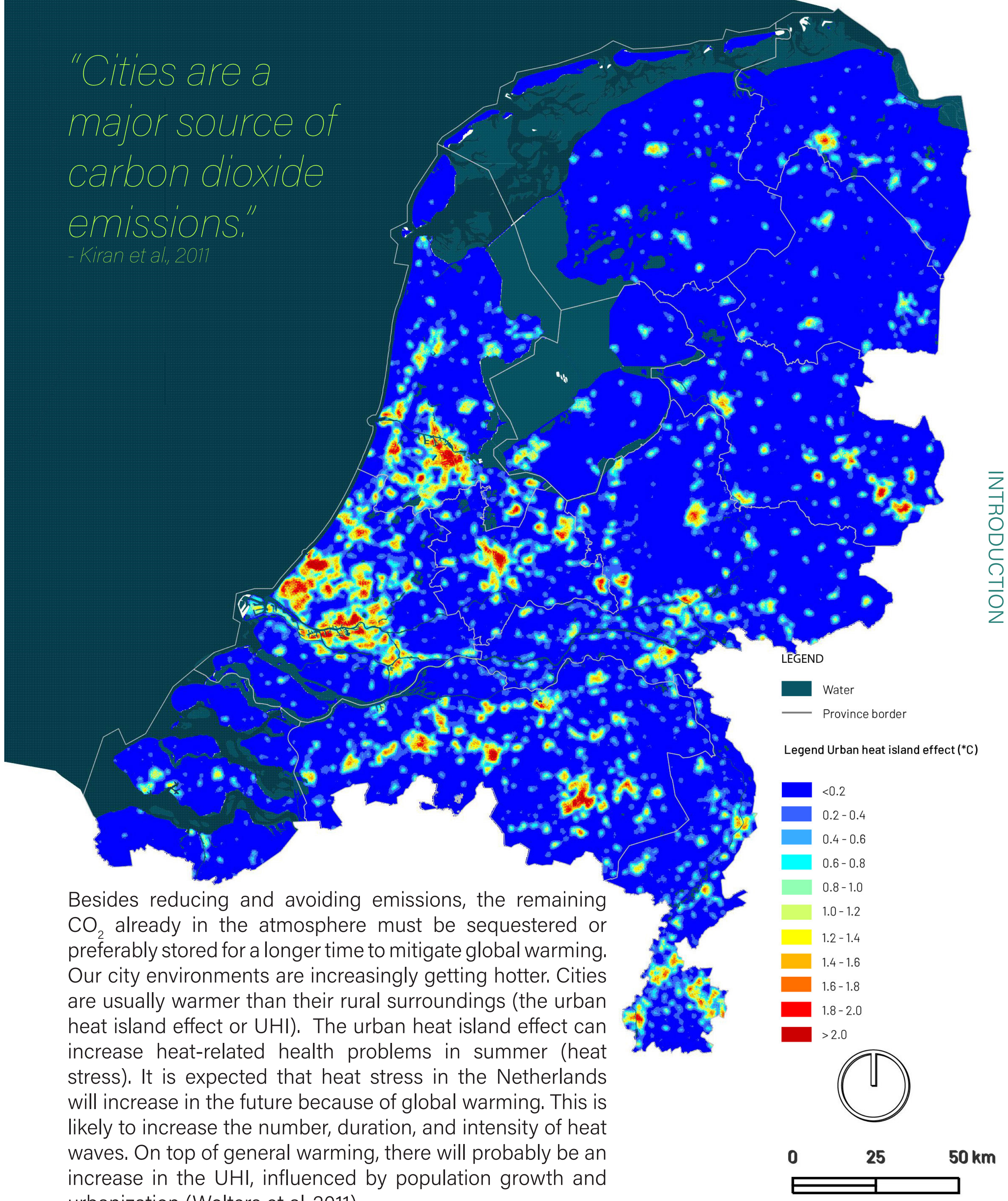


INTRODUCTION

Of the greenhouse gases (see textbox), CO_2 has the biggest contribution to global emissions, with 65 percent (Bhattacharyya et al., 2021). The first systematic measurements of atmospheric CO_2 were taken in 1958 at Mauna Loa, Hawaii. The CO_2 level measured was roughly 315 ppm (Bhattacharyya et al., 2021). On 17 October 2021, the measurements at Mauna Loa Observatory showed atmospheric levels of 417.28 ppm (NASA,2021). Also, with measurements of CO_2 levels in glacial cores, we can conclude that the present CO_2 levels are greater than they have been. They have been higher than from the first measurement in Hawaii in 1958, but also in the last 20,000 years (from the Last Glacial Maximum to 1850, from 185 ppm to 280 ppm) (NASA,2021). Measurements show a sudden increase since the industrial era (1850). With this, we can conclude that human activity has increased CO_2 levels in the atmosphere by roughly 49% (NASA,2021). This is mostly due to fuel burning in the built environment for activities such as building heating, urban mobility, and cooking. In the period between 2010 and 2019, luckily just 55% of the emitted fossil fuel CO_2 has remained in the atmosphere. This missing 45 % has been stored by the ocean and the terrestrial biosphere (Dunn et al., 2021)..

figure 1.1.1.2 Urban heat island effect.
data from GIS by RIVM, 2018 (https://nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/metadata/a87f5ca8-f354-4ff6-adc3-70f1bf6b78e3?tab=general)

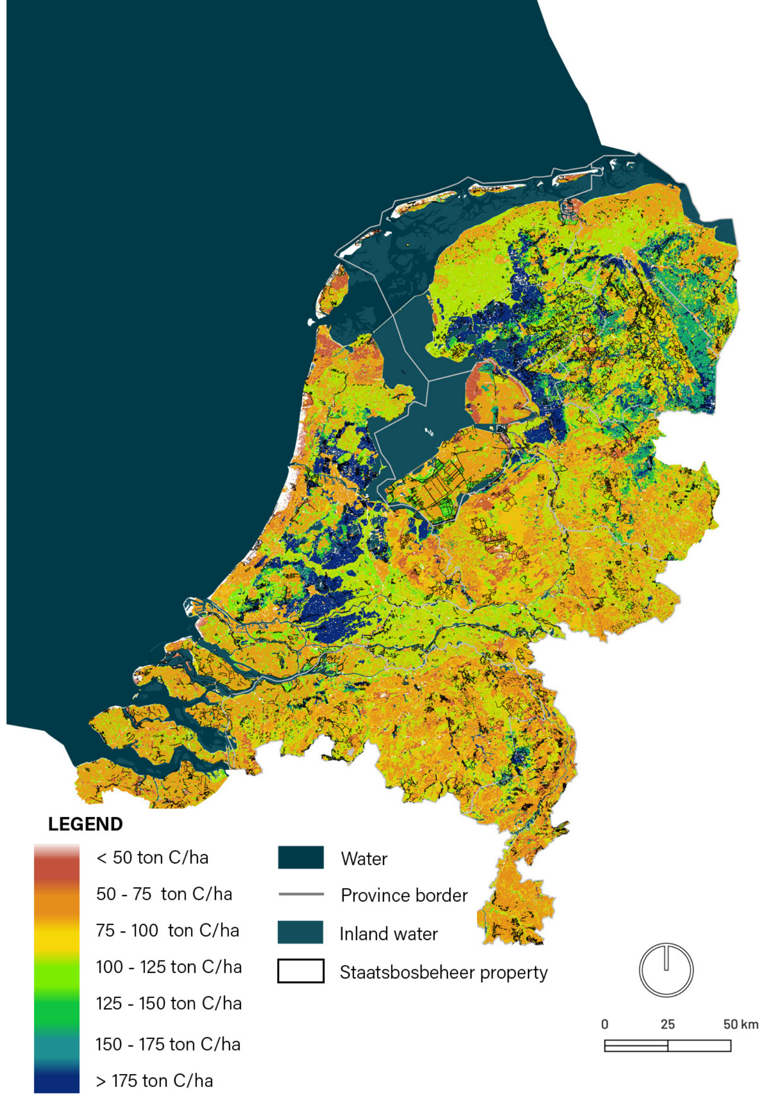
"Cities are a major source of carbon dioxide emissions."
- Kiran et al., 2011

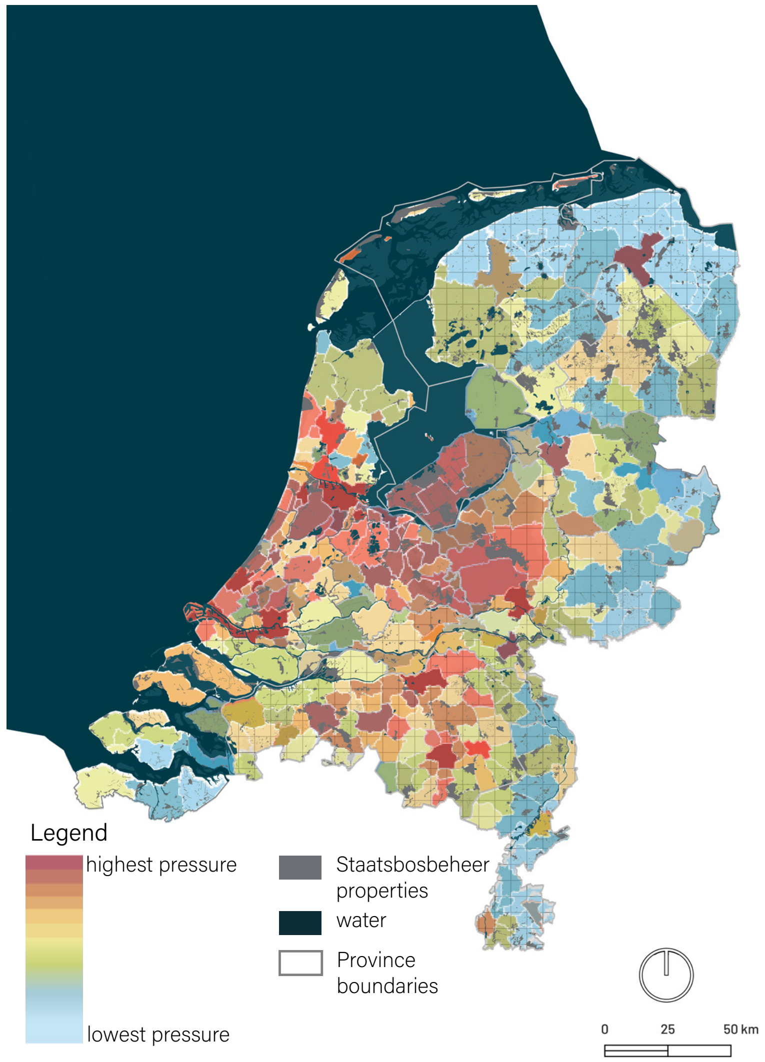


Besides reducing and avoiding emissions, the remaining CO_2 already in the atmosphere must be sequestered or preferably stored for a longer time to mitigate global warming. Our city environments are increasingly getting hotter. Cities are usually warmer than their rural surroundings (the urban heat island effect or UHI). The urban heat island effect can increase heat-related health problems in summer (heat stress). It is expected that heat stress in the Netherlands will increase in the future because of global warming. This is likely to increase the number, duration, and intensity of heat waves. On top of general warming, there will probably be an increase in the UHI, influenced by population growth and urbanization (Wolters et al.,2011).

INTRODUCTION

figure 1.12.1 Woningdeal locations data from "volkhuisvestingnederland.nl" by Ministerie van binnenlandse zaken en koninkrijksrelaties, 2022. (https://www.volkshuisvestingnederland.nl/onderwerpen/woningbouwimpuls/projecten-woningbouwimpuls)





1.1.2 Housing need in the Netherlands

The Netherlands is expected to have 18.8 million inhabitants by 2035. Because of this, among other reasons, the demand for housing will naturally increase. To meet the growing demand, a total of 845,000 homes will have to be built between 2020 and 2030. In 2020 there was a shortage of 331,000 homes (4.2 percent of the housing stock). The aim is to reduce this deficit to 2% by 2035 (Rijksoverheid, 2020). The Government is stimulating provinces, municipalities, and developers to annually build 75.000 new homes (Nationale Woonagenda). This shortage is mostly located in urban areas. Urban areas have a shortage of affordable housing. Most housing is planned in the west of the Netherlands. These locations often overlap with locations where carbon is stored in the soil as the soil in the west often consists of peat. In figure 1.12.2 Carbon reservoir in the soil of the Netherlands, you can see that these areas can hold more than 175 tons of carbon per hectare.

figure 1.12.2 Carbon reservoir in the soil of the Netherlands. by author with data from GIS RIVM Atlas Natuurlijk Kapitaal, 2022 (https://nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/metadata/c207ab90-f6a0-4f70-85ca-1eb1961080d5?tab=relations)

figure 1.12.3 Housing pressure in the netherlands. made with data from "BPD.nl"by BPD, 2021. (https://www.bpd.nl/actueel/persberichten/woningdruk-blijft-hoog-in-randstad-en-loopt-op-in-aantal-provincies/)

1.1.3 From Theory to Practice

There are numerous scientific studies done about climate adaptation and mitigation. Nevertheless, there is a gap in knowledge, examples, strategies, and imagination on how to realize the goals determined in literature in real life (Wandl et al. 2014).

Secondly, the importance of carbon storage has just recently been underscored in the climate agreements of November 2021 but has not been extensively studied yet in the context of urban design. Urban design is essential in the realization of climate goals. The Sustainable Development Goals of the UN one of the SDGs is named Sustainable cities and communities (SDG Nederland, 2022). The research that is found on carbon storage is mostly focused on agriculture. In an urbanized country like the Netherlands, the border between the countryside and the city is less and less visible. Because of this, it is important to study this in the context of the built environment too (Brink, 2021).

figure 1.1.3 SDG's UN which apply for (re) Carbon City. from "pwc.nl" by UN, 2022, (https://www.pwc.nl/nl/onze-organisatie/corporate-sustainability/sustainable-development-goals.html)

1.1.4 Visions from practice: Staatsbosbeheer

Green metropolis vision

One of the partners of the 2021-2022 graduation studio Urban Ecology & Eco-Cities is Staatsbosbeheer. They have asked the studio to make an analysis and design that fits in their Groene Metropool vision. This thesis is one of the nine student projects that can be seen as an approach to making the Green Metropolis vision concrete for a specific region or city.

'De Groene Metropool' is a program introduced by Staatsbosbeheer to contribute to a healthy and attractive living and business climate in dutch cities. They pursue the development of a green metropolis. They describe it as: "a green (nature) and blue (water) network that flows through the whole country, from the city centers to the nature reserves" (Staatsbosbeheer c., 2021). Its mission is to connect every Dutch person, including urban residents, to the green network. Staatsbosbeheer is concerned with establishing physical connections in the landscape, which better connect the city with the surrounding landscape.

They pursue the following goals (Staatsbosbeheer c., 2021):

- *To offer residents the opportunity to use a green network with a varied level of facilities as directly connected to their home*
- *The areas managed by Staatsbosbeheer are in line with the (needs of) city dwellers, which will increase the possibilities for use and thus the social value of the areas.*
- *To provide conditions for a healthy and attractive living and business climate.*
- *To let the wishes, behavior, and needs of people form the basis for the choices they make for the management of the areas, the cooperation with partners, and the way in which they publicize all (recreation) options.*

Carbon storage vision

Staatsbosbeheer wants to reduce the excess CO_2 in the air in order to contribute to the Climate Agreement. This means a reduction of at least 49 percent by 2030. Peat areas must emit 1 megaton less CO_2 by 2030 (Staatsbosbeheer, 2021). They want to create 5000 hectares of extra forest and raise the water level in 5000 hectares of peatlands to contribute to the sequestration of CO_2. Staatsbosbeheer could play a significant role as it manages more than 30,000 hectares of peatland itself.

"Staatsbosbeheer has added the following principles in their policy (Staatsbosbeheer (b), 2021):

- *We implement climate measures together with other organizations and contribute our knowledge and experience to bind CO_2,*
- *We are going to plant extra forest and actively contribute to the rehydration of peat areas, as a contribution to the Climate Agreement.*
- *Where possible, we are clearing land for wind and solar energy and for tidal power stations in collaboration with partners.*
- *We supply sustainable wood and bio-based raw materials.*
- *We are developing climate buffers to better respond to more extreme weather as a result of climate change.*
- *We make our forests more robust and resilient by planting trees and shrubs with a positive effect on forest composition and growth place, this is part of climate smart forest management.*

Their business plan 2020-2025 is translated into the following specific objectives:

- *They aim to create 5,000 hectares of new forest by 2030 to contribute even more to CO_2 sequestration. We will use 2,500 hectares of this in the coming business plan period.*
- *Over the next 10 years, we will rehydrate 5,000 hectares of peatlands. We will realise half of this in the next 5 years.*
- *Within 5 years we want to reuse the green (residual) material from our areas from 75 to 85 percent. With the highest possible application, of course."*

1.2 PROBLEM FIELD DEFINITION

In order to mitigate and adapt to climate change, it is important to restore and preserve peatlands. The Woningdeals now struck are planning to build housing mainly in the west of the Netherlands, on top of our own carbon sinks.

One of the biggest layers of peat in the Netherlands is situated in Gouda. This creates opportunities to prevent the emission of CO_2 and store carbon in the peat soil in Gouda. However, the Woningbouw agenda states that new housing should be built in Gouda too (see figure 1.2.1). A big expansion area is situated in the west of the city bordering a Staatsbosbeheer property.

Building on peat soil brings a lot of problems with it. As a result of dewatering in the polder of gouda and many other locations, many peat areas have dried up, causing the dead plant material in peat to come into contact with oxygen, causing 'oxidation.' This causes CO_2 to be released and the soil sinks. Rewetting stops soil subsidence and increases biodiversity in the peatlands (Staatsbosbeheer, 2021). The traditional way of building worsens the subsidence and in turn, causes the houses to sink. This is an unsustainable way of building.

With the destruction of peat areas, biodiversity is lost. So, from an ecological point of view, it is important to preserve this specific ecosystem. This project brings the opportunity and challenge to explore the building of our urban environments in an eco-friendly way.

This project aims to find a synergy between the three problems, the need to store carbon, the need to build housing, and the need to build nature inclusive. It results in a design proposal that is supported by ecological evidence and knowledge via a pattern language for (re)carbon city.

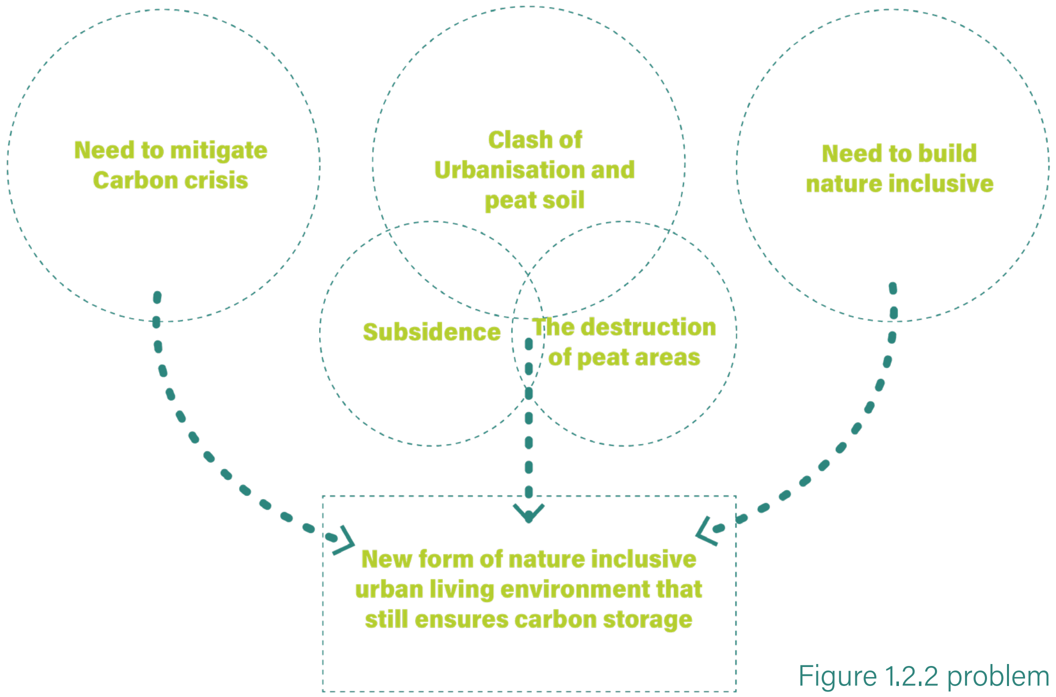


Figure 1.2.2 problem field

"The built environment is hard to decarbonize but has a pivotal role in climate-change mitigation amid rapid urbanization."
-Pomponi et al., 2020

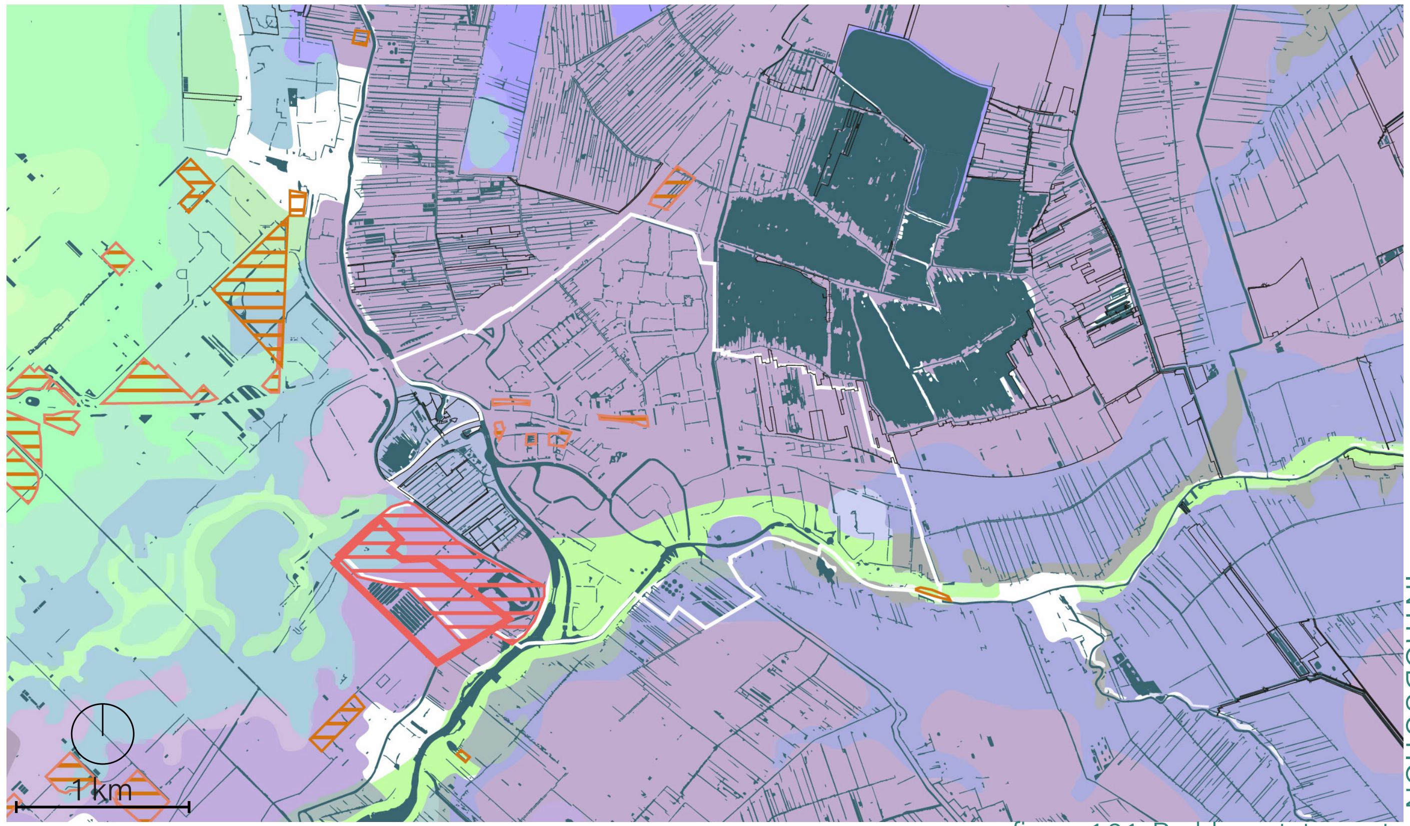


figure 1.2.1 Problem statement.
by author (2022) with GIS

LEGEND
- Chosen location
- Planned expansion/densification
- Staatsbosbeheer properties
- Water
- Peat
- Clay
- Petgaten

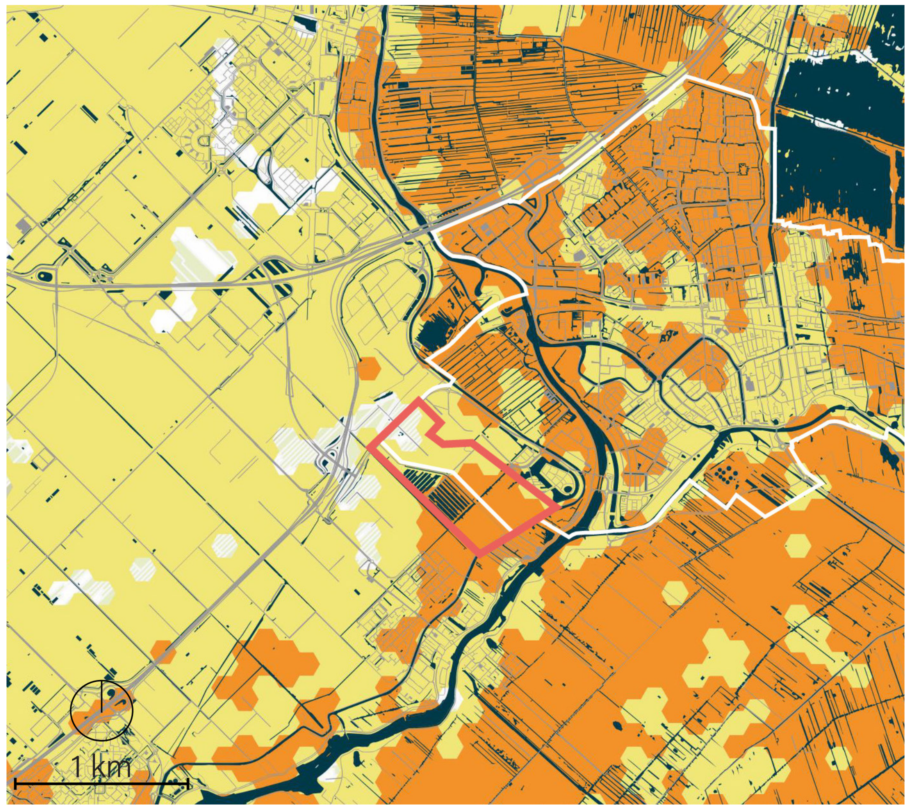


figure 1.2.3 Soil subsidence. by author,2022, data from GIS. Provincie Zuid-Holland (https://nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/metadata/A604012E-53EC-4FC2-B39B-019957D67F7C)

LEGEND
- Chosen location
- high sensitivity subsidence
- medium sensitivity subsidence
- Water

1.3 GETTING TO KNOW WESTERGOUWE

1.3.1 Existing Situation

Westergouwe is a new expansion location approximately 2 to 3 km southwest of the city center of Gouda. Due to its location on the provincial road, Westergouwe is for many people the ‘first encounter’ with Gouda (Adviesbureau Witpaard - partners, 2008)

The existing landscape exists of the orthogonal structure of the open polder. The tours of the Zuidplaspolder are always 400 meters apart. Between the tours there is a regular pattern of ditches (40 meters apart), resulting in a systematic landscape Currently, the area is mainly used as agricultural land, and grassland. And at the borders of the area, some solitaire dwellings are found, some former farms.

1.3.2 Existing Development

The development of Westergouwe will be phased. The Westergouwe zoning plan (adopted in October 2008) has been drawn up, containing plans for a high-quality residential area with facilities and a green-blue zone. Phases 1 and 2 are already or almost built, and phase 3 is now designed for. The area of this project consists of the land that has not been put sand on, and where the ‘original’ landscape still shows. This will contain the land of phase 3 partially.

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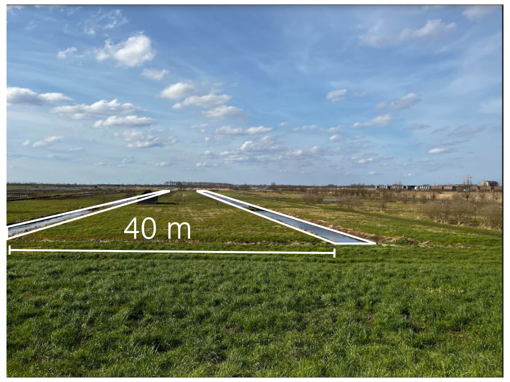


6.

figures 1.3.1 westergouwe location

figures 1.3.2 satellite image location from "google maps.nl"
(https://www.google.nl/maps/@52.0024003,4.6792561,2872m/data=!3m1!1e3!5m1!1e4)

figure 1.3.4.2 Already built neighbourhood, by author

1.3.3 Westergouwe masterplan

The housing task of Gouda is not only based on the autonomous population growth of the municipality itself but also arises from the task that Gouda is a central municipality that can house the demand from the region (Bügelhajema, 2021). Westergouwe has been designated to be an expansion area for more relaxed green urban living.

The urban design of Westergouwe is based on approximately 2.300 to 3.400 homes in a neighborhood with a multitude of different living environments. Westergouwe after phases 1 and 2 houses a lot of high-priced housing. Phase 3 will house more social housing for lower-income future inhabitants.

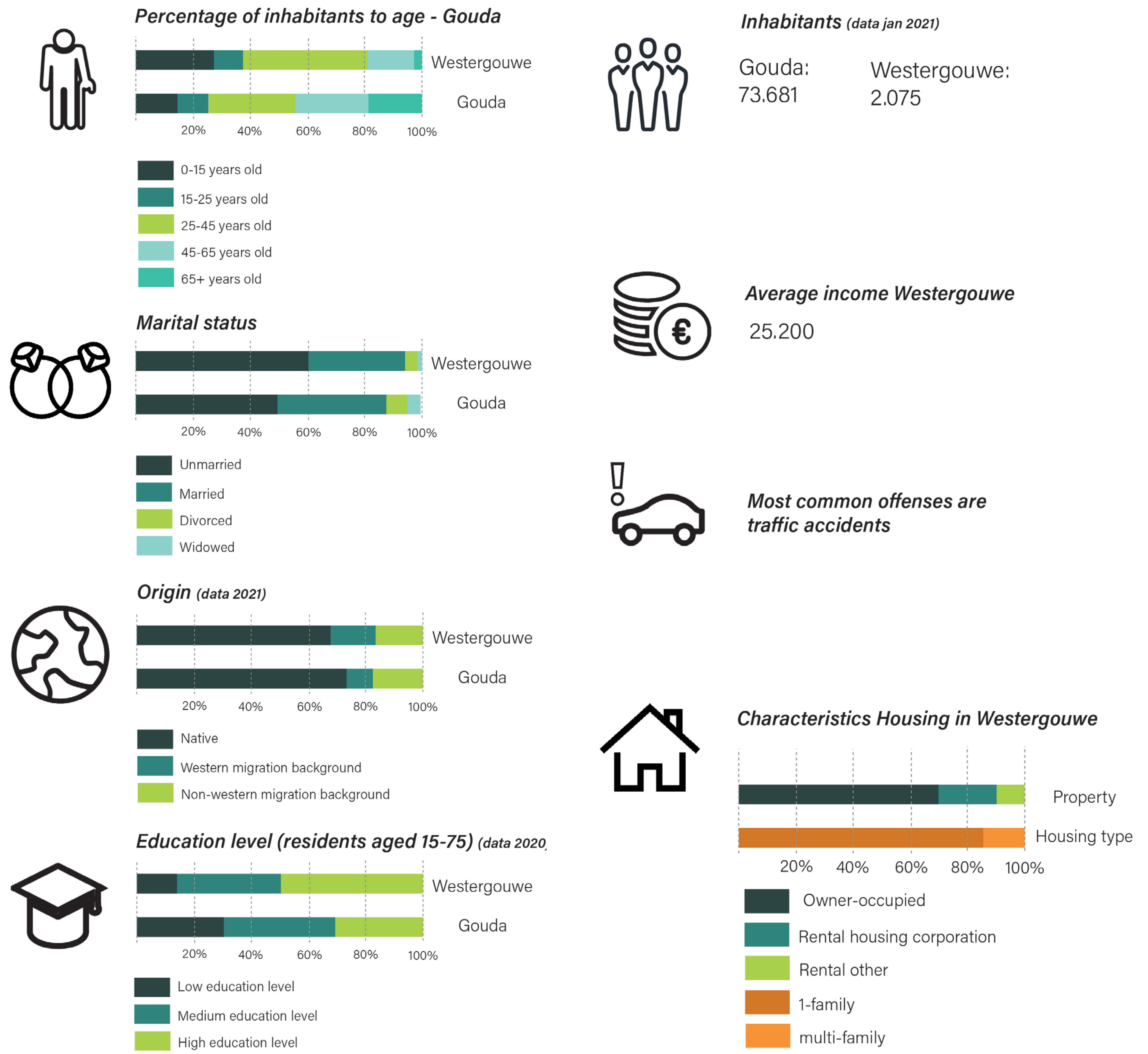


Figure 1.3.4.1 Statistics municipality of Gouda. by author with data from "allecijfers.nl", 2022, (https://allecijfers.nl/gemeente/gouda/#:~:text=Gemeente%20Gouda%20heeft%20afgerond%20een,9%20wijken%20en%2051%20buurten.)

1.3.4 Orientating in the Landscape

Westergouwe is located just outside of the low peat area in which the rest of Gouda is situated. It is found in the 'droogmakerij landscape'. When we zoom into the' droogmakerij landscape', we can distinguish that Westergouwe is situated in the 'peat rest landscape' in particular. This landscape was developed through digging out of the peat soil for obtaining peat as a fuel.
In figure 1.3.3.2 you can see that the soil of Westergouwe mostly is consisting of peat. This can be as thick as 4 to 6 meters in the area. The north of the area has a mixture of mostly clay and a thin layer of peat.

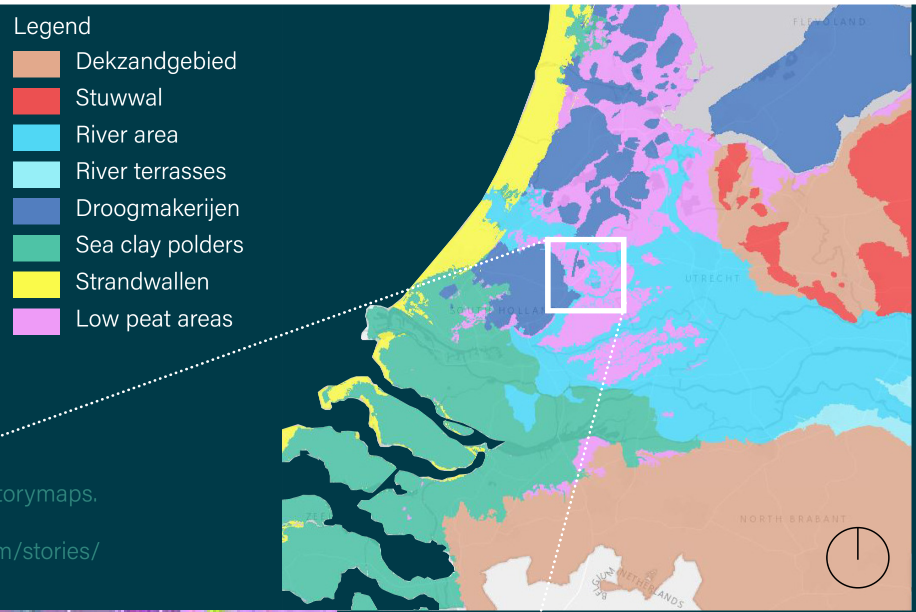


figure 1.3.3.1 Landscape types from "storymaps.arcgis.com" by Basiskaart Natuurlijk Systeem Nederland, 2022 (https://storymaps.arcgis.com/stories/ef96875dedf14847a62ac16114b49295)

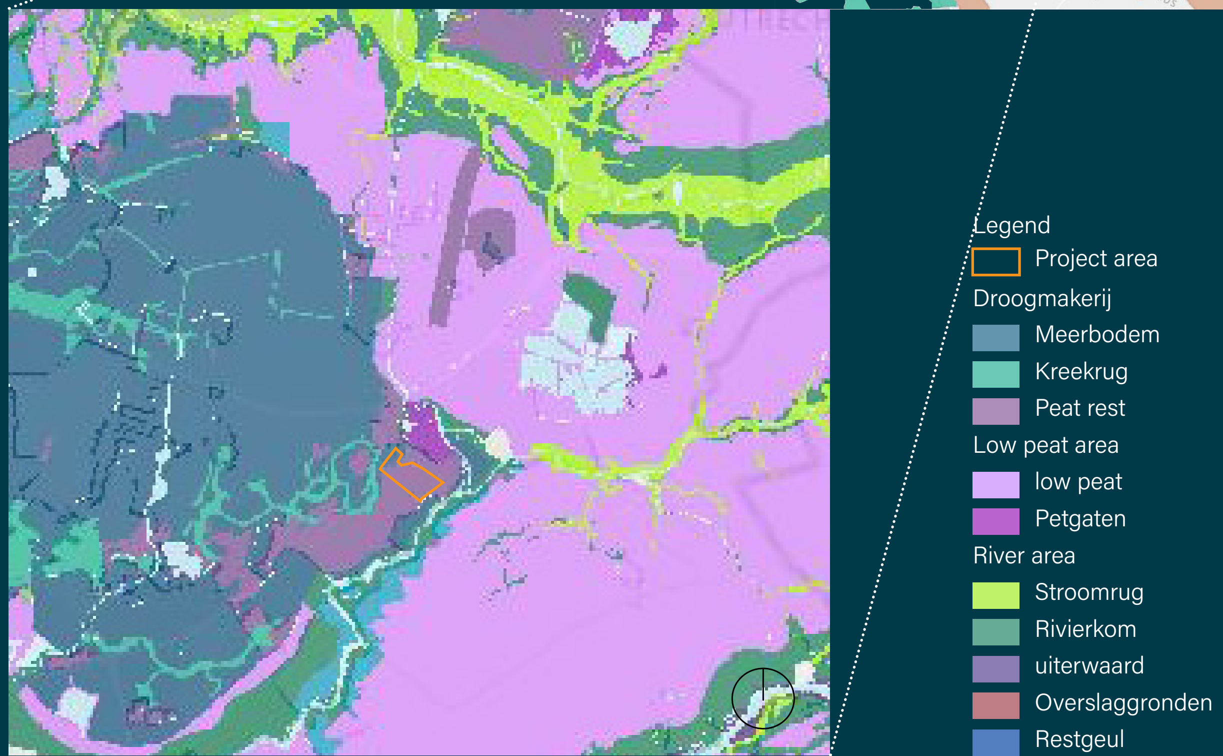


Figure 1.3.3.2 Soil types in Westergouwe by author made with data from GIS

LEGEND

- Koopveengronden op rietveen of zeggerietveen
- Koopveengronden op bosveen
- Aangemaakte petgaten
- Moerige eerdgronden met een moerige bovengrond of moerige tussenlaag op niet-gerijpte zavel of klei
- Kalkarme leek-/woudeerdgronden; klei
- Kalkrijke leek-/woudeerdgronden; zavel
- Koopveengronden op (meestal niet-gerijpte) zavel of klei, beginnend ondieper dan 1.2 m
- Liedeerdgronden; klei
- Water
- Project location

H2. APPROACHING

CONTENT H2.

2.1 RESEARCH AIM

The aim of this project is to create a design proposal that is supported by ecological evidence and knowledge via a pattern language for a residential area in Westergouwe. This design explores a way to build a living environment on top of peat soil in an ecologically responsible way, trying to preserve the carbon in the soil and store carbon in itself. After the design is a small strategy done and will be looked at the possibility to implement the design at other locations.

2.2 RESEARCH QUESTIONS

Main research question:

How can the urban living environment on rewetted peat soil contribute to carbon storage in Westergouwe?

Sub-research questions

The guides of the project are fourteen specific sub-research questions (see figure 2.3) that underpin the focus of the separate phases of the thesis project: framing, analyzing, designing, strategizing, generalizing, and transferring. In framing will the most important themes be explained, followed by analyzing where the location is further looked at to make a design proposal in designing. In strategizing is looked at how this design could be implemented through time and which stakeholders would be involved. In generalizing is the pattern language shown that is used while making the project. And finally, a phase of transferring is done, where is looked at what of the design can be transferred to other designers to make their own (re)carbon city.

2.3 RESEARCH APPROACH

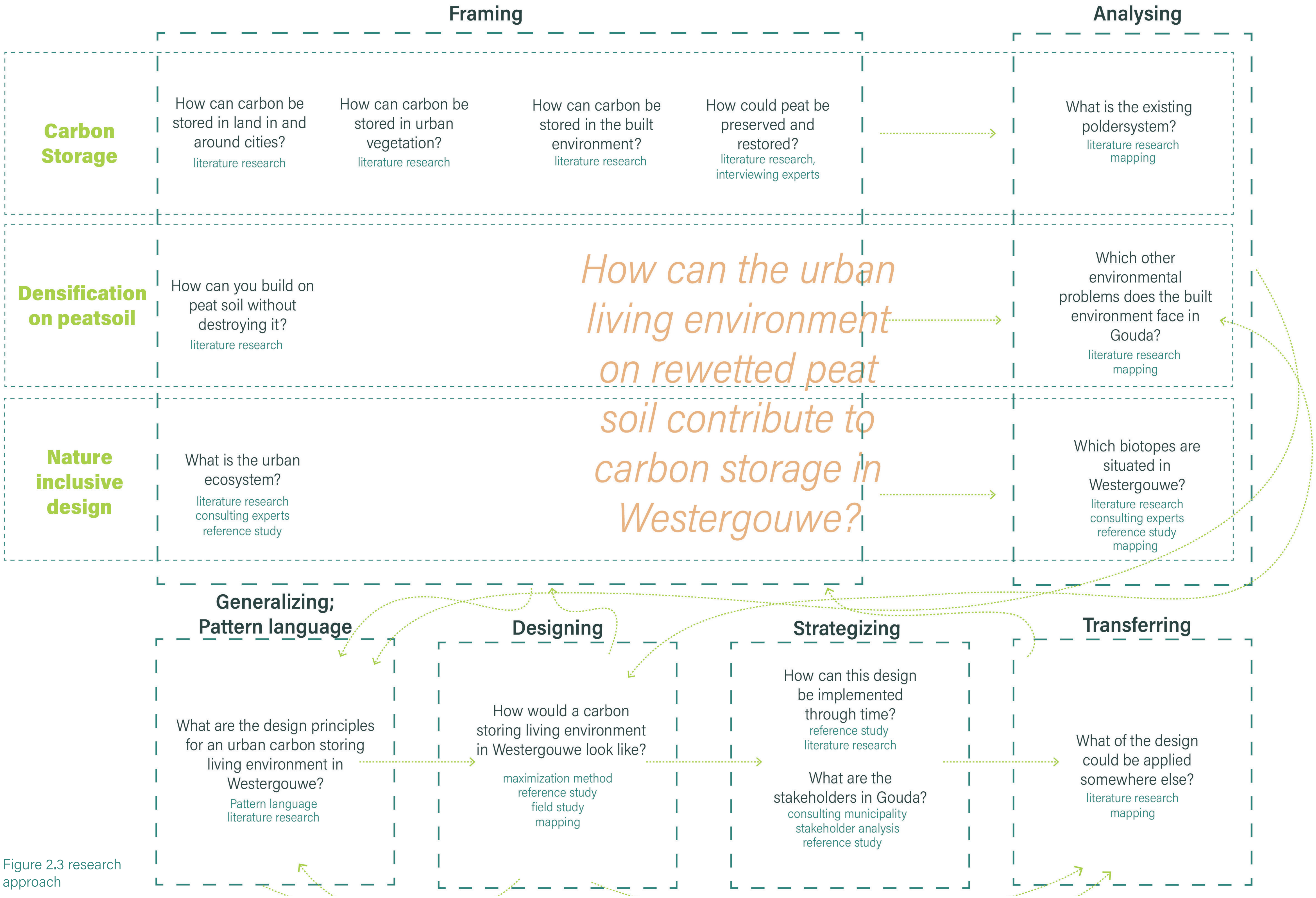


Figure 2.3 research approach

2.4 METHODS

Literature Research

Literature research is used throughout the project. Literature is the base for the theoretical framework. Data is gathered through books, google scholar & research gate.

Reference Study

Reference study is used in the analysis to get a grip on the assignment and gather knowledge about the subjects, It is used in the design as an example, and in the strategy, it is used to see how the design is implemented.

Pattern language

A pattern language could be made because of different reasons. For example, it could be a communication tool or a design tool, a way to structure and understand a complex system to create a coherent design. The pattern language could be represented in a graph which is called a pattern field. The connections between patterns are essential to creating a coherent field.

The reason this method is used in this project is because the author wants to translate a technical/environmental problem into a design. This means that technical research papers are translated into design principles.

The pattern field is something that stays dynamic while the project progresses and after finishing this project can be something to use and to be added to by other designers.

Fieldwork

Site Visit is a personal visit where the author makes personal observations and documents this with photos and sketches.

Internet Searches are used to gather data more quickly. Google maps has been used to quickly understand the site. Various other sites are used to get an understanding of the context of the place.

Mapping

Mapping is used in different stages of the project. First, it is used to form the context in the problem statement, in the analysis to understand the site better and identify the problems and opportunities, in the design it is a way to discover, design, and communicate, in the strategy, it is also used as a communication tool and lastly in the recommendations it is used to communicate ideas for designers and other planners. The data for mapping is collected from different sources. Examples are Google Maps, QGIS, National Georegister, PDOK, and Klimaat Effect Atlas.

Maximization Method

This method consists of three phases; maximization, optimization, and integration. In the maximization phase, a design is made focussing solely on one subject. For the optimization phase, the designer combines different maximizations into one design that optimizes all subjects. The integration phase, brings together the optimization with another subject and makes the design more feasible/realistic. This additional subject can be a conflicting subject, a subject that aligns with additional goals, or a subject that you as a designer want to characterize the place.

The maximization method is a quick way to make a basis for a design. It is also important to set a time constraint for this phase. This way you make decisions quickly. The author could use this method to take the subject of a carbon city to the extreme. This method forces the author to be bold in the design, and that is what she aspires to be in the design.

Stakeholder analysis

This method is used to get a better understanding of the realization of a carbon city. Most climate goals are big assignments that can be overwhelming for urban planners to contribute to. By translating the design into understandable interventions and dividing these among the stakeholders, this assignment can be less intimidating for future planners and other parties.

The data for this analysis is found through fieldwork and reference reviews.

H3. FRAMING

3.1 THE CARBON CYCLE

"Carbon is the backbone of life on Earth. We are made of carbon, we eat carbon, and our civilizations, our economies, our homes, our means of transport, are built on carbon"
- Nasa Earth observatory,2013

The carbon cycle moves from rocks, the ocean, the atmosphere, plants, soil, and fossil fuels. The carbon that comes into the atmosphere results in warmer temperatures on Earth. Fortunately, the carbon cycle maintains a balance that keeps the whole amount of carbon on the planet from entering the air. Carbon would have to travel through rocks, soil, sea, and atmosphere for approximately 100-200 million years to complete a full round around the slow carbon cycle.

On the other side, the rapid carbon cycle only takes a single lifetime. Plants and phytoplankton collect carbon dioxide from the atmosphere and store it in their cells. Plants and plankton use solar energy to mix carbon dioxide and water to generate sugar and oxygen. Sugar is broken down by plants to obtain the energy they require to thrive. Plants or plankton are eaten by animals who decompose the plant sugar for energy. Plants and plankton die and degrade, releasing carbon dioxide into the air again (Riebeek, 2011).

The rapid and slow carbon cycles, if left alone, preserve a generally constant carbon content in the air, soils, vegetation, and sea (Riebeek, 2011). However, every change in the quantity of carbon in one reservoir has an influence on the others.

CONTENT H3.

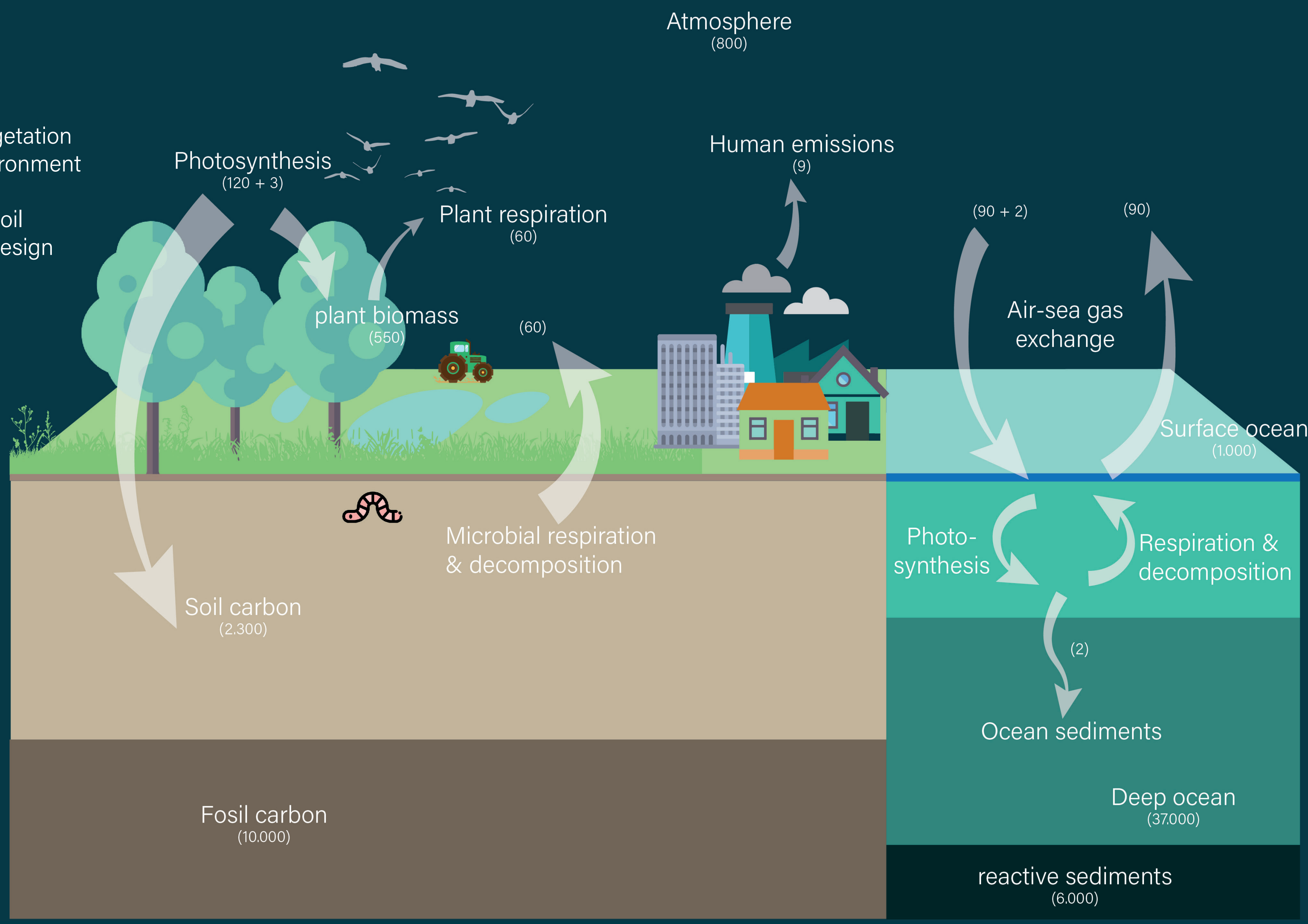


Figure 3.1.1 The fast carbon cycle. Based on diagram The Carbon Cycle. from "earthobservatory.nasa.gov" By Holli Riebeek. June 16, 2011 (https://earthobservatory.nasa.gov/features/CarbonCycle)

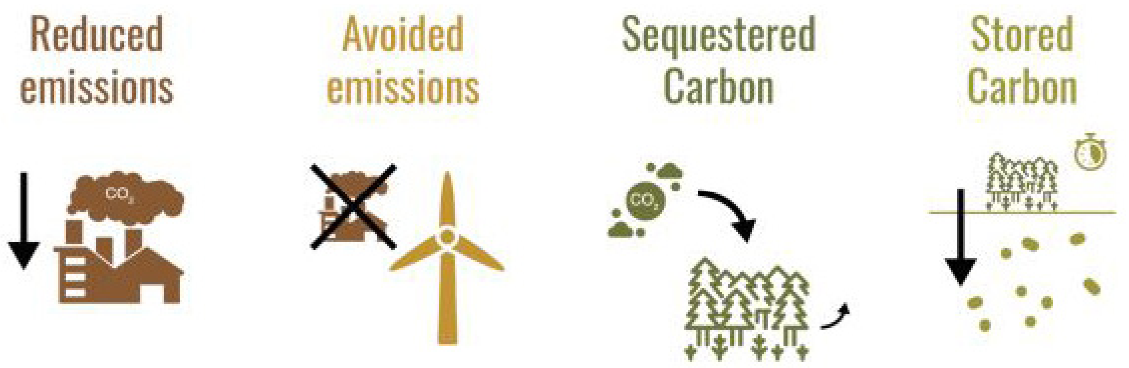


figure 3.2.1 ways to reduce carbon from the atmosphere by Climate Cleanup and ASN bank, 2021 (https://climatecleanup.org/wp-content/uploads/2022/01/Construction-Stored-Carbon-V8-11-2021-5.pdf)

3.2 CO_2 EXTRACTION

To accomplish the Paris Agreement's aim of keeping global warming to 1.5 degrees Celsius, greenhouse gas emissions must be zero by 2050. This will necessitate not just cutting current emissions but also extracting carbon dioxide from the atmosphere (Lebling & Northrop, 2020). The amount of CO_2 that needs to be removed from the atmosphere by the Netherlands is 1500 Gt to help reverse global warming (Climate Cleanup, 2020). and around 10-20 billion tons of CO_2 per year through 2100, globally (Lebling & Northrop, 2020). In order to remove the excess CO_2 from the atmosphere, we can do 4 things. 1) We can reduce emissions, 2)we can avoid emissions, 3)we can sequester carbon 4) and we can store carbon for a longer period of time (Climate Cleanup, 2020). For bringing global warming to a halt, it is important that we should not choose one solution. The combination of these is the best option. As this project is going to focus on the last two solutions, the author would like to stress that the first two solutions, reducing and avoiding emissions, are crucial for the future of the planet.

For removing the excess carbon, regenerating nature is by far the most effective way. First, because it is much cheaper than current technological methods, but second if we do not focus on nature-based solutions we'll be living in a completely desertified society in which we as human beings might perhaps somewhat survive but certainly do not thrive.

In the period between 2010 and 2019, just 55% of the emitted fossil fuel CO_2 has remained in the atmosphere. This missing 45 % has been stored by the ocean and the terrestrial biosphere (Dunn et al., 2021). CO_2 rates are mostly rising because of emissions. How much the concentration of CO_2 is increasing is mostly due to the exchange of carbon from the soil or vegetation on land and the atmosphere.

Reduced Emissions

With this option, emissions of CO_2 are less by reducing the activities that cause emissions. This also takes technical advancement about being as energy efficient as possible and reducing energy consumption. An example of reduced emissions is the improved disposal of waste methane. By reusing methane for power generation carbon is reduced from the atmosphere (Global Carbon Project, 2021).

Avoided Emissions

You can also avoid emissions by replacing the existing activities with low-emission products or activities. For example when fossil energy is replaced by renewable alternatives like wind or solar or when building materials like concrete are replaced by low-emission materials like bamboo. Although knowledge about renewable energy has come a long way, this requires a greater change in infrastructure, more research, and larger investments.

Sequestered Carbon

Sequestration is the process of immobilizing carbon that is free in the atmosphere or water into a long-term carbon reservoir. This is a vulnerable process but has additional benefits, like increasing biodiversity, reducing the urban heat island effect, and creating health benefits.

Stored Carbon

Carbon Storage is a period of time during which an amount of carbon stays immobilized. It describes the carbon stock over time. "Soils are the largest terrestrial reservoir (Figure 3.2.2) and may provide the best way to remove carbon from the atmosphere" (Institute of Agriculture and Natural Resources, 2019).

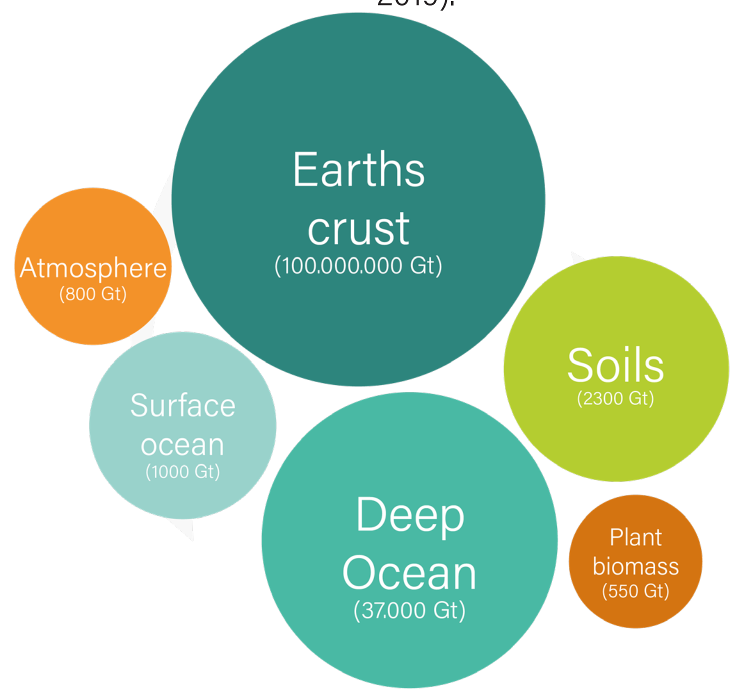


figure 3.2.2 Earth's carbon reservoirs (in gigatons) from "cropwatch.unl.edu" by author based on illustration Earth's carbon reservoirs (in gigatons),2021, (https://cropwatch.unl.edu/2019/cover-crops-and-carbon-sequestration-benefits-producer-and-planet)

3.3 STORED CARBON

3.3.1 Urban Vegetation

Planting trees is maybe the most commonly known way to capture carbon. Forests and soil capture about 30 percent of carbon emissions (climate.nasa.gov, 2019). But trees are not the only vegetation that can capture carbon. Plants in general have the ability to sequester CO_2 through photosynthesis and thus can store carbon in plant biomass and the soil (Fares et al., 2017).

Also in the city may urban vegetation lower CO_2 concentrations from the air. This is observed in studies that compared urban to rural areas and the presence of vegetation (Fares et al., 2017). The benefit of urban vegetation can be up to 18 kg CO_2/year per tree (Kiran et al., 2011). The carbon sequestration of urban vegetation is not regular through time. As plants use carbon in photosynthesis during the daytime and at night emit carbon in response to respiration (Fares et al., 2017).

Strategies to improve the carbon intake of urban vegetation are (Korean Institute of Landscape Architecture, 1998) :

- Planting species with high photosynthetic capacity,
- Sunlight-guaranteed road and building layout for street trees,
- Planting of shade-tolerant species in the north of buildings,
- Relocation of utility lines and minimised pruning.

The Urban environment provides benefits and cons for vegetation to grow in. For example, the high concentration of CO_2 is like a fertilizer for plants, promoting more efficient photosynthesis (Fares et al., 2017). However, the city can also provide environmental stresses and in the extreme wrong circumstances turn urban vegetation into carbon sources (Fares et al., 2017).

Vegetation not only provides benefits for carbon sequestration but also provides other benefits like a cooling effect on the microclimate by shading the ground surface and indirectly through transpiration (Kiran et al., 2011).

3.3.1 krimpenerwaard, by author

3.3.2 The built environment

The building sector has an important role in our transition to a climate-friendly city. The sector emits a huge share of carbon emissions. The built environment, buildings and construction, accounts for about 40% of global final energy use and energy and process-related emissions (Pomponi et al., 2020). To reduce atmospheric carbon, it is important to improve materials, technologies, and strategies in this sector (Capps, 2021).

Carbon storing building materials
One way to store carbon is to use bio-based materials in our buildings. Because of their storage capacity, carbon-storing materials are essential for the transition toward zero-carbon urbanizations. (Pomponi et al., 2020). However, this task is not an easy one, as the use of steel and cement are ingrained in the sector, which are carbon-intensive to produce.

Building constructions, envelopes, and insulation are the most typical uses for carbon-storing materials (Pomponi et al., 2020).

- Timber: Timber has been used as a construction material for millennia and is becoming more popular as a low-carbon option. It has a growing promise to compete with steel and reinforced concrete in construction structures.
- Bamboo Bamboo is a fast-growing bio-based building material that can be cultivated all over the planet and has the ability to address the rising need for building structures in the Global South while also storing carbon.
- insulation materials Blown cellulose, cork, and hempcrete are examples of insulating materials that minimize the amount of energy required to heat and cool a structure while simultaneously storing carbon.

Wooden buildings
In particular, wooden buildings store a lot of carbon as the dry mass of wood is 50% carbon (Kuittinen, 2015). For wooden buildings to be built we need production forests to be harvested and managed sustainably. Awareness of the importance of harvesting sustainably needs to be raised and forest certification should be highlighted in sourcing.
With the idea to store carbon in wooden construction materials, it is beneficial to ensure that they will stay in the building as long as possible.
When wooden construction components are no more in use, they can be reused or recycled into new items. This will keep atmospheric carbon locked away and stopped from contributing to the greenhouse effect.
Rest material may be burned as carbon-neutral biofuel to replace fossil fuels after a recycling loop (Kuittinen, 2015). The residual ashes can be utilized as compost to promote forest growth and increase carbon sequestration, or as a replacement for cement to reduce concrete's co_2 emissions.

Figure 3.3.2.1 displays materials that store more carbon than they emit while producing them. On top of this, they are grown on peatsoil, creating the possibility to grow them locally.

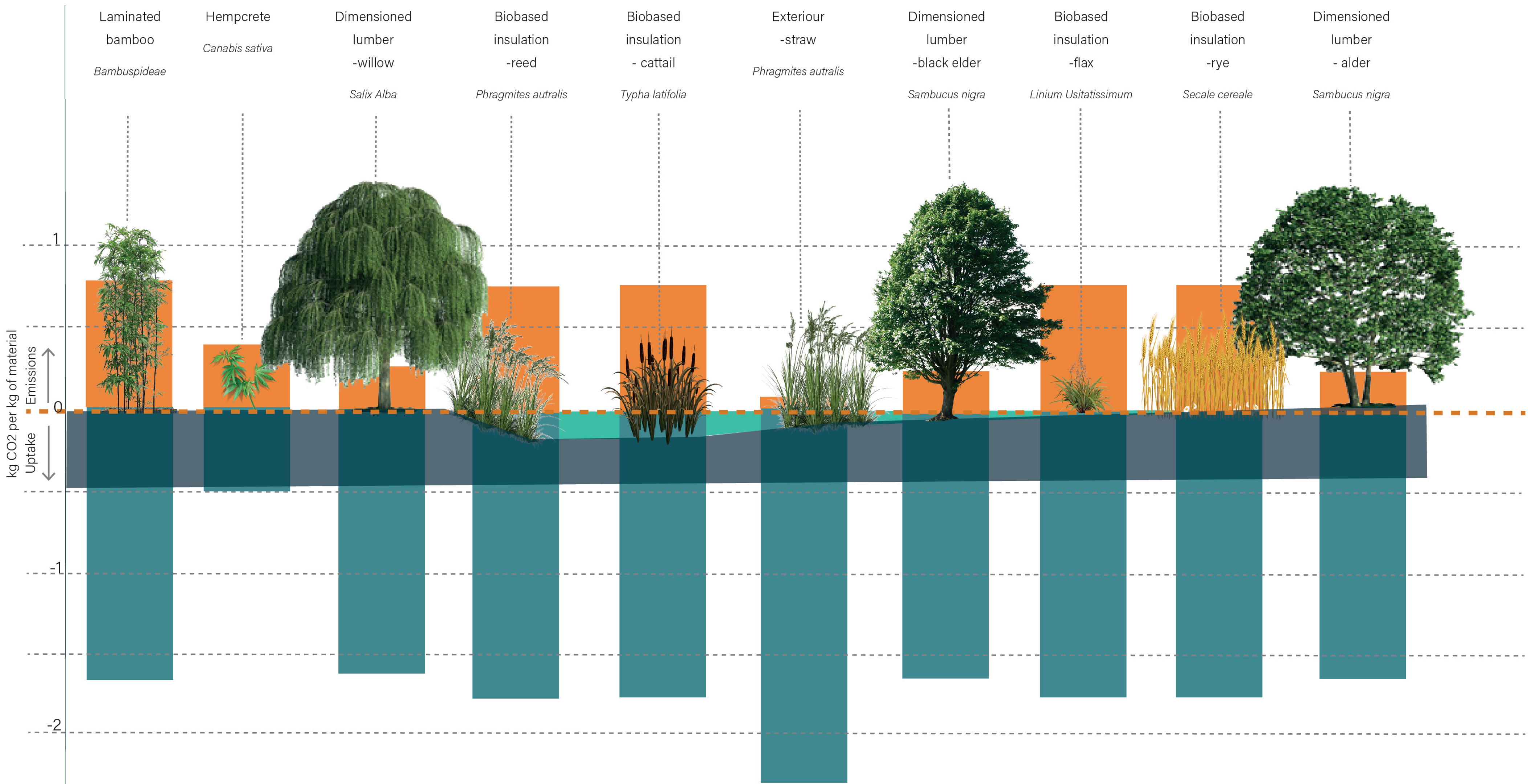


figure 3.3.2.1 Peat-based carbon-storing building materials. by author based on farm of the Future by R. Kobben, 2021, (https://repository.tudelft.nl/islandora/object/uuid%3A20f019f6-0a50-4d44-8dc1-3c83b8743fad?collection=education) and on Pomponi, F., Hart, J., Arehart, J. H., D'Amico, B., 2020 (https://cdrlaw.org/wp-content/uploads/2020/09/PIIS2590332220303626.pdf)

3.3.3 Peatsoil

Soil currently holds 2300Gt of carbon of the earth's reservoir and after the ocean, it is the biggest natural stock of carbon. In particular, peatlands are very important when looking at the context of climate change because they can absorb CO_2 and emit CO_2 and CH4 (Harenda, 2018). When the conditions are right, like the natural state, peatlands are usually carbon sinks. Peat can hold twice as much as the entire world's biomass due to the high carbon concentration in the peat (50%). This is why the protection and restoration of these ecosystems should be a priority (Harenda, 2018).

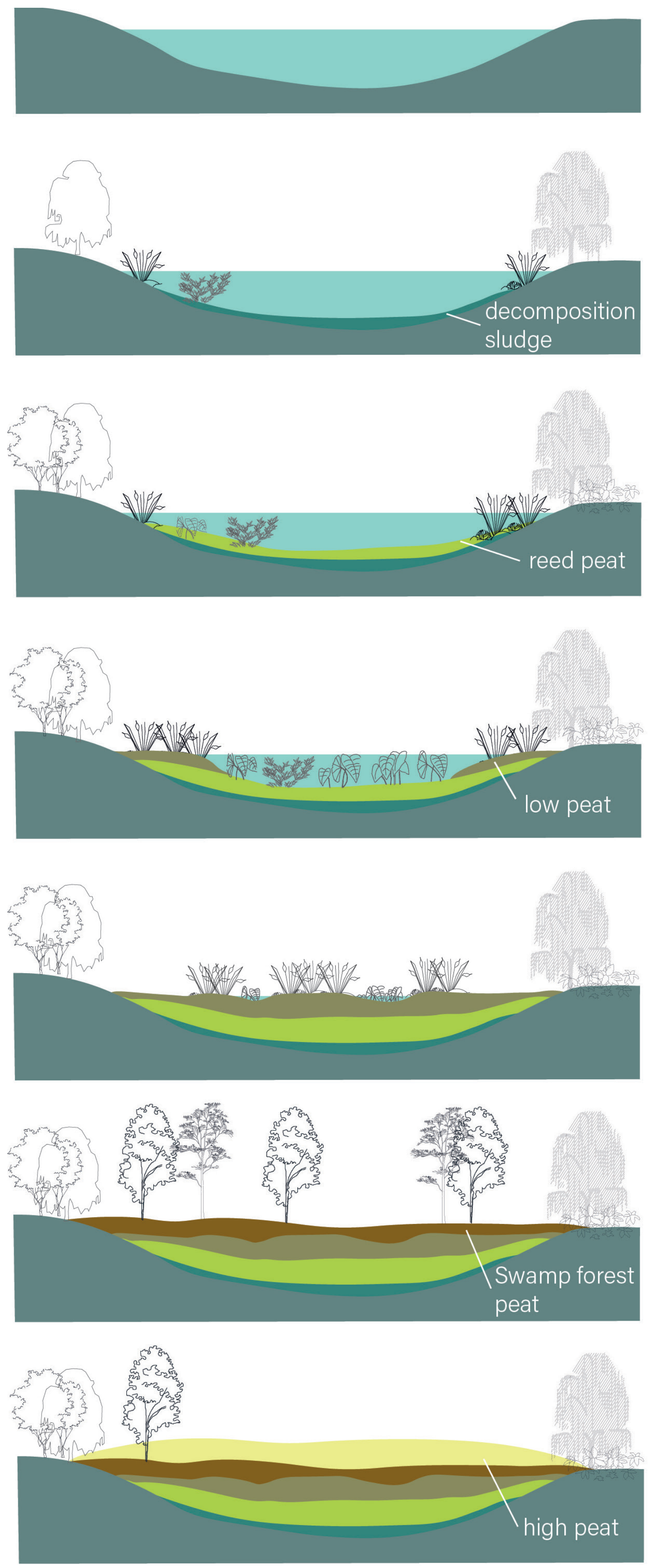
<u>The formation of peat</u>

Peatlands are formed by several processes, of which photosynthesis and respiration are the basic processes that make peatland a carbon sink. Peatlands have a high humidity level which creates anoxic conditions that slow down the decomposition processes of organic matter. Peat accumulates carbon when the rate of organic matter decomposition is lower than the amount of primary production in the ecosystem. The carbon accumulation is dependent on the humidity of the area. The highest accumulation was observed in young Sphagnum peatland in coastal regions (Harenda, 2018).

<u>Preservation of peat</u>

In the past peatlands have been damaged or fully ruined by human activity during the previous two centuries because of the creation of farming grounds (Harenda, 2018). Farming grounds were created using drainage, creating level instabilities. The second driver for bog loss is peat extraction for fuel and industrial reasons. Peatlands have also vanished by changes in landscape retention, such as river valley floods, or destruction because of the mining of solid minerals, petroleum, and natural gas extraction. An example of why the destruction of peatland is so harmful to the environment was found in Canada. Here around 11.4–4.73 million tons of stored carbon were released during the preparation for bituminous sand mining (Harenda, 2018).

Also in the Netherlands peat soil is found. For example, about 25% of the provincial territory of South Holland consists of peat soil that is more or less sensitive to subsidence due to peat oxidation. The peat layer has a thickness varying from 0.4 m to more than 5 m. With the continuation of the current land use and management, the peat soil will decrease on average by approximately 1 cm per year. In the Netherlands, peat oxidation contributes about 2% to national emissions (Provincie Zuid-holland, 2022).



open water is created

The remains of dead, free-floating aquatic plants and animals form a layer of peat sludge on the bottom. Riparian plants slowly push forward towards the lake.

The peat silt is covered by rotting plant remains (reed peat). The lake becomes shallower; the water surface becomes smaller.

A thick layer of plants (mainly peat moss) 'slides' along the surface to the center.

The lake has completely grown over ('landed') The surface is at the same level as the bank (low moor)

The peat bogs are richly overgrown with grasses and herbaceous plants. Later on, shrubs and trees will follow. The remnants of this vegetation form the swamp forest peat.

The peat moss chokes the trees that make up the swamp forest. The remains of these form raised bogs with the peat moss. In the middle it is high, sloping to the shores of the original lake.

figure 3.3.3.1 the succession of peat by author. based on Afb. 7.21 Successie: het ontstaan van hoogveen by "stedentipsvoortrips.nl" (https://www.stedentipsvoortrips.nl/flora/relaties-vier-successiebb.htm)

Peatlands can be preserved by raising the groundwater table near the surface since water is the most essential component determining the development of peatlands (Harenda, 2018). Rewetting can considerably lessen the negative environmental effects of peatland draining. This can be done for example by ditch closing or pumping less in the polder (Tanneberger et al, 2022). Increased water levels, however, do not guarantee successful regeneration since high groundwater levels may not be enough for peatland regeneration.

8 cm in 3,5 years!

figure 3.3.3.2 Vegetation development in Omhoog met het Veen/addmireNL from *Herstel van een veenvormende veenmosvegetatie op voormalige landbouwgrond in veenweidegebieden.* Bas van de Riet/Onderzoekcentrum B-WARE , 2018 (https://www.landschapnoordholland.nl/files/2020-01/Van%20de%20Riet%20et%20al%202018_Eindrapportage%20Omhoog%20het%20het%20Veen%202013-2017_def.pdf) Copyright of Bas van de Riet/Onderzoekcentrum B-WARE. Reprinted with permission

Project Omhoog met het Veen

In the project Omhoog met het Veen, the team of Onderzoekcentrum B-WARE (van de Riet et al., 2018) monitored peatgrowth during four growing seasons. In this project, they transformed old agricultural grassland into quacking bogs. After only 3.5 years, the Sphagnum moss had generated an 8-12 cm thick fresh layer of newly created peat which consisted mostly of undecomposed light brown peat mosses. If peat would keep this growth rate, 1 meter of peat could be grown in about 54 years. It restored the hydrological qualities of the former agricultural soil (nutrient-rich fossil peat) and helped with the growth of fen species. They established that in order to grow sphagnum peat, good water management is needed. The surface water in the polder was not suitable so they used precipitation to flood the fields. They concluded that nutrient-rich soil is also able the inhabit sphagnum. But they stressed that good management (mowing) is important for sphagnum not to be outcompeted before a stable layer has developed.

3.4 BUILDING ON PEAT SOIL

Figure 3.4.1 Floating Homes by Public Domain Architecten. from "fermacell.nl" by Hielke Grootendorst, 2021 (https://www.fermacell.nl/nl/referenties/havenlofts-nassauhaven-in-rotterdam)

Figure 3.4.2 Amphibious houses. from "Amfibisch wonen: naar een volwassen woonvorm?" by Werncke Husslage, 2008 (https://woordsmit.nl/wp-content/uploads/2013/12/pdf2008_SW03-Amfibisch-wonen.pdf)

Figure 3.4.3 Stilt Houses from pixabay by mikezwei (https://pixabay.com/nl/photos/stilt-huis-visserij-huis-hut-340883/)

Figure 3.4.4 Tiny houses from pixabay by milivigerova (https://pixabay.com/photos/tiny-house-cabin-chalet-house-5984298/)

The Netherlands has been adapting to subsidence and soft soil for centuries. One way the Dutch did this is by regulating the ground level. However, this system appears to have limits, and that finiteness is already noticeable in some areas (Provincie Zuid-holland, 2022). Also the way of building on top of the peat layer is causing problems. Under the influence of weight, for example by an asphalt road or a sand pack, the ground is compressed 0.5 cm to 2 cm per year.

Floating Houses

An option to build on wet soils is by building floating houses. Floating houses are permanently fixed in a horizontal direction and can move vertically with the water level. The floating houses shown in figure 3.4.1 are secured on a concrete tank and are immersed in water to a depth of half a story (Rohmer, 2022). There must be at least 1 meter of water under the floating body of the house in order to guarantee good water quality (Deltares, 2008). When designing for a floating home it is important that the water level variation must be taken into account, so that the house is accessible at the time of inundation.

Amphibious Houses

An amphibious house is suited for a dry and wet situation. In addition to a traditional foundation, the amphibious house also has a floating body as a base. Also for this type it is important to keep the water level variation into account (Deltares, 2008).

Stilt houses

Pole houses are constructed on poles, raised from the ground. They may be created in a number of locations, although they are mostly built in tropical climate countries. Pole homes are often built over water, although they may also be made on sand or land surfaces. The most typical purpose for constructing a stilt house is to avoid floods or vermin infestation. The major reason to do this type of housing in (re)carbon city is that pole houses are deemed environmentally friendly since they can be constructed quickly and without causing considerable damage to the landscape. The raised home can make the rewetting of the peat soil possible.

Light weight materials

Subsidence is accelerated by city development. Buildings, roads, etc. compress the soil causing CO_2 to release from the peat soil. By building with light materials this effec can be reduced. An example of light building structures are tiny houses.

3.5 NATURE INCLUSIVE DESIGN

The ecosystem

Tansley (1935) was one of the first to define an ecosystem as a system that encompassed the entire complex of physical components that make up the biome's environment. He considered not only the biotic factors but also the abiotic factors of the system.
Ecosystems should not be looked at separately from each other. The ecosystem is an entity that is changing to its surroundings and is open to its outside (Ponge, 2015). Tansey indicates explicitly that there is no limit of size attributed to ecosystems. This is why we should also look at ecosystems on a global scale. Climate change and in particular the greenhouse effect, and the global ecosystem are intertwined (Ponge, 2015).

Ecosystem services

Ecosystems provide numerous services for mankind. When ecosystems fall, they can not provide humankind the services that are so needed for our survival, such as food, materials, energy, water, etc. Ecosystems are the basis of our world (Richard & Luo, 2004).
Ecosystems respond to biotic and abiotic factors. Climate change is influencing the world's ecosystems and they are highly affected by the change in temperature. On the other hand, ecosystems also affect the climate the other way around. For example, ecosystems play key roles in regulating the carbon cycle and the flow of energy. Because of this, they can play a role in the shaping of the weather, the climate, the atmospheric composition, and thus in climate change (Richard & Luo, 2004).

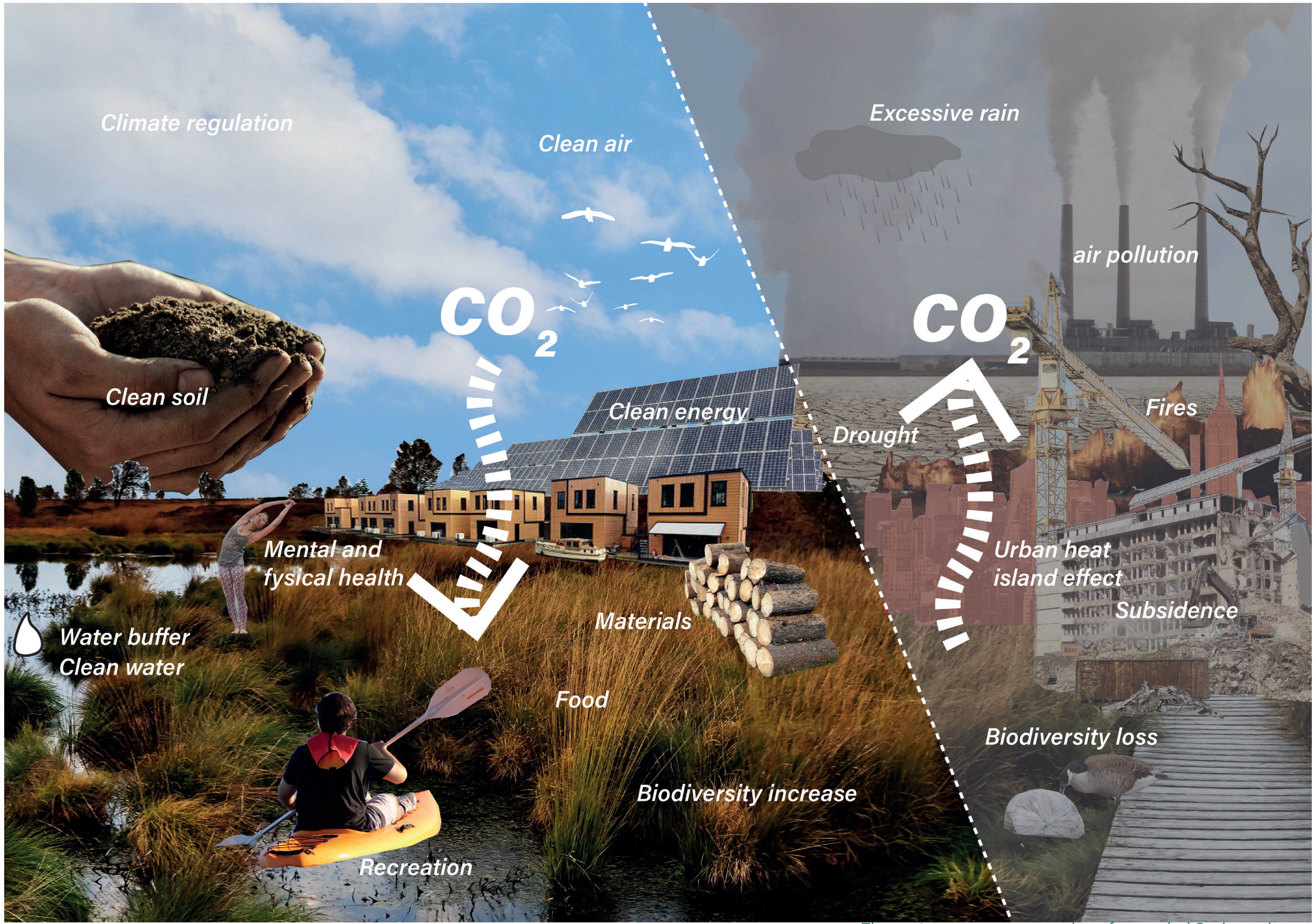


Figure 3.5 ecosystem services from a (re)Carbon city

The urban ecosystem

When thinking about nature, people think about rural landscapes. Just recently has the view on nature and city changed into a more blended perspective.
For people who live in the city, urban ecosystems such as the garden provide essential functions. The necessity to include ecological services into urban development is becoming increasingly apparent (Ahern et al, 2014).

Designing nature-inclusive cities

Nature-inclusive design is a way of looking at nature as an integral part of the design and the whole of functions and adaptations that are to be realized (Vink et al., 2020). Nature-inclusive design is important to create resilient cities. One way is to first establish connections with the biotic and the abiotic city we create. And secondly to take the demand made from the ecology of species and the functions of the city into account as interrelated

Stipphout (2020) in the 'eerste gids voor natuurinclusief ontwerpen' defines three steps to create a nature friendly design:

- Think of the city as a mountain landscape
- Define the urban biotopes
- Design with variation in sizes, scales, and porosity and design for different uses and maintenance.

H4. ANALYZING

CONTENT H4.

INTRODUCTION
In this chapter further context is analyzed to get a good understanding of the subjects needed to answer the main research question. This is done by looking into the historical landscape, the accessibility of the neighborhood, and the green areas surrounding Gouda. It answers the following sub-research questions: Which other environmental problems does the built environment face in Gouda? What is the existing polder system in Westergouwe? And which biotopes are found in Westergouwe? This all creates a basis on which the designing chapter is built on through extracting patterns from the knowlegde obtained in this chapter. These patterns can be found in the chapter Generalizing.

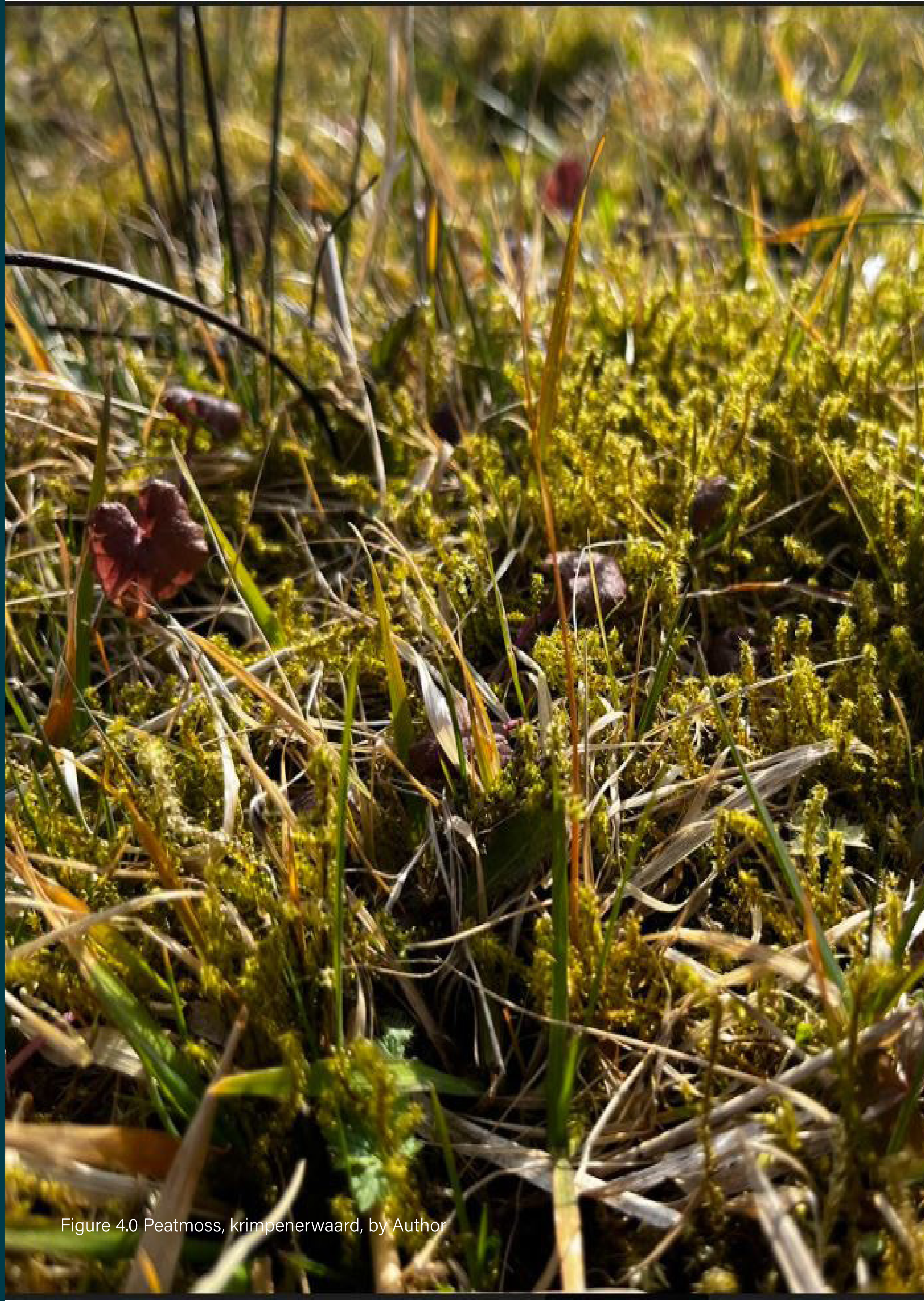


Figure 4.0 Peatmoss, krimpenerwaard, by Author

4.1 THE HISTORICAL LANDSCAPE

About a thousand years ago, the area consisted of an extensive peat wilderness. It was a swampy landscape that was difficult to access, in which swamp forests with mainly birch, alder, and willow grew (Knoester, 2010). The first inhabitants settled on the high sand and clay ridges along the Hollandse IJssel and the Rotte, which reclaimed some land with ditches and waterways from the high peat bogs to the Ijssel.

Around the 17th century, the peat had been subsiding so much that the then-existing drainage methods were not sufficient anymore and the first windmills were placed. Arable farming wasn't possible for some time now and the reclaimed areas in the surroundings were mainly pastureland.

Since the demand for peat increased in the 16th century, the pastures in the polder yielded more due to peat extraction, creating these big peat lakes. Later, the peat was also dredged below the water level, sometimes up to a few meters. This created large tracts of land that were underwater. A landscape was created such as can still be seen at the Reeuwijkse Plassen. The lakes were separated by higher roads along which people built their houses

In the 17th and 18th centuries, the need to drain grew and people started to drain the peat lakes in the surrounding areas. The peat lake in Zuidplas which was the biggest and deepest in South Holland was reclaimed relatively late in the 19th century because of economical means and size. But eventually was drained due to becoming a danger for Moordrecht.

By the 20th century, Gouda and Moordrecht were expanding to the Gouwe. And the Gouwe is made into canal. And in 2000 the industrial areas, near Broekhuizen and the industrial area near the A21 in the north of the area, are made. After this, the area remains relatively empty and is used as farm land.

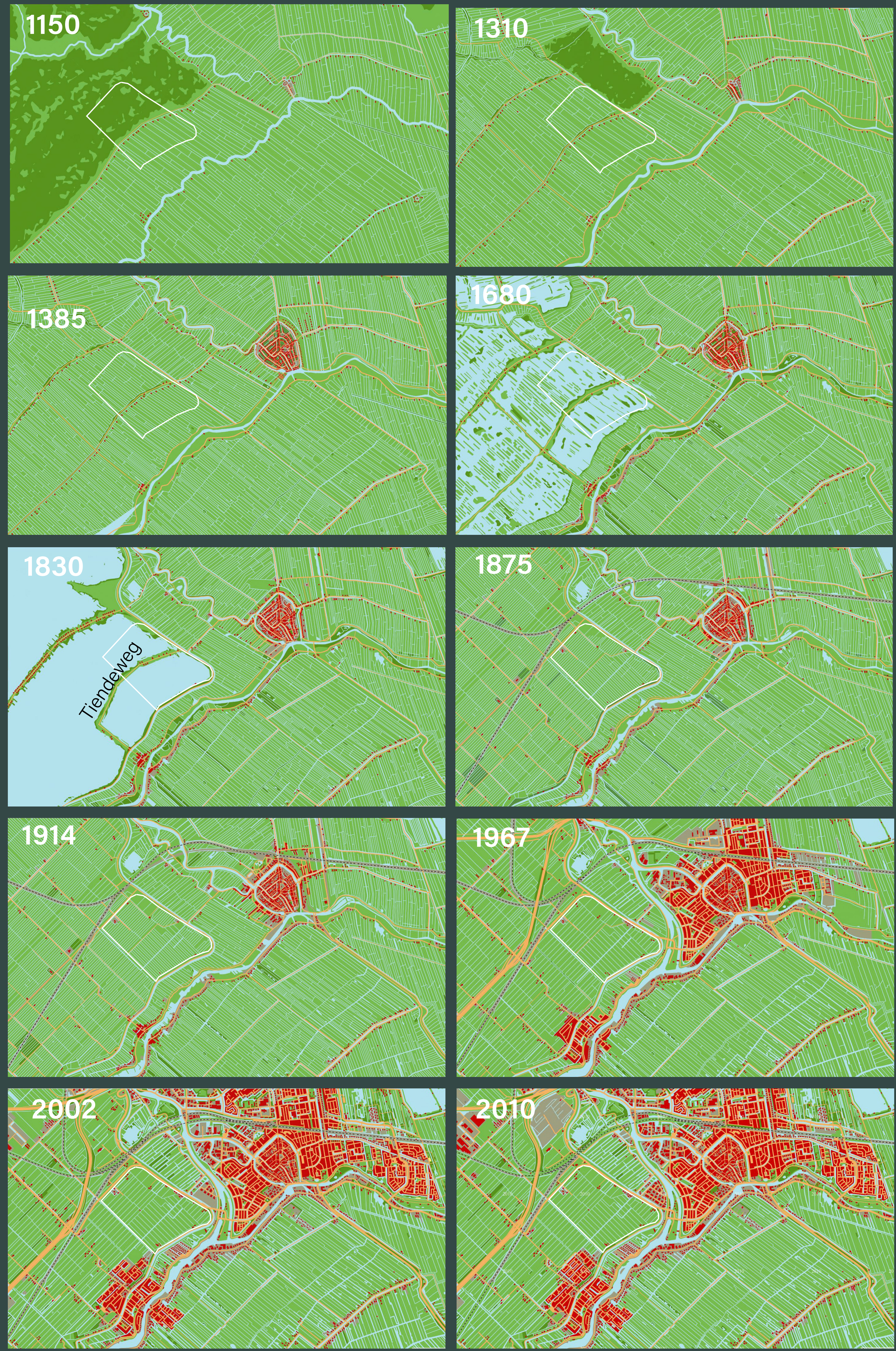


Figure 4.1 history of the landscape. from "mappinghistory.nl". 2021 (https://mappinghistory.nl/)

4.2 GOUDA FACING CLIMATE CHANGE

heat stress

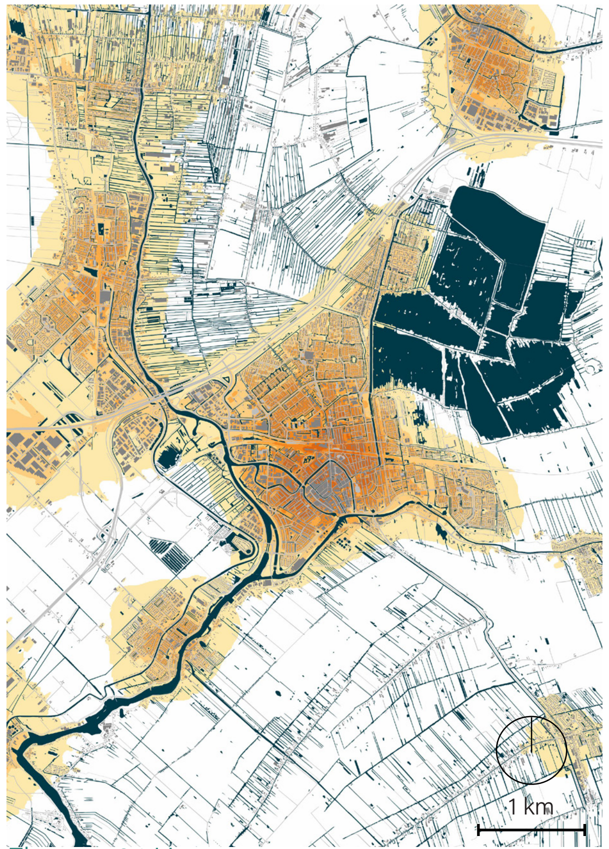


Figure 4.2.1 Heat stress. made by author with GIS data by RIVM. 2017 (https://nationalgeoregister.nl/geonetwork/srv/dut/catalog.search#/metadata/a87f5ca8-f354-4ff6-adc3-70f1bf6b78e3)

Legend
- < 0,32 graden
- 0,32 - 0,64 graden
- 0.64 - 0,95 graden
- 0,95 - 1,27 graden
- 1,27 - 1,59 graden
- 1,59 - 1,91 graden
- 1,91 - 2,22 graden
- > 2,22 graden

Heat stress is occurring mostly in the inner center of Gouda. The data of this figure which is measured in 2017 is showing the situation as Westergouwe was not been fully built. This is why in this image, almost no heat stress is shown. But the author predicts that when Westergouwe outside of the project area is fully built the heat stress will be rising. With the new design, the heat stress will be limited because of the permeable surfaces. Placing green structures in Westergouwe can provide cooling for the rest of the city as it is in a southwest orientation (see chapter Generalizing, pattern Cooling spots).

Water nuisance

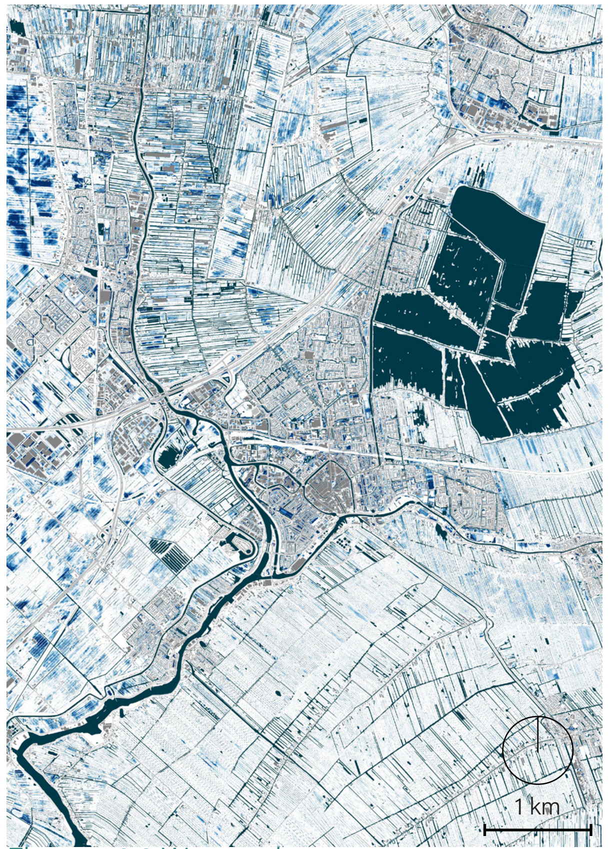


Figure 4.2.2 Water nuisance. by author made with GIS data Klimaat effect atlas Waterdiepte bij extreme neerslag landelijk, 2018 (https://www.klimaateffectatlas.nl/nl/)

Legend
- 0.30 m
- 0.00 m

With the changing climate, rainfall will be heavier and less often. It is important that designers take this into account. This means that water should not be transferred immediately to the sewer system and water buffers must be designed. Heavy rainfall in Westergouwe is now causing rain to collect in some places at a height of 0,20 m.

Risk of drought

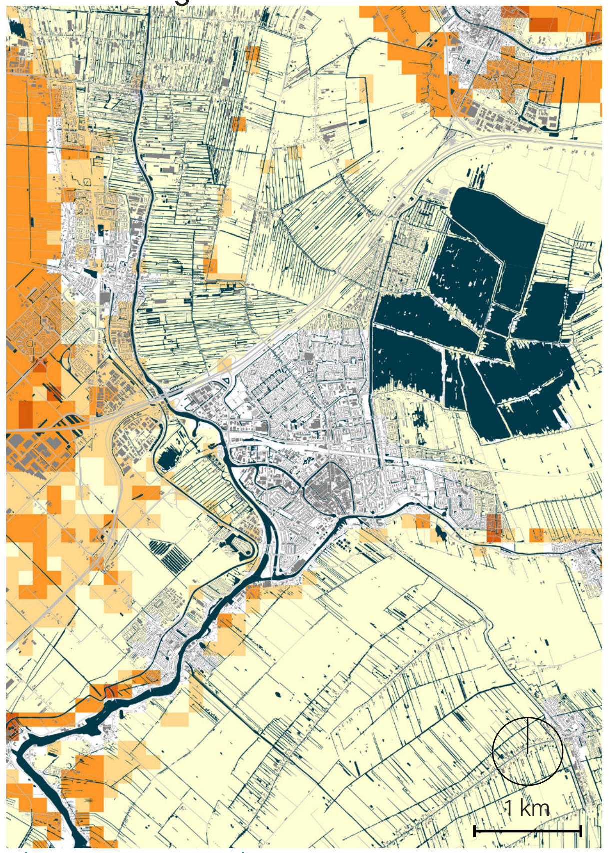


Figure 4.2.3 Drought. by author made with GIS data Klimaat effect atlas. Droogte Impact Risico droogtestress Huidig, 2019. (https://www.klimaateffectatlas.nl/nl/)

Legend
- <7 %
- 7-15 %
- 15-22 %
- 22-30 %
- >30 %

The map shows how much yield loss occurs. This loss is due to a shortage of water. The map is based on how many mm of water a continuous grass cover in a year is deficient during a continuous period of 10 days. Westergouwe itself does not have much yield loss but the area in the north of the area does.

Flooding Risk

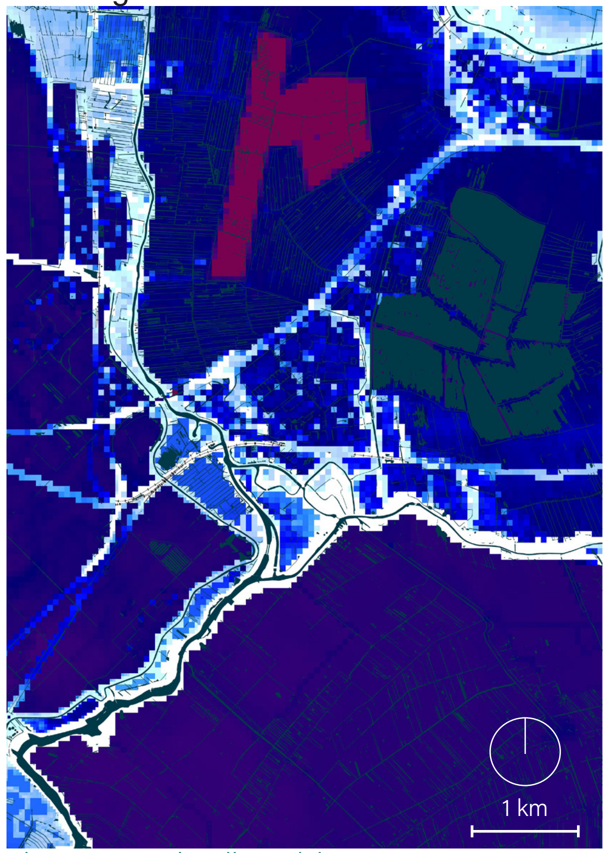


Figure 4.2.4 Flooding Risk. made by author made with GIS data Overstromingsbeeld doorbraak primaire waterkeringen. Provincie Zuid-Holland, 2022 (https://www.nationalgeoregister.nl/geonetwork/srv/api/records/FDB1AE60-802D-44D7-91EA-E15263570205)

Legend
- 5 m
- 0 m

This map shows the floodable area and maximum water depths that can occur after a primary flood defense breach. Primary flood defenses are dikes, dams, dunes, and structures that provide protection against water from the major rivers, large lakes, and the sea. If this would happen the water in Westergouwe would be about 3.35 meters deep.

ANALYZING

4.3 ACCESSIBILITY TO GREEN

4.3.1 existing green structure

This is the green-blue plan of Gouda. If you look at the surroundings of Gouda, you will see that many ecological structures have already been established around Gouda. Gouda itself draws its ecological structure along the major infrastructures and in the north of Gouda. Large green areas in Gouda are the Goudse Hout and other areas around the Reeuwijkse Plassen. Staatsbosbeheer also has a large area on the west side of Gouda that is included in the green-blue plan. What was striking was that there are no veins in the south of Gouda and the center.

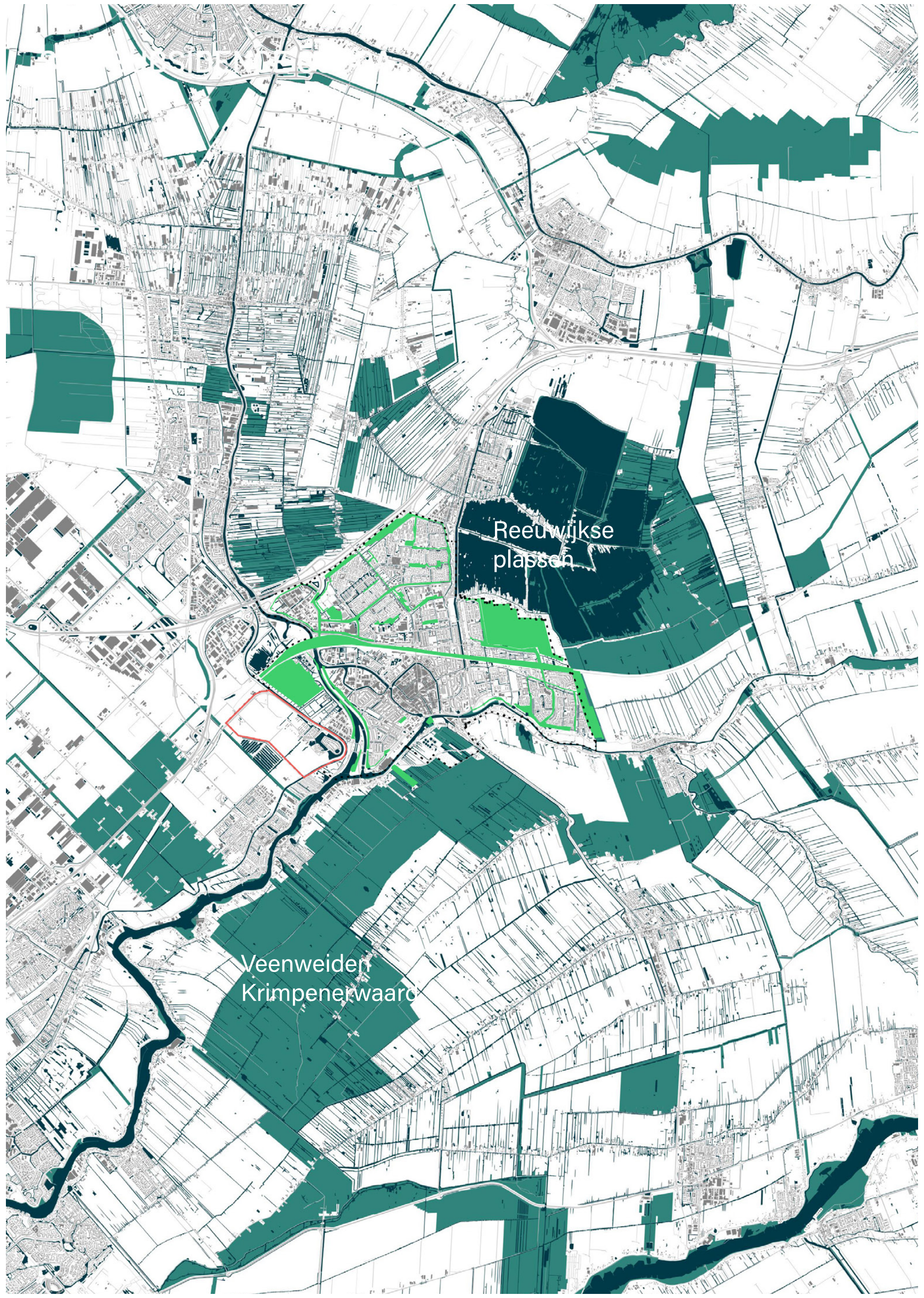


Figure 4.3.1 Existing greenstructure

Legend
- project location
- water
- planned ecological structure municipality of Gouda
- NNN structure
- roads
- buildings

4.3.2 The green network from Westergouwe

In the three maps on the right is the walking, cycling, and driving time for 5, 10, and 20 minutes shown. You can see that Westergouwe is not very well reachable for Gouda. However, for Moordrecht is the blue-green zone reachable in 20 min. So this area could provide green space for the residents in Moordrecht too.

By bike is the current green-blue zone well connected in 5 min for the whole future neighborhood. In 10 min the whole of Moordrecht and the west of Gouda can also reach it. However, the roads and water bodies in between gouda are barriers in visitors path. Also in 20 minutes in the Krimpenerwaard reachable. This means that visitors could travel from the Veenweiden to the future peat nature in Westergouwe

The accessibility by car is very well, by car Westergouwe could provide recreation for Rotterdam, Moordrecht, Zuidplas, Waddinxveen and other surrounding villages.

Legend
- 5 min
- 10 min
- 20 min
- NNN areas
- water
- roads

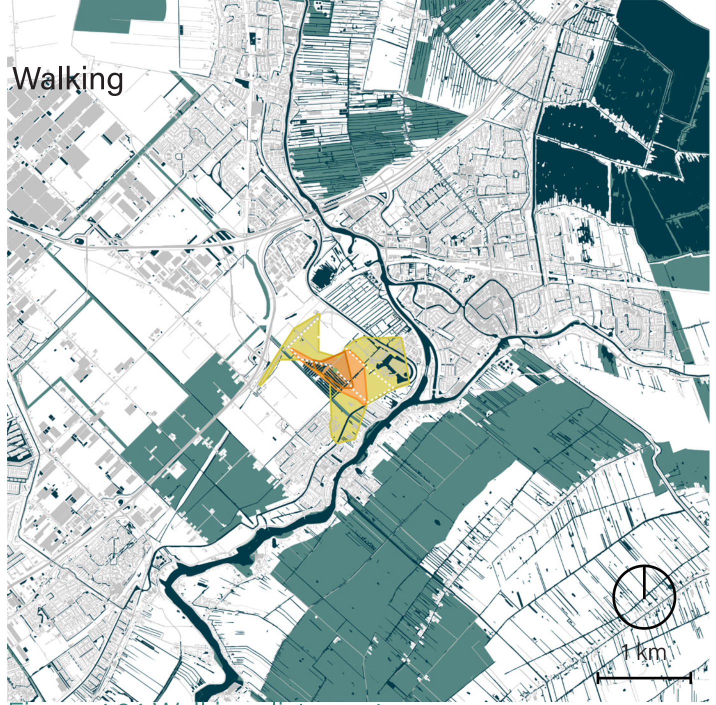


Figure 4.3.1 Walking distance to green

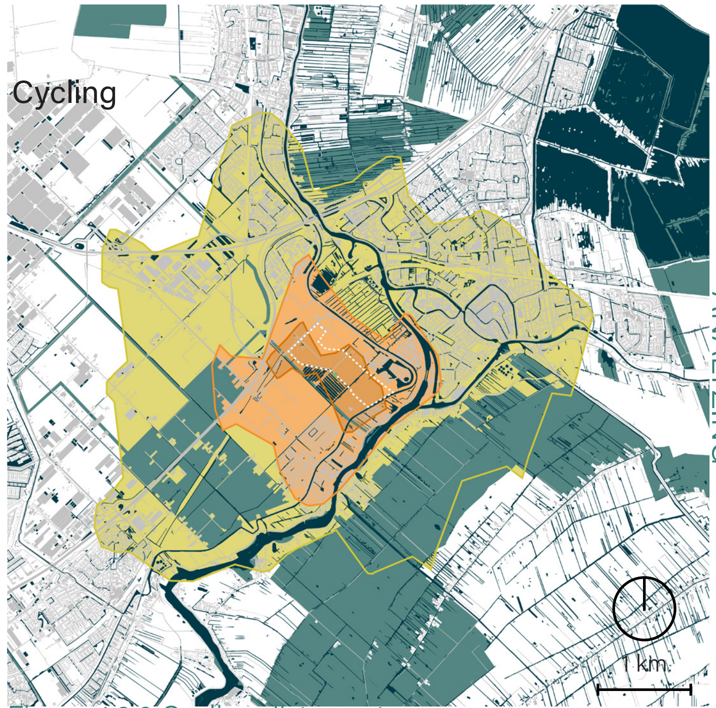


Figure 4.3.2 Cycling distance to green

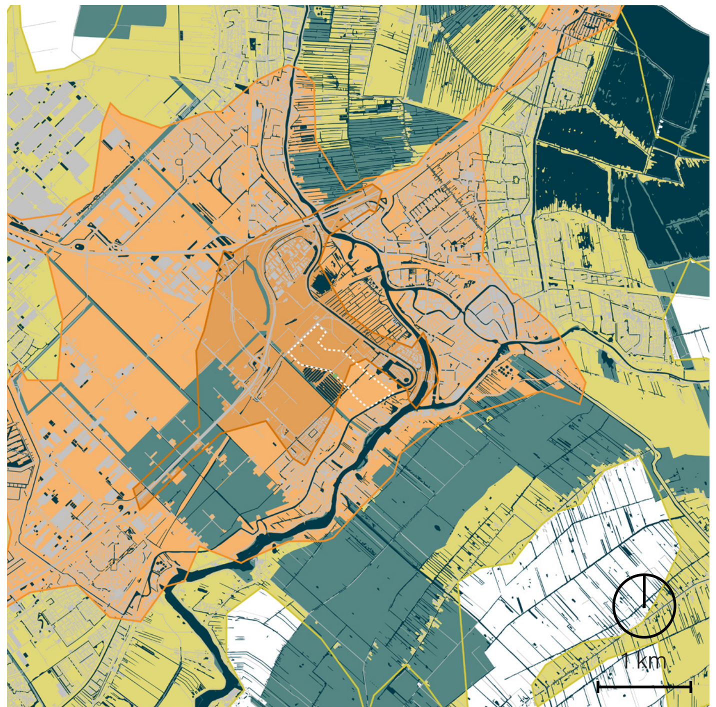


Figure 4.3. Driving distance to green

4.4 GOING TO WESTERGOUWE

<u>By train and bus</u>
By public transport, a visitor could take the Rotterdam-Gouda-Utrecht railway and stop at the Gouda stop. From the station, a bus continues their journey to the area.

<u>By foot</u>
Regional walking routes go through the area between the green-blue zone and Westergouwe, and along the Burgemeester van Dijkesingel. There are also routes along the ring dyke, the Hollandse IJssel, and the provincial road to Moordrecht. What is missing is a direct route from Moordrecht into Westergouwe, to strengthen the reachability to nature for Moordrecht.

<u>By car</u>
The Westergouwe area is located along the Rotterdam-Gouda-Utrecht line and nearby A20 and A12. It is located close to exit 18. To go to Gouda West you would have to drive past this neighborhood on the provincial road.

<u>By bike</u>
No regional cycling routes are going through Westergouwe. However, there are routes in the vicinity of Westergouwe, bicycle routes along the N207 and N456, a bicycle route along the Gouwe Canal, a bicycle route under the dike along the Hollandsche IJssel, and a bicycle route over the lock island via the district Short Akkeren to the city center.

<u>By boat</u>
Through boat is the area reachable by the Hollandse Ijssel, which means that visitors have to dock their boat at the harbor at Voorhaven. Sailing routes on the ring dyke now reach Moordrecht.

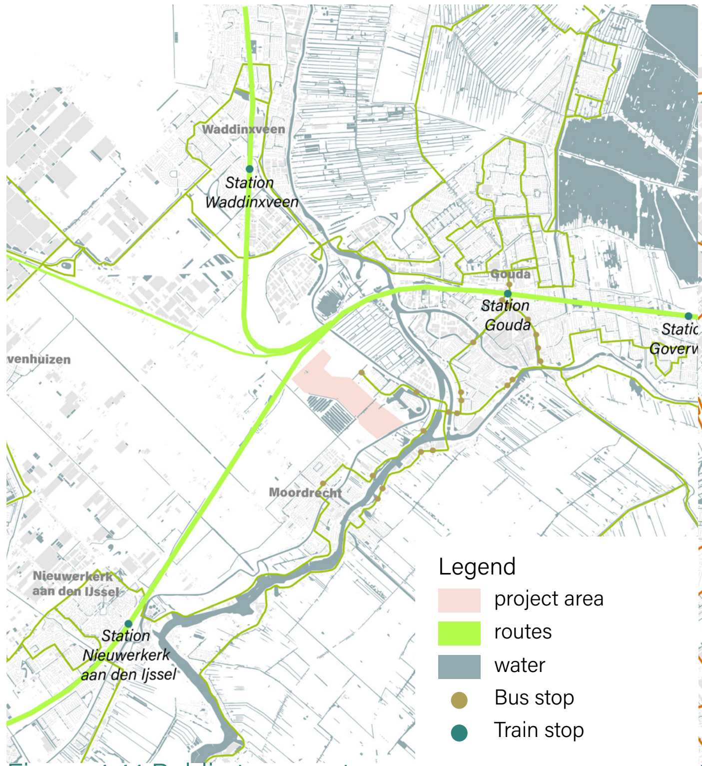
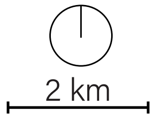


Figure 4.4.1 Public transport



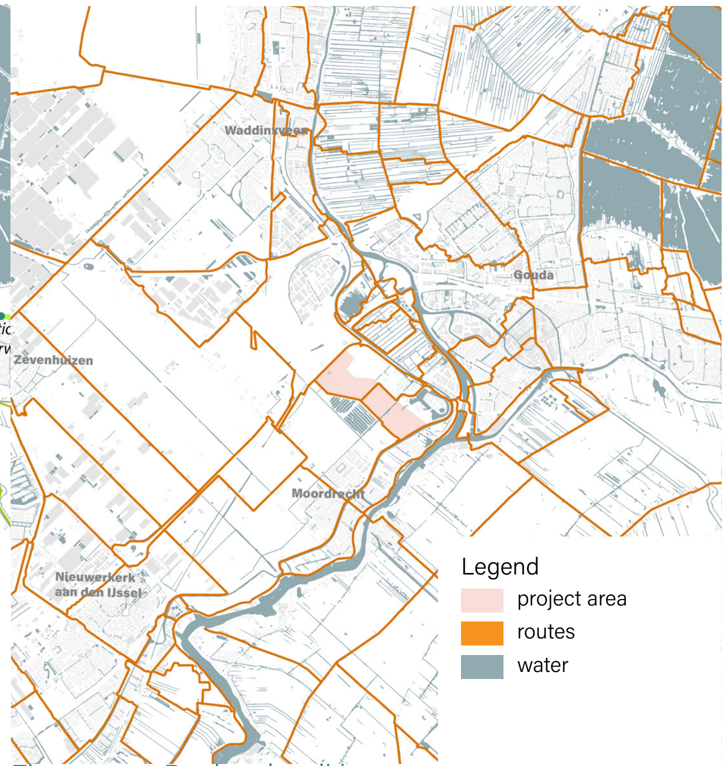


Figure 4.4.2 Regional walking routes. by author with GIS data from by stichting wandelnet, 2022 (https://geodata.nationaalgeoregister.nl/regionale-wandelnetwerken/wms?)

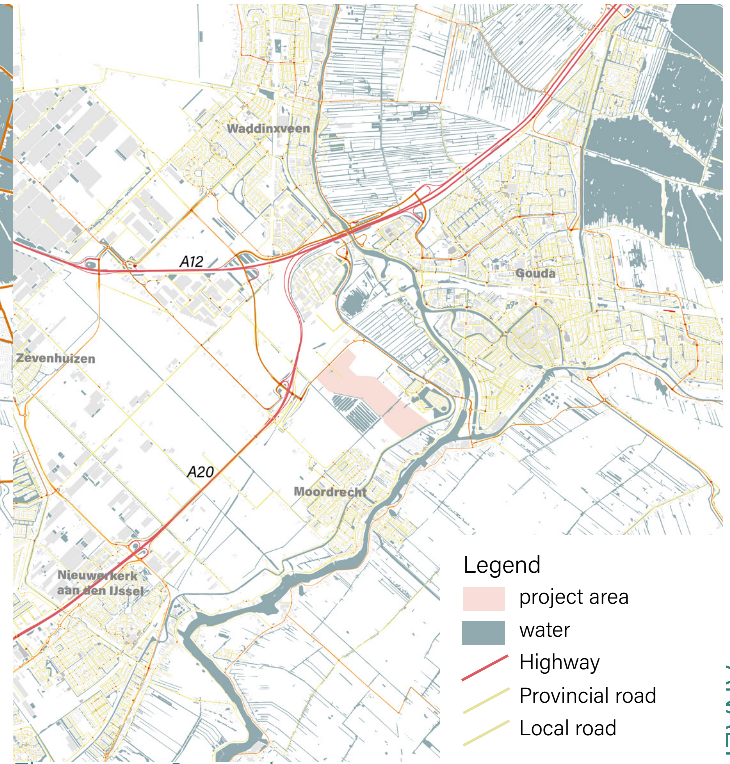


Figure 4.4.3 Car roads. by the author made with GIS data from Top 10.nl. top10nl_wegdeel., 2022, (https://app.pdok.nl/brt/top10nl/download-viewer/)

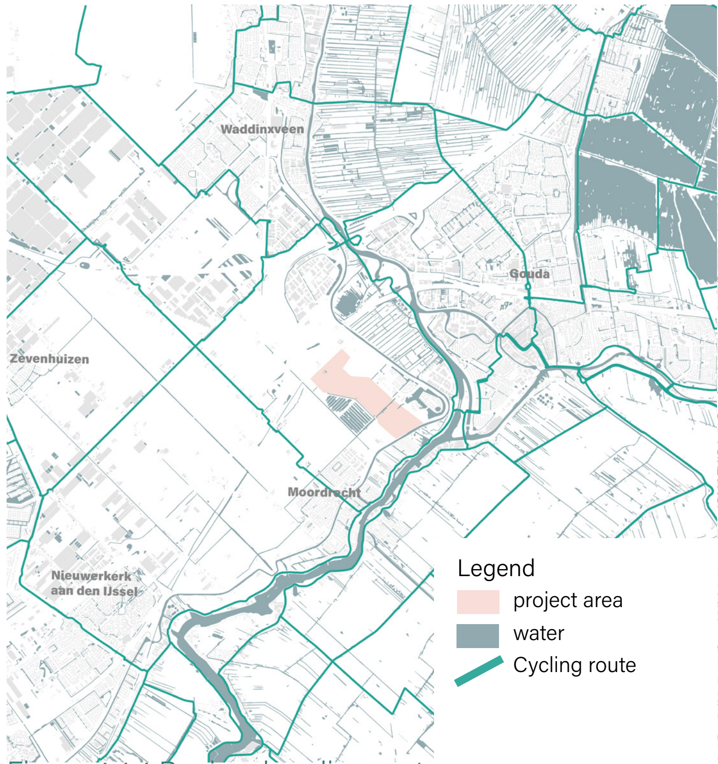


Figure 4.4.4 Regional cycling routes. by author with GIS data Regionale Fietsnetwerken. (https://geodata.nationaalgeoregister.nl/regionale-fietsnetwerken/wms)

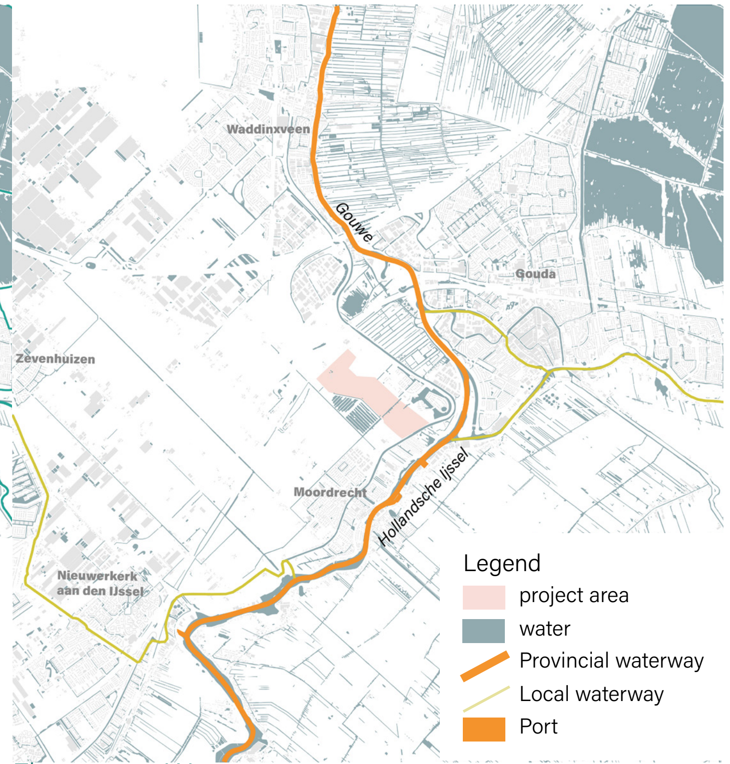


Figure 4.4.5 Waterways

ANALYZING

4.5 THE ZUIDPLASPOLDER

4.5.1 Poldersystem

In the 19th century, it was decided to drain the lake with steam pumping stations and the polder was put into use as a large-scale agricultural production landscape. The existing polder structure is more than 100 years old (Kuiper compagnions, 2021). The structure consists of a ring canal and ring dike, with a rational system of orthogonal 'tochten' and ditches in between. From the ring canal, the water is discharged into the Hollandse Ijssel, making use of the height differences in the polder (North-South direction). Along the ringdike you can find the five villages of Moordrecht, Nieuwerkerk aan den IJssel, Zevenhuizen, Moerkapelle and Waddinxveen and recently Westergouwe. Between the 'tochten' are open fields between a succession of ditches. This efficient land division produces a landscape with long lines and great openness.

Gemaal Zuidplas pumps the water to the Ringvaart. From there it flows to the Abraham Kroes Gemaal. This is a pumping station that drains both the polder and the Ringvaart. This discharges the water into the Hollandsche IJssel. Gemaal Zuidplas is responsible for the area above the dotted line with some intermediate works. For extreme situations or in an emergency we can open the 'north-south connection' Then the waterboard can either use the Zuidplas or the Bierhoogt pumping station, or we can use both to pump out the precipitation. Gemaal Bierhoogt pumps the water over the old creek ridge, a slight elevation, in the Zuidplaspolder.

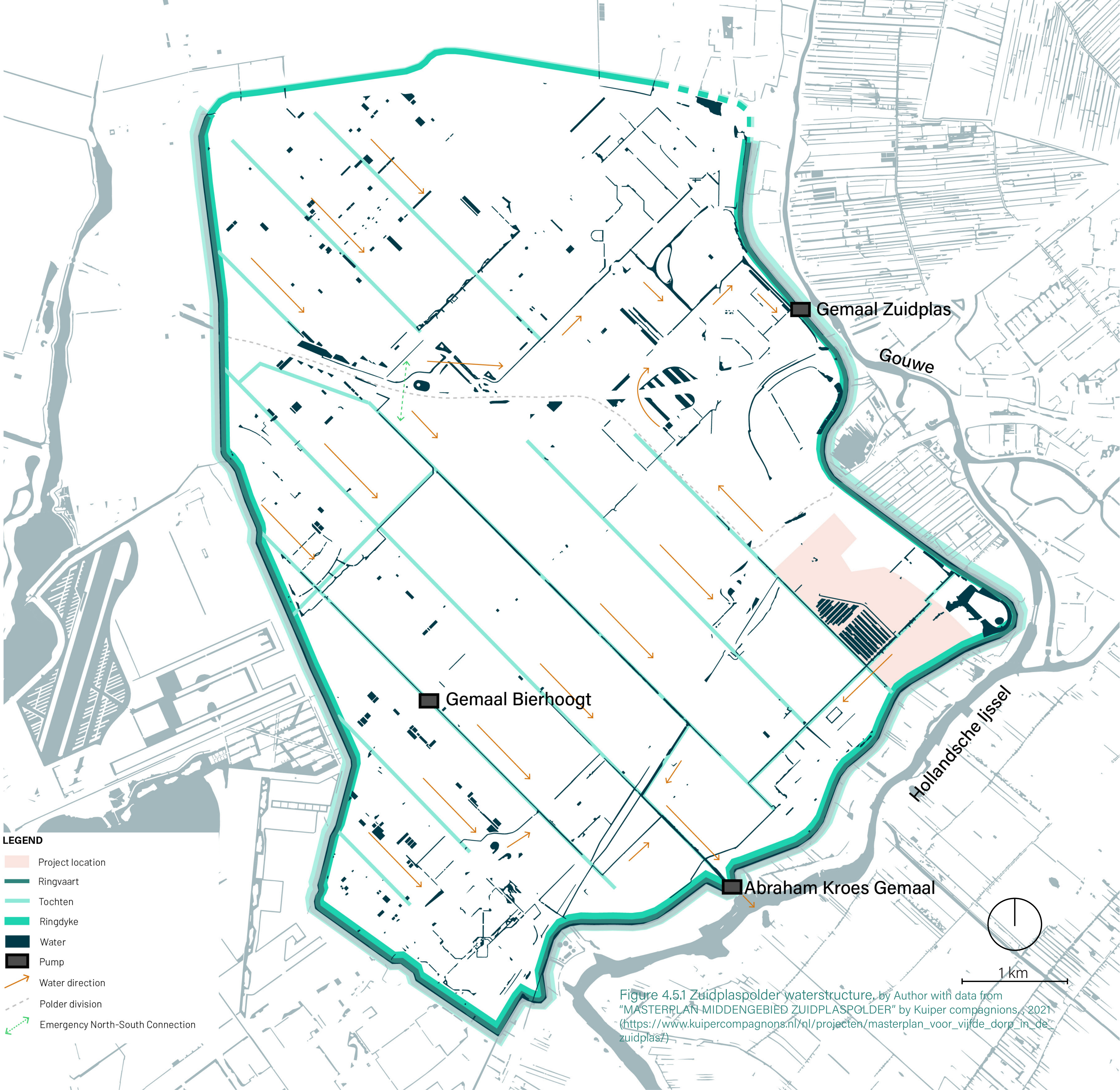


Figure 4.5.1 Zuidplaspolder waterstructure, by Author with data from "MASTERPLAN MIDDENGEBIED ZUIDPLASPOLDER" by Kuiper compagnions., 2021 (https://www.kuipercompagnons.nl/nl/projecten/masterplan_voor_vijfde_dorp_in_de_zuidplas/)

4.5.2 Threats in the Zuidplaspolder

To grow peat in Westergouwe, the water quality of the area should be good and the nutrient level should be nutrient-poor to neutral. In figure 4.5.2 is the functional use of the Zuidplaspolder shown. Functions like the greenhouses and business parks in the area can pollute the water needed for the area. However, the biggest threats to the water quality are agricultural functions. Farmers use fertilizers that seep into the polder water. This causes eutrophication in the ditches and causes biodiversity loss. As the water flow of Westergouwe is flowing from the area and not into the area, most dangers are avoided. But it would be unwise to use unfiltered polder water for the design. It is important to keep an eye on the bordering business park Het Ambacht in Moordrecht in this regard although the main flow of water is moving away from the area

Legend
- buildings
- roads
- water
- bussinessparks
- harbour
- greenhouses
- waste management
- arable farming
- grasslands
- orchard
- tree farm

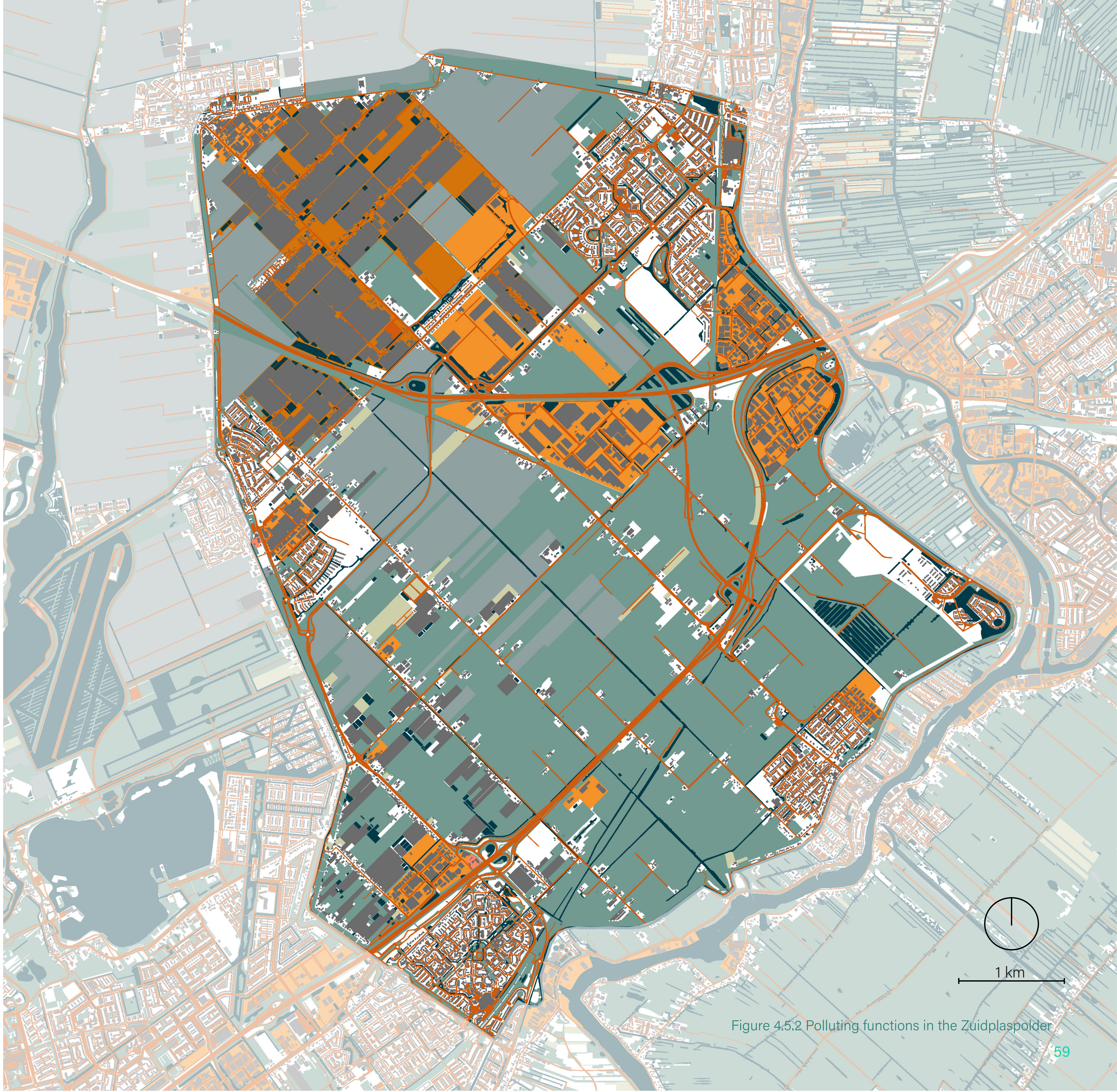


Figure 4.5.2 Polluting functions in the Zuidplaspolder

4.6 THE BIOTOPES OF WESTERGOUWE

The project location currently almost entirely consists of old agricultural grasslands. In the south, some reedlands have developed, that were dried out when the author visited the site. Recently, new wetlands are created in the destined green-blue zone to improve biodiversity in the area. However, nature has not developed fully here. It is still grasslands with few swamp vegetation around the water bodies. Some bird species have established themselves here. The traditional neighborhood of Westergouwe also houses biotopes, which include the buildings and the gardens. here. The neighborhood of phases 1 and 2 are biotopes too, which includes the buildings and the gardens.

Figure 4.6 Existing biotopes in Westergouwe

4.7 CONCLUSION

<u>Which other environmental problems does the built environment face in Gouda?</u>
The author predicts that when Westergouwe phases 1 and 2 are fully built the heat stress will be increasing. However, building a nature-inclusive, permeable new neighborhood alongside it, can provide cooling for the rest of the city. Other environmental problems that Gouda is facing are water nuisance and flooding risk. This is why it is important to create a big water buffer for water storage in drought and storage for excessive precipitation.

<u>How could Westergouwe provide green for Gouda and surroundings?</u>
Gouda has many ecological structures but lacks green structures in the south and the city center. This way, Westergouwe could provide green for these areas. However because of big barriers between gouda and Westergouwe, it could be more suited to provide green for Moordrecht.
In 20 minutes reach cyclists could travel from Westergouwe to de Veenweiden in Krimpenerwaard.

<u>How accessible is Westergouwe itself?</u>
The area is quite well connected via public transport and car. The area is also connected via regional walking routes, but by bike, no regional routes are going through the area. By adding routes through the area Westergouwe can become a more integral part of the urban fabric.

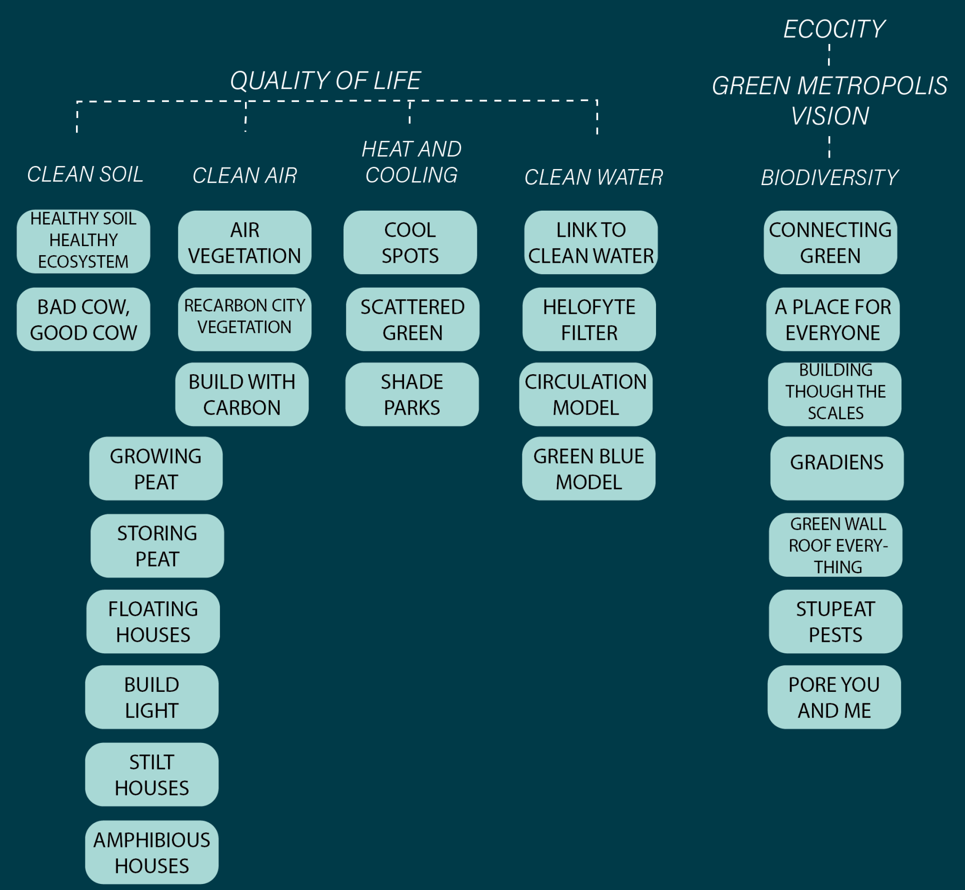
<u>What is the existing polder system in Westergouwe?</u>
To grow peat in Westergouwe, the water quality of the area should be good and nutrient-poor to neutral. The Zuidplaspolder houses too many polluting functions to rely on the polder water, so it would be advised to use rainwater or filtered water.

<u>Which biotopes are found in westergouwe?</u>
The project location is right now mostly consisting of old agricultural grasslands and some wetlands where nature still needs to rewild.

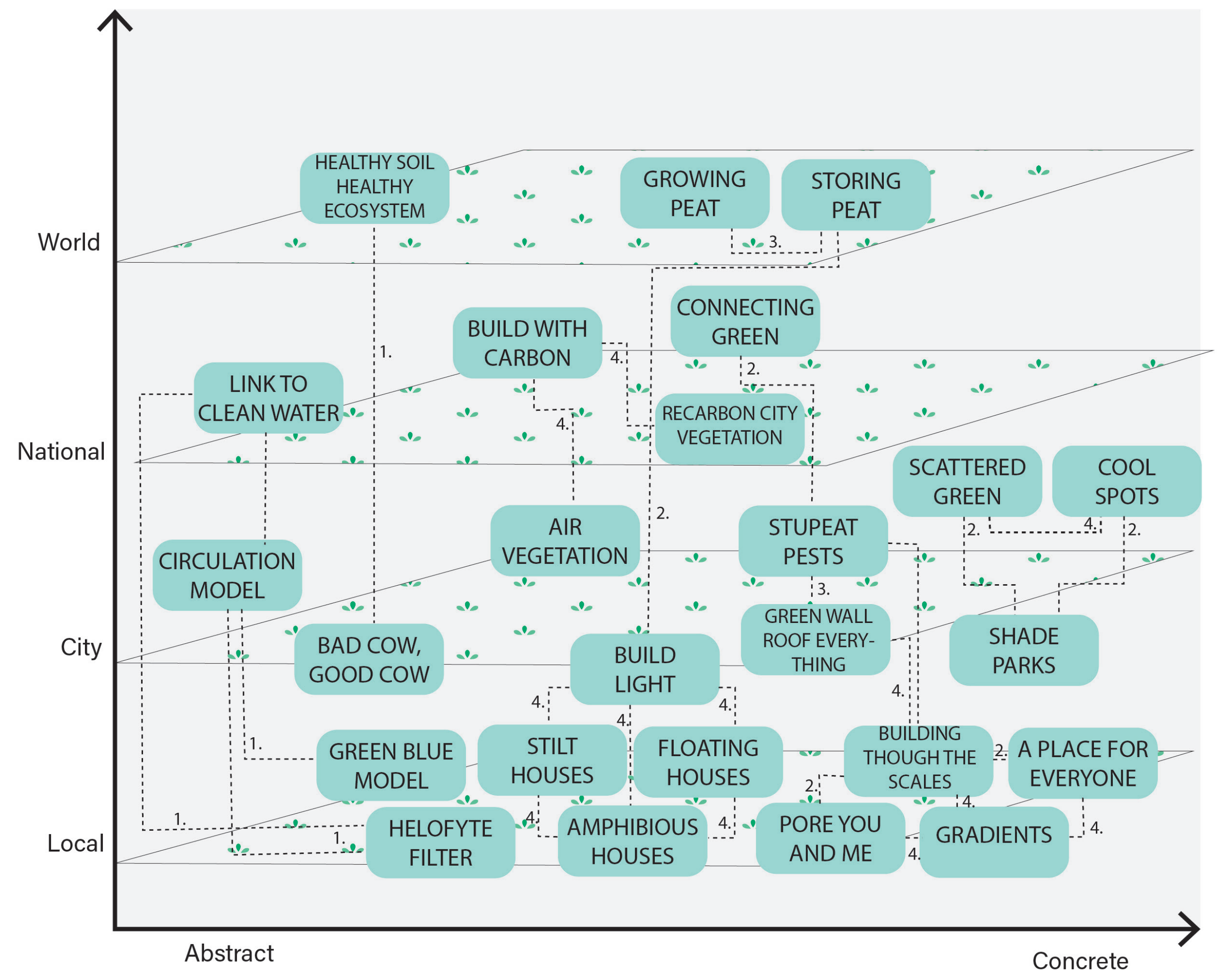
H5. GENERALIZING

CONTENT H5

The following chapter is consisting of a pattern language that is collected while making the (re)carbon city project. The pattern language is constructed throughout all the project stages and is used in the design as design principles. The pattern language is a generalization made to help future designers with their own specific designs. The patterns can be categorized into the subjects listed below. In this chapter, you can find a pattern field diagram, showing the connections between the patterns and a list of individual patterns.



5.1 PATTERN FIELD



1. One pattern contains/generalizes other small scale patterns
2. Two Patterns are complementary and one need the other for completeness
3. Two patterns solve different problems that overlap and coexist on the same level
4. Two patterns soulve the same problem in alternative, equally valid ways
5. Distinct patterns share a similar structure, thus implying a higher level connection

Figure 5.1 Pattern Field (re)Carbon City

PATTERNS

GENERALIZING

GROWING PEAT

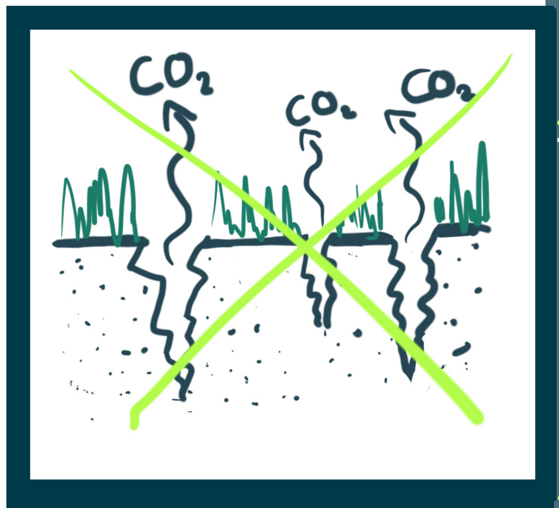
General, especially zone 2

Hypothesis — **Growing peat can subtract carbon from the atmosphere.**

Theoretical Back-up — Peat soil can capture CO_2 out of the air by photosynthesis. Peatlands have a high humidity level which creates anoxic conditions that slow down the decomposition processes of organic matter. Peat accumulates carbon when the rate of organic matter decomposition is lower than the amount of primary production in the ecosystem (Harenda, 2018).

Practical implication — By rewetting, peat soil can grow. Rewetting can be done by the construction of small retention devices to stop the wateroutflow with a ditch drainage system (Harenda, 2018). Less pumping in the polder to raise water levels to the surface to maintain anaerobic soil conditions (Tanneberger et al., 2020).

STORING PEAT



General, especially zone 1

Hypothesis — **Peat is preserved by creating the right conditions.**

Theoretical Back-up — Several variables influence how long carbon stays in the soil once it is absorbed as organic matter.

Practical implication — Through the microbial activity, good soil aggregation reduces the oxidation of carbon in the soil to CO_2 (Amado et al., 2006). Adding organic matter to the soil through residues slows the rate of carbon loss by lowering soil temperature (Zomer et al., 2017).

HEALTHY SOIL , HEALTHY ECOSYSTEM

General, zone 4

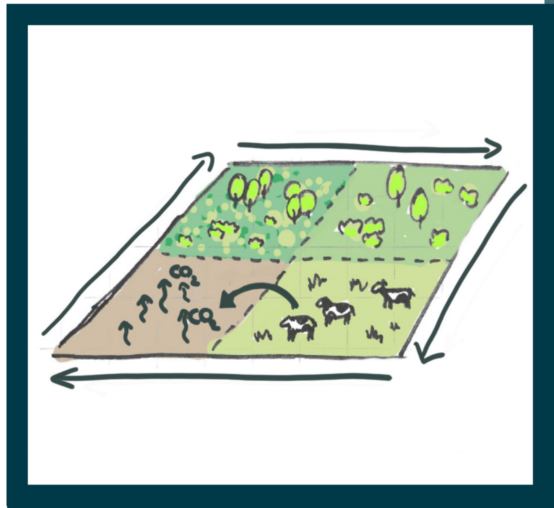
Hypothesis — **A healthy soil means less carbon dioxide in the air.**

Theoretical Back-up — Carbon dioxide is used by plants that filter CO_2 out of the air, which transfer this to the roots. These roots contain bacteria that use/store the carbon. In this way, soil has a unique ability to store carbon dioxide in the ground. Storing carbon dioxide in the soil means less global warming.

Practical implication — To create healthy soil, we should take care of the microbes in the soil. For example, farmers should avoid tillage/plowing, avoid the use of toxic chemicals, and the use of artificial fertilizer. Also, open bare land should be changed into overgrown land to keep/store CO_2.

GENERALIZING

BAD COW, GOOD COW



General, zone 4

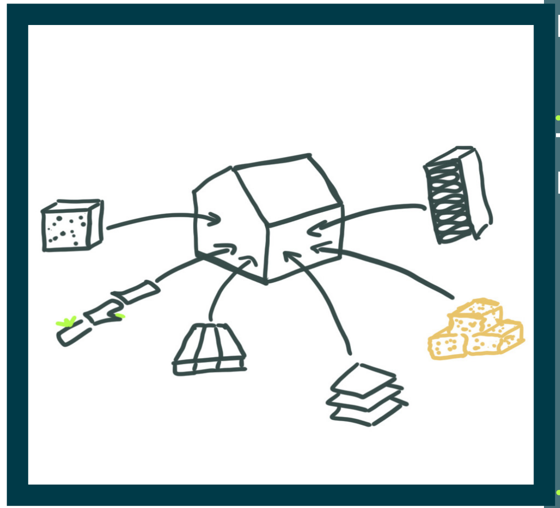
Hypothesis — **cattle regenerate soil**

Theoretical Back-up — Cattle are quite controversial today when it comes to environmental goals, but cattle could also be used in a beneficial way. Carbon dioxide is used by plants that filter CO_2 out of the air, which transfer this to the roots. These roots contain bacteria that use/store this. The cattle eat the plants and it end up in the feces. This way the feces contain these microbes.

Practical implication — The implementation of unconventional forms of agriculture can regenerate the soil. For example, by managed grazing which moves the cattle regularly. Microbes are inserted in the land, and the land is given the time to regenerate. Also, agroforestry in combination with cattle (silvopasture) is a form that could be implemented.

PATTERNS

BUILD WITH CARBON



General

Hypothesis — **Construction materials can store carbon in the built environment.**

Theoretical Back-up — Building constructions, envelopes, and insulation are the most typical uses for carbon-storing materials (Pomponi et al., 2020).

Practical implication — Some materials that can store carbon are: (Pomponi et al., 2020)

- Timber: as a structural material
- Bamboo is a fast-growing bio-based structural material
- insulation materials such as blown cellulose, cork, and hempcrete

STILT HOUSES

zone 3 and 4

Hypothesis — **Stilt houses are a solution to preserve peat while building.**

Theoretical Back-up — Pole houses are constructed on poles, raised from the ground. They may be created in a number of locations, although they are mostly built in tropical climate countries. Pole homes are often built over water, although they may also be made on sand or land surfaces. The most typical purpose for constructing a stilt house is to avoid floods or vermin infestation.

Practical implication — The houses in (re)carbon city Houses can be built on stilts. The raised home can make the rewetting of the peat soil possible and additionally they do not put a lot of pressure on the ground beneath.

BUILDING LIGHT

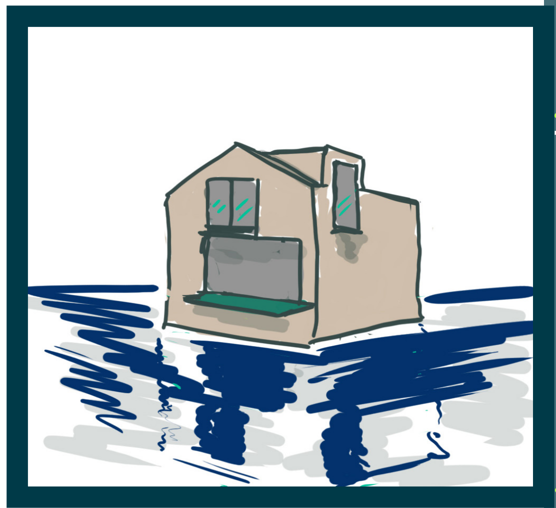
General

Hypothesis — **Light building materials reduce pressure on peat soil.**

Theoretical Back-up — Heavy materials used in the built environment put pressure on the peat soil, causing subsidence and thus the release of carbon into the atmosphere. Buildings, roads, etc. compress the soil causing CO_2 to release from the peat soil.

Practical implication — (re) Carbon city can use light building materials to reduce subsidence. An example of light building structures are tiny houses.

FLOATING HOUSES



zone 1

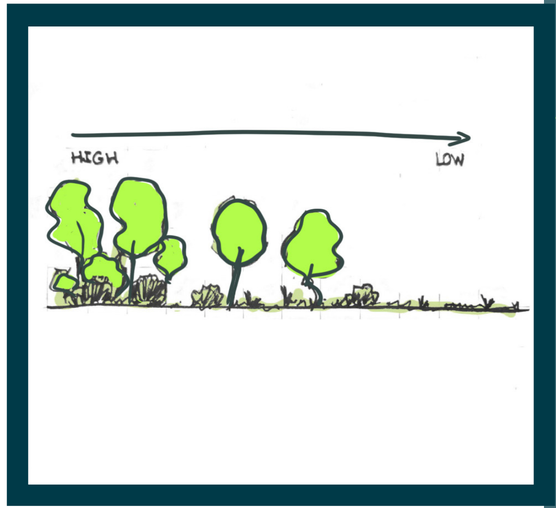
Hypothesis — **Floating houses are a solution to preserving peat areas.**

Theoretical Back-up — Building floating houses accommodate wet soils and can move with the growing water level. Also because they float on top of the water, they do not put pressure on the peat itself.

Practical implication — Floating houses are permanently fixed in a horizontal direction and can move vertically with the water level. Floating houses float on a ponton and need at least a meter of water underneath them in order to maintain water quality (Deltares, 2008). When designing a floating home it is important to design the public space around the house to also respond to the fluctuation of the water.

PATTERNS

AIR VEGETATION



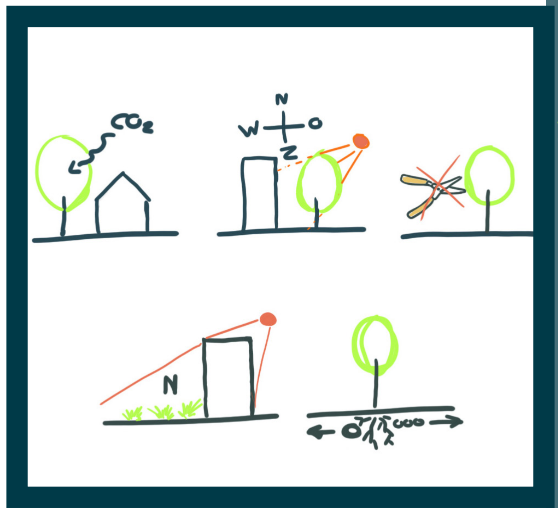
General

Hypothesis **Vegetation in urban areas optimizes air quality.**

Theoretical Back-up Vegetation types characterized by a more complex structure in combination with the absence of management (pruning, irrigation and fertilization) have a higher capacity to provide air purification services. By contrast, lawns, which have a less complex structure and are highly managed, were associated to a lower capacity to provide air purification. (Viera, 2018)

Practical implication By designing for complex green spaces in urban areas and managing these at high spatial resolutions ecosystem services like improving air quality are optimized (Viera, 2018). This could be done by making green spaces have a complex composition, with a lot of circumferences, and a lot of layers like trees, shrubs, and herbaceous layers.

(RE)CARBON CITY VEGETATION



General

Hypothesis **Urban vegetation can capture CO_2 out of the air.**

Theoretical Back-up Strategies to improve the carbon intake of urban vegetation are (Korean Institute of Landscape Architecture, 1998):

Practical implication

- planting species with high photosynthetic capacity
- Sunlight-guaranteed road and building layout for street trees
- planting of shade-tolerant species in the north of buildings
- Relocation of utility lines
- minimised pruning

CONNECTING GREEN

General

Hypothesis **Connecting urban green spaces improves urban biodiversity.**

Theoretical Back-up In urban areas, green spaces are frequently dispersed across the landscape. These green places provide biota with necessities like food, refuge, and compatible partners. As a result, accessibility to these natural places is critical for biota survival and long-term population viability (Kirk et al, 2018).

Practical implication The connection between green spaces could be made with green corridors, or with disconnected features such as vegetation along roadways, or isolated trees, a patch of flowering shrubs, or fallen logs, which may form 'stepping stones.'

BUILDING THROUGH THE SCALES

General

Hypothesis **Using variation in shapes and sizes of buildings stimulates biodiversity in the city.**

Theoretical Back-up Stipphout (2020) defines the importance of a variation in sizes and scales in her 'eerste gids voor natuurinclusief ontwerpen.' And she calls it in one of her three steps to creating a nature-inclusive design.

Practical implication Every species has its own preferences, by creating a variated landscape of shapes and sizes, a lot of different species will find the area attractive. Which in turn is improving biodiversity.

PATTERNS

PORE YOU AND ME

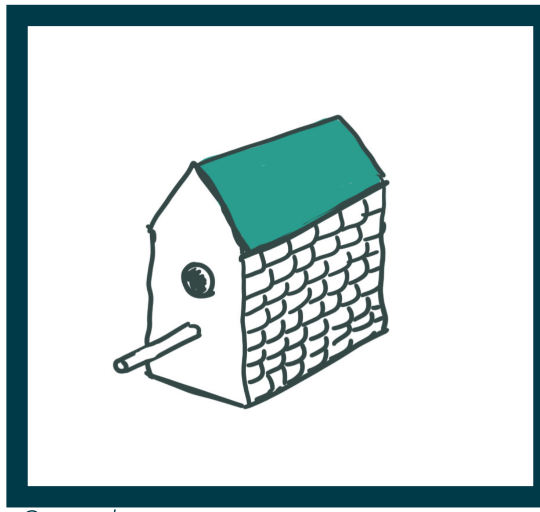
General

Hypothesis **The use of porous building materials stimulates biodiversity in the city.**

Theoretical Back-up Stipphout (2020) in the 'eerste gids voor natuurinclusief ontwerpen' defines three steps to create a nature friendly design. In one of them, she mentions the use of porous materials. More porosity means more chance for biota to establish themselves in the built environment.

Practical implication You can think about cracks in walls, a stone with holes for the pavement, or for example climbing opportunities can be created on walls for plants.

A PLACE FOR EVERYONE



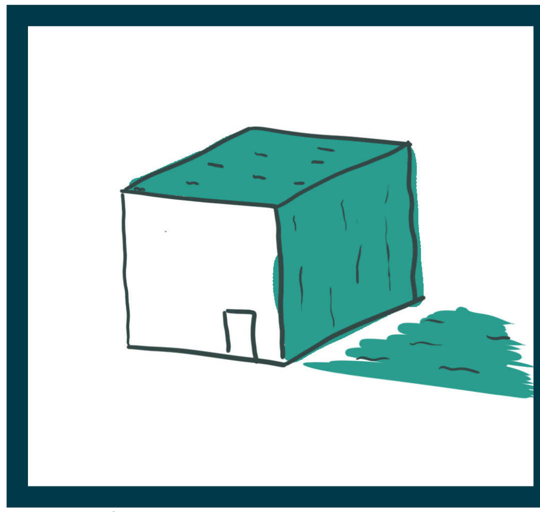
General

Hypothesis **Nesting places in the built environment improve biodiversity in the city.**

Theoretical Back-up A way to attract animals to live in the city is to include habitats for them in the city. Biota can provide us with numerous ecoservices that will improve our quality of life (bouwnatuurinclusief.nl, 2022)

Practical implication Species you can target are for example birds, bats, and other animals in your buildings. This can be done very simply, for example by leaving a butt joint open. But there are also standard solutions such as nesting stones on the market.

GREEN WALL, ROOF, EVERYTHING



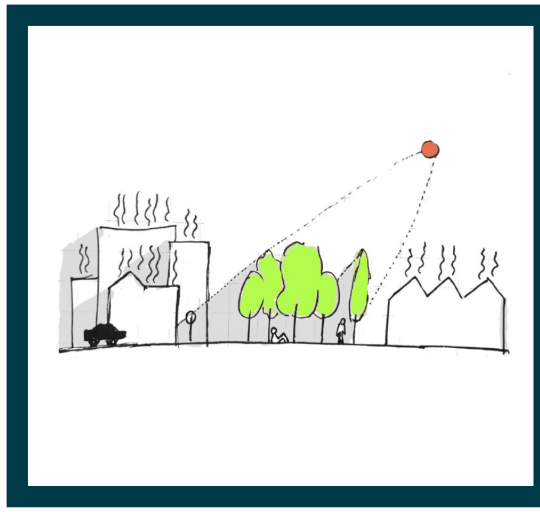
General

Hypothesis **Green walls or roofs improve the built environment.**

Theoretical Back-up Green roofs and walls provide a lot of benefits for the built environment. (bouwnatuurinclusief.nl, 2022). It improves biodiversity, saves energy and costs, provides health benefits, improves safety and social cohesion, provides air purification qualities, reduces heat stress, and can provide water buffering and retention.

Practical implication Use of green wall or roof. The use of plants that attract butterflies, or provide shelter in the vegetation for birds can further improve biodiversity

SHADE PARKS



General

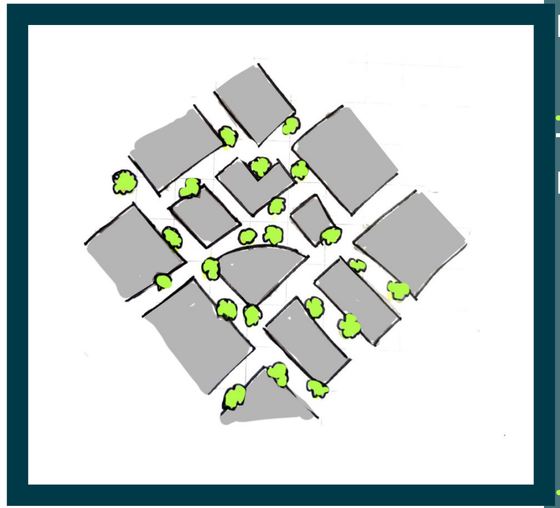
Hypothesis **Parks create urban microclimates that facilitate cooling for urban residents.**

Theoretical Back-up trees can catch a lot of sunlight and can provide shade for the citizen. buildings can do this too, depending on the orientation of the street and the street profile. However, in order to offer cool spaces, recreation and help biodiversity, parks are more suited than scattered green (Gehrels et al, 2016).

Practical implication Adding trees with large crowns can help with solar radiation. especially deciduous trees are helpful as they provide shade in summer and do not block sunlight in the winter.

PATTERNS

SCATTERED GREEN



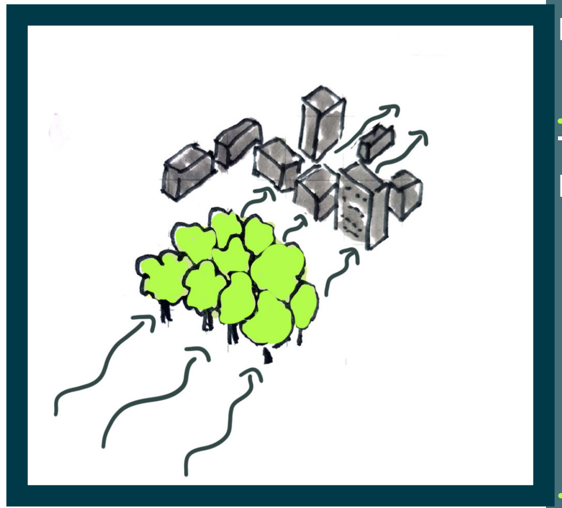
General

Hypothesis — **Planting trees along the side of the street all over the city improve local human thermal comfort on hot days.**

Theoretical Back-up — Trees reduce the mean radiant temperature in particulair. The evaporation of the trees helps prevent a rise in the air temperature. The effect will be mainly noticable at the city or neighbourhood scale. (Gehrels et al, 2016) In order to improve the urban environment, spreading out green elements of the city is the most effective.

Practical implication — By the planting of trees all along the streets, the thermal comfort in the city is improved. The planting of the streets should be done consciously. For example, in streets with a lot of traffic, too many trees can create a negative effect, It can create a tunnel in which exhaust fumes linger in the street.

COOL SPOTS



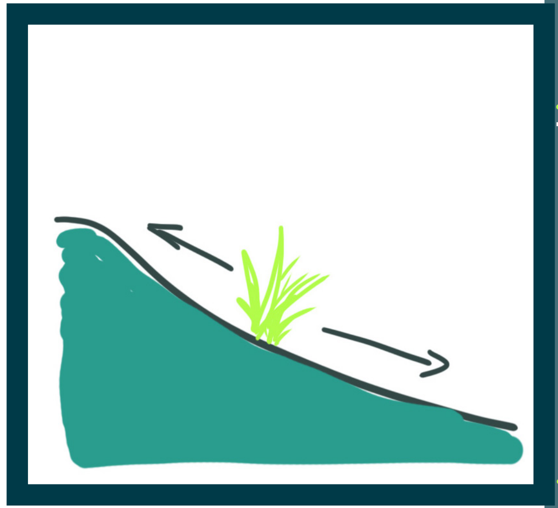
General

Hypothesis — **The placing of parks or places with a high density of green strategically cools the city.**

Theoretical Back-up — Parks or high-density green spaces (cool spots) with more than 90% of vegetation have cooling abilities for the city (Gehrels et al, 2016). The green space cools the air that is blowing through and around the spot.

Practical implication — By placing this windward towards the city, the spots have the most effect (Gehrels et al, 2016). As the dominant wind orientation of the Netherlands is south-west cool spots could be placed on the south-west side of cities.

GRADIENTS



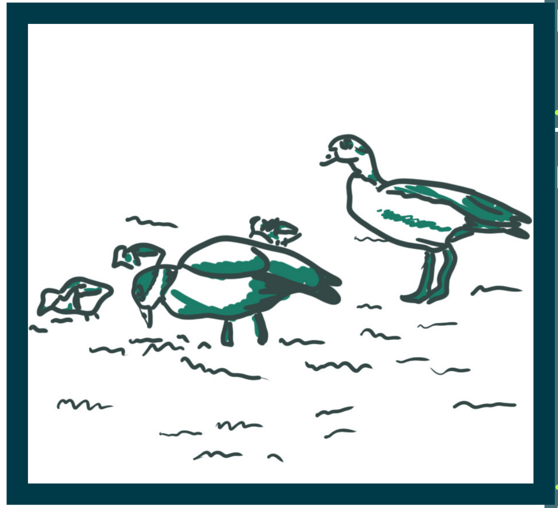
General

Hypothesis — **Creating gradients provides resilient ecosystems.**

Theoretical Back-up — Forming gradients creates a range of conditions where species can find their specific place on their liking on that gradient. And thus will attract a range of species. More diversity of species means a more resilient ecosystem. When the circumstances change. like changing water levels, the species can move to the new desired place on the gradient (Vink et al., 2020).

Practical implication — Make gently descending slopes in order to provide enough space. A variant of this are nature-friendly borders along the water line.

STUPEAT PESTS



General

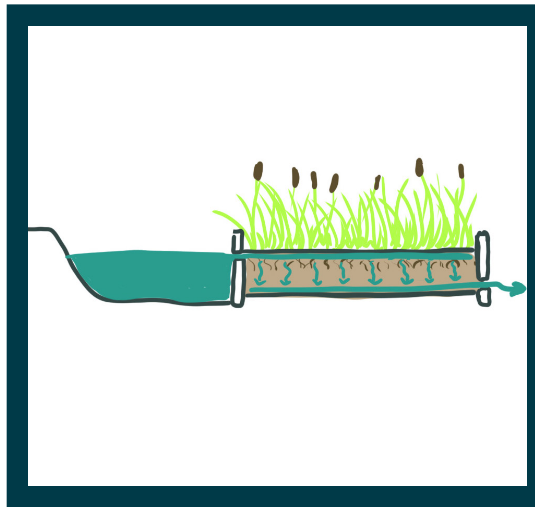
Hypothesis — **Pests can be prevented.**

Theoretical Back-up — Pests that are found in the built environment are for example rats, geese, pigeons, gulls, mosquitos, and stone marten. For example, the Egyptian geese can cause some recreational areas or beaches to become unusable because of their droppings (Vink et al., 2020).

Practical implication — Pests are almost always the result of an ecosystem that is not in balance. A diverse and stable ecosystem is the best defense against nuisances and pests. For example, If you want to prevent that rats or mouses are in abundance, you could implement nesting places for owls (Vink et al., 2020).

PATTERNS

HELOFYTE FILTER



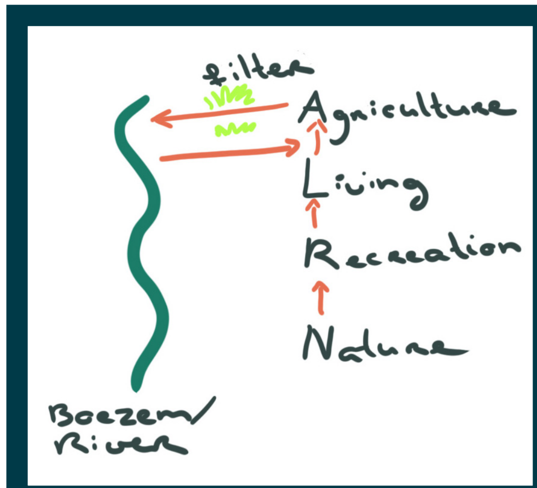
General

Hypothesis — **Helofyte filters can be a good sollution to purify nutrients rich water.**

Theoretical Back-up — Specially created swamps with reed plants can remove more than 60 percent of the nitrogen or 40 percent of the phosphate from drain and ditch water with a controlled water supply (Haan et al., 2012).

Practical implication — An Helofyte filter can be a good measure for agricultural water to remove nitrogen or phosphate, as the water comes from the areas that have too many nutrients in them, reducing biodiversity in the surrounding areas. These filters are inexpensive, however do take some space. A solution could be to link this filter to other functions, such as water storage, recreation, or biomass production (Haan et al., 2012).

LINK TO CLEAN WATER



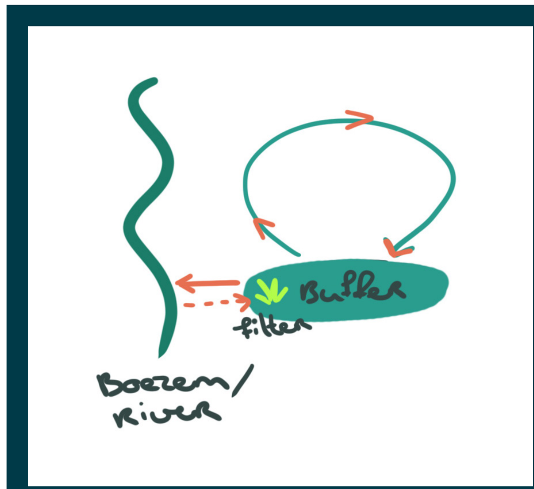
General

Hypothesis — **The link model ensures water quality.**

Theoretical Back-up — The Link model (Schakelmodel) is meant for water systems that include city and nature areas. The principle used in this model is to let water flow from damnatory functions to clean functions (Tjalingii & Berendsen, 2007).

Practical implication — By designing the water system to go from 'clean' functions to 'dirty' functions, a functioning water system is created. This means to let the water flow from a nature function, to recreation, to living, to agriculture.

CIRCULATION MODEL



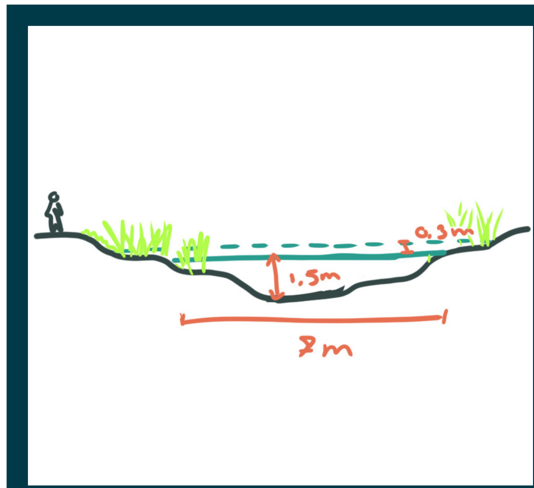
General

Hypothesis — **The circulation model provides the water quality needed for peat to grow.**

Theoretical Back-up — This model is meant for city neighborhoods where a personal water system is possible. A circular surface water system is implemented where no inlet from the boezem is needed.

Practical implication — This is done by creating a circular water system with a water buffer which is used when the waterlevel in summer is too low. With a pump, the water level is regulated to the desired water level. The water is filtered with a helofyte filter. For circulation, a pump is used (Tjalingii & Berendsen, 2007).

GREEN BLUE MODEL



General especially zone 4

Hypothesis — **The green-blue model is a way to ensure water quality in green-blue strips.**

Theoretical Back-up — The green-blue model is a solution for waterways in a green strip. This entails making steps in the water where the reed can grow. These will prevent children to fall into the water and is simultaneously a way to filter the rainwater that will flow into the canal (Tjalingii & Berendsen, 2007).

Practical implication — The dept that is in the middle of the waterway is at least 1,5 meters so that with extreme freeze there is still space for fishes to go. Also if the canal is at least 7 meters, the water will not be warmed up very fast in summer, which will prevent algae to grow.

H6. DESIGNING

CONTENT CHAPTER 6

INTRODUCTION

In the following chapter the sub-research question 'How would a carbon-storing living environment in Westergouwe look like?' is answered. In the chapter Framing and Analyzing, the context is created for this chapter. Also, the pattern language in Generalizing was used to create a design proposal for Westergouwe. This is firstly done by using the scenario design method. Here a design experiment was done by imagining how Westergouwe would look like, using only one type of housing so only floating houses, only pole houses, only amphibious houses, or only tiny houses. From this design exercise, some principles/ lessons have been learned that are used for the final (re)CarbonCity masterplan; Veenstad. After showing the master plan, some aspects of the design that were at the core are explained in more detail, like the water design and the ecology design, and the infrastructure design. After this, the zones of Veenstad are explained in more detail. And lastly, the development of the design through time is discussed and the final design is quantified to show the contribution of the design for society.

Figure 6.0 Peat nature,
by author in Krimpenerwaard.

6.1 SCENARIO DESIGN

6.1.1 Floating houses

SWOT SCENARIO FLOATING HOUSES

internal	**Strengths** - able to preserve peat - deep water for waterquality - nothing needs to be put in the soil - flexible layout over time, easy to move and remove	**Weaknesses** - have to dig out peat in order to create deep enough water - parking is not possible at the house directly - landscape is touched heavily - not able to have bigger functions like big shops or schools - not that much space for public space and services
External	**Opportunities** - able to withstand rising waterlevels - provides a big buffer for excessive rain water for Moordrecht and Gouda - provides recreational green for Gouda - Connects NNN with eachother	**Threats** - with succesion peat houses could be removed in order to give peat space

POSSIBLE FUNCTIONS

- small ~80 m² single-family homes
- small restaurants
- small shops
- swimming area
- recreational waterways
- Rainwater buffer

POSSIBLE TARGET GROUP

- students (25+)
- young couples (25-45)
- singles with 1 or 2 children

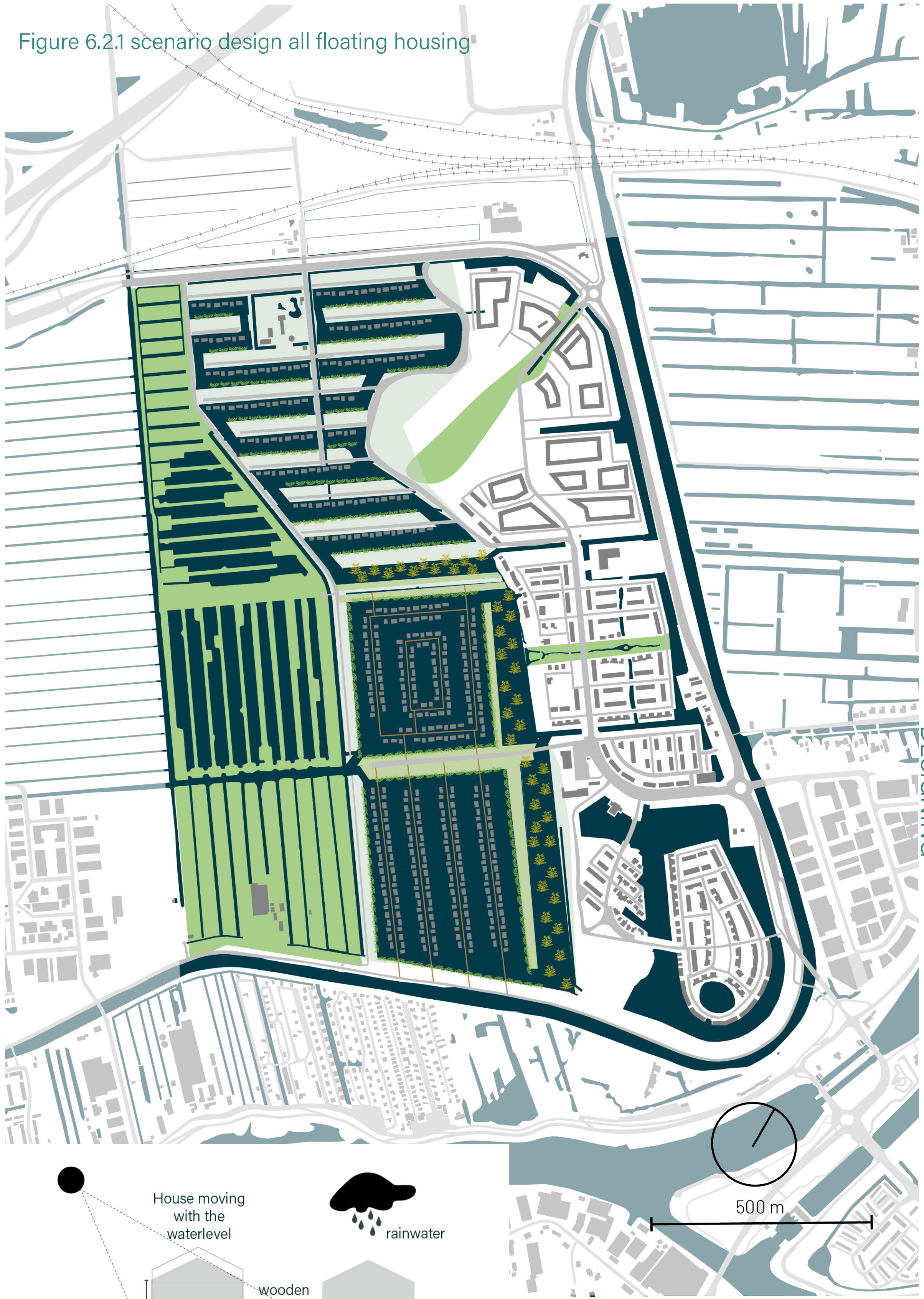


Figure 6.2.1 scenario design all floating housing

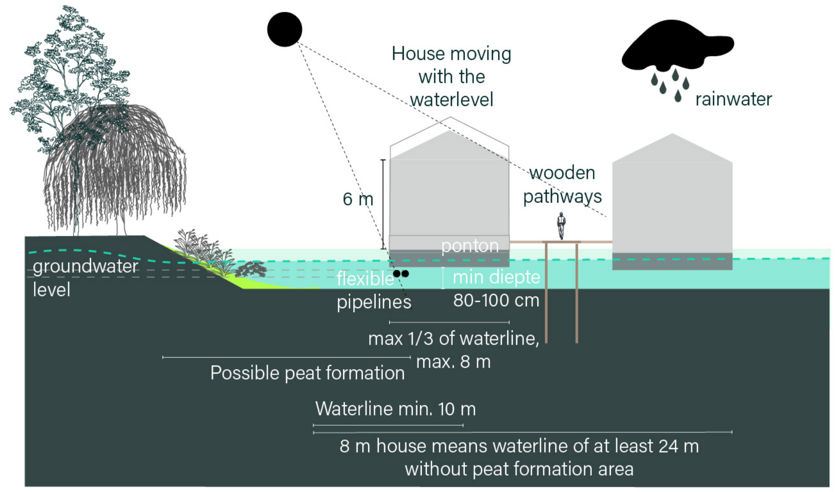


Figure 6.2.2 systemic section floating housing

DESIGNING

6.1.2 Pole houses

SWOT SCENARIO POLEHOUSES

internal	**Strengths** - able to preserve peat -able to grow peat underneath until height poles - layout based on landscape - landscape still visible after build - able to house relatively bigger function ~ permanent layout	**Weaknesses** - parking is not possible at the house directly - public spaces/ facilities are only possible at the dry parts - poles need to be put in the soil> needs to be done carefully and strategically - open character is lost ~ permanent layout
External	**Opportunities** - able to withstand rising waterlevels to a certain extent - provides a medium buffer for excessive rain water for Moordrecht and Gouda - provides recreational green for Gouda - Connects NNN with eachother	**Threats** - Climate change> water gets to warm

POSSIBLE FUNCTIONS

- bigger ~120 m² single-family homes
- Multi-family Row Houses
- medium restaurants
- Rainwater buffer
- medium shops like supermarket
- school
- offices

POSSIBLE TARGET GROUP

- families with children (30-45)
- elderly couples (65+)

DESIGNING

Figure 6.2.3 scenario design all pole houses

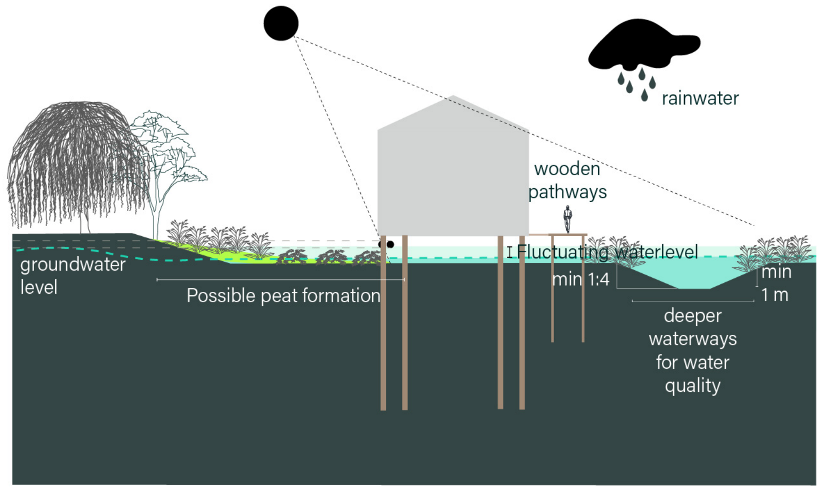


Figure 6.2.4 systemic section pole houses

DESIGNING

6.1.3 Amphibious houses

SWOT SCENARIO AMPHIBIOUS HOMES

internal	**Strengths** - able to preserve peat -able to grow peat along side it - nothing needs to be put in the soil - semi flexible layout over time, easy to move and remove - layout based on landscape - landscape still visible after build -layout still has open character	**Weaknesses** - parking is not possible at the house directly - not able to have bigger functions like big shops or schools - public spaces/ facilities are only possible at the dry parts
External	**Opportunities** - able to withstand rising waterlevels - provides a medium buffer for excessive rain water for Moordrecht and Gouda - provides recreational green for Gouda - Connects NNN with eachother	**Threats** - Climate change> water gets to warm

POSSIBLE FUNCTIONS

- medium ~100 m² single-family homes
- small restaurants
- small shops
- Rainwater buffer

POSSIBLE TARGET GROUP

- young couples (25-45)
- couples with 1 or 2 small children (30-45)
- singles with 1 or 2 children (45-65)

Figure 6.2.5 scenario design all amphibious houses

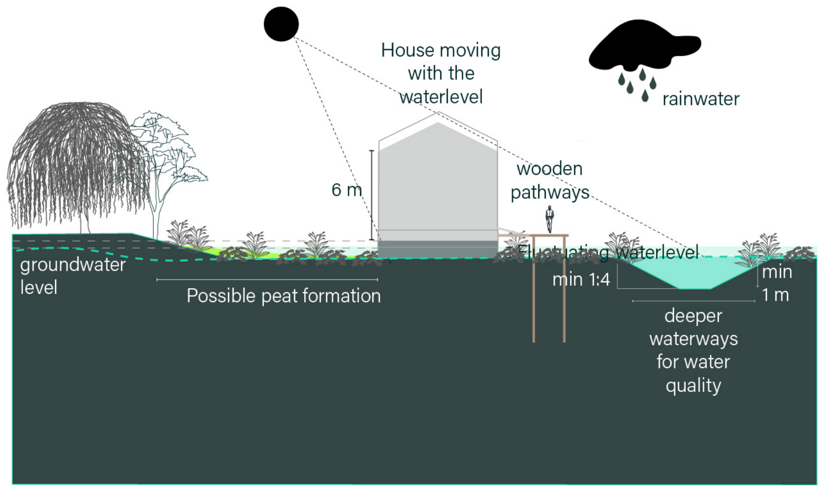


Figure 6.2.6 systemic section amphibious houses

LEGEND
- Water
- Rain water
- Green
- Roads
- Buildings
- Wooden pathways
- Parking

6.1.4 Tiny Houses

SWOT SCENARIO TINY TERP HOUSES

internal	**Strengths** -able to grow peat along side it - flexible layout over time, easy to move and remove -layout still has open character	**Weaknesses** - not able to have bigger functions like big shops or schools, only housing - public spaces/ facilities are only possible at the dry parts - have to make terp, which
External	**Opportunities** - provides a medium buffer for excessive rain water for Moordrecht and Gouda - provides recreational green for Gouda - Connects NNN with eachother	**Threats** - not able to withstand high rising waterlevels only to a certain extent

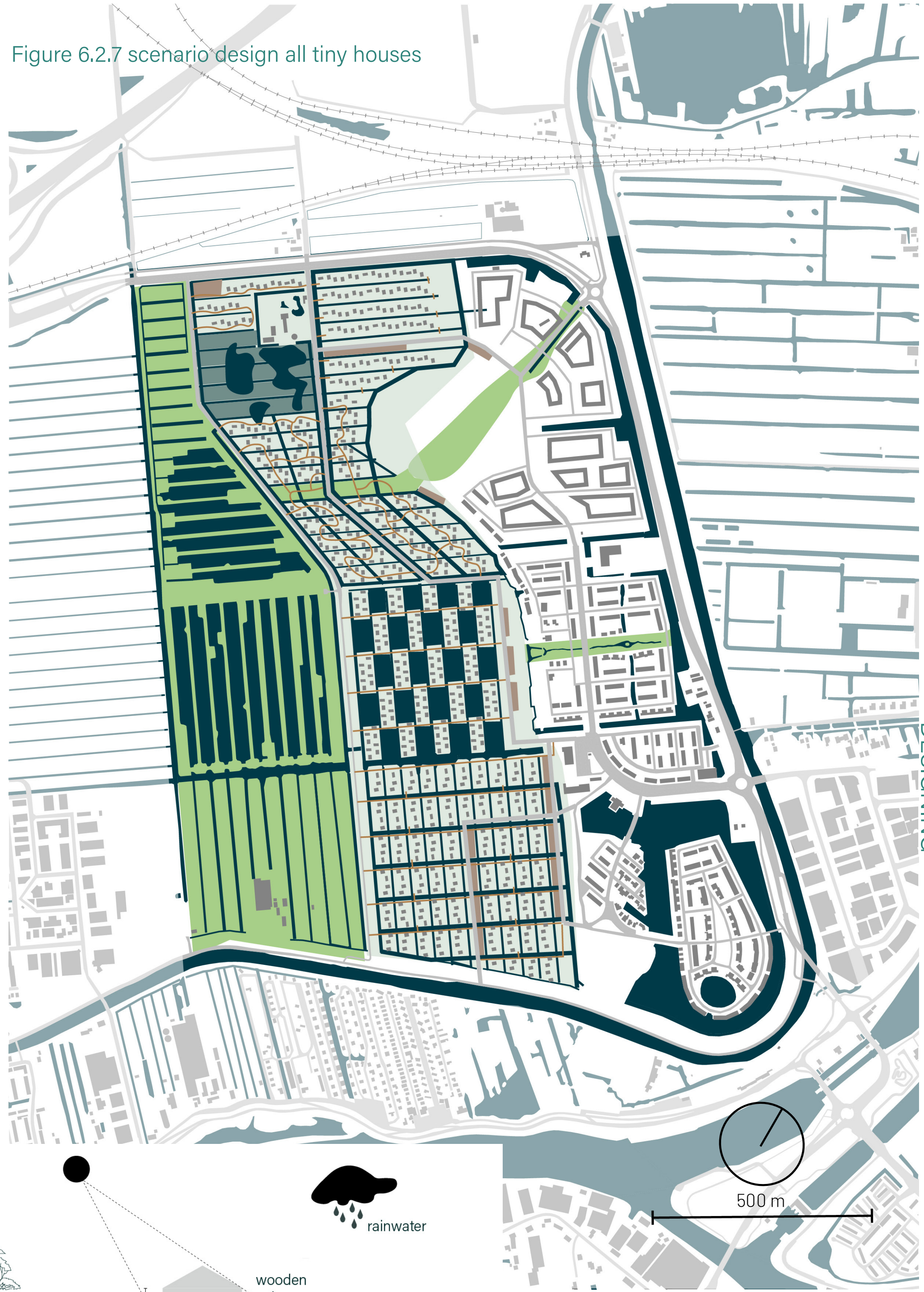
POSSIBLE FUNCTIONS

- small ~50m² homes
- wet community garden
- Rainwater buffer

POSSIBLE TARGET GROUP

- young couples (25-45)
- students (18-25)

Figure 6.2.7 scenario design all tiny houses



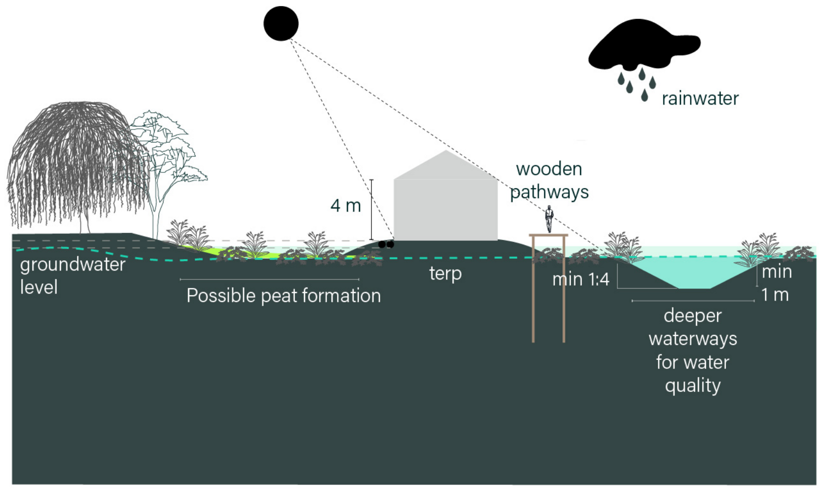


Figure 6.2.8 systemic section tiny houses

LEGEND

- Water
- Wet community garden
- Green
- Roads
- Buildings
- Wooden pathways
- Parking

6.1.5 Conclusion Scenario Design

Since floating houses have to have at least 1 meter of water depth to float and maintain water quality, they would either need a water body that is dug in the peat soil or the water body would have to be higher than the existing ground level of the polder. The first option would be controversial towards the vision to preserve the peat soil. However, the waterbody needed for floating houses does make for a big water buffer. Floating houses have a limit on the size of the building, which does not accommodate for bigger functions, like big supermarkets or schools.

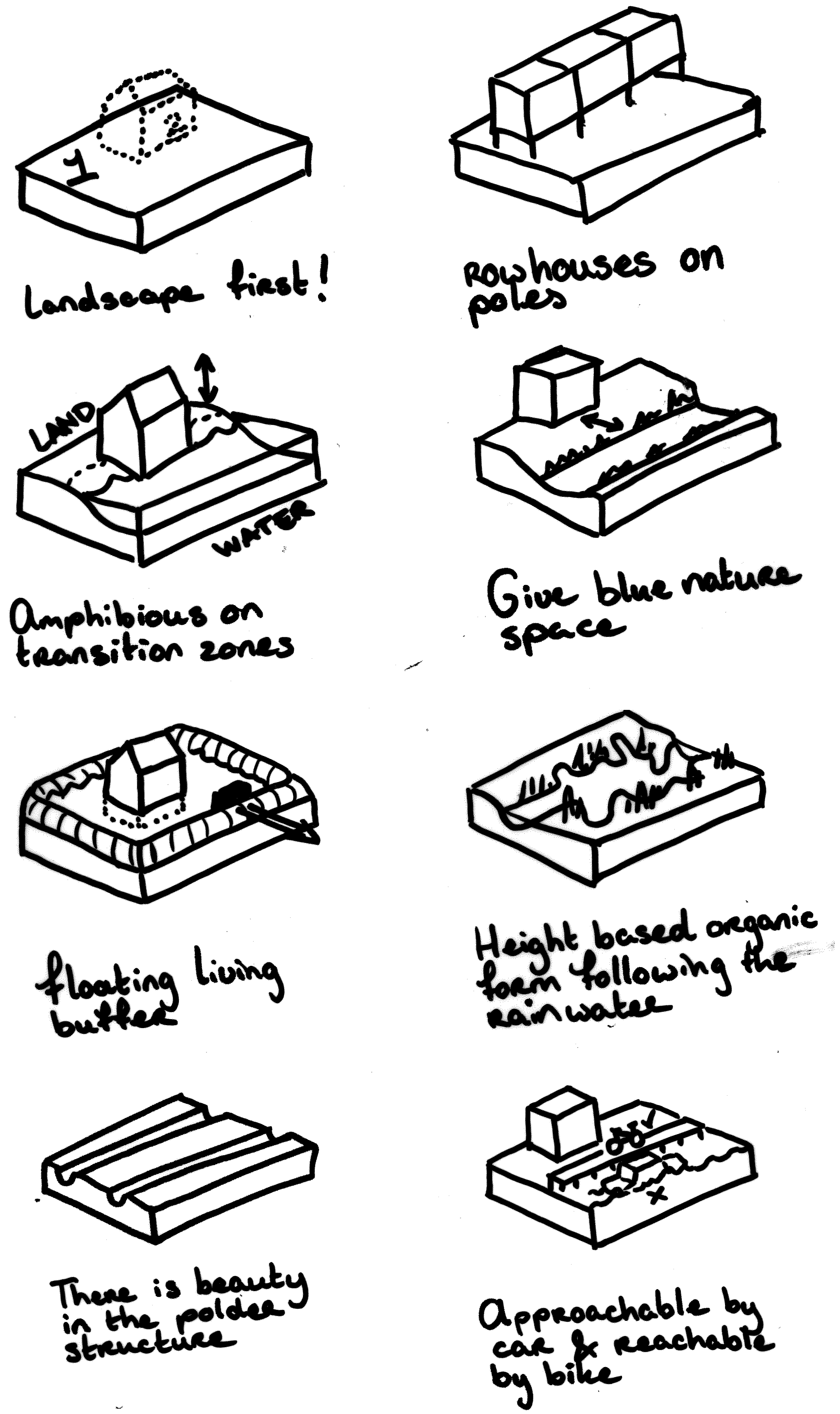
Houses on poles also accommodate wet soil. This option is less invasive to the existing landscape, which is why the design in this scenario follows the landscape and is more organic in the places where water will collect when raising the water level, and more orthogonal in the drier places. Housing on poles can be bigger than the other scenarios, which can provide functions like restaurants, a supermarket, and a school. This type can also be row houses, which can provide housing for a lower segment.

Amphibious housing also calls for interaction with the natural landscape. In particular, the fluctuation of the water level, and the perception of the rising water level. The amphibious homes scenario is also based on the height difference of the area and the homes are placed in the transition areas of water and land. When it rains these waterbodies get bigger and the houses float. Peat can grow around the houses where water is collected.

Tiny houses need to be placed on dry land, that is why mini terps (islands) need to be made. These terps need to be made of clay, which means that even though the tiny houses are made of lightweight materials, the terp itself will put pressure on the soil. Around the terps, peat can be preserved and grown. This option is a nice wink to the history of our relationship with water.
After consideration is chosen to not include the tiny houses as the terp will be destructive to the peat soil. Also, the floating houses were not a favorite because of the need to dig out the peat soil to accommodate the floating houses, but after identification of the elements needed for the design, a water buffer is needed to keep the rest of the area wet in the summertime. That is why a reservoir with floating houses is placed in the clay soil area in the north.

Another element that became apparent in this design exploration was that the existing landscape must act as the basis for the design. That is why the amphibious houses are placed in the area where rain has the most influence, and the pole houses are placed in the drier parts.

Figure 6.2.9 Learned elements



6.2 VEENSTAD

After having learned the lessons obtained during the scenario designs and further design exploration, a master plan for Westergouwe that is called Veenstad has been made. In the following pages the design is explained in further detail from the aspects of water, infrastructure, and ecology.

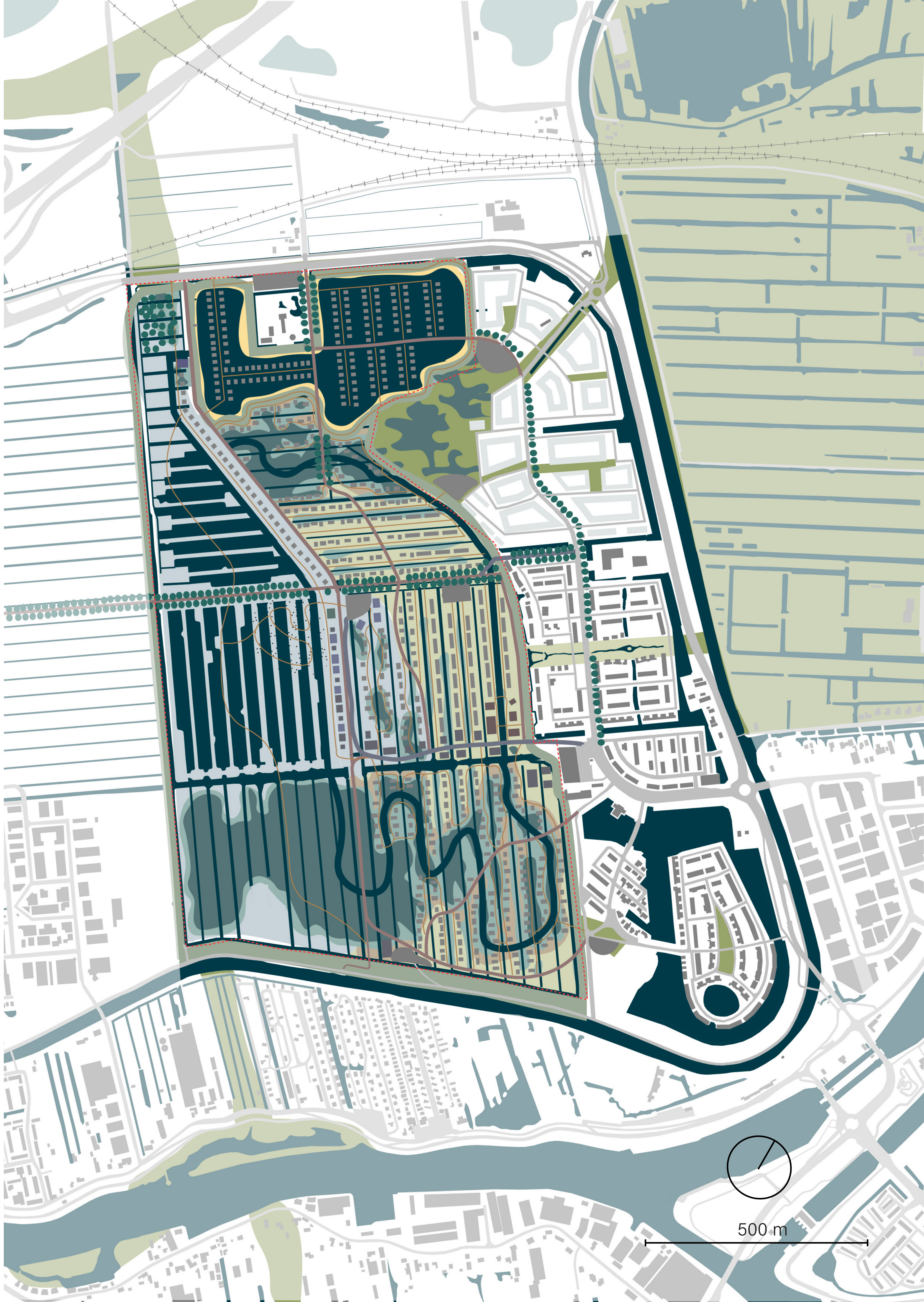


Figure 6.4 Masterplan design

LEGEND

- Water deeper than 1 m
- Water 0,3m
- Water after rain
- Dyke
- Car accesable roads
- Houses
- Buildings old design, not build yet
- offices and shops
- School building
- Recreational center
- Horeca
- Parking
- Main raised bicycle roads
- Pedestrian/ bicycle paths
- raised car accesable road
- Playnature
- Green outside of project area
- Project Area

6.3 (DE)POLDERING

In order to preserve and grow peat. Rainwater needs to be isolated in the area. This is done by creating a polder in the polder. The area is going to be surrounded by dykes. In order to maintain water levels in the area a reservoir is created. In appendix 1. rough calculations are done and the fluctuation of the reservoir is considered. After consideration, a fluctuation of 1,6m is chosen because of the size of the reservoir, the ability to house all rainwater that falls on the area throughout the year, and the ability to provide an extra 0,2 meters in summertime via a pumping station. The created water system is a circular system so that the water quality of the peat areas can be maintained (see chapter Generalizing, pattern Circulation model). In the area, most of the existing ditches are used to create a flow in the area. The main canal is added to the area to increase the speed of the water even more and to create a way for transportation through the new neighborhood. Different zones are created based on the amount of water already in the area and the current height. There is a slight slope to the west, so water will collect in zone 2. This zone will be constantly wet. Zone 3 will fill up more if it has rained creating this organic wetland. Zone 4 is based on the existing wet polder structure and will be drier in comparison to the rest of the area.

1. ***WATER RESERVOIR***
water:
highly fluctuating
0 to 1,6 m

2. ***CONSTANTLY WET***
water:
constantly wet
0 to 0,2 m

3. ***PERIODICALLY WET***
water:
periodically wet when rain
- 0,2 to 0,2 m

4. ***HUMID***
water:
humid
-0,3 to 0 m

5. ***POCKET***
water:
dry

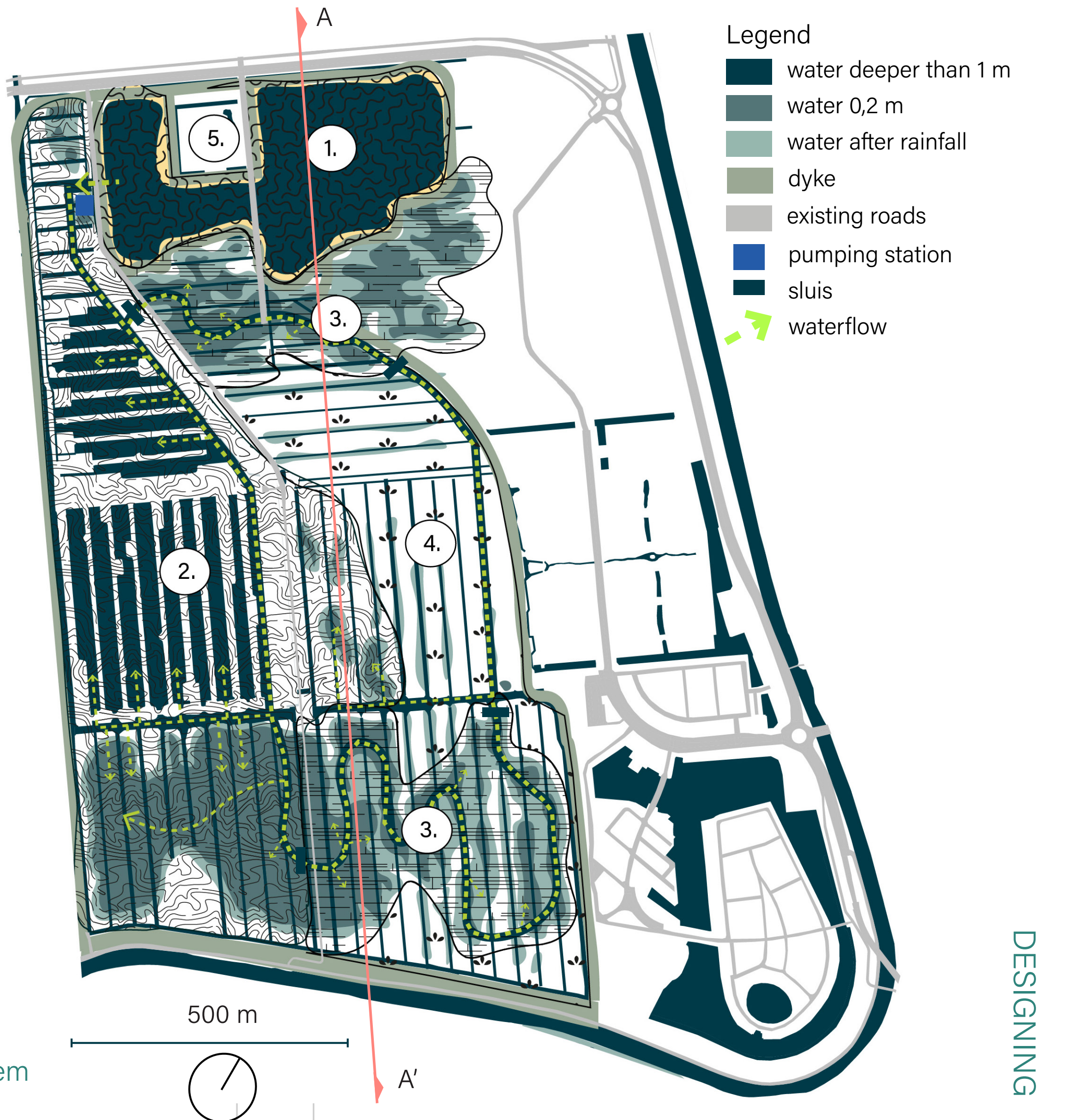


Figure 6.3.1 New Watersystem

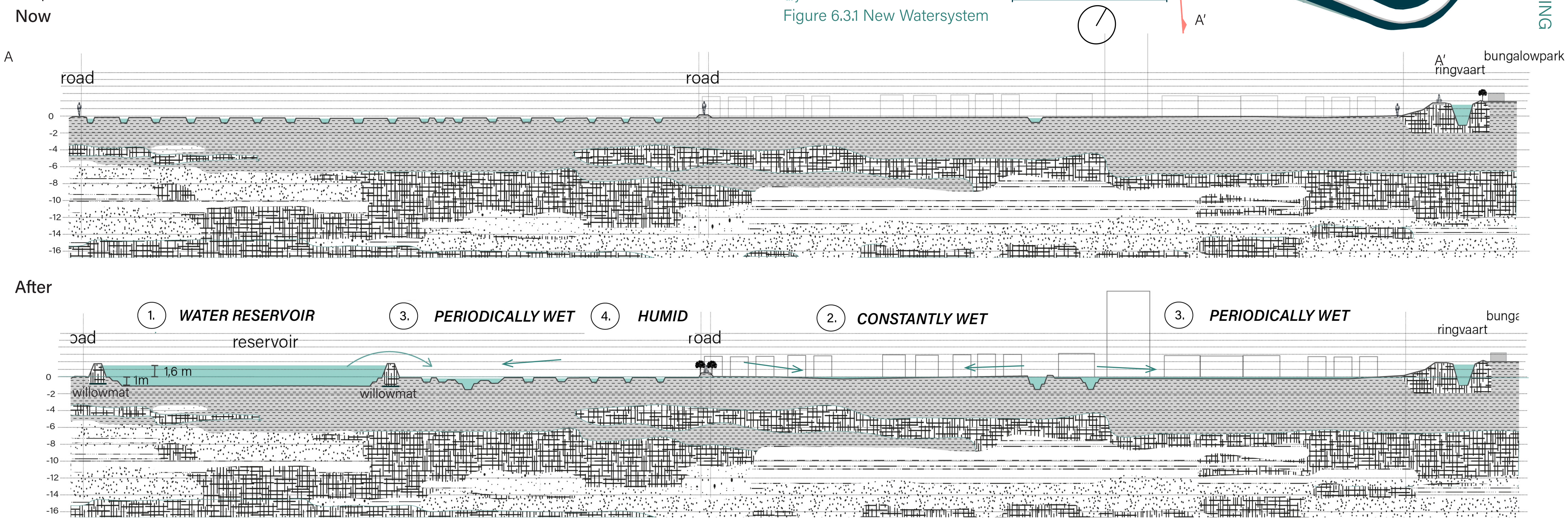


Figure 6.3.2 Watersystem section now and after realisation

1:5000

6.4 MOVING THROUGH A WETLAND

It is important that the water bodies and green structures will not become natural borders, preventing the neighborhood to have a lively public space. In order to make it an integral part of Gouda, a car-accessible road is made so that recreational visitors can be in the heart of the new nature. From this point, many recreational functions are found. Also, public transport routes are extended to this area. The main canal can be used as a way of transportation through the neighborhood. Besides this recreational starting point, most parking space is found at the borders of Veenstad. This means that to reach your house you would have to walk or cycle over raised floating wooden pathways. The area is meant to serve not only Gouda but also Moordrecht. To strengthen the connection is the historical road to gouda, the Tiendeweg, reintroduced. This is a reminder of the times of the peat lakes. This road will be higher than the surrounding landscape, highlighting the history of the landscape.

Figure 6.4.2 Fly ash from "common.wikimedia.org" By F. Belayali, 23 June 2019 , - Own work (https://commons.wikimedia.org/w/index.php?curid=79896350). CC BY-SA 4.0 not modified

Figure 6.4.3 Waterways. By P. van der Sluijs, 6 May 2016 (https://commons.wikimedia.org/w/index.php?curid=48601400) CC BY-SA 3.0

Figure 6.4.1 Raised wooden pathways. from pixabay by Pexels (https://pixabay.com/nl/photos/pad-wetlands-buitenshuis-1839000/)

Figure 6.4.4 Floating pathways. from "flickr.com" by Province of British Columbia, 2008, (https://www.flickr.com/photos/bcgovphotos/15358939273) CC BY-NC-ND 2.0

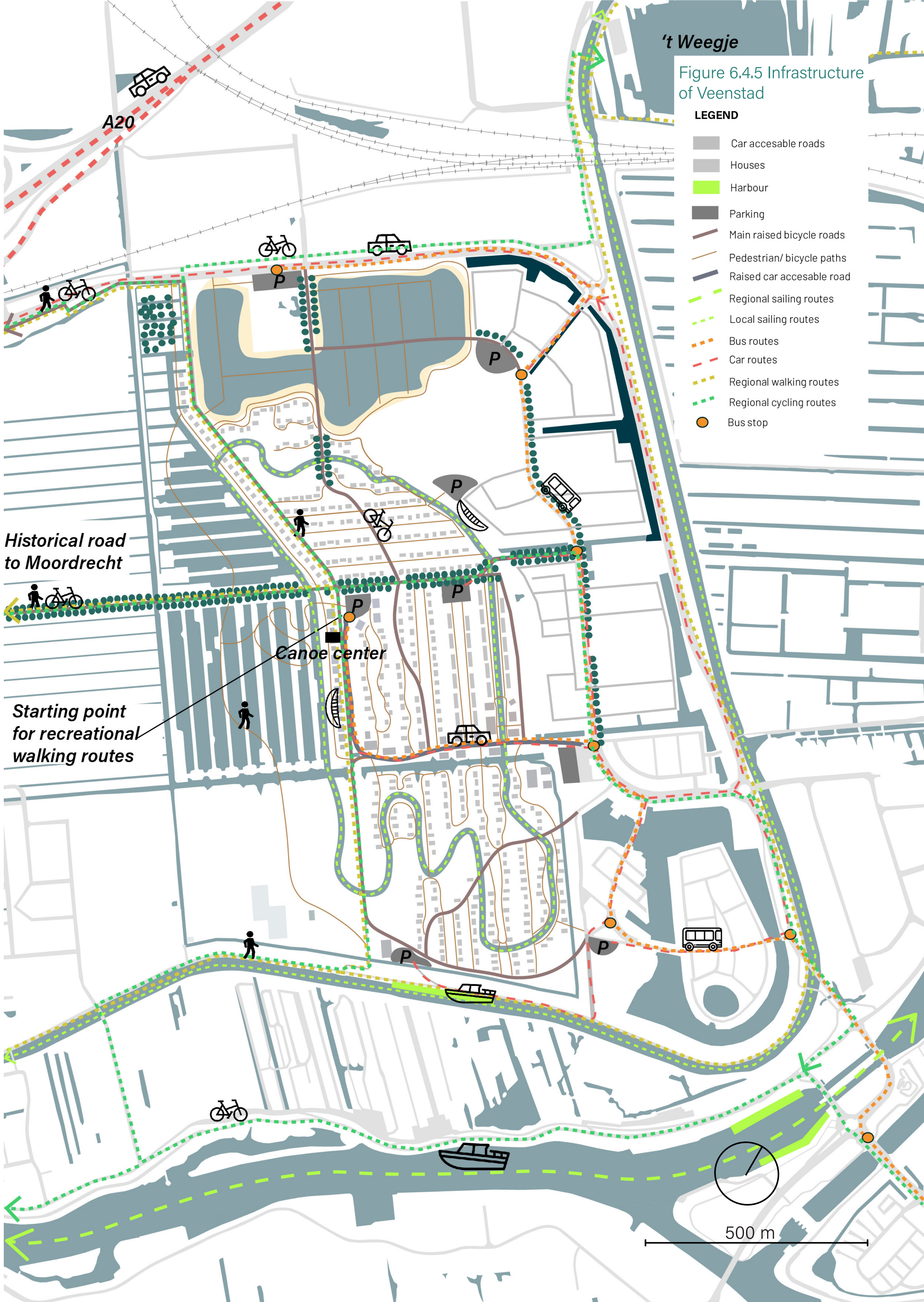


Figure 6.4.5 Infrastructure of Veenstad

DESIGNING

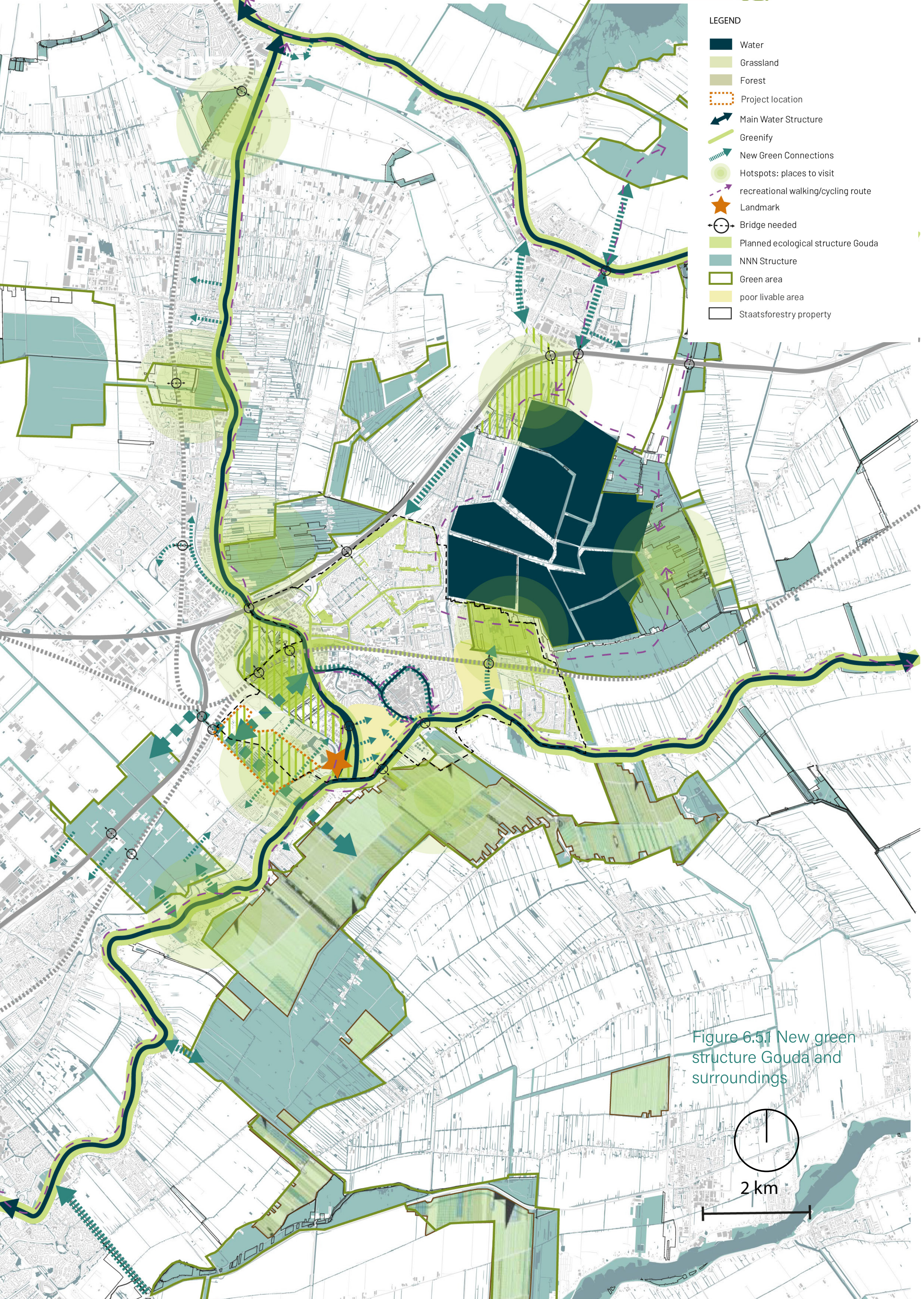


Figure 6.5.1 New green structure Gouda and surroundings

6.5 A PALETTE OF BIOTOPES

1. ***LIVING RESERVOIR***

water:
highly fluctuating (+-1,6m)

biotopes:
-reedland
-willow forest

2. ***PEAT NATURE PARK***

water:
constantly wet; 0 m to +0,20 m

biotopes:
-mesotrophic marchland
-quacking bog

3. ***RAIN GARDEN***

water:
- 0,20 m to 0 m

biotopes:
- humid reed peat meadow
- alder forest

4. ***PEAT POLDER NATURE***

water:
- 0,30 m

biotopes:
- peat meadow
- peat roughs
- ash alder forest

5. ***GARDENS***

water:
dry

biotopes:
- garden biotope

6. ***WADIPARK***

water:
periodically wet when it has rained

biotopes:
- wadi

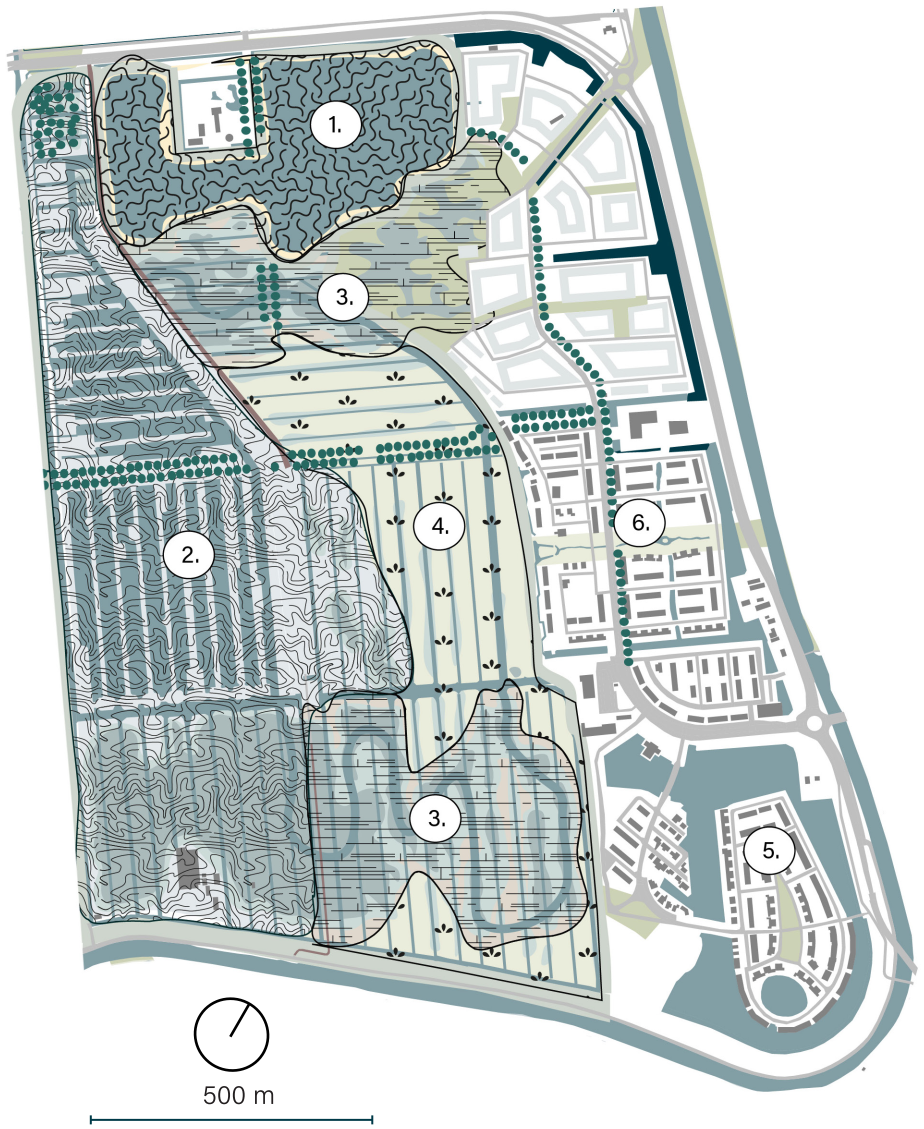


Figure 6.5.2 Biotopes map

The biotopes of Veenstad will show a variety of nature types on peat, showing the beauty of our dutch 'nature'. Each zone has a different water level influencing the biota that will grow in that zone. Zone 1 is situated on clay soil and the water level is highly fluctuating, perfect for reedlands and willows. In zone 2 peat growth is given full freedom, connecting the NNN structures in Krimpenerwaard to Moordrecht and 't Weegje. Zone 4 peat polder nature is an example of how our old polders could be transformed into beautiful peat meadows and peat roughs with minimal rewetting.

If you live in the new neighborhood you will be able to have nature at your doorstep. And from this nature, you will be able to step into a bigger green structure creating the green metropolis. The main structure of this green network will consist of the big rivers, de Gouwe and the Hollandse Ijssel with our area at the crossroad of the rivers. (explained in 'Eco Metropolis', Cobben et al., 2022) This area can provide green for the west and center of gouda where big green structures are missing, but also for Moordrecht and Waddinxveen. In the next chapter, each zone and its biotopes are explained in more detail.

6.6 NEW ZONES

6.6.1 Zone 1 Living Reservoir

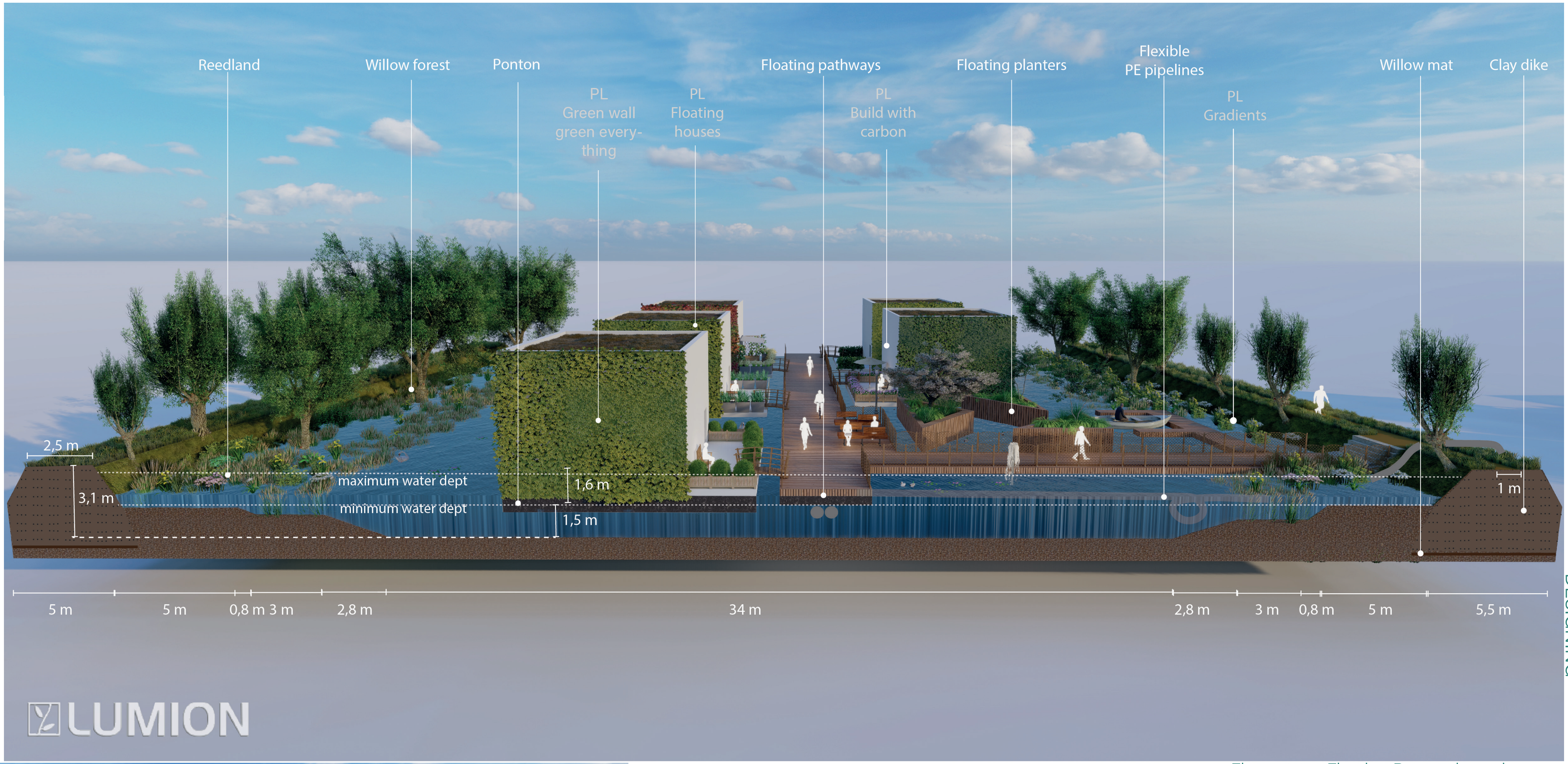
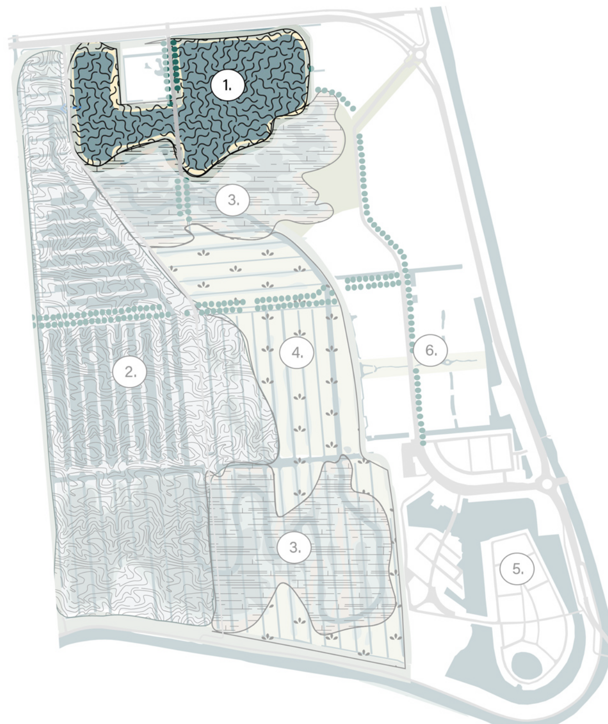


Figure 6.6.1.1 Floating Reservoir section

Figure 6.6.1.2 Floating Reservoir impression

To maintain water levels in the other zones. A reservoir is created. This will fluctuate highly, this means that the experience of when it has rained or not and if it is summer when the reservoir will be low and in winter when it will be high, will be different. In order to accommodate the fluctuation, buildings and infrastructure will all be floating on pontoons. The houses are built from CO_2 storing materials like wood and reed and willow. Inhabitants will enjoy nature with their own canoe or sit on their floating balcony.



DESIGNING

In appendix 2 a list of species can be found for these biotopes

Biotopes for zone 1 Living Reservoir

The living reservoir is situated on the clay soil in the area. Here the topsoil will be removed to remove the eutrophic top layer from the former agricultural area.
The water level in this area will be highly fluctuating.

REEDLAND

Figure 6.6.1.3 Reedland biotope collage
(see reference list)

Reedlands are created on the nature-friendly borders of the reservoir where the water is shallow. Reedlands are biotopes for birds and insects. Birds nest in the thick reed and geese eat it. In order to keep the reservoir nutrient-poor, it is important that the reed in the reservoir is mowed and removed in wintertime (Jansen, 2022). Because of the biota that live there, this needs to be done strategically in order to disturb them as less as possible.

WILLOW FOREST

Figure 6.6.1.4 Willow forest biotope collage
(see reference list)

Willow forest develops in very wet conditions on clay soils. These forests can even be underwater for the whole winter. On the borders of the reservoir, willows will grow on the nature-friendly borders as the reservoir will be highest in winter but the border will be dry in summer. On the dykes pollard willows will grow.
This biotope will house a lot of birds, and in old willow forest herons and spoonbill breed in colonies. In order to create willow forests, maintenance is stopped in certain areas along the reservoir.

6.6.2 Zone 2
Peat nature park

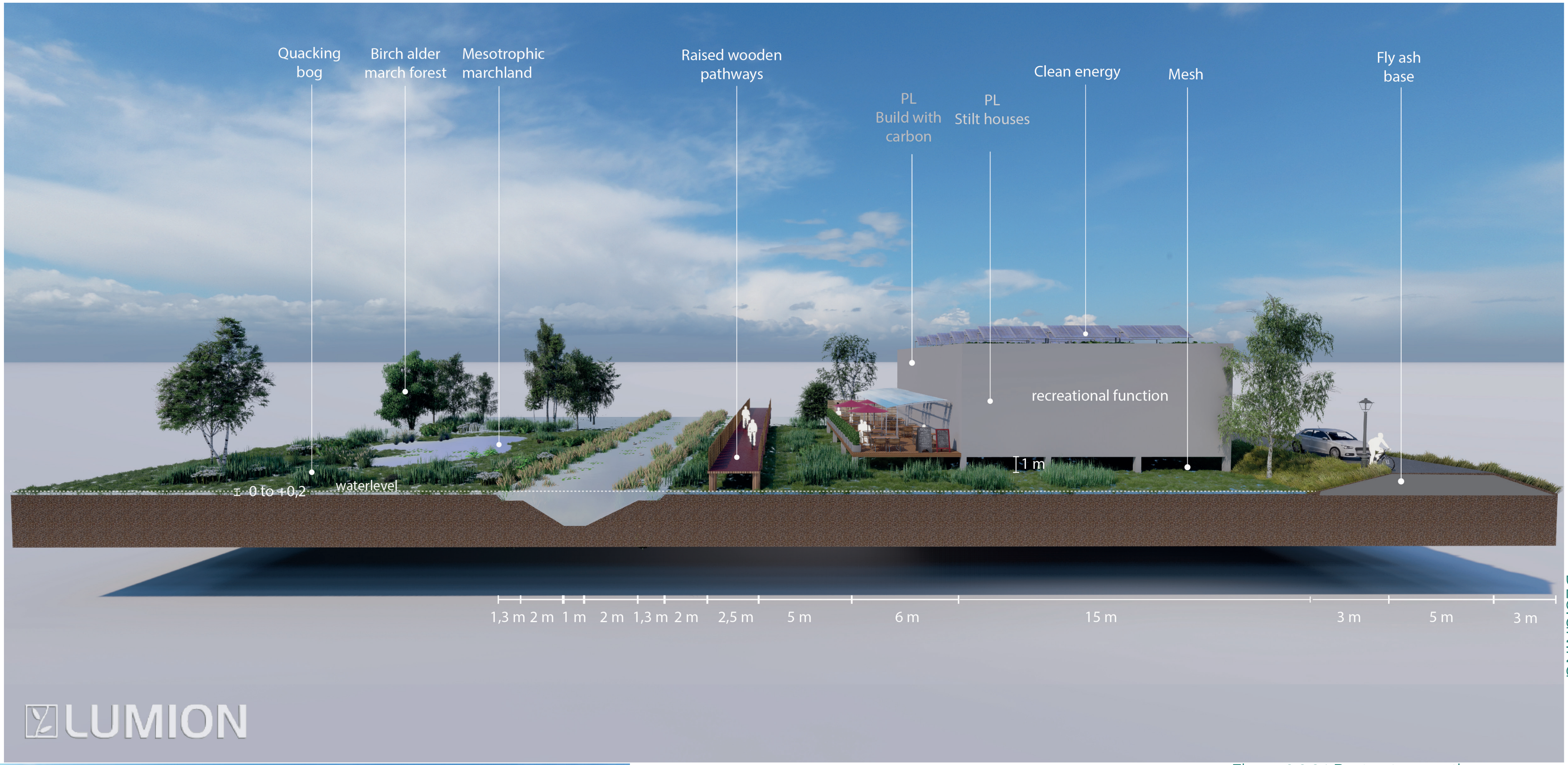


Figure 6.6.2.1 Peat nature section

Figure 6.6.2.2 Peat nature impression

In zone 2 peat nature, people from in and around Veenstad will be able to enjoy nature and recreate here. In this zone, nature will be given the most space of all zones. The water level will be kept at a constant level so peat is allowed to grow constantly. Along this zone, a lot of recreational functions are found. People that are walking or cycling through the region will be able to stop for a break on their walking and cycling routes to enjoy a drink or learn more about peat nature in the knowledge center.
The biotopes that are selected for this zone are mesotrophic marchland, quacking bog, and birch alder march forest. These biotopes are successions of each other so through time so this area will be very dynamic in appearance.

Biotopes for zone 2 Peat Nature

Here the layer of formerly agricultural land needs to be removed, After this, dried peat moss should be sewn on top. A constantly wet environment is created of -20 to +20 cm water level relative to the summer water level. The following biotopes are all phases in the peatland wetland succession; from mesotrophic marchland to quacking bog to birch alder march forest. If no maintenance is done in 15 years everything will be a young forest (Jansen, 2022).

MESOTROPHIC MARCHLAND

Figure 6.6.2.3 mesotrophic marchland biotope collage
(see reference list)

Mesotrophic marches are created in open shallow water that is fed by groundwater or purified polder water on a peat bed. In this biotope species like curlew, snipe and porchard are present. Also, plants like bogbean and march cinquefoil are common. Other biota you can find here are dragonflies, salamanders, and frogs. This nature type is hard to maintain. One solution is to recreate a big reservoir that keeps the area wet in summer. Because of this reason is zone 1; Living Reservoir created.

QUACKING BOG

Figure 6.6.2.4 Quacking bog biotope collage
(see reference list)

Quacking bogs are created by floating aquatic plants that are becoming increasingly solid. Quacking bog becomes more acidic due to rainwater, giving more and more peat moss (sphagnum) a chance. It consists of a fairly thin reed layer and often a moss layer, rich in peat moss. The vegetation is low and very open, reeds and other high swamp plants are only present here and there. (BIJ12, 2022) These biotopes are very species-rich plants like march fern, march Lousewort, and bog asphodel. A lot of insects are present because of the rich flora, Also march butterflies and a lot of dragonflies occur (Jansen, 2022). Due to the changed water management, stadia of succession become rougher and rougher much faster than under natural conditions. Mowing slows this process down. Peatmoss can hold CO_2 very well it is because of this that mowing is necessary in order to maintain this type in Westergouwe

BIRCH ALDER MARCH FOREST

Figure 6.6.2.5 Birch alder forest biotope collage
(see reference list)

The forests that develop from quacking bogs are forests on wet sites on peaty soils with dominant species such as the birch and alder. They can tolerate being underwater in the winter but not as much as willows. When there is a lot of influence from rainwater (especially in raised bogs), the soft birch and undergrowth of peat mosses and dwarf shrubs dominate, when under the influence of groundwater, the black alder and marsh plants dominate (BIJ12, 2022). In Westergouwe this is dependent on the supply from the reservoir. Species that can be found in this biotope are breeding birds and insects. In order to achieve this stage, no maintanance is done.

6.6.3 Zone 3 Rain garden

Figure 6.6.3.1 Rain Garden section

Figure 6.6.3.2 Rain garden impression

Zone 3 rain garden is more dependent on rainwater so when it has rained the water will be higher than when it has not rained, moving the amphibious houses up and down. People that live here will experience the changing water daily. The biotopes that are found here are humid reed peat meadow and alder forests. Inhabitants are able to sit on their shared balcony looking over their children growing up and playing in nature.

Biotopes for zone 3 Rain garden

The rain garden will have a humid peat landscape, which will be influenced by rainwater. Also here the topsoil will be removed to remove nutrients. The water level will be +20-30 cm above the summer level. This zone also holds 2 stages of succesion: humid peat reed meadow to alder forest. Which one of the stages is located where is depended on the land use and maintenance.

HUMID PEAT REED MEADOW

6.6.3.3 Humid peat reed meadow biotope collage (see reference list)

In this biotope species like buttercup, ragged robin and rattle are found. Also insects and small mammals like this type of environment. This biotope houses sometimes meadow birds like the godwitt but because this type will be combined with housing, the meadow bird will not like Westergouwe. In winter, geese will find this area attractive.

ALDER FOREST

6.6.3.4 Alder forest biotope collage (see reference list)

Without mowing and grazing the previous biotopes change into an alder forest. If you want to speed up the process, planting alder in specific spaces will speed up the process. In zone rain garden is chosen to let alder grow in strategic spaces like the back of the houses but is chosen not to help by planting. The humid older forest is very important for birds and mammals like willow tit.

6.6.4 Zone 4 Peat Nature

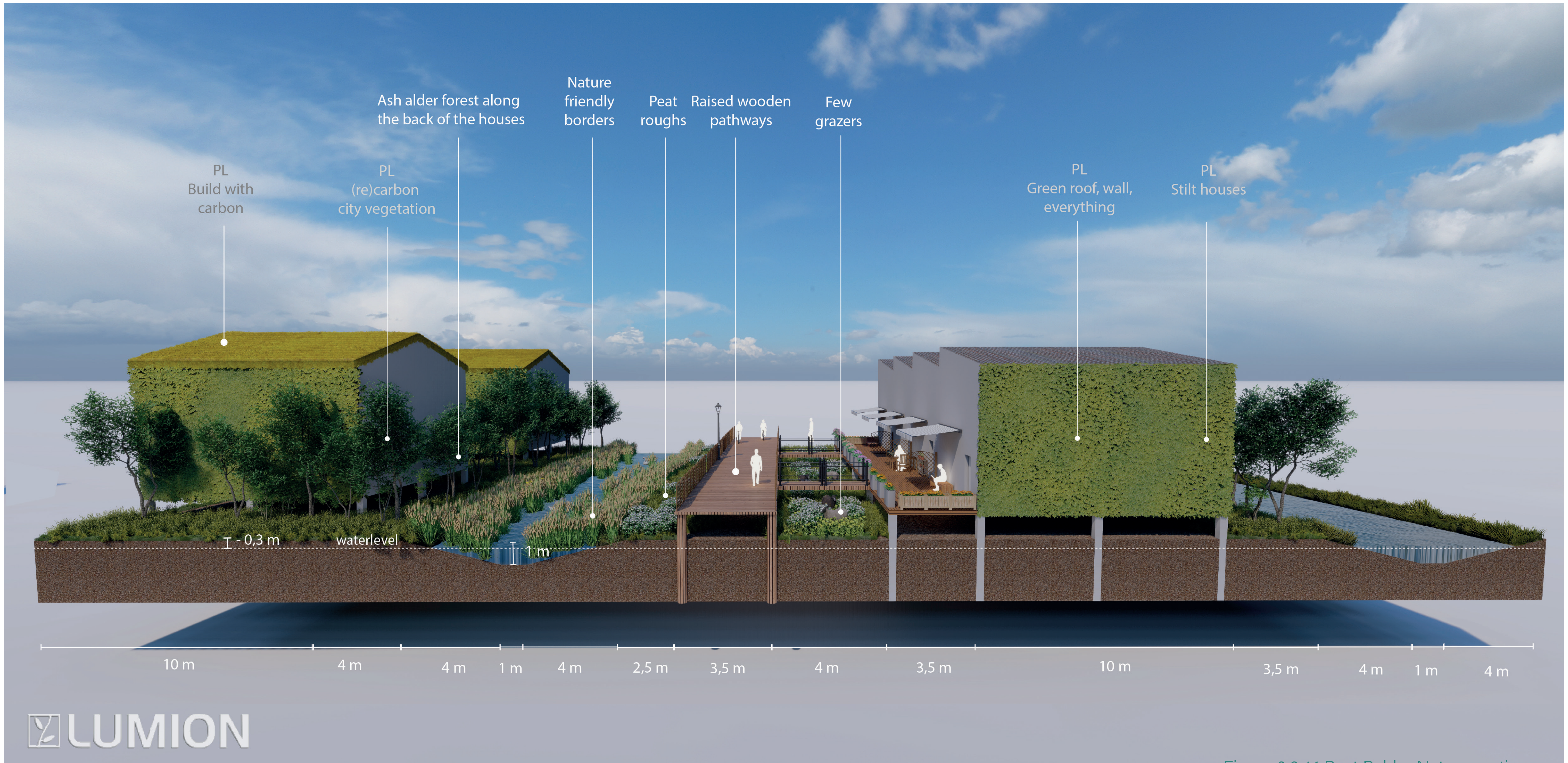


Figure 6.6.4.1 Peat Polder Nature section

Figure 6.6.4.2 Peat Polder Nature impression

The last zone is an example of what polders can be with minimal rewetting. The old orthogonal structure is kept to show that polders can be beautiful. The old ditches are made nature friendly by widening the borders. In the front of the houses, you can find at first the biotope peat meadow but pretty quickly peat roughs are developing as peat meadow would require a lot of grazers which would damage the peat growth with their manure. Around your house would walk just a few sheep to maintain the peat rough.

Biotopes for zone 4 Peat Polder Nature

This zone will house a the relatively dryer peat biotopes. Here the water level will be 0 to -30 in summer. But this area will also be kept wet in order to prevent the oxidation of the peat soil. This soil can be used more extensively. This is why it is placed in the area with the most center functions. If one of the three biotopes will arise is dependent on the grazing and mowing of the area (Jansen, 2022).

PEAT MEADOW

Figure 6.6.4.3 Peat meadow biotope collage (see reference list)

PEAT ROUGHS

Figure 6.6.4.4 Peat roughs biotope collage (see reference list)

ASH ALDER FOREST

Figure 6.6.4.5 Ash Alder forest biotope collage (see reference list)

For Westergouwe it has been chosen to let peat meadow undergo succession because in order to maintain this biotope a lot of grazing/ mowing would be needed. Grazers would produce manure which would be bad for zone 2 Peat Nature to grow peat. In this zone species like buttercup, daisy, dandelion, and sorrel are found. Other biotas that are found are a lot of insects, small mammals, and birds (Jansen, 2022).

Peat Roughs require few grazers so this biotope is more suited for Westergouwe. In these zones, many tall flowery plants grow which are attractive to a lot of insects and seed-eating birds. For this biotope, it is not always necessary to excavate the top layer as peat roughs make the soil layer more nutrient by themselves.

For this type, the topsoil does not have to be removed. In this biotope, alder appears but also has ash and elm on the drier parts. In older forests, you can find wood anemone and celandine and many birds. Woodanemoon and celandines will be stimulated by planting tubers, bulbs, and rhizomes.

6.7 DESIGN THROUGH TIME

The neighborhood will look different over time. In order to grow peat and make a nature-inclusive neighborhood, nature is given more space than in traditional neighborhoods. Nature is not a static phenomenon. This means that people will have to keep adapting to the nature found in Veenstad. And in turn, the inhabitants can also shape the nature around them. The biotopes selected in Veenstad are mostly successions of each other. This means for example, if you live in zone 3 Rain garden, for the first 5 to 10 years you will live with a humid reed peat meadow around you, and slowly you will see that alder forest is growing around you after some time.

Also, peat growth will change the landscape as the height of the public space will change. So through time, the flat landscape will transform into a land of hills and relief.

And lastly, the water level will change with time. Although it will be a subtle aspect as it will be done very slowly. This also means that in the long run (longer than 15 years), biotopes will shift from drier biotopes to more humid biotopes. For example, peat polder nature will become to inhabit the biotopes of rain garden. Raingarden will have the biotopes of peat nature. And lastly, peat nature will keep its biotopes as it grows along with the water level. Eventually, all of the neighborhood will have the biotopes of peat nature.

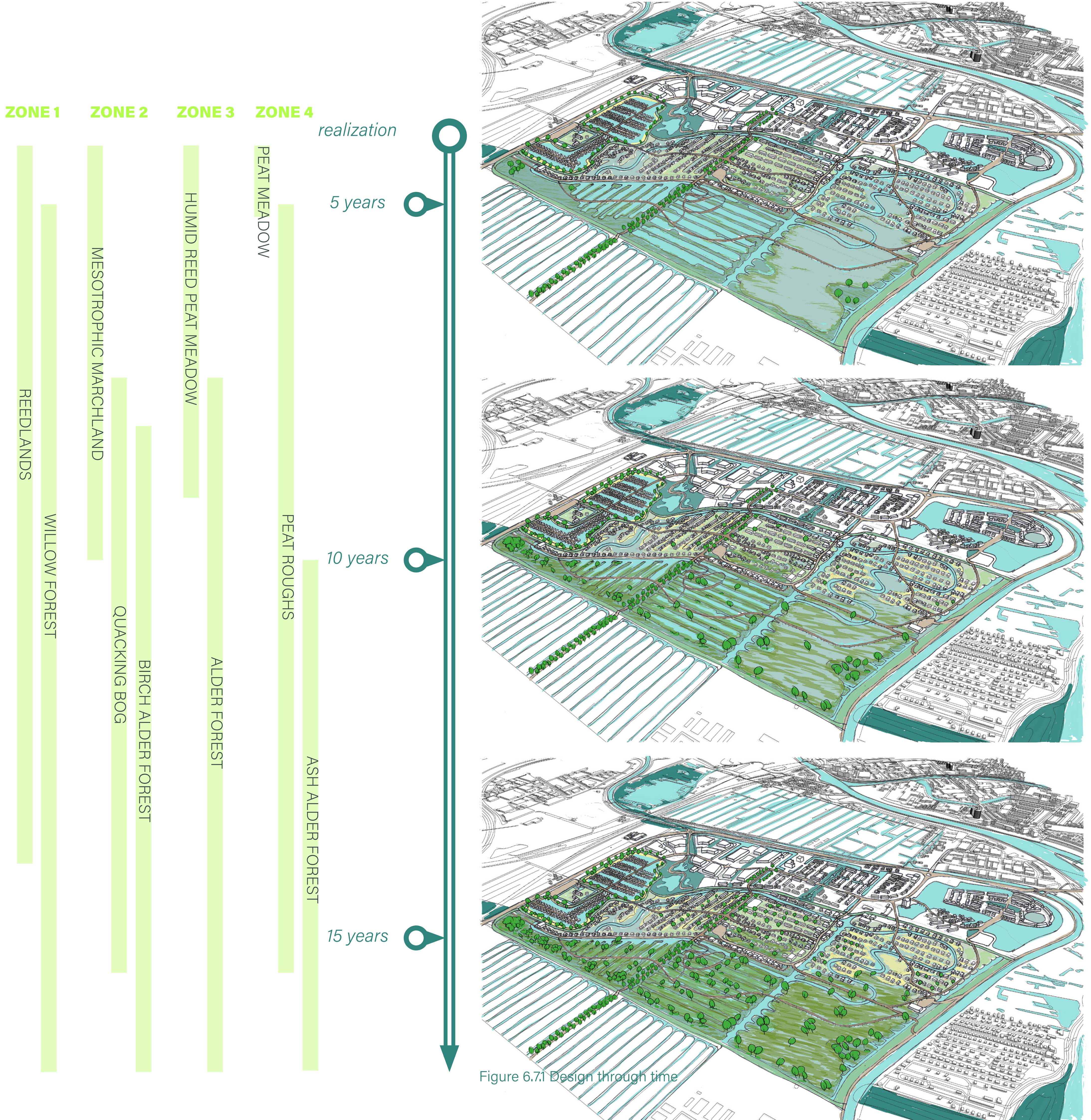


Figure 6.7.1 Design through time

6.8 QUANTIFYING VEENSTAD

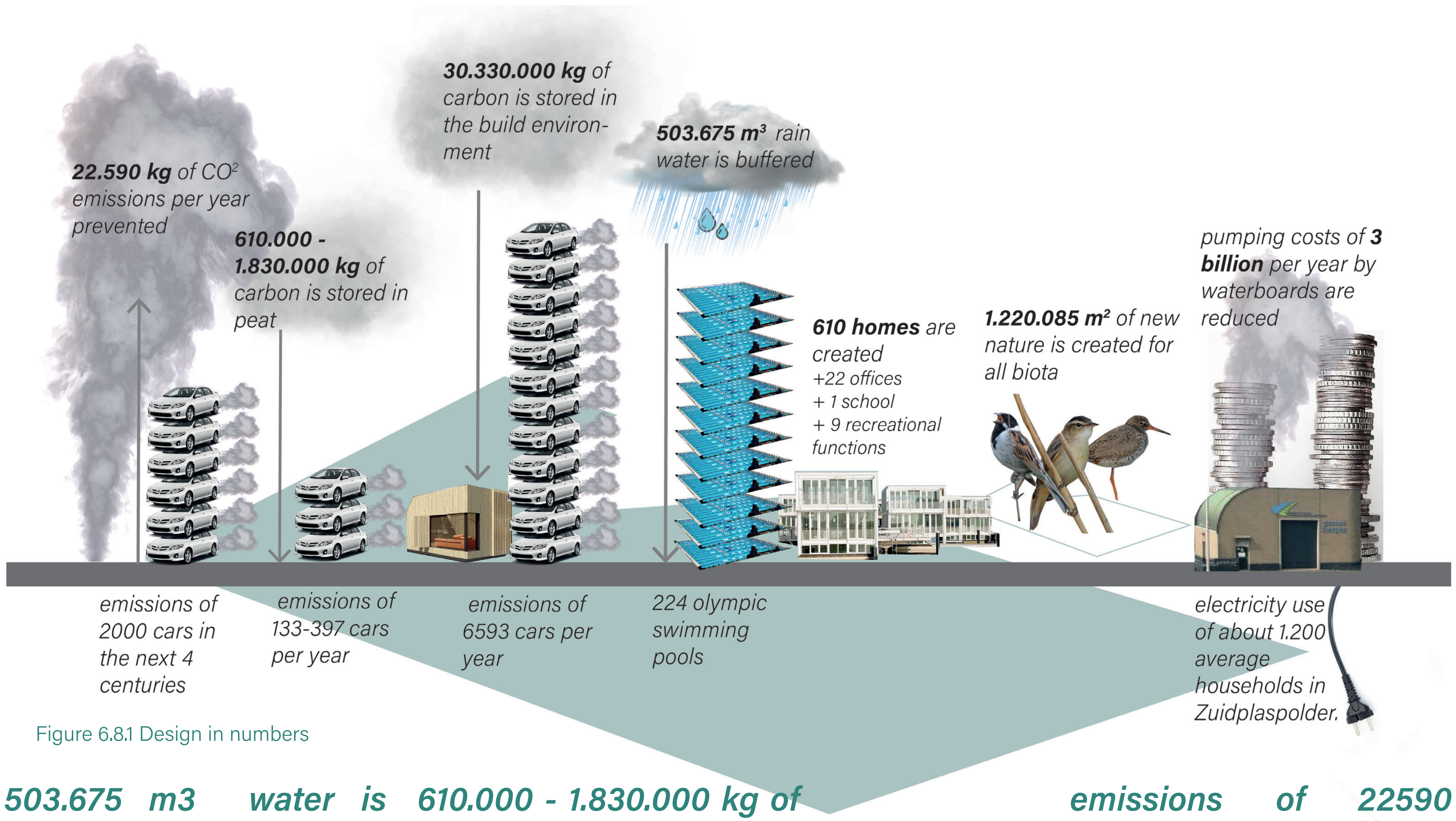


Figure 6.8.1 Design in numbers

503.675 m3 water is buffered in the area

In Gouda, there is an average of 853 mm of rainfall per year (Climate-data.org, 2022). Of this water, 255 to 412 mm evaporates again in an average dutch city (Jacobs, et al, 2015). The uncertainty in the degree of sealed surfaces, in particular, causes a considerable spread in the estimates of evaporation. Since the design consists of mostly unsealed nature, for this situation the highest number is taken. This makes for an excess of 441 mm/year. The area is designed so that it can buffer all the rainwater that falls upon the area.

610.000 - 1.830.000 kg of carbon is stored

Raising the water level in peat by 10 to 40 centimeters can store 5 to 15 tons more CO_2 per hectare (Staatsbosbeheer d., 2022). Which would mean that in an area like Westergouwe 610.000 to 1830.000 kilograms are stored in the peat. This is the same as the emissions of carbon dioxide of 133 - 397 cars per year.

emissions of 22590 kg of CO_2 per year are prevented

Every mm of soil subsidence leads to 2259 kg of CO_2 emissions per hectare per year (van den Akker et al., 2010) As the subsidence in the area is about 10 mm per year, the CO_2 emissions would be about 22590 kg of CO_2 per year. This is the same as the emissions of 2000 cars in the next 4 centuries.

610 homes are made

+ 1 school
+ 22 offices and shops
+ 9 recreational functions

The existing structure vision says that 3.462 to 4.000 houses and a 'green blue' zone needs to be built. In rapport Bestemmingsplan Westergouwe (Stedenbouwkundig adviesbureau Witpaard-partners, 2008) they plan for 1402 to 1725 homes in phases 1 and 2, which are already built, and 845 tot 889 homes in the to be build area outside of the project area.
The new Carbon city design would put the count of homes to be: about 2250 to 3000 homes. In this scenario, the housing goals of the municipality would not be reached. A way to still reach the goal would be to densify the to be build phase 3 design.

costs of 3 billion euros per year can be reduced

Waterboards use a lot of energy, especially electricity. With the production of electricity, Fossil fuels are used which in turn release CO_2 into the atmosphere. Currently uses Hoogheemwaterschap Schieland en Krimpenerwaard 3.250 MWh of energy. This is comparable with the electricity use of about 1.200 average households (Hoogheemwaterschap Schieland en Krimpenerwaard b., 2022). By pumping less, less energy needs to be used. Current costs of all waterboards in the netherlands combined are about 3 billion euros per year (Homolová et al, 2019). By raising water levels in the polder, these costs could be reduced.

H7.
STRATEGIZING

CONTENT CHAPTER 7

INTRODUCTION
The chapter Strategizing discusses how the design for Veenstad in the chapter Designing could be realized. Firstly, an analysis is made of which stakeholders there are in Veenstad and which roles these parties could have. And secondly, a proposal on how Veenstad could be realized in phases is shown, connecting stakeholders to the phases.

Figure 7. 0 Green-Blue zone Westergouwe, by author

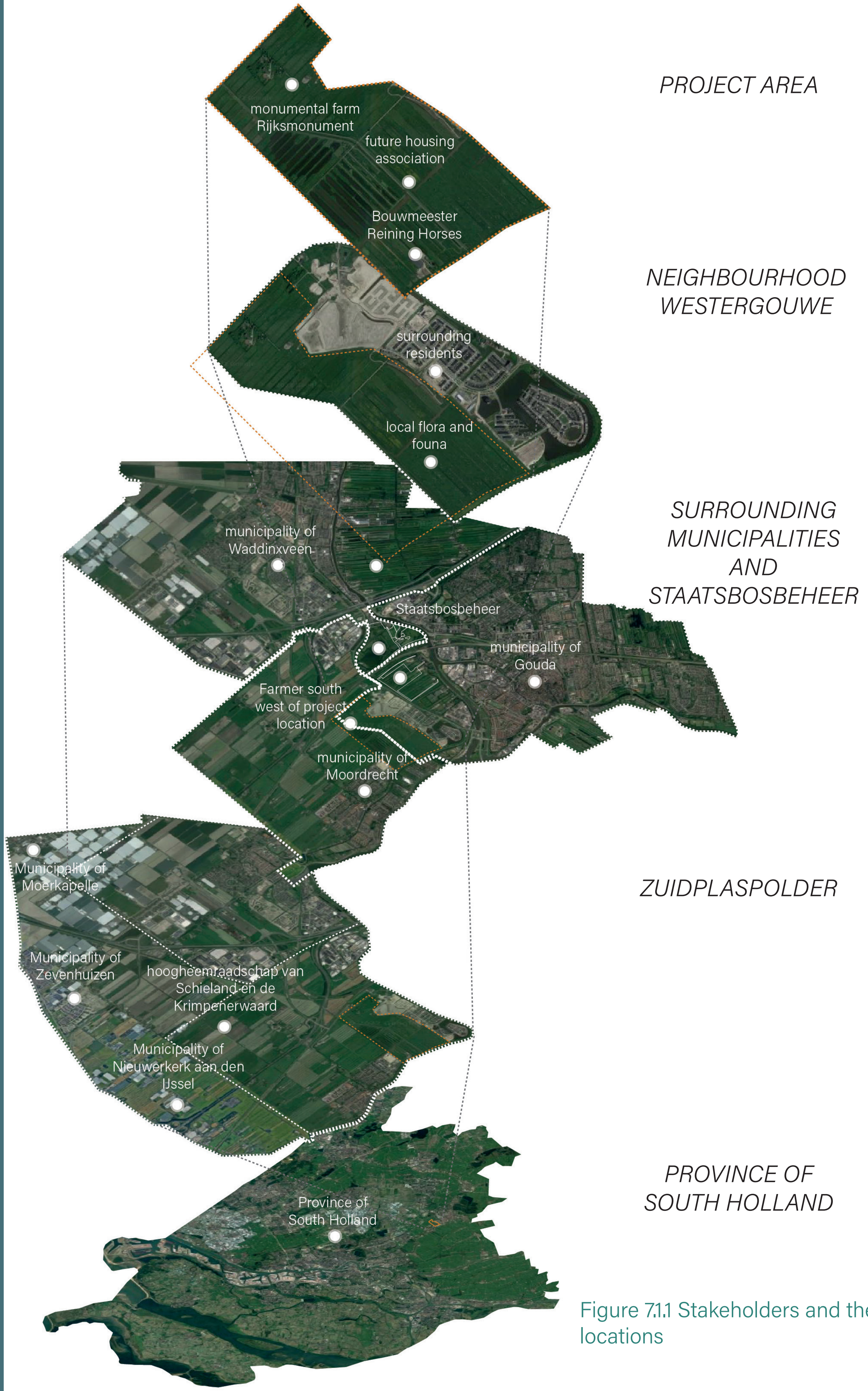


Figure 7.1.1 Stakeholders and their locations

7.1 STAKEHOLDERS

Stakeholder	***Interest (low/medium/high)***	***power on proposed design (low/medium/high)***	***means***
Surrounding residents	high concerning their direct surrounding living environment	low their own property, rights if their property is harmed	/
Staatsbosbeheer	medium concerning their metropolis vision	big organization, has bordering properties in the west around the area and 't Weegje	can have a dialogue with the municipality about green structures, money
Hoogheemraadschap van Schieland en de Krimpenerwaard	high	protect the land from the water and ensure that the water is clean and regulates water levels in the zuidplas polder	manages dykes, locks and pumping stations in the area between Rotterdam, Zoetermeer, Gouda and Schoonhoven
Farmer east of project location	high concerning its land	medium power over property	/
Province of South holland	medium	medium	influence, money, information
RET	medium	high controls bus routes	money, can change bus routes, Has employees to drive busses
Municipality of Gouda	high concerning their land	high can ensure the build of the design	Owns the land of the project area., connections, rights
Monumental farm Rijksmonument	High concerning its land and surroun-dings	Medium Owns the area with the house and some land around it.	Has the rights over his land, needs to be bought out Rijksmonument
Bouwmeester Reining Horses	High concerning its land and surroundings	Medium Owns the manege and some land	Has the rights over his land, needs to be bought out
farmer east of project location	Medium	medium	Money,
Local flora and fauna	High	low	None
Municipality of Moordrecht	Medium	high can ensure the build of the design	Owns the land of the project area., connections, rights
Municipality of Waddinxveen	Low	medium	Can talk with Staatsbosbeheer about their properties
Future investors	High concerning its land and surroundings	Owns the manege and some land	Has the rights over his land, needs to be bought out
Other municipalities in polder: Moerkapelle, Zevenhuizen, Nieuwerkerk aan den Ijssel	Medium	medium	Money,

Figure 7.1.2 Diagram Stakeholders

The stakeholders of the area are shown in the diagrams on these pages. The project area is situated in Gouda and Moordrecht. This makes it that the two municipalities will have to work closely together. In the power-interest diagram in figure 7.1.3, are the stakeholders shown that have to be managed closely, kept informed, kept satisfied, and monitored. A stakeholder that the author wants to underscore, is the flora and fauna, a stakeholder that is placed in the diagram on low power but high interest, but can not express their opinion or can be 'kept informed.' So it will be the responsibility of future designers and plan makers to voice these opinions.

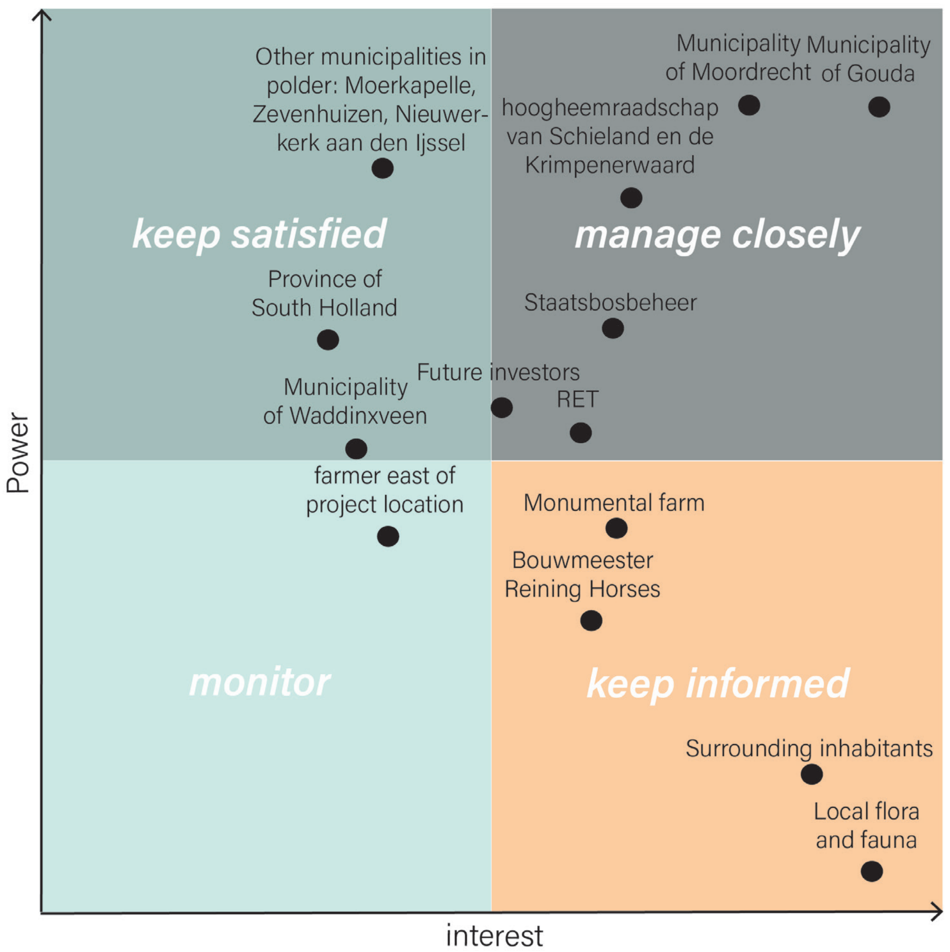


Figure 7.1.3 Power-interest diagram stakeholders

7.1.1 The zuidplaspolder

Because of the great social importance of CO_2 emission reduction and subsidence, and the major impact of rewetting of peat, it is evident that national, regional and local governments play a key role in guiding this transition. As guidelines could be held the European Green Deal for the coordination of CO_2 reduction. But these have to be translated into regional goals, agreements, processes, and implementation programs. (Breman,2022). Rewetting the polder area will require local initiatives and custom-made strategies. The municipalities of the Zuidplaspolder will have to consider local interests and design these interests synergetically with the goal of rewetting the peatland neighborhood. They will have to be consistent with their goals to maintain support.

The new use of space will require the change of ownership and change of utilization, This can be done by instruments such as lot exchange, restructuring, and compensation or investment in innovation projects surrounding peat, helping and financing business models and an award system (Breman, 2022).

The Hoogreemwaterschap of Schieland and Krimpenerwaard will have a crucial role in the transition as they control the water level. By gradually adapting the water level to the new functions the inhabitants in the area are given the opportunity to move along. It is important that long-term visions are made that work with this water level (Breman, 2022).

A way to fund the inhabitants of the polder towards this transition could be for example the proceeds of the avoided emissions of greenhouse gases. This could compensate entrepreneurs for the declining income from primary agricultural production in a wet environment. Another way to finance the transition could be the avoided costs of damage to infrastructure and buildings. A study from PBL (2016) has estimated that future subsidence costs up to 2050 could be 2 billion in damage to infrastructure and foundations in rural areas and even €21 billion for urban areas.

7.1.2 Hoogheemraadschap Schieland en Krimpenerwaard

Het hoogheemraadschap Schieland en Krimpenerwaard was established to ensure 'dry feet and sufficient and clean water' (Hoogheemraadschap van Schieland en de Krimpenerwaard, 2017). The first part of this vision is adverse to the (re)carbon city vision in the short term as we aspire to rewet the soil. However, looking into the future, the (re)carbon city vision will prevent flooding. Thus the waterboard is a stakeholder that can be our biggest friend or our biggest adversary. This is why it needs to be managed closely and needs to be convinced early to achieve our goals.

Carbon emission goals

The Unie van Waterschappen and the central government have made agreements about reducing the emission of harmful substances (Hoogheemraadschap van Schieland en de Krimpenerwaard, 2022). These agreements are contained in the 2010 Climate Agreement. It states that in 2020 we will emit 30% less harmful substances than in 1990 (Unie van Waterschappen,2020). In 2050 they will emit even fewer harmful substances.

Sustainable development

In their vision they say that they have experienced the effects of climate change more and more often because of drought and intensive precipitation. Also, they will have to plan for flooding and deteriorating water quality. On top of that, they mention that they plan to reduce CO_2 emissions annually by 1% and in 2050 they plan for no net emissions of greenhouse gases. To do this they mention that they want to reduce their energy use, by reducing their demand and producing their own energy in sustainable ways. However, they never mention the peat soil on which they operate.

Biodiversity

They want to contribute to increasing biodiversity (Hoogheemraadschap van Schieland en de Krimpenerwaard, 2020). They are envisioning to:

- Create a green-blue network
- Promote pollinators
- Promote red list species

This is in line with the (re)carbon city as it increases biodiversity, creates a green-blue network and it promotes red list species.

STRATEGIZING

7.2 PHASING AND STAKEHOLDERS

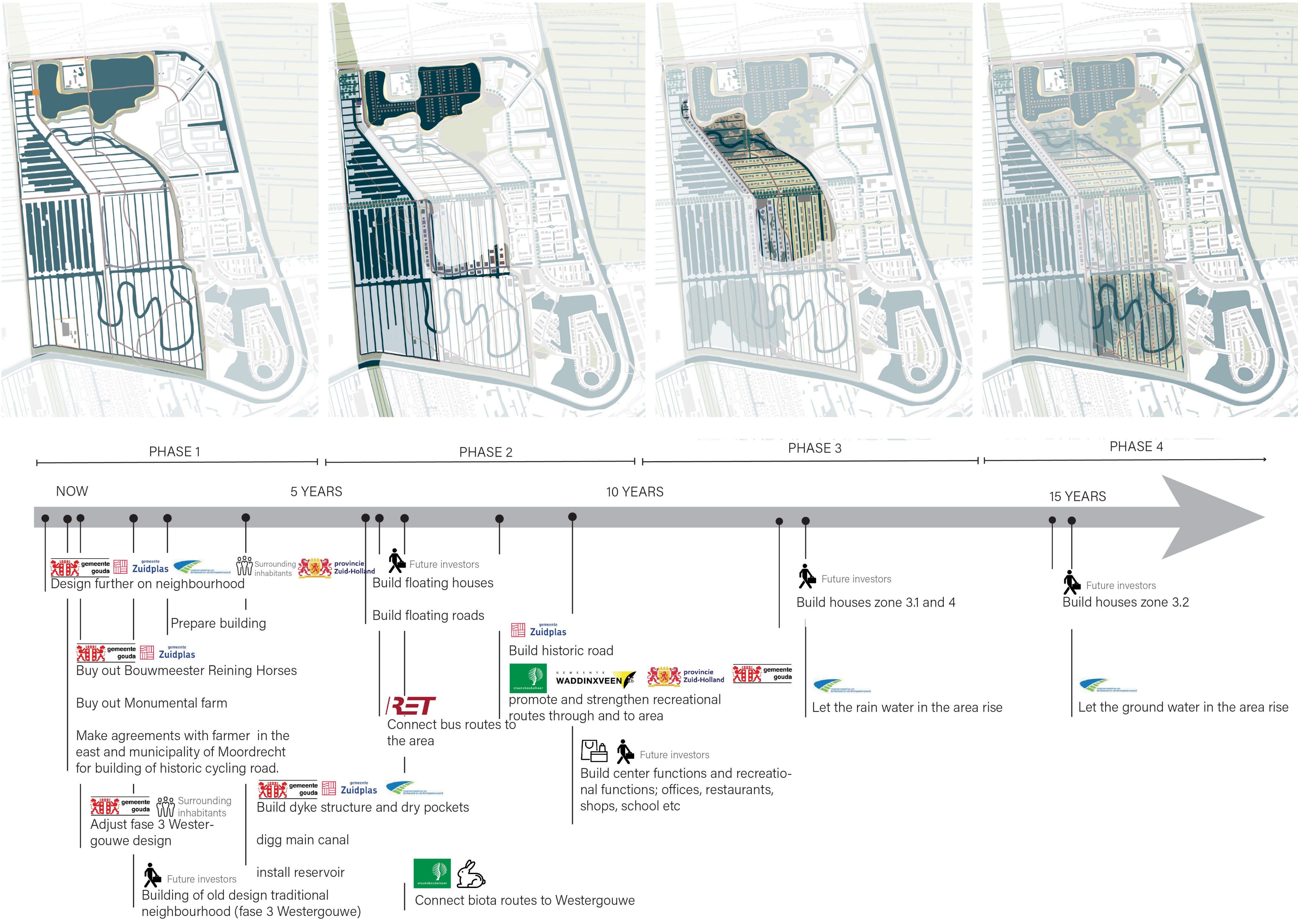


Figure 7.2.1 Phasing of Veenstad

The Veenstad design requires long-term planning and preparation. Rewetting with rainwater can be done relatively early but raising polder levels will take much longer to realize. The neighborhood will be built in phases.

In the first phase, a lot of preparation needs to be done, like contacting stakeholders and further design of Westergouwe. After the design is prepared, the basis for the design could be created; the water system. This should be done in close collaboration with the waterboard.

In phase 2 the reservoir is finished and the floating houses are placed. This is done relatively early in the process to create funding for the big nature that is created in Westergouwe.

Phase 3 consists of the build of most of zone 3 and zone 4 entirely.

And finaly in the last phase, zone 3 in is finished in the south.

Complete rewetting of the area can be done after the building of the houses and infrastructure. This is unfortunate as the vision states that rewetting should be done as soon as possible, but is done after the realization as it is very difficult to build in wet conditions.

H8. CONCLUDING

Main Research Question:
How can the urban living environment on rewetted peat soil contribute to carbon storage in Westergouwe?

The Dutch are famous for their water management and their polder structure. But this polder system is finite. With rising sea levels and climate change, maintaining the polder structure as we are using it now, would be unsustainable. With the existing system come problems like subsidence, biodiversity loss, and the emission of CO_2 because of the oxidation of the underlying peat soil.

SRQ 1. How could carbon be stored?

One of the ways to store carbon from the atmosphere is in peat soil. Another way to store carbon is to store carbon in vegetation or the built environment itself. Buildings and infrastructure can be made with construction materials such as timber, bamboo, blown cellulose, cork, and hempcrete which store carbon for the duration of the life span of the material.

SRQ 2. How could peat soil be preserved and restored?

Peat soil is one of the biggest carbon reservoirs so the preservation of peatlands is very important. Peat can be preserved by creating a high humidity level which creates anoxic conditions that slow down the decomposition processes of organic matter. Growing peat in (re)carbon city can be done by raising the water level since water is the most essential component determining the development of peatlands. This is done bit by bit, to keep wetting the peat moss through time

SRQ 3. How can you build on peat soil without destroying it?

In order to preserve the peat soil, the area is rewetted. In addition, traditional housing would put too much weight on the peat soil and cause subsidence. This means that the traditional housing types do not apply to Veenstad. To densify Westergouwe, new building typologies need to be introduced. New housing types like floating houses, amphibious housing, and houses on poles, do accommodate a wet soil underneath.

SRQ 4. What is the urban ecosystem?

The urban ecosystem is the system that encompassed the entire complex of physical components that make up the biome's environment in the city. This includes biotic factors but also the abiotic factors of the system. The urban ecosystem should be extensively designed for in future neighborhoods. The ecosystems and landscape are at the core of (re)carbon city. By designing with and not against nature, the design provides numerous services for mankind, such as food, materials, energy, water, etc. This provides opportunities to regulate the carbon cycle and the climate. Designing with nature does not only mitigate the climate but it is also a way to adapt to the climate.

SRQ 5. What is existing poldersystem in Westergouwe?

The polder in which Westergouwe is situated is the Zuidplaspolder. To grow peat in Westergouwe, the water quality of the area should be good and the nutrient level should be nutrient-poor to neutral. The Zuidplaspolder houses too many polluting functions to rely on the polder water, so it would be advised to use rainwater or filtered water.

SRQ 6. Which other environmental problems does the built environment face in Gouda?

Gouda faces heat stress which in the future will worsen because of global warming and densification. Also, water nuisance and flooding risk are big environmental problems we need to design for. Heavy rainfall in Westergouwe is causing rain to collect in some places and if primary flood defenses would fail, the water in Westergouwe would be about 3.35 meters high. This is why it is important to create a big water buffer for water storage in times of drought and storage for excessive precipitation.

SRQ 7. Which biotopes are found in Westergouwe?

The project location is right now mostly consisting of old agricultural grasslands and some wetlands where nature still needs to rewild.

SRQ 8. What are the design principles for a carbon-storing neighborhood in Westergouwe?

In the chapter Generalizing. A pattern language is shown that is collected while doing the (re)carbon city project. The patterns show design principles for the next designers/planners that take on the assignment of creating a (re) carbon city.

SRQ 9. How would a carbon-storing living environment in Westergouwe look like?

A carbon-storing living environment would not look like the traditional neighborhood that you and I would know of. In Veenstad, this means that buildings, infrastructure, and public space are different. These spaces can be floating or raised. Think about floating wooden pathways, floating planters, waterways, or raised wooden pathways to your own balcony. Around your house, you find several peat biotopes, that are dependent on a regulation system for the water level. Rainwater is collected in a reservoir which is also combined with floating houses to make optimal use of the space. The neighborhood is a dynamic space that changes with the seasons and years as the ecology changes and the peat grows.

SRQ 10. How can this design be implemented through time?

(re)Carbon cities call for an integrated approach where national, regional, and local governments play a key role in guiding the realization. A design objective like this calls for a long-term strategy and design for the future.

SRQ 11. What of the design could be applied somewhere else?

The last subquestion is answered in the next chapter transferring. Recommendations are done for locations that have the same urgency to implement this type of neighborhood. Also, a method is extracted out of the project, showing the elements that need to be taken into account. And lastly in the reflection are the lessons learned and limitations of the research project written.

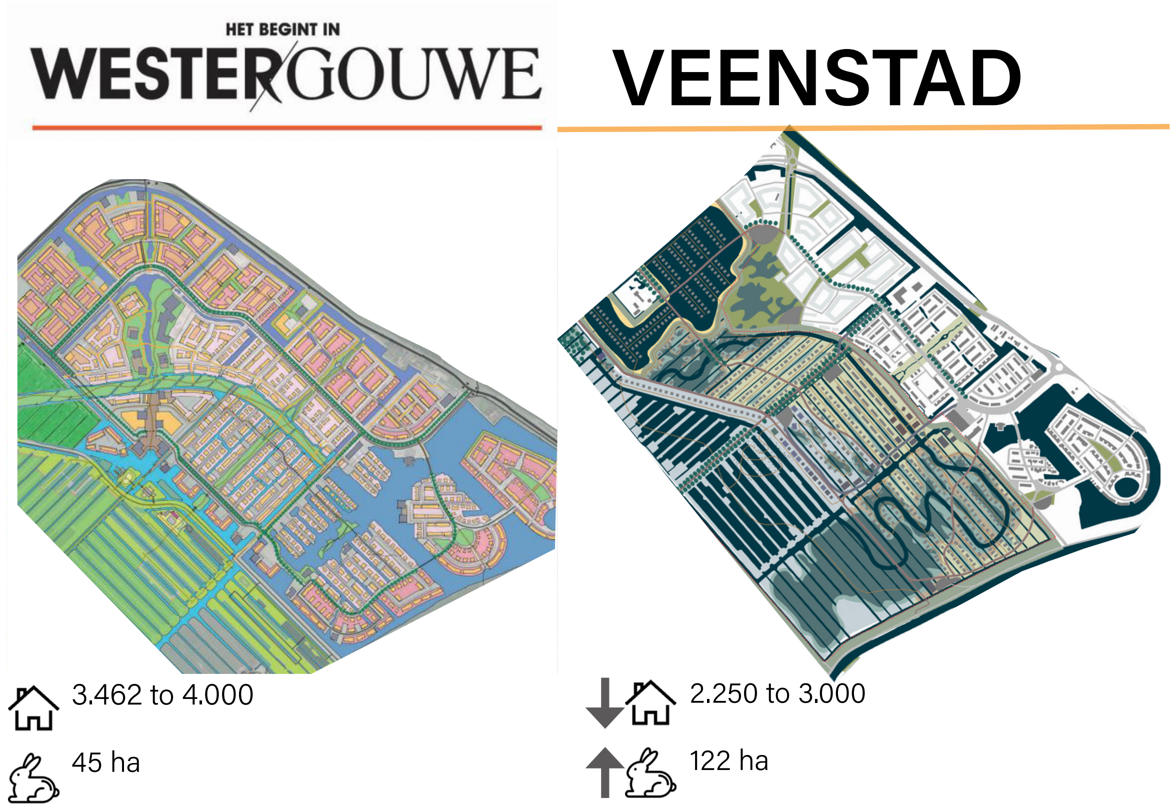


Figure 7.2.1 Comparison original structure vision and Veenstad

MRQ: How can the urban living environment on rewetted peat soil contribute to carbon storage in Westergouwe?

To answer the main research question, Carbon can be stored in the urban living environment by the preservation of the peat soil, planting vegetation, and the use of carbon-storing materials. And with strategic use of space and different water management, the urban living environment can even grow peat soil to store even more carbon and to some extent reverse the sinking of the land. By realizing Veenstad an estimation is made that 610.000 - 1.830.000 kg of carbon could be stored and the emissions of 22590 kg of CO_2 per year can be prevented.

The design not only contributes to carbon storage but also contributes to increasing biodiversity and providing housing. Unfortunately, in comparison with traditional neighborhoods, Veenstad does not provide as much housing. And it does not reach the planned housing goals for Westergouwe. However, the author believes that this kind of neighborhood is worth researching and designing further, as it provides numerous other benefits for its inhabitants and the city as a whole, like providing water buffering and also the reduction of pumping costs.

The research problem has rarely been studied in combination with the built environment which is why research is limited. Because of this, the research on which these conclusions are made are also limited. Thus, this project should be seen as a framework for further research and a way to inspire. Nevertheless, this design is relevant for many locations in the Netherlands. So hopefully municipalities will create their own specific (re)carbon city.

H9. TRANSFERRING

CONTENT CHAPTER 9

In this chapter is looked at the project as a whole and looked at what could apply to next researchers and designers to realize their own (re)carbon city. A method is substracted as a guideline. Secondly, other locations are pointed out where this project could be relevant to realize. This does also include a map of Staatsbosbeheer's relevant locations.

Figure 9.0 Westergouwe ditches, by author

9.1 FOR URBAN DESIGNERS, PLANNERS AND LANDSCAPE ARCHITECTS

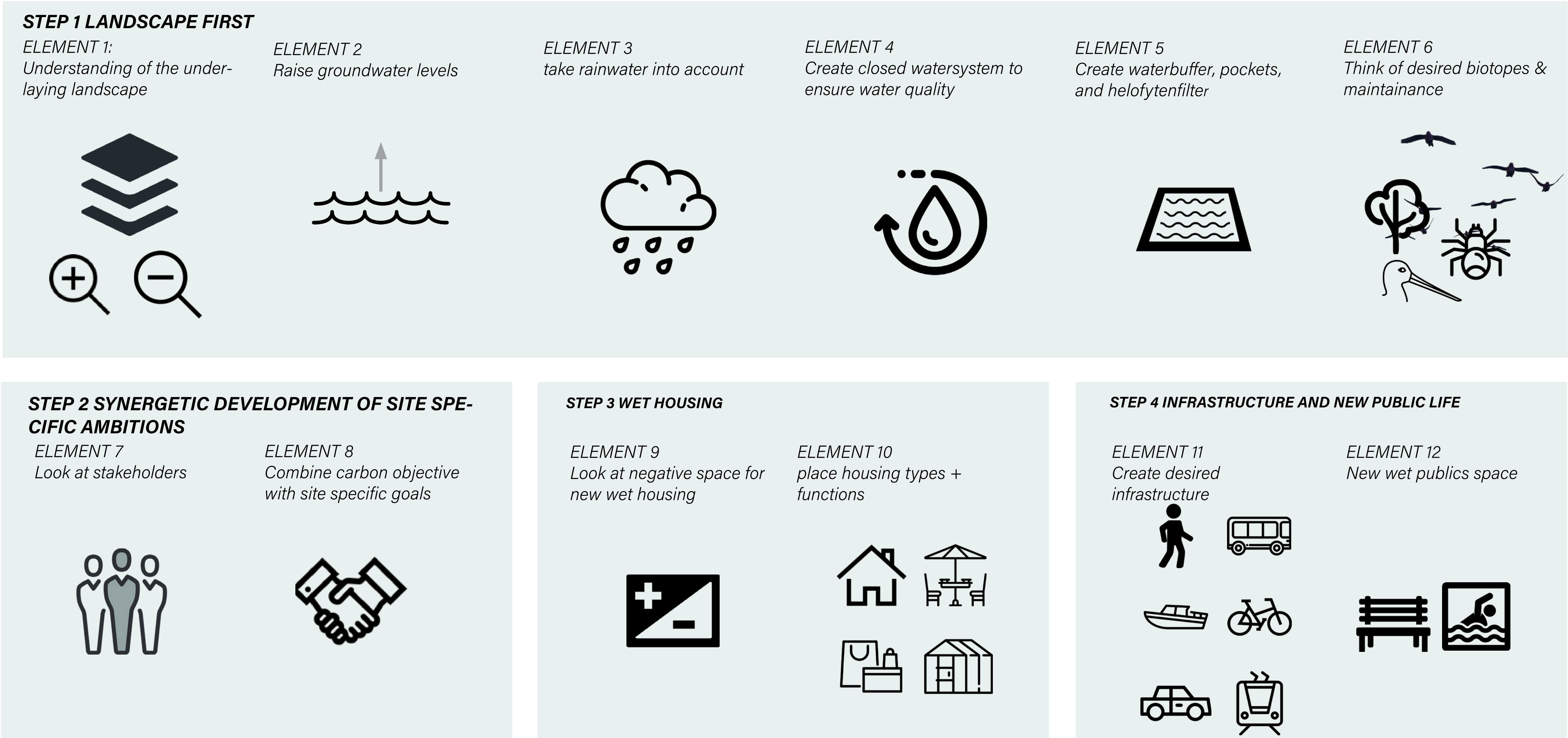


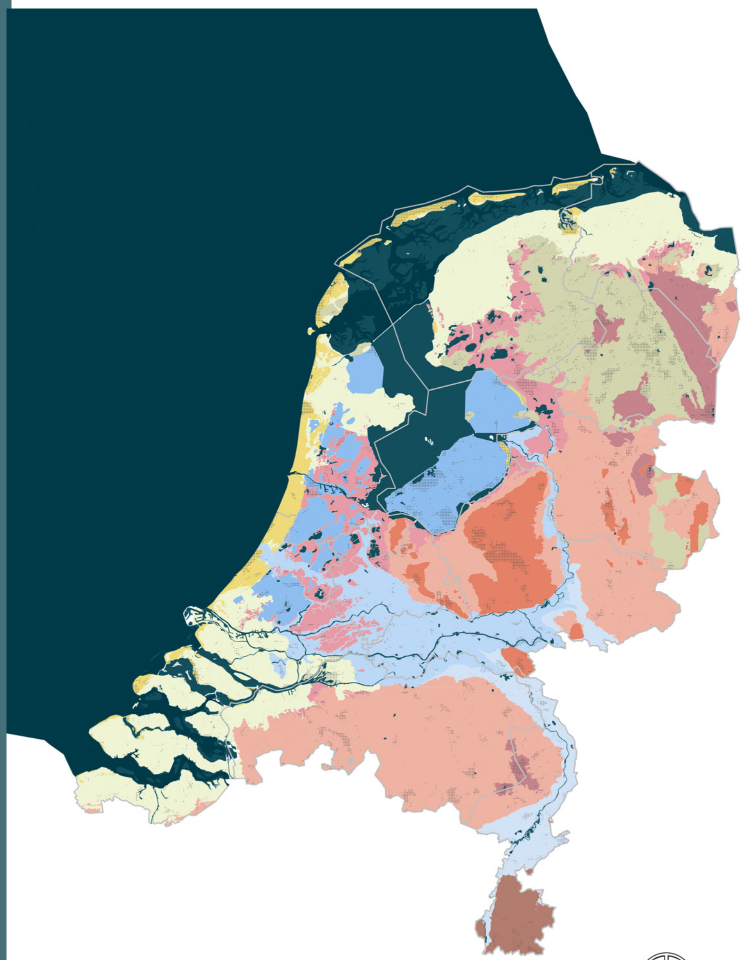
Figure 9.1.1 Extracted method

To transfer the knowledge of this project to other designers, planners, and other plan makers, the author has substracted a method to make their own (re)carbon city. Step 1 would be to put the landscape first. Subjects like soil layers. water quality, water levels, water nuisance, flooding risk, drought, and biota are subjects that first need to be analyzed, to create a basis for the design. By creating a landscape-based design, "a transdisciplinary effort is done to safeguard sustainable and coherent development, to guide and shape changes which are brought about by socio-economic and environmental processes, and to establish local identity through tangible relationships to a region" (Nijhuis & Jauslin, 2015). It creates the basis for other aspects of the design, creating sustainable guidelines and conditions for further development.

The next step is consisting of the people, as the author calls it. In this phase should be talked with local and regional stakeholders about their site-specific goals. This is important as rewetting the polder area will require local initiatives and custom-made strategies. This big transition can be a way to develop other local interests and ambitions that can be synergetically realized. This way support and willingness to participate in the transition are created early on. Looking back at the project, the author should have done this step in more detail and earlier in the process to make a more feasible design. So the author hopes that through this method, others do not make this mistake.
After creating the conditions in steps 1 and 2, the neighborhood can be set up with steps 3 and 4.

9.2 FOR OTHER SITES; LETS GO NATIONAL!

Peat can be grown on all kinds of soil within the right conditions, like water quality and water level. So this design can be applied in most areas where water can be isolated.
Nevertheless, the priority to implement this design is in some places higher than in other locations. One reason to implement this design is in places where the soil holds a lot of carbon. The areas with the most carbon in the soil are colored blue and green in figure 1.1.2.2. Staatsbosbeheer owns a lot of areas where the need to preserve peat and its carbon would be high.



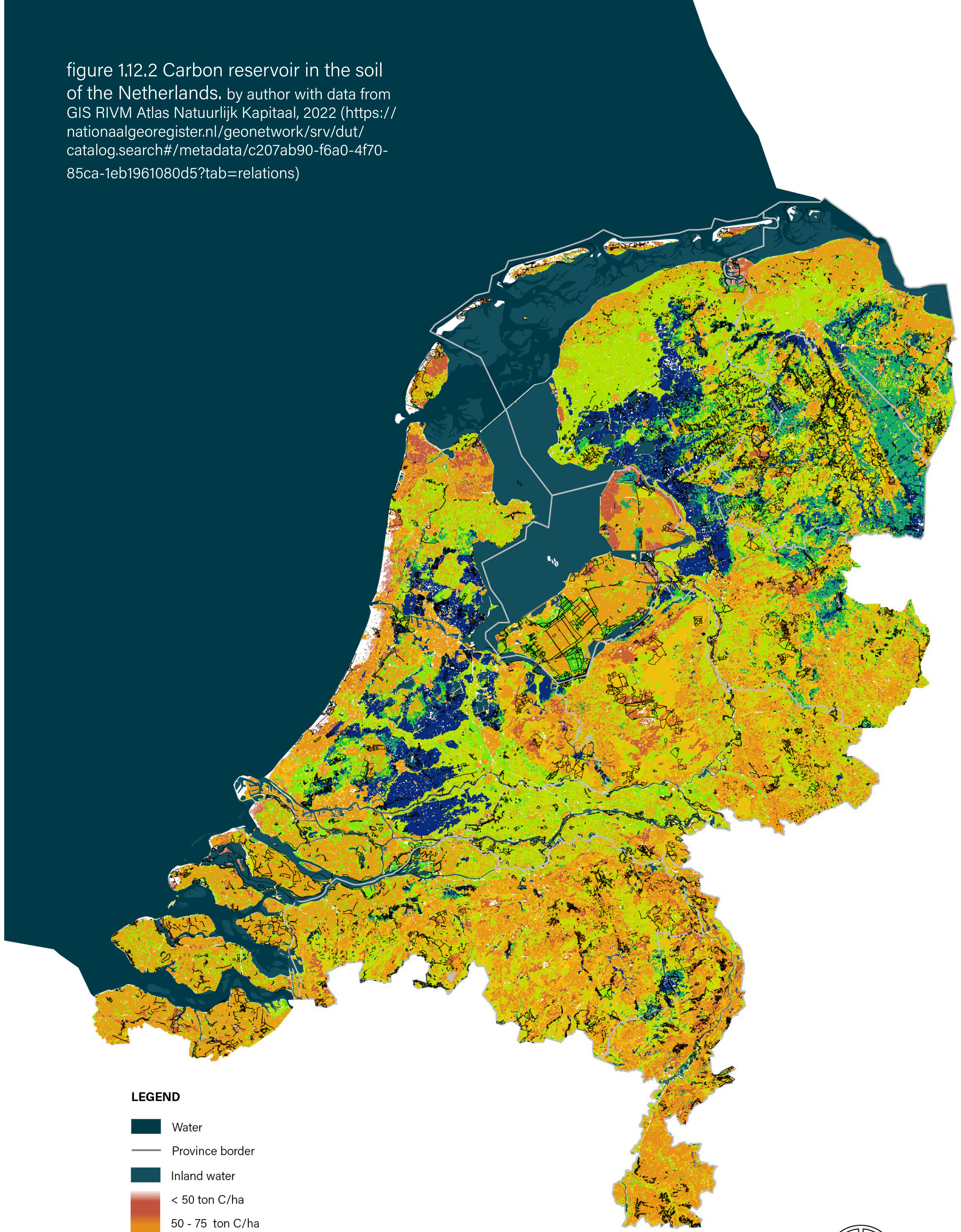
LEGEND

- Water
- Province border
- Inland water
- Seawalls and inner dune edges
- Sea clay polders
- Low peatland
- Polders
- River area
- River terraces
- Moraines
- Boulder clay area
- Wind born sand area
- Former high peat areas
- Hills and loes area

0 25 50 km

Figure 9.2.1 soil map of the Netherlands

figure 1.12.2 Carbon reservoir in the soil of the Netherlands. by author with data from GIS RIVM Atlas Natuurlijk Kapitaal, 2022 (https://nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/metadata/c207ab90-f6a0-4f70-85ca-1eb1961080d5?tab=relations)



LEGEND

- Water
- Province border
- Inland water
- < 50 ton C/ha
- 50 - 75 ton C/ha
- 75 - 100 ton C/ha
- 100 - 125 ton C/ha
- 125 - 150 ton C/ha
- 150 - 175 ton C/ha
- > 175 ton C/ha
- Staatsbosbeheer property

0 25 50 km

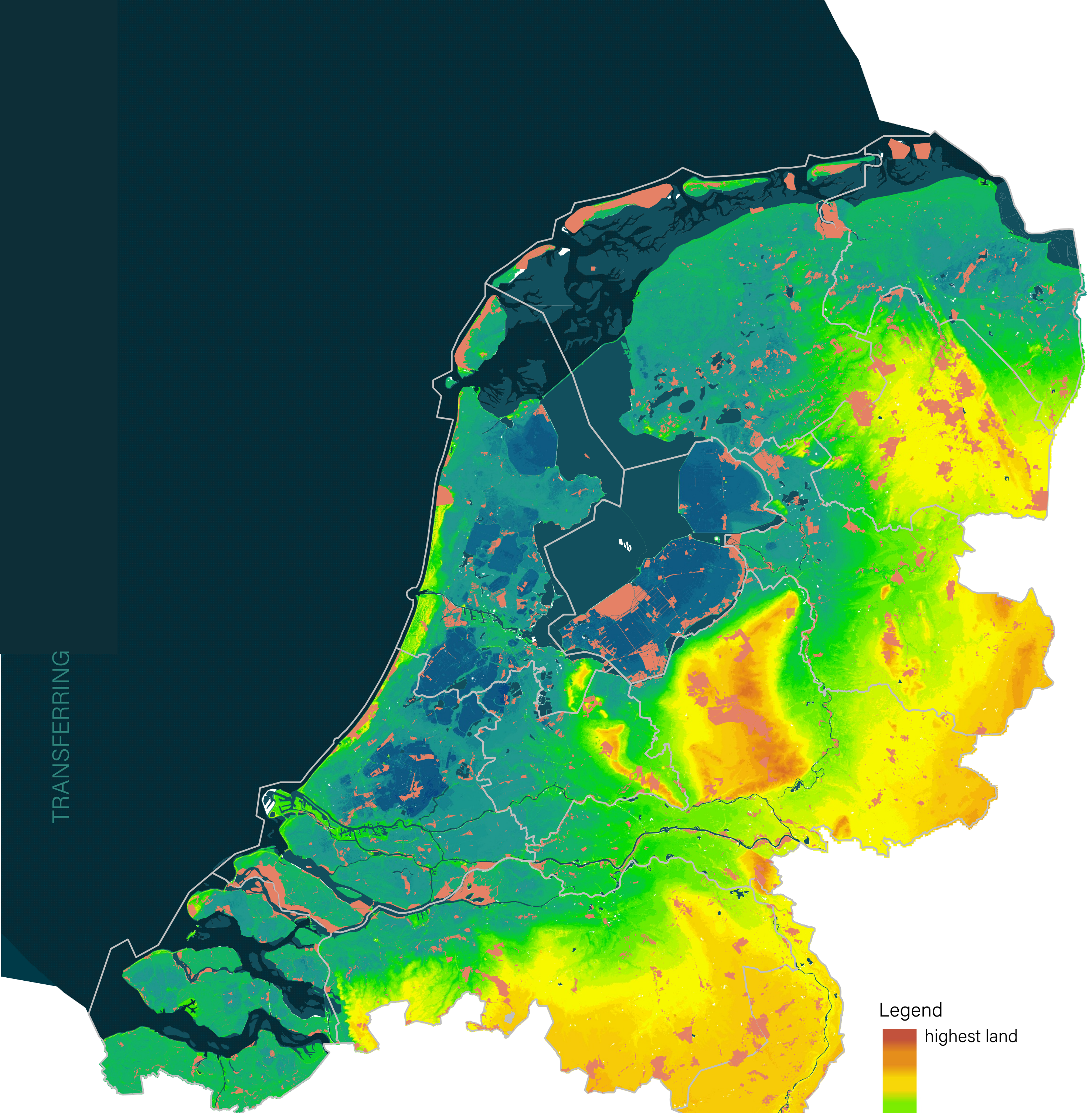


Figure 9.2.2 Height map of the Netherlands

But with climate change and rising sea levels, the urgency does not only limit the design to the carbon crisis but also to the polder system itself. The knowlegde of how to design for a wet environment becomes more important every day as the polder system is not an infinite system and the limits of this system are seen already today. This makes it so that the design is relevant for the whole of the western Netherlands.

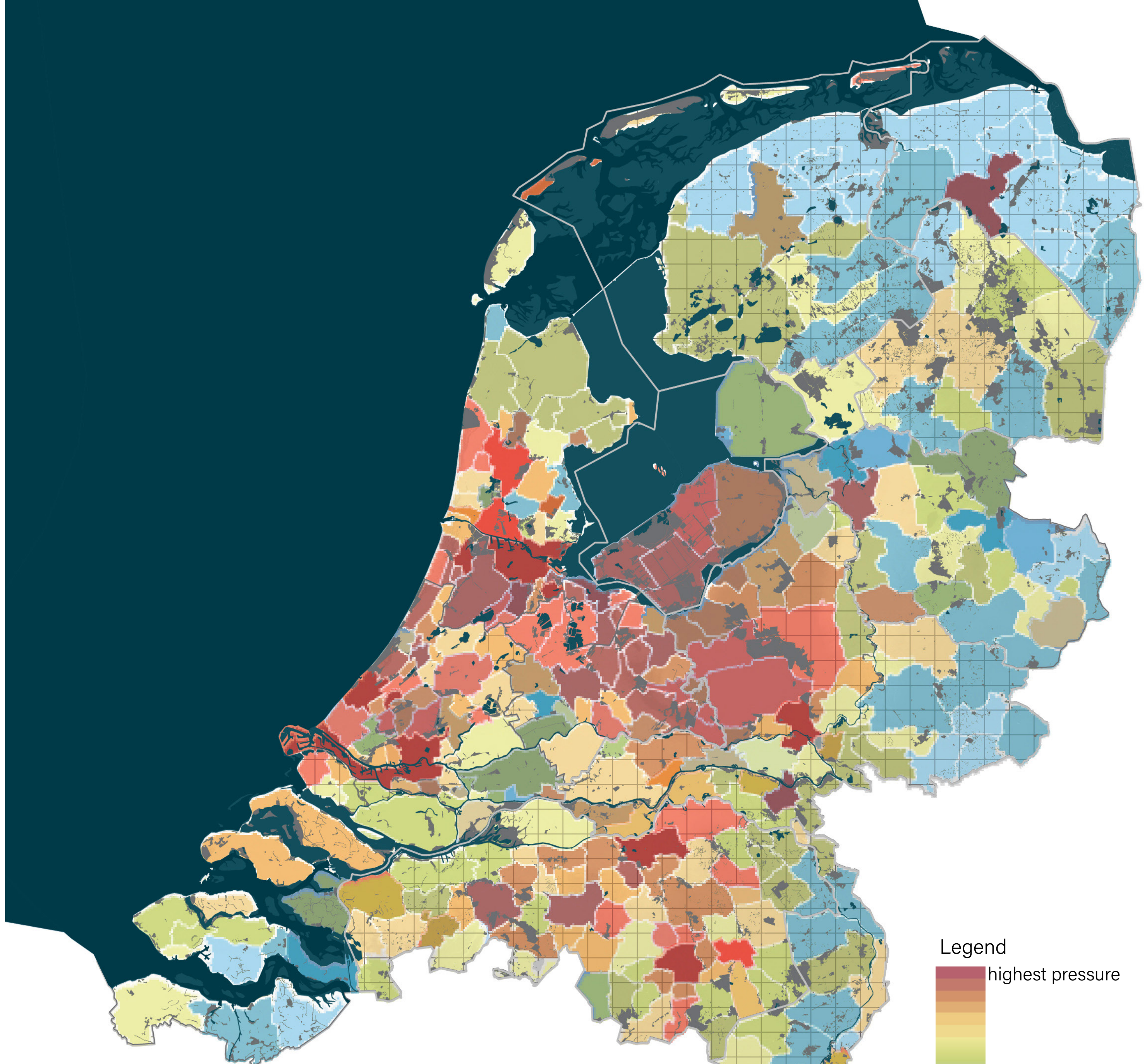


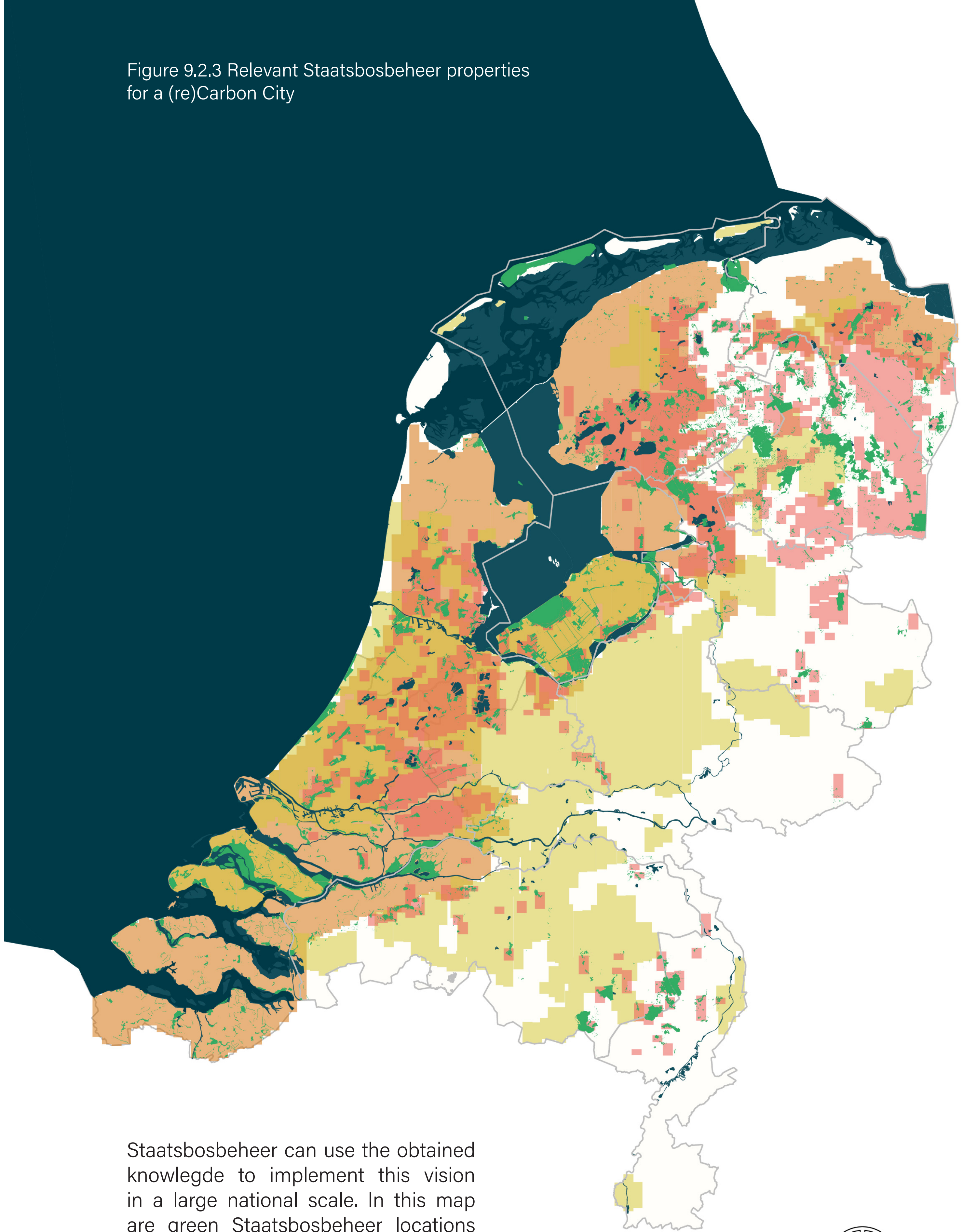
figure 1.12.3 Housing pressure in the netherlands. made with data from "BPD. nl"by BPD, 2021. (https://www.bpd.nl/actueel/persberichten/woningdruk-blijft-hoog-in-randstad-en-loopt-op-in-aantal-provincies/)

As the housing pressure in the west of the Netherlands is high, this design could be a solution, combining carbon storage and preservation and providing housing. However, this solution does not provide all housing needed to suffice the housing need as it is not possible to build with heavy materials in this way. This is why this solution could be a good example for municipalities where the need for housing is not that high.

Examples of municipalities that meet all three urgencies:

De ronde Venen
Nieuwkoop
Woerden
Ouder Amstel
Amsterdam
Wijdemeren
Eemnes
Bunschoten
Bodegraven
Reeuwwijk
Alphen aan den Rijn
Oudewater
Krimpenerwaard
Pijnacker
Nootdorp
Rotterdam
Zoeterwoude
Capelle aan den Ijssel
Kaag en Braasem
Voorschoten
Gooise meren
Landsmeer
Watermeer
Oostzaan
Zaanstad
Wassenaar
Uitgeest
Alkmaar
Midden Delfland

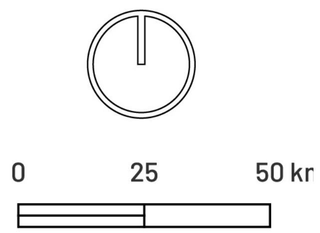
Figure 9.2.3 Relevant Staatsbosbeheer properties for a (re)Carbon City



LEGEND

- Water
- Province border
- Inland water
- 1. Carbon preservation urgency
- 2. Low land urgency
- 3. Housing pressure urgency
- SBB property within or near urgency areas 1. and 2.

Staatsbosbeheer can use the obtained knowlegde to implement this vision in a large national scale. In this map are green Staatsbosbeheer locations shown where at least the carbon preservation urgency or the low-land urgency exists. Many locations have all three urgencies, so staatsbosbeheer could be a significant player in realising (re)Carbon cities.



H10. REFLECTING

CONTENT H9

This chapter includes a reflection on the (preliminary) results of the research and design in the graduation phase. It discusses:

1. Lab: the relationship between the graduation topic and the studio topic and the master Urbanism,
2. Approach: whether the first planned approach worked or not and the relationship between the research and design,
3. Approach and scientific, societal and profesional relevance; the understanding of the research objective and the scientific/societal value and transferability of the project. This is also discussed in relation to the approach and methods
4. Ethical considerations : the ethical issues and dillemmas that the author encountered while working on the project.
5. An argument: the feedback that was given by the mentors, and how this was translated back into the work
6. Lessions learned: What the author has learned from the overall project

Lab

The studio under which this project is done is Urban ecology and Eco-cities (UECL). This studio uses the lens of urban ecology to improve the quality of life and environmental performance in cities through planning, especially design and engineering (TU Delft, 2021). In this studio the focus is on landscape/urban design or urban planning that uses the basic natural qualities often described in ecosystem services or nature-based solutions/urbanism.
Making site-specific spatial design or spatial strategies that improve spatial quality, and better spatial experiences. The project is fitting into this studio because the basic natural qualities, the peat polder landscape, are taken as a starting point for the design of a new neighborhood improving the quality of life for the (surrounding) inhabitants. This design is based on scientific research which is also one of the learning objectives of the master Urbanism (TUDelft, 2022).

Approach

My project approach consisted of six parts. This process was not a linear process but all parts are interrelated. These were: a theoretical framework, an analysis of some important topics related to the problem, an outcome of the design assignment, a small strategy, a recommendation for other designers and Staatsbosbeheer, and lastly a pattern language. This last part is used as a bridge between research in the theoretical framework & analysis, and design.
Christopher Alexander (1977) described a pattern as: "Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice". In this description, he mentions that the pattern consists of a description of a solution, but patterns could also be for example made from criteria. I mostly used pattern language as a way to structure and understand a complex system to create a coherent design. As the design problem of this project is a relatively scarcely researched subject, this was difficult to do. But with the pattern language slowly my knowledge grew.
For the design, I envisioned using the maximization method, consisting of three phases; maximization, optimization, and integration. With this method, the user makes focusing solely on one subject/flow, which is then combined into one design that optimizes all subjects/flows. The integration phase brings together the optimization with another subject and makes the design more feasible/realistic (Wandl & Aalbers, 2022). In the end, I chose to use instead of the maximization method, a scenario design. "A scenario can be considered an experimental stage set for design and planning practice, and a conceptual framework for disciplinary development." (Jonas, 2001, p.1) After beginning with the first phase of my envisioned maximization, the outcomes were focused on a housing type and I felt like I did not grasp the project area enough to make a draft design combining just the housing types. However, this study was a way of getting to know the area. After this exploration, I identified the most important elements for the basis of the design, and these elements led to the final master plan. It was a way to research through design. As Jonas describes it, the method was a way to set the stage for the design; to just start the design process.

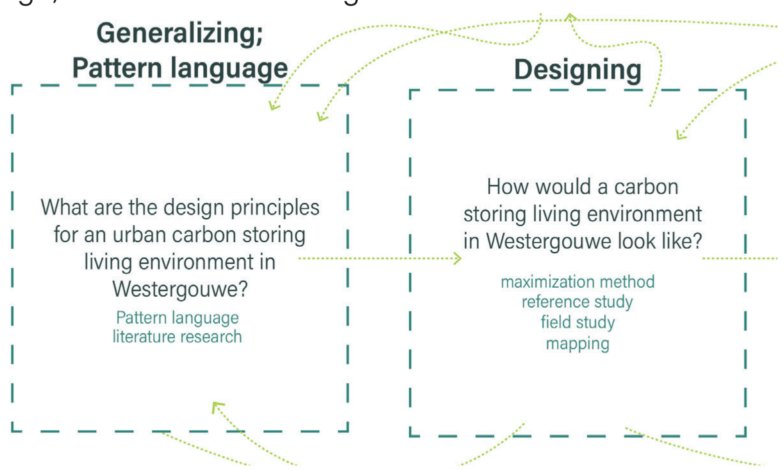


Figure 10.1 part of the research approach

Approach and scientific, societal and profesional relevance

Scientific framework
The final design is a proposal and prediction of how the peat landscape and the urban environment could come together while simultaneously storing carbon and preventing carbon to be emitted into the air. As carbon storage in peat is just widely acknowledged in the climate agreements of November 2021, it has not been studied extensively, nevertheless studied in an urban context. This causes the project to be based on the limited literature that can be found. Nevertheless, this project can serve as a framework in which more detailed research can be done.

Societal framework
The urgency of this project is rising. Current society is causing climate change by worsening the greenhouse effect (Dunn et al., 2021). With the reduction of greenhouse gasses, within a few years, the increase in global temperatures would begin to level out. What we do today will be felt in less than a decade (NASA, 2022). Of course, this project only would reduce emissions by a small part, but If implemented in for example in the Western Netherlands, or globally in other places where the relevancy is high, this would have a significant share in flattening the curve.

Staatsbosbeheer and Carbon storage
One of the partners of the studio Urban Ecology and Ecocities is Staatsbosbeheer. Staatsbosbeheer is aiming to create 5000 hectares of extra forest and raise the water level in 5000 hectares of peatlands to contribute to the sequestration of CO_2. Staatsbosbeheer manages more than 30,000 hectares of peatland itself (Staatsbosbeheer, 2021). This design, if realized would contribute to this vision with 22590 kg of CO_2 every year prevented into the air, 30.330.000 kg of carbon stored in the buildings, and 610.000 to 1830.000 kg of carbon stored additionally in the peat. In other words, the stored amount of carbon of approximately the emissions of 6726 to 7190 cars per year and the additional reduction of CO_2 emissions of 2000 cars in the next 4 centuries. These are the quantities of just one neighborhood. This means that if Staatbosbeheer would implement this idea in some of its properties, it could contribute to its vision substantially.

Professional framework
As I am educated as an urban designer, much disciplinary-specific knowledge on soil, nature, and ecology is lacking. To get a basic understanding of the problems while facing the design aim, experts in ecology, water technology, the polder system, and landscape technology were consulted. Nevertheless, more research is needed in order to make the design feasible and ready to build. As an urban designer, the author has knowledge about:
'how to integrate social, cultural, economic and political perspectives with the natural and man-made conditions of the site in order to shape and plan for more sustainable development. Analysing urban environments and urban developments academically in a critical way and proposing new solutions for an efficient, sustainable, and liveable organization and management of the urban environment.' (TUDelft, 2022).
The project is valuable in the sense that the combination of techniques and expert knowledge is translated into a vision of what it would look like and what social, cultural, and economic perspectives would come into play. Because of the difficulty in technical aspects, more time is spent on the combination of environmental factors like water management and ecology in combination with the built environment. If more time would be spent, more research should be done on these three topics. This project is mainly done by performing desk studies, research by design, and some expert interviews, however, this study could have been improved by interviewing the municipality and more stakeholders to get a more in-depth understanding of the project and to create a realistic design.
Hopefully, this project will serve as an inspiration for other designers and plan makers and will be built on in the future.

Ethical considerations

Less housing, more nature
While doing this project, the author came across some ethical dilemmas. One of them is the consideration of this new type of housing. The Netherlands is facing a growing demand for housing. To meet the growing demand, a total of 845,000 homes will have to be built between 2020 and 2030. The project does not allow high-density homes. This would mean that if this vision would be implemented in the whole of the Western Netherlands, we would not meet the demand. Nevertheless, the quality of life for its inhabitants and surrounding inhabitants would increase. Designers and plan makers would have to make use of this type of neighborhood strategically.
This type of Neighborhood is now typically designed for the higher segment. Without more advances to make this type of neighborhood also inclusive for people with less money, this type of neighborhood would not be suitable for the entire housing demand.

Islands
By raising the groundwater level, I understands that a lot of land in the west of the Netherlands will be unusable with the current use they now have. To make the decision to impact a lot of inhabitants' life in this way is a very difficult process. The first places to implement would have to be strategically picked. Also, extensive conversations need to be held with the stakeholders involved.

REFLECTING

<u>The world of tomorrow</u>
Another ethical consideration to make is that we do not only design for our generation but also for our children and their children. We could say that they have as much right for the same quality of life as our generation does. This means that we have to think about our actions on the planet so that they could have the right to clean air, access to nature, and live in a healthy environment.

An argument

The main feedback I was given was that the storyline was not yet very coherent and understandable. The carbon crisis can be a subject that is invisible to the naked eye. This makes it difficult to understand why this design should be implemented for people that are not experts in the matter. In this project, I have tried to make this phenomenon more concrete by quantifying the benefits and translating the scientific literature into a visible design. So that people who would come to live in the neighborhood would find it an attractive place to live in although they do not understand the carbon crisis.

Lessons learned

What I have learned while making this project is how to plan and set my own assignment. The art of making a schedule is a difficult one. Baselmans (2022) describes 4 steps:
Step 1: Write down all the tasks you need to do.
Step 2: Prioritize the tasks.
Step 3: For all tasks, indicate approximately how much time they will take. Also, calculate some extra time per task. In addition, it is good to take a 15-minute break after 1 hour of concentrated work.
Step 4: Make your final plan now. Determine how much time you have to work on these tasks. You can then schedule the tasks based on the prioritization and time effort
As this is a year-long project, I had to do this process repeatedly. For step 1, the list of tasks would change throughout the process as I got a better understanding of the assignment that I eventually formulated. I found step 2 in perticular quite difficult. Especially because of the broad spectrum of the assignment of the master and the studio. Everything was possible. An assessment of what was most important to do at that moment was constantly occurring. Also, after a schedule was made, I would find it difficult to keep to that schedule. One of the reasons was because of all the things that could be done and the interrelation between the different parts. You would find me working on one thing and later found me working on something that needed to be adjusted because of the change in the other, not finishing the first thing first. This would also occur sometimes because of doing step 3 incorrectly. A lot of unexpected things happen while working on a project and if there was no extra time calculated, this would mess up the planning too.

Another thing that I have learned from this project is that I want to continue to work in the eco-city specialization in my further career.
"Urban ecology is the systems-based understanding of biotic and physical elements that occur in urban areas. It recognizes the interactions between natural systems and social and cultural systems, among others. Urban ecology places particular importance on the primacy of natural systems in contributing to livelihoods, well-being and resilience, and focuses on the interdependence of key resources (such as food, water and energy) and their impact on city development" (United Nations, 2016 p.27).
In this quote is explained that urban ecology uses the natural system as the basis for the development of urban environments that improve livelihoods, well-being, and resilience; In other words, contributes to the quality of life. Through this project, I learned about the importance of designing with the existing landscape. Letting the landscape serve as a basis for the built environment. The method that is filtered from this project also confirms that.

REFLECTING

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Figure 6.1.1.3 Reedland biotope collage:
Ranunculus lingua. Flogaus-Faust, R. (7 July 2018) Greater spearwort (Ranunculus lingua) near Allmendingen, Germany [Photograph] CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=70885110 at 27-05-2022 used in collage

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Figure 6.6.1.4 Willow forest biotope collage:
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Hippolais icterina. By Stefan Berndtsson (June 16, 2014) Härmsångare / Icterine Warbler Hippolais icterina, Petgardetrask, Kalmar, Sweden - Härmsångare / Icterine Warbler, [Photograph] CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=41276489 at 27-05-2022 used in collage

Figure 6.6.2.3 mesotrophic marchland biotope collage
Botshol. Provincy Utrecht. Botsholl [Photograph] from https://www.provincie-utrecht.nl/onderwerpen/natuur/natura-2000/botshol#gebied at 7-3-2022

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Circus cyaneus. Matteo Sorrentino (25 februari 2009) Eigen werk Albanella reale maschio (Circus cyaneus) blauwe kiekendief. [Photograph] CC BY-SA 3.0 https://creativecommons.org/licenses/by-sa/3.0/ from https://commons.wikimedia.org/wiki/File:Albanella-reale-maschio.jpg#/media/Bestand:Albanella-reale-maschio.jpg at 17-03-2022 used in collage

Pedicularis palustris. Peters, K. (28 October 2006) -- Fabelfroh 11:17, - zelf gefotografeerd, [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1316706 used in collage

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Dactylorhiza praetermissa. by Hans Hillewaert (28 May 2008) Southern Marsh-orchid. Belgium [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4127758 at 17-03-2022 used in collage

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Caltha palustris Door TeunSpaans, (22 April 2004) [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1740903 at 17-03-2022 used in collage

Figure 6.6.2.4 Quacking bog biotope collage
Succisa pratensis Blauwe knoop By Kristian Peters (25 February 2007)-- Fabelfroh 09:32, (UTC) [Photograph] CC BY-SA 3.0, from https://commons.wikimedia.org/w/index.php?curid=1714771 at 25-0-2022 used in collage

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Liparis loeselii. by Kristian Peters (02 july 2006) Fabelfroh 07:12, 30 October 2006 (UTC) - zelf gefotografeerd, [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1323595 at 25-01-2022 used in collage

Pyrgus malvae. by Svdmolen - Eigen werk, (5 May 2007) Pyrgus malvae [Photograph] CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=2060991 at 25-01-2022 used in collage

Lycaena dispar. by Jeffdelonge - Eigen werk, (31 July 2005) Lycaena dispar large copper, male. Vantoux-et-Longevelle 70700 France. [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=249261 at 25-01-2022 used in collage

Boloria selene. by James Lindsey (26 May 2004) Picture taken in Commanster, Belgian High Ardennes . Species: Boloria selene. [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1680620 at 25-01-2022 used in collage

Sphagnum quinquefarium By HermannSchachner - Own work,(9 October 2014) Sphagnum quinquefarium [Photograph] CC0, https://commons.wikimedia.org/w/index.php?curid=46099497 at 25-0-2022 used in collage

Hammarbya paludosa By Len Worthington (4 July 2010) - https://www.flickr.com/photos/lennyworthington/5914417855/in/photolist-a1CWnD-CyJ2Kr, [Photograph] CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=77567488 at 25-0-2022 used in collage

Figure 6.6.2.5 Birch alder forest biotope collage
Birch alder march forest. O+bn Natuurkennis. N14.02 Hoog- en laagveenbos.
[Photograph] From https://www.natuurkennis.nl/natuurtypen/n14-vochtige-bossen/n14-02-hoog-en-laagveenbos/algemeen-n1402/ at 26-04-2022

Alnus glutinosa. Common Alder.' By Lazaregagnidze - Own work,(9 August 2011) [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=32415874 at 24-05-2022 used in collage

Andromeda polifolia. By Lavendelhei.jpg: Wenkbrauwalbatrosderivative work: Bff - Lavendelhei.jpg, Andromeda polifolia flowering in nature reserve Koppången, Dalarna, Sweden [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=7639232 at 24-05-2022 used in collage

Hypericum elodes By Aroche - Own work, (17 August 2006) Hypericum elodes in Sheep's Head, Ireland (West Cork .[Photograph] CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=1063456 at 24-05-2022 used in collage

Dendrocopos major. By Usitea - Own work, (11 April 2013) Grote bonte specht. [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=26059809 at 24-05-2022 used in collage

Comarum palustre. By gailhampshire (3 June 2011) Unknown description. from Cradley, Malvern, U.K - ?, [Photograph] CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=50003189 at 24-05-2022 used in collage

Carex nigra. By Jeroenj - Own work, (8 May 2019) Carex nigra in wet grassland [Photograph] CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=100212348 at 24-05-2022 used in collage

Gentiana pneumonanthe. Door Oscar den Uijl - Eigen werk, (5 August 2012) Gentiana pneumonanthe in the Gildehauser Venn, Germany. [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=20564919 at 24-05-2022 used in collage

6.6.3.3 Humid peat reed meadow biotope collage
Humid peat meadow. O+bn Natuurkennis. N10.01 Nat schraalland [Photograph] From https://www.natuurkennis.nl/natuurtypen/n10-vochtige-schraalgraslanden/n10-01-nat-schraalland/algemeen-n1001/ at 26-04-2022

Erica tetralix. By gailhampshire (14 June 2017) from Cradley, Malvern, U.K - Cross-leaved Heath Erica tetralix, Catacol Isle of Arran. NR915495 [Photograph] CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=73442335 at 9-6-2022 used in collage

6.6.3.4 Alder forest biotope collage
Alder forest. By Dimaniznik - Own work, (26 September 2015) [Photograph] CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=49986414

viola palustris . By Ocrdu - Own work ,(28 April 2013) [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27273528

carex echinata. By Elke Freese - Self-photographed, (1 June 2006) [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1067399

Myotis daubentoni By Gilles San Martin (2009) from Namur, Belgium - Myotis daubentoni, [Photograph] CC BY-SA 2.0, from https://commons.wikimedia.org/w/index.php?curid=7850696 at 13-6-2022 used in collage

Figure 6.6.4.3 Peat meadow biotope collage
peat meadow. O+bn Natuurkennis. N10.02 Vochtig hooiland [Photograph] from https://www.natuurkennis.nl/natuurtypen/n10-vochtige-schraalgraslanden/n10-02-vochtig-hooiland/Algemeen-N1002/ at 26-04-2022

Sphagnum quinquefarium By HermannSchachner - Own work, (9 October 2014) [Photograph] CC0, https://commons.wikimedia.org/w/index.php?curid=46099497 at 25-0-2022 used in collage

Hammarbya paludosa By Len Worthington - [Photograph] https://www.flickr.com/photos/lennyworthington/5914417855/in/photolist-a1CWnD-CyJ2Kr, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=77567488 at 25-0-2022 used in collage

Figure 6.6.2.5 Birch alder forest biotope collage
Birch alder march forest. O+bn Natuurkennis. N14.02 Hoog- en laagveenbos. [Photograph] From https://www.natuurkennis.nl/natuurtypen/n14-vochtige-bossen/n14-02-hoog-en-laagveenbos/algemeen-n1402/ at 26-04-2022

Alnus glutinosa. By Lazaregagnidze - Own work, (9 August 2011) Alnus glutinosa Common Alder.' [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=32415874 at 24-05-2022 used in collage

Andromeda polifolia. By Lavendelhei.jpg: Wenkbrauwalbatrosderivative work: Bff - Lavendelhei.jpg, Andromeda polifolia flowering in nature reserve Koppången, Dalarna, Sweden [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=7639232 at 24-05-2022 used in collage

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Comarum palustre. By gailhampshire (3 June 2011) Unknown description. from Cradley, Malvern, U.K - ?, [Photograph] CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=50003189 at 24-05-2022 used in collage

Carex nigra. By Jeroenj - Own work, (8 May 2019) Carex nigra in wet grassland [Photograph] CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=100212348 at 24-05-2022 used in collage

Gentiana pneumonanthe. by Oscar den Uijl - Eigen werk, (5 August 2012) Gentiana pneumonanthe in the Gildehauser Venn, [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=20564919 at 24-05-2022 used in collage

6.6.3.3 Humid peat reed meadow biotope collage
Humid peat meadow. O+bn Natuurkennis. N10.01 Nat schraalland [Photograph] From https://www.natuurkennis.nl/natuurtypen/n10-vochtige-schraalgraslanden/n10-01-nat-schraalland/algemeen-n1001/ at 26-04-2022

Erica tetralix. By gailhampshire (14 June 2017) Catacol Isle of Arran. NR915495 from Cradley, Malvern, U.K - Cross-leaved Heath Erica tetralix, [Photograph] CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=73442335 at 9-6-2022 used in collage

6.6.3.4 Alder forest biotope collage
Alder forest. By Dimaniznik - Own work, (26 September 2015) [Photograph] CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=49986414

viola palustris . By Ocrdu - Own work, [Photograph] CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27273528

carex echinata. By Elke Freese - Self-photographed, [Photograph] CC BY-SA 3.0, 1 June 2006https://commons.wikimedia.org/w/index.php?curid=1067399

Myotis daubentoni By Gilles San Martin (2009) from Namur, Belgium - Myotis daubentoni, [Photograph] CC BY-SA 2.0, from https://commons.wikimedia.org/w/index.php?curid=7850696 at 13-6-2022 used in collage

Figure 6.6.4.3 Peat meadow biotope collage
peat meadow. O+bn Natuurkennis. N10.02 Vochtig hooiland [Photograph] from https://www.natuurkennis.nl/natuurtypen/n10-vochtige-schraalgraslanden/n10-02-vochtig-hooiland/Algemeen-N1002/ at 26-04-2022

Figure 6.6.4.4 Peat roughs biotope collage:
Peat rough. Prachtlint.nl. Bloemrijke ruigte [Photograph] from https://www.prachtlint.nl/inrichten/hoge-bloemrijke-ruigte/ at 15-5-2022

Figure 6.6.4.5 Ash Alder forest biotope collage
Ash alder forest. Johnny Cornelis. Voorjaarsbeeld van een Essen-Elzenbos. Natuurtype: Essen-Elzenbos. Bos t'Ename, Oudenaarde. [Photograph] From https://www.ecopedia.be/natuurtypes/natuurtype-essen-elzenbos at 26-4-2022

APPENDIX

CONTENT

APPENDIX 1 WATER STORAGE CAPACITY

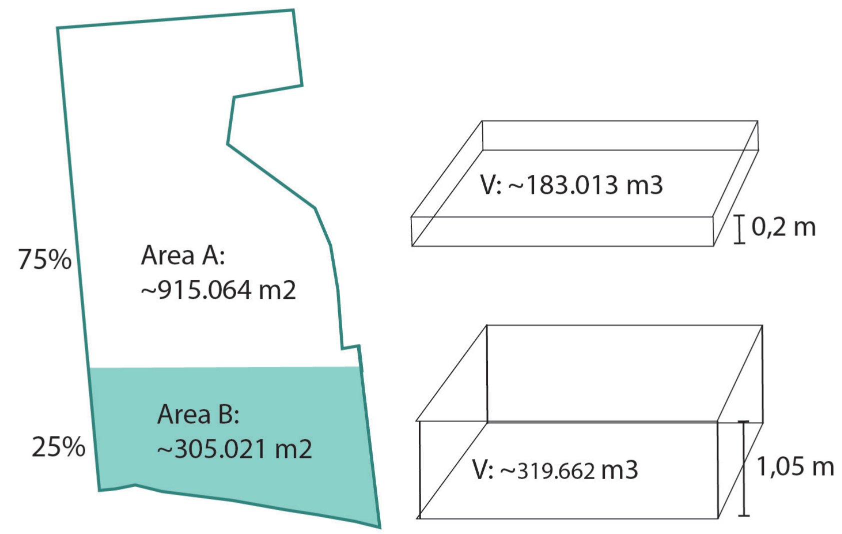
Area:
~ 1.220.085 m2

853 mm rain per year
evaporation: 853-412 = 441 mm/year left
= ~ 502.675 m3 rain that can be collected

Volume B= rain - AreaA*storing capacityA
502.675 m3 - (915.064*0,2) =
502.675 m3 - 183.013 m3 = ~319.662 m3

height B= VolumeB / AreaB
~319.662 /305.021 =
h= 1,05 m

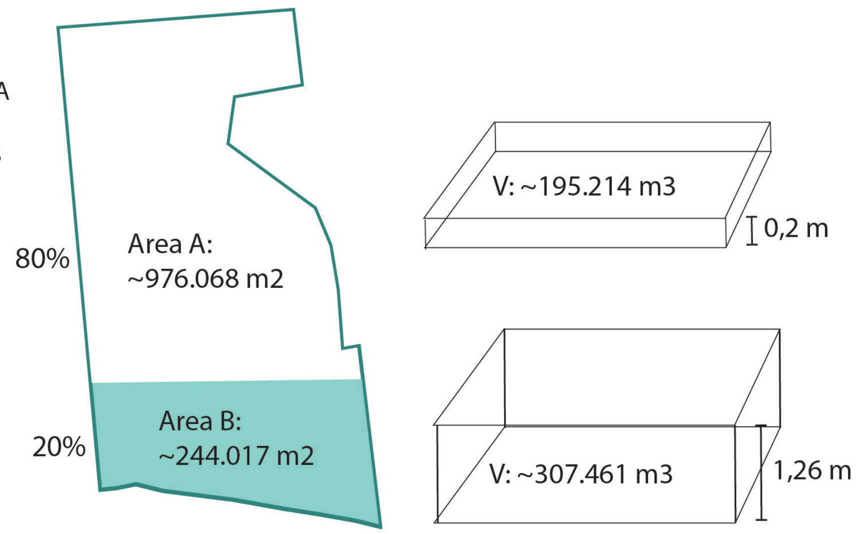
If area A is empty then
Volume B / AreaA = hA
319.662 m3/915.064 m2 =
then area B could fill area A 0,34 m



Volume B= rain - AreaA*storing capacityA
502.675 m3 - (976.068*0,2) =
502.675 m3 - 195.213,6 m3 = 307.461 m3

height B= VolumeB / AreaB
307.461 /244.017 =
h= 1,26 m

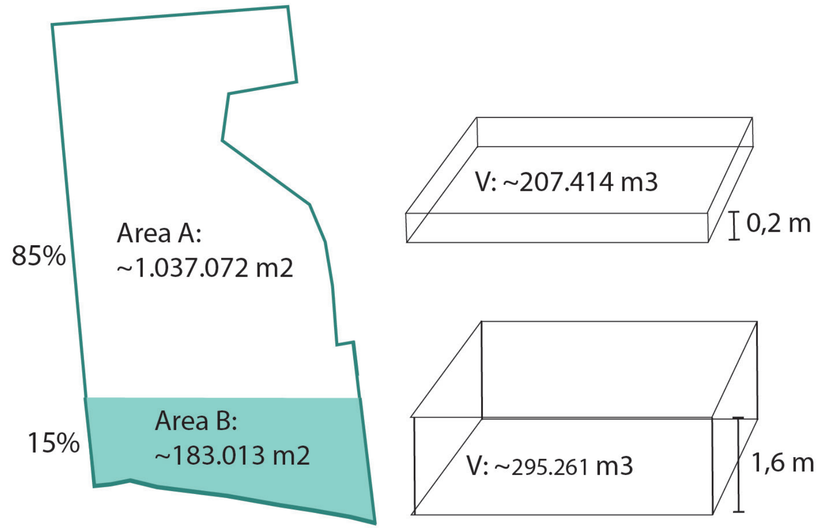
If area A is empty then
Volume B / AreaA = hA
307.461 m3/976.068 m2 =
then area B could fill area A 0,31 m



Volume B= rain - AreaA*storing capacityA
502.675 m3 - (1.037.072*0,2) =
502.675 m3 - 207.414,4 m3 = ~295.261 m3

height B= VolumeB / AreaB
~295.261 /183.013 =
h= 1,6 m

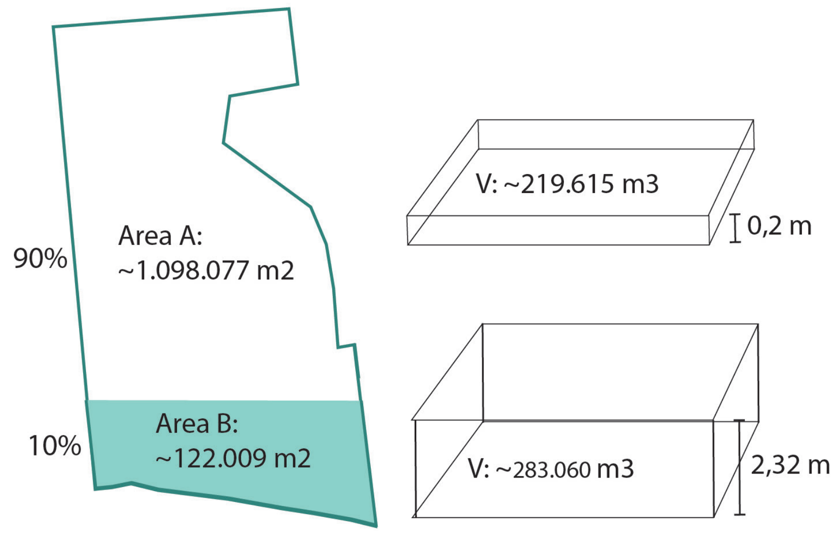
If area A is empty then
Volume B / AreaA = hA
295.261 m3/1.037.072 m2 =
then area B could fill area A 0,28 m



Volume B= rain - AreaA*storing capacityA
502.675 m3 - (1.098.077*0,2) =
502.675 m3 - 219.615,4 m3 = ~283.060 m3

height B= VolumeB / AreaB
~283.060 /122.009 =
h= 2,32 m

If area A is empty then
Volume B / AreaA = hA
283.060 m3/1.098.077 m2 =
then area B could fill area A 0,26 m



APPENDIX

APPENDIX 2.1 LIST OF SPECIES LIVING RESERVOIR

REEDLAND
NL- LATIN - EN

Plants:

- *Bitterzoet - Solanum dulcamara - Woody nightshade*
- *Blauw glidkruid - Scutellaria galericulata-Common skullcap*
- *Blauwe watereereprijs - Veronica anagallis-aquatica- Blue water speedwell*
- *Echte valeriaan - Valeriana officinalis - Valerian*
- *Galigaan - Cladium mariscus Great fen-sedge*
- *Gele lis - Iris pseudacorus -Yellow iris*
- *Gele waterkers - Rorippa amphibia- Great yellowcress*
- *Gevleugeld hertshooi - Hypericum tetrapterum- Square stalked St. John's wort*
- *Gewone dotterbloem - Caltha palustris subsp. palustris - Marsh marigold*
- *Gewone engelwortel - Angelica sylvestris - Wild angelica*
- *Gewone smeerwortel - Symphitum officinale - Common comfrey*
- *Gewone waterbies - Eleocharis palustris- Common spike-rus*
  Groot hoefblad - Petasites hybridus - Butterbur
- *Grote boterbloem - Ranunculus lingua Greater spearwort*
- *Grote egelskop - Sparganium erectum Branched bur-reed*
- *Grote kattenstaart - Lythrum salicaria - Purple loosestrife*
- *Grote lisdodde - Typha latifolia - Bulrush*
- *Grote watereppe - Sium latifolium - Great water parsnip*
- *Grote waterweegbree - Alisma plantago-aquatica- Common water-plantain*
- *Grote wederik - Lysimachia vulgaris - Yellow loosestrife*
- *Haagwinde - Convolvulus sepium - Hedge bindweed*
- *Harig wilgenroosje - Epilobium hirsutum - Great willowherb*
- *Heelblaadjes - Pulicaria dysenterica - Common fleabane*
- *Kale jonker- Cirsium palustre- Marsh thistle*
- *Kalmoes - Acorus calamus - Sweetflag*
- *Kleine egelskop - Sparganium emersum - Branched bur-reed*
- *Kleine lisdodde - Typha angustifolia - Lesser bulrush*
- *Kleine watereppe - Berula erecta Lesser water - parsnip*
- *Koninginnekruid - Eupatorium cannabinum- Hemp agrimony*
- *Lange ereprijs - Veronica longifolia - Long-leaf speedwell*
- *Mannagras - Glyceria fluitans - Floating sweetgrass*
- *Mattenbies - Schoenoplectus lacustris - Common club-rush*
- *Moerasandoorn - Stachys palustris - Marsh Woundwort*
- *Moeraslathyrus - Lathyrus palustris - Marsh pea*
- *Moerasmelkdistel - Sonchus palustris - Marsh sow-thistle*
- *Moerasspirea - Filipendula ulmaria - Meadowsweet*
- *Moerasvergeet-mij-nietje - Myosotis scorpioides subsp. scorpioides - Water forget-me-not*
- *Moeraswederik - Lysimachia thyrsiflora - Tufted loosestrife*
- *Moeraswolfsmelk - Euphorbia palustris - Marsh spurge*
- *Moeraszegge - Carex acutiformis - Lesser pond-sedge*
- *Oeverzegge - Carex riparia - Great pond-sedge*
- *Pitrus - Juncus effusus - Soft rush*
- *Pluimzegge - Carex paniculata subsp. paniculata - Greater tussock sedge*
- *Poelruit - Thalictrum flavum - Common meadow-rue*
- *Pijlkruid - Sagittaria sagittifolia - Arrowhead*
- *Riet - Phragmites australis - Common reed*

Plants:

- *Rietgras - Phalaris arundinacea - Reed Canary-grass*
- *Slangenwortel - Calla palustris - Bogarum*
- *Slanke waterkers - Nasturtium microphyllum - Narrow-fruited water-cress*
- *Stijve zegge - Carex elata - Tufted sedge*
- *Viltige basterdwederik - Epilobium parviflorum - Hoary willowherb*
- *Watertorkruid - Oenanthe aquatica - Fine-leaved water-dropwort*
- *Waterzuring - Rumex hydrolapathum - Water dock*
- *Wolfspoot - Lycopus europaeus - Gipsywort*
- *Zwanenbloem - Butomus umbellatus - Flowering rus*

Jansen, S. (2022), Flora of Dutch habitats. Table of the most common plants in the Netherlands selected by environment. unpublished manuscript. april 2022. TU-Delft

WILLOW FOREST
NL- LATIN - EN

Trees:

- *Es - Fraxinus excelsior - Common ash*
- *Schietwilg - Salix alba - White willow*
- *Turkse kraakwilg en Basterdkraakwilg -Salix euxina en Salix x fragilis - Crack-willow*
- *Zomereik - Quercus robur - Pedunculate oak*
- *Zwarte els - Alnus glutinosa - Common alder*
- *Zwarte populier - Populus nigra - Black poplar*

Shrubs and low trees:

- *Amandelwilg - Salix triandra - Almond willow*
- *Bittere wilg - Salix purpurea - Purple willow*
- *Gelderse roos - Viburnum opulus - Guelder rose*
- *Grauwe wilg en Rossige wilg - Salix cinerea - Grey willow*
- *Hazelaar - Corylus avellana - Hazel*
- *Katwilg - Salix viminalis - Basket willow*
- *Vogelkers - Prunus padus - Bird cherry*
- *Zwarte bes - Ribes nigrum - Black currant*
- *Bosanemoon - Anemone nemorosa - Wood anemone*
- *Bosereprijs - Veronica montana - Wood speedwell*
- *Boswederik - Lysimachia nemorum - Yellow pimpernel*
- *Elzenzegge - Carex elongata - Elongated sedge*
- *Gele dovenetel - Lamiastrum galeobdolon - Yellow archangel*
- *Groot heksenkruid - Circaea lutetiana Enchanter's-nightshade*
- *Groot springzaad - Impatiens nolitangere - Touch-me-not balsam*
- *Hop - Medicago lupulina - Hop*
- *Knikkend nagelkruid - Geum rivale - Water avens*
- *Kruipend zenegroen - Ajuga reptans - Bugleweed*
- *Moerasvaren - Thelypteris palustris - Marsh fern*
- *Slanke sleutelbloem - Primula elatior - Oxlip*
- *IJle zegge - Carex remota - Remote sedge*

Herbs:

- *Bosanemoon - Anemone nemorosa - Wood anemone*
- *Bosereprijs - Veronica montana - Wood speedwell*
- *Boswederik - Lysimachia nemorum - Yellow pimpernel*
- *Elzenzegge - Carex elongata - Elongated sedge*
- *Gele dovenetel - Lamiastrum galeobdolon - Yellow archangel*
- *Groot heksenkruid - Circaea lutetiana Enchanter's-nightshade*
- *Groot springzaad - Impatiens nolitangere - Touch-me-not balsam*
- *Hop - Medicago lupulina - Hop*
- *Knikkend nagelkruid - Geum rivale - Water avens*
- *Kruipend zenegroen - Ajuga reptans - Bugleweed*
- *Moerasvaren - Thelypteris palustris - Marsh fern*
- *Slanke sleutelbloem - Primula elatior - Oxlip*
- *IJle zegge - Carex remota - Remote sedge*
- *Adderwortel - Persicaria bistorta - Common bistort*
- *Echte koekoeksbloem - Silene flos-cuculi - Ragged robin*
- *Echte valeriaan - Valeriana officinalis - Valerian*
- *Gestreepte witbol - Holcus lanatus - Yorkshire-fog*
- *Gewone brunel - Prunella vulgaris - Selfheal*
- *Gewone dotterbloem - Caltha palustris subsp. palustris - Marsh marigold*
- *Gewone smeerwortel - Symphitum officinale - Common comfrey*
- *Grote pimpernel - Sanguisorba officinalis - Great burnet*
- *Grote ratelaar - Rhinanthus angustifolius - Greater yellow rattle*
- *Grote wederik - Lysimachia vulgaris - Yellow loosestrife*
- *Hennegras - Calamagrostis canescens - Purple small-reed*
- *Kale jonker- Cirsium palustre - Marsh thistle*
- *Kleine ratelaar - Rhinanthus minor - Little yellowrattle*
- *Kleine valeriaan - Valeriana dioica - Marsh valerian*
- *Knolsteenbreek - Saxifraga granulata - Meadow saxifrage*
- *Kruipende boterbloem - Ranunculus repens - Creeping buttercup*
- *Margriet - Leucanthemum vulgare - Oxeye daisy*
- *Moerasbeemdgras - Poa palustris - Swamp meadow-grass*
- *Moeraskruiskruid - Jacobaea paludosa - Fen ragwort*
- *Moerasrolklaver - Lotus pedunculatus - Large bird's-foot-trefoil*
- *Moerasspirea - Filipendula ulmaria - Meadowsweet*
- *Moerasvergeet-mij-nietje - Myosotis scorpioides subsp. scorpioides - Water forget-me-not*
- *Moerasviooltje - Viola palustris - Marsh violet*
- *Moeraswalstro - Galium palustre - Marsh bedstraw*
- *Moeraswederik - Lysimachia thyrsiflora T - ufted loosestrife*
- *Moeraszegge - Carex acutiformis - Lesser pond-sedge*
- *Penningkruid - Lysimachia nummularia - Creeping-Jenny*
- *Pinksterbloem - Cardamine pratensis - Cuckoo-flower*
- *Poelruit - Thalictrum flavum - Common meadow-rue*
- *Ruwe smele - Deschampsia cespitosa - Tufted hair-grass*

Jansen, S. (2022), Flora of Dutch habitats. Table of the most common plants in the Netherlands selected by environment. unpublished manuscript. april 2022. TU-Delft

APPENDIX 2.2 LIST OF SPECIES PEAT NATURE

MESOTROPHIC MARCHLAND

NL- LATIN - EN

Plants:

- *Armbloemige waterbies - Eleocharis quinqueflora - Few-flowered spike-rush*
- *Bevertjes - Briza media - Quaking grass*
- *Brede orchis - Dactylorhiza majalis - Broad-leaved marsh orchid*
- *Duinrus - Juncus anceps - Northern green rush*
- *Echt duizendguldenkruid - Centaurium erythraea - Common centaury*
- *Geelhartje - Linum catharticum - Fairy flax*
- *Grote kattenstaart - Lythrum salicaria - Purple loosestrife*
- *Grote ratelaar - Rhinanthus angustifolius - Greater yellow rattle*
- *Kleine ratelaar - Rhinanthus - minor Little yellowrattle*
- *Kleine valeriaan - Valeriana dioica - Marsh valerian*
- *Knopbies - Schoenus nigricans - Black bog-rush*
- *Kruipwilg - Salix repens - Creeping willow*
- *Moeraswalstro - Galium palustre - Marsh bedstraw*
- *Moeraswespenorchis - Epipactis palustris - Marsh helleborine*
- *Paddenrus - Juncus subnodulosus - Blunt-flowered rush*
- *Parnassia - Parnassia palustris - Grass of parnassus*
- *Rietorchis - Dactylorhiza praetermissa - Spotted orchid*
- *Ruw walstro - Galium uliginosum - Fen bedstraw*
- *Sierlijke vetmuur - Sagina nodosa - Knotted pearlwort*
- *Slanke gentiaan - Gentianella amarella - Autumn gentian*
- *Stijve ogentroost - Euphrasia stricta - Rigid eyebright*
- *Strandduizendguldenkruid - Centaurium littorale - Seaside centaury*
- *Teer guichelheil - Anagallis tenella - Bog pimpernel*
- *Vleeskleurige orchis - Dactylorhiza incarnata - Early marsh-orchid*
- *Watermunt - Mentha aquatica - Watermint*
- *Zeegroene zegge - Carex flacca Glaucous sedge Zomprus - Juncus articulatus Jointed rush*

Plants:

- *Adderwortel - Persicaria bistorta - Common bistort*
- *Echte koekoeksbloem - Silene flos-cuculi - Ragged robin*
- *Echte valeriaan - Valeriana officinalis - Valerian*
- *Gestreepte witbol - Holcus lanatus - Yorkshire-fog*
- *Gewone brunel - Prunella vulgaris - Selfheal*
- *Gewone dotterbloem - Caltha palustris subsp. palustris- Marsh marigold*
- *Gewone smeerwortel - Symphitum officinale- Common comfrey*
- *Grote pimpernel - Sanguisorba officinalis - Great burnet*
- *Grote ratelaar - Rhinanthus angustifolius - Greater yellow rattle*
- *Grote wederik - Lysimachia vulgaris - Yellow loosestrife*
- *Hennegras - Calamagrostis canescens - Purple small-reed*
- *Kale jonker- Cirsium palustre - Marsh thistle*
- *Kleine ratelaar - Rhinanthus minor - Little yellowrattle*
- *Kleine valeriaan - Valeriana dioica - Marsh valerian*
- *Knolsteenbreek - Saxifraga granulata - Meadow saxifrage*
- *Kruipende boterbloem - Ranunculus repens- Creeping buttercup*
- *Margriet - Leucanthemum vulgare - Oxeye daisy*
- *Moerasbeemdgras - Poa palustris - Swamp meadow-grass*
- *Moeraskruiskruid - Jacobaea paludosa - Fen ragwort*
- *Moerasrolklaver - Lotus pedunculatus - Large bird's-foot-trefoil*
- *Moerasspirea - Filipendula ulmaria - Meadowsweet*
- *Moerasvergeet-mij-nietje - Myosotis scorpioides subsp. scorpioides- Water forget-me-not*
- *Moerasviooltje - Viola palustris - Marsh violet*
- *Moeraswalstro - Galium palustre - Marsh bedstraw*
- *Moeraswederik - Lysimachia thyrsiflora - Tufted loosestrife*
- *Moeraszegge - Carex acutiformis - Lesser pond-sedge*
- *Penningkruid - Lysimachia nummularia - Creeping-Jenny*
- *Pinksterbloem - Cardamine pratensis - Cuckoo-flower*
- *Poelruit - Thalictrum flavum - Common meadow-rue*
- *Ruwe smele - Deschampsia cespitosa - Tufted hair-grass*
- *Scherpe boterbloem - Ranunculus acris -Meadow buttercup*
- *Scherpe zegge - Carex acuta -Slender tufted-sedge*
- *Tweerijige zegge - Carex disticha -Brown sedge*
- *Veelbloemige veldbies - Luzula multiflora- Heath wood-rush*
- *Veldrus - Juncus acutiflorus - Sharp-flowered rush*
- *Waterkruiskruid - Jacobaea aquatica - Marsh ragwort*
- *Watermunt - Mentha aquatica - Watermint*
- *Wilde kievitsbloem - Fritillaria meleagris - Snake's head fritillary*
- *Witte munt - Mentha suaveolens - Round-leaved mint*
- *Zomerklokje - Leucojum aestivum - Summer snowflake*
- *Zomprus - Juncus articulatus - Jointed rush*
- *Zompvergeet-mij-nietje - Myosotis laxa subsp. cespitosa- Tufted forget-me-not*
- *Zwarte zegge - Carex nigra - Common sedg*

Jansen, S. (2022), Flora of Dutch habitats. Table of the most common plants in the Netherlands selected by environment. unpublished manuscript. april 2022. TU-Delft

Breeding birds:

- *Baardman - Panurus biarmicus*
- *blauwborst - Luscinia svecica*
- *blauwe kiekendief - Circus cyaneus*
- *bruine kiekendief,*
- *buidelmees,*
- *grote karekiet,*
- *grote zilverreiger,*
- *klein waterhoen,*
- *kleinst waterhoen,*
- *kwak,*
- *lepelaar - Platalea leucorodia*
- *porseleinhoen - Porzana porzana*
- *purperreiger - Ardea purpurea*
- *rietzanger - Acrocephalus schoenobaenus*
- *roerdomp - Botaurus stellaris*
- *snor,*
- *sprinkhaanzanger,*
- *waterral,*
- *woudaap.*

Dragonflies

- *Bruine korenbout - Libellula fulva)*
- *donkere waterjuffer,*
- *gevlekte glanslibel - Somatochlora flavomaculata*
- *gevlekte witsnuitlibel,*
- *glassnijder,*
- *noordse winterjuffer,*
- *sierlijke witsnuitlibel,*
- *vroege glazenmaker.*

Bij 12 (2021) N05.03 Veenmoeras (nieuw per 1-1-2021). Flora en Fauna. from https://www.bij12.nl/onderwerpen/natuur-en-landschap/index-natuur-en-landschap/natuurtypen/n05-moerassen/n05-03-veenmoeras/ at 25-04-2022

QUACKING BOG

Plants:

- Beenbreek - Narthecium ossifragum - Bog asphodel
- Bevertjes - Briza media - Quaking grass
- Biezenknoppen - Juncus conglomeratus - Compact rush
- Blauwe knoop - Succisa pratensis - Devil's-bit scabious
- Blauwe zegge - Carex panicea - Carnation sedge
- Cranberry - Vaccinium macrocarpon - Cranberry
- Draadgentiaan - Cicendia filiformis - Yellow centuary
- Eenarig wollegras - Eriophorum vaginatum - Hare's-tail cottongrass
- Geelgroene zegge - Carex demissa - Yellow sedge
- Gevlekte orchis - Dactylorhiza maculata - Heath spotted-orchid
- Gewone dophei - Erica tetralix - Cross-leaved heath
- Gewone waternavel - Hydrocotyle vulgaris - Marsh pennywort
- Kale jonker- Cirsium palustre - Marsh thistle
- Kleine valeriaan - Valeriana dioica - Marsh valerian
- Kleine veenbes - Vaccinium oxycoccos - Small cranberry
- Kleine zonnedauw - Drosera intermedia - Oblong-leaved sundew
- Klokjesgentiaan - Gentiana pneumonanthe - Marsh gentian
- Knolrus - Juncus bulbosus - Bulbous rush
- Kruipwilg - Salix repens - Creeping willow
- Lavendelhei - Andromeda polifolia - Bog rosemarym
- Liggend hertshooi - Hypericum humifusum - Trailing St. John's-wort
- Liggende vleugeltjesbloem - Polygala serpyllifolia - Heath milkwort
- Melkeppe - Peucedanum palustre - Milk parsley
- Moerashertshooi - Hypericum elodes - Marsh St. John's-wort
- Moerasstruisgras - Agrostis canina - Velvet bent
- Moerasviooltje - Viola palustris- Marsh violet
- Pijpenstrootje - Molinia caerulea - Purple moor-grass
- Ronde zonnedauw - Drosera rotundifolia- Round-leaved sundew
- Ruw walstro - Galium uliginosum - Fen bedstraw
- Snavelzegge - Carex rostrata- Bottle sedge
- Spaanse ruiter - Cirsium dissectum - Meadow thistle
- Sterzegge - Carex echinata - Star sedge
- Tandjesgras - Danthonia decumbens- Heath-grass
- Tormentil - Potentilla erecta - Tormentil
- Trekrus - Juncus squarrosus - Heath rush
- Valkruid - Arnica montana - Arnica
- Veelbloemige veldbies - Luzula multiflora - Heath wood-rush
- Veenbies - Trichophorum germanicum - Deergrass
- Veenpluis - Eriophorum angustifolium - Common cottongrass
- Veenreukgras - Anthoxanthum nitens- Holy grass
- Veldrus - Juncus acutiflorus Sharp-flowered rush
- Wateraardbei - Comarum palustre - Marsh cinquefoil
- Waterdrieblad - Menyanthes trifoliata - Bogbean
- Witte snavelbies - Rhynchospora alba - White beak-sedge
- Zeegroene muur - Stellaria palustris - Marsh stitchwort

Jansen, S. (2022), Flora of Dutch habitats. Table of the most common plants in the Netherlands selected by environment. unpublished manuscript. april 2022. TU-Delft

Plants:

- Drijvende egelskop - Sparganium angustifolium- Floating bur-reed
- Drijvende waterweegbree - Luronium natans- Floating water plantain
- Duizendknoopfonteinkruid - Potamogeton polygonifolius- Bog pondweed
- Gesteeld glaskroos - Elatine hexandra- Six-stamened waterwort
- Kleinste egelskop - Sparganium natans Least bur-reed
- Oeverkruid - Littorella uniflora - Shoreweed
- Ondergedoken moerasscherm - Helosciadium inundatum- Lesser marshwort
- Pilvaren - Pilularia globulifera - Pillwort
- Plat blaasjeskruid - Utricularia intermedia- Intermediate bladderwort
- Teer vederkruid - Myriophyllum alterniflorum- Alternate water-milfoil
- Waterviolier - Hottonia palustris- Water-violet

Daybutterflies:

- aardbeivlinder - Pyrgus malvae
- groentje,
- grote vuurvlinder - Lycaena dispar
- zilveren maan - Boloria selene

Bij 12. N06.01 Veenmosrietland en moerasheide - Flora en fauna. from https://www.bij12.nl/onderwerpen/natuur-en-landschap/index-natuur-en-landschap/natuurtypen/n06-voedselarme-venen-en-vochtige-heiden/n06-01-veenmosrietland-en-moerasheide/ at 25-04-2022

BIRCH ALDER MARCH FOREST

Plants:

- Beenbreek - Narthecium ossifragum - Bog asphodel
- Bevertjes - Briza media - Quaking grass
- Biezenknoppen - Juncus conglomeratus - Compact rush
- Blauwe knoop - Succisa pratensis - Devil's-bit scabious
- Blauwe zegge - Carex panicea - Carnation sedge
- Cranberry - Vaccinium macrocarpon - Cranberry
- Draadgentiaan - Cicendia filiformis - Yellow centuary
- Eenarig wollegras - Eriophorum vaginatum - Hare's-tail cottongrass
- Geelgroene zegge - Carex demissa - Yellow sedge
- Gevlekte orchis - Dactylorhiza maculata - Heath spotted-orchid
- Gewone dophei - Erica tetralix - Cross-leaved heath
- Gewone waternavel - Hydrocotyle vulgaris - Marsh pennywort
- Kale jonker- Cirsium palustre - Marsh thistle
- Kleine valeriaan - Valeriana dioica - Marsh valerian
- Kleine veenbes - Vaccinium oxycoccos - Small cranberry
- Kleine zonnedauw - Drosera intermedia - Oblong-leaved sundew
- Klokjesgentiaan - Gentiana pneumonanthe - Marsh gentian
- Knolrus - Juncus bulbosus - Bulbous rush
- Kruipwilg - Salix repens - Creeping willow
- Lavendelhei - Andromeda polifolia - Bog rosemarym
- Liggend hertshooi - Hypericum humifusum - Trailing St. John's-wort
- Liggende vleugeltjesbloem - Polygala serpyllifolia - Heath milkwort
- Melkeppe - Peucedanum palustre - Milk parsley
- Moerashertshooi - Hypericum elodes - Marsh St. John's-wort
- Moerasstruisgras - Agrostis canina - Velvet bent
- Moerasviooltje - Viola palustris- Marsh violet
- Pijpenstrootje - Molinia caerulea - Purple moor-grass
- Ronde zonnedauw - Drosera rotundifolia- Round-leaved sundew
- Ruw walstro - Galium uliginosum - Fen bedstraw
- Snavelzegge - Carex rostrata- Bottle sedge
- Spaanse ruiter - Cirsium dissectum - Meadow thistle
- Sterzegge - Carex echinata - Star sedge
- Tandjesgras - Danthonia decumbens- Heath-grass
- Tormentil - Potentilla erecta - Tormentil
- Trekrus - Juncus squarrosus - Heath rush
- Valkruid - Arnica montana - Arnica
- Veelbloemige veldbies - Luzula multiflora - Heath wood-rush
- Veenbies - Trichophorum germanicum - Deergrass
- Veenpluis - Eriophorum angustifolium - Common cottongrass
- Veenreukgras - Anthoxanthum nitens- Holy grass
- Veldrus - Juncus acutiflorus Sharp-flowered rush
- Wateraardbei - Comarum palustre - Marsh cinquefoil
- Waterdrieblad - Menyanthes trifoliata - Bogbean
- Witte snavelbies - Rhynchospora alba - White beak-sedge
- Zeegroene muur - Stellaria palustris - Marsh stitchwort
- Zompzegge - Carex canescens - White sedge
- Zwarte zegge - Carex nigra - Common sedge

Trees:

- Zachte berk - Betula pubescens - Downy birch
- Zomereik - Quercus robur - Pedunculate oak
- Zwarte els - Alnus glutinosa - Common alder

Shrubs:

- Geoorde wilg - Salix aurita - Eared willow
- Sporkehout - Frangula alnus - Alder Buckthorn
- Wilde gagel - Myrica gale - Bog myrtle
- Zwarte appelbes - Aronia x prunifolia - Purple chokeberry

Herbs and dwarf shrub

- Gewone dophei - Erica tetralix - Cross-leaved heath
- Moerasviooltje - Viola palustris - Marsh violet
- Pijpenstrootje - Molinia caerulea - Purple moor-grass
- Tormentil - Potentilla erecta - Tormentil

Jansen, S. (2022), Flora of Dutch habitats. Table of the most common plants in the Netherlands selected by environment. unpublished manuscript. april 2022. TU-Delft

Breeding birds:

- blauwborst,
- boomkruiper,
- gekraagde roodstaart,
- grauwe vliegenvanger,
- grote bonte specht,
- kleine bonte specht,
- matkop, nachtegaal,
- wielewaal

Bij 12. N14.02 Hoog- en laagveenbos - Flora en fauna. from https://www.bij12.nl/onderwerpen/natuur-en-landschap/index-natuur-en-landschap/natuurtypen/n14-vochtige-bossen/n14-02-hoog-en-laagveenbos/ at 25-04-2022

APPENDIX 2.3 LIST OF SPECIES RAIN GARDEN

HUMID REED PEAT MEADOW

NL- LATIN - EN

Plants:

- Drijvend fonteinkruid - Potamogeton natans- Floating-leaved pondweed
- Kikkerbeet - Hydrocharis morsus-ranae Frogbit
- Krabbenscheer - Stratiotes aloides Water soldier
- Ondergedoken moerasscherm -Helosciadium inundatum- Lesser marshwort
- Ongelijkbladig fonteinkruid -Potamogeton gramineus - Various-leaved pondweed
- Paarbladig fonteinkruid - Groenlandia densa- Opposite-leaved pondweed
- Waterdrieblad - Menyanthes trifoliata Bogbean
- Waterviolier - Hottonia palustris Water-viole
- Drijvende egelskop - Sparganium angustifolium- Floating bur-reed
- Drijvende waterweegbree - Luronium natans- Floating water plantain
- Duizendknoopfonteinkruid -Potamogeton polygonifolius- Bog pondweed
- Gesteeld glaskroos - Elatine hexandra Six-stamened waterwort
- Kleinste egelskop - Sparganium natans Least bur-reed
- Oeverkruid - Littorella uniflora Shoreweed
- Pilvaren - Pilularia globulifera Pillwort
- Plat blaasjeskruid - Utricularia intermedia- Intermediate bladderwort
- Teer vederkruid - Myriophyllum alterniflorum- Alternate water-milfoil

Jansen, S. (2022), Flora of Dutch habitats. Table of the most common plants in the Netherlands selected by environment. unpublished manuscript. april 2022. TU-Delft

Plants:

- Aardaker - Lathyrus tuberosus - Tuberous pea
- Beemdkroon - Knautia arvensis - Field scabious
- Beemdlangbloem - Schedonorus pratensis - Meadow fescue
- Beemdooievaarsbek - Geranium pratense - Meadow cranesbill
- Brandpastinaak - Pastinaca sativa subsp. urens- Wild parsnip
- Dagkoekoeksbloem - Silene dioica - Red campion
- Fluitenkruid - Anthriscus sylvestris - Cow parsley
- Gele morgenster - Tragopogon pratensis subsp. pratensis - Goat's-beard
- Gestreepte witbol - Holcus lanatus - Yorkshire-fog
- Gewone agrimonie - Agrimonia eupatoria - Agrimony
- Gewone berenklauw - Heracleum sphondylium - Hogweed
- Gewone brunel - Prunella vulgaris - Selfheal
- Gewone engelwortel - Angelica sylvestris - Wild angelica
- Gewone ereprijs - Veronica chamaedrys - Germander speedwell
- Gewone hoornbloem - Cerastium fontanum subsp. vulgare - Common mouse-ear
- Gewone smeerwortel - Symphitum officinale - Common comfrey
- Gewone vogelmelk - Ornithogalum umbelatum - Star of Bethlehem
- Gewoon speenkruid - Ficaria verna - Lesser celandine
- Gewoon timoteegras - Phleum pratense - Timothy
- Glad walstro - Galium mollugo subsp. erectum - Hedge bedstraw
- Glanshaver - Arrhenatherum elatius - False oat-grass
- Goudhaver – Trisetum flavescens - Yellow oat-grass
- Grasmuur - Stellaria graminea - Lesser stitchwort
- Groot streepzaad - Crepis biennis - Rough hawk's-beard
- Grote bevernel - Pimpinella major - Greater burnet-saxifra
- Grote vossenstaart - Alopecurus pratensis - Meadow foxtail
- Gulden boterbloem - Ranunculus auricomus - Goldilocks buttercup
- Heksenmelk - Euphorbia esula - Leafy spurgeHondsdraf - Glechoma hederacea Ground-ivy
- Jakobskruiskruid - Jacobaea vulgaris subsp. vulgaris- Tansy ragwort
- Karwijvarkenskervel - Dichoropetalum carvifolia - Milk parsley
- Kleine klaver - Trifolium dubium - Lesser trefoil
- Knolboterbloem - Ranunculus bulbosus - Bulbous buttercup
- Knolsteenbreek - Saxifraga granulata - Meadow saxifrage
- Knoopkruid - Centaurea jacea - Brown knapweed
- Kropaar - Dactylis glomerata - Cocksfoot
- Kruipend zenegroen - Ajuga reptans - Bugleweed
- Kruipende boterbloem - Ranunculus repens - Creeping buttercup
- Maarts viooltje - Viola odorata - Sweet violet
- Madeliefje - Bellis perennis - Daisy
- Margriet - Leucanthemum vulgare - Oxeye daisy
- Muskuskaasjeskruid - Malva moschata - Musk-mallow
- Paarse morgenster - Tragopogon porrifolius - Salsify
- Peen - Daucus carota - Wild carrot
- Pinksterbloem - Cardamine pratensis - Cuckoo-flower
- Rode klaver - Trifolium pratense- Red clover

Plants:

- Veldlathyrus - Lathyrus pratensis - Meadow vetchling
- Veldsalie - Salvia pratensis - Meadow clary
- Veldzuring - Rumex acetosa - Common sorrel
- Viltig kruiskruid - Jacobaea erucifolia - Hoary ragwort
- Vlasbekje - Linaria vulgaris - Common toadflax
- Vogelwikke - Vicia cracca - Tufted vetch
- Weidehavikskruid - Pilosella caespitosa - Meadow hawkweed
- Wilde cichorei - Cichorium intybus - Chicory
- Witte klaver - Trifolium repens - White clover
- Boerenkrokus - Crocus tommasinianus - Tomasini's crocus
- Gewone vogelmelk - Ornithogalum umbelatum - Star of Bethlehem
- Gewoon sneeuwklokje - Galanthus nivalis - Snowdrop
- Herfsttijloos - Colchicum autumnale - Meadow saffron
- Oosterse sterhyacint - Scilla siberica - Siberian squill
- Trompetnarcis - Narcissus pseudonarcissus subsp. major - Wild daffodil
- Vroege sterhyacint - Scilla bifolia - Alpine squill
- Wilde kievitsbloem - Fritillaria meleagris - Snake's head fritillary
- Wilde narcis - Narcissus pseudonarcissus subsp. pseudonarcissus- Wild daffodil
- Winterakoniet - Eranthis hyemalis - Winter aconite
- Zomerklokje - Leucojum aestivum - Summer snowflake

Jansen, S. (2022), Flora of Dutch habitats. Table of the most common plants in the Netherlands selected by environment. unpublished manuscript. april 2022. TU-Delft

ALDER FOREST
NL- LATIN - EN

Plants:

- Beenbreek - Narthecium ossifragum - Bog asphodel
- Bevertjes - Briza media - Quaking grass
- Biezenknoppen - Juncus conglomeratus - Compact rush
- Blauwe knoop - Succisa pratensis - Devil's-bit scabious
- Blauwe zegge - Carex panicea - Carnation sedge
- Cranberry - Vaccinium macrocarpon - Cranberry
- Draadgentiaan - Cicendia filiformis - Yellow centuary
- Eenarig wollegras - Eriophorum vaginatum - Hare's-tail cottongrass
- Geelgroene zegge - Carex demissa - Yellow sedge
- Gevlekte orchis - Dactylorhiza maculata - Heath spotted-orchid
- Gewone dophei - Erica tetralix - Cross-leaved heath
- Gewone waternavel - Hydrocotyle vulgaris - Marsh pennywort
- Kale jonker- Cirsium palustre - Marsh thistle
- Kleine valeriaan - Valeriana dioica - Marsh valerian
- Kleine veenbes - Vaccinium oxycoccos - Small cranberry
- Kleine zonnedauw - Drosera intermedia - Oblong-leaved sundew
- Klokjesgentiaan - Gentiana pneumonanthe - Marsh gentian
- Knolrus - Juncus bulbosus - Bulbous rush
- Kruipwilg - Salix repens - Creeping willow
- Lavendelhei - Andromeda polifolia - Bog rosemarym
- Liggend hertshooi - Hypericum humifusum - Trailing St. John's-wort
- Liggende vleugeltjesbloem - Polygala serpyllifolia - Heath milkwort
- Melkeppe - Peucedanum palustre - Milk parsley
- Moerashertshooi - Hypericum elodes - Marsh St. John's-wort
- Moerasstruisgras - Agrostis canina - Velvet bent
- Moerasviooltje - Viola palustris- Marsh violet
- Pijpenstrootje - Molinia caerulea - Purple moor-grass
- Ronde zonnedauw - Drosera rotundifolia- Round-leaved sundew
- Ruw walstro - Galium uliginosum - Fen bedstraw
- Snavelzegge - Carex rostrata- Bottle sedge
- Spaanse ruiter - Cirsium dissectum - Meadow thistle
- Sterzegge - Carex echinata - Star sedge
- Tandjesgras - Danthonia decumbens- Heath-grass
- Tormentil - Potentilla erecta - Tormentil
- Trekrus - Juncus squarrosus - Heath rush
- Valkruid - Arnica montana - Arnica
- Veelbloemige veldbies - Luzula multiflora - Heath wood-rush
- Veenbies - Trichophorum germanicum - Deergrass
- Veenpluis - Eriophorum angustifolium - Common cottongrass
- Veenreukgras - Anthoxanthum nitens- Holy grass
- Veldrus - Juncus acutiflorus Sharp-flowered rush
- Wateraardbei - Comarum palustre - Marsh cinquefoil
- Waterdrieblad - Menyanthes trifoliata - Bogbean
- Witte snavelbies - Rhynchospora alba - White beak-sedge
- Zeegroene muur - Stellaria palustris - Marsh stitchwort
- Zompzegge - Carex canescens - White sedge
- Zwarte zegge - Carex nigra - Common sedge

Trees:

- Zachte berk - Betula pubescens - Downy birch
- Zomereik - Quercus robur - Pedunculate oak
- Zwarte els - Alnus glutinosa - Common alder

Shrubs:

- Geoorde wilg - Salix aurita - Eared willow
- Sporkehout - Frangula alnus - Alder Buckthorn
- Wilde gagel - Myrica gale - Bog myrtle
- Zwarte appelbes - Aronia x prunifolia - Purple chokeberry

Herbs and dwarf shrubs:

- Gewone dophei - Erica tetralix - Cross-leaved heath
- Moerasviooltje - Viola palustris - Marsh violet
- Pijpenstrootje - Molinia caerulea - Purple moor-grass
- Tormentil - Potentilla erecta - Tormentil

Jansen, S. (2022), Flora of Dutch habitats. Table of the most common plants in the Netherlands selected by environment. unpublished manuscript. april 2022. TU-Delft

APPENDIX

Birds:

- Holenduif
- Houtduif
- Ransuil
- Groene specht
- Grote bonte specht 5
- Boerenzwaluw
- Boompieper
- Witte kwikstaart
- Winterkoning
- Heggenmus
- Roodborst
- Merel
- Zanglijster
- Grote lijster
- Spotvogel
- Tuinfluiter
- Zwartkop
- Fluiter
- Tjiftjaf
- Fitis
- Goudhaan
- Staartmees
- Kuifmees
- Zwarte mees
- Koolmees
- Pimpelmees
- Boomklever
- Boomkruiper
- Gaai
- Ekster
- Kauw
- Zwarte kraai
- Spreeuw
- Vink
- Putter
- Kneu

Bats:

- Watervleermuis
- Gewone/Grijze grootoorvleermuis
- Franjestaart
- Baard/Brandtsvleermuis

Dragonflies:

- Bruinrode heidelibel
- Grote keizerlibel
- Paardenbijter
- Vuurjuffer

Opstaele, B, (2011)Uitgebreid bosbeheerplan. Elsenbos from https://www.natuurenbos.be/sites/default/files/beheerplan_elsenbos.pdf at 13-6-2022

APPENDIX

APPENDIX 2.4 LIST OF SPECIES PEAT POLDER NATURE

PEAT MEADOW
NL- LATIN - EN

Plants:

- addertong,
- adderwortel,
- beemdooievaarsbek,
- bevertjes,
- bleke zegge,
- bosbies,
- brede orchis,
- draadrus,
- gevlekte orchis,
- gevleugeld hertshooi,
- gewone dotterbloem,
- grote pimpernel,
- gulden boterbloem,
- harlekijn,
- herfsttijloos,
- karwijselie,
- kleine valeriaan,
- klimopwaterranonkel,
- melkviooltje,
- moeraskartelblad,
- moerasstreepzaad,
- moesdistel,
- noords walstro,
- noordse zegge,
- platte bies,
- polei,
- rietorchis,
- rode ogentroost,
- trosdravik,
- verfbrem,
- vleeskleurige orchis,
- waterkruiskruid,
- herfsttijloos,
- weidekervel,
- weide-vergeet-mij-nietje,
- welriekende nachtorchis,
- wilde kievitsbloem,
- zilte rus,
- zwartblauwe rapunzel
-

Birds:

- scholeksters
- kieviten,
- grutto's,
- slobeenden,
- visdieven
- wilde eenden.
- gele kwikstaart,
- kemphaan,
- kwartelkoning,
- tureluur,
- watersnip

Butterflies:

- *aardbeivlinder,*
- *bont dikkopje,*
- *bruine vuurvlinder,*
- *donker pimpernelblauwtje,*
- *pimpernelblauwtje,*
- *zilveren maan,*
-

Grasshoppers:

- *moerassprinkhaan,*
- *zompsprinkhaan*

BIJ12.nl N10.02 Vochtig hooiland from https://www.bij12.nl/onderwerpen/natuur-en-landschap/index-natuur-en-landschap/natuurtypen/n10-vochtige-schraalgraslanden/n10-02-vochtig-hooiland/ at 13-06-2022

PEAT ROUGHS
NL- LATIN - EN

Plants:

- Akkerkool - Lapsana communis - Nipplewort
- Boerenwormkruid - Tanacetum vulgare - Common tansy
- Dagkoekoeksbloem - Silene dioica - Red campion
- Dolle kervel - Chaerophyllum temulum - Rough chervil
- Fluitenkruid - Anthriscus sylvestris - Cow parsley
- Geel nagelkruid - Geum urbanum - Wood avens
- Gevlekte dovenetel - Lamium maculatum - Spotted deadnettle
- Gewone engelwortel - Angelica sylvestris - Wild angelica
- Gewone klit - Arctium minus - Common burdock
- Grote brandnetel - Urtica dioica - Stinging nettle
- Grote kaardenbol - Dipsacus fullonum - Wild teasel
- Heggendoornzaad - Torilis japonica - Upright hedge-parsley
- Heggenduizendknoop - Fallopia dumetorum - Copse bindweed
- Heggenwikke - Vicia sepium - Bush vetch
- Hondsdraf - Glechoma hederacea - Ground-ivy
- Kleefkruid - Galium aparine - Cleavers
- Kruisbladwalstro - Cruciata laevipes - Crosswort
- Look-zonder-look - Alliaria petiolata - Garlic mustard
- Pijpbloem - Aristolochia clematitis - Birthwort
- Robertskruid - Geranium robertianum - Herb-Robert
- Stinkende ballote - Ballota nigra subsp. meridionalis - Black horehound
- Stinkende gouwe - Chelidonium majus - Greater celandine
- Witte dovenetel - Lamium album - White dead-nettle
- IJle dravik - Anisantha sterilis - Barren brome
- IJzerhard - Verbena officinalis - Vervainn
- Zevenblad - Aegopodium podagraria - Ground elde

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ASH ALDER FOREST
NL- LATIN - EN

Trees:

- Beuk - Fagus sylvatica - Beech
- Es - Fraxinus excelsior - Common ash
- Gladde iep - Ulmus minor - Small-leaved elm
- Grauwe abeel - Populus x canescens - Grey poplar
- Haagbeuk - Carpinus betulus - Hornbeam
- Ratelpopulier - Populus tremula - Aspen
- Ruwe iep - Ulmus glabra Wych - elm
- Wilde lijsterbes - Sorbus aucuparia - Rowan
- Wintereik - Quercus petraea - Sessile oak
- Witte abeel - Populus alba - White poplar
- Zoete kers - Prunus avium - Wild cherry
- Zomereik - Quercus robur - Pedunculate oak
- Zwarte populier - Populus nigra - Black poplar

Shrubs and low trees:

- Aalbes - Ribes rubrum - Red currant
- Boswilg - Salix caprea - Goat willow
- Dauwbraam - Rubus caesius - Dewberry
- Duindoorn - Hippophae rhamnoides - Seabuckthorn
- Eenstijlige meidoorn - Crataegus monogyna -Single-seed hawthorn
- Egelantier - Rosa rubiginosa - Sweet briar
- Framboos - Rubus idaeus - Red raspberry
- Gelderse roos - Viburnum opulus - Guelder rose
- Gewone vlier - Sambucus nigra - Common elder
- Hazelaar - Corylus avellana - Hazel
- Hondsroos - Rosa canina - Dog-rose
- Hulst - Ilex aquifolium - Common holly
- Kruisbes - Ribes uva-crispa - Gooseberry
- Mispel - Mespilus germanica - Medlar
- Rode kornoelje - Cornus sanguinea - Dogwood
- Sleedoorn - Prunus spinosa - Blackthorn
- Spaanse aak - Acer campestre - Field maple
- Taxus - Taxus baccata - Yew
- Trosvlier - Sambucus racemosa - Red-berried elder
- Tweestijlige meidoorn - Crataegus laevigata - Midland hawthorn
- Vogelkers - Prunus padus - Bird cherry
- Wegedoorn - Rhamnus cathartica - Buckthorn
- Wilde kardinaalsmuts - Euonymus europaeus - Spindle
- Wilde liguster - Ligustrum vulgare - Wild privet
- Zuurbes - Berberis vulgaris - Barberry
- Zwarte braam - Rubus sectie - Rubus Blackberry

Herbs:

- Bosaardbei - Fragaria vesca - Wild strawberry
- Bosandoorn - Stachys sylvatica - Hedge woundwort
- Bosanemoon - Anemone nemorosa - Wood anemone
- Bosgierstgras - Milium effusum - Wood millet
- Witte klaverzuring - Oxalis acetosella - Wood-sorrel
- Boskortsteel - Brachypodium sylvaticum - False-brome
- Bosvergeet-mij-nietje - Myosotis sylvatica - Woodforget-me-not
- Boszegge - Carex sylvatica - Wood sedge
- Brede stekelvaren - Dryopteris dilatata - Broad buckler-fern
- Daslook - Allium ursinum - Bear's garlic
- Drienerfmuur - Moehringia trinervia - Three-nerved sandwort
- Gulden sleutelbloem - Primula veris - Cowslip
- Gele dovenetel - Lamiastrum galeobdolon - Yellow archangel
- Gevlekte aronskelk - Arum maculatum - Lords-and-ladies
- Bleeksporig bosviooltje - Viola riviniana - Common dog Violet
- Grote muur - Stellaria holostea - Greater stitchwort
- Grote veldbies - Luzula sylvatica - Great wood-rush
- Gulden boterbloem - Ranunculus auricomus - Goldilocks buttercup
- Klein springzaad - Impatiens parviflora - Small balsam
- Klimopereprijs - Veronica hederifolia - Ivy-leaved speedwel

Herbs:

- Adderwortel - Persicaria bistorta - Common bistort
- Blauwe anemoon - Anemone apennina - Apennine windflower
- Blauwe druifjes - Muscari botryoides - Grape hyacinth
- Bosgeelster - Gagea lutea - Yellow star-of-Betlehem
- Bosooievaarsbek - Geranium sylvaticum - Wood crane's-bill
- Bostulp - Tulipa sylvestris - Wild tulip
- Daslook - Allium ursinum - Bear's garlic
- Donkere ooievaarsbek - Geranium phaeum - Mourning widow
- Gele anemoon - Anemone ranunculoides - Yellow anemone
- Gevlekt longkruid - Pulmonaria officinalis - Common lungwort
- Gewone vogelmelk - Ornithogalum umbelatum - Star of Bethlehem
- Gewoon sneeuwklokje - Galanthus nivalis - Snowdrop
- Grote sneeuwroem - Scilla forbesii - Glory of the snow
- Hartbladzonnebloem - Doronicum pardalianches - Leopard's-bane
- Holwortel - Corydalis cava - Bulbous corydalis
- Italiaanse aronskelk - Arum italicum - Italian lords-and-ladies
- Knikkende vogelmelk - Ornithogalum nutans - Drooping star-of-Bethlehem
- Knolsteenbreek - Saxifraga granulata - Meadow saxifrage
- Kuifhyacint - Muscari comosum Tassel - grape hyacinth
- Lenteklokje - Leucojum vernum - Spring snowflake
- Lievevrouwebedstro - Galium odoratum - Sweetscented bedstraw
- Maarts viooltje - Viola odorata - Sweet violet
- Oosterse sterhyacint - Scilla siberica - Siberian squill
- Stengelloze sleutelbloem - Primula vulgaris- Wild primrose
- Vingerhelmbloem - Corydalis solida - Bird in a bush
- Vroege sterhyacint - Scilla bifolia - Alpine squill
- Weegbreezonnebloem - Doronicum plantagineum Plantain-leaved leopard's bane

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Trees:

- Es - Fraxinus excelsior - Common ash
- Schietwilg - Salix alba - White willow
- Turkse kraakwilg en Basterdkraakwilg -Salix euxina en Salix x fragilis - Crack-willow
- Zomereik - Quercus robur - Pedunculate oak
- Zwarte els - Alnus glutinosa - Common alder
- Zwarte populier - Populus nigra - Black poplar

Shrubs and low trees:

- Amandelwilg - Salix triandra - Almond willow
- Bittere wilg - Salix purpurea - Purple willow
- Gelderse roos - Viburnum opulus - Guelder rose
- Grauwe wilg en Rossige wilg - Salix cinerea- Grey willow
- Hazelaar - Corylus avellana - Hazel
- Katwilg - Salix viminalis - Basket willow
- Vogelkers - Prunus padus - Bird cherry
- Zwarte bes - Ribes nigrum - Black currant

Herbs

- Bosanemoon - Anemone nemorosa - Wood anemone
- Bosereprijs - Veronica montana - Wood speedwell
- Boswederik - Lysimachia nemorum - Yellow pimpernel
- Elzenzegge - Carex elongata - Elongated sedge
- Gele dovenetel - Lamiastrum galeobdolon - Yellow archangel
- Groot heksenkruid - Circaea lutetiana - Enchanter's-nightshade
- Groot springzaad - Impatiens nolitangere - Touch-me-not balsam
- Hop - Medicago lupulina Hop
- Knikkend nagelkruid - Geum rivale - Water avens
- Kruipend zenegroen - Ajuga reptans - Bugleweed
- Moerasvaren - Thelypteris palustris - Marsh fern
- Slanke sleutelbloem - Primula elatior - Oxlip
- IJle zegge - Carex remota - Remote sedge

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