

MANGROVE MARVELS

Revitalising Surinam's coastal landscape through vernacular design.

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* All drawing and photos were taken by the author herself with the exception of those noted otherwise.



ACKNOWLEDGEMENT

About two years ago, I decided to do the masters in landscape architecture. To be honest, I was not sure if this was really what I wanted, but I felt like starting something new. In looking back, this was the best choice I made during my studies. I am happy to have met so many fun and lovely fellow students and teachers, and I have enjoyed the past two years very much.

I am also very happy that I was allowed to research mangroves in Suriname for my graduation research. I would like to thank all the people in Surinam who helped me with this research. In particular, I would like to thank two power women from GreenGrowthSuriname, Gwendolyn and Lindsay. They helped me a lot with building contacts within Suriname. I also want to thank Benito Aloema, the guide of the two indigenous communities at Galibi. He showed me the Tijger Bank and shared a lot of helpful knowledge with me about the customs of the indigenous community.

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ABSTRACT

Keywords: Sea level rise adaptation, Mangrove restoration, wetland management, Indigenous knowledge, Surinam, community engagement.

Climate change is leading to an increased probability of flooding of coastal areas. This creates a major problem especially in developing countries. The communities in the coastal area can take little or no measures against sudden climate disasters such as storms and floods.
Suriname is one of these developing countries. Most of the population lives in the coastal area. In many places, the coastal protection cannot withstand climate problems such as sea level rise and is therefore more prone to storms and floods. Protection from the sea consists mainly of a natural dike of mangrove forests. In their natural state, the trees retain sediment from and thus grow with the sea level. They also form a nutrient-rich ecosystem on which humans and animals depend. Parties affected by the mangrove forests no longer know how to interact with the environment in a healthy way and live at the expense of the forests. There are communities in the areas, such as the indigenous tribal communities, who have knowledge on how to interact with the forests in a sustainable way. However, the groups have hardly any rights, are not taken serious and are constantly deprived of their living areas.
As a result, these forests are rapidly decreasing and can no longer provide proper protection for people, animals and the areas behind.
Many residents fear eroding coastlines and no longer trust mangrove forests. They lobby for sea dykes but there is little money for this in Suriname. Besides, these dykes have to be maintained and heightened all the time after construction and there is no money for this either.
This thesis, Mangrove Marvels, will focus on the relationship between humans and the mangrove landscape. The aim is to develop a toolbox of design principles that serve as guidelines for sustainable handling of this ecosystem. By applying these design principles, mangroves will have the opportunity to recover and be able to fulfil their crucial role in protecting the landscape.



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1 INTRODUCTION

1.1 Surinam

Suriname is a developing country in northern South America (World Bank, 2024). It is located just above the equator between the Guianas and is part of the Amazon rainforest. The country has the highest percentage of land area covered by forest of any country in the world, some 93% (Keepsurinamegreen, 2021). It has a tropical climate (Menke, J., et al., 2024) and is rich in vibrant ecosystems and natural resources (World Bank). To the north, Suriname borders the Atlantic Ocean (Menke, J., et al., 2024).



1.2 People and culture

Suriname, has a diverse population with about 623,000 inhabitants with at least 10 different ethnic groups (World Bank, 2024) (Government of the republic of Surinam, 2024). This diversity can partly be traced back to suriname's colonial past (Menke, J., et al., 2024), but is also partly something of recent years. It makes Suriname have a great diversity of cultures and especially of Asian influences. Something that makes Suriname special compared to the rest of South America (Government of the republic of Surinam, 2024).

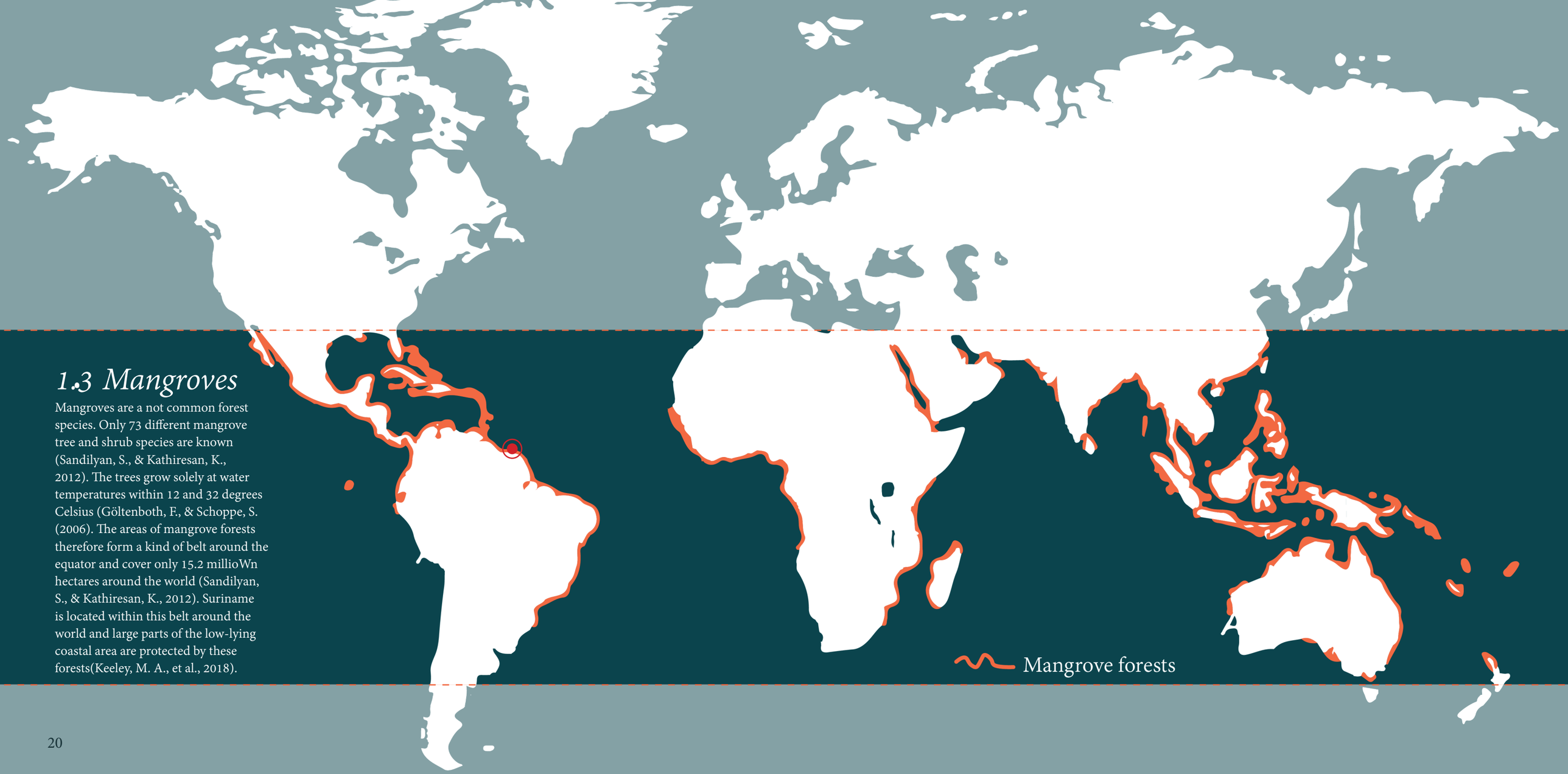
The Surinamese economy is heavily dependent on natural resources such as bauxite, gold and petroleum, which provide a significant part of the public sector, with gold alone accounting for more than three quarters of exports. However, this dependence makes Suriname vulnerable to external shocks (World Bank, 2024).

Although the Surinamese economy experienced rapid growth from 2001 to 2014, it contracted in 2015. The following years were marked by several challenges, including a fiscal crisis in 2020, exacerbated by the COVID-19 pandemic. This led to a fall in GDP, higher unemployment and increased poverty, affecting about 26% of the population by 2020. Addressing these challenges requires sustainable economic reforms and social intervention to secure Suriname's long-term prosperity (World Bank, 2024).



1.3 Mangroves

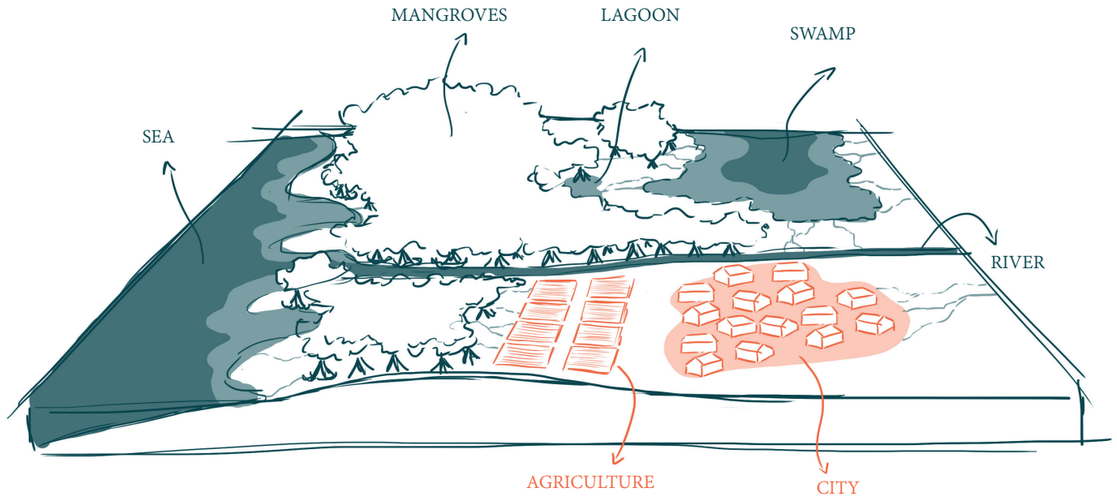
Mangroves are a not common forest species. Only 73 different mangrove tree and shrub species are known (Sandilyan, S., & Kathiresan, K., 2012). The trees grow solely at water temperatures within 12 and 32 degrees Celsius (Göltenboth, F., & Schoppe, S. (2006). The areas of mangrove forests therefore form a kind of belt around the equator and cover only 15.2 millioWn hectares around the world (Sandilyan, S., & Kathiresan, K., 2012). Suriname is located within this belt around the world and large parts of the low-lying coastal area are protected by these forests(Keeley, M. A., et al., 2018).



2.0 FASCINATION

2.1 Suriname's Coastal Plain

As a child, I got to know Surinam and its nature. Nature in Surinam is overwhelmingly beautiful. Vegetation grows incredibly fast and all abandoned plots are filled up in no time. So the fact that 93% of the land area (Keepsurinamegreen., 2024) is covered with forest and protected by mangrove forests suits Surinam very well in my opinion. The mangrove forests function as a natural dike system and provide protection for the coastal area instead of grey structures like dikes. Despite the fact that mangroves are often a difficult area to access, these areas are incredibly important for people and animals in and around the mangroves.



2.2 Natural coastal dyke system

‘I can link all 17 SDGs to mangrove forests and to a dike only 1, protection’ - Prof S. Naipal

Most of the Coastal Areas are protected by traditional grey structures like dikes, breakwaters and breakwaters. With increasing floodrisk due to sea level rise, these structures need to be strengthened and heightened (Van Hespen et al., 2023). Nature-based solutions are increasingly being recognised as a solution and mangrove forests, as one of these nature-based coastal protection solutions, can provide protection against violent wind and water currents, thus reducing threats such as hurricanes and storms (Spalding et al., 2014).
The functioning services of mangrove forests can be explained through two types of ecosystem services, regulation and production services.

REGULATION

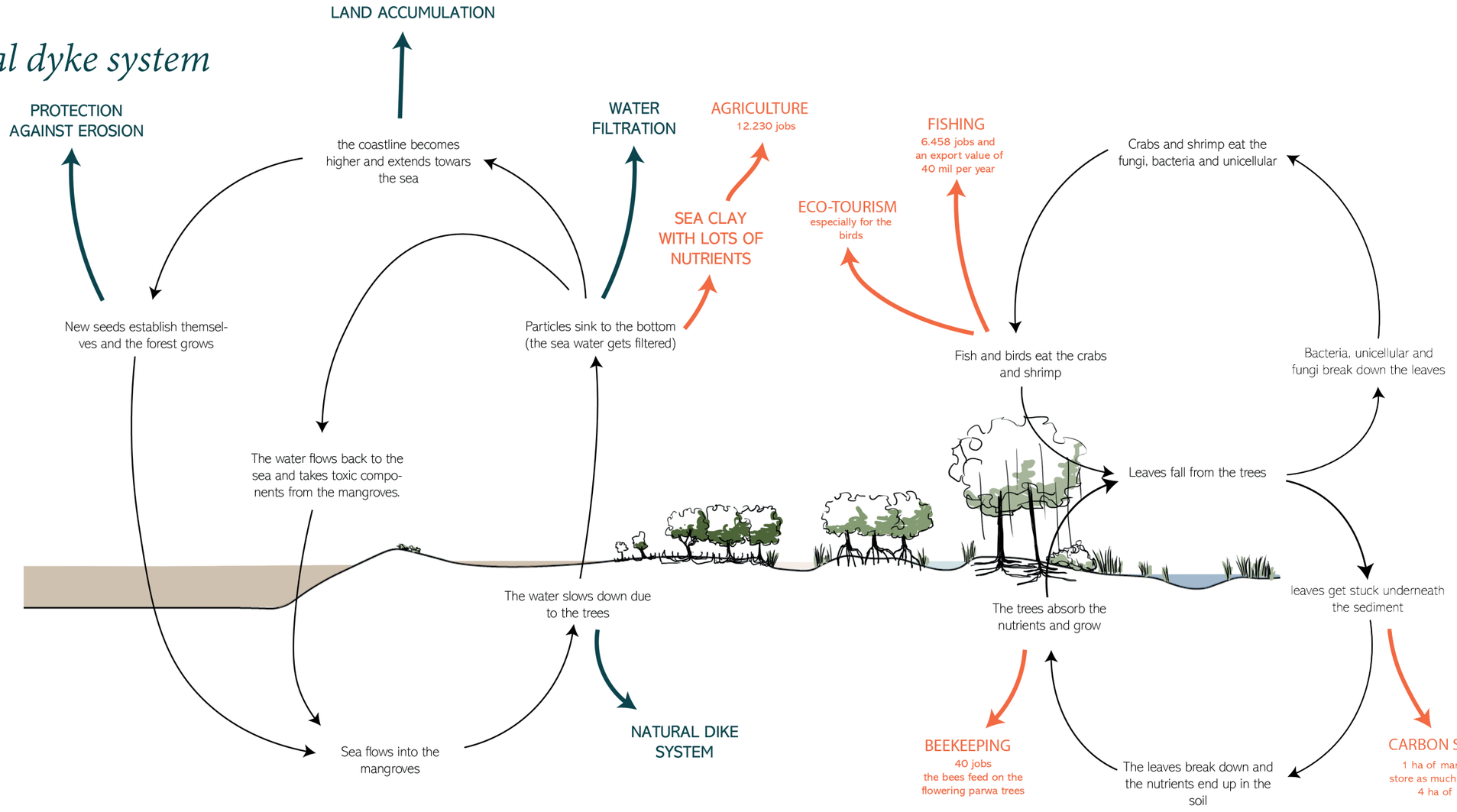
Mangrove forests grow in between sea and land and therefore act as a buffer against storms. The roots of the trees reduce currents and waves and this allows clay and sand particles to sink to the ground (Spalding et al., 2014). This not only filters the water, but as the particles build up, land is slowly created. If enough mud has remained, trees can continue to grow and drop seedlings. As a result, land can even accrete (Suriname Conservation Foundation (SCF), 2022). The dynamic nature of mangrove forests means they are able to adapt quickly to changes such as a rapidly increasing layer of sediment particles due to sea level rise (McIvor et al., 2013). This also makes them a more sustainable and especially cheaper solution for the future compared to grey structures such as sea dykes(McIvor et al., 2013).
On the other hand, however, the dynamic nature of mangrove forests also ensures that the forests can experience large differences in area (Toorman et al., 2018). For this, it is important that the forests are given enough space and that a zone is available where the forests have this opportunity and where one does not depend on protection by this forest.

PRODUCTION

Besides the regulation services provided by the mangroves, they also provide production services, making them an important source of food and income for the inhabitants of the coastal zone. It starts with the growth of the trees as they grow in which CO_2 is stored (Rivera-Monroy et al., 2017). In addition, the areas also store CO_2 as the leaves of the trees are quickly submerged in sediment. The CO_2 is then directly stored in the soil. Mangrove trees therefore store on average 3 to 4 times more CO_2 than rainforest (Suriname Conservation Foundation (SCF), 2022) People also use the wood of the mangrove trees (Keeley, M. A., et al.,2018).
The organic material that is not directly stored in the soil forms the basis the food web of the mangroves and areas beyond. As a result, the diversity of animal species in and around the mangroves is high (De Dijn, B., et al., 2018). Ecotourism and fishing can therefore constitute major sources of income (Suriname Conservation Foundation (SCF), 2022).



2.2 Natural coastal dyke system



3.0 PROBLEM FIELDS

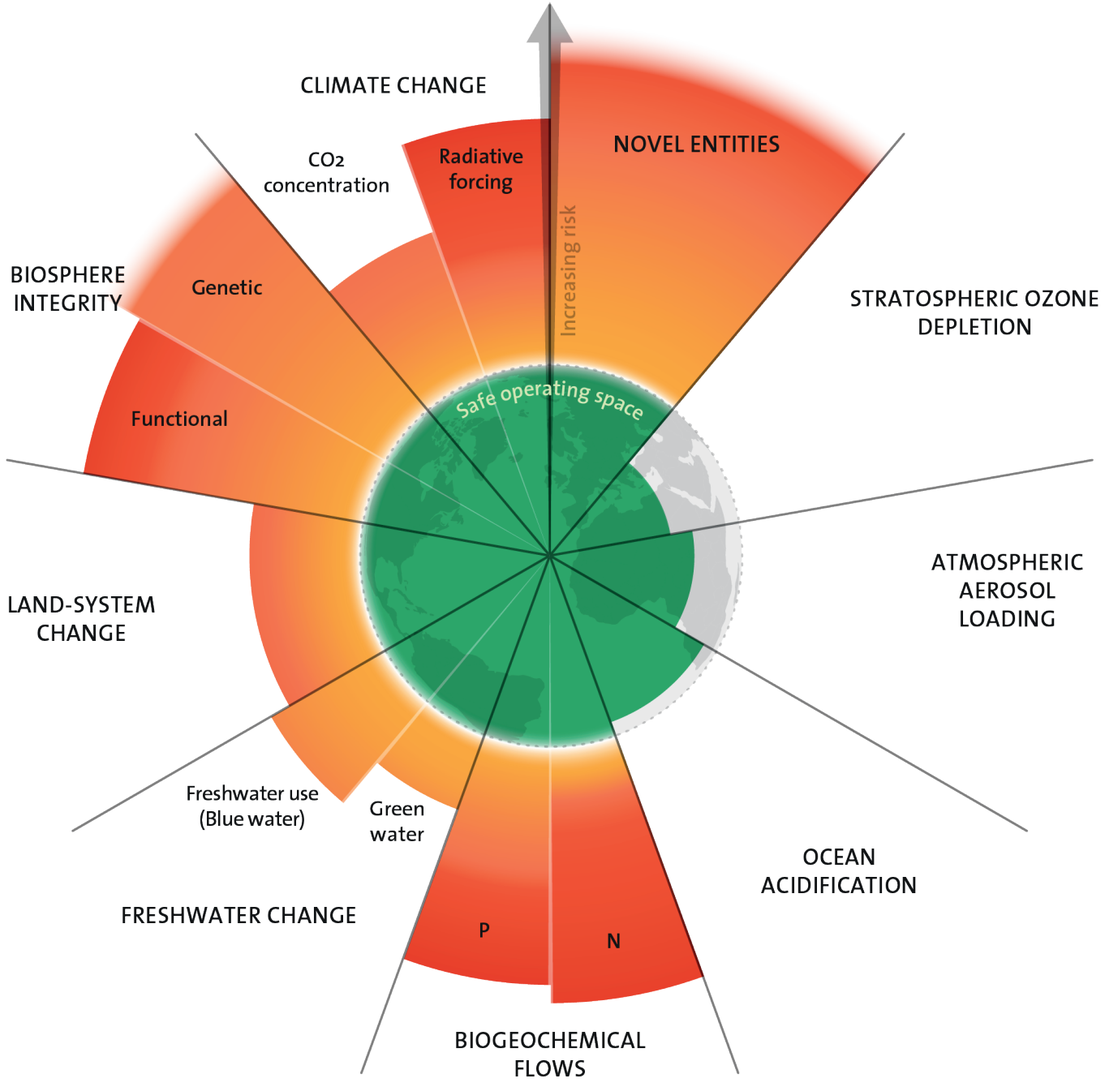
3.1 Unsustainable way of living

Paul Crutzen's discovery on the role of nitrogen oxides in stratospheric ozone depletion made it clear that the ozone layer's ability to protect life on Earth has been greatly reduced. In 2000, he introduced the term 'Anthropocene' for the current era, in which human influence on biological, atmospheric and geological processes is so severe that the effects will extend over several centuries (Janssen & Schuilenburg, 2021). This influence leads to the destruction of biodiversity, degradation of land, forests and oceans, pollution of air and water, and destabilisation of the Earth system. This causes a general destruction of the basis of our livelihood (Henry et al., 2020).



3.2 Planetary boundaries world

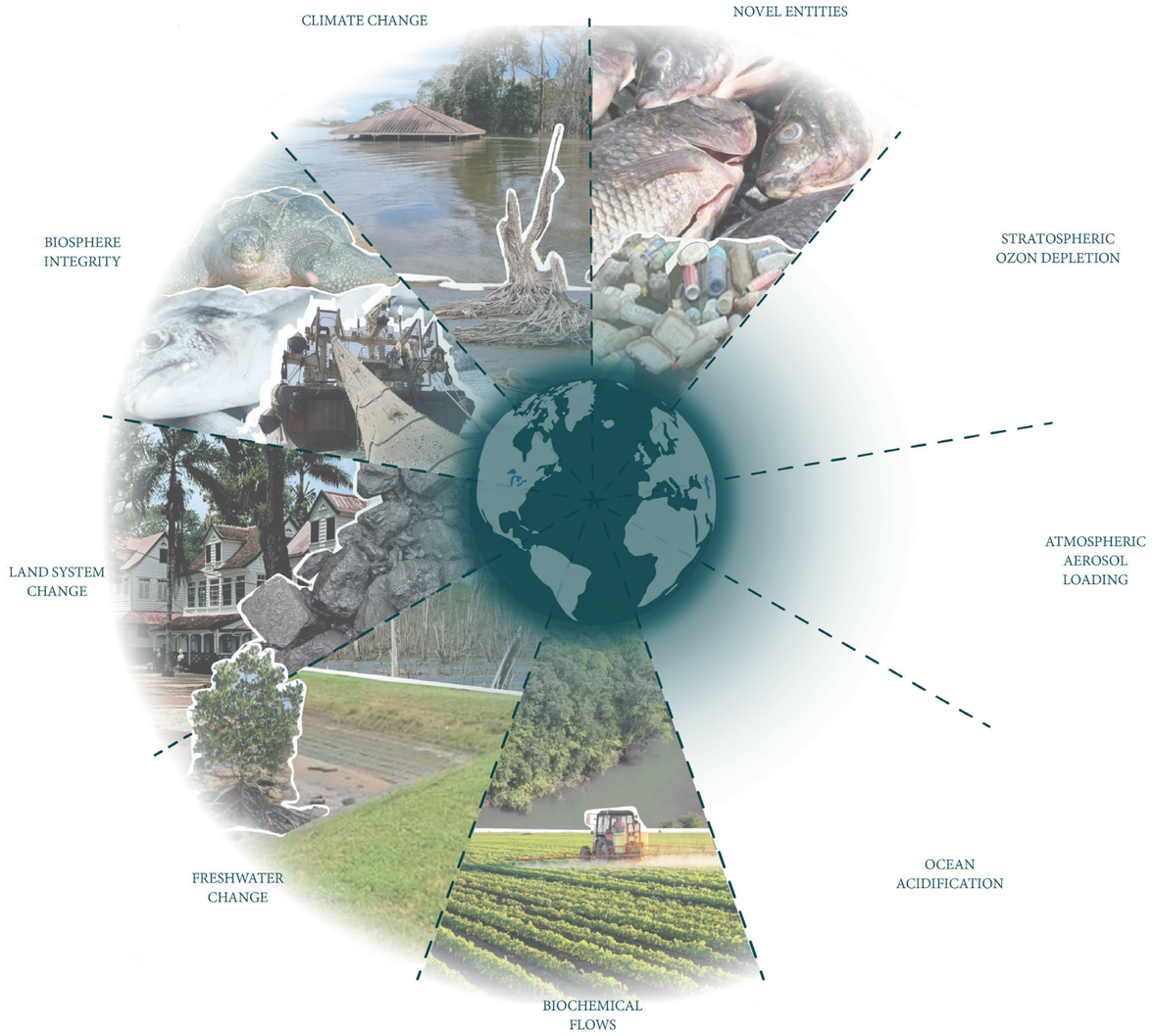
To better understand the causes and impact of climate change, one must look at the earth as an integrated self-regulating system. The unsustainable way of living of the present puts unprecedented pressure on that system. As a result, it unbalances the equilibrium in which the earth now finds itself. This sets in motion several destructive processes (Richardson, K., et al, 2023). Richardson K. et al states 'In a recent study, it was shown that several regional climate tipping points, relevant for stabilising the global system, have already been or are close to being transgressed, thus weakening global resilience capacity.'
The diagram on the right shows different categories of climate change boundaries and the state of these processes. Now we will zoom in further on Suriname to show what effects these earthbound processes have on Suriname as a country.



Stockholm Resilience Centre (2023), The evolution of the planetary boundaries framework, Stockholm University.

3.3 Planetary boundaries Suriname

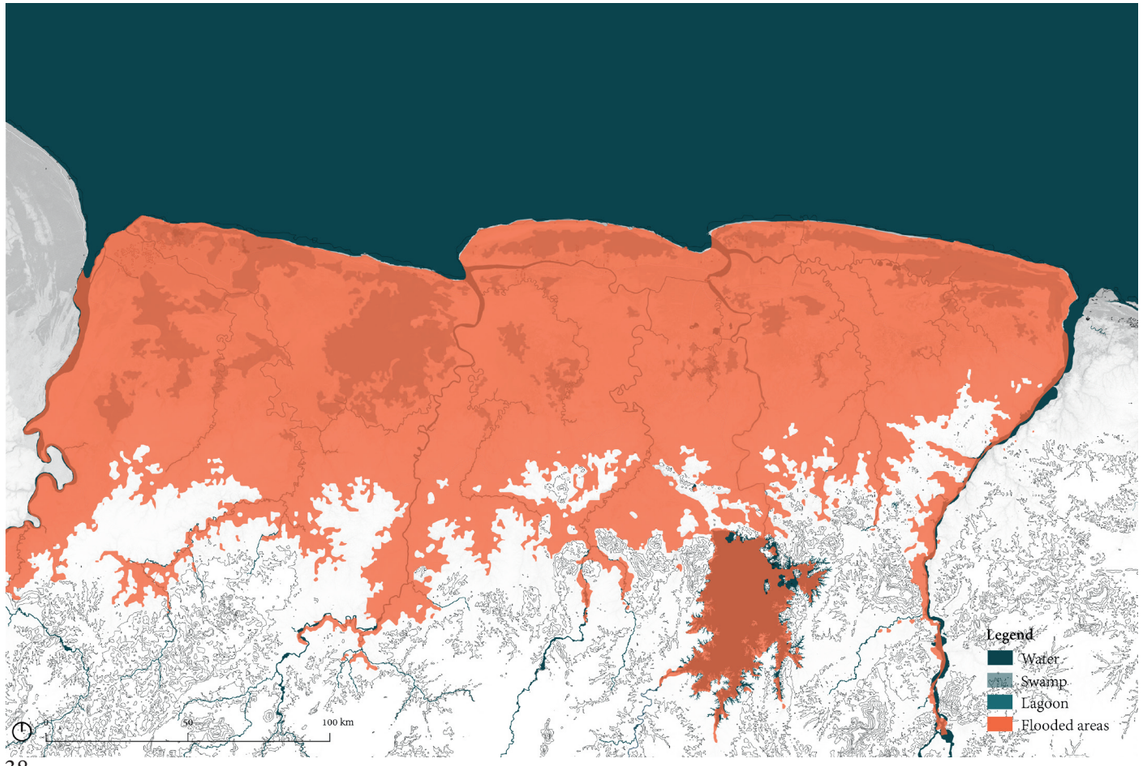
The diagram to the right shows the effects of plantary boundaries in suriname itself. Three of the nine are unclear, therefore they have been left blank (Hansson, P., et al., 2022). However, the other six have a clear impact on Suriname. This is depicted in the diagram on the right. These processes increase the vulnerability of the coastal zone and the coastal area is no longer protected against climate disasters such as storms and flooding (De Dijn, B., et al., 2018). The most pressing boundary here is Climate change which brings sea level rise and increased risk of flooding and inundation (Van Hespen, R., 2023).



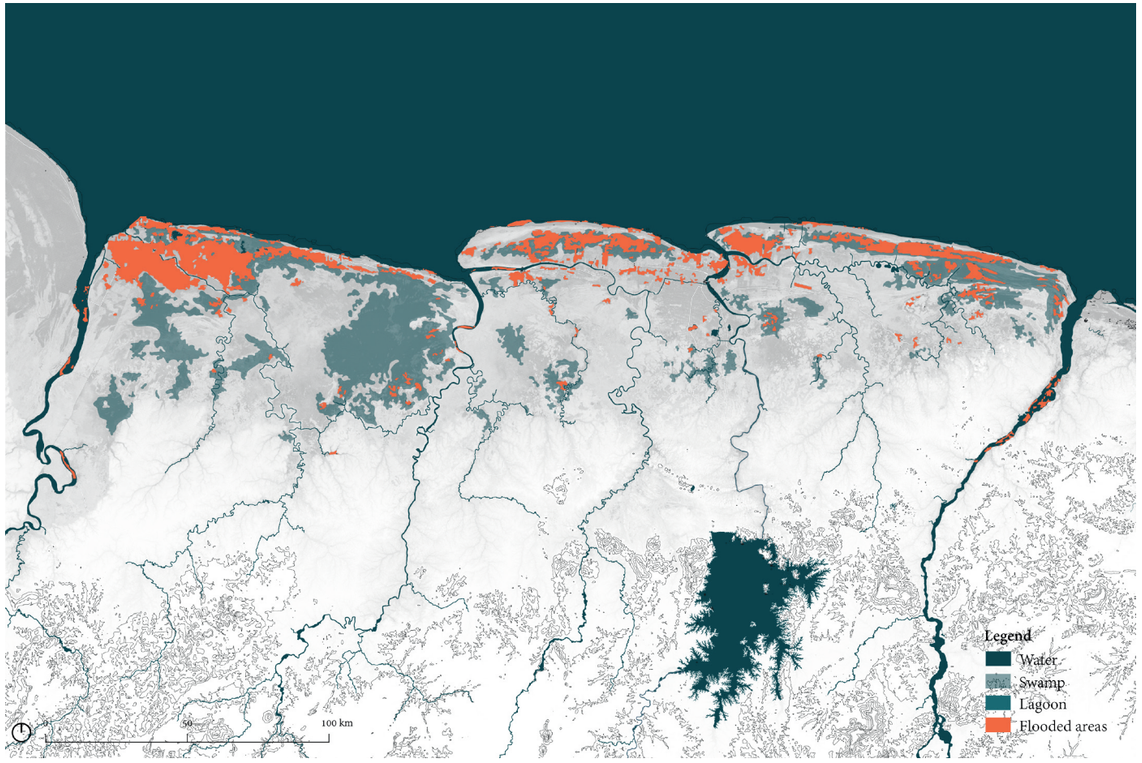
3.4 Sea level rise

Surinam is in the top 10 of developing countries with the highest percentage of affected people by SLR (Dasgupta, S., et al ., 2007). To show the effect of sea level rise, I use expectations from the research of (Winkelmann et al., 2015). The Antarctic ice sheet contains a mass of ice equivalent to a sea level rise of 58m. This mass could actually cause a 58m SLR in the event that humanity would burn up the currently available supply of fossil fuels(Winkelmann et al., 2015). The first map shows which parts of the coastal zone would be underwater at accute SLR of 58m (Floodmap, n.d.). However, this would not be the case for about 2,000 years. (Winkelmann et al., 2015). The second map shows the flooded parts of suriname at an SLR of 3m (Floodmap, n.d.). Which could be the case in 100 years(Winkelmann et al., 2015).

SEA LEVEL RISE 60M (4000)

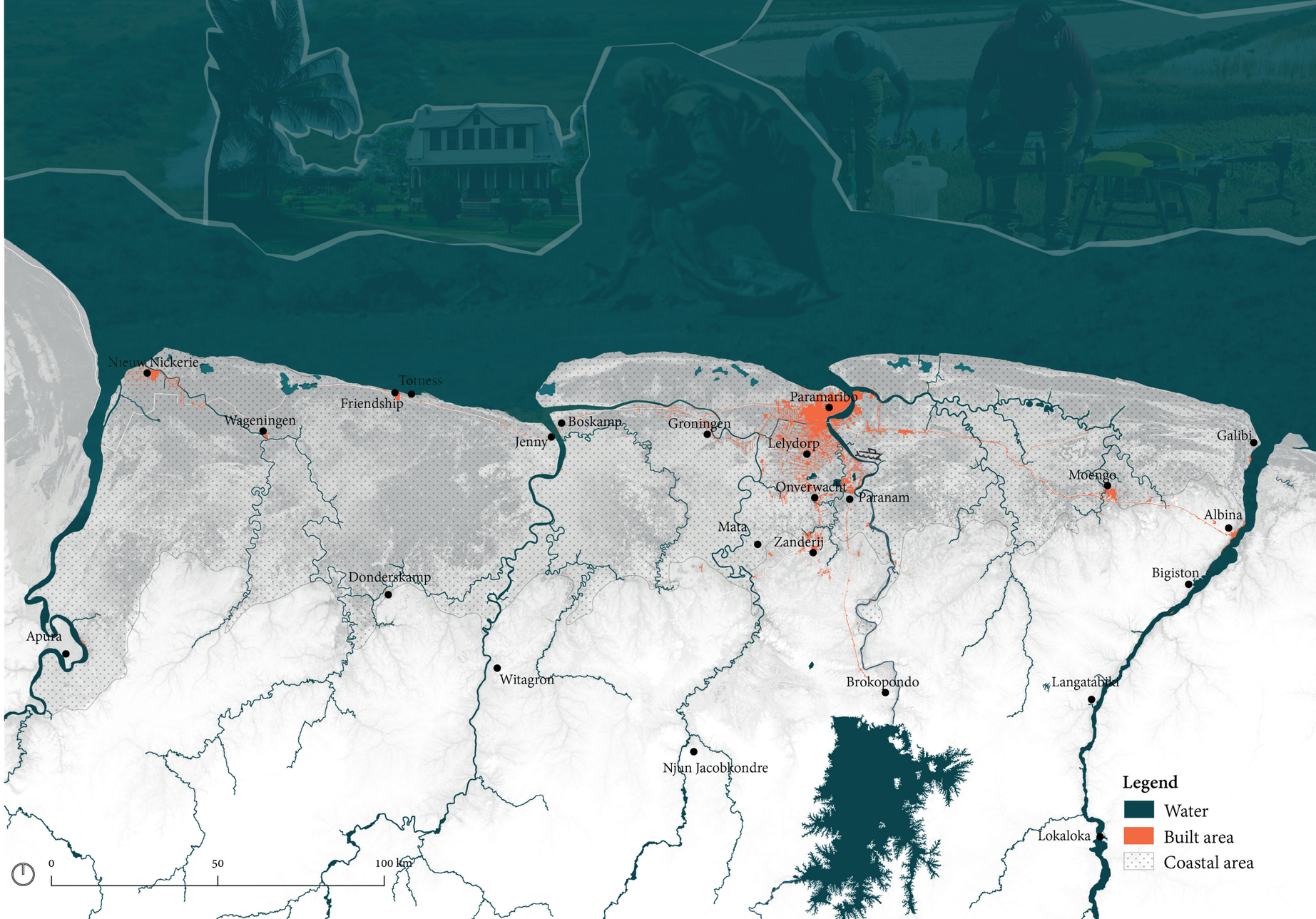


SEA LEVEL RISE 3M (2100)



3.5 *Dependence*

Most of suriname's population in the coastal area (Raj, 2018). They depend not only on the coastal defense and other regulation services provided by the mangroves, but also on the production services (Suriname Conservation Foundation (SCF), 2022). Therefore restoring mangrove forests and using them as a nature based coastal protection source would be the best option.



3.6 *Timeline*

First, the Surinamese coastal areas were inhabited by various tribes of indigenous peoples, the largest groups being the Arowaks and Caribs. They lived in a sustainable way with their environment so the impact they made was small. The arrival of Europeans started a new era. Initially, they started trading, but soon moved to colonisation. With colonisation came the construction of plantations and to maximise agricultural production, the land was drained, adapting the terrain to the needs of crops such as sugarcane, coffee and cotton. An influx of diverse groups, including Jewish farmers, enslaved Africans, Dutch settlers and farmers and later contract workers from India and Indonesia. Each group brought unique cultural traditions, which contributed to the present diversity of Surinamese society (Buddingh, H., 2017).



500
Arowaks settle permanently in suriname. They live in the coastal area on mounds and have sedentary agriculture

1100
Caraïbs reach Suriname and take territories of Arowaks

1529
First Europeans reach South america.

end 16th century
European traders reach suriname and start trading with indigenous groups.

17th century
Europeans take land and start plantati-ons. They bring enslaved Africans to Surinam and force them to labour on the plantations.

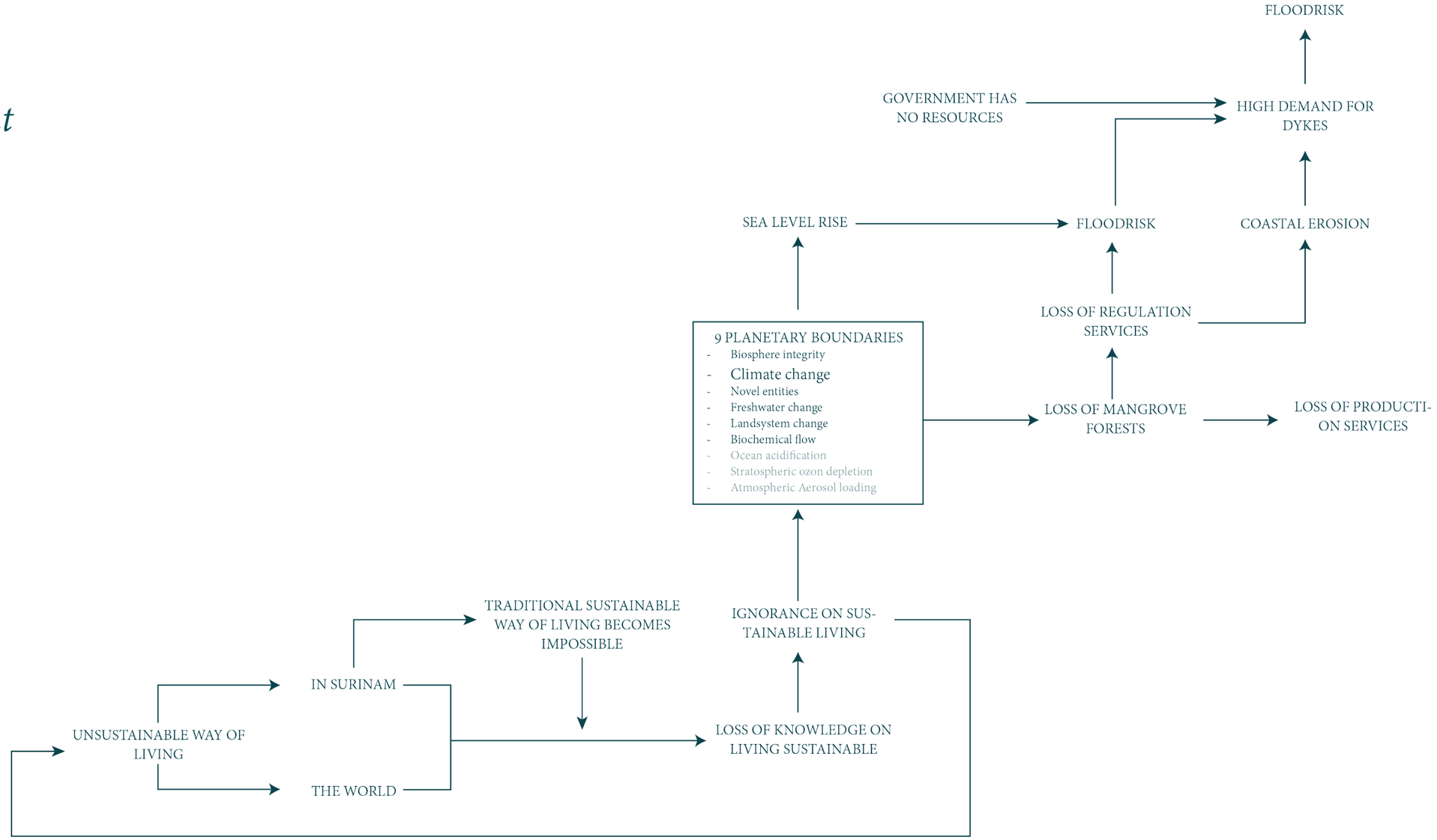
end 17th century
War between indigenous and europeans

1868
After slavery, europeans bring Hindustani people from India to work on the plantations.

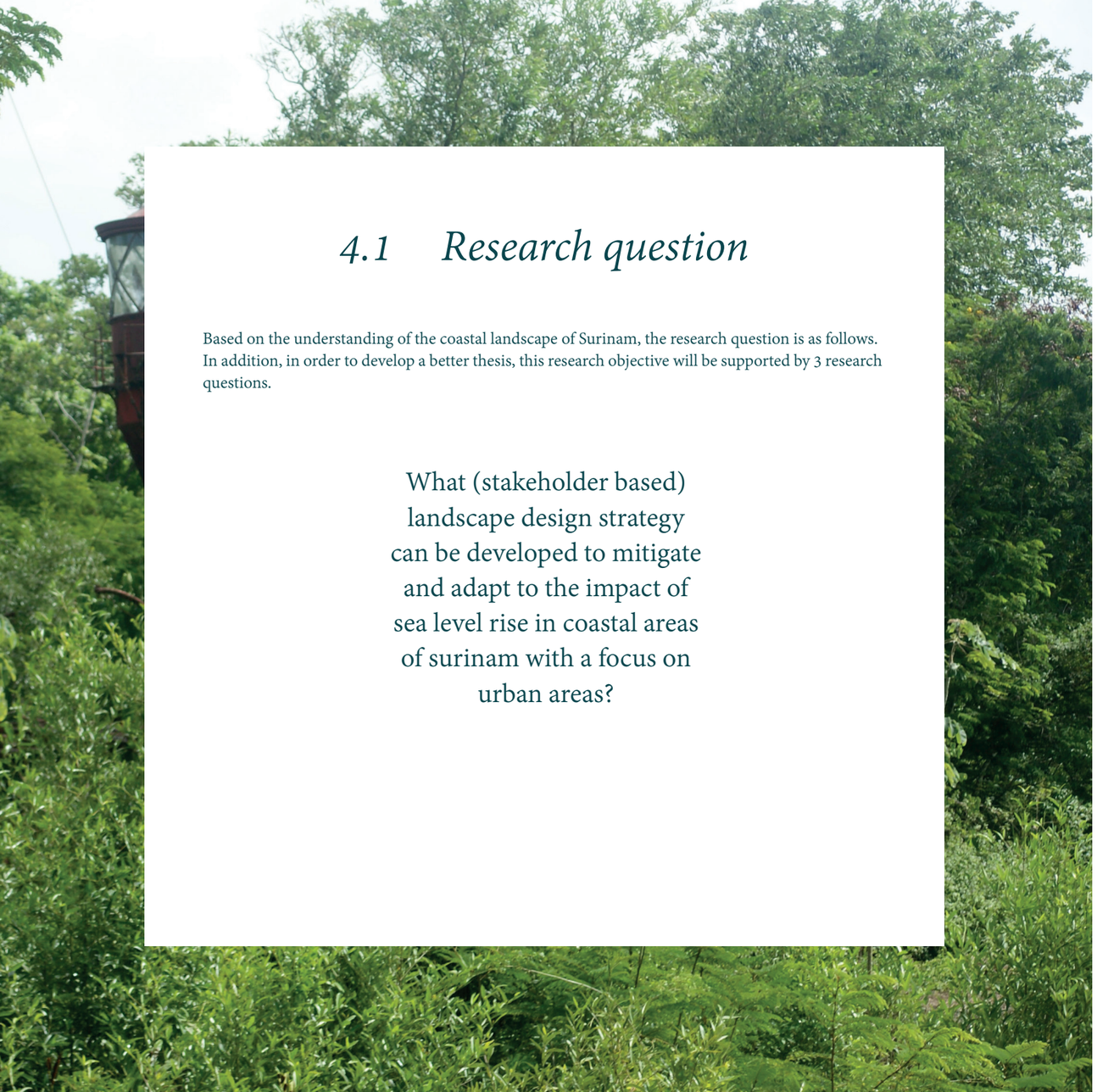
1890
Later on they also bring Javanese people to Surinam to work on the plantations.

3.7 Problem statement

Unsustainable living in the world, and specifically in Suriname, makes traditional sustainable ways of living impossible (Henry et al., 2020). This ignorance and the tremendous impact of humans on the earth puts pressure on the planet, which manifests itself in multiple destructive planetary processes (Richardson, k., 2023). These processes cause the disappearance of mangroves, resulting in the loss of both regulation and production services (Van Hespen, R., et al., 2023). On the other hand, climate change leads to sea level rise (Richardson, k., 2023). The disappearance of regulation services, combined with sea level rise, causes an increase in flood risk (Van Hespen, R., et al., 2023).



4.0 RESEARCH STATEMENT



4.1 Research question

Based on the understanding of the coastal landscape of Surinam, the research question is as follows. In addition, in order to develop a better thesis, this research objective will be supported by 3 research questions.

What (stakeholder based) landscape design strategy can be developed to mitigate and adapt to the impact of sea level rise in coastal areas of surinam with a focus on urban areas?

4.2 Sub-questions

1)	To understand the study area and the coastal landscape system of surinam.	What is the spatial impact of the 9 planetary boundaries and sea level rise on the mangroves and coastal area of Surinam?
2)	Exploring other ways to engage with nature nd the coastal environment in Surinam.	What can be learned from the customs and the way of life of indigenous and other communities?
3)	Ensure that the vision and design is by and for the Surinamese people.	How can local communities and other stakeholders help to co-create a toolbox that can serve as the basis for a spatial vision for the future?

5.0 METHODOLOGY

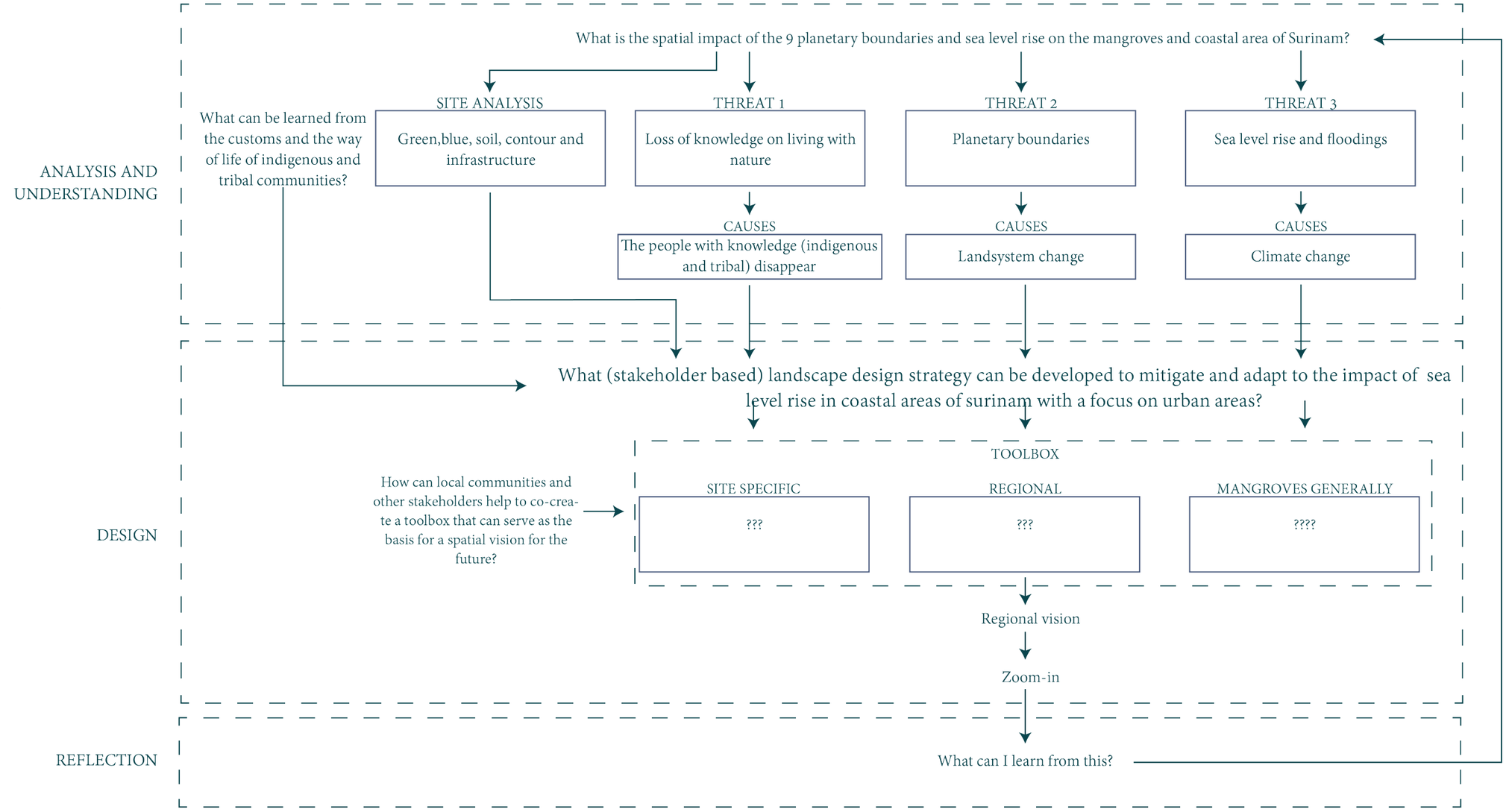
5.1 Methodology

The thesis consists of three parts: 'Analysis and Understanding', 'Design' and 'Reflection'. These parts are essential to get a clear understanding of the situation and possible solutions.

The first phase, 'Analysis and Understanding', begins with two sub-questions. The first sub-question, *What is the impact of the 9 planetary boundaries and sea level rise on the mangroves and the coastal area of Surinam?'*, helps draw a more comprehensive outline of the situation, threats and causes. At the same time, the question *'What can be learned from the customs and way of live of indigenous and tribal communities?'* will be used to seek knowledge that could serve as a basis for solutions to these threats to the mangroves.

The third sub-question, *'How can local communities and other stakeholders help to co-create a toolbox that can serve as the basis for a spatial vision for the future?'* is complementary to the previous sub-questions. This specifically looks at how people can be involved in developing and implementing solutions. This collection of knowledge can then serve as a basis for answering the main question: *What (stakeholder based) landscape design strategy can bedeveloped to mitigate and adapt to the impact of sea level rise in coastal areas of Surinam with a focus on urban areas?'* The result is a toolbox that can be further developed for a specific area in Suriname.

Through this structured approach, a clear picture of the current challenges and potential solutions can be developed, focusing on traditional knowledge and local involvement.



5.2 Methods and Approach

Each of the questions in the thesis is thoroughly investigated using different research strategies and various types of data.
The table shown here specifies for each question what data is needed, where it can be found, what research strategies are employed, and what the desired outcome of the research is.

	RESEARCH QUESTION	DATA THAT IS NEEDED	WHERE TO FIND THIS DATA	RESEARCH STRATEGIES	EXPECTED OUTCOME
	What is the spatial impact of the 9 planetary boundaries and sea level rise on the mangroves and coastal area of Surinam?	Site analysis (green, blue, geology and contour structures and infratructure)	QGIS, Government database	description, classification, logical systems	Analysis of threats and the systems behind them on the mangroves and the coastal area. Elaborated in flows ,cross-sections and maps.
ANALYSIS AND UNDERSTANDING	What can be learned from the customs and the way of life of indigenous and tribal communities?	Data of the current livestyles of indigenous and tribal communities and historical research on these communities. Data on how to include these communities in the design and implementation of the project.	Platforms from indigenous and tribal communities, interviews, Books, NGO's	etnography, description, classification, engaged action	An overview of the way of the life of indigenous and tribal communities now and in the past. This should bring out useful elements and highlight the overall importance of preserving and supporting these communities.
	How can local communities and other stakeholders help to co-create a toolbox that can serve as the basis for a spatial vision for the future?	Outcomes of the previous analysis, interviews with stakeholders, referen-ce projects, data on current news affairs in surinam and data on user-friendly toolboxes.	Reference projects, News websites, Government websites	etnography, description, engaged action, design projection	A clear overview of co-creation aspects
DESIGN	What landscape design strategies can be developed to mitigate the impacts of the planetary boundaries and sea level rise in the coastal area of Surinam?	The previous analysis, reference projects	Interviews, Reference projects, Websi-tes, Previous research.	modelling, experimenting	Toolbox of strategies that provide spatial landscape solutions to the previously mentioned threats. Based on knowledge of indigenous and tribal communities and landscape architec-tural techniques.
REFLECTION	What can be learned from this?	Previous research and design	-	evaluation	Reflection and evaluation

5.3 *Theoretical Framework*

This thesis is structured into four parts: research base, research for design, research by design and conclusion and reflection. Each phase contributes to forming a clear understanding of the situation, problems and possible solutions.

RESEARCH BASE

The first phase, the research base, lays the foundation by identifying the problem and focusing on two main topics: planetary boundaries and knowledge of indigenous and tribal communities. These topics are thoroughly supported by various sources, which is important for understanding the context and challenges facing Suriname and possible solutions.

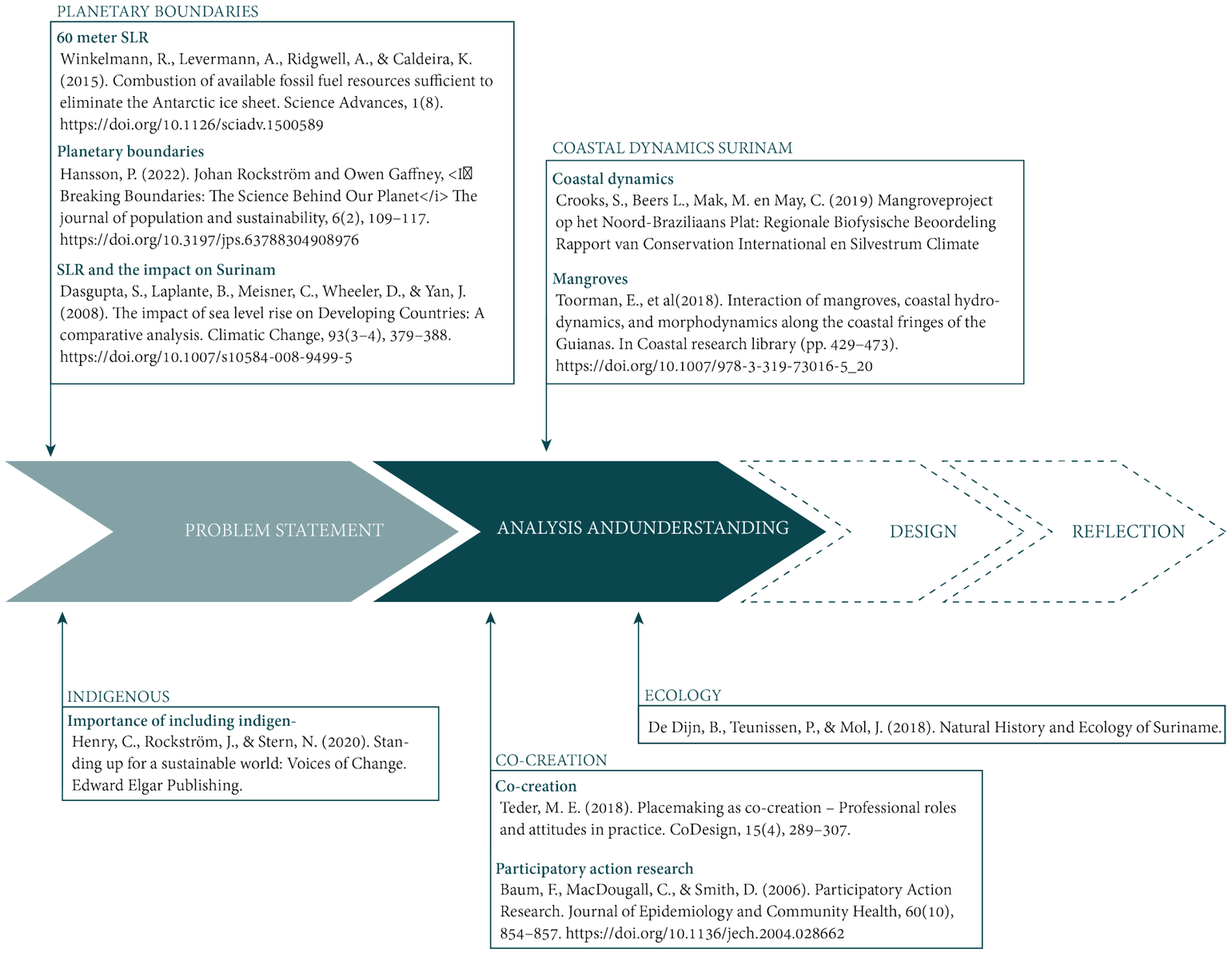
RESEARCH FOR DESIGN

Next comes the analysis and understanding phase, which is based on understanding research for design. Here, specific research is conducted that serves as a basis for the design phase (Nijhuis S., et al., 2020). Important aspects of this research include coastal dynamics , co-creation and ecological research. This phase is crucial to develop a clear understanding of the interactions between natural processes and human activities, and to gather the necessary knowledge to develop effective design strategies.

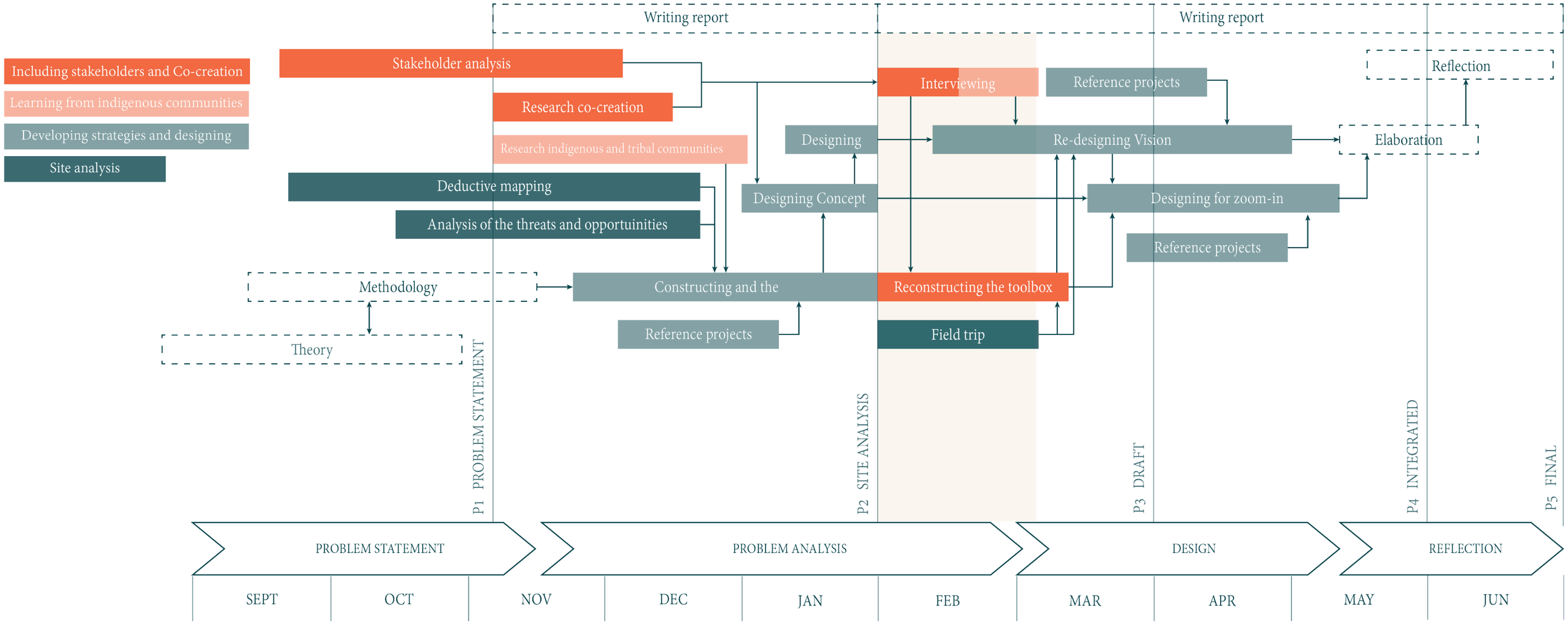
RESEARCH BY DESIGN

The third phase, research by design, focuses on research through design itself. In this process, the design process acts as the main research tool. By creating designs and prototypes, assumptions are tested and practical solutions are explored (Nijhuis, S., et al., 2020). This provides the opportunity not only to gain theoretical insights, but also to develop direct implementations that can help strengthen the resilience of coastal areas to sea level rise and other threats.

Through this structured approach, the thesis can not only offer a thorough analysis of the current situation and challenges, but also propose concrete guidelines and strategies that can be applied In the coastal area of Suriname and possibly other mangrove areas.



5.4 Timeline


Including stakeholders and Co-creation
Learning from indigenous communities
Developing strategies and designing
Site analysis
Writing report
Writing report
Stakeholder analysis
Research co-creation
Research indigenous and tribal communities
Deductive mapping
Analysis of the threats and opportuinities
Interviewing
Reference projects
Designing
Re-designing Vision
Reflection
Elaboration
Designing Concept
Designing for zoom-in
Reference projects
Methodology
Theory
Constructing and the
Reconstructing the toolbox
Reference projects
Field trip
P1 PROBLEM STATEMENT
P2 SITE ANALYSIS
P3 DRAFT
P4 INTEGRATED
P5 FINAL
PROBLEM STATEMENT
PROBLEM ANALYSIS
DESIGN
REFLECTION
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN

5.5 *Scope and Relevance*

The picture on the right page shows the sea dyke at Weg naar Zee, an agricultural area once protected from the sea by mangroves. This is no longer the case. Currently, this dike is the only defence against the sea. However, the dyke constantly breaches, causing saline seawater to enter the area and cause crops to fail.
During the month I was in Suriname, the dyke breached once. When I heard about this, I went here and took this photo. Soon after, the dike breached twice more. Weg naar Zee as an area currently acts as a buffer against the sea for the capital Paramaribo, but the coastline is constantly eroding. This problem of erosion occurs not only here, but also in several other places along the coast in Suriname and in other mangrove areas worldwide.
Restoring the mangroves can not only protect the land behind and the capital from erosion and flooding, but also provide new economic opportunities for Weg naar Zee residents and other Surinamese.
The problem of eroding coastal areas is too big to solve at once in this thesis. Nevertheless, perhaps this thesis could be a small step in the process towards a nature based solution for coastal protection through mangroves.





II. RESEARCH FOR DESIGN

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6.0 ANALYSIS AND UNDERSTANDING

6.1 Collection of data

The research for this thesis was done using written (scientific) sources, interviews and my own interpretation of fieldwork in Surinam. The map shows the place where I have been as part of the research.

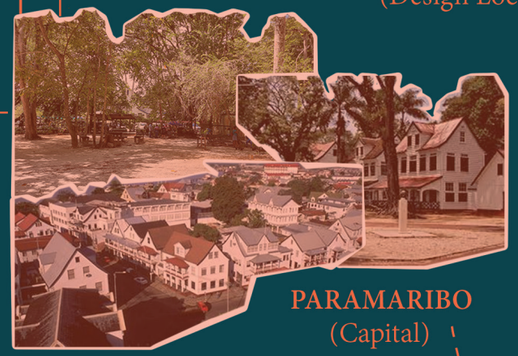


NIEUW NICKERIE
(Sea Dike)

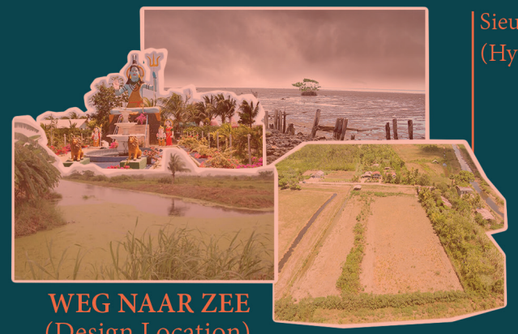
VIDS -
Sathyam Noersalim

N. Ardjkoeman
Local boatsman

Green Growth Suriname -
Lindsay Goossens
and Gwendolyn Smith



PARAMARIBO
(Capital)



WEG NAAR ZEE
(Design Location)

Sieuwnath Naipal
(Hydrologist)



PLANTAGE BAKKIE
(old plantations in
natural environ-
ment)

Guide
Benito Aloema



GALIBI
(indigenous com-
munitie takes care
of mangroves)

Oliver Smith
(Architect)



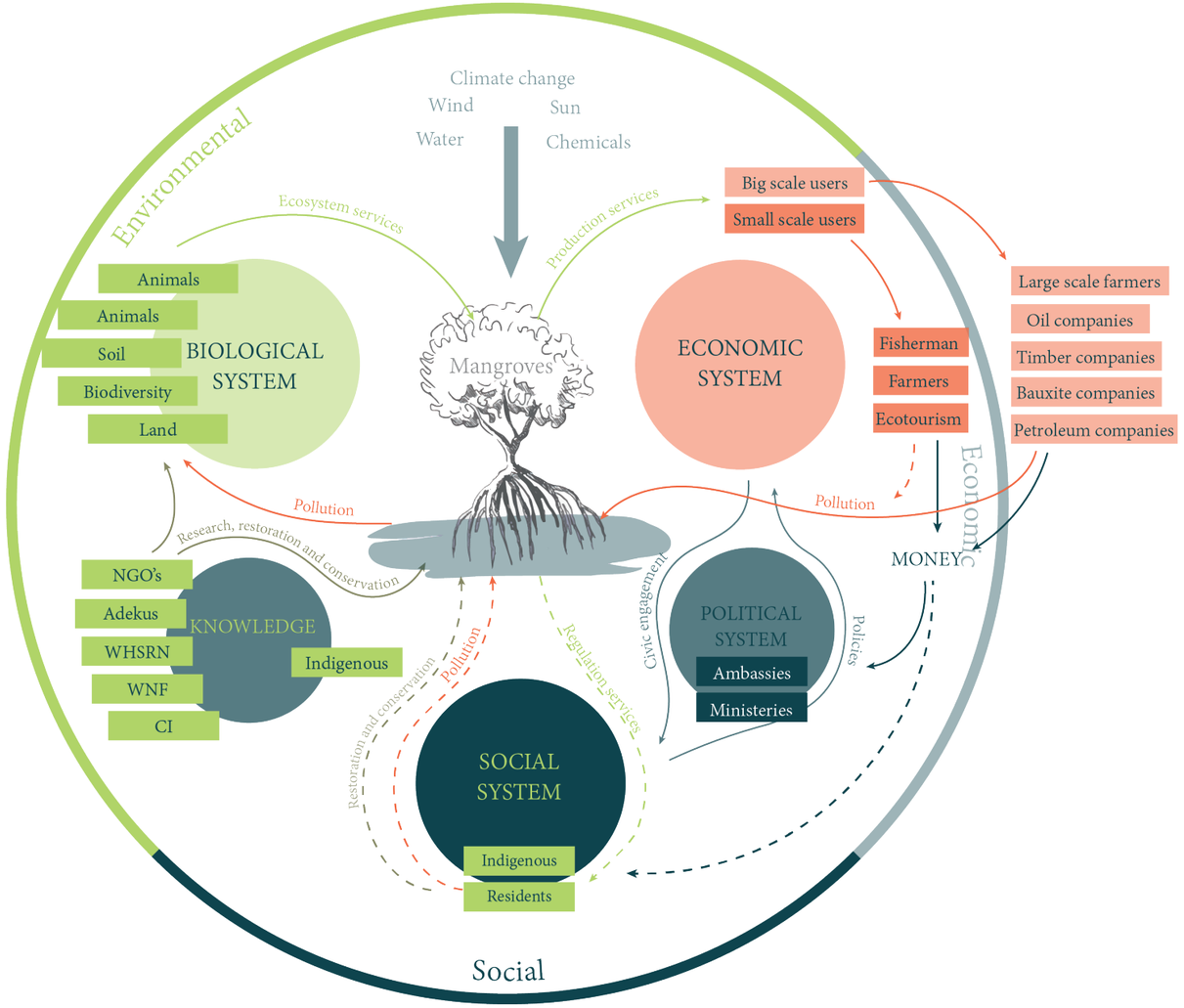
PARANAM

6.2 Stakeholders

The diagram on the right shows the different stakeholders and influential abiotic factors surrounding the mangrove system. The diagram illustrates the relationships between these different actors and their interactions with the ecosystem
For users and residents, mangroves provide both regulatory and production services. However, the parties benefiting from these services generally do not operate in a sustainable manner and therefore have a negative impact on the mangroves. These negative influences manifest themselves mainly through pollution, blockages and physical containment of the mangrove areas.

These harmful influences affect the biological system of the mangroves, throwing it out of balance. This disrupted system can then no longer provide the necessary foundation that mangroves need. As a result, negative influences from users and residents become worse, leading to a vicious cycle of degradation.
Residents of the area are also negatively affected by the deterioration of mangroves, but often do not have the means to move (Source). However, the government, which should put rules in place to regulate businesses and users, does little. Moreover, many of the areas where mangroves are doing badly are issued as concessions, which limits the government's ability to intervene. In addition, the government lacks financial resources to invest in mangrove restoration and accretion.

There is also a group with knowledge about mangroves and sustainable management practices. This group currently has limited positive impact on mangroves through pilot projects and new insights. Their impact is still too small to reverse negative trends, but they represent an important source of hope and innovation.



6.3 Introduction to the Mangroves

Mangrove trees are species-dependent on specific conditions of the water system in which fresh and brackish water sources, connections between these sources and quantity and fluctuation of water form a vital basis. (Göltenboth, F., et al., 2006). This part of research will therefore first focus on mangrove trees themselves. Then it will look at the connections with the water system and thereafter what this means for the coastal zone and the role ecology plays in this. It will then focus on threats and opportunities for the mangrove system.



6.4 Meet the Mangroves

Mangroves are essential components of coastal ecosystems and act as a natural barrier protecting both marine and terrestrial environments from the adverse effects of wind, waves and floods (Gijón Mancheño, A., 2022). In addition to their protective function, mangrove forests play a crucial role in improving water quality by filtering pollutants and retaining sediment. In addition, sediment retention in turn helps combat coastal erosion (Menke, J., et al., 2024).

From an ecological perspective, mangrove forests provide habitat for a wide variety of organisms, including many species of fish, birds and shellfish that depend on the forests for reproduction, breeding and feeding (Keeley. M. A., et al., 2018). Despite being resistant to salt water, mangrove populations around the world have declined sharply due to increasing coastal development and land-use changes. The decline in mangrove populations highlights the need for conservation measures to protect these coastal ecosystems and the numerous benefits they provide (Menke, J., et al., 2024).

Suriname has 3 species of mangrove trees, each with a specific function in coastal accretion and specific needs.

BLACK MANGROVE

The Black Mangrove, or Parwa (Avicennia germinans), is a small tree or shrub reaching heights of 3-12 meters (Fern, K., 2014). It is typically the first mangrove species to colonize mudflats, although it is most commonly found on the landward side of mangrove swamps (Fern, K., 2014). These trees are equipped with radiating cable roots and vertical breathing roots (Göltenboth, F., et al., 2006). However, they cannot withstand prolonged periods of high water levels as their breathing roots need to stay above water (Fern, K., et al., 2014). Black Mangroves are highly tolerant of elevated salinity levels (De Dijn, B., et al., 2018). Their seeds, which develop while still attached to the tree, can float on seawater and are carried by spring tides to mudflats where they establish roots before the next tide (S. Naipal, personal interview, 21 Feb. 2024). The wood of the Black Mangrove is strong and suitable for furniture making, though it is often used to smoke fish (Keeley. M. A., et al., 2018).

RED MANGROVE

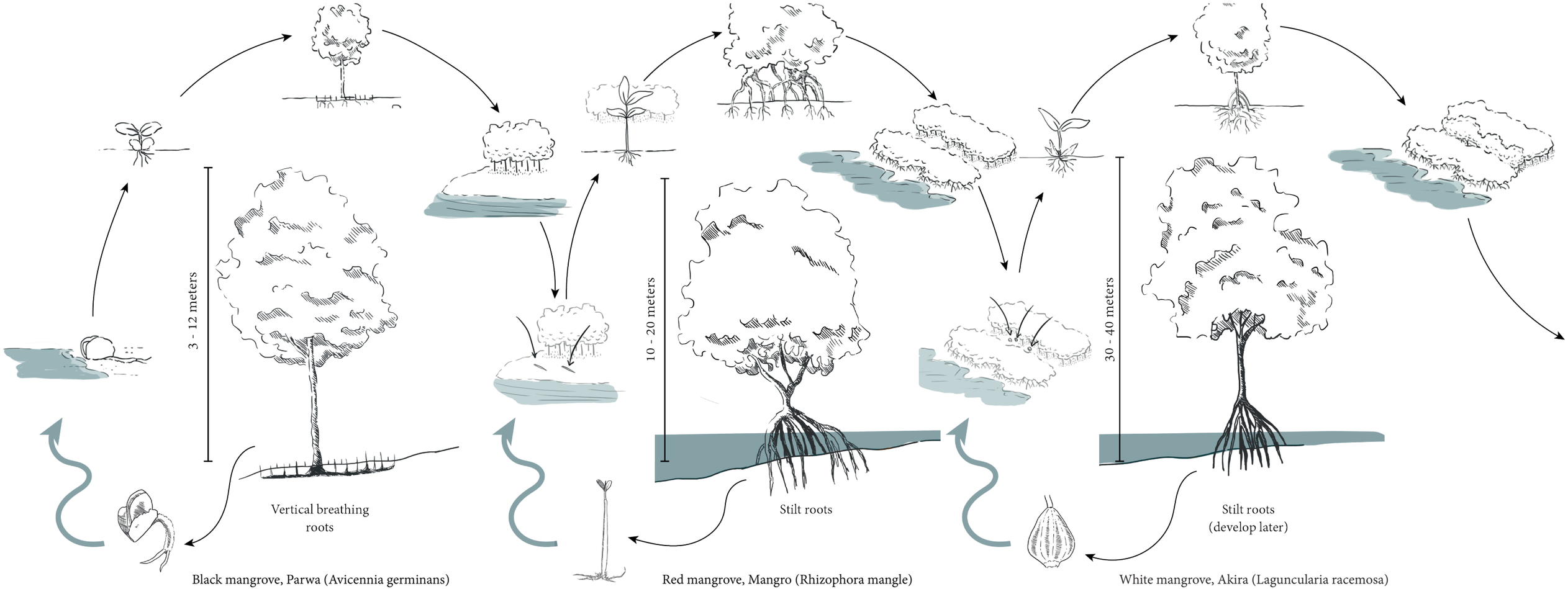
The Red Mangrove, or Mangro (Rhizophora mangle), grows along coastlines and riverbanks (De Dijn, B., et al., 2018). This species can reach heights of 10 to 20 meters, with some individuals growing up to 35 meters tall (Marek, P., 2024). Red Mangroves are characterized by their stilt roots, which extend above ground from the trunk and grow downwards into the soil, where they develop an extensive underground root system (Göltenboth, F., et al., 2006). These stilt roots provide the tree with stability, allowing it to withstand waves and currents effectively. While Red Mangroves handle tidal fluctuations well, they are less tolerant of high salt concentrations (Fern, K., et al., 2014). The tree produces small fruits from which needle-shaped seeds emerge, and these seeds, like many other mangrove species, begin germinating while still on the tree (Marek, P., 2024). Upon reaching the soil, the seeds immediately start to develop roots (Marek, P., 2024).

WHITE MANGROVE

The White Mangrove, or Akira (Laguncularia racemosa), begins to grow once the Black and Red Mangroves are already established, occupying the zone between them and extending further inland (S. Naipal, personal interview, 21 Feb. 2024). This tree can reach heights of 30 to 40 meters (Andreu, M., 2022). It features root systems similar to those of the Red Mangrove, though these roots develop later (S. Naipal, personal interview, 21 Feb. 2024). White Mangroves produce white flowers in clusters at the ends of branches year-round. Their fruits are small green capsules that germinate on the tree and float on water until deposited (Fern, K., 2022). The wood of the White Mangrove is strong, making it suitable for construction and furniture, and it is also used for medicinal purposes (Andreu, M., 2022).



6.4 Meet the mangroves



6.5 Coastal accretion

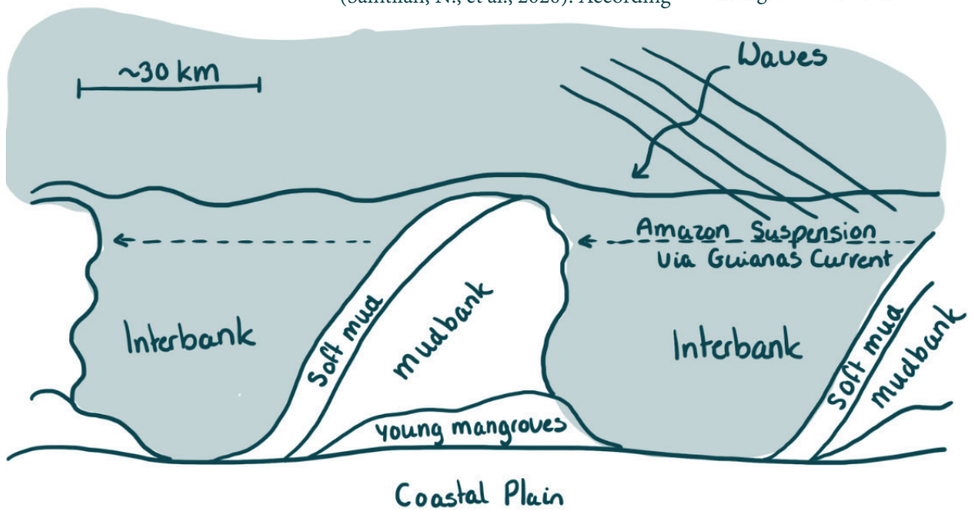
Suriname's coastal plain is located between the Orinoco and the Amazon. The coast has been built up for thousands of years with mud moved up the coast in the form of migrating mud banks originating from the Amazon. Both the old and young coastal plain are formed in this way. Coastal accretion is a dynamic process. With an increase in sediment supply from a mudbank or reduction in wave energy, the mangrove forest can grow and coastal accretion takes place. However, with a sharp decrease in sediment supply or during storms, the coast will be prone to partially shrink again (Crooks, S., et al., 2019).

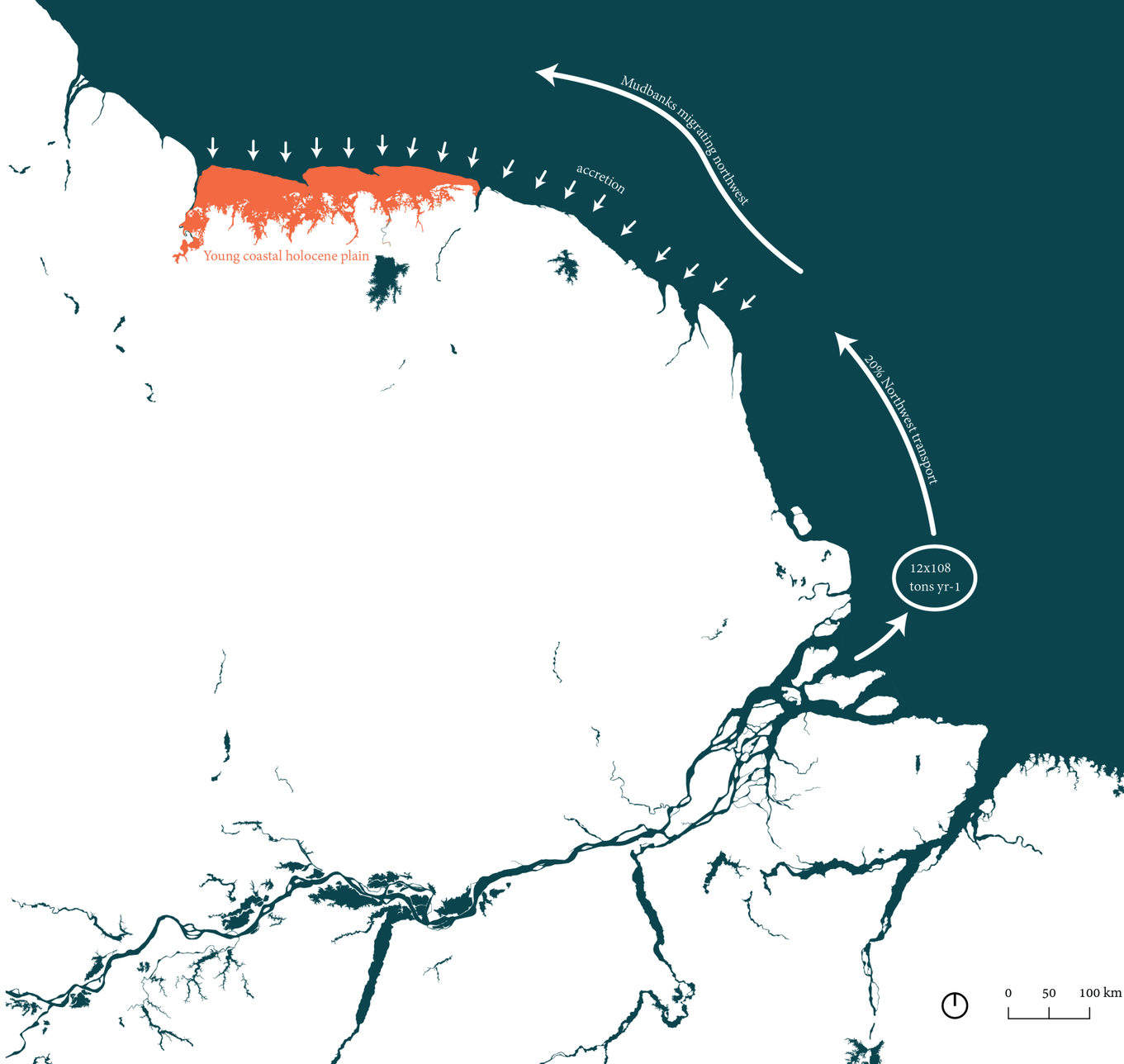
SEA LEVEL RISE

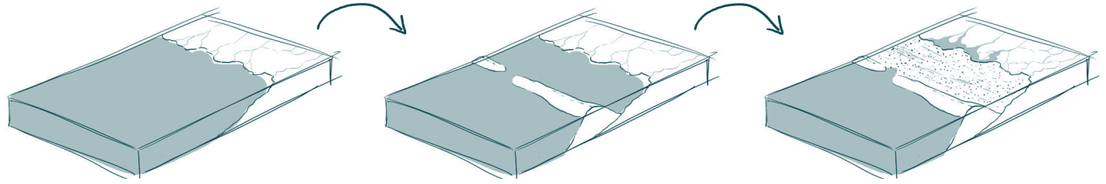
With sea level rise, vertical accretion of mangroves generally increases; this is often accompanied by the landward migration of the mangroves. This will also increase CO_2 storage. A reference for this process is the period at the beginning of the Holocene, just after the last ice age. During this period, sea levels rose very rapidly in a short period of time, leading to the shrinking of the Surinamese coastal plain. From the time the sea level reached the level of 6 mm per year, the coastline remained the same. The mangrove trees were able to grow vertically with the sea level at this rate of rise (Saintilan, N., et al., 2020).

Currently, trends show sea level rising at approximately 3.4 mm per year (Saintilan, N., et al., 2020). According to the sea level rise trend identified earlier in this thesis, the maximum sea level would rise about 3 metres within 100 years, meaning it would rise at an average rate of 30 mm per year. This is five times the rate that mangrove forests can handle.

However, for mangrove forests with a higher amount of supplied sediment, this limit can be higher. In addition, the aforementioned numbers are based on mangrove forests from the early Holocene. These forests grew in a natural way. Mangrove forests can cope with a higher rate of sea level rise when the supply of sediment is higher (Saintilan, N., et al., 2020). Thus, retaining sediment as much and as fast as possible is very important for mangrove accretion.

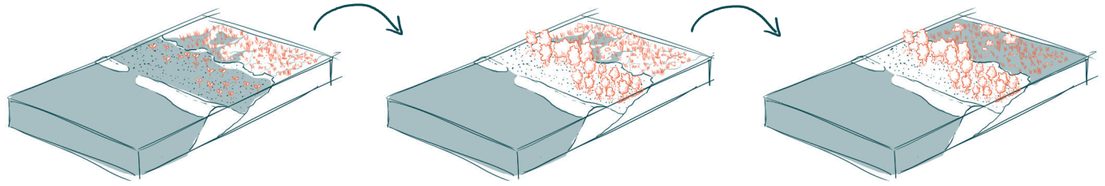






Formation sand ridge with coarse sand from the river.

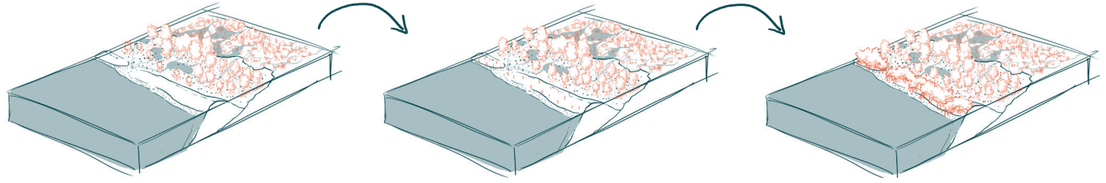
Force of seawater decreases causing mud deposition and the formation of a mudflat. Due to this mudflat, water from land becomes trapped in the old coastal plain.



During spring tide the mudflat floods and the deposits germinated seeds of black mangrove trees (Avicennia germinans) on the mudflat

Before the next spring tide, the seeds have already taken root and are starting to grow.
A brackish herbaceous swamp forms on the old coastal plain.

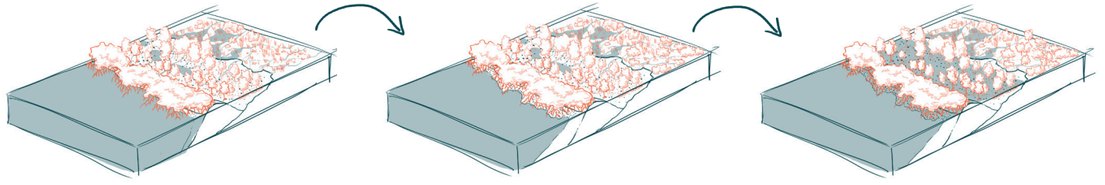
During the rainy season this swamp becoms fresh and during the dry season it becomes brackish again.



A black mangrove forest with lagoons is forming.

Once this forest is established, red mangrove(Rhizophora mangle) trees start growing in front of the the black mangrove forest.

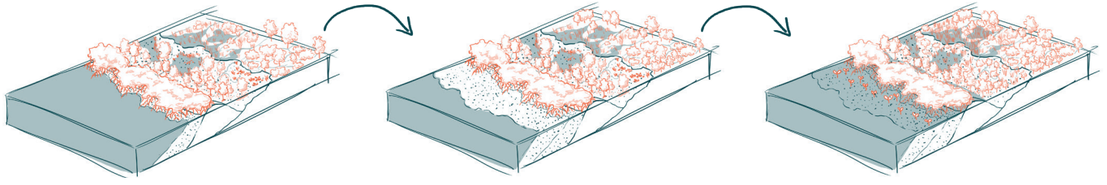
A belt of red mangrove trees is forming and inbetween the two species of trees a third species, white mangroves (Laguncularia racemosa) is settling.



The mangrove forest continues to develop.

The red mangroves continue to grow and retain new sediment.

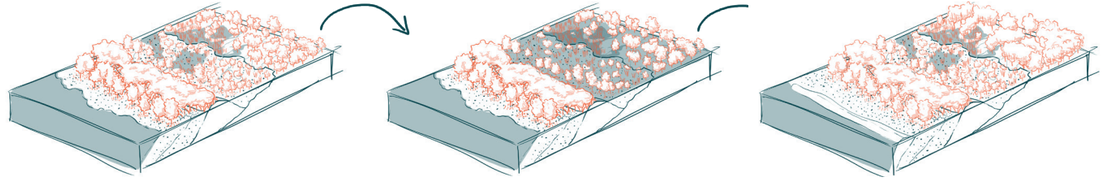
Only during spring tide the black mangroves flood. After this, the water evaporates and the soil becomes more saline.



After a while the soil becomes hypersaline and part black mangrove trees die of. Hypersaline herbaceous form on higher parts and hypersaline lakes on the lower parts.

A Mudbank arrives at the shore and settles

During the next spring tide black mangrove seedlings are deposited by the sea. The marshes behind the mangroves no longer flood and become less saline. The swamps in the old plain become fresh.



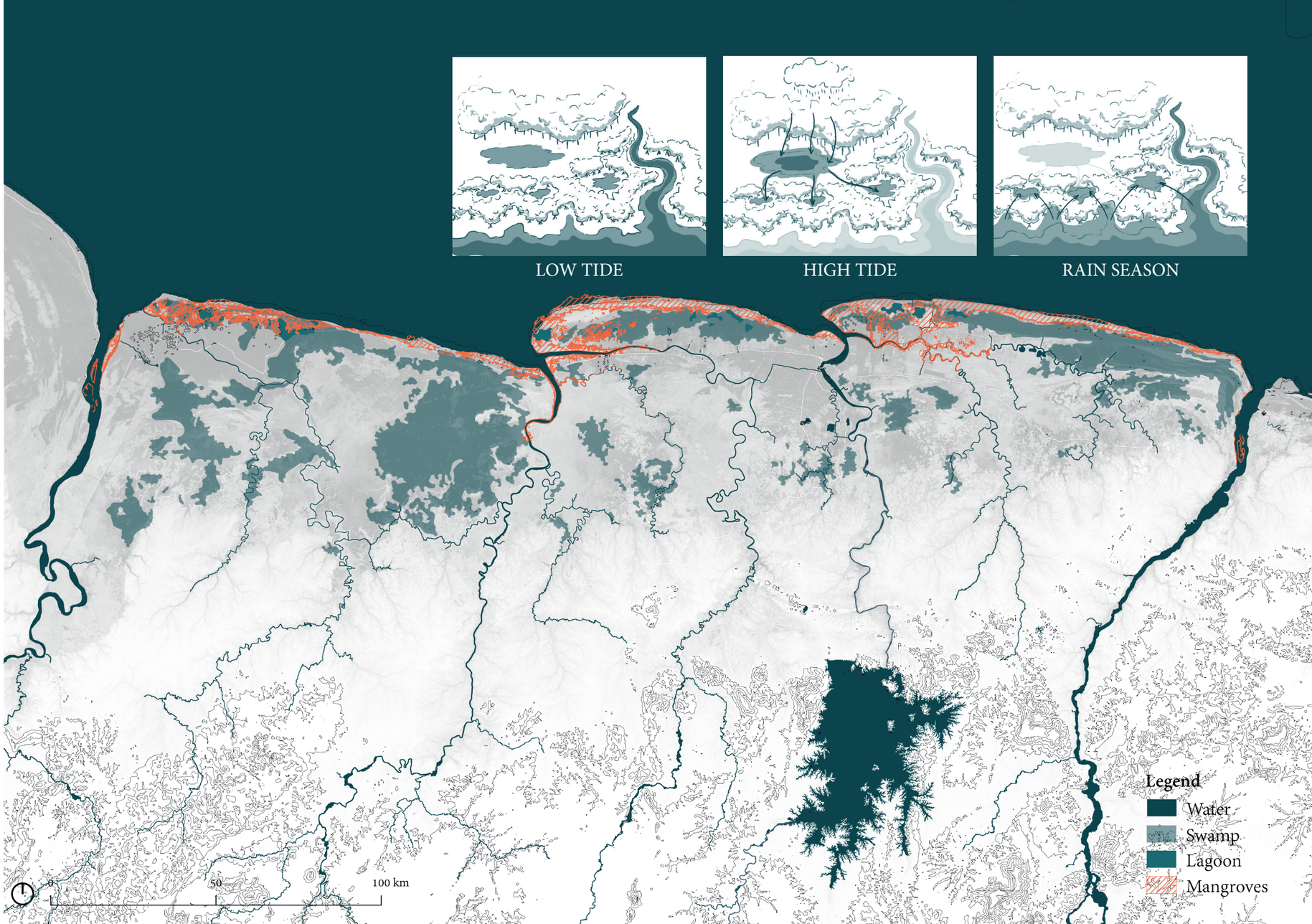
A new belt of parwa trees develops.
Savannahs and swamp wood forms on the old coastal plain.

During the rainy season, fresh and brackish water swamps completely with fresh water. With less influence from the sea, they become increasingly fresh.

A new sand ridge develops. The swampwood changes to swamp forest and the savannah become swamp wood.

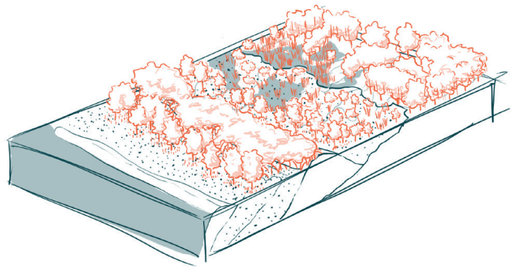
6.6 Mangroves and Hydrology

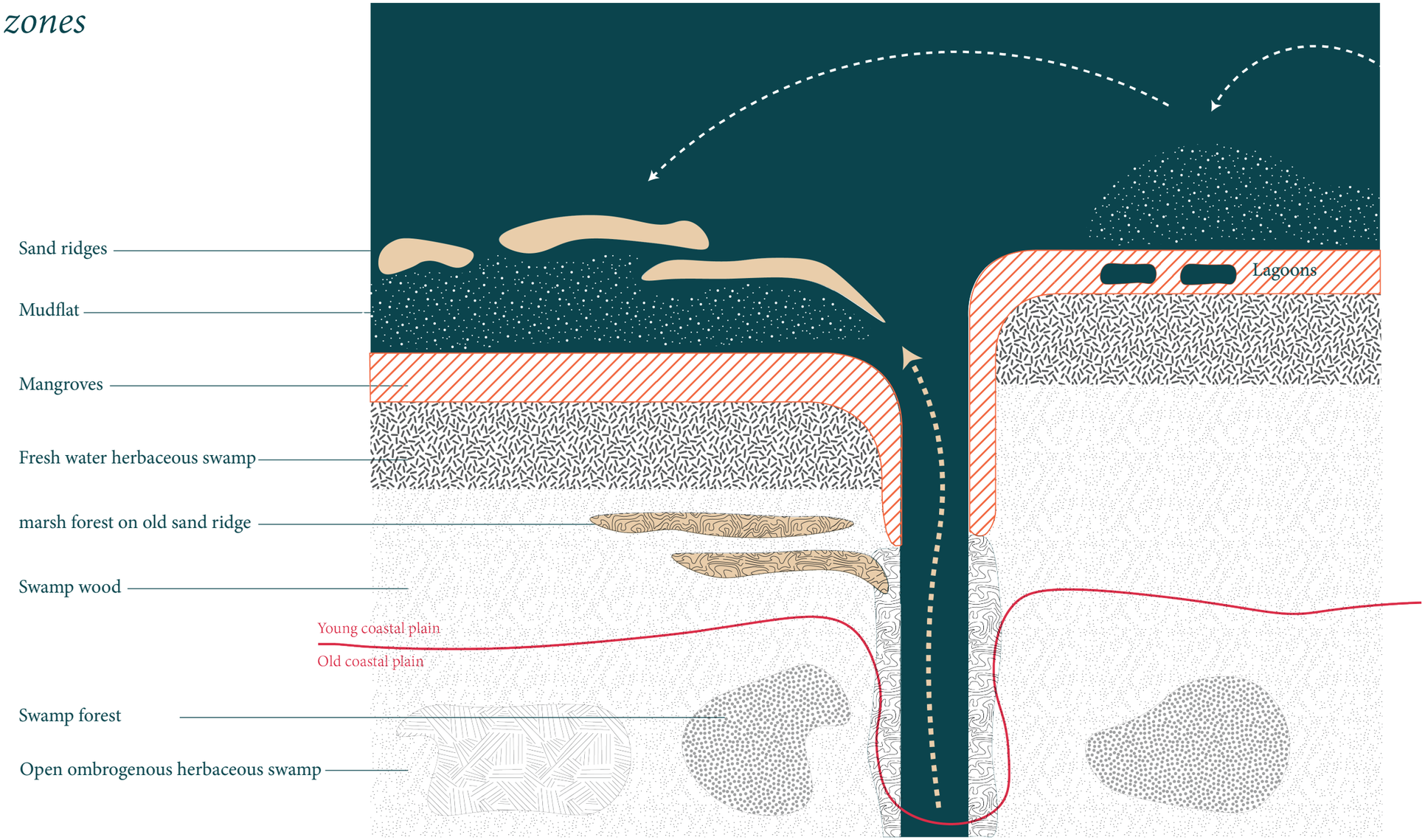
Mangrove species require different conditions for each species in terms of tidal differences, soil and salinity (Gijón Mancheño, A., 2022). These specific conditions are provided by the water system. Saline water is supplied by tides from the sea. The lagoons and swamps in and behind the mangroves provide a buffer of salt, brackish and fresh water. The rivers, creeks and rain provide more fresh water. In the rainy season, this creates more and fresher water and in the dry season when evapotranspiration plays a bigger role, the water stands lower and has a higher salt concentration (De Dijn, B., 2018).



6.7 Introduction of the eco zones

The different water bodies, as described earlier, form part of several ecological zones that extend behind the mangroves(See the map). These ecological zones play a crucial role in regulating and buffering water quantities, as well as maintaining water quality. For a well-functioning mangrove system, it is crucial that these other zones also function in an optimal way (De Dijn, B., et al., 2018). The following pages will explain how the water functions in these areas.

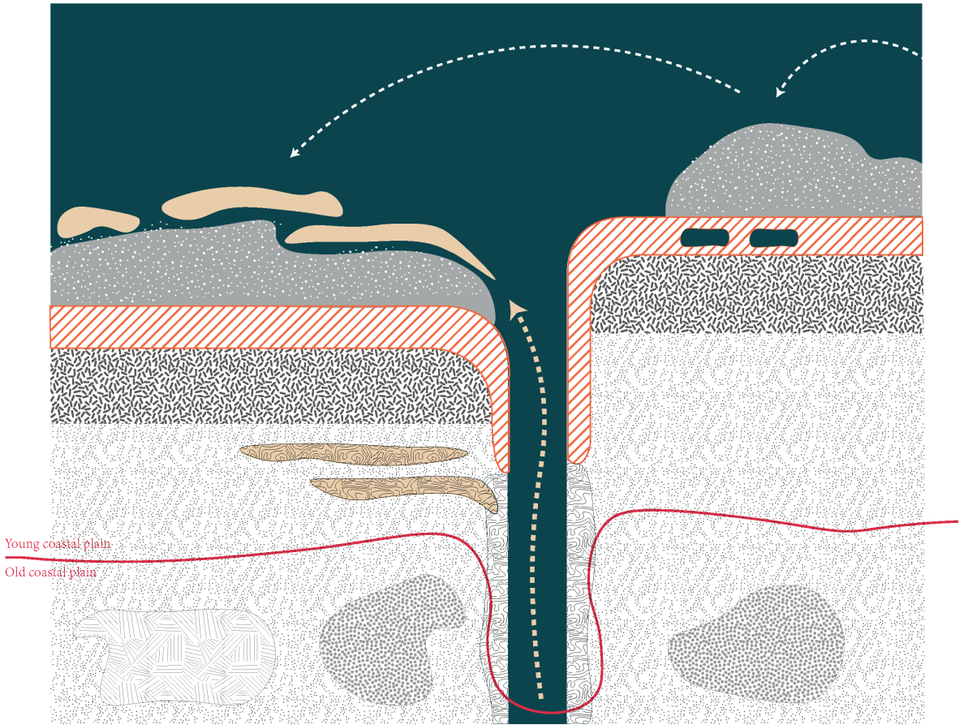




6.7.1 *Tidal differences*

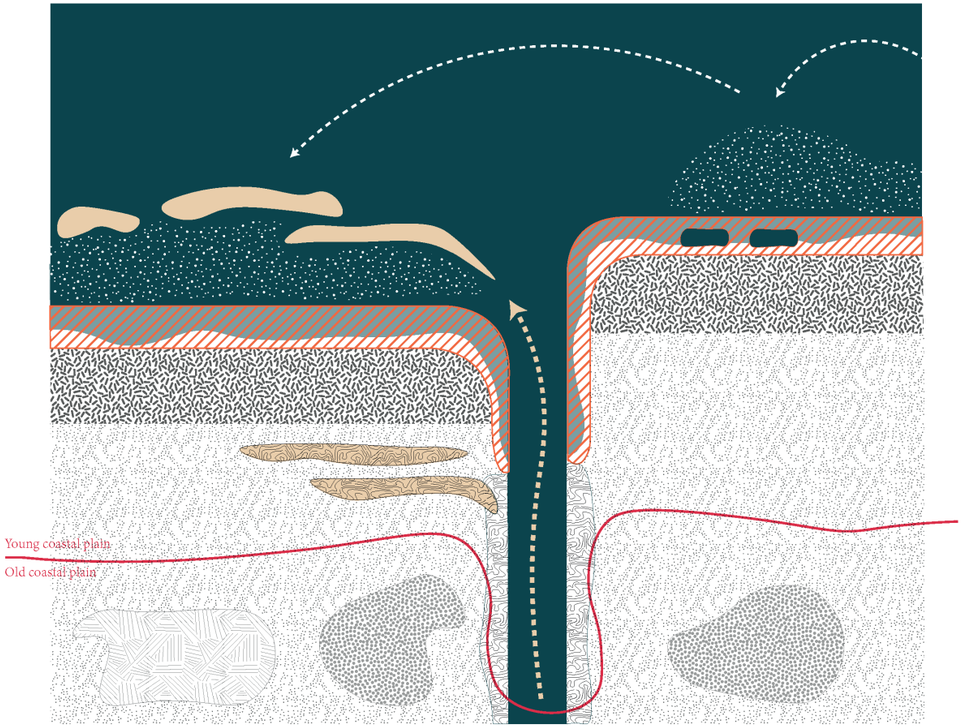
The two maps show the difference between high and low tides. At low tide, the water can flow back to the sea, leaving most of the mangroves drained. The mud banks along the coast, which serve as a buffer for the mangroves, are also largely drained. Small creeks form and help drain toxic substances from both the mangroves and other organisms (De Dijn, B., 2018).

LOW TIDE



At high tide, the sea water rises about a metre, flooding the mud flats and part of the mangroves. Mainly the coastal area near the sea is inundated. The flow of the water slows down due to the mudflats and the roots of the trees, giving sediment particles a chance to sink to the bottom, causing the coastline to grow. During high tide, parts of the sandbanks still remain above water (De Dijn, B., 2018). During spring tides, the water can rise as high as 3 metres, causing seawater to penetrate the mangrove forests deeper than during normal conditions.

HIGH TIDE



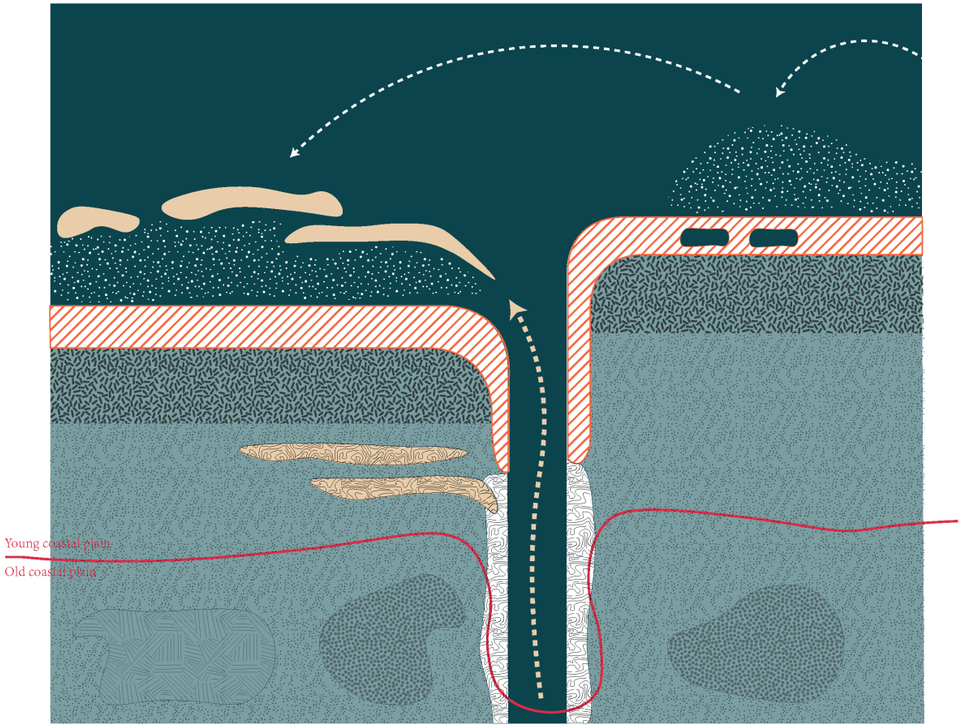
6.7.2 Seasonal differences

The following maps show the difference between the dry and rainy seasons. On the maps, water-saturated areas are marked in blue. Water-saturated areas are places where the soil is completely waterlogged, without necessarily being under water.

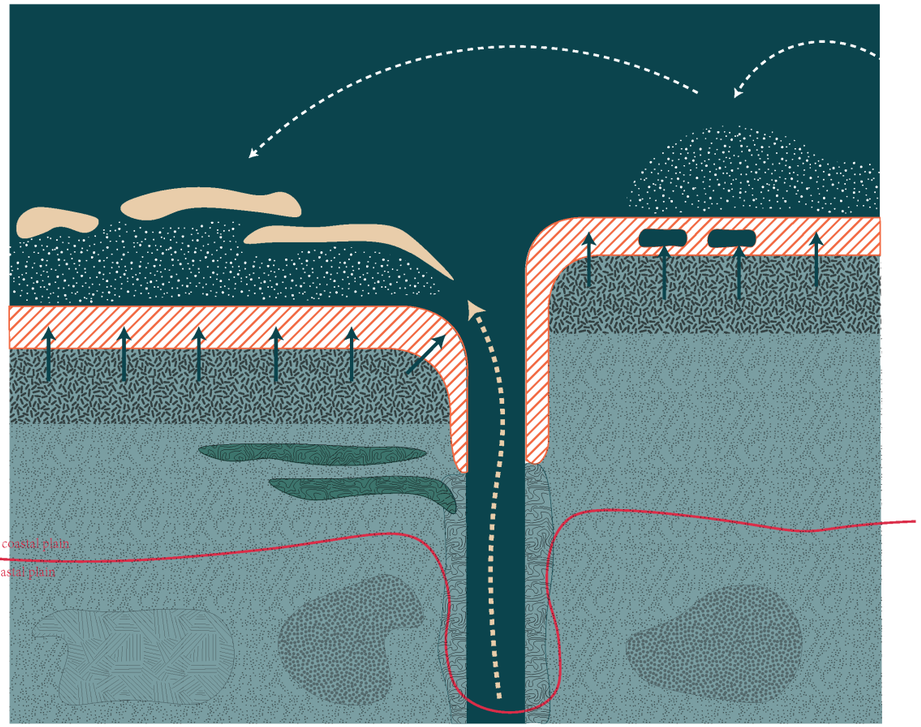
During the dry season, all swamp areas are waterlogged, while other areas are not. Because during this season the influence of seawater is greater than that of rainwater, the inland part of the mangroves becomes saltier, and part of the marsh becomes brackish.

In the rainy season, the marsh areas are partly submerged, with a layer of up to 1 metre. The wetlands are then waterlogged. During this period, creeks form and drain water into the swamp areas. Rivers and creeks drain more water during this period, so the swamps and mangroves receive more water through both rainfall and runoff. This makes the swamps more fresh and the mangrove zone more brackish than saline again (De Dijn, B., 2018).

DRY SEASON



RAINY SEASON



6.8.1 *Eco zones - mangrove zone*

SAND RIDGE

Some parts of the coastline contain sand ridges, mainly around estuaries. During high tides, some parts flood, while other higher parts remain dry (De Dijn, B., 2018).
The higher-lying parts of these sand ridges are covered with species-poor herbaceous beach vegetation, such as Ipomoea pes-caprae (Dagoeblad), Canavalia maritima (Baybean) and Stenotaphrum secundatum (St. Augustine grass) (Lindeman, J., 1952). These areas also serve as important nesting sites for four species of aquatic turtles (De Dijn, B., 2018).

MUDFLAT

Mudflats emerge from clay sediment from the amazon rivers. The bottom substrate is soft brackish mud. During high tide the mudflats are under water (normal tide: 1m, spring tide 3m). During low tide the mudflats fall dry. Despite the high amount of nutrients, photosynthesis is limited due to the low light penetration in the muddy water. Most common are floating colonies of Phaecytis(algae), living in small gelatine spheres. Besides this also bacteria and diatoms live in this mud. Together they form the base of the foodweb (De Dijn, B., 2018). Birds like Arenaria interpres (steenloper) and especially migratory birds like Calidris pusilla (Semipalmated Sandpipers), Charadrius semipalmatus (Semipalmated Plovers), Limnodromus griseus (Short-billed Dowitchers) and invertebrates like Liocarcinus depurator (Swimming crab) feed on these (WHSRN, 2024).

MANGROVE FOREST

Mangrove forests develop when the first black mangrove seedlings start growing on the new mudflats. A mature mangrove forest consists of three types of mangrove trees; Avicennia germinans (Parwa or Black mangroves), Rhizophora mangle (Mangro or Red mangroves) and Laguncularia racemosa (Akira or White mangrove).
The conditions required are specific to each tree species and depend on soil, altitude and fresh and salt water supply(De Dijn, B., 2018).
Due to the dense vegetation, the forests are important breeding grounds for invertebrates like Goniopsis cruentata (Mangrove root crab), fish like Megalopidae (Tarpon) and birds like Fregata magnificens (Fregate bird). These juveniles later migrate to other areas outside the mangroves or are food for larger species living just outside the mangroves (De Dijn, B., 2018).

MUDFLAT



SAND RIDGE



MANGROVE FOREST



6.8.2 *Eco zones - Herbaceous swamps*

HYPERSALINE SWAMP

Hypersaline swamps form at lower sites where freshwater inflows are small and brackish water is supplied only during spring tides. The water stays here and evaporates, causing the salinity in these swamps to rise rapidly (De Dijn, B., 2018).
Black mangrove trees that first grew here die off and the new vegetation consists of low succulents, grasses and aguatic plants with high salt tolerance such as Eleocharis mutata (scallion grass), Sporobolus virginicus and Sesuvium protulacastrum (Krapéwiwiri)(Lindeman, J. (1952). and the same birds species as mudflats and mangroves.
Important breeding places for fish and invertebrates. Birds feed on these juvenile fish species (De Dijn, B., 2018).

BRACKISH HERBACEOUS SWAMP

Same as hypersaline lakes but fresh water supply is bigger. During dry periods these swamps are brackish and during rainy season they're fresh (De Dijn, B., 2018). Plants that grow in these swamps are for example Eleocharis mutata (scallion grass), paspalum vaginatum, Cyperus giganteus (papaja gras) and Acrostichum aureum (Lindeman, J.,1952).
These lakes provide important breeding places for fish and invertebrates. Birds feed on these juvenile fish species (De Dijn, B., 2018).

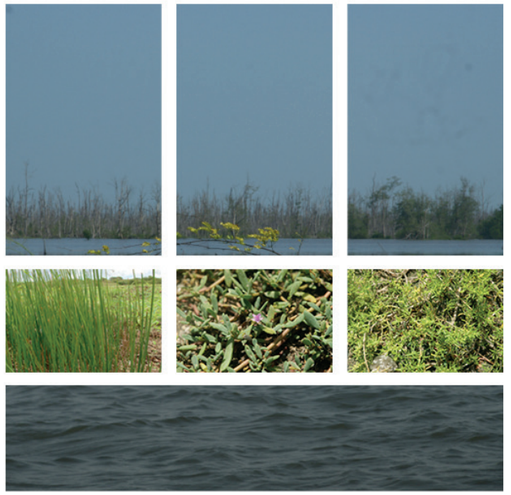
FRESH WATER HERBACEOUS SWAMP

Fresh water swamps are perenially flooded or at least waterlogged. The water is fresh and mostly stagnant. during rainy season it flows towards the mangroves (De Dijn, B., 2018).
A few Black mangrove trees can still grow in these swamps. Other swamps are dominated by herbslike Typha domingensis(Langagrasi), Cyperus gigantus(Prasorograsi) and Montrichardia aborenscens (Mokomoko), scattered groups of shrubs and trees sucha as black and white mangroves and Machaeriums Lunatums(Brantimakka) and hydrophytes (Lindeman, J.,1952).
Examples of swamp invertebrates are Pipa Pipa (Surinam toad) and Pomacea bridgesii (air-breathing apple snail) (De Dijn, B.,2018).

BRACKISH HERBACEOUS SWAMP



HYPERSALINE SWAMP



FRESH WATER HERBACEOUS SWAMP



6.8.3 *Eco zones - forests*

MARSH FOREST

Marsh forest has a tall stature (>25m) and occurs on land which is seasonally shalllowly inudated with fresh water. During the dry season the upper soil layer dries out. Marsh forests are most common on old river bank deposits (old sandridges) and riperian banks. Marsh forest soil is well-draining and holds an extensive network of small channels (10-50cm deep) that fill up with water during the rainy season. and discharge water during the dry season (De Dijn, B., 2018).
Common marsh forest trees are Hura crepitans (Posentri), Eperua falcata (Walaba), Carapa (Krapa) and Pachira Aguatica (Watracacao) (Lindeman, J., 1952).

SWAMP WOOD

Herbaceous swamps slowly turn into swamp wood. Swamp forest with one layer of mature trees (10-25m) which is perenially flooded (De Dijn, B., 2018).
Species Erythrina fusca (kofimama), Triplaris (Mierenhout) and Pterocarpus(Watrabébé) (Lindeman, J.,1952).

SWAMP FOREST

Swamp wood turns later on into swamp forest with three layers of mature trees (25-30m) which is perenially flooded (De Dijn, B., 2018).
Species Virola Surinamensis (babun udu), Symphonia globulifera(Mataki) and Euterpe oleracaea (pina) (Lindeman, J.,1952).

SWAMP WOOD



MARSH FOREST

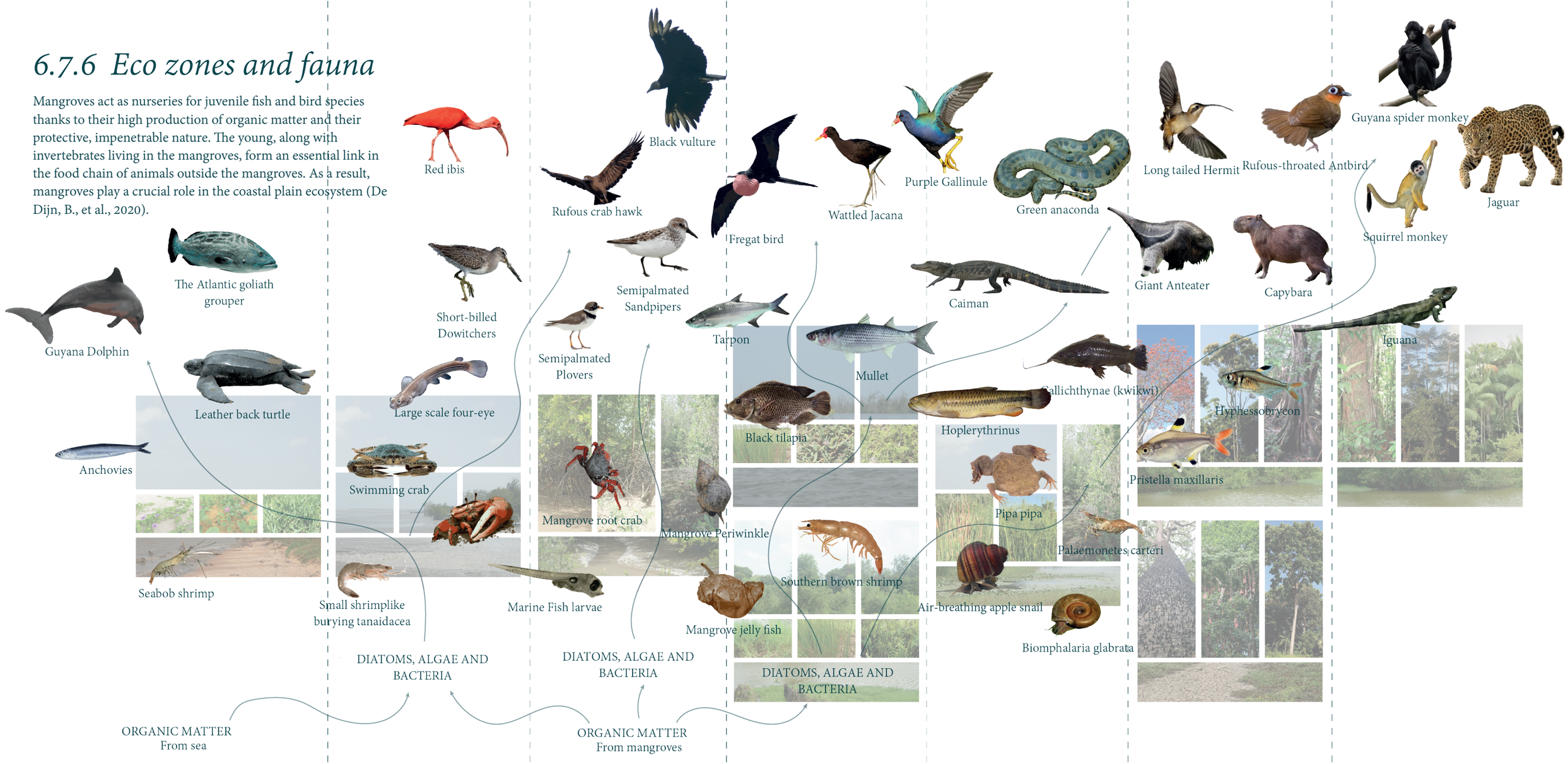


SWAMP FOREST



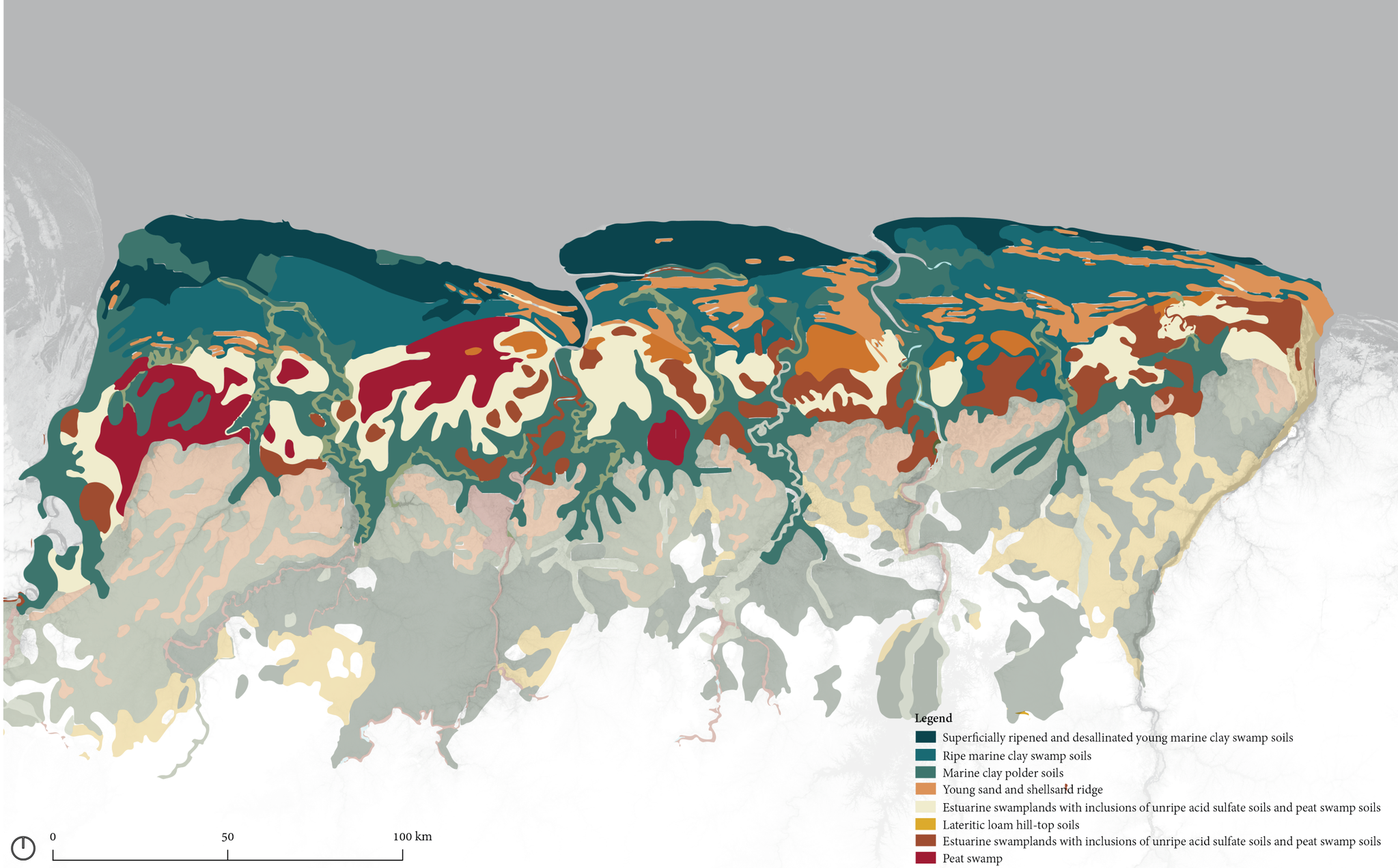
6.7.6 *Eco zones and fauna*

Mangroves act as nurseries for juvenile fish and bird species thanks to their high production of organic matter and their protective, impenetrable nature. The young, along with invertebrates living in the mangroves, form an essential link in the food chain of animals outside the mangroves. As a result, mangroves play a crucial role in the coastal plain ecosystem (De Dijn, B., et al., 2020).



6.9 Soil

The entire coastal plain was formed by deposited sediment, consisting mainly of clay but also sand. Because of this formation by the sea, the coastal plain is quite low. Due to the different conditions in soil composition and location relative to other areas, ecological zones form and the soil is constantly changing. For example, there are places where peat begins to form (De Dijn, 2018)(Anton de Kom University of Suriname. (2018).



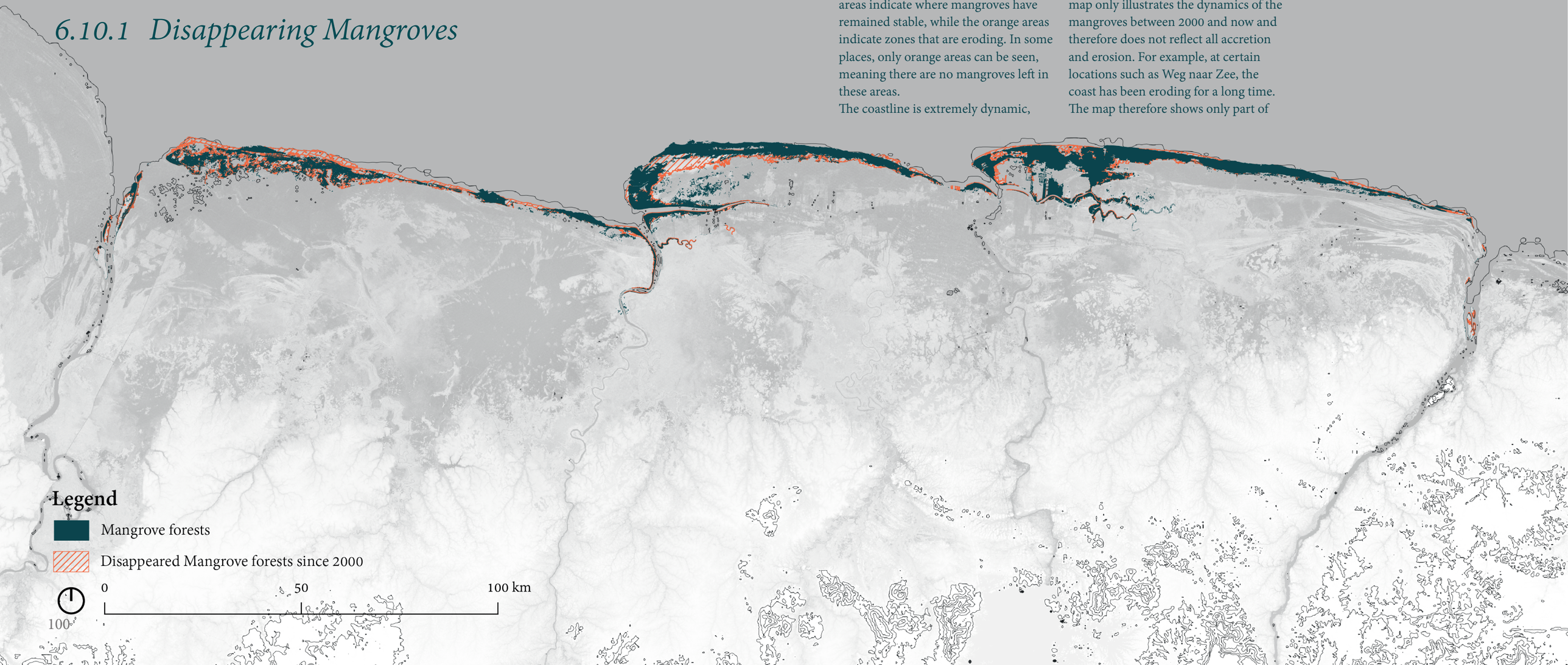
6.10 Threats

The mangroves and coastal swamps are part of a complex ecological system and are defined by and are defined by how sediments, water and plants interact with each. This interaction is completely dependent on hydrology. When one of these systems becomes unbalanced or stops functioning entirely, the specific conditions that mangroves need to survive disappear (Crooks, s., et al., 2019). As a result, the mangroves disappear, leading to the loss of natural coastal defences. This section discusses the disappearance of mangroves and its causes.



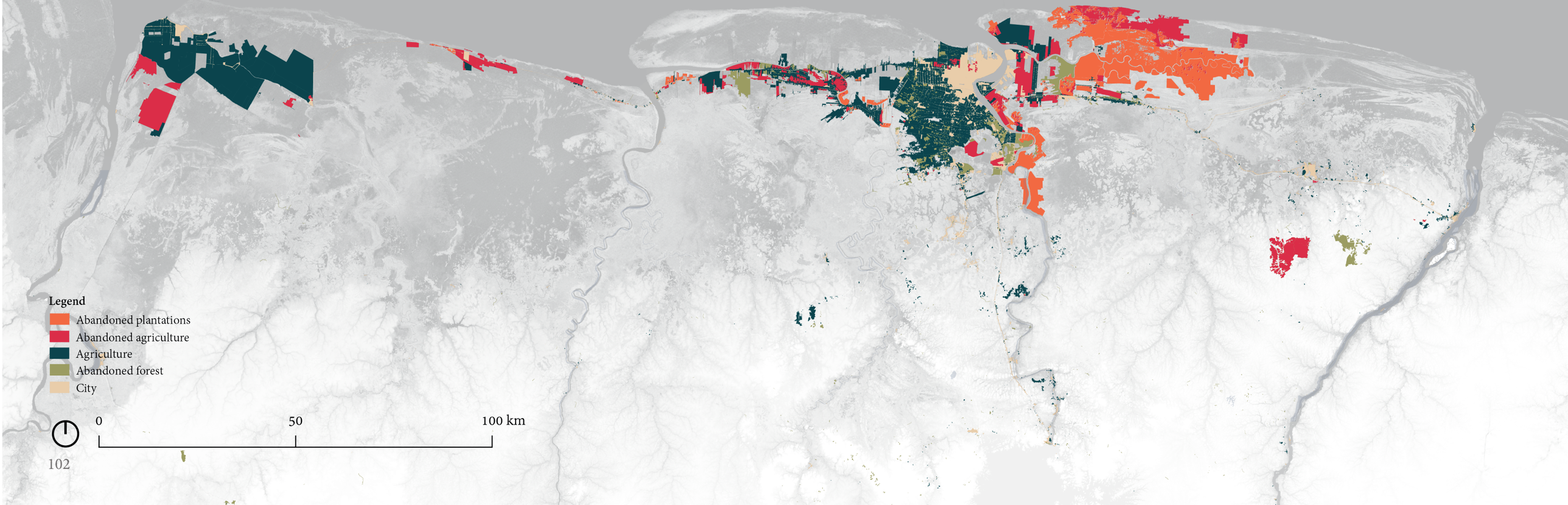
6.10.1 *Disappearing Mangroves*

This map shows the difference in the area of mangroves between the year 2000 (blue and orange together) and the current situation (blue). The blue areas indicate where mangroves have remained stable, while the orange areas indicate zones that are eroding. In some places, only orange areas can be seen, meaning there are no mangroves left in these areas.
The coastline is extremely dynamic, constantly growing and eroding. However, due to various causes discussed on the following pages, the coast is currently eroding more. This map only illustrates the dynamics of the mangroves between 2000 and now and therefore does not reflect all accretion and erosion. For example, at certain locations such as Weg naar Zee, the coast has been eroding for a long time. The map therefore shows only part of the mangroves that have disappeared.



6.10.2 *Blocking water ways*

The natural regulation of water quantity is essential for the survival of mangroves. Both too much and a lack of water can cause mangroves to disappear. As described earlier, in a natural situation, the coast of Suriname consists mainly of mangrove forests, swamps and wetlands. The soil in these areas is saturated with water (De Dijn). When the wetlands along the coast are drained for new purposes, such as agriculture or housing development, the soil collapses, leading to over-supply of water for vegetation. The direct consequence is the loss of habitat and associated ecosystem services (Crooks, s., et al., 2019).
In addition, these new uses often require groundwater to be fully fresh. As a result, people start regulating the inflow and outflow of fresh and saline water so that the areas become completely fresh. This creates an imbalance in the natural system for the mangroves (Crooks, s., et al., 2019).



6.10.2 *Blocking water ways*

BLOCKING FRESH WATER

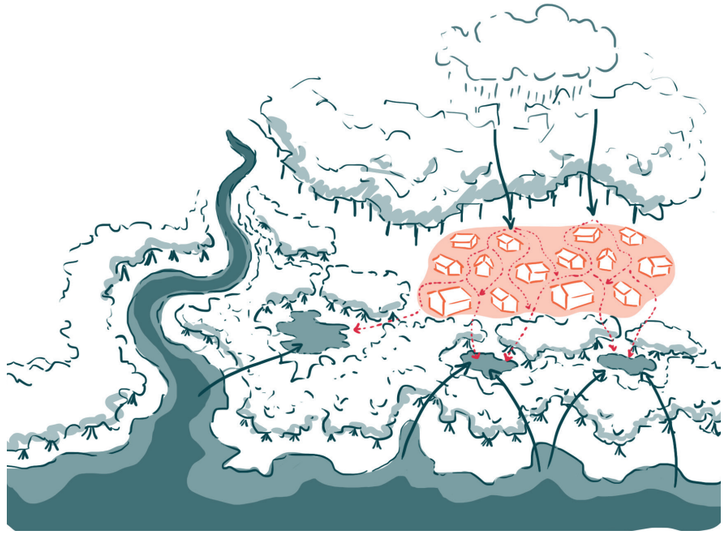
When the flows of freshwater are blocked by cities, agriculture or abandoned areas, the mangrove forests and lagoons are only under influence by the sea (brackish water). During dry periods the water evaporates and the lagoons and mangroves become extremely saline. As a result of this, the vegetation and the animals are dying off. (De Dijn, B., 2018).

BLOCKING BRACKISH WATER

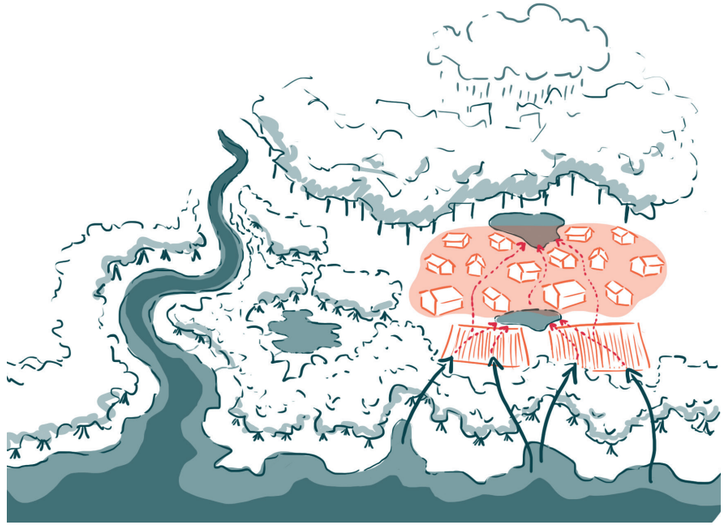
When the brackish water flows are blocked of from the mangrove forests and lagoons. The water stays in the same place. Toxic components from mangrove trees and animals can not flush out to the sea. This components build up and in the vegetation and animals will die off. (De Dijn, B., 2018).

INFRASTRUCTURE

Infrastructure constructed within the dynamic border of the mangrove area becomes exposed to erosion threats when a passing mudbank disappears, leading to lowering of the coastal elevation. This can also happen when mangroves have disappeared at this location. The presence of dykes can make this situation worse by reinforcing wave energy and preventing sedimentation (Crooks, s., et al., 2019). The natural management of water flows and room for the natural system is crucial to maintain the balance of mangrove ecosystems and protect the coastal zone.

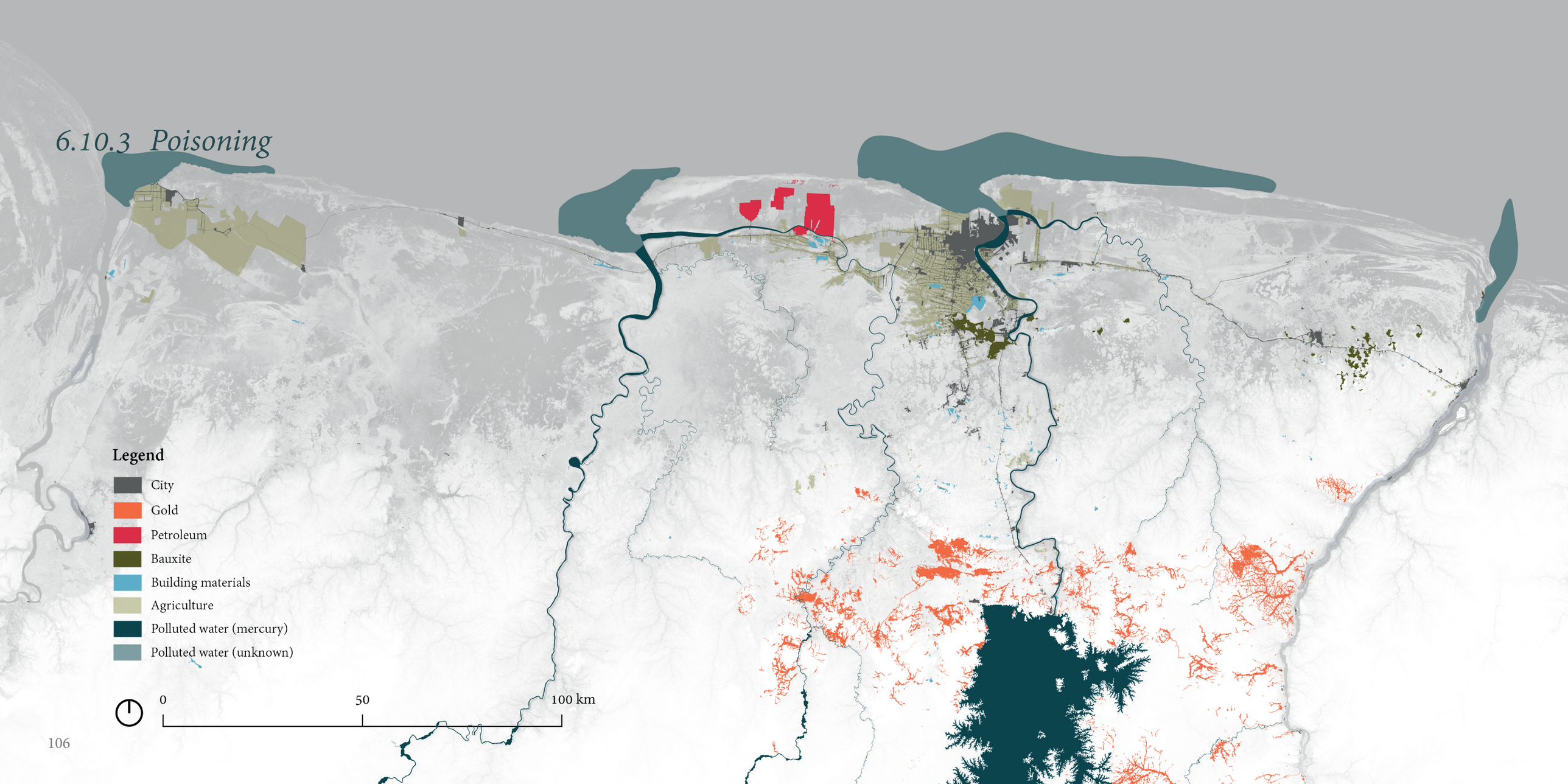


BLOCKAGE OF FRESH WATER



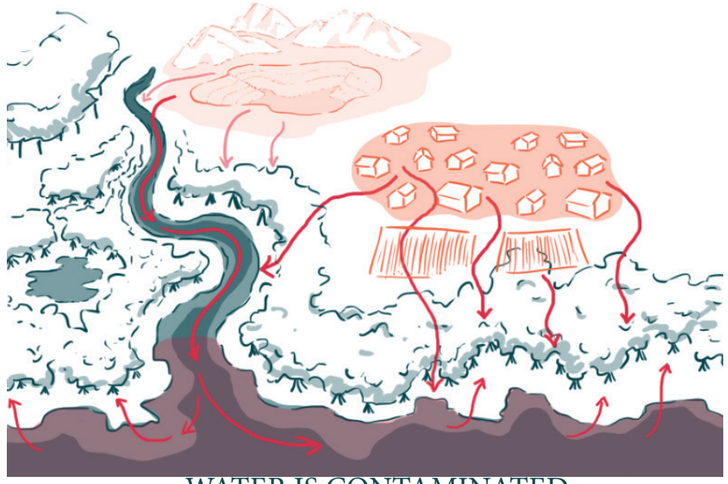
BLOCKAGE OF BRACKISH WATER

6.10.3 Poisoning



6.10.4 Poisoning

Mangroves are exposed to various sources of toxic substances, including cities, agriculture, mining and industrial areas, and oil spills (Tjitrodipo, K., et al., 2015). The use of pesticides in agriculture leads to the pollution of water that reaches the mangroves. Urban areas contribute to pollution through waste discharge (Keeley, M. A., et al., 2015). Mining activities, especially mercury pollution, are a serious threat. High amounts of mercury have been found in coastal mud. While it is not known whether this has direct effects on the mangrove trees themselves, it does affect surrounding ecosystems. When these ecosystems become unbalanced, mangroves are also affected (Legg, E. D., et al., 2015).
As mentioned earlier, mangroves are very dependent on hydrology. They release wastes into the water and filter out other wastes. If the mangrove areas are closed and the water is kept in the same area, the toxins build up (Keeley, M. A., et al., 2015). This leads to poisoning of the trees themselves. So maintaining a balanced water balance is crucial to keep the mangroves and the surrounding life alive.



WATER IS CONTAMINATED

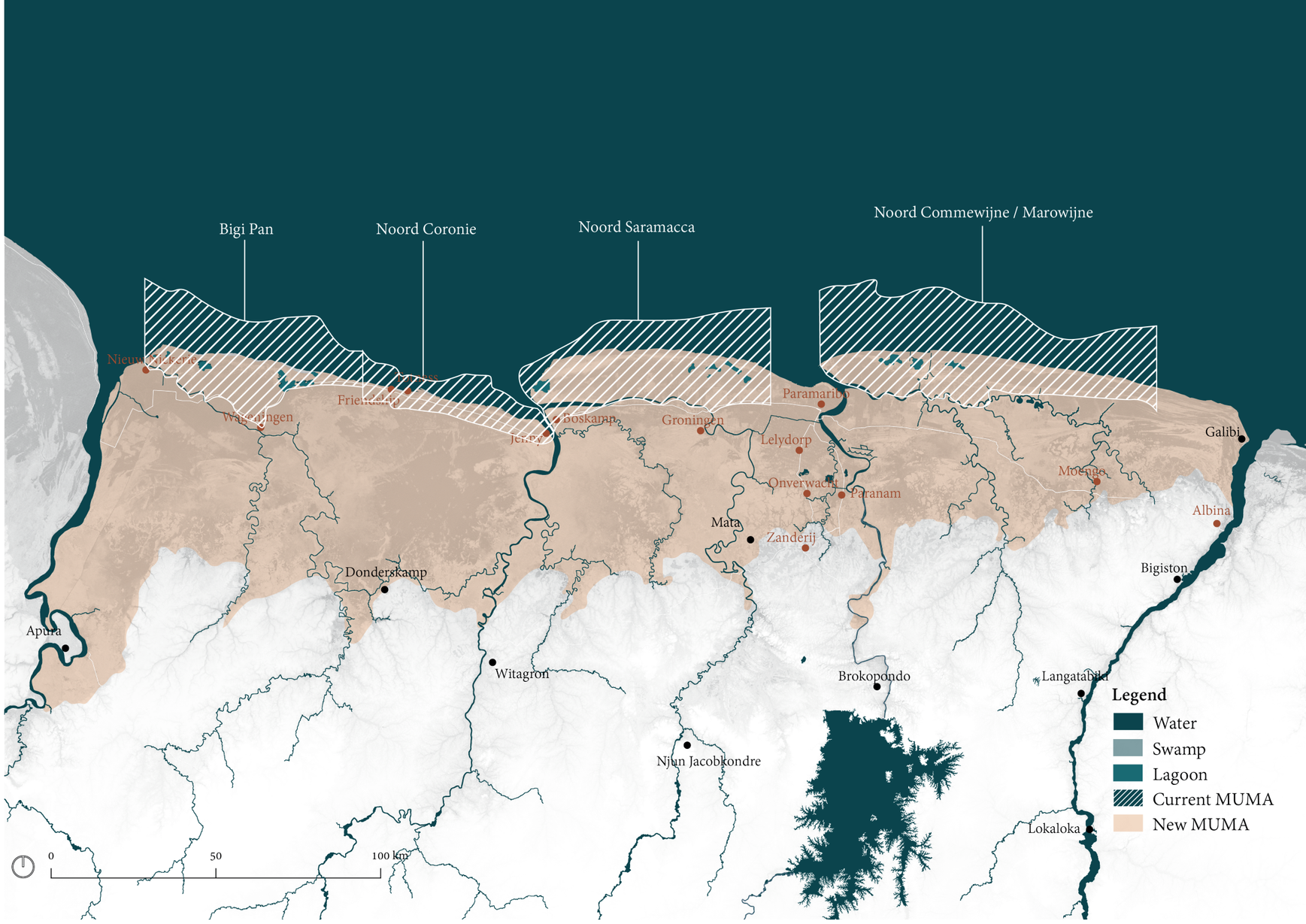
6.11 Opportunities

This part of the understanding section will set out the opportunities for the development project. The opportunities consist of both local and non-local knowledge. The non-local knowledge is derived from other mangrove projects around the world. How was it implemented in these projects, what did it result in and what could I use from this.
Local knowledge comes from the cultures of various ethnic groups in Suriname, especially the Indigenous and Tribal tribes. In addition, there is also knowledge from the initiatives started by Surinamese and ensure the preservation of nature, cultivation of indigenous plants and also promote the growth of mangroves.



6.11.1 Nature and MUMA

About 93% of Suriname's land area is covered by forest (Keep suriname green, 2023). Here, a distinction can be made between Terrestrial and inland waters protected areas and marine and coastal protected areas. The country has a total of 22 protected areas. Where a total of 14.52% of the Terrestrial land inland waters cover is protected and of the marine and coastal protected areas only 1.54% of the total cover. This results in a total of only 16% protected area compared to 93% nature.
Four of the 20 areas are located in coastal area cover and are protected as a Multiple Use Management Area(MUMA)(Protected Planet | Suriname, n.d). A MUMA is a protected area where the ecosystem services of the area can be used in a sustainable way. The purpose of a MUMA is to prioritise the recovery, conservation and wise use of natural ecosystems (WHSRN Executive Office, 2019). Wise use involves adapting and adjusting maintenance and use based on the ecological character of an area (Ramsar Convention Secretariat, 2010). This allows people to live, work, recreate and restore ecology at the same time. One MUMA coastal area could restore mangroves and other needed ecosystems and would provide coastal protection. The map shows what this MUMA would then cover in terms of land area if the entire young coastal plain became a muma compared to the current MUMA's. To make the coastal plain a MUMA, a couple of design principles are important.
Creating room for the water system and ecology. This means making room for the swamps and marshes that should be located on these sites. For this to be successful, the water system must also be adapted. This must be based on the natural system, which means, among other things, letting salt water back in. In addition, housing, infrastructure and agriculture must be adapted to the natural system. So that people can continue to live in these areas.



6.11.2 Other mangrove areas

GUYANA

Guyana can serve as an example for Suriname because it is right next to Suriname and many conditions are similar. In the time period from 2010 to 2023, there were a total of 37 projects and restoring more than 500 ha of mangroves. Different methods were used to grow land for these projects.
A key finding was that different methods appear to work in different places. It is important to study the conditions well in advance so that the design is site-specific and has the best chance of success. These four methods are stone or geotextile groynes, sand ridges or sediment trapping units in the form of wooden poles. Projects in Guyana have proven that land accretion using these methods works relatively quickly. Monitoring accretion periods is important because these periods can accelerate land accretion. This can be acted upon by placing trapping units at the right time, thus retaining sediment extra quickly.
However, two important lessons also emerge from the projects.
The first is the limited knowledge about mangrove accretion among contractors, the government and locals. This makes it difficult to engage the locals in particular and may cause them to work against the projects (L. Jack, Presentation Conservation international, 29.Feb.2024)
Another important point is the difference between guayana and suriname in investment in restoring mangroves. The Guyanese government has invested in this since 2010. This is not the case in Suriname and it also remains to be seen whether the government is uber capable of doing so. (S.Naipal, personal interview, 21.Feb.2024)

INDONESIA

Demak(indonesia) is a province of Java and faces a similar situation to suriname. The province is affected by erosion, floods and land loss. In 2015, they started the building with nature approach. This was started by a collaboration of the indonesian government, wetlands international and Ecoshape after the construction of a sea dike and mass planting of mangrove trees failed .
A number of key learning points can be taken from this project.
There should be more emphasis on making good conditions for the mangroves. The mangroves will then start growing on their own in a fairly short time.
Aquaculture (shrimp) goes well with growing and maintaining the mangroves.
Mangroves are a very dynamic system. Pieces are constantly disappearing and new pieces are being added. So this does require constant adjustment to the situation. And a certain area is not safe to live in.
Combining bottom-up empowerment of local communities and government engagement through policies, plans and research at different scales ensured more successful and cheaper implementation of the nature-based solutions for this specific location. And last but not least,Paying Bio-rights for when locals decide to cooperate with the new system and agree to move to new more sustainable sources of income (Tonneijck, F., et al ., 2024).

CONCLUSION

Perhaps the most important lesson to be learnt from the other mangrove areas is that it is not possible to transfer the solutions for one place to the next mangrove area. Both projects also showed that building with nature, and in this case mangroves, as a concept is still not far developed and certainly not widely accepted. Much more attention needs to be focused on the possibilities and much more work and experimentation needs to be done with it to get a clear picture.W



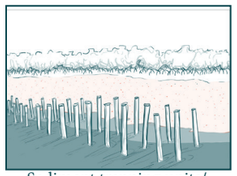


Guyana
(Conservation international)

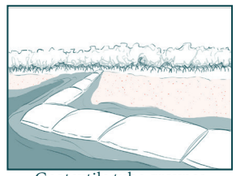


Demak, Java, indonesia (wetlands international)

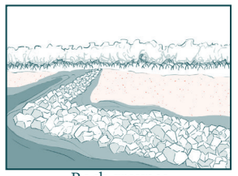
SEDIMENT TRAPPING



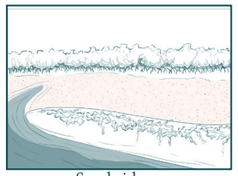
Sediment trapping units/ brushwood dams



Geotextile tube groynes

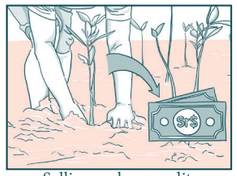


Rock groynes

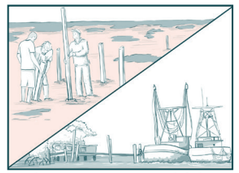


Sand ridges

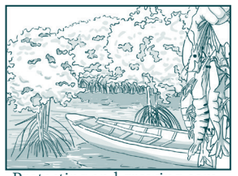
COMBINING PRODUCTION SERVICES WITH GROWING THE COAST



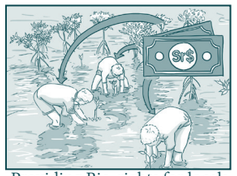
Selling carbon credits



Sediment trapping and fishing



Protecting and growing combined with aquaculture



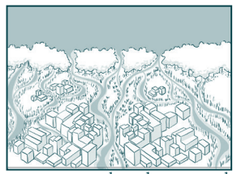
Providing Bio-rights for locals

6.11.3 *Indigenous and Tribal communities*

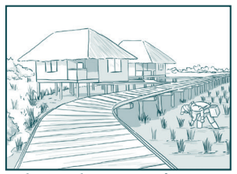
The indigenous people are a relatively small but important population group in Suriname. They are the oldest ethnic group and know better than anyone how to live with their environment in a sustainable way. The Surinamese government has not yet recognised this and their rights for the collective land ownership of the indigenous people.
For this study, the focus is on Galibi. This consists of two villages; Langamankondre and Christiaankondre and is located in close to the coast at the estuary of the Marowijne River. This is where the kaliña live. They live mainly from the income from fishing, agriculture, hunting and ecotourism (Benito Aloema, personal communitcation, 18, February, 2024).
According to the kaliña, everything, both living and non-living objects, is connected. If one gets out of balance, the rest will also get out of balance and harmful consequences such as disease, natural disasters and other accidents will occur (VIDS et al., 2006).
The main rules they follow to maintain this balance are; One should not take more than needed and one should avoid using juveniles. These two rules are also an important basis for the process of converting the coastal zone to a MUMA. Based on these two rules, one could both protect and use the ecosystems (VIDS et al., 2006).
In addition, indigenous people use biomimicry for agriculture (mimics natural forest cycle), housing (mimics mangrove trees) and grow mainly indigenous crops.



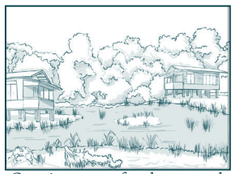
ADJUSTING TO THE NATURAL SYSTEM



water system based on natural system. letting brackish water back in.

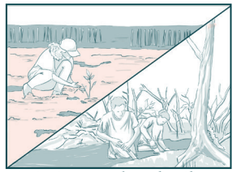


adapting housing, infrastructure and agriculture to the natural watersystem.

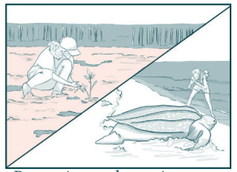


Creating room for the natural watersystem and ecology.

COMBINING PRODUCTION SERVICES WITH PROTECTION

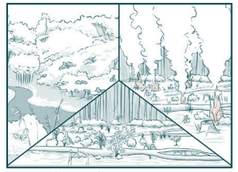


Protection combined with use of trees

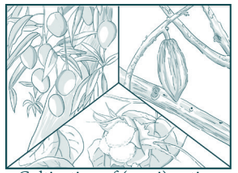


Protecting and growing combined with eco-tourism

LEARNING FROM THE INDIGENOUS



agriculture that mimics natural forest cycles



Cultivation of (semi) native crops

6.11.4 Local initiatives

‘Suriname has more than 93% land area covered with forest, which is something that is owned by all of us and that we can be proud of’ - Lindsay Goossens, Green Growth Suriname, 20.feb.2024)

IMPORTANCE OF CO-CREATION

Co-creation is important for two main reasons. First, locals need to be involved to prevent people from not understanding and working against the projects and to prevent people from continuing with their current unsustainable way of life. Many people no longer believe that mangroves can still be a solution (O. Smith, personal interview, 12.Feb.2024).
Locals may not want to cooperate with the project then and may even work against it.
Jack L. (29.Feb.2024) Mentioned in her presentation that local community members in Guyana started breaking the sediment trapping units despite having organised education days.
In addition, people like to cut the wood from the Parwa trees because it is hard wood and people like to have it for building things and they smoke fish with it (Nijbroek, R. P., 2014).
Local knowledge is extremely invaluable when it comes to protecting and restoring the environment (Henry, C., et al., 2020). In Suriname, this knowledge includes not only traditional practices rooted in different cultures, but also local initiatives aimed at conservation.

CULTURE

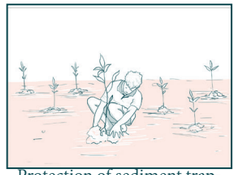
In an interview with Ninghin Ardjkoeman (boatman), he explained that the Hindu community has traditionally had a diverse vegetarian food culture but this is slowly disappearing because vegetarian food is seen as something for poor people (N. Ardjkoeman, personal interview, 11.feb.24).
In addition, Plantage Bakkie, an old plantation where people nowadays focus on telling the story of the history that took place on the plantations and the knowledge from the different cultures that is more and more being lost. The owners have created a garden with native and non-native (non-invasive Asian and African) species. They show which plants thrive in specific areas, help preserve traditional knowledge that might otherwise be lost (B. Spek, Guided Tour Plantation

IMPORTANT INITIATIVES

Moreover, there are individuals like Professor Naipal, a hydrologist, who figured out that Suriname’s mangrove forests are invaluable and can protect the coastal zone now and in the future. Despite limited resources and staff, he works tirelessly to implement pilot conservation projects (S. Naipal, Personal Interview, 21.Feb.2024).
Organisations like Green Growth Suriname also play a crucial role by increasing Surinamese pride in their country’s natural beauty. By promoting this pride, they hope to bring unity to a divided society, while raising awareness about the importance of conservation and sustainability for Suriname’s future. These local initiatives and individuals are invaluable in preserving and restoring the natural environment (Lindsay Goossens, Personal interview, 20.Feb.2024).



PLANTING AND PROTECTION



Protection of sediment trapping units and the trees

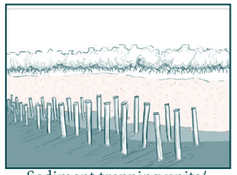


Planting seedlings



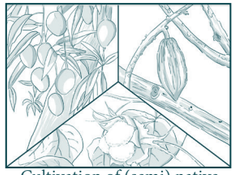
Nurseries for mangrove trees

SEDIMENT TRAPPING



Sediment trapping units/ brushwood dams

LEARNING FROM INDIGENOUS



Cultivation of (semi) native crops



III. RESEARCH BY DESIGN

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7.0 DESIGN STRATEGY

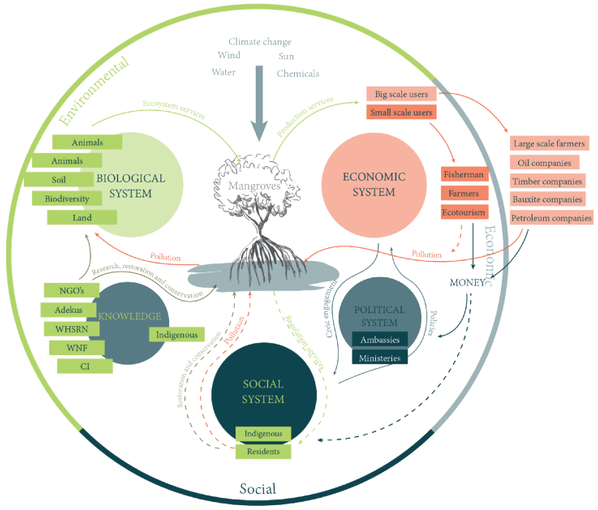


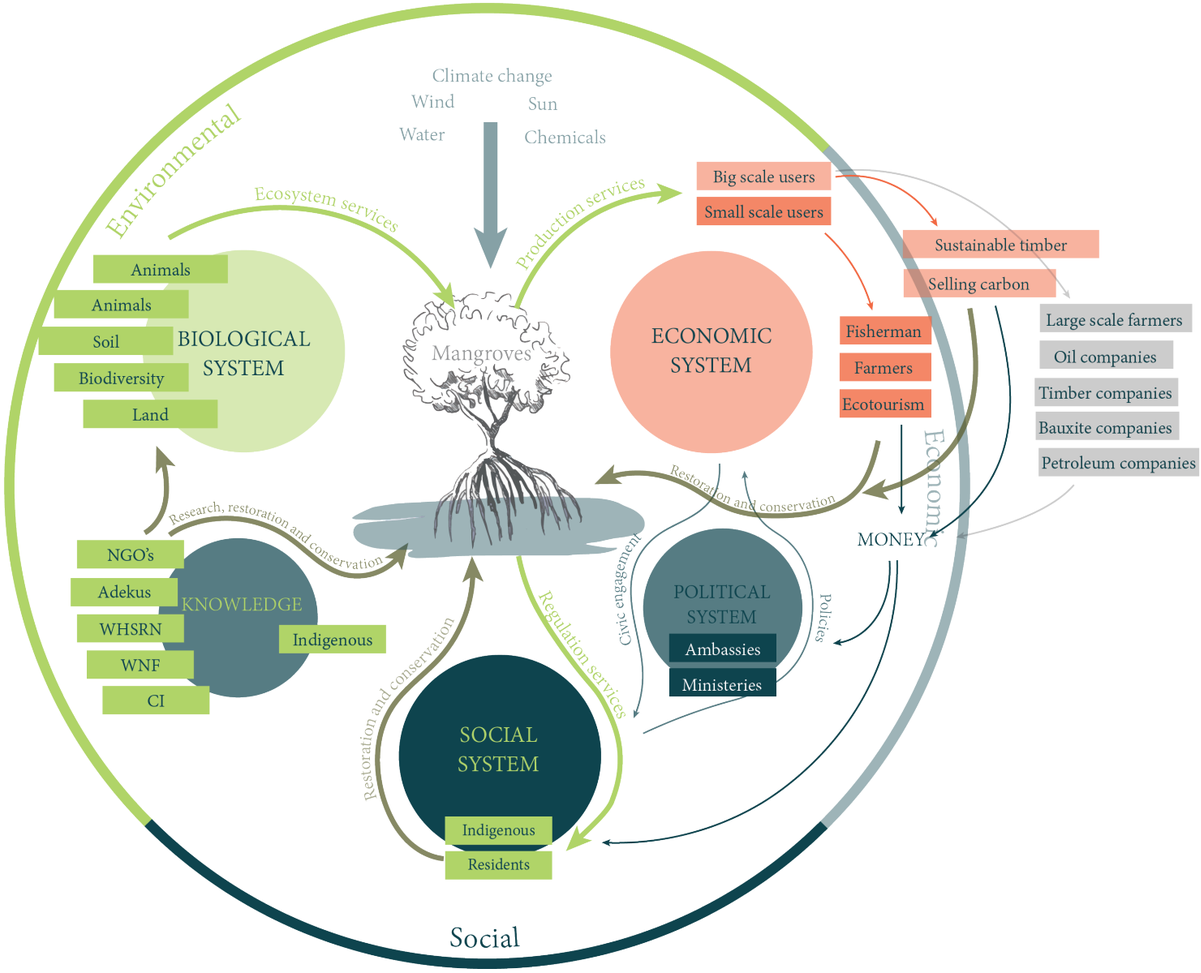
7.1 Design strategy

A toolbox has been developed as a strategy for promoting mangrove growth in Suriname. This toolbox is based on the opportunities mentioned earlier and is built around three design goals, each of which is further subdivided into different categories of design principles. The toolbox was designed with stakeholder input, and for its development, involvement of local people is essential. By applying these design principles, the aim is to create a base that provides space for water and nature, promotes the growth and protection of mangrove systems, and introduces new ways to adapt to changing conditions. This base aims to restore the coastline and optimise the delivery of regulatory and production services. To illustrate this more clearly, the toolbox is then developed spatially for the mangrove area at Weg naar Zee and the area behind it, Paramaribo.

7.2 Stakeholders in new situation

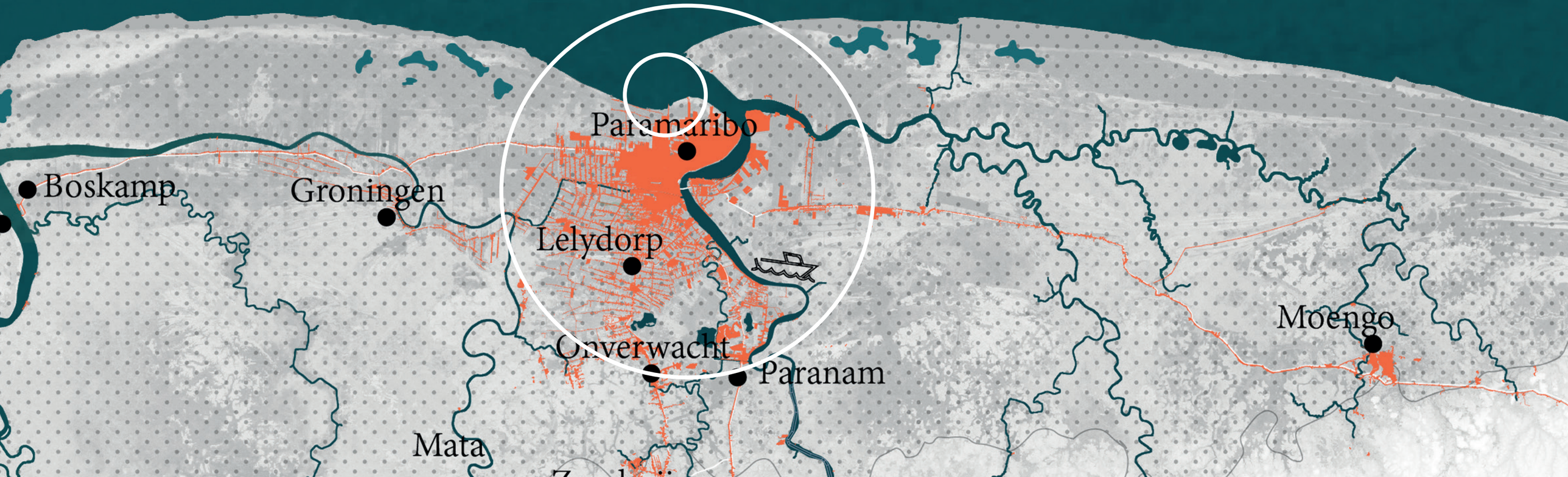
In the new situation, users and residents have adapted their handling of the mangrove system. As a result, these groups are now actively contributing to the restoration and conservation of the mangroves. For this to happen, some major polluters need to be excluded. By applying the toolbox in the relevant area, expert knowledge and research is effectively used. This toolbox provides guidelines and design principles based on sustainable handling and the needs of the mangrove ecosystem. Thanks to the elimination of major negative influences from polluting parties and the positive incentives from knowledge institutions, the biological system has a chance to recover. This recovery provides a basis for mangrove accretion, which in turn contributes to the further stabilisation and protection of the coastline. The new balance between human activities and the natural mangrove system creates a more resilient and sustainable ecosystem.





7.3 *Location*

We will zoom in on Paramaribo, and then zoom in even deeper on Weg naar Zee. The focus is specifically placed on this site because the Weg naar Zee area could serve as an example for other parts of the coast in Suriname (Nijbroek, R. P., 2014). This is because almost all mangrove trees have disappeared here, while directly behind this spot lies the capital. Because of this confluence of problems, When there is a solution for this area, other areas can be tackled in a similar way.'



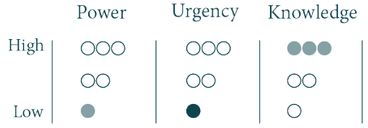
7.4 *Stakeholders at Weg naar Zee*

Described below are the partners to be involved in this area.



ADEKUS

ABOUT:
University of surinam.
With Professor Naipal in particular.

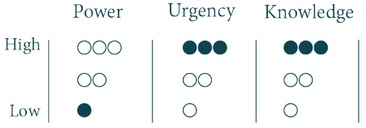


ROLE:
Play an important part in mangrove growth research and pilot projects at Weg naar Zee.



Indigenous

ABOUT:
Oldest ethnic group in suriname.
Have long-standing knowledge of the natural environment in Suriname.

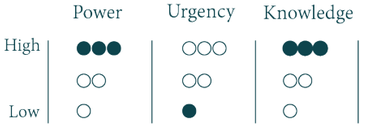


ROLE:
They have knowledge about sustainable management of nature and protection. key aspects of this include agriculture, housing and production resources from mangroves.
Indigenous people have knowledge of native vegetation which makes them a key actor in restoring nature.



NGO's

ABOUT:
These non-governmental organisations focus on the coastal protection in Surinam.

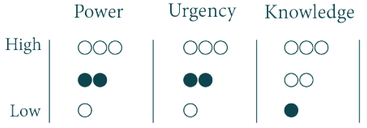


ROLE
NGOs have knowledge on mangrove accretion through pilots and research from othe areas with mangrove forests such as indonesia and Guyana.
Important NGO's at road to sea are CI and deltares.



Government

ABOUT:
The system of social control under which the right to make laws, and the right to enforce them, in Suriname.

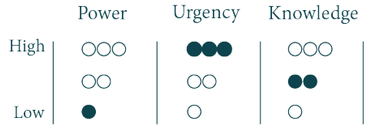


ROLE:
She has the power to make change and direct parties. On the other hand, there is too little investment and too little action from the government. The government could be seen as the bottleneck of the solution to this problem.



Residents Weg naar zee

ABOUT:
Residents from Weg naar zee. These people often also work in this area as farmers, fishermen or have other small companies. And usually grow some of their own food.

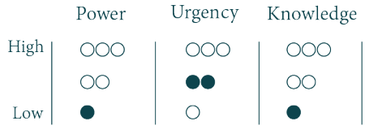


ROLE:
The people living at Weg naar zee have a great interest in restoring coastal protection, but have little influence on the situation themselves. Some of the people here have already left. Those who remain, however, have no means to leave. They are completely dependent on the government.



Residents Paramaribo

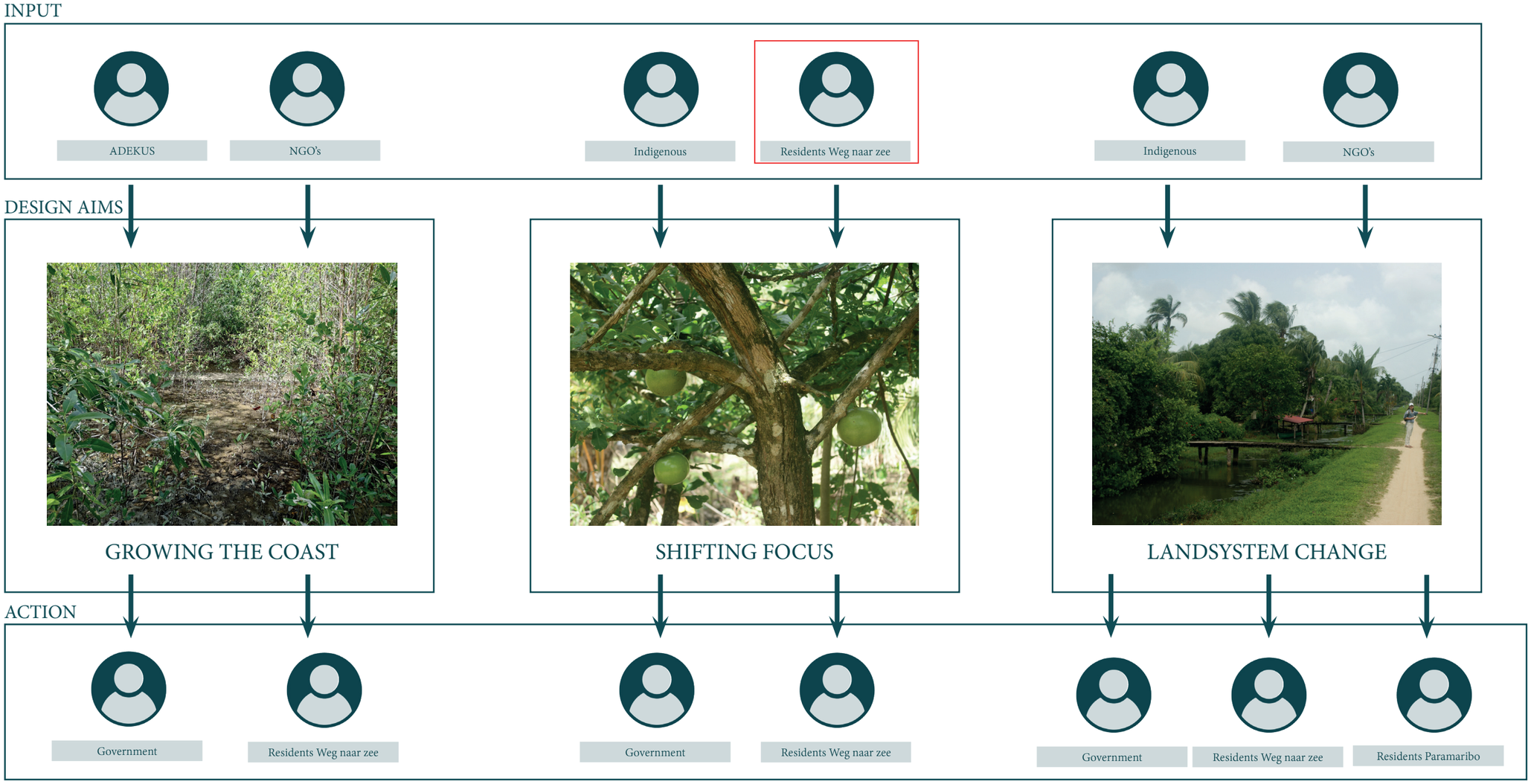
ABOUT:
Paramaribo residents do not interact a lot with Road to the Sea. There is, however, a Hindu temple by the sea that is important to a significant number of people.
However, the residents of Paramaribo depend on well-functioning coastal protection and on products that could be produced in this area.



ROLE:
Residents of Paramaribo are not directly affected by the eroding coast. However, they will eventually be affected by sea level rise and erosion. This is because Weg naar zee currently acts as a the only buffer between Paramaribo ad the sea.

7.5 *Design aims*

Certain stakeholders have been used as inspiration in establishing specific design aims within this thesis. These design aims form the core of the design strategy and were then further developed into concrete design principles. These principles form the guidelines and starting points for implementing the design.
Actually implementing these design principles requires other partners. These stakeholders play a crucial role in translating the design principles into concrete actions and interventions. By working together with the parties involved, an effective and sustainable approach can be guaranteed for realising the goal of protecting the coastal zone.

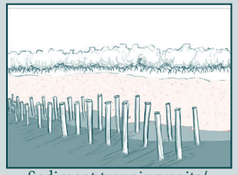


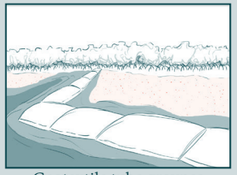
7.6 *The Toolbox*

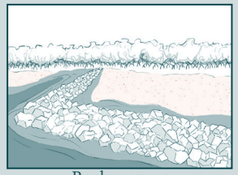
This toolbox is an elaboration of the previously mentioned design aims are subdivided into categories in which the design principles fall.
The following pages will explain per design aim how the design principles can be applied.

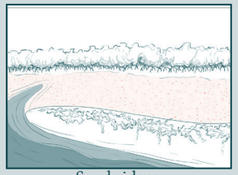
GROWING THE COAST

TRAPPING SEDIMENT

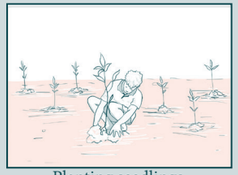

Sediment trapping units/ brushwood dams


Geotextile tube groynes


Rock groynes

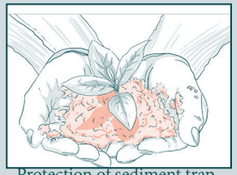

Sand ridges

PLANTING


Planting seedlings


Nurseries for mangrove trees

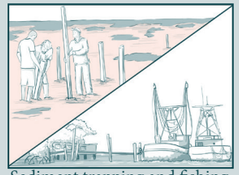
PROTECTION

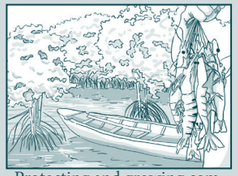

Protection of sediment trapping units and the trees

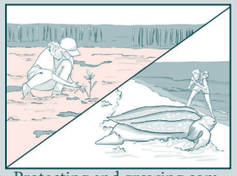
SHIFTING FOCUS

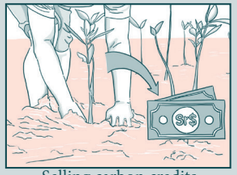
COMBINING PRODUCTION SERVICES WITH GROWING THE COAST

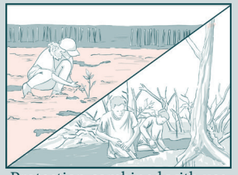

Providing Bio-rights for locals


Sediment trapping and fishing


Protecting and growing combined with aquaculture

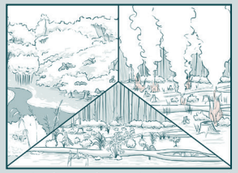

Protecting and growing combined with eco-tourism


Selling carbon credits


Protection combined with use of trees

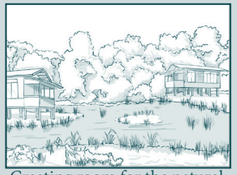
LEARNING FROM THE INDIGENOUS

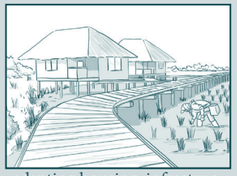

Cultivation of (semi) native crops

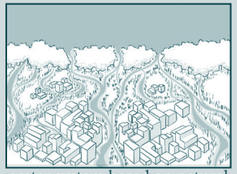

agriculture that mimics natural forest cycles

LANDSYSTEM CHANGE

ADJUSTING TO THE NATURAL SYSTEM


Creating room for the natural watersystem and ecology.


adapting housing, infrastructure and agriculture to the natural watersystem.


water system based on natural system. letting brackish water back in.

7.6.1 Toolbox - landsystem change

The design aim Landsystem change consists of three design principles and focuses through these on adapting built-up areas to the new water system and ecosystem. This includes adapting the water system so that water can flow back, creating more space to capture water to promote ecological zones, and adapting houses and infrastructure to the new system. Important partners in this process are the residents of Weg naar Zee and Paramaribo, as well as the government.

PARTNERS



Residents Paramaribo

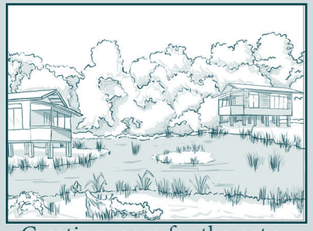


Residents Weg naar zee

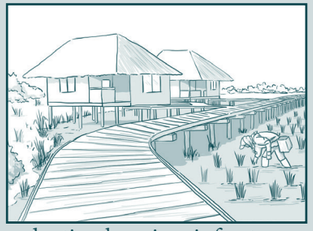


Government

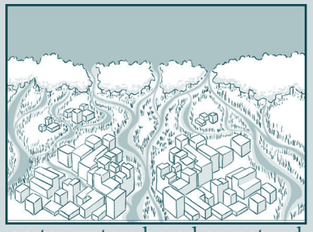
ADJUSTING TO THE NATURAL SYSTEM



Creating room for the natural watersystem and ecology. making space for swamps and marshes.



adapting housing, infrastructure and agriculture to the natural watersystem.



water system based on natural system. letting brackish water back in.

7.6.2 Toolbox - Growing the coast

The ‘Growing the Coast’ strategy is divided into the design principles of ‘Protection’, ‘Trapping Sediment’, and ‘Planting’. The focus of these principles is mainly on creating an optimal environment for mangrove trees to establish and grow. Although planting also takes place, this forms a smaller part of the strategy. Most of the growth is expected to come from natural growth, allowing mangroves to establish and develop naturally.

Important stakeholders to be involved are residents and the government. Their involvement and cooperation are essential to ensure the success of this strategy and to ensure a sustainable approach to shoreline restoration.

PARTNERS

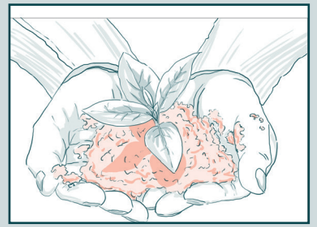


Government



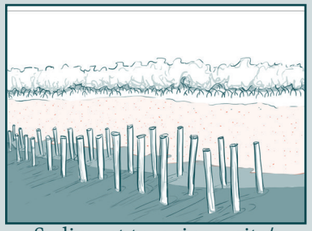
Residents Weg naar zee

PROTECTION

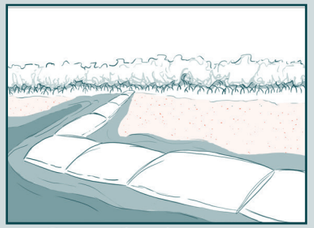


Protection of sediment trapping units and the trees

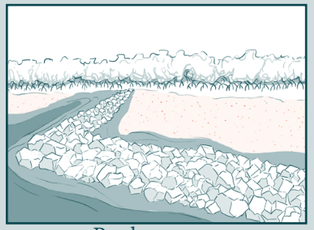
TRAPPING SEDIMENT



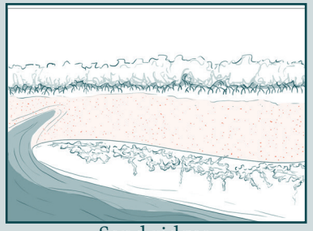
Sediment trapping units/ brushwood dams



Geotextile tube groynes

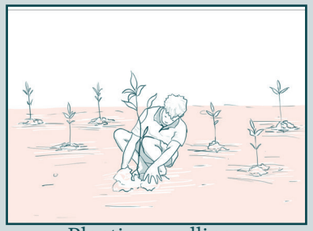


Rock groynes



Sand ridges

PLANTING



Planting seedlings



Nurseries for mangrove trees

7.6.3 *Toolbox - Shifting focus*

Shifting focus can be divided into two categories of design principles: 'Combining Production Services with Growing the Coast' and 'Learning from the Indigenous'.
The design principles under 'Combining Production Services with Growing the Coast' show examples of sustainable ways to live off the production services of the mangroves, and how these can be combined with promoting mangrove growth and conservation.
'Learning from the Indigenous' focuses mainly on cultivating native plants and mimicking forest cycles.

PARTNERS



Government

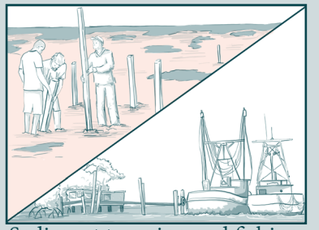


Residents Weg naar zee

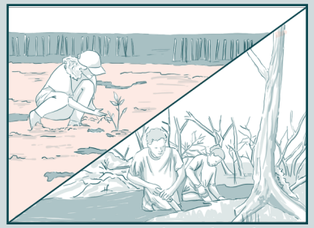
COMBINING PRODUCTION SERVICES WITH GROWING THE COAST



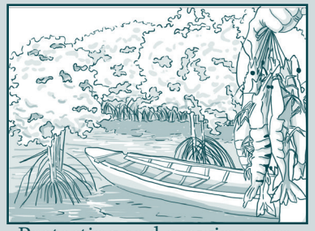
Providing Bio-rights for locals



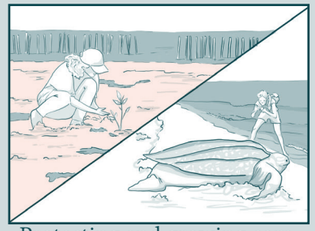
Sediment trapping and fishing



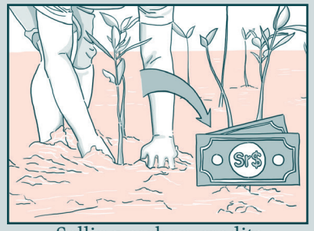
Protection combined with use of trees



Protecting and growing combined with aquaculture

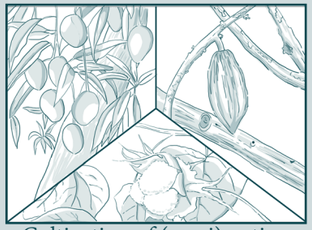


Protecting and growing combined with eco-tourism

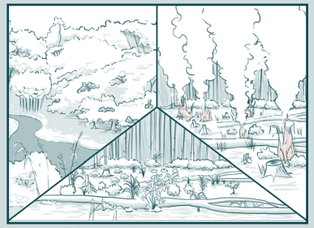


Selling carbon credits

LEARNING FROM THE INDIGENOUS



Cultivation of (semi) native crops



agriculture that mimics natural forest cycles

7.7 Concept

'By implementing all the design aims, the concept of a MUMA in coastal areas is created. MUMA stands for 'Multiple Use Management Area', in which people may live, work and recreate. However, promoting coastal growth and maintaining the natural ecosystem of the coastal area are key. This means promoting the well-being of the mangrove forests, making them healthy and strong. This also strengthens the services provided by the mangroves.'



8.0 DESIGN EXPLORATION



8.1 Landsystem Change

To properly explain the design principles, for the design aim landsystem change, we will first look at the scale of the city to see what design changes are necessary to make the new system work. It will then zoom in on Weg naar Zee to explain it in more detail.

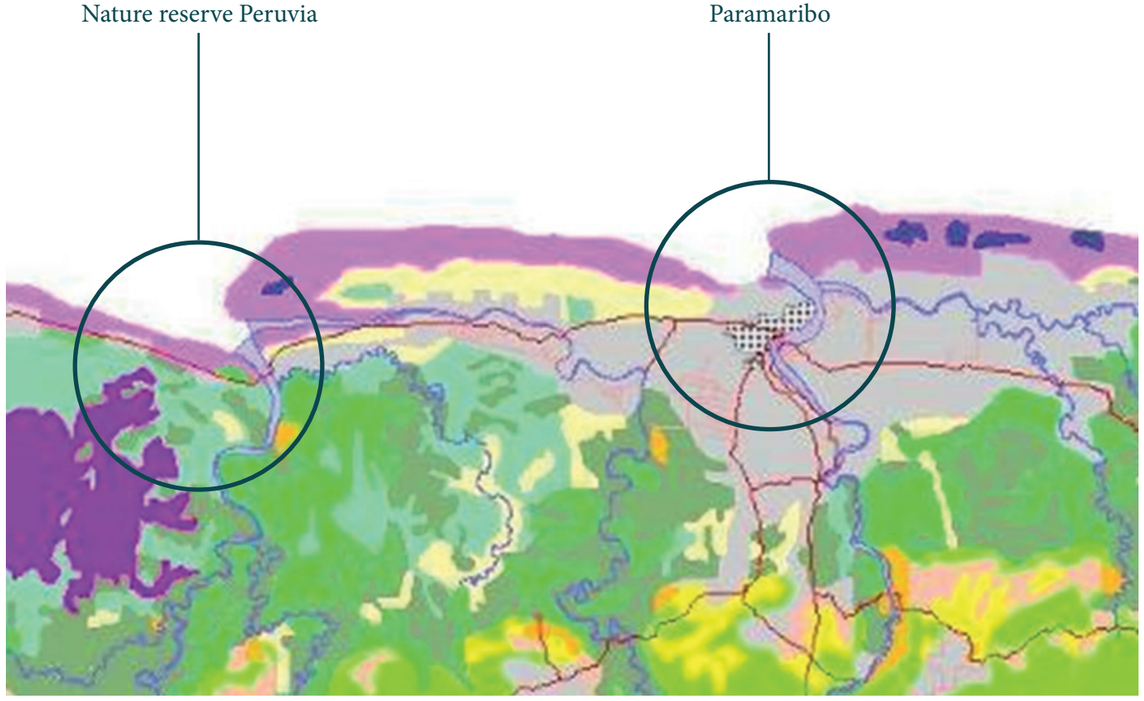
8.1.1 Missing Eco zones

In order to adapt the city of Paramaribo to its natural water system, we must first look at what eco zones might have originally been there. Currently, the eco zones in the Paramaribo area have completely disappeared (Passfield, K., et al., 2011). This is the white area on the map shown on the right.

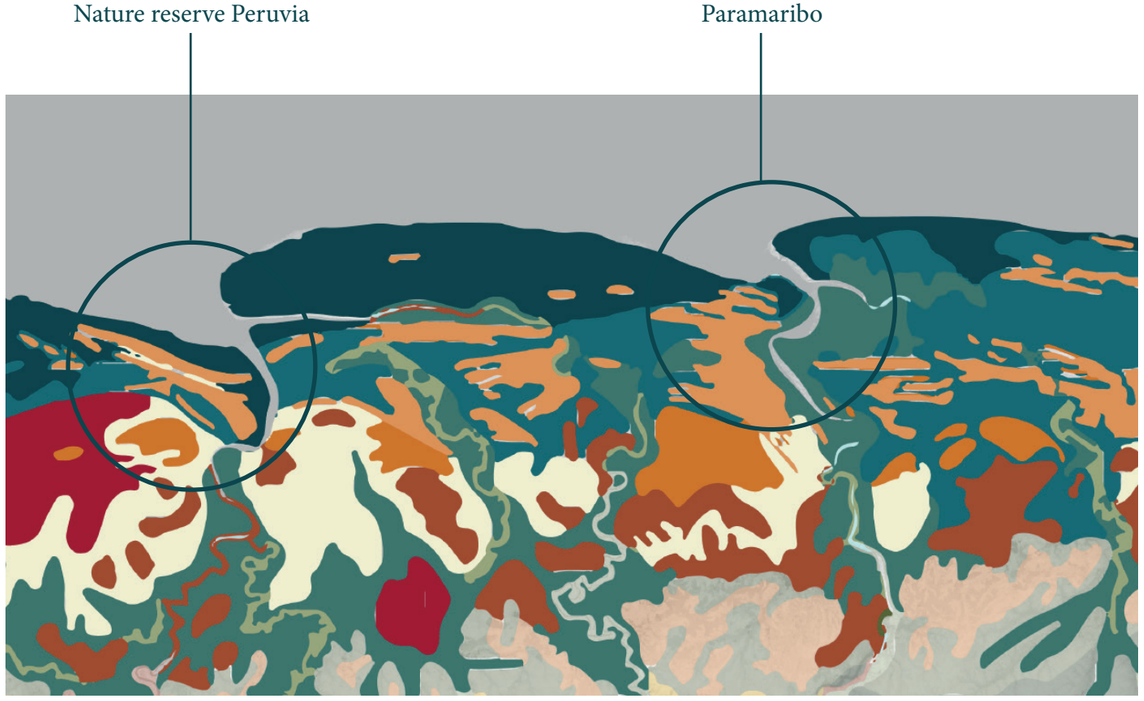


8.1.2 *Re-constructing the Eco zones*

Using the maps shown below together, a reconstruction of the eco zones that should occur in paramaribo can be made. In the soil and vegetation maps, the soil types of the area where paramaribo is located are compared with those of a similar area where the nature reserve Peruvia is located. As this is a protected nature reserve, the vegetation types are still mostly in their natural state (Passfield, K., et al., 2011). Using the soil types here and in paramaribo, a reconstruction of the vegetation types in paramaribo could be made. It is important to note, however, that paramaribo lies on more old sand ridges. As a result, in many places slightly drier Marsh forests are more likely to form and peat is less likely to form.



Passfield, K., et al. (2011), Ecosystems of Suriname.



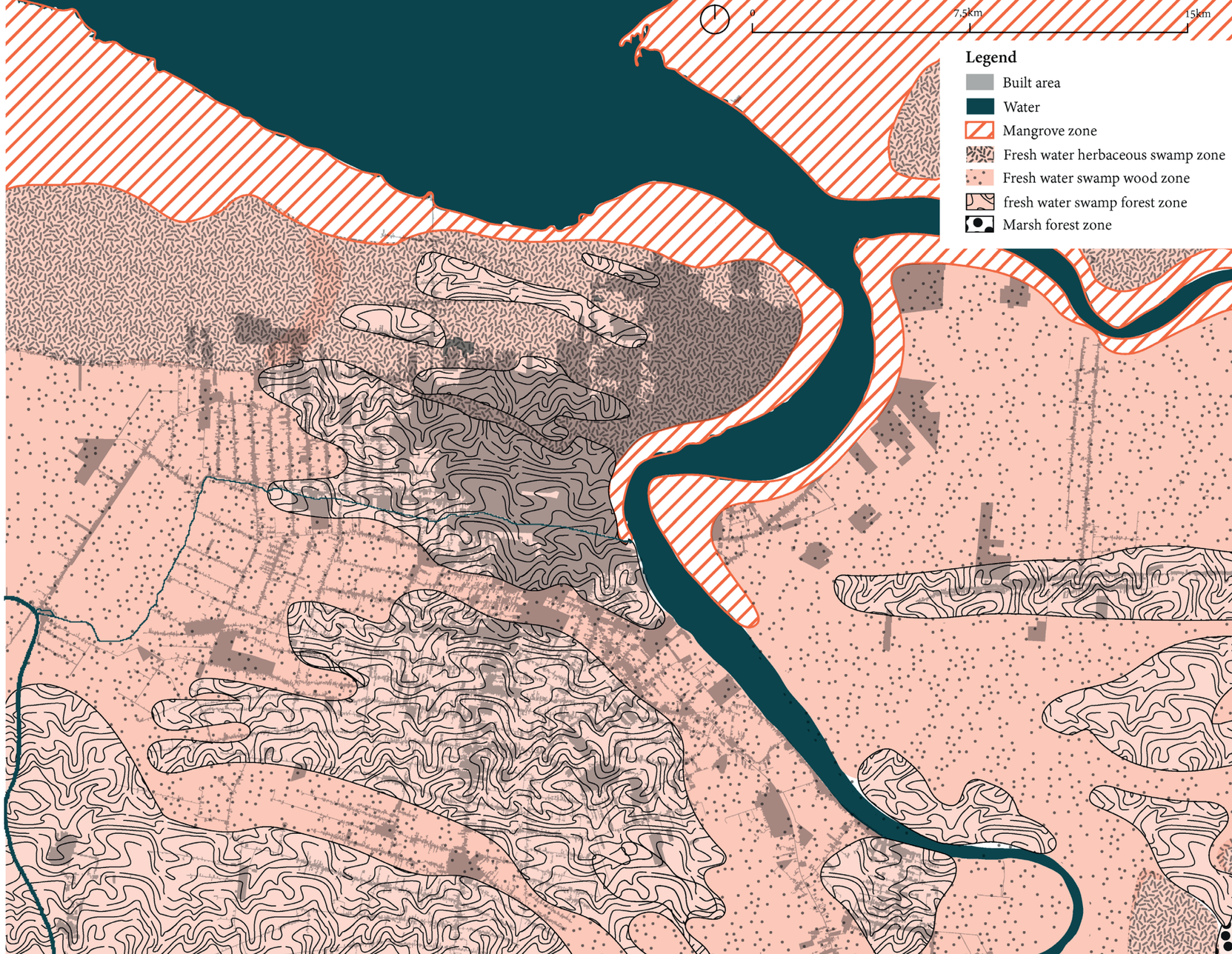
8.1.3 reconstructing the Eco zones

The adjacent map shows a new desired distribution of ecozones. To create a robust foundation for the water system and mangroves, it is essential to actually restore these ecozones.



8.1.4 Eco zones in paramaribo

The map shown here zooms in further on Paramaribo. The capital would consist largely of swamp and partly of marsh forest. This means that much more water would therefore have to be stored in the ground.



8.1.5 *The current watersystem*

The current water system is based on the old plantation system and is built to drain off the water as quickly as possible, using sluices to keep out the salt water and not necessarily all canals are connected (Erftemeijer, P., et al., 2009), which means that there is stagnant water in many places, which quickly becomes dirty and which quickly becomes a breeding ground for mosquitoes, for example.



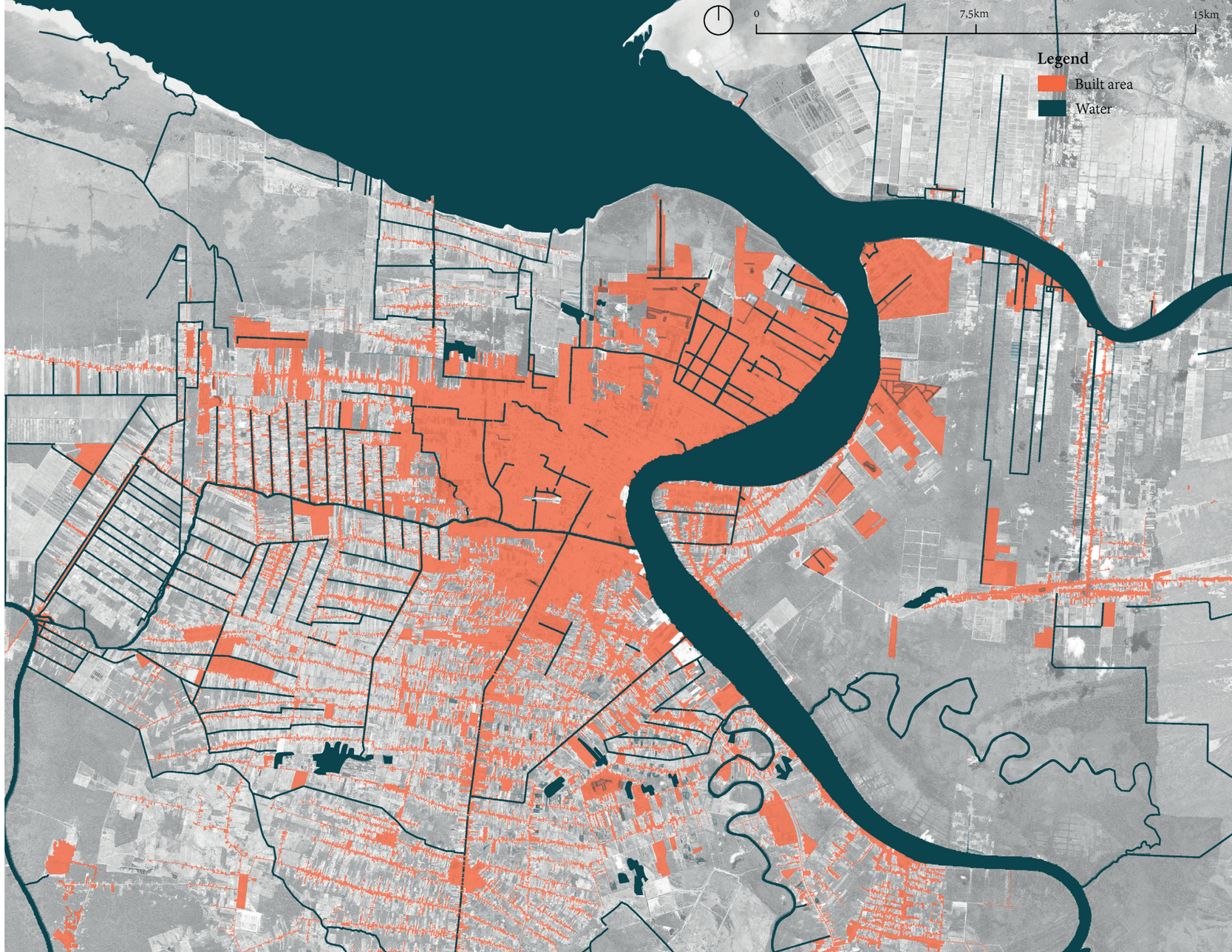
Unconnected drainage canals are breeding spots for musquitos.



Watersystem adapted to infrastructure, agriculture and housing. It is polluted.

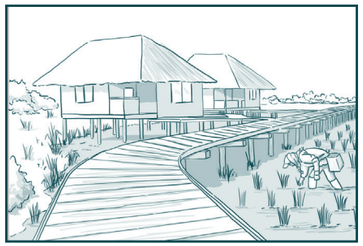


Water system is based on plantation system. Sluices keep fresh water in and salt water out.

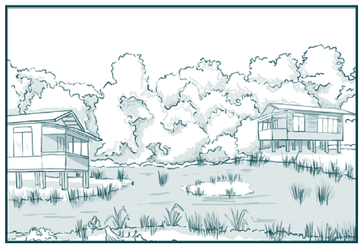


8.1.6 Creating room and Adapting

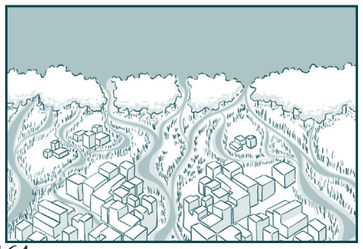
The map next to this text shows that the first thing to do is to adapt the waterways to a new situation where water is not drained as quickly as possible. It is also important to clear the zones where the wetlands should be. These areas should in fact be waterlogged, and therefore the main focus should be on creating space for the water and adapting building and infrastructure.



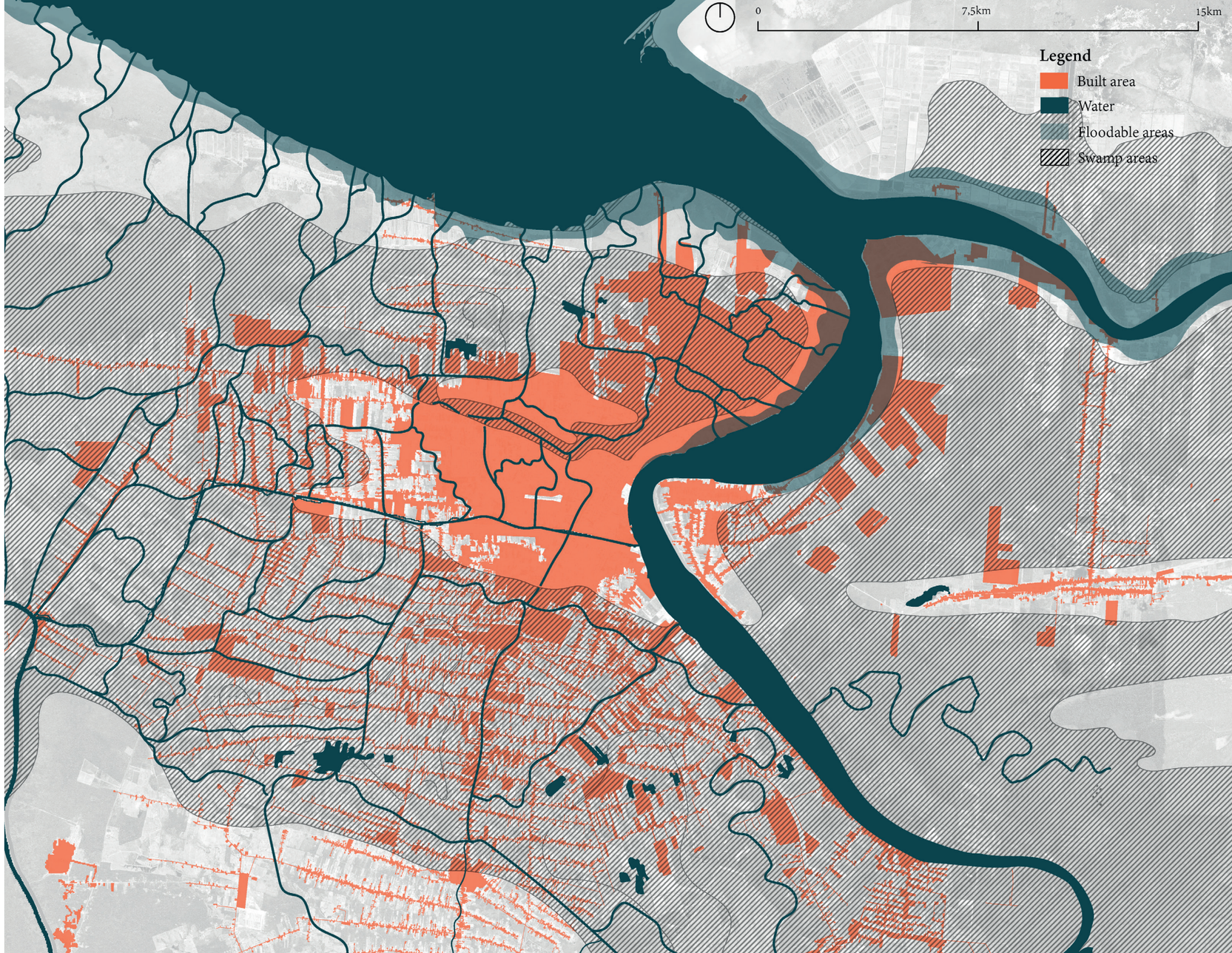
Adapting housing, infrastructure and agriculture to the natural watersystem.



Creating room for the natural watersystem and ecology. making space for swamps and marshes.

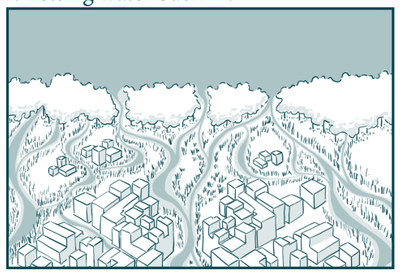


Water system based on natural system. letting brackish water back in.

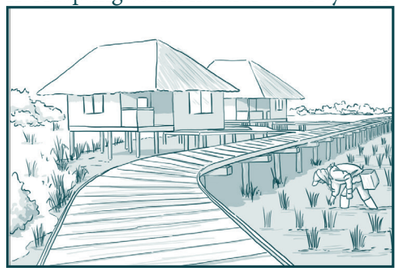


8.1.6 Creating room and adapting

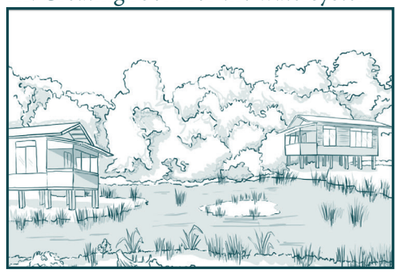
I. Letting water back in.

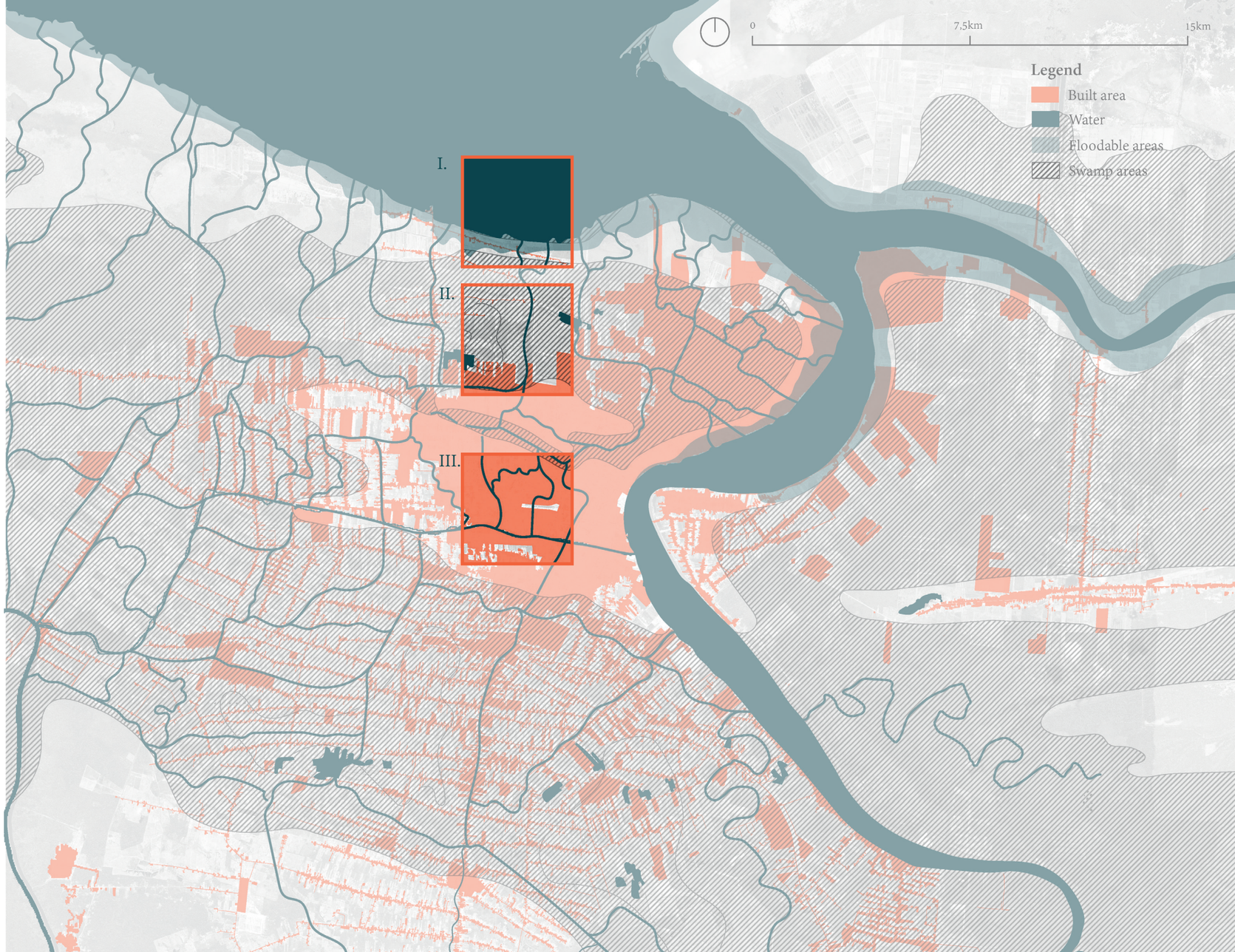


II. Adapting to the natural water system



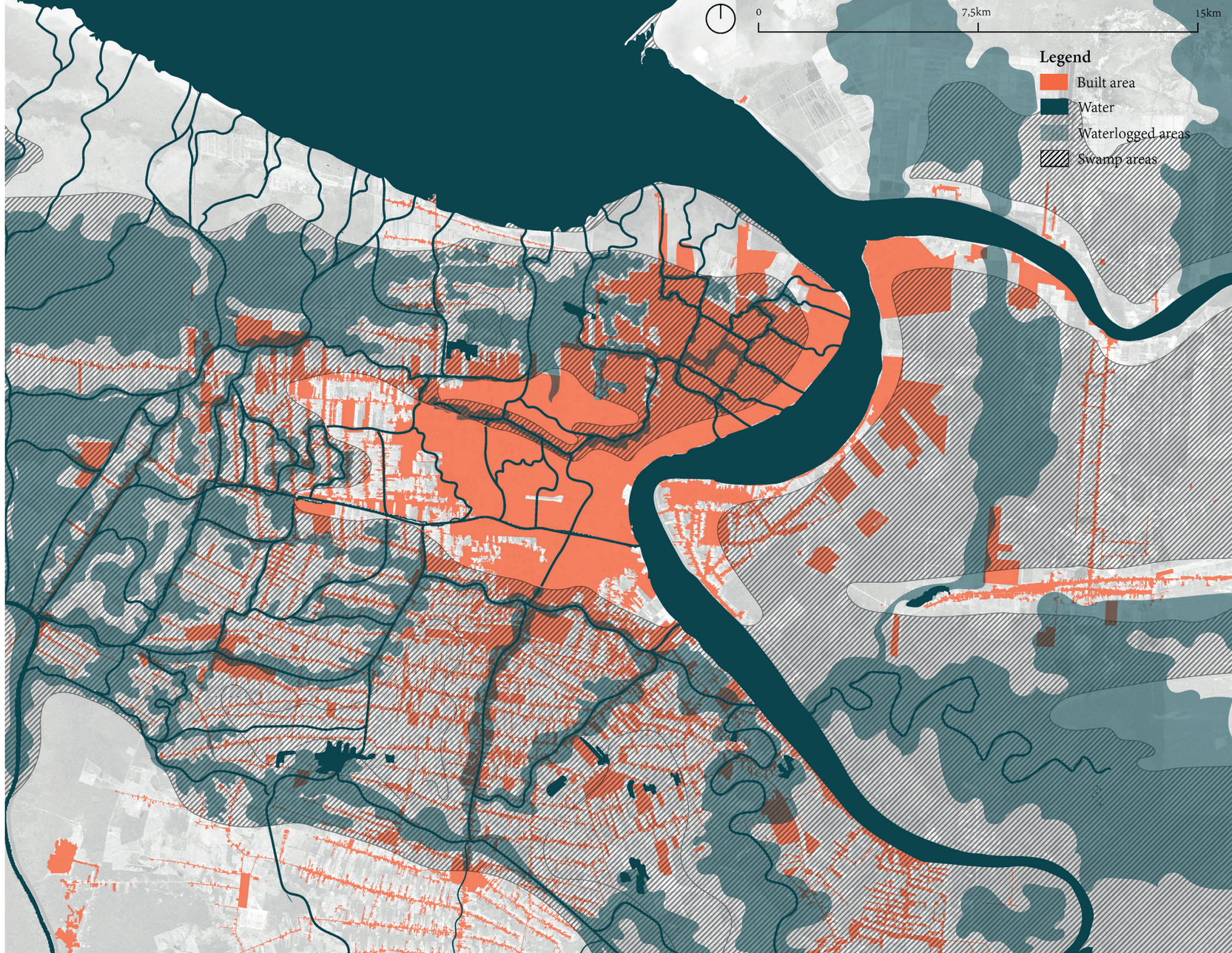
III. Creating room for the watersystem





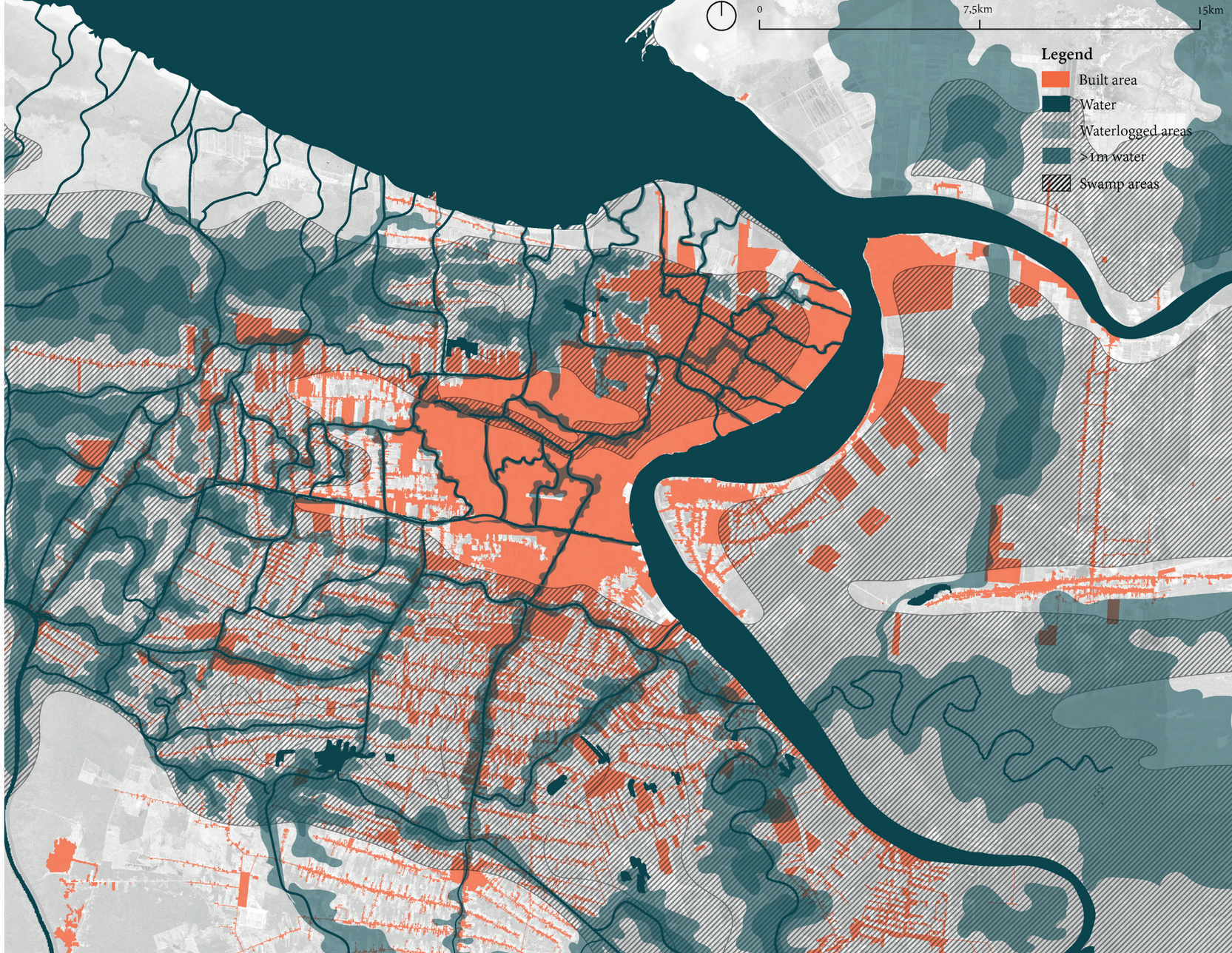
8.1.7 *The watersystem - Dry season*

The new water system leaves room for swamp areas to be fully saturated with water during the dry season. The ground is saturated with water but there is a small layer of water above the ground at most. The marsh areas are dry during this time (De Dijn, B., 2018). This new system leaves space for the natural planting to grow back.



8.1.8 *The watersystem - Rainy season*

During the rainy season, several swamp areas do flood. There is then a layer of water of up to about 1 metre. During this period of the year, the marshes are waterlogged and streams of up to 50 cm have formed in this zone to drain the water (De Dijn, B., 2018).



8.1.9 *Landsystem change Visionmap*

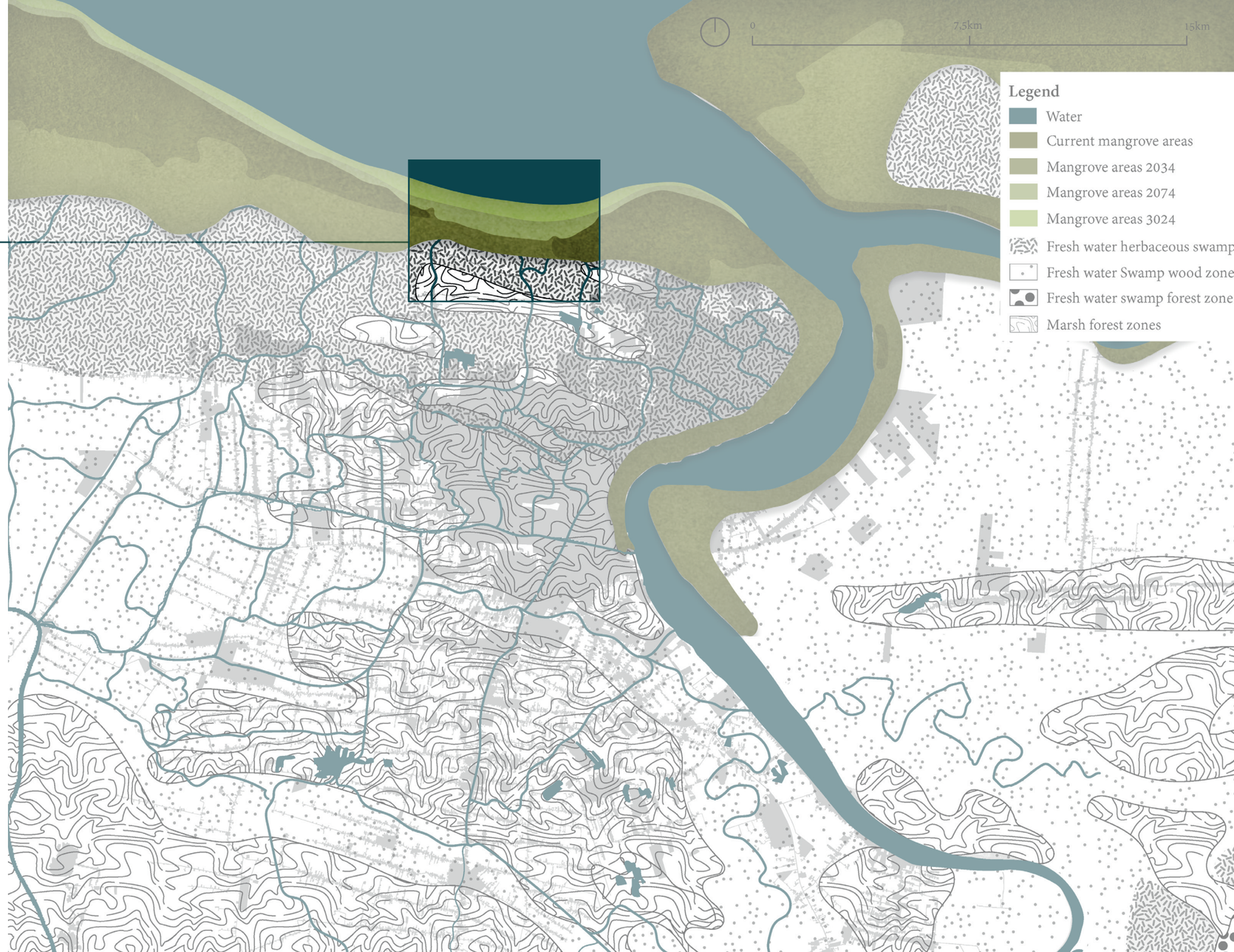
Once the city and surroundings are adapted to the new water system and eco zones, mangroves could grow again. The map opposite shows the current mangroves and those that would be grown in the future. For the mangroves to grow in certain parts, space must also be made in the city. However, this is necessary to protect the city from the sea even in the future.



8.1.10 *Mangroves (Weg naar Zee)*

Mangroves

Weg naar Zee is an agricultural area located in the north of Paramaribo. It is important in protecting Paramaribo from the sea, as it acts as a buffer between the sea and the city. However, rapid erosion is taking place in this area, as there are hardly any mangrove forests left. This can be clearly seen in the cross-sections below, based on map material from Google Earth.
Although the area is mainly agricultural, crops are seriously threatened by sea pressure, leading to crop failures and the departure of residents who have the means to go elsewhere.
Those without resources, however, are left behind and are dependent on the government's actions. Besides, there is also Hindu temple in the area, which is an important place for many people.

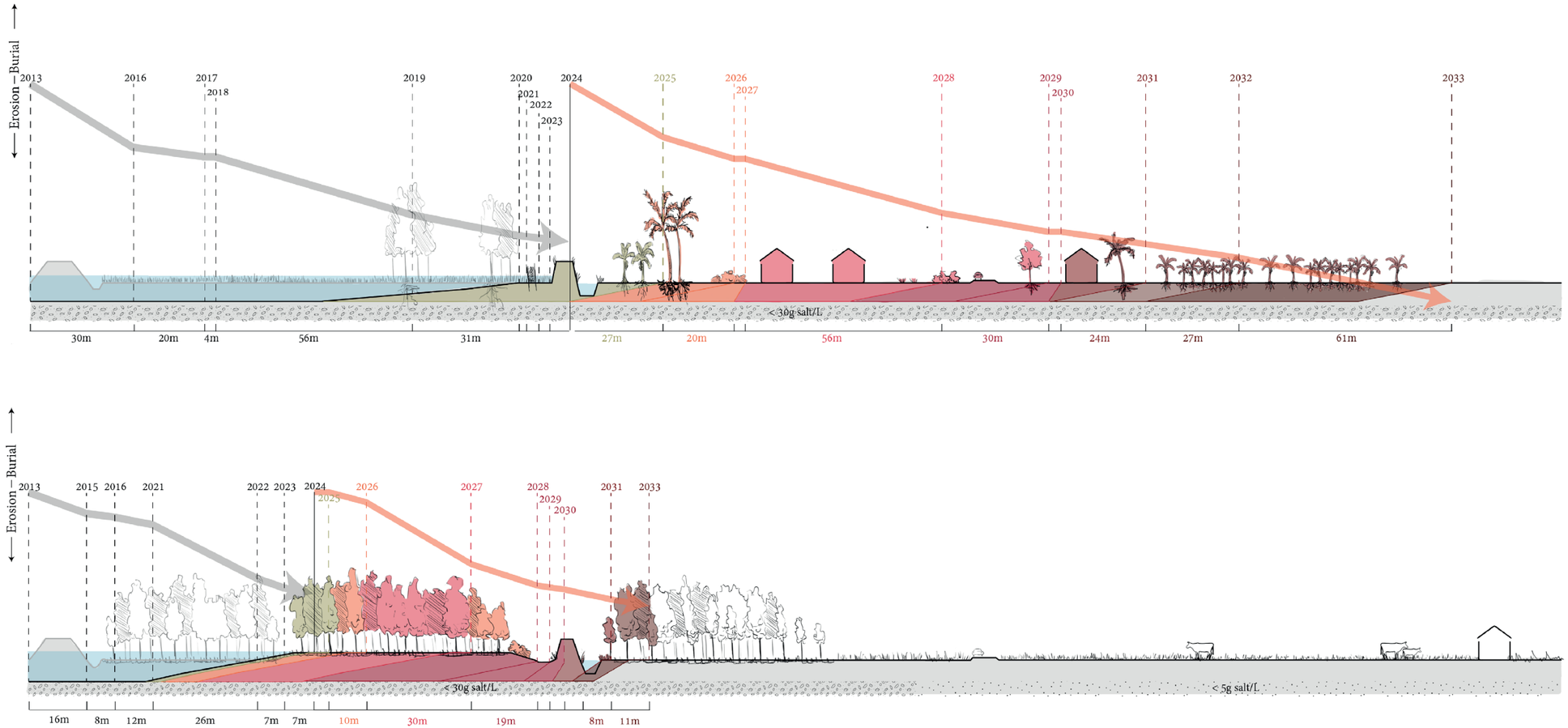


8.1.11 Erosion at Weg naar Zee

Based on Google Earth maps of the past 10 years, I made a reconstruction of coastal erosion (in grey). Based on this, I made a prediction for the next 10 years (coloured part), in case nothing was changed. These predictions are shown in the cross-sections to the right.

The top cross-section shows a location where mangroves were no longer present. At this location, the only protection from the sea was a dyke about 3 metres high. The erosion here is significant, as natural protection by mangroves is missing.

The lower cross-section shows an area where mangrove forest is present, but not in sufficient quantity and, moreover, this part is under pressure from hinterland land use. As a result, the mangrove forest cannot optimally fulfil its function as natural coastal protection. Which leads to the coast eroding as a result.



8.1.12 *Current watersystem*

As mentioned earlier, road to sea is mainly land farming area and the structure of the landscape is made to allow the land to drain as quickly as possible. Where these channels touch the sea, sluices have been built to allow the fresh water to drain to the sea at low tide, but keep the salt water out at high tide.



Unconnected drainage canals.breeding spots for musquitos



Watersystem adapted to infrastructure, agriculture and housing. It is polluted



Water system is based on plantation system. Sluices keep fresh water in and salt water out.

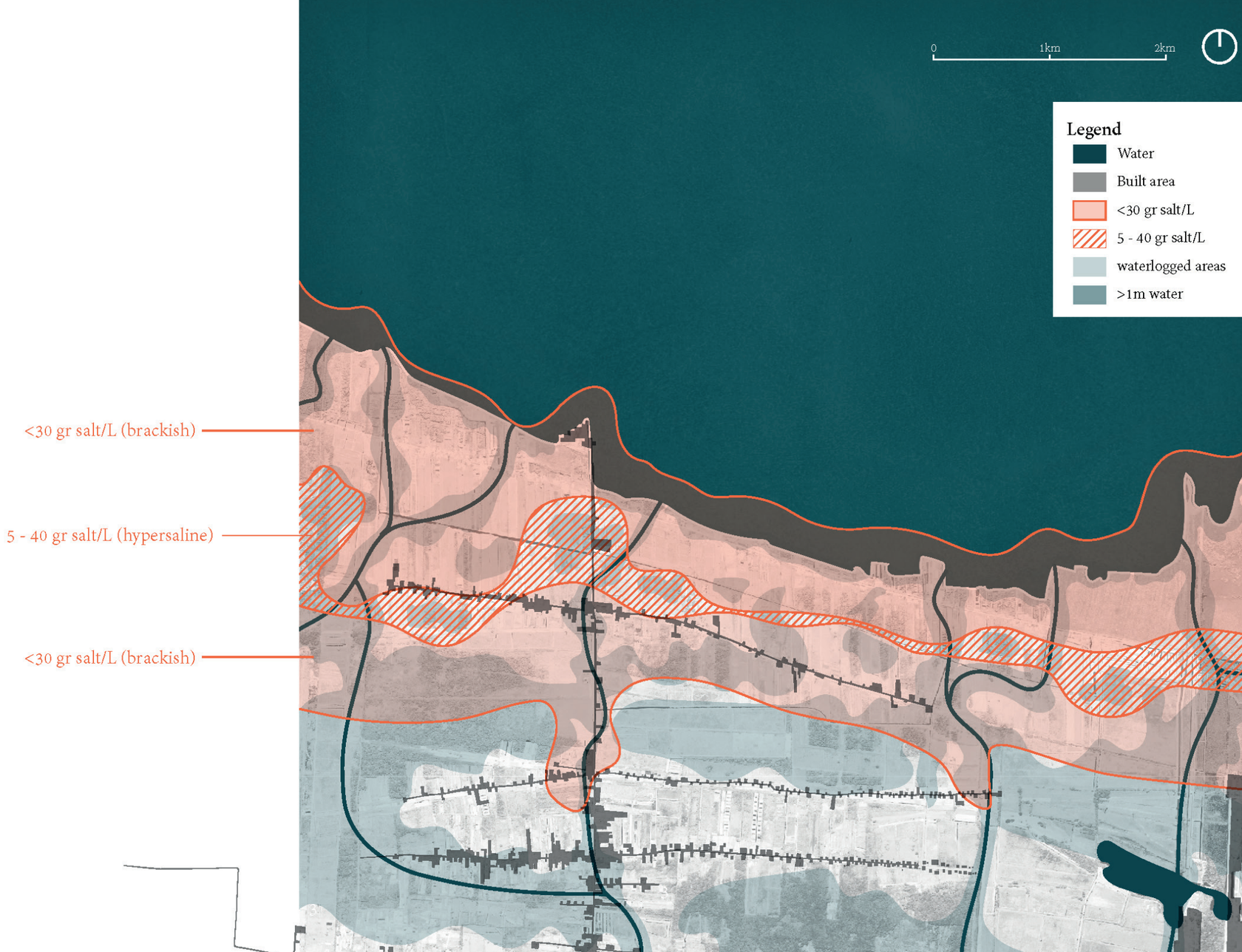


The sea dike is in a very bad condition



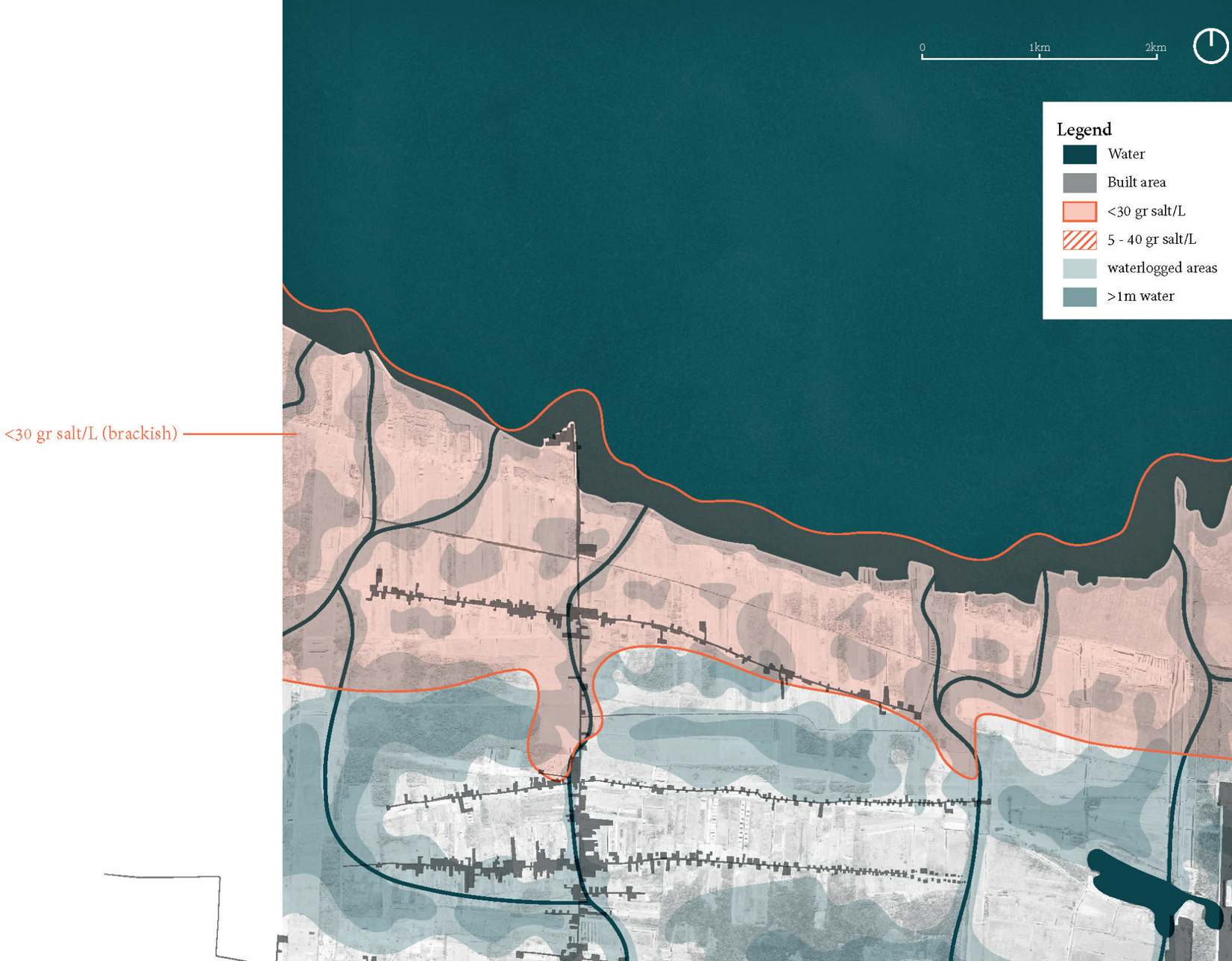
8.1.13 New watersystem - Dry season

In the new situation, water is allowed more space, infrastructure and buildings are adapted to the water network and it becomes possible for sea water to flow back into the land. During the dry season, the swamp areas are waterlogged and the marshes are dry. The waterlogged areas are coloured light blue on the map. Instead of a hard boundary between fresh and salt water, a transition zone has been created. during the dry period, this transition zone contains a hypersaline belt. The spots are mainly under the influence of sea water, which reaches these spots only during spring tides. The sea water is more brackish than salty (40g/L) but as the water evaporates, these spots become increasingly saline. At some point, these places become so saline that the Black mangrove trees can no longer withstand it and die. This creates hypersaline swamps and lakes. Further inland, the influence of fresh water becomes stronger and the swamps become brackish again. When the influence of the seawater disappears completely, the swamps become fresh.



8.1.14 *New watersystem - Rainy season*

During the rainy season, the influence of freshwater from inland is much stronger. Part of the brackish water zone becomes fresh water and the hypesaline zone disappears almost completely. The swamps are still waterlogged and are completely submerged <1m in several places. During the rainy season, the marshes are also waterlogged and creeks have formed to drain the water.





8.2 *Growing the coast*

The design aim 'Growing the Coast' results in 3 different categories of design principles. Now follows an elaboration of these three categories on Road to the Sea.
The first step in the process of accumulation is burial. Burial is the process by which sediment is retained in a particular place. This can be done naturally as explained in the research for design at growing the coast. It can also be done artificially by constructing sediment trapping units. Based on the techniques used in Guyana, I have added four ways as design principles. Currently, there have already been pilot projects using sediment trapping units in the form of poles. However, this has not had much success at this site so far. Therefore, I will use one of the other techniques for this purpose.

8.2 Sediment trapping

As with reconstructing vegetation zones, for this design aim Weg naar Zee will also be compared with similar zone on the coast. This time, the Tijgerbank will serve as an example. The Tijgerbank is in a similar location to Road to Sea, but unlike Road to Sea, it is growing (Google Earth, 2024).

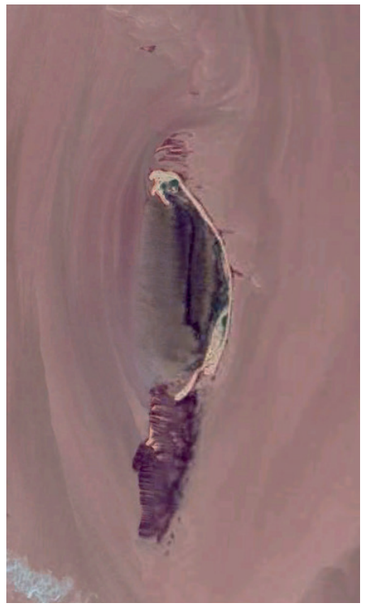


8.2.1 *The Tijgerbank at Galibi*

The Tijgerbank was initially created by an accumulation of coarse sand from the Marowijne River. Subsequently, sediment (carried by the sea) from the Amazon River deposited here behind it. Shortly afterwards, the first Black mangrove trees started growing and now, after about ten years, it is completely filled with trees and used as a nesting place by sea turtles and as a habitat by birds. The Tijgerbank is protected by an indigenous community (Aloema B., Personal interview, 18.Feb.2024).



2013



2019

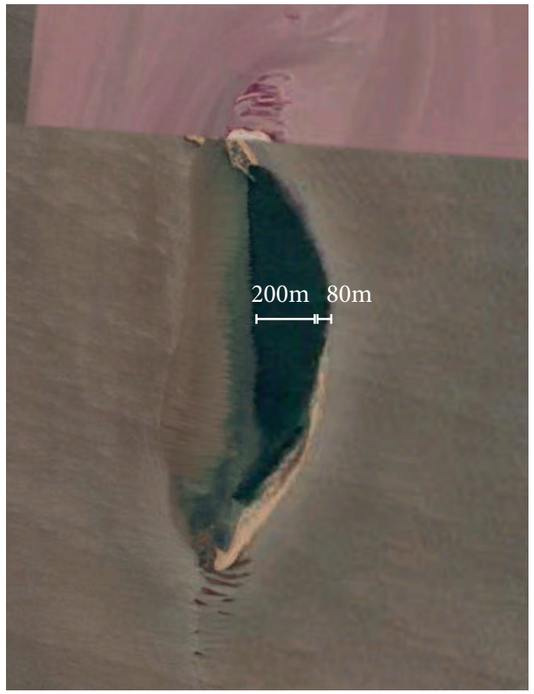


2023

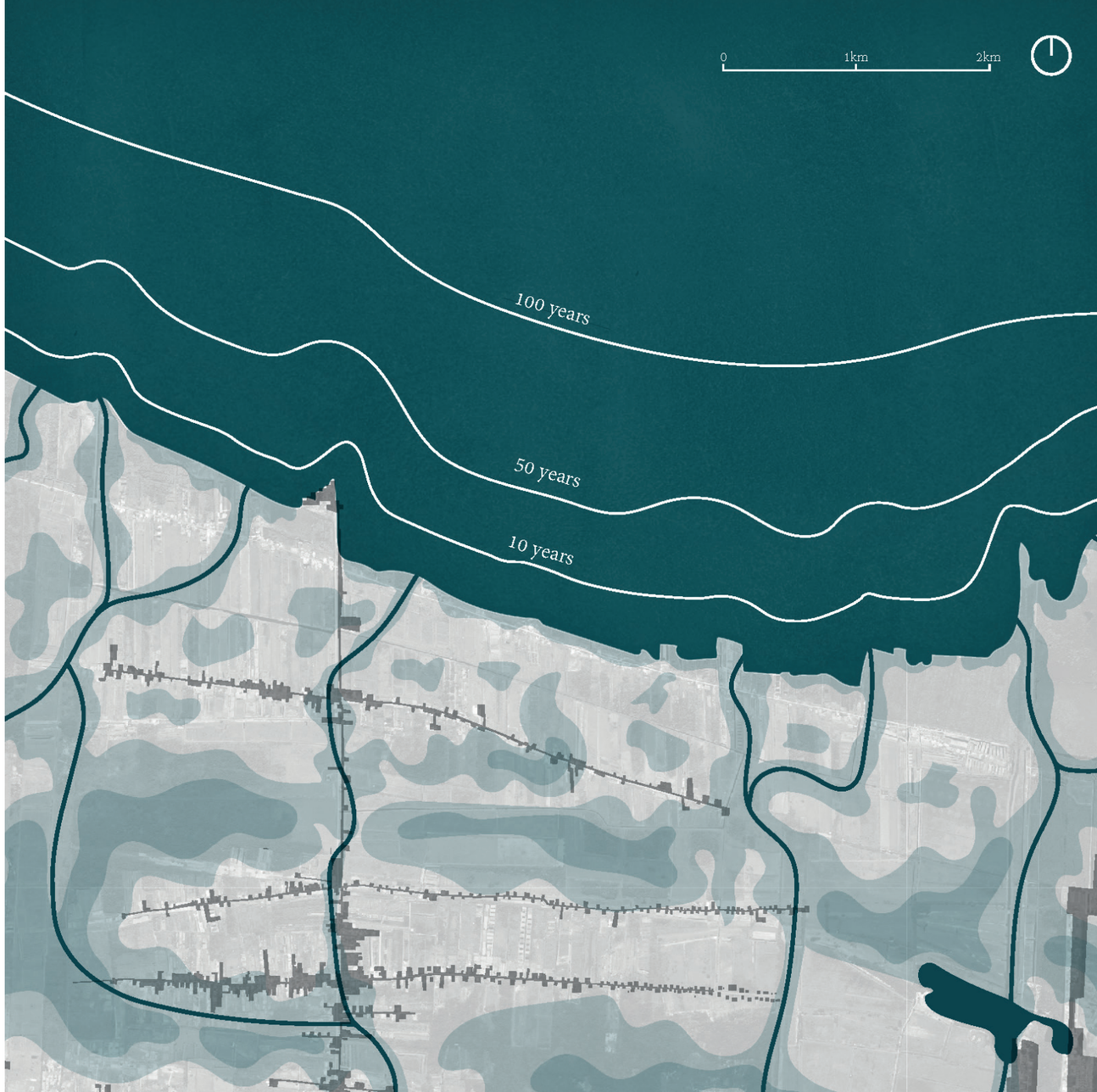


8.2.2 The Tijgerbank at Galibi

The width of the sandbank is about 80 metres and the forest that has emerged behind it has a width of 200 metres. I use these dimensions for the design at Weg naar zee (Google earth Pro, 2024). This means the coast can grow up to 200 metres in 10 years, a kilometre in 50 years and 2 kilometres in 100 years.



Google earth Pro (2023) Tijgerbank 2023



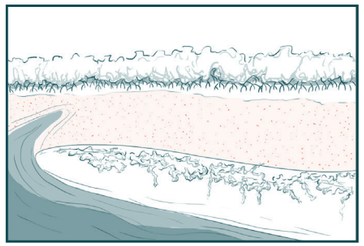
8.2.3 *Sediment from Suriname Rivier*



When heading out to sea, the coast is not growing but rather eroding. It is not exactly clear to why this is happening. People speculate about the influence of the dredging of the Surinam River and the construction of the dam that changed the quantities and dynamics of the water supply. Currently, the dredged material is dumped on the western bank of the Suriname river (daily suriname). However, this should be deposited offshore from Weg naar zee so that it can be used as sand ridge.

8.2.4 New System

The map next to this text shows that the first thing to do is to adapt the waterways to a new situation where water is not drained as quickly as possible. It is also important to clear the zones where the wetlands should be. These areas should in fact be waterlogged, and therefore the main focus should be on creating space for the water and adapting building and infrastructure.



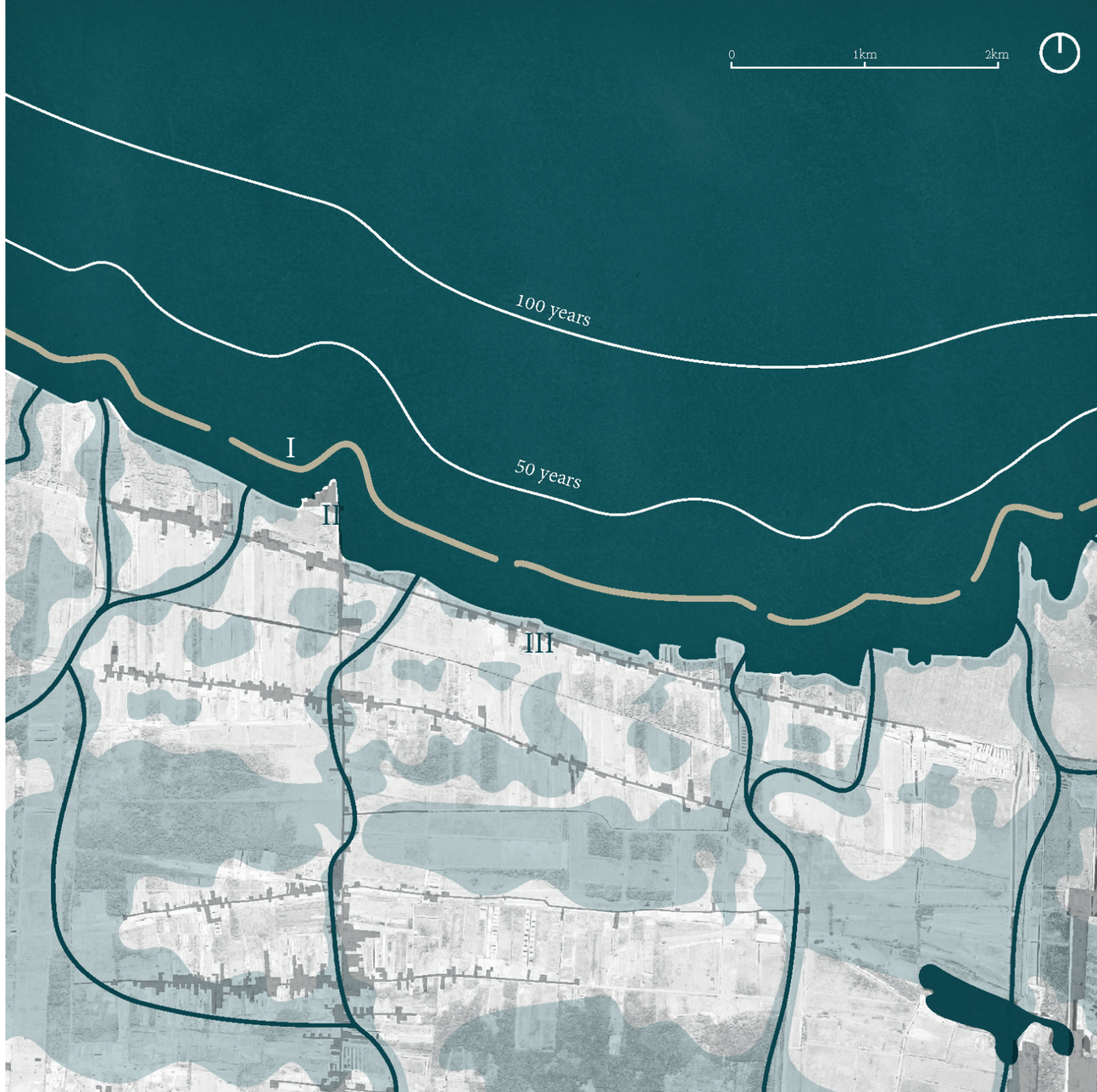
I. Trapping sediment by using sand ridges



II. Temple should remain in this place because the connection with the sea is very important.



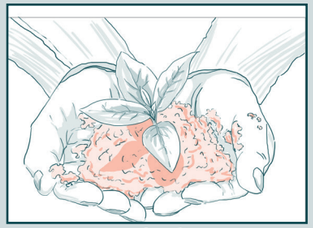
III. Houses and building that are built to close to the shore need to be moved.



8.2.5 *Growing the coast*

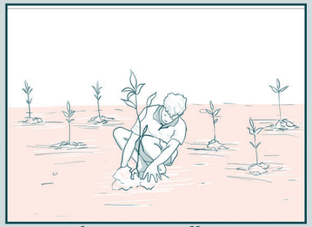
The moment sufficient burial has taken place, one can move on to tree growth . This can be done by planting, even though natural tree growth is more successful (Gijón Mancheño, A., 2022). However, this may not be fast enough in the first phase. So planting in the first phase is necessary. Next, one must protect the ridges and mangroves so that they can continue to develop as quickly as possible without problems.

PROTECTION

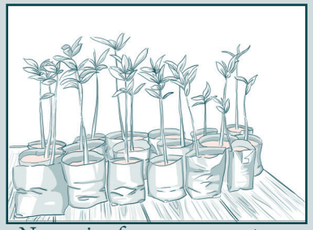


Protection of sediment trapping units and the trees

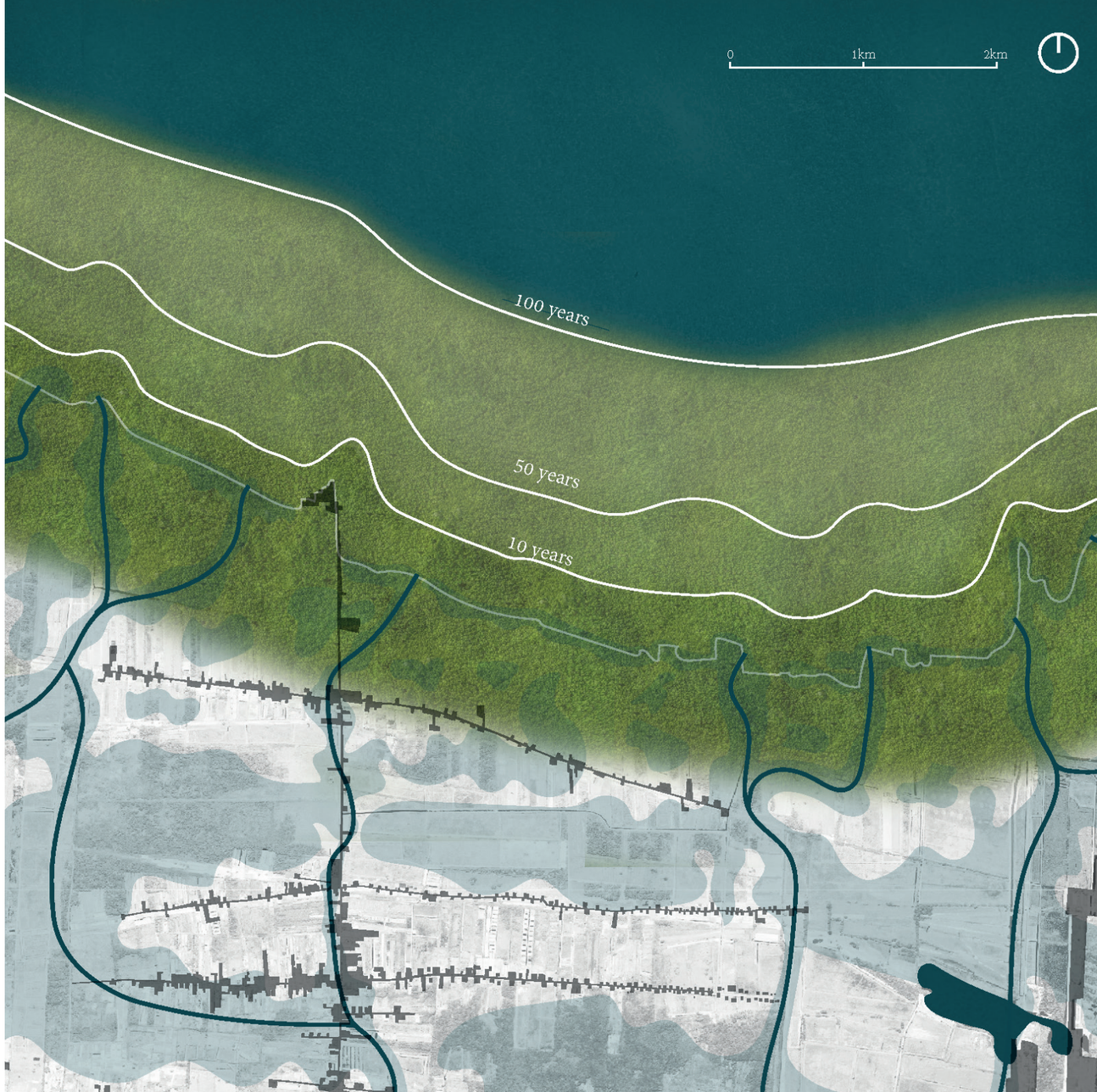
PLANTING



Planting seedlings



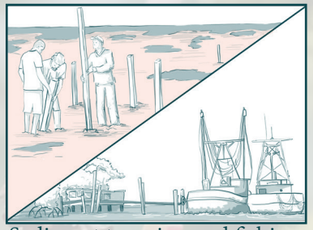
Nurseries for mangrove trees

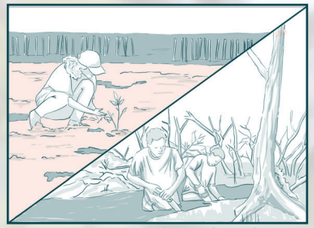


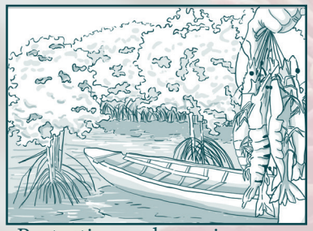
COMBINING PRODUCTION SERVICES WITH GROWING THE COAST

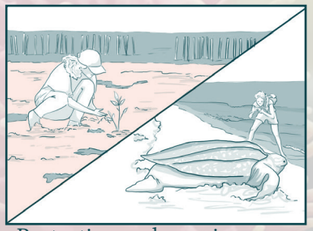


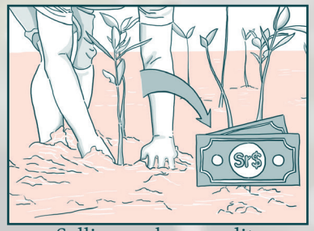
Providing Bio-rights for locals


Sediment trapping and fishing


Protection combined with use of trees

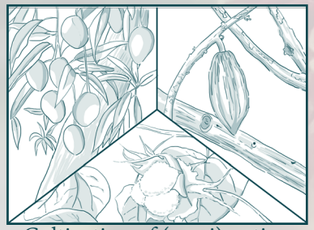

Protecting and growing combined with aquaculture

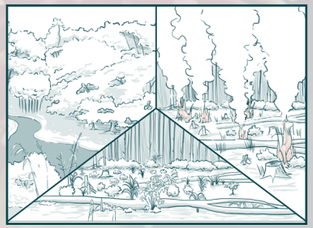

Protecting and growing combined with eco-tourism



Selling carbon credits

LEARNING FROM THE INDIGENOUS


Cultivation of (semi) native crops

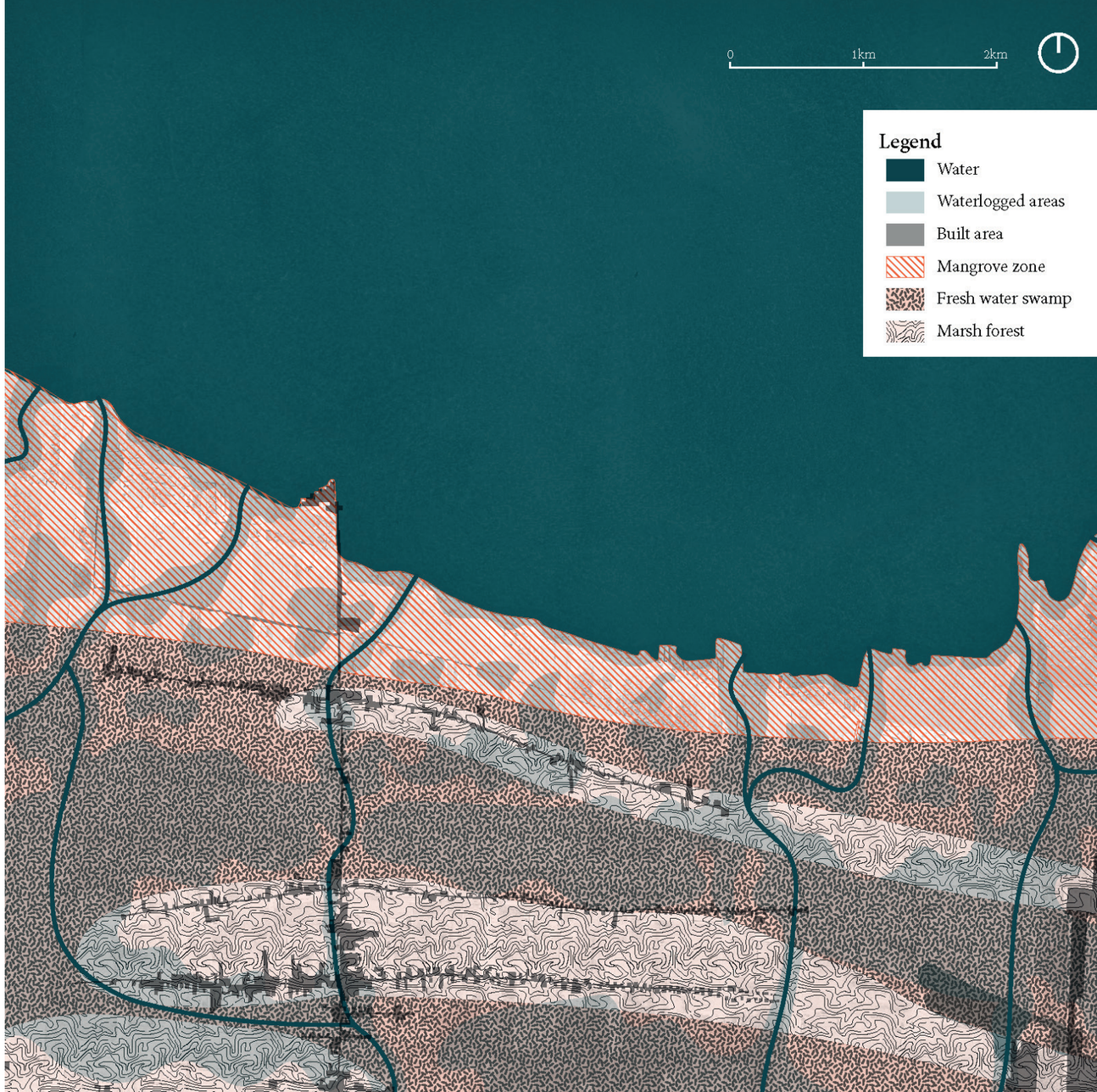

agriculture that mimics natural forest cycles

8.3 Shifting focus

Mangrove growth requires a change in the water system, the landscape and the way people live here. This requires a different view of what becomes possible in this new area. The design principles that follow from the design aim shifting focus are not intended as a final design but as first steps in living together with this new system.

8.3.1 The Eco zones

The map shows the different eco zones found in Weg naar Zee. This starts with the mangrove zone that also includes sand ridges, mudflats and hypersaline lakes. It also features swamp zones, which will consist mainly of Herbaceous swamps in the first epoch and later transition to swamp wood and forest. Then lastly, a number of marshes are also located in the area on which marsh forests should grow. As with the city of Paramaribo, the water network work needs to be adapted to this so that this can occur.



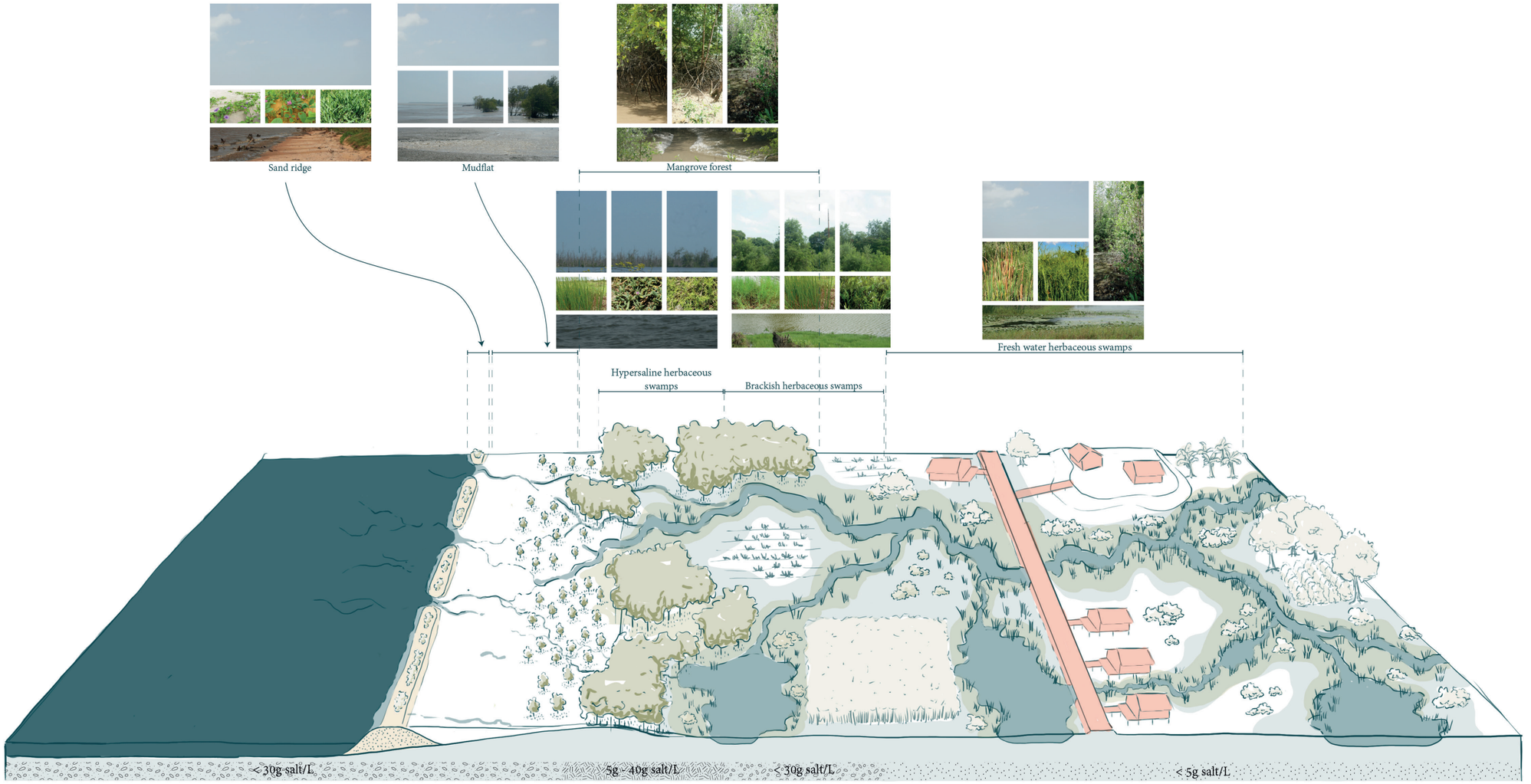


8.3.2 *Weg naar Zee now and in a 100 years*

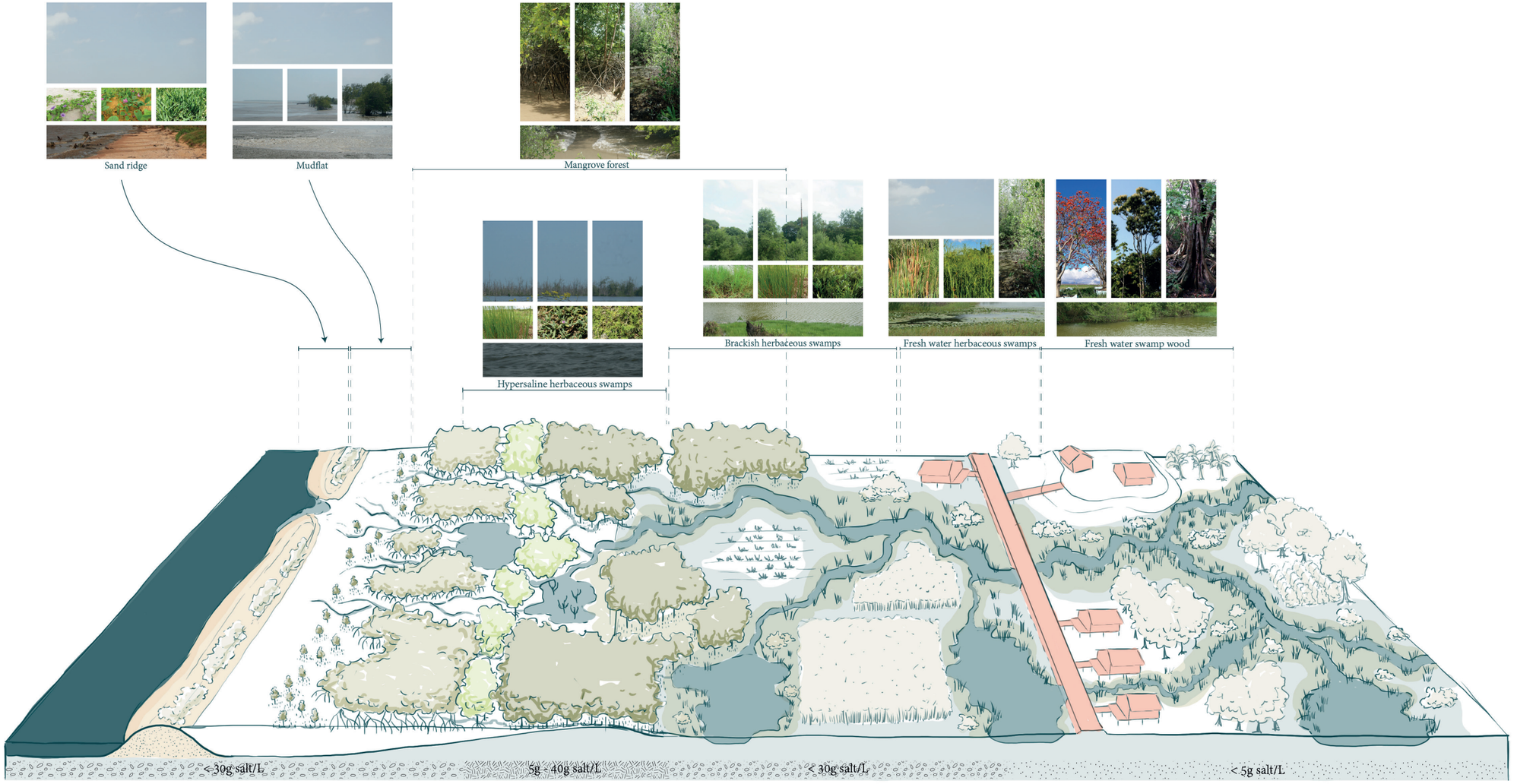
With the mangrove landscape, it is important to remember that this is an incredibly dynamic landscape. The eco zones that occur in the first 10 years will slowly diversify and change into other eco-zones as the coast grows. The drawings below give a schematic representation of which eco zones are present in different years. The first shows the landscape in 10 years, the second in 50 years and the third in 100 years.

The following pages will use the drawing of 50 years from now to show for each eco zone what possibilities there are here in terms of production resources and housing.

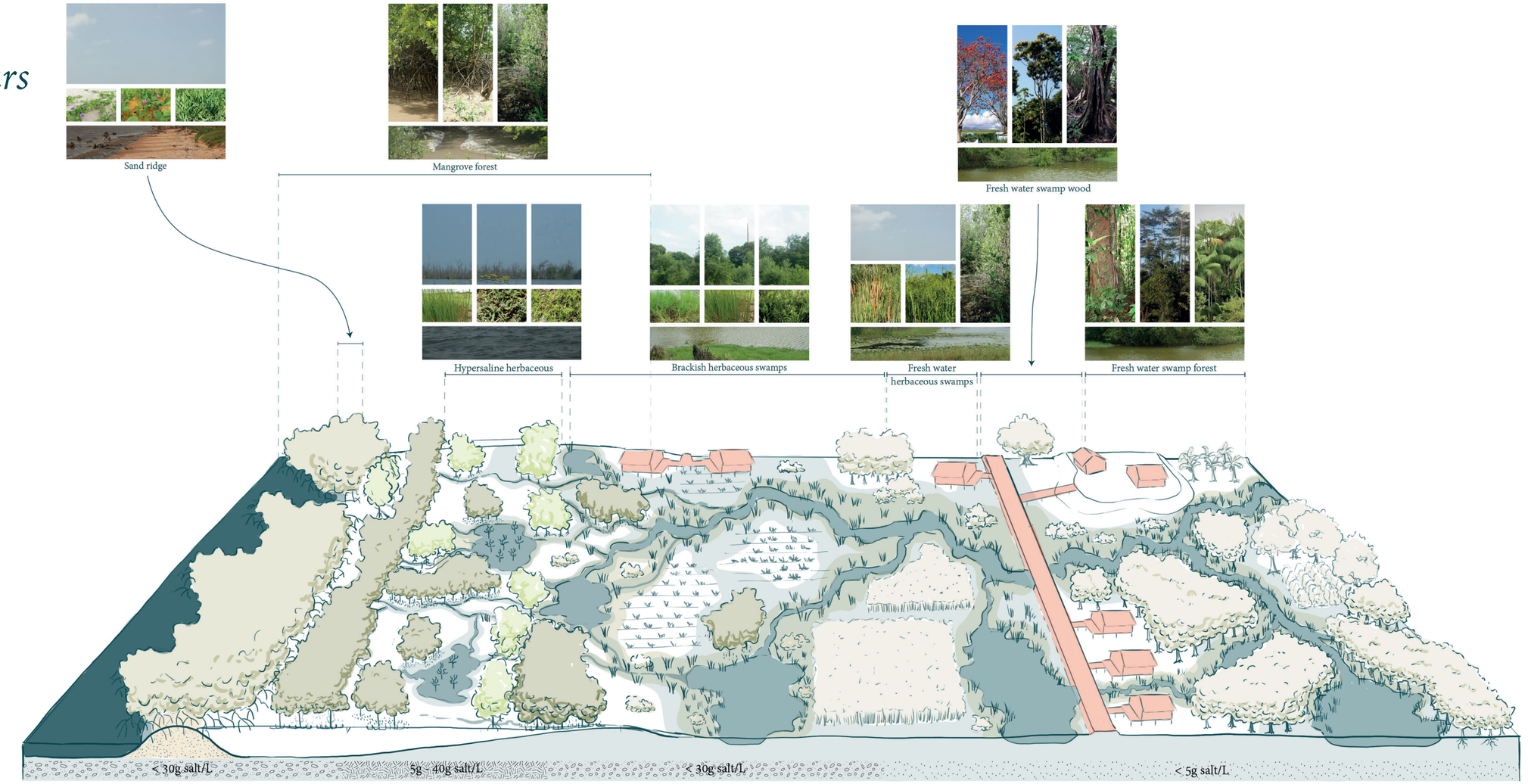
8.3.3 *10 years*


Sand ridge
Mudflat
Mangrove forest
Fresh water herbaceous swamps
Hypersaline herbaceous swamps
Brackish herbaceous swamps
< 30g salt/L
5g - 40g salt/L
< 30g salt/L
< 5g salt/L

8.3.4 50 years

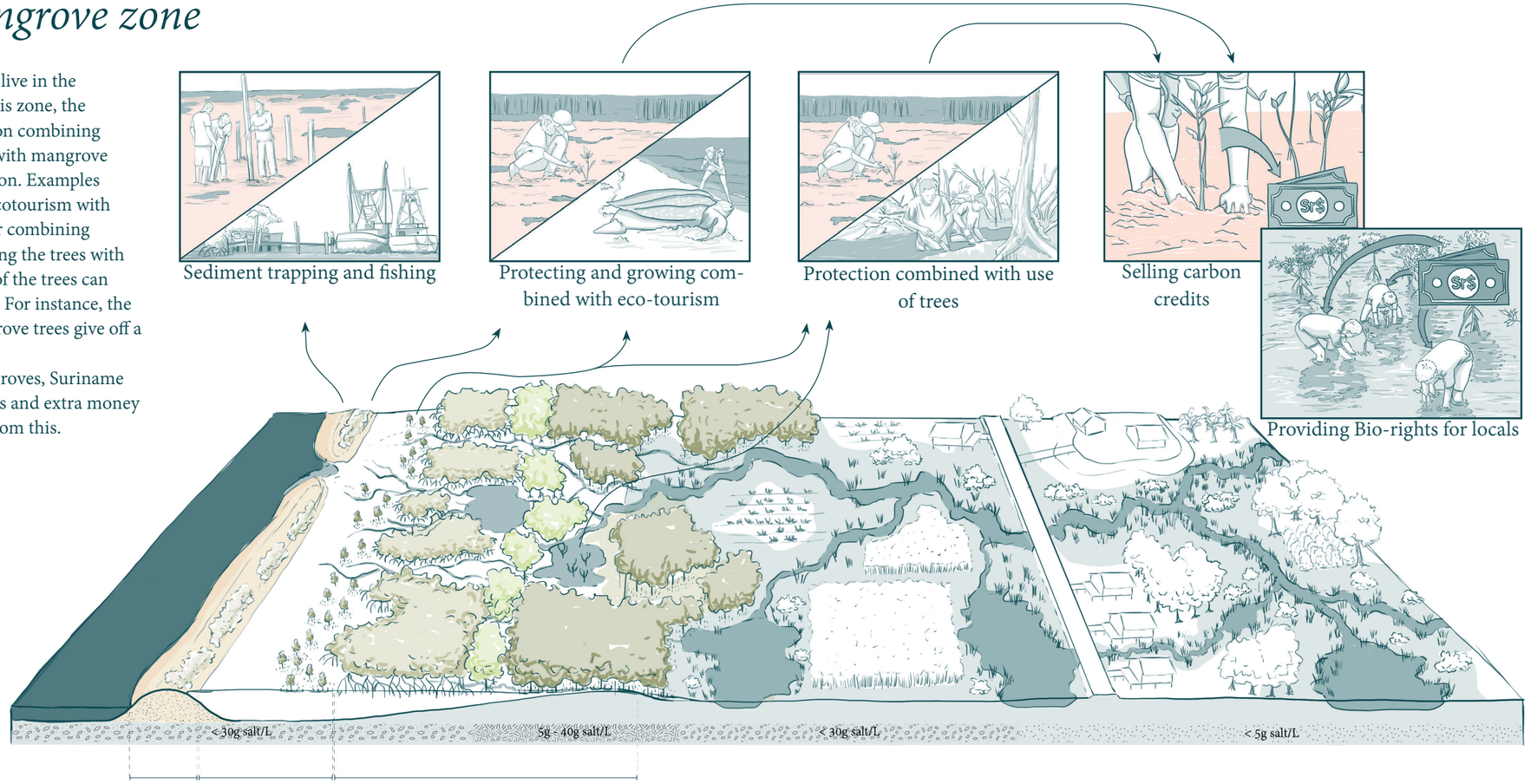

Sand ridge
Mudflat
Mangrove forest
Hypersaline herbaceous swamps
Brackish herbaceous swamps
Fresh water herbaceous swamps
Fresh water swamp wood
< 30g salt/L
5g - 40g salt/L
< 30g salt/L
< 5g salt/L

8.3.5 100 years



8.3.6 *mangrove zone*

People can no longer live in the mangrove zone. In this zone, the intention is to focus on combining production services with mangrove planting and protection. Examples include combining ecotourism with planting new trees, or combining planting and protecting the trees with logging. Some parts of the trees can also be used for food. For instance, the leaves of Black mangrove trees give off a salty taste.
By growing the mangroves, Suriname can sell carbon credits and extra money can then be earned from this.




Sand ridge


Mudflat


Mangrove forest

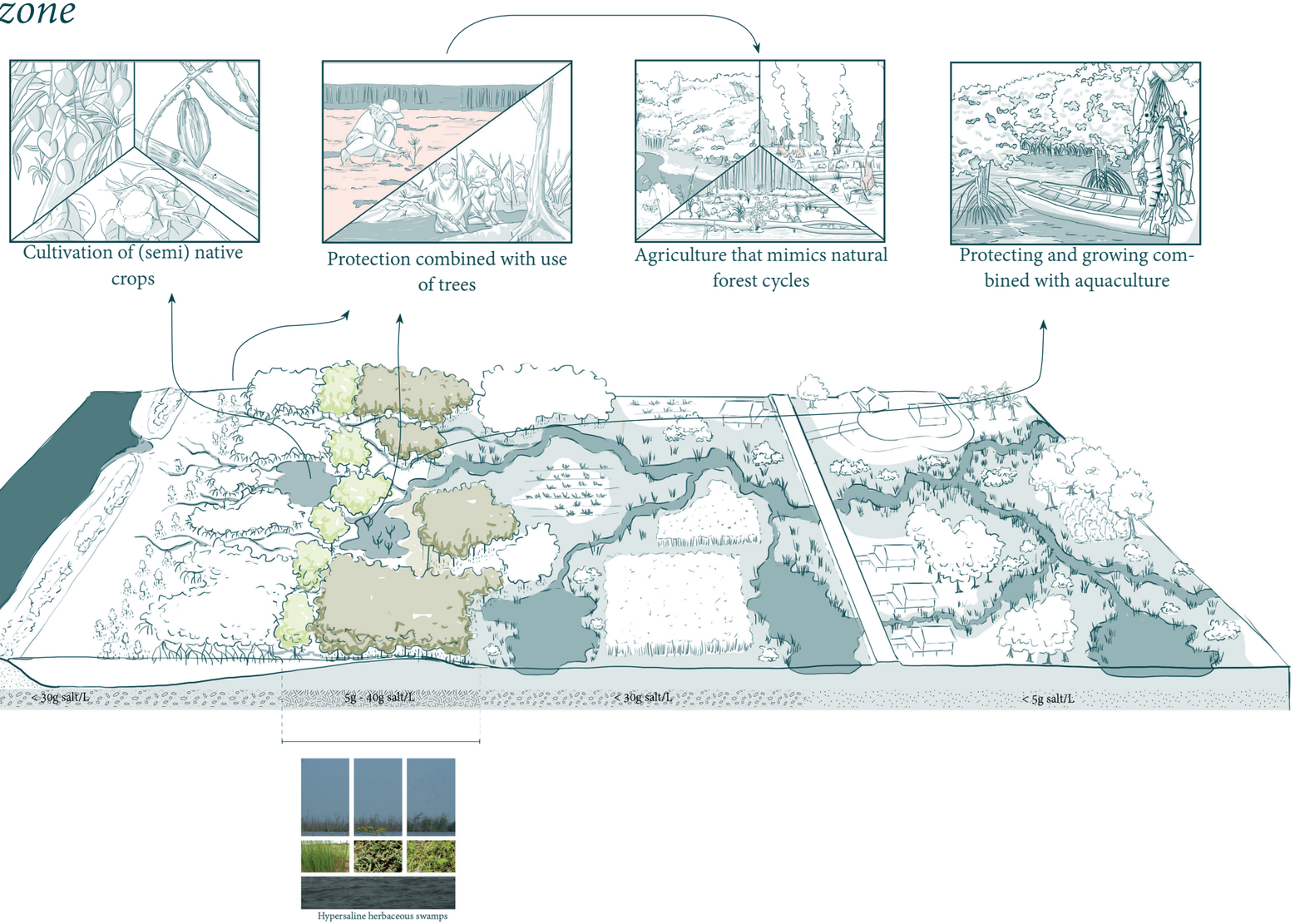
EXAMPLES OF PLANTS THAT CAN BE CULTIVATED

Parwa (Avicennia germinans)


Mangrove tree with edible leaves

8.3.7 *Hyper saline zone*

In the hypersaline zone, one can focus on cutting down the old mangrove trees. Because the trees cannot handle the salinity, they die. These trees can be cut down. In addition, shrimp can be farmed here, fishing can be done and native salt-tolerant plants can be grown in a way that mimics the natural cycles.



EXAMPLES OF PLANTS THAT CAN BE CULTIVATED

Amandra (Terminalia catappa)



Edible

Sesuvium portulacastrum



Edible
grows around the hypersaline lakes
originates from Surinam

Bitter bean (Parkia speciosa)



Edible
originates from Asia

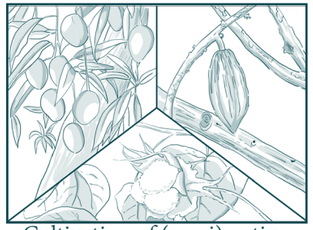
Basra maho (hibiscus tiliaceus)



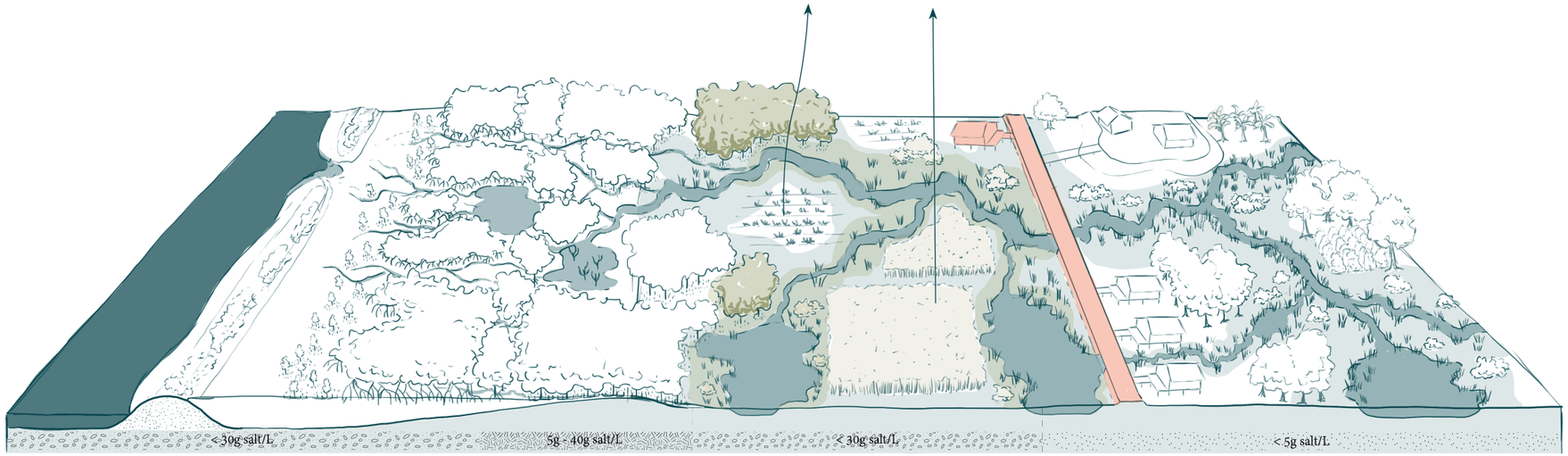
wood can be used for wood-working and construction
originates from surinam

8.3.8 *Brackish water zone*

In this zone, it is best to focus on (semi) native salt-tolerant plants. However, the plants cultivated here must also be able to withstand low levels of salt in the water and soil, as the salt content in these areas varies greatly seasonally. Starting from this zone it is also safe to live here. So, people can live in adapted buildings in these areas.



Cultivation of (semi) native crops





Brackish herbaceous swamps

EXAMPLES OF PLANTS THAT CAN BE CULTIVATED

Brantimaka (Machaerium lunatum)



Medicinal use originates from Surinam

Bamboe klein (Bambusa glaucescens)



Edible can also be used for paper making Originates from Indo-

Wilde dadelpalm (Phoenix reclinata)



edible fruits Originates from Africa.

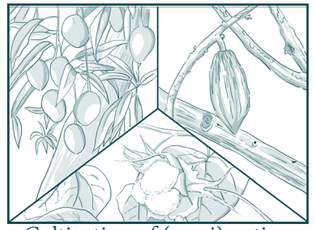
Mira-udu (Triplaris Surinamensis)



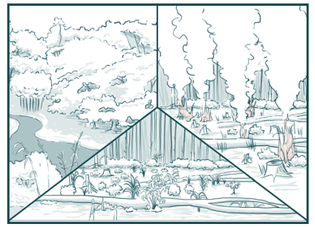
can be used for wood production

8.3.9 *Fresh water swamp zone*

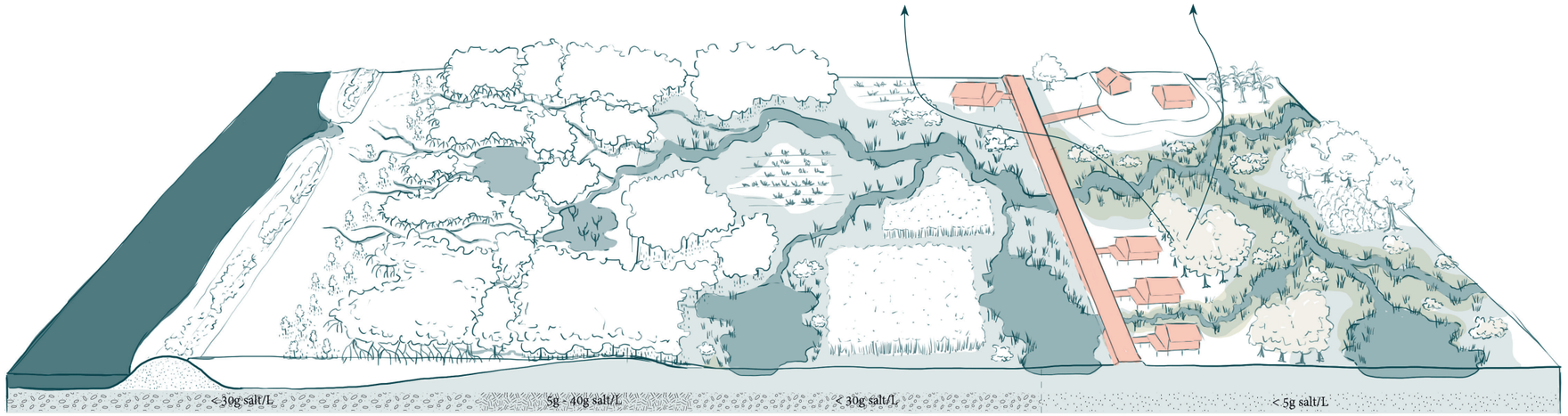
In the freshwater swamp zone, one can grow the plants shown here. To maintain the change in landscape, it is best to grow low/shrubby crops such as rice and cotton first. As the landscape slowly changes from herbaceous swamp to swamp wood, one can slowly switch to trees, such as banana, cocoa and noni trees.



Cultivation of (semi) native crops



Agriculture that mimics natural forest cycles





Fresh water herbaceous swamps



Fresh water swamp wood



Fresh water swamp forest

EXAMPLES OF PLANTS THAT CAN BE CULTIVATED

Katoen (Gossypium barbadense)



can be used for textile production.

Tribal rice types



Rice species from tribal communities.

Trinitario cacao (Theobroma cacao)



Tree that produces edible cacao beans.

Dibri apra(Morinda citrifolia)



Tree with Medicinal leaves and fruits. Originates from India

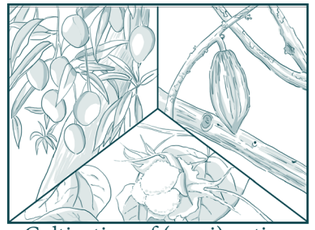
Bakba (Musa sp.)



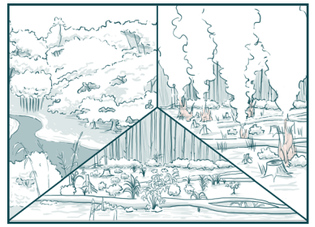
Tree with edible fruits. Leaves are often used as decoration Originates

8.3.10 *Marsh zone*

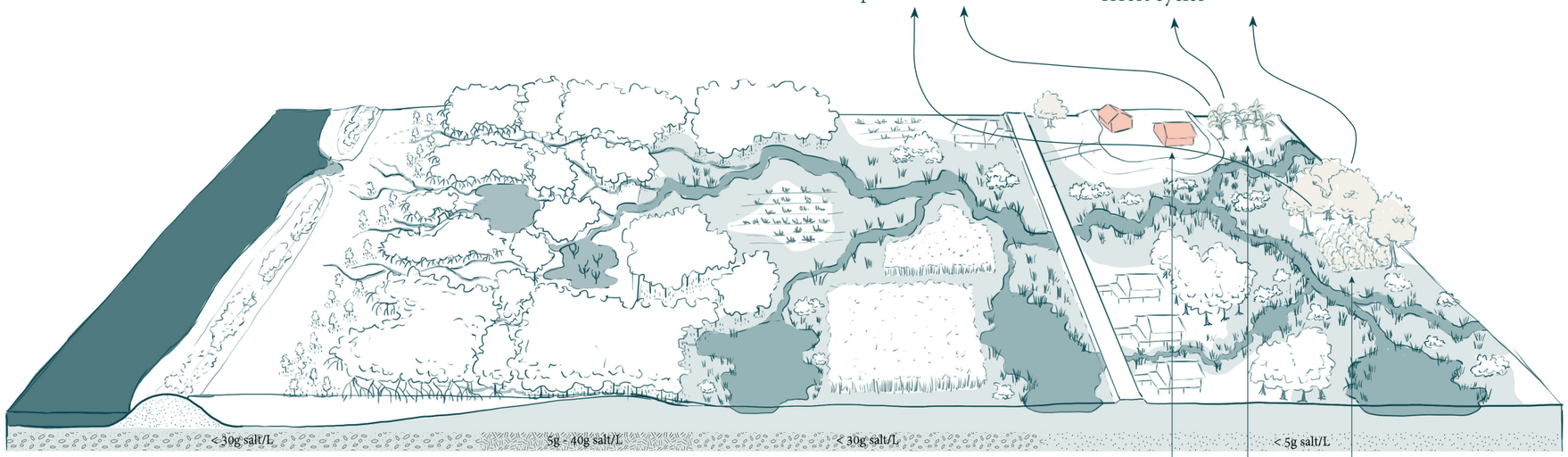
This zone is naturally more vegetated with trees. Therefore, I have mainly focused on growing crops on trees here. Examples include tamarind, mango, coffee, etc.



Cultivation of (semi) native crops



Agriculture that mimics natural forest cycles





Marsh forest

EXAMPLES OF PLANTS THAT CAN BE CULTIVATED

Kasyu (Anacardium occidentale)



Tree with edible fruit and nuts
Originates from Surinam.

Manja (Mangifera indica)



Tree with edible fruits
Originates from India

Krabasi (crescentia cujete)



Small tree with big fruits that can be used for Medicinal purposes, Kitchen tools or art.

Kofi (Coffea arabica)



Bush that produces coffee beans.
Originates from Africa

Tamaling (Tamarindus indica)



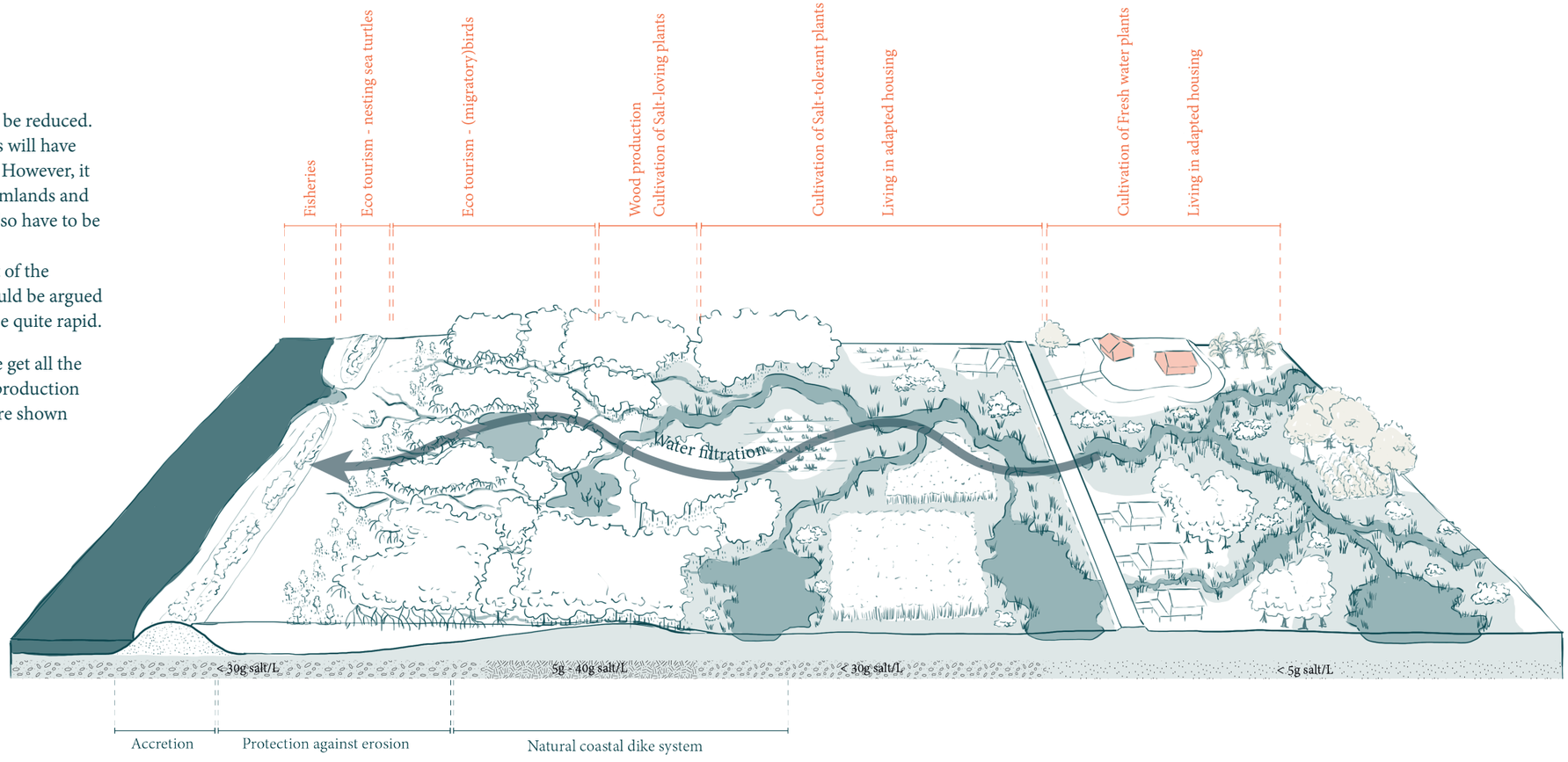
Slow growing tree which produces edible fruits.
Wood can be used for furniture.

8.4 Co-creation

For making these changes, stakeholders are important. The residents from Weg naar zee need to be involved in the changes and new activities in the area. On the one hand, this is for their benefit, these people have no means to move away from this area. On the other hand, people are an opportunity for developments in the area. They have local knowledge and could help build this new layout of the landscape.

Initially, people would have to give something up. Mangrove forests are a very dynamic way of coastal protection. In natural situation, the coast is constantly growing and eroding. This does make the mangrove zone itself a dangerous place to live. Some of the houses would have to move, and accessibility to the sea will be reduced. Many crops and farmlands will have to be (partly) abandoned. However, it is also the case that the farmlands and houses would otherwise also have to be given up.
Based on the development of the TIjgerbank, however, it could be argued that developments could be quite rapid.

After this, however, people get all the enhanced regulation and production services in return. These are shown here.



8.5 Development over time



8.6 Zoning



SHORE

- Fisheries
- Ecotourism
- Protection
- Planting
- Space for water

FRESH WATER SWAMP

- Adjusted housing
- Adjusted agriculture
- Making room for water
- Protection

MARSH FOREST

- Adjusted housing
- Adjusted agriculture
- Making room for water

MANGROVES

- Fisheries
- Protection

HYPERSALINE / BRACKISH SWAMP

- Adjusted housing
- Fisheries
- Timber production
- Adjusted agriculture
- Making room for water
- Protection



8.7 Zoom-ins

8.7 *Zoom-ins*

III. Hindu temple

II. Ingipipaweg

I.Henri Fernandesweg



9.7.1 Zoom-in - Henri Fernandesweg



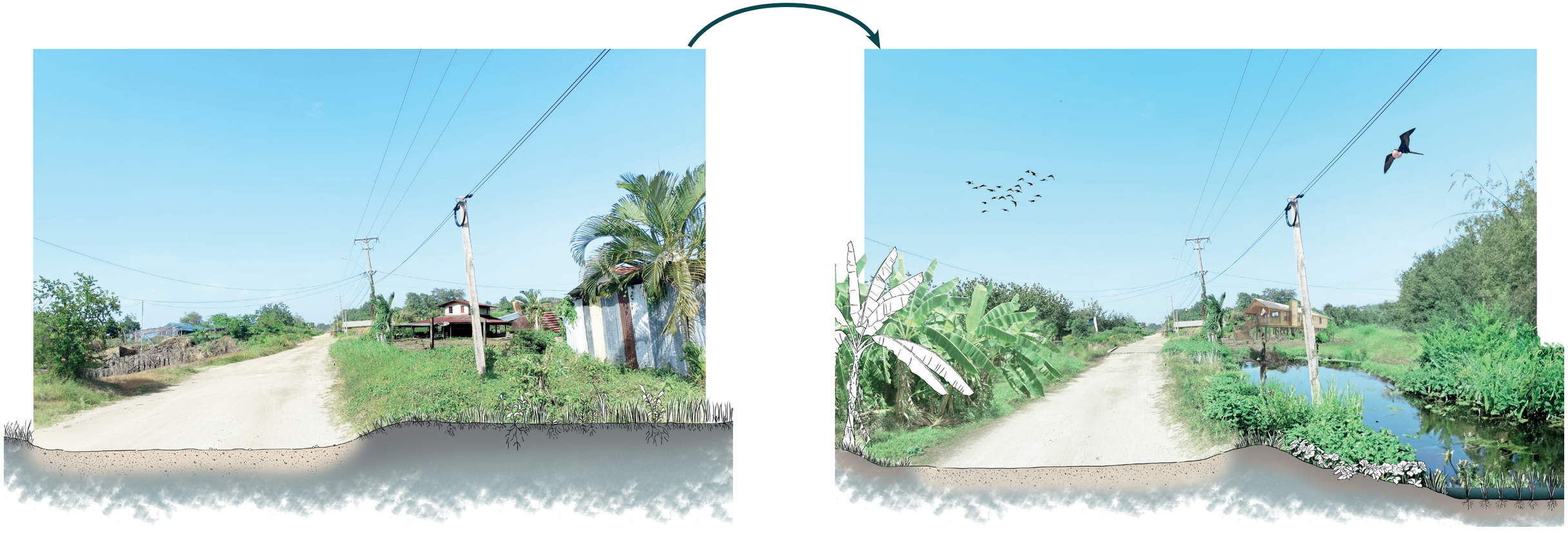
I.Henri Fernandesweg



9.7.2 Zoom-in - Ingipipaweg

II. Ingipipaweg





9.7.3 Zoom-in - Hindu Temple

III. Hindu temple






Sr$



IV. CONCLUSION AND REFLECTION

9 CONCLUSION	246 - 245
9.1 Relevance of the toolbox	248
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9.0 Conclusion

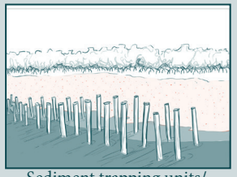


9.1 Relevance of the toolbox

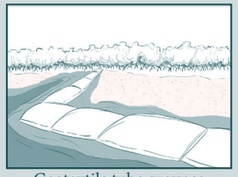
9.1 *The Toolbox*

GROWING THE COAST

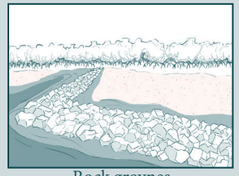
TRAPPING SEDIMENT



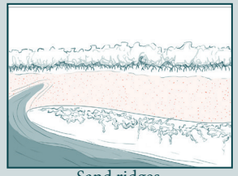
Sediment trapping units/ brushwood dams



Geotextile tube groynes



Rock groynes

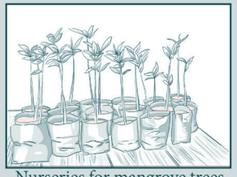


Sand ridges

PLANTING

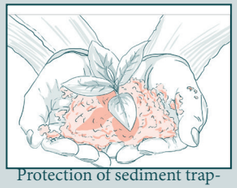


Planting seedlings



Nurseries for mangrove trees

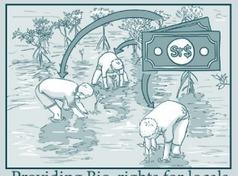
PROTECTION



Protection of sediment trapping units and the trees

SHIFTING FOCUS

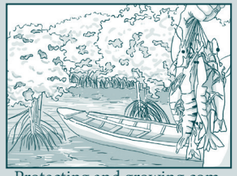
COMBINING PRODUCTION SERVICES WITH GROWING THE COAST



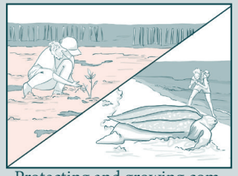
Providing Bio-rights for locals



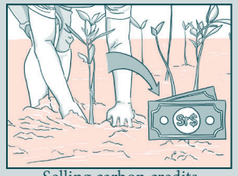
Sediment trapping and fishing



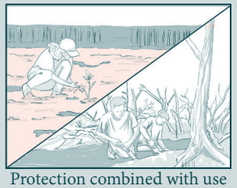
Protecting and growing combined with aquaculture



Protecting and growing combined with eco-tourism



Selling carbon credits

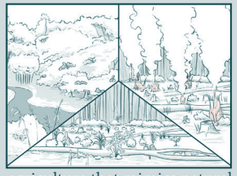


Protection combined with use of trees

LEARNING FROM THE INDIGENOUS



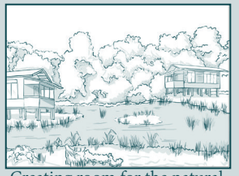
Cultivation of (semi) native crops



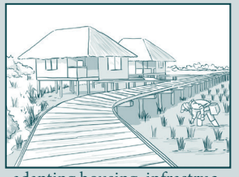
agriculture that mimics natural forest cycles

LANDSYSTEM CHANGE

ADJUSTING TO THE NATURAL SYSTEM



Creating room for the natural watersystem and ecology.



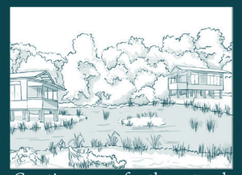
adapting housing, infrastructure and agriculture to the natural watersystem.



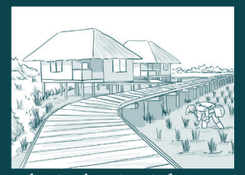
water system based on natural system. letting brackish water back in.

Landsystem change - Adjusting to the natural system

WEG NAAR ZEE



Creating room for the natural watersystem and ecology.

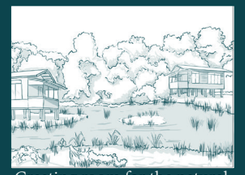


adapting housing, infrastructure and agriculture to the natural watersystem.

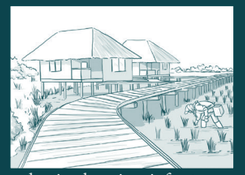


water system based on natural system. letting brackish water back in.

COASTLINE SURINAME



Creating room for the natural watersystem and ecology.

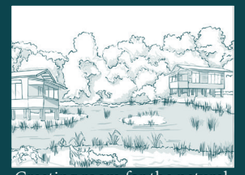


adapting housing, infrastructure and agriculture to the natural watersystem.

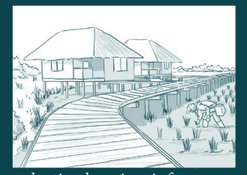


water system based on natural system. letting brackish water back in.

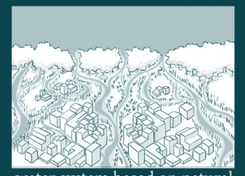
ALL MANGROVE ZONES



Creating room for the natural watersystem and ecology.



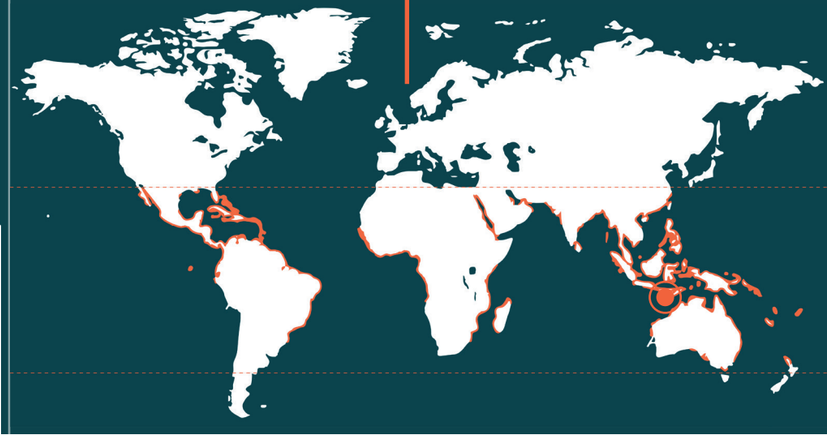
adapting housing, infrastructure and agriculture to the natural watersystem.



water system based on natural system. letting brackish water back in.

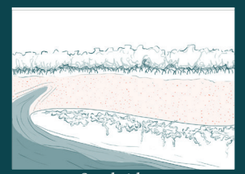






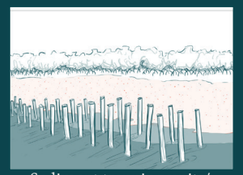
Growing the coast - Sediment trapping

WEG NAAR ZEE

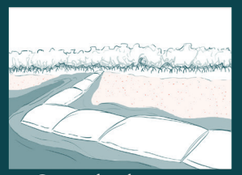


Sand ridges

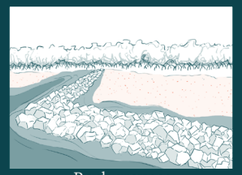
COASTLINE SURINAME



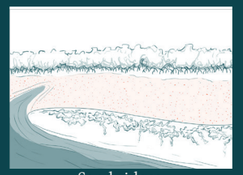
Sediment trapping units/ brushwood dams



Geotextile tube groynes

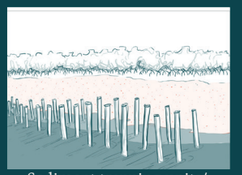


Rock groynes

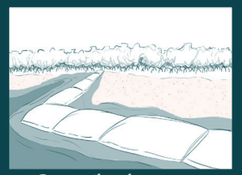


Sand ridges

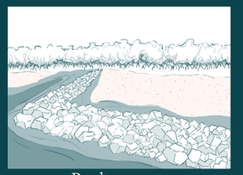
ALL MANGROVE ZONES



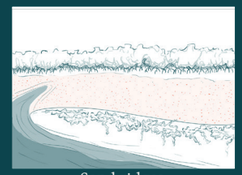
Sediment trapping units/ brushwood dams



Geotextile tube groynes



Rock groynes



Sand ridges







Growing the coast - Planting and Protection

WEG NAAR ZEE



Planting seedlings



Protection of sediment trapping units and the trees



Nurseries for mangrove trees

COASTLINE SURINAME



Planting seedlings



Protection of sediment trapping units and the trees



Nurseries for mangrove trees

ALL MANGROVE ZONES



Planting seedlings



Protection of sediment trapping units and the trees



Nurseries for mangrove trees

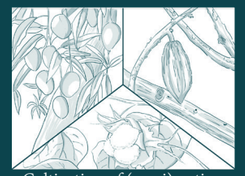




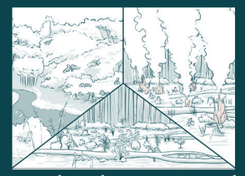


Shifting focus - Learning from the indigenous

WEG NAAR ZEE

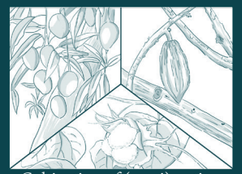


Cultivation of (semi) native crops

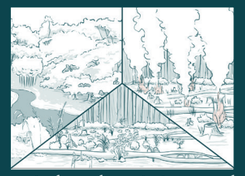


agriculture that mimics natural forest cycles

COASTLINE SURINAME



Cultivation of (semi) native crops



agriculture that mimics natural forest cycles

ALL MANGROVE ZONES





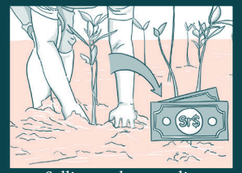


Shifting focus - Combining production and growing

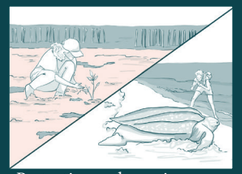
WEG NAAR ZEE

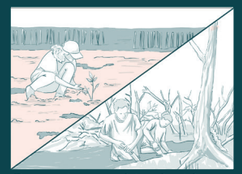

Providing Bio-rights for locals


Sediment trapping and fishing


Selling carbon credits


Protecting and growing combined with aquaculture

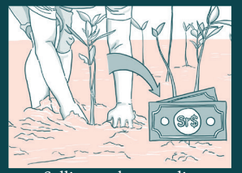

Protecting and growing combined with eco-tourism


Protection combined with use of trees

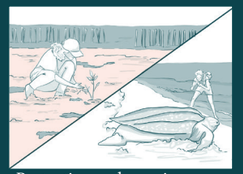
COASTLINE SURINAME

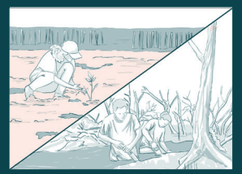

Providing Bio-rights for locals


Sediment trapping and fishing


Selling carbon credits


Protecting and growing combined with aquaculture

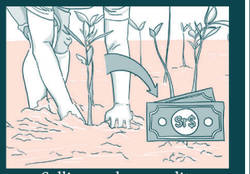

Protecting and growing combined with eco-tourism


Protection combined with use of trees

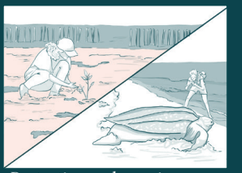
ALL MANGROVE ZONES

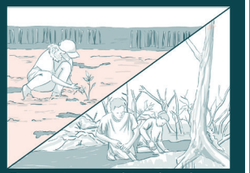

Providing Bio-rights for locals


Sediment trapping and fishing


Selling carbon credits


Protecting and growing combined with aquaculture


Protecting and growing combined with eco-tourism


Protection combined with use of trees









9.2 Conclusion

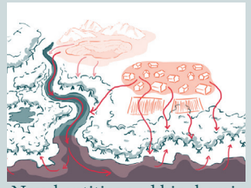
This thesis answers all three sub-questions and the main question through research and elaboration in the form of a toolbox and landscape design. The thesis will now conclude by briefly summarising the approach and elaboration of all the sub-questions and finally the main question.

How can local communities and other stakeholders help to co-create a toolbox that can serve as the basis for a spatial vision for the future?

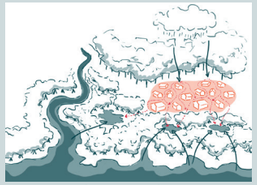
Local communities and other stakeholders can contribute in various ways to co-create a toolbox that serves as a basis for a spatial vision for the future. Government plays an important role in regulating sustainable use of the coastal zone. NGOs and exemplary projects are important for testing and sharing knowledge about mangroves. Ecology is the basis for mangrove functioning and should be integrated into the toolbox. Collaboration with sustainable businesses is essential for income from both residents and government. Local communities are paramount to be involved in the process. They possess valuable knowledge about the area and are crucial in its rehabilitation. Moreover, they can seriously thwart projects if they are not involved. By working together and pooling expertise from different sectors, local communities and other stakeholders can help to create an effective toolbox that enables a sustainable spatial vision for the future.

What is the spatial impact of the 9 planetary boundaries and sea level rise on the coastal area of Surinam?

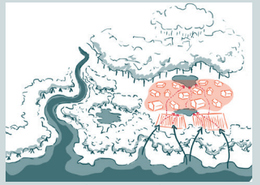
Most important planetary boundaries



Novel entities and biochemical flows

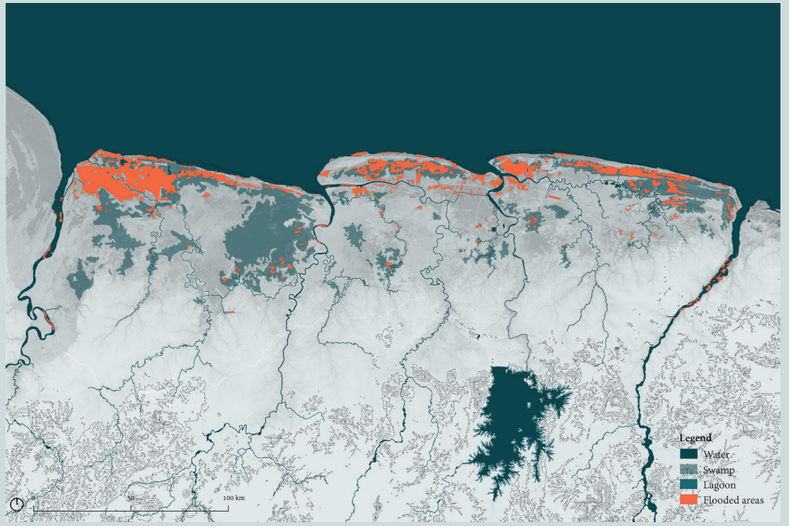


Fresh water change



Landsystem change

Sea level rise as a result of Climate change

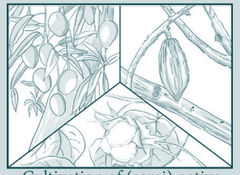


What is the spatial impact of the 9 planetary boundaries and sea level rise on the coastal area of Surinam?

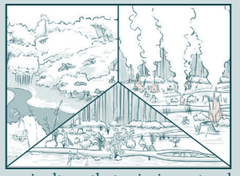
Suriname's coastal zone is very vulnerable to sea level rise, with natural protection in the form of mangrove forests severely damaged and in many places no longer able to act as a buffer. Traditional protection methods, such as grey infrastructure structures, are not only expensive but will also be insufficient to withstand the effects of climate change. Without intervention, the coastal zone is at risk of flooding.
Therefore, it makes sense to look at natural coastal protection, with mangroves and associated ecological zones forming the basis for an effective approach. This Nature-based Coastal Protection, can help strengthen the resilience of the coastal ecosystem and provide sustainable protection against the impacts of climate change and sea level rise.

What can be learned from the customs and the way of life of indigenous and tribal communities?

Mimicing natural cycles

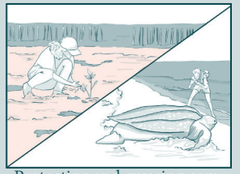


Cultivation of (semi) native crops

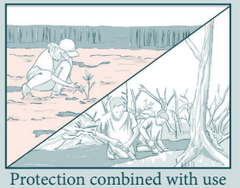


agriculture that mimics natural forest cycles

Protection an use combined

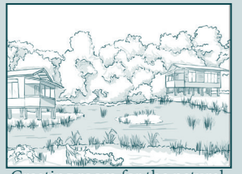


Protecting and growing combined with eco-tourism

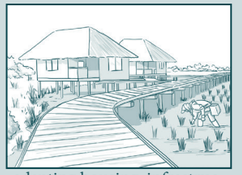


Protection combined with use of trees

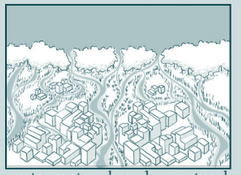
Adapting to the natural environment.



Creating room for the natural watersystem and ecology.



adapting housing, infrastructure and agriculture to the natural watersystem.



water system based on natural system. letting brackish water back in.

What can be learned from the customs and the way of life of indigenous and other communities?

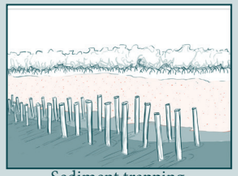
The research into the culture and lifestyles of indigenous and other communities revealed several solutions, which form the basis for several design principles in the toolbox.
However, the main lesson that emerged from this is the realisation that much valuable knowledge about coexistence with mangroves, coming from different cultures and research, is often not known or even slowly lost. Therefore, the biggest challenge in protecting the coast through mangrove restoration is to disseminate this knowledge about mangroves, their functioning, sustainable use and, above all, their crucial role as part of the coastal ecosystem. Indeed, mangroves are the crucial basis for the protection and survival of both human and animal communities in the coastal zone.

How can local communities and other stakeholders help to co-create a toolbox that can serve as the basis for a spatial vision for the future?

learning from other mangrove areas



Providing Bio-rights for locals

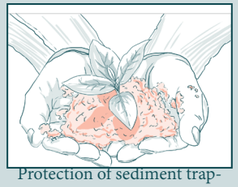


Sediment trapping

Including locals



Planting seedlings



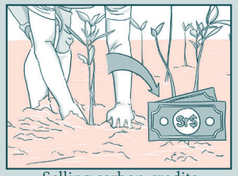
Protection of sediment trapping units and the trees



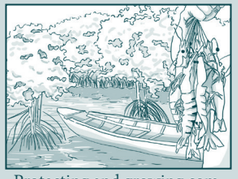
Nurseries for mangrove trees



Sediment trapping and fishing



Selling carbon credits



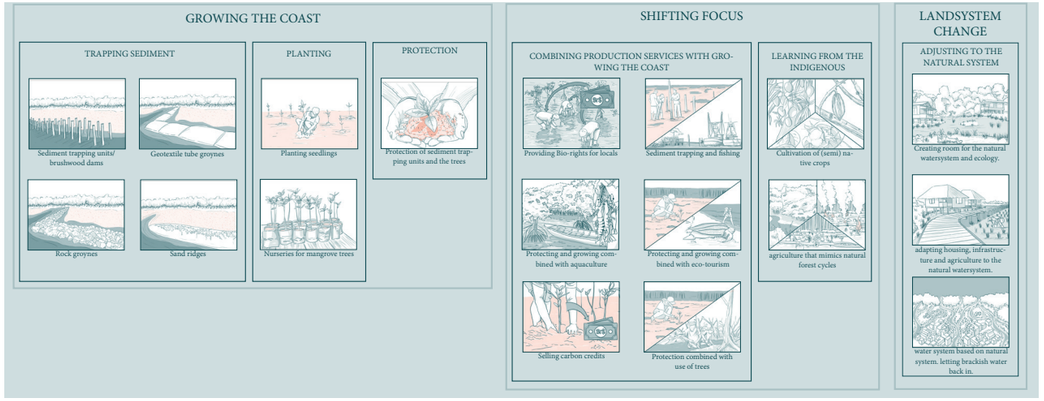
Protecting and growing combined with aquaculture

What **(stakeholder based)** landscape design strategies can be developed to **mitigate** the impacts of the **planetary boundaries** and **sea level rise** in the coastal area of **Suriname**?

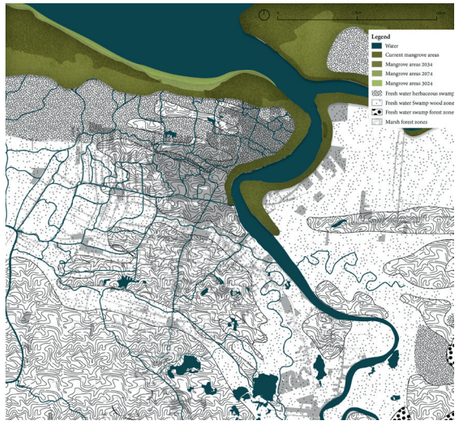
A stakeholder-based landscape design strategy to reduce and adapt to the impact of sea level rise in coastal areas of Suriname, with a focus on urban areas, is the development of a toolbox. This toolbox is composed of three different design goals, which were further developed into design principles. These principles were then applied on a large scale to Paramaribo and demonstrated on a smaller scale for Weg naar Zee.

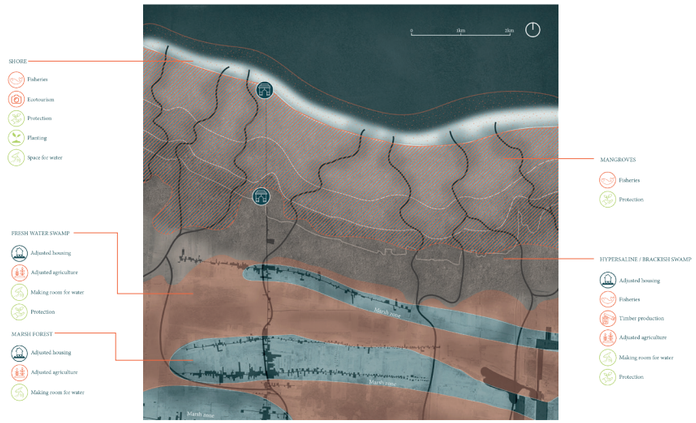
Some of the toolbox developed can also be applied in other mangrove areas in Suriname and even in other mangrove areas worldwide. This approach, based on a wide range of stakeholders, provides a broad and adaptable strategy to strengthen both the vulnerability and resilience of coastal communities to climate change and sea level rise.

TOOLBOX



SPATIAL DESIGN





REFLECTION

RESEARCH AND DESIGN

The subject of using mangroves as Nature-based coastal protection is quite big and there are an awful lot of factors involved. Normally, with a design project, you don't have time to delve into this and you choose at most a few to base your design on. With more time, however, you have time to delve into this but quickly end up with an endless amount of information.
All the factors affect both mangroves, the landscape and even the possible ways of interacting with or growing mangroves to some extent. Like, for instance, the ways of catching sediment to speed up the burial process. The more I delved into this, the more information was added. On the other hand, it also became more and more obscure. For instance, as far as I could find out from many pilot projects, it is still not exactly clear why one solution works in one place and not in another, and other uncertain factors such as moving sandbanks also come into play. This is just one example but I came across more and more of these factors. So there were also the effects of planetary boundaries where the effect of Sea level rise due to climate change is somewhat obvious I included this in the design. However other effects of climate change like drastic changes in rainfall and average temperature will also have an effect but, this would make the study much bigger and more complex.
There are then also the Green/Grey solutions. These are solutions where mangrove forests are combined with seawalls or other traditional structures. However, I left these out of the study because I could then focus the research less on protecting the coastal area by means of mangroves and the necessities of mangroves.
However, this would be worth investigating since mangroves are thus super dynamic and therefore relatively unpredictable.

SCOPE AND RELEVANCE

Since, as far as I could find out, there were still mostly no clear rules of thumb on these subjects, I took similar situations as examples and based my design on them. However, I have no idea whether this would actually work at Weg naar zee. I think more research into mangroves is incredibly important. On the one hand, because other projects and science show that mangroves could be a climate-proof solution and, on the other, because the problem of eroding coastal areas is incredibly urgent. The thesis could perhaps be seen as one of the small projects in which it could make a very small step in the research on coastal protection with mangrove trees.

THE PROCES

I realise I should have looked at example projects earlier. Exploring existing projects offered partly solutions for certain factors about which there was a lot of information but no clear outcome or rule of thumb. I also note that my design choices were mainly based on research. While I feel I may not have designed much 'myself' and I feel that many of the solutions emerged directly from my research, I think a design process based on research and analysis can provide a good basis for decision-making in this case. In short, this project has taught me that a combination of studying exemplary projects and research is essential for well-thought-out design. Although my creative input can sometimes seem indirect, I am positive that my choices have been thought through by in-depth analysis.

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