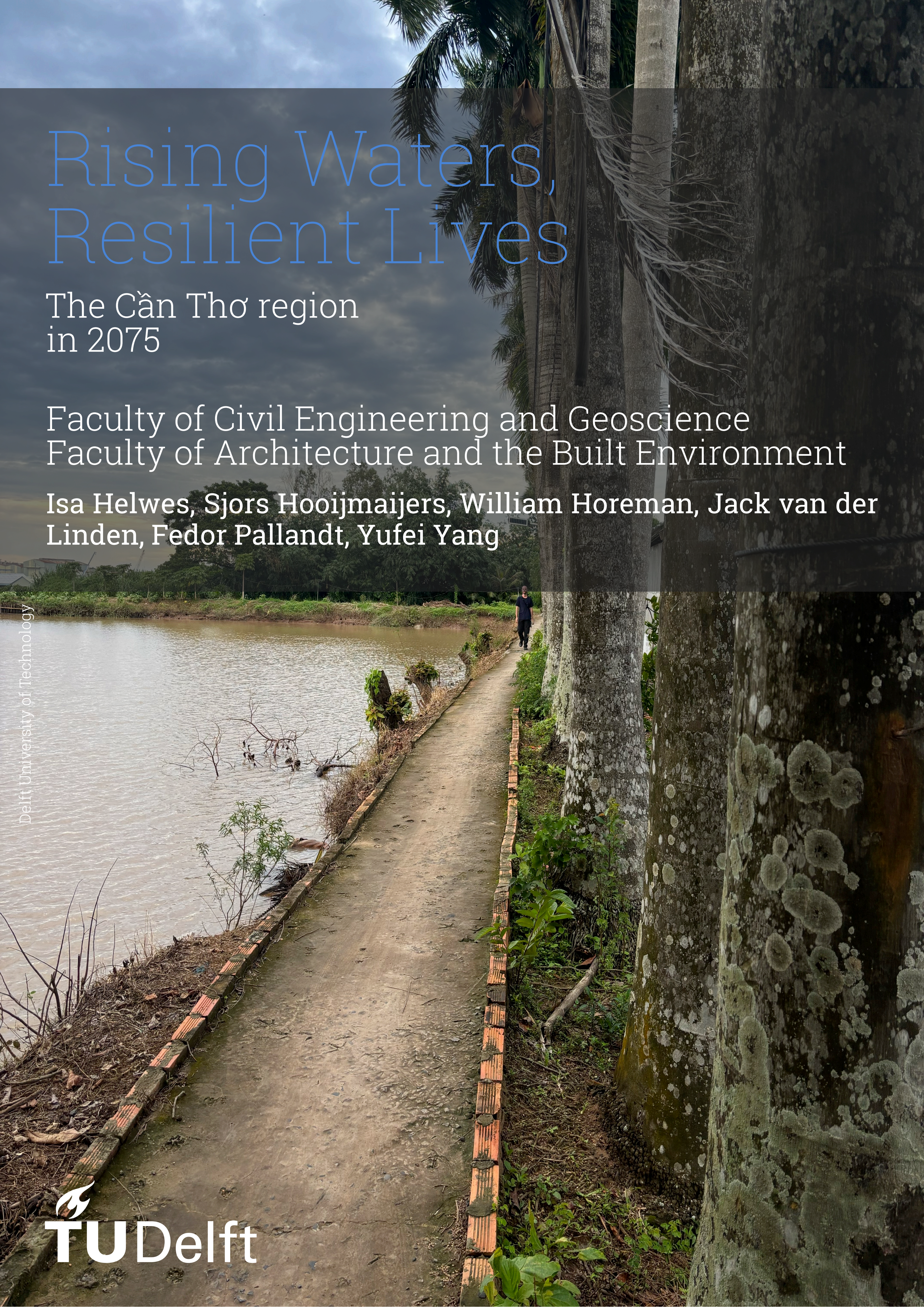

Rising Waters, Resilient Lives

The Cần Thơ region in 2075

Faculty of Civil Engineering and Geoscience
Faculty of Architecture and the Built Environment

Isa Helwes, Sjors Hooijmaijers, William Horeman, Jack van der Linden, Fedor Pallandt, Yufei Yang

Delft University of Technology

TU Delft

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by

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Cover:	Palm trees along an aquaculture site on Con Son Island, Cần Thơ, Vietnam
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TU Delft

Preface

This report presents an interdisciplinary study and design proposal focused on sustainable, water-resilient futures for delta societies, specifically the Mekong Delta. Developed in collaboration with TU Delft's Delta Futures Lab, this project brought together students from geo-engineering, civil engineering, architecture, and environmental policy, creating a dynamic approach to delta resilience. This report will interest architects, engineers, designers, Delta Futures Lab, and academic partners like Cần Thơ University, as it offers insights into innovative, multidisciplinary solutions for managing delta environments. Our sincere gratitude goes to the local experts who guided our fieldwork: Van Pham Dang Tri (climate change insights), Dinh Diep Anh Tuan (practical expertise), Lam Thi Hoang Oanh and Chung Hoang Chuong (socio-cultural history), Sylvie Tram Nguyen (land use), and Manh Hung Phan from ICOE (Ho Chi Minh) (environmental strategies). Their contributions were invaluable.

This project was made possible through the generous support of the Delft Infrastructures and Mobility Initiative (DIMI) and Funding Ambitious Students TU Delft (FAST), whose funding enabled our fieldwork in Cần Thơ, Vietnam. Their support allowed us to engage deeply with the local environment and Vietnamese culture, enriching the project immeasurably. We are also grateful to Delta Futures Lab for providing a multidisciplinary platform to explore delta management solutions and to the Cần Thơ University staff for their hospitality, lectures, and immersive field experiences. Special thanks to our supervisors: Luca Luario, for challenging us to push beyond disciplinary boundaries; Anne Baars, for her invaluable guidance on technical feasibility; Sophia Arbara, for enriching our understanding of the region's socio-historical layers; Boas Peters, for introducing us to research by design, which shaped our vision; and Jeroen Hoving and Joep Storms, for their formal supervision from TU Delft's Faculty of Civil Engineering and support throughout.

We hope you enjoy reading this report.

November 8, 2024

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@ MDP 369
Delft, December 2024

Summary

The Mekong Delta, an area crucial for Vietnam's food production, and home to diverse communities, faces increasing environmental threats as climate change intensifies, such as rising sea levels, land subsidence, and salinity intrusion. These challenges are further increased by socio-economic demands, making sustainable water management essential. To address this, the central research question explored is: How can the Mekong Delta coexist with water in the future in a sustainable and resilient way, leveraging traditional knowledge and practices to address future environmental and socio-economic challenges, by taking the island Cồn Khương as a case study? While extensive research has highlighted the vulnerability of the Mekong Delta, this study specifically focuses on integrating traditional knowledge with new innovative solutions and stakeholder engagement strategies to create an adaptable design.

The project uses a multidisciplinary approach, integrating technical designs, stakeholder analysis, and scalable management frameworks to address this question. Key technical solutions for Cồn Khương Island include a soft dike system that combines engineering with ecological restoration to enhance flood resilience and biodiversity. Moreover, floating pontoons are being created to adjust to fluctuating water levels. These pontoons incorporate houses, agricultural farms, and renewable energy sources to encourage independence and reduce their environmental impact. These technical solutions are meant to align with the delta's natural cycles, supporting long-term ecological health. Furthermore, a structured stakeholder engagement strategy complements these designs by fostering multi-level governance. Different groups of stakeholders are engaged through a power-interest matrix, ensuring active involvement from those with significant influence and interest. Sector-specific management strategies in urban, agricultural, sustainable, water, and financial planning support the regional adaptation of national policies. Together, these methods create a scalable framework that can be applied across various regions within the Mekong Delta.

The findings from Cồn Khương Island demonstrate a model of water management that is both resilient and scalable. It effectively considers the needs of the local community while also meeting international sustainability criteria. This multidisciplinary, integrative approach, presents a model that can be used across the Mekong Delta, suggesting that flexible water management, in line with both traditional and innovative practices, can enhance resilience and socio-economic stability. These findings provide valuable insights for other vulnerable regions facing environmental change and emphasize a pathway for sustainable adaptation in the Mekong Delta.

Contents

1 Introduction

This project is conducted for the Delta Futures Lab, a multidisciplinary network at TU Delft that brings together MSc students, researchers, and professionals to develop leadership skills in the spatial planning, engineering, and governance of river deltas. The Multidisciplinary Project is conducted in a group of six students and focuses on a problem related to a Master's program. This project is part of the Multidisciplinary plus Honours Programme Project. The project brings together five Master's students from Civil Engineering, each specializing in different master tracks, such as Hydraulic and Offshore Structures, Construction Management and Engineering, Geo-Energy Engineering, and Structural Engineering. The Engineering students will collaborate with an Honours Programme student from the Faculty of Architecture, who specializes in the track of Urbanism and Building Sciences.

By combining expertise from different disciplines, the students work together to develop a comprehensive design for the river delta. Each student approaches the design from the perspective of their discipline, delving deeper into aspects related specifically to their area of specialization. This collaborative approach allows the design problem to be explored from multiple angles, leading to a more holistic and robust solution. The process of working together and engaging in interdisciplinary discussions enables students to learn from one another, creating a collaborative environment and enhanced understanding across fields.

In this report, the focus lies on the Mekong Delta, a crucial and dynamic region facing numerous environmental and socio-economic challenges. The Mekong Delta is a vast 40,000-square-kilometer region in southwestern Vietnam, where the Mekong River flows into the South China Sea (Figure 1.1). Stretching over 4,800 kilometers from the Tibetan Plateau through China, Myanmar, Laos, Thailand, Cambodia, and Vietnam, the Mekong River forms an extensive network of rivers, canals, and wetlands in the delta. This network has served as a major trade hub for centuries, connecting regions in Southeast Asia. Today, most villages in the Mekong Delta still revolve around waterways, which are often more accessible through water than roads. These waterways are not just routes of transportation but are also vital sources of life and livelihood for the region's inhabitants.

Figure 1.1: Mekong River and Mekong Delta (EcoShape, n.d.)

The Mekong Delta accounts for about 12.2% of Vietnam's total surface area and is home to over 21.5 million people, or 19% of the country's population (Tri et al., 2023). It is a critical area for Vietnam's economy and food production, being one of the world's most productive agricultural regions, especially for rice, fruits, vegetables, and fish. About 61% of the delta's land is used for rice cultivation and 12% for aquaculture. This implies that at least 73% of the area is dedicated to food production, and therefore contributes to the primary livelihood of residents (Tri et al., 2023). For example, 15 million farmers in the delta produce over a ton of rice per person annually, which is enough to feed 60 million people worldwide (Columbia GSAPP, 2023). In 2021, the GDP of the Mekong Delta was approximately VND 823 trillion, equivalent to about 33.259 billion euros, and 12 % Vietnam's total GDP (UNDP, 2023). In summary, the Mekong Delta is crucial to Vietnam as it is home to millions of people, it serves as a major hub for food production and contributes significantly to Vietnam's economy.

However, the future of the Mekong Delta is increasingly uncertain due to the results of climate change and human activities evolving over history. For centuries, the Mekong Delta's water systems were managed sustainably through adaptive, locally-driven approaches. However, during the colonial era, policies shifted toward centralized, technocratic control, leading to the construction of large-scale infrastructure projects such as canals, dikes, and dams to boost agricultural production. This shift accelerated around the 1970s with the implementation of the "Rice First" policy, which aimed to transform the delta into a major agricultural hub (Biggs et al., 2009). While this policy succeeded in increasing rice production, it also contributed to growing uncertainty about the delta's future.

Hydropower dams, for instance, bring major environmental concerns, particularly on the Lan Thuong in China. These dams have reduced water flow to Vietnam's Mekong Delta, affecting 1.7 million hectares of acid soils and worsening droughts. This contributed to saltwater reaching over 100 kilometres inland, damaging agriculture and freshwater supplies (Tri et al., 2023). The lack of sediment flow has also caused riverbank erosion and landslides, threatening the delta's stability and the livelihoods of millions who rely on agriculture and aqua culture (Huy et al., 2021) (Lau et al., 2023). These issues only get worse with the large-scale sand mining practises that take place. Research by Lau et al. (2023) shows that sand mining leads to riverbed deepening, sediment loss, bank instability, increased erosion, salinity intrusion, and declining water quality. Together, these factors do not only further disrupt the ecosystem, but impact the livelihood of the Mekong Delta as well. Farmers, for example, face declining agricultural productivity due to saltwater intrusion, rendering rice fields infertile and forcing many to shift from rice cultivation to saltwater shrimp farming.

Not only direct anthropogenic activities but also the results of global climate change will have significant effects on the Mekong Delta. With a projected sea level rise of 1 meter by 2100, up to 47.3% of the Mekong Delta could be at risk of permanent inundation. The increased sea water level in combination with increased rainfall intensity will worsen flooding, especially during the wet season. In some areas, the duration of inundation could increase from 72 days per year currently to 270 days by 2030 and 365 days by 2050, affecting infrastructure, homes, and agricultural lands (Tri et al., 2023). The delta is also experiencing land subsidence due to excessive groundwater extraction, which compounds the effects of sea level rise. Land subsidence rates in the Mekong Delta range from 1 to 4 cm per year, meaning that certain areas could sink by up to 40 cm in the next few decades. This subsidence increases the delta's vulnerability to flooding and permanent inundation, putting at risk the livelihoods of millions of people (Tri et al., 2023) .

These severe (environmental) threats, in broader context of the Mekong River and Mekong Delta, impact local communities and urban areas in the Mekong Delta in smaller context. This also applies to Cần Thơ city, where our group of students participated in workshops, field trips, and site visits to study flood protection measures such as dyke works and sluices, agricultural sites as well as aquaculture practices like fish farms. Cần Thơ City's current policy focuses on economic modernization and urban development and constructing hard-edged infrastructure such as dykes and seawalls to protect against seasonal floods (Columbia GSAPP, 2023). However, elaborate studies on flood-resilient urban designs question such policies (Long et al., 2020). These flood protection mechanisms overlook the fact that strengthening flood control in one area can trigger a chain reaction, potentially causing negative impacts on other urban landscapes. There seems to be a shortage of effective approaches and solutions for achieving urban sustainability, flood management, and resilience in response to climate change. Van Long et al. (2020) describe urban resilience as the capacity to handle unexpected and uncertain natural disasters, and they define flood resilience as the capacity to endure floods rather than prevent them, to avoid catastrophic outcomes. Sustainability on the other hand is "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 2023) .

In conclusion, despite efforts in urban planning and infrastructure development in the Mekong Delta, many current strategies focus on hard-engineered solutions. These can create new problems, be unsustainable, or struggle to adapt to future challenges, lacking the flexibility needed for resilience. Additionally, there is a growing need to integrate more holistic and adaptive approaches that consider the dynamic interactions between natural (water) and human systems. Traditional knowledge and practices, which have evolved over centuries to manage water and sustain livelihoods in the delta, offer valuable insights into sustainable living with water. By learning from these time-tested methods and combining them with modern scientific and technological advancements, there is an opportunity to develop sustainable and resilient solutions that are better suited to the unique socio-environmental context of the Mekong Delta. Taking all these factors into account, this report aims to develop a vision for the Mekong Delta guided by the main research question:

How can the Mekong Delta sustainably and resiliently coexist with water by 2075, leveraging traditional knowledge and practices to address future environmental and socio-economic challenges, by taking the island Cồn Khương as a case study?

2 Problem Analysis

As of 2024, the Mekong Delta faces many threats, of which many will become more severe towards 2075 and beyond. These threats are economical, environmental and social in origin. This section will focus on the environmental threats of the Mekong Delta region in Vietnam. Note that the issues described in this chapter are connected to one another. For instance, sea level rise causes more saltwater intrusion, and sand mining causes more riverbank erosion. In Table 2.1, a summary of these environmental threats is displayed. At the end of this section, a diagram will be presented in Figure 2.12, displaying the causality of the environmental threats, and the relations among them.

2.1. Environmental threats

Environmental Threat	Description
Coastal erosion	Due to various factors such as rising sea levels, deforestation, subsidence, and reduced sediment inflow, the Mekong Delta coast is experiencing increased erosion. This erosion is leading to a reduction in land area, which in turn heightens the risk of flooding and saltwater intrusion.
Deforestation	The destruction of mangrove forests and wetlands caused by development and agricultural expansion diminishes natural protection against erosion and storm surges.
Ecosystem degradation	The combination of human activity and climate change is threatening the biodiversity and ecological balance of the delta.
Extreme weather events	Droughts can result in crop failure and subsidence. Extreme rainfall events can cause flooding, especially in urban areas with much concrete cover and jammed drainage systems due to waste.
Land subsidence	Due to groundwater extraction for drinking water and agricultural purposes, land subsidence can occur due to the oxidation of dry peat.
Pollution	Agricultural runoff, industrial discharges, and inadequate waste management contribute to water pollution, impacting both the environment and human health.
Riverbank erosion	Riverbank erosion leads to loss of land, damage to infrastructure, and impacts local communities.
Saltwater intrusion	Due to a combination of sea level rise, loss of forests, droughts, and groundwater extraction, saltwater intrusion can occur. This affects agriculture and drinking water quality.
Sand mining	Sand mining causes increased riverbank erosion, disrupts ecosystems, and induces a sediment imbalance.
Sea level rise	Due to the enhanced greenhouse effect, sea levels are rising. This results in saltwater intrusion and loss of land.
Sediment budget	Due to dams located upstream for hydropower generation, the amount of sediment influx has severely decreased. This leads to a reduction in delta progradation.

Table 2.1: An oversight of environmental threats affecting the Mekong Delta as of 2024.

2.1.1. Deforestation

Mangrove forests are extremely profilic ecosystems, providing numerous goods and services both to the coastal environment and its residents (Kathiresan, 2012). These forests are home to a large variety of wildlife, like fish, crabs and shrimps, and are an essential source of food for coastal communities. They also trap sediments, which could otherwise flow into the sea, and therefore limit the amount erosion and sediment transport (Winterwerp et al., 2020). Mangroves also act as a barrier to waves coming from the sea and the river, and there act as a storm barrier (Dominicis et al., 2023). So this reason, as well because of the prevention of erosion, mangroves can prevent floods. Mangroves furthermore also prevent saltwater intrusion (Phan & Stive, 2022), and act as a carbon sink.

The literature online regarding land protection using mangrove is almost all focused on coastal protection. This is because mangroves flourish in brackish water, as mangrove trees are more resistant for these conditions than other flora (American-Museum-of-Natural-History, 2024). However, mangrove can also grow is freshwater (Bernardino et al., 2022) (Krauss & Ball, 2012). But since mangrove trees are less competitive in this environment than non-mangrove trees, freshwater mangrove is rare (Krauss et al., 2022). Nonetheless there are examples of freshwater mangrove for riverbank protection (Sumanusajonkul, 1996)

A more common type of forest in coastal freshwater floodable areas are melaleuca forests. These forests are similar to mangrove forests, but grow in freshwater wetlands instead in coastal saltwater or brackish areas. In Figure 2.1 one can see where these types of forests occur. Melaleuca wetlands provide various significant services to ecosystems and humankind. These ecosystem services include provisioning of habitats for wide variety of flora and fauna, protection of peat, soil and water resources, prevention of soil acidification and enhancement of water quality (Dang et al., 2023). Maleleuca forests could also act as a nature based solution to reduce coastal erosion (T. Nguyen, 2018).

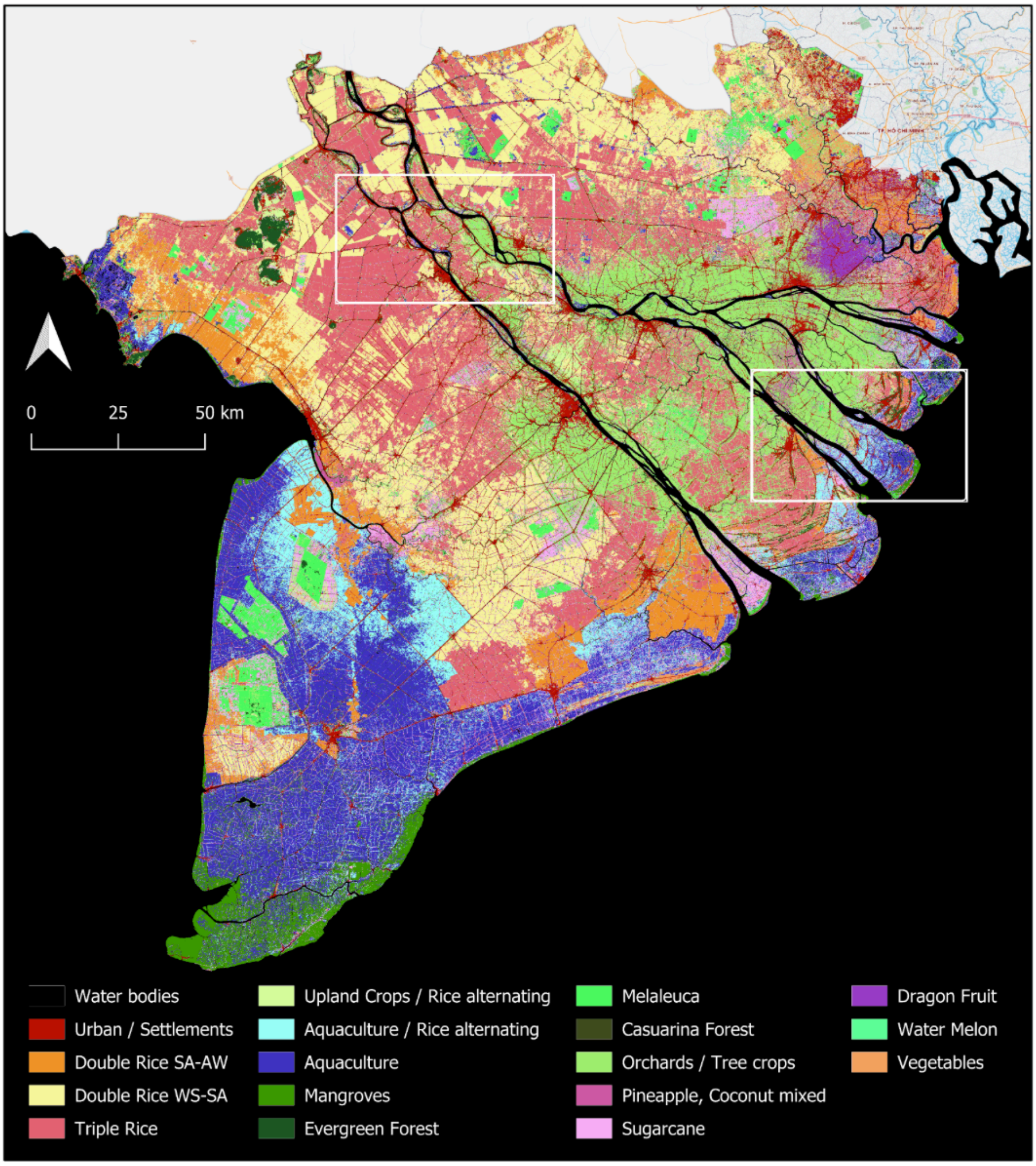


Figure 2.1: Classification of land cover in the Mekong delta obtained form a Sentinel-2 time series (2021-2023) (Kupfer et al., 2024).

However, vast areas of the delta have been subject to deforestation. Between 1988 and 2019, 32% of total mangrove forest area was replaced by secondary vegetation or anthropogenic landscapes (Mokievsky et al., 2020). For melaleuca wetlands, only 1.7% of the area present in 1816 remained in 2016 (H. H. Nguyen et al., 2016).

To conclude, it is important to preserve these forests, as they could be important for coastal- and riverbank protection, biodiversity and reduce erosion.

Figure 2.2: An areal photo taken above Can Gio, where deforestation practices can be clearly observed.

2.1.2. Extreme weather events

Due to climate change, more extreme weather events like extreme rainfall and droughts will take place (Newman & Noy, 2023) (Bolan et al., 2024). This will lead to more flooding and agricultural damage (Mekong-River-Commission, 2020). Storage on floodplains has been reduced due to development of the area (Mekong-River-Commission, 2020). The Mekong River Commission strategy promotes coordinated floodwater management and the creation of additional storage in wetlands and behind dams to build climate resilience and manage flood and drought risks. This remains a challenge since suitable storage areas are disappearing due to wetland reclamation, population growth in potential reservoir areas, and the construction of dams and other infrastructure that are now in the way of more optimal infrastructure (H. H. Nguyen et al., 2017).

Figure 2.3: Flooding in Cần Thơ in September 2019 due to extreme weather (Saigoneer, 2019).

2.1.3. Land subsidence

Land subsidence in the Mekong Delta is a major environmental issue driven primarily by excessive groundwater extraction, soil compaction, and urbanization (Minderhoud et al., 2019) (L. E. Erban et al., 2014). The sinking land increases the region's vulnerability to flooding, saline intrusion, and coastal erosion, threatening agriculture, infrastructure, and the livelihoods of millions (Minderhoud et al., 2017). As of 2019, the mean elevation of the Mekong delta was at 0.8 meters above sea level (Minderhoud et al., 2019). While mitigation strategies, such as reducing groundwater use and improving water management, can help slow the process, addressing subsidence is essential for the delta's long-term sustainability in the face of climate change and rising sea levels (Zoccorato et al., 2018).

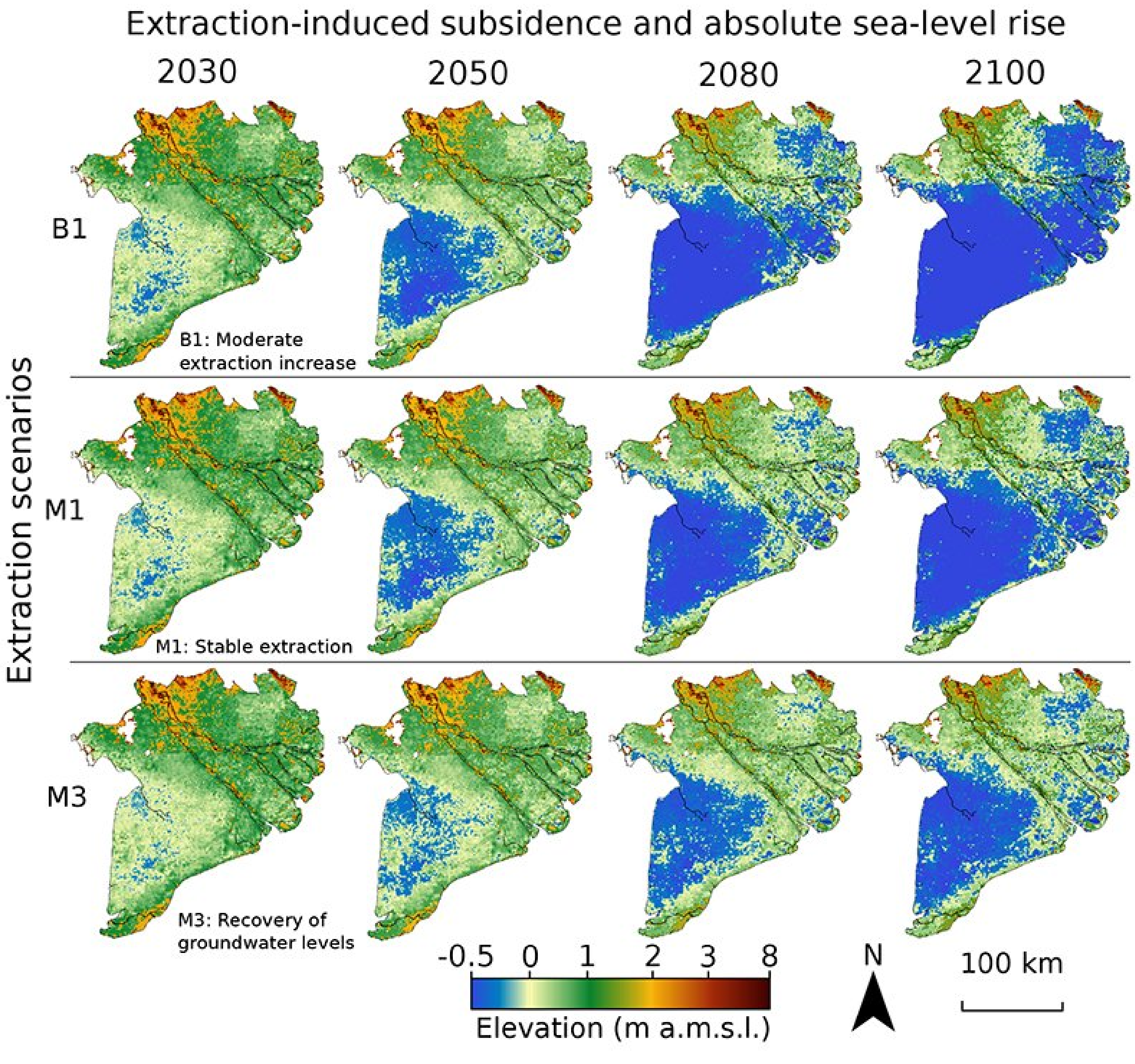


Figure 2.4: Extraction-induced subsidence and absolute sea-level rise (Minderhoud et al., 2019).

More information can be found in chapter 12 regarding subsidence.

2.1.4. Pollution

The Mekong Delta is facing severe pollution challenges that impact its environment, biodiversity and local communities. There are however different types of pollution which can be classified.

Air Pollution

This is a relatively small problem, as there are no major emitters present in the Mekong Delta (Sung et al., 2019).

Waste Pollution
Waste pollution remains a major issue in the Mekong Delta, especially in the urban areas, as can be seen in Figure 2.5. The Mekong River is thereby also one of the ten major rivers in the world that provide up to 95% of plastic waste to the world's oceans (Mekong-River-Commission, 2019). In 2017, more than 37 thousand tons of plastic per year was discharged in the South Chinese Sea from the Mekong delta in Vietnam (Schmidt et al., 2017). Poor waste management systems exacerbate the issue, with local waterways often clogged by plastic debris.

Water Pollution
Water pollution in the Mekong Delta is a significant issue, primarily driven by agricultural runoff and aquaculture (Buschmann et al., 2008) (Ahn et al., 2010). Pesticides, fertilizers, and chemicals from farming contribute to high nutrient levels, leading to eutrophication and harmful algal blooms (Sebesvari et al., 2012). Additionally, the rapid expansion of fish and shrimp farming has resulted in the discharge of untreated wastewater into rivers and canals, further degrading water quality and harming biodiversity in the delta (Kieu-Le et al., 2023).

Figure 2.5: Waste in Cần Thơ

2.1.5. Saltwater intrusion

Due to a combination of a rise in sea level, subsidence of land, extraction of groundwater and construction of dams, saltwater intrusion is currently a large issue in the Mekong Delta (Eslami et al., 2021). If river water exceed the allowable salinity limit of 0.25 kg/m^3, the water cannot be used for freshwater supply, both for domestic and agricultural purposes (Van Kessel et al., 2021). The rising saline level due to this intrusion, can each as high as 4 grams per liter (DRAGON Institute, 2022). Furthermore, rice as a crop is very vulnerable to higher salt levels, more saline environments will therefore result in smaller yields or even complete crop failure. This will not only result in a loss of food security, but it will also heavily affect the livelihoods of the farmers who depend on their rice production and other freshwater crops (Ziaul Haider & Zaber Hossain, 2013). Currently, research focuses on building dikes and sluice gates to block seawater, shifting to salt-tolerant crop varieties, improving water management practices and promoting international cooperation for better regulation of upstream dam projects (Dung, 2024).

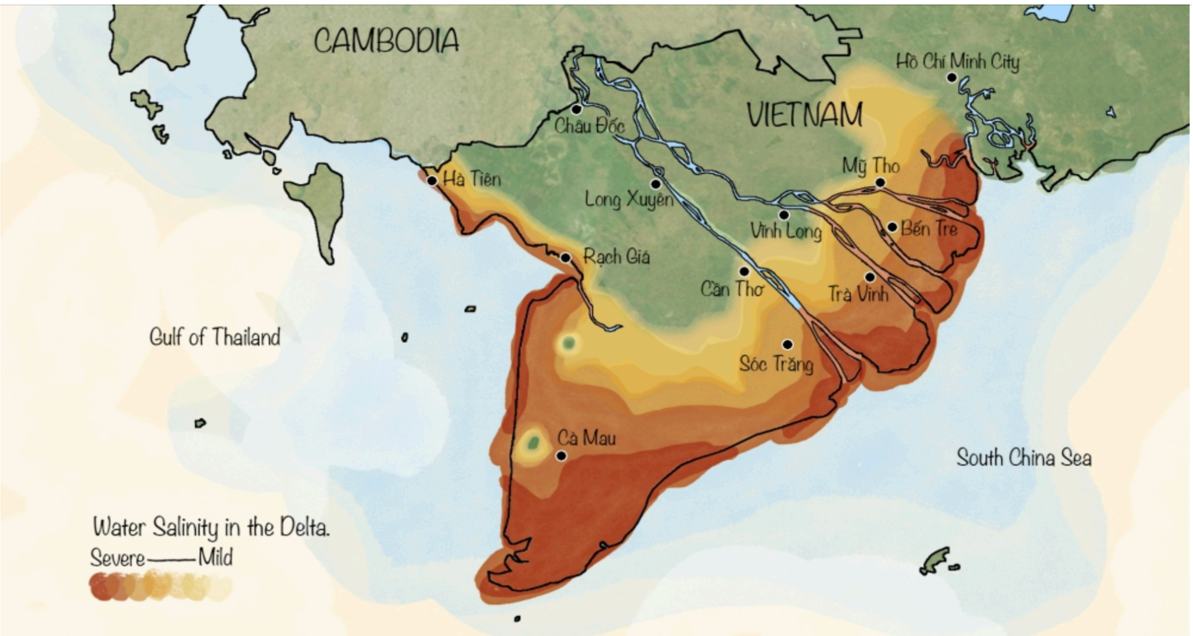


Figure 2.6: Saltwater intrusion in the Mekong Delta (Osborne, 2020)

2.1.6. Sand mining

Illegal sand mining in the Mekong Delta is a significant environmental issue that threatens the region's ecosystem and the livelihood of millions of people (Yuen et al., 2024) (Park, 2024). One of most severe consequences of illegal sand mining is riverbank erosion (Tran et al., 2023). The removal of sand destabilizes the riverbed, causing the banks to collapse. This can lead to the loss of agricultural land, homes and infrastructure. Governments and environmental organizations have recognized the threat posed by illegal sand mining and are attempting to address it through stricter regulations, improved monitoring and increased penalties (Earth-Journalism-Network, 2024). These efforts however face significant challenges due to high demand, corruption, and the difficulty of patrolling such a large and complex river system (Yuen et al., 2024).

Figure 2.7: A sand storage site. According to the local tour guide, this sand was illegally mined in Cambodia.

2.1.7. Sea level rise

The Mekong Delta is one of the world's most vulnerable regions to sea level rise, due to its low-lying geography, complex river systems and reliance on agriculture. Sea level rise induces problems like increased likelihood of flooding, saline intrusion and coastal erosion. The Mekong Delta is naturally prone to seasonal flooding, but sea level rise exacerbates the situation by causing more frequent and severe floods. With an increase of 30 centimeters in sea level, large portions of the delta, which lies on average only 0.8 meter above sea level, are at risk of inundation (Minderhoud et al., 2019) (van Aalst et al., 2023) (Toan, 2014).

According to research, large parts of the Mekong Delta will be prone to annual flooding in 2050 (Smajgl et al., 2015). To mitigate for these challenges, Vietnam has been investing in sea walls, dikes and other flood defenses to protect the delta from rising waters. Forest restoration is a nature-based solution that can help reduce erosion, and act as a buffer against storm surges (Hens et al., 2018) (Menendez et al., 2020).

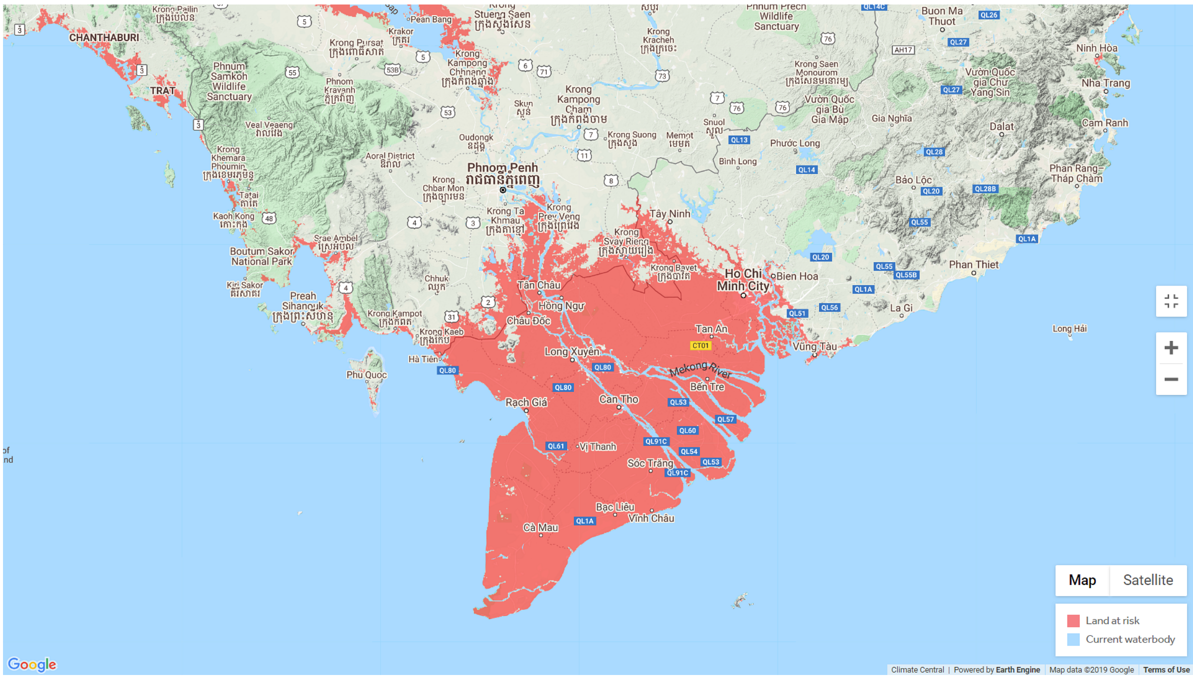


Figure 2.8: A flooding scenario published in Nature (Kulp & Strauss, 2019) projected on the on the current elevation map of southern Vietnam. The red area highlights area that will be annually flooded.

2.1.8. Sediment budget

The sediment budget relates to the balance between the sediment supplied by the Mekong River and the sediment lost through processes like erosion and subsidence. Sediment plays a crucial role in maintaining the delta's landmass, supporting agriculture and protecting against coastal erosion and flooding. However, factors like dams and hydropower projects, sand mining, subsidence and sea level rise are currently negatively affecting the sediment budget. This leads to increased coastal erosion, land subsidence, a loss of agricultural productivity and salt intrusion (Kondolf et al., 2018) (Reuters-Graphics, 2024) (Eslami et al., 2019).

Over the last decades, 209 hydropower dams have been constructed along the Mekong River, stretching from Yunnan in China to Cambodia (Stimson-Center, 2024).

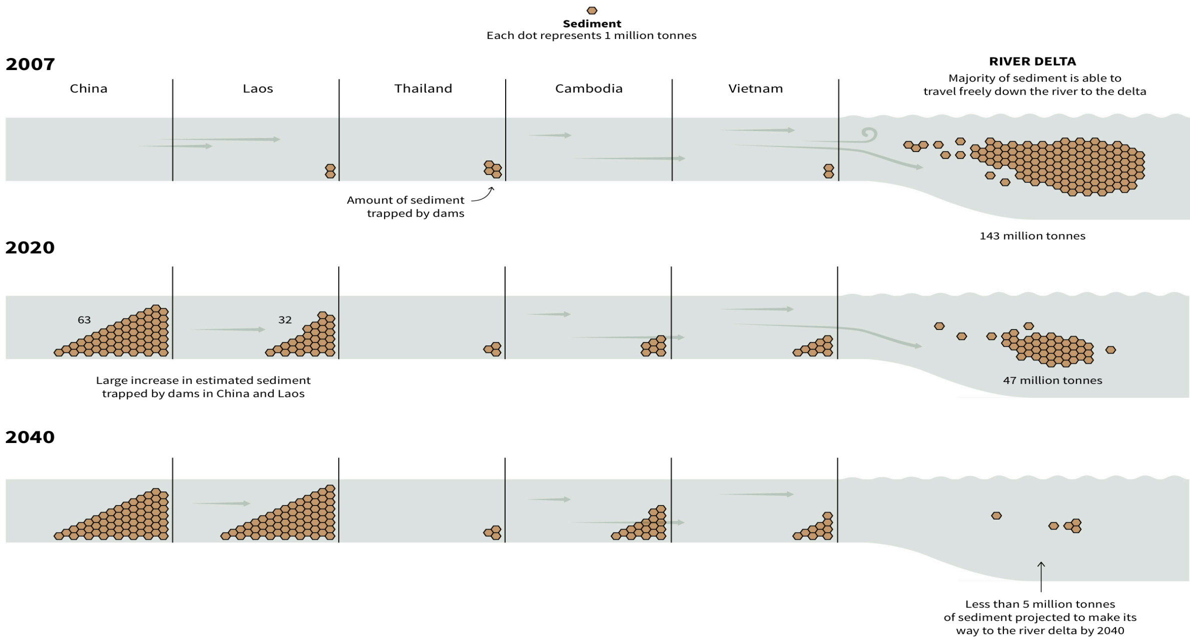


Figure 2.9: Less than 5 million tonnes of sediment projected to makes its way to the river delta by 2040 (Kapoor et al., 2022).

2.2. The Vulnerability of the Productive Landscape

On a delta scale, the shift towards intensive triple rice cropping in agricultural practices have reduced the delta's flood water retention areas, exacerbating drought and saltwater intrusion risks (Figure 2.10) (Tran et al., 2018) (H. H. Nguyen et al., 2017). Also, the resilience of the coastal zone of Mekong delta has been affected by both the sea level rise and the changing fluvial hydrological process. Mass decimation of forests and shoreline erosion resulting from expanding agriculture, aquaculture, and rapid urban expansions weakened the delta's natural defenses against storm surges and rising sea levels (Figure 2.11. This ecological degradation, in turn, disrupts crop production and the livelihood of certain shrimp species,impacting both agricultural yields and aquaculture practices in freshwater ecosystems.

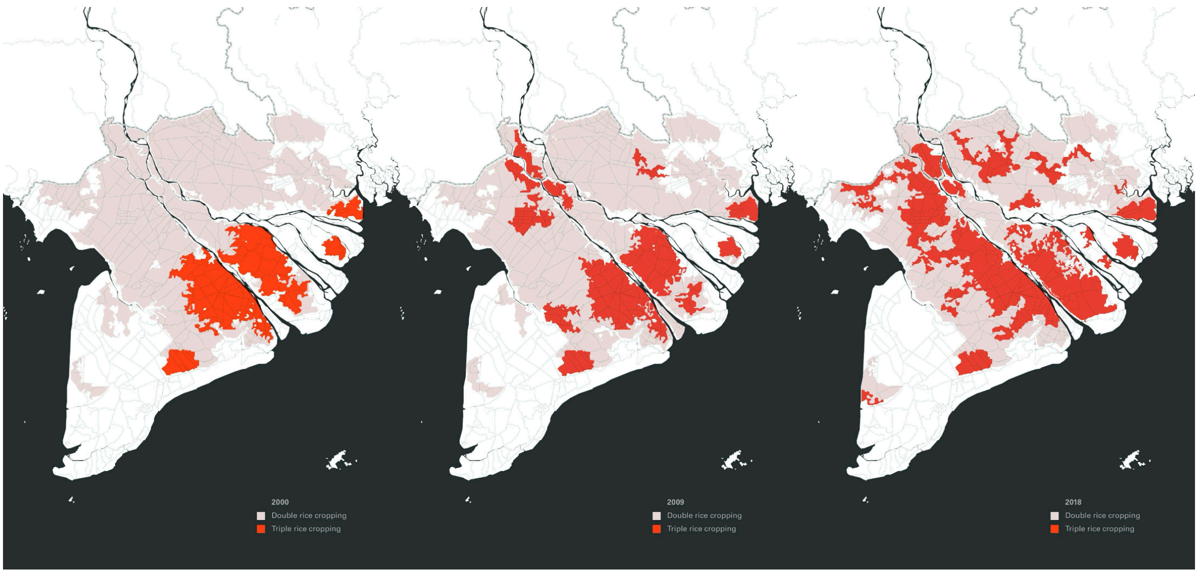


Figure 2.10: Agriculture in the Mekong Delta: transition from double rice-cropping in 2000, 2009 and 2018 (Tran et al., 2018).

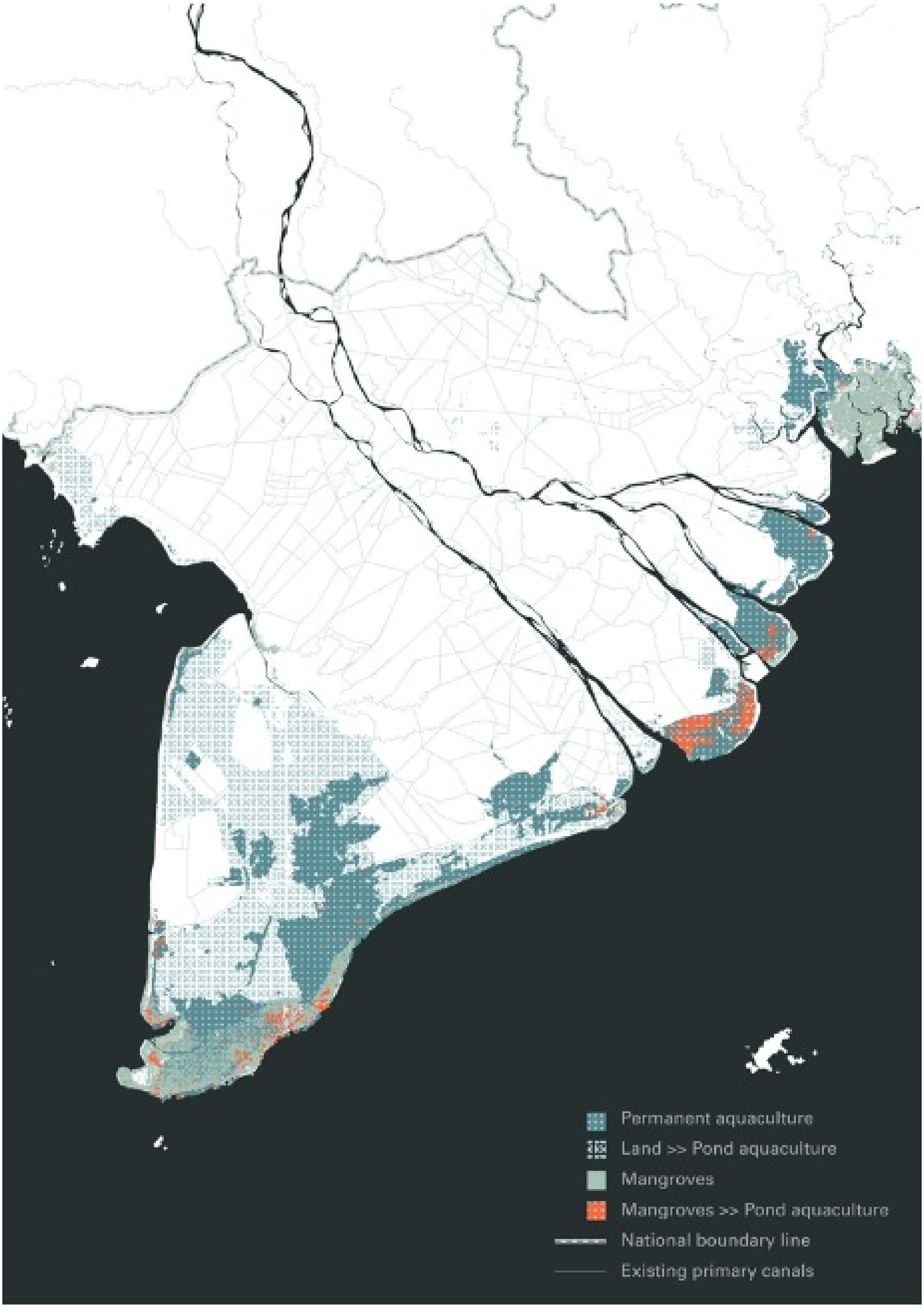


Figure 2.11: Map of Mangrove and Pond aquaculture conversion 1999-2022 (Clarks-Labs, 2024)

2.3. Summary

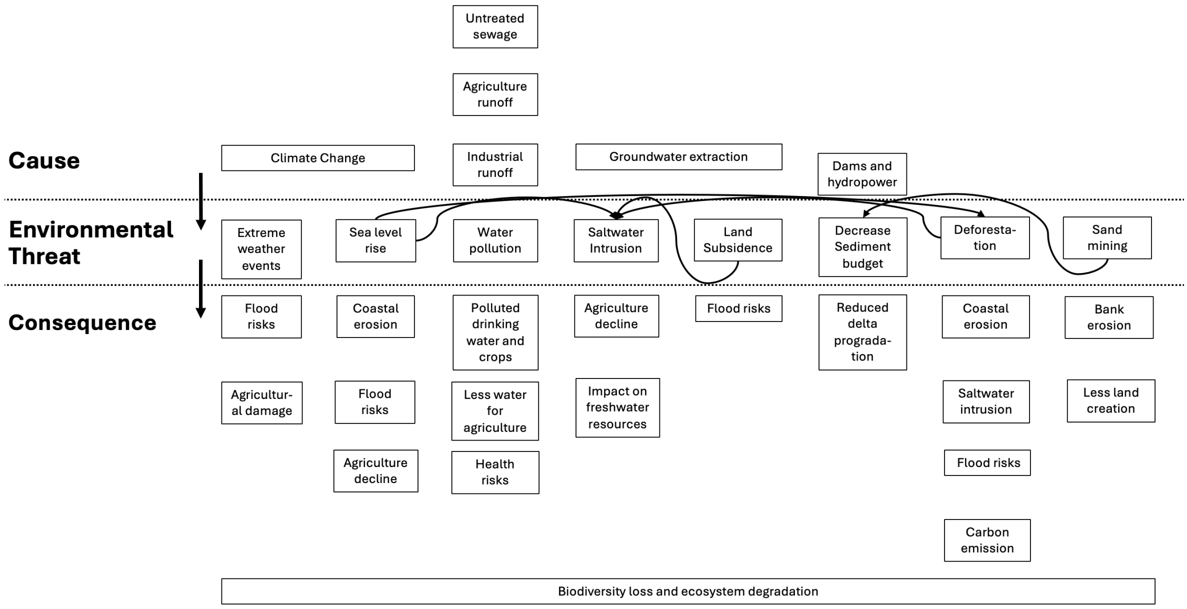


Figure 2.12: A diagram showing the causality for each environmental threats present in the Mekong Delta, while also showing the their interrelationships (by all authors, 2024).

In Figure 2.12, one can see an oversight of the causality of the environmental threats, as well as the relations among each other. Only environmental causes were considered. Deforestation has for instance an economic cause, and is therefore not included. It can furthermore be observed that some environmental threats create other environmental threats. Several environmental threats namely cause, like sea level rise and deforestation, saltwater intrusion. The hierarchy as presented in the diagram is therefore not absolute but relative.

3

Project structure

This chapter outlines the key elements of the project, including the problem statement, research questions, objectives, and methodologies. It begins by identifying the main research question. The central research question is supported by several sub-research questions, each reflecting the expertise of the multidisciplinary team members. The chapter further details the project's objective to design sustainable, water-resilient solutions, drawing on traditional knowledge and local practices. Furthermore, the methodologies, including fieldwork and research by design, are discussed as integral to developing these solutions. Finally, a brief timeline is given of the report.

3.1. Main-research question

The issues mentioned in Table 2.1 are considered as the main problems this report addresses. The aim is to explore innovative adaptation and/or mitigation design solutions to address these challenges and promote sustainable living in the Mekong Delta. The main research question is formulated as follows:

How can the Mekong Delta coexist with water in the future in a sustainable and resilient way, leveraging traditional knowledge and practices to address future environmental and socio-economic challenges, by taking the island Cồn Khương as a case study?

More elaborate information on the location of the case study is stated in section section 5.1.

3.1.1. Multidisciplinary team and Honours Master Program collaboration

This multidisciplinary team consists of 6 students from different studies: Construction Management and Engineering, Civil Engineering and Applied Earth Sciences and Urbanism & Building Sciences. The general idea for the collaboration between the different disciplines is that by integrating knowledge and methods from different disciplines a balanced and multi-perspective approach is achieved for creating design solutions. The Honours Master Program will ultimately answer a research question related to coastal areas: '*How can the productive coastal areas of the Mekong Delta accommodate the environmental challenges related to climate change and integrate traditional water management practices while addressing the needs of the community?*'. However, two out of the four sub-research questions for the HMP research question are relevant to answering the main research question of this paper and therefore offer an extra perspective to the MDP project. By considering all these different disciplines an overview was presented below, showing how each discipline can be used for the design:

- Isa Helwes: Civil Engineering; Hydraulic and Offshore Structures
  Floating structures, Hydrodynamic models, Modelling and Optimalization
- Sjors Hooijmaijers and Fedor Pallandt: Construction Management and Engineering
  Stakeholder analysis, Risk analysis, Project management, Modelling
- William Horeman: Engineering & Policy Analysis, Applied Earth Sciences; Geo-Energy Engineering
  Geology, Soil Mechanics, Remote Sensing
- Jack van der Linden: Civil Engineering; Structural Engineering
  Structures, Modelling
- Yufei Yang: Urbanism and Building Sciences
  Design Thinking and Problem Solving, Model-Making and Visualization

3.1.2. Individual contribution & Sub-Research question

Each student will focus on the sub-questions related to their specific master discipline. However, the group is required to submit a single, cohesive report and a unified vision. Therefore, it is crucial for each student to clearly outline how they plan to individually contribute and collaborate on the overall report, ensuring their work is integrated but also multidisciplinary, and comes together in one vision. Below, a list with each student's expectations is presented.

Isa Helwes:

My Master in Civil Engineering equips me to make a meaningful contribution to the project. With a specialization in floating structures, I can help develop small-scale solutions that align with the overall urban planning and design vision. Additionally, my Minor in Offshore Wind Energy provides valuable insights into renewable energy. I aim to combine these two areas of expertise to create an innovative and multi-functional floating design for Cồn Khương Island. I envision my work being adaptable, not just for this specific location, but also for promoting sustainable and resilient living with water throughout the Mekong Delta. I believe this is achievable thanks to my knowledge of hydrodynamic modeling and optimization techniques. To achieve optimal results, I will collaborate closely with Jack, who is specialized in structural responses. Together with William, I will identify the extreme load cases caused by the environmental conditions. Furthermore, it is important for me to communicate effectively with Yufei, who focuses on the larger scale vision, to develop an integrated system. Finally, my work will be *assessed for feasibility based on the stakeholder and risk analysis conducted by Sjors and Fedor. If needed, adjustments may be made to my design.*

- **Interpretation main question:**

  In my part, a design will be made for a efficient, reliable and resilient floating pontoon using local knowledge and material. The feasibility in this project consist of impact of numerical analysis, impact of the reliability assessment on the design choices and the technical feasibility. First, the design philosophy and design parameters are described. The river conditions will be reported at the Cồn Khương Island on the basis of the derived environmental data. Next, a selection of the concept design is made using determination and evaluation. The numerical part describes the modelling approach, implementation and interpretation of the results. Eventually, a life-cycle assessment for the concept is made.

- **Sub questions:**

  How can we build a modular floating pontoon with local construction methods and materials to facilitate living on water?

Sjors Hooijmaijers:

My master in Construction Management and Engineering gives me an interesting position within the project. My master focuses on stakeholder analysis, policy, risk management and strategy implementation. Therefore, especially compared to some of the others, focus not only on the design or technical solution, but the viability and implementation of this design. My background in architecture and structural design gives me an advantage, as I also have intricate knowledge about the technical solutions. For this project, I will closely work with Fedor. My focus, however, is on design and integration, which works well with the scope of this project. To answer our sub-question, Fedor and I will focus a lot on the stakeholder analysis, where we will write a stakeholder strategy. This will help scale our vision to the bigger region of the Mekong Delta. Therefore contributing heavily to the implementation of design.

- **Interpretation main question:**

  In the context of Construction Management and Engineering, this research will focus on developing and implementing a strategy that minimises adverse environmental and socio-economic impacts. Understanding the responsibilities and objectives of important stakeholders, such as local governments, developers, and communities, and how their engagement might influence effective and resilient water management systems, will be crucial to this research. Furthermore, the research will emphasize scalability to ensure that the solutions developed for the Cần Thơ region can be adapted and applied across other vulnerable areas in the Mekong Delta.

- **Sub question:**

  What framework can be developed to effectively engage stakeholders in Cần Thơ for future water management scenarios, while ensuring the scalability of this strategy in the Mekong Delta?

William Horeman:

At first, I will focus on the problem analysis, to make sure we as a group are tackling the right problems in the design of the island for 2075. One of the main problems for the island in the future is flood risk, which is caused by sea level rise, subsidence and extreme weather events. By quantifying and mapping the extent of these problems, we will be able to create a design which is fit-for-purpose based on science. Afterwards, I will focus on the design of the soft dykes, as river processes and sedimentation are a crucial aspect for these constructions. For this, I will work in close collaboration with the designers, to make sure that the soft dykes are in collaboration with our design values.

- **Interpretation main question:**

  Applied Earth Sciences focuses on quantifying current and future environmental problems through data obtained from remote sensing techniques. Subsidence and sea level rise quantification, and therefore flooding, are examples of applications based on remote sensing. The Geo-Energy track of Applied Earth Sciences focuses on the subsurface of the earth. Sedimentation processes are *prominent subject within this track, which could be used for the design of a soft dyke that will have to be designed with nature.*

- **Sub questions:**

  Which locations are most prone to flooding on the Cồn Khương island?

  How would a soft dykes look like on Cồn Khương island?

Jack van der Linden:

My specialisation in Structural Engineering will add a very technical perspective to the project which will balance the design and management disciplines. The skills possessed by a structural engineer are analytical analysis, modelling, programming and technical design. These skills will specifically prove them self to be useful when having to make design decisions which are dependent on technical feasibility. In order to contribute to the main research question I have formulated sub-research questions about redesigning the way people can live, either on floating houses or in stilt houses. Further elaboration on these sub research questions is presented in the next section. By answering these questions from a technical and architectural standpoint the main research question is also answered at a very small scale level.

- **Interpretation main question:**

  As a structural engineer, my interpretation of the main research question mainly focuses on the technical feasibility of the desired solutions. My role is to ensure that the vision outlined in this project can be pragmatically transformed into practical, real-world design implementations. This involves analysing the structural integrity, resilience, and functionality of the proposed designs to ensure they can withstand environmental conditions.

  In essence, my interpretation of the main question can be summarized as: How can the innovative design concepts and strategies proposed in this project be technically realised, ensuring that they are not only structurally sound but also adaptable, resilient, and sustainable?

  To achieve this, I will focus on translating conceptual ideas, like the floating pontoon, into technically feasible structures by evaluating material choices, load-bearing capacities, and long-term durability under environmental stresses.

- **Sub questions:**

  How can we build a modular floating pontoon with local construction methods and materials to facilitate living on water?

Fedor Pallandt:

For my Master's in Construction Management and Engineering, I will primarily focus on stakeholders, policy, strategy implementation, and risk management. For sub-questions related to these topics, I will collaborate closely with Sjors, who is in the same program but following a different track. My focus is on systems and engineering, which involves modeling and optimizing systems. If relevant to our sub-research questions, this perspective may be integrated.

With my background in architecture, I also plan to contribute to the project's vision and design. In implementing engineering solutions like dikes, sluices, or other civil structures, non-technical aspects such as social, environmental, or economic factors are often overlooked. It is crucial to integrate these components. Therefore, I will collaborate closely with Jack, Isa, and William to develop solutions that are not only technically feasible but also address these diverse fields. I will actively participate in the design process, working on the vision by creating sketches, maps, and visualizations, which will require strong collaboration with Youfei.

- **Interpretation main question:**

  In the context of Construction Management and Engineering, this research will focus on developing and implementing a strategy that minimises adverse environmental and socio-economic impacts. Understanding the responsibilities and objectives of important stakeholders, such as *local governments, developers, and communities, and how their engagement might influence effective and resilient water management systems, will be crucial to this research. Furthermore, the research will emphasize scalability to ensure that the solutions developed for the Cần Thơ region can be adapted and applied across other vulnerable areas in the Mekong Delta.*

- **Sub questions:**

  What framework can be developed to effectively engage stakeholders in Cần Thơ for future water management scenarios, while ensuring the scalability of this strategy in the Mekong Delta?

Yufei Yang:

As a Landscape Architecture student, my research and design work focuses primarily on the spatial elements and how they interact with people, while also understanding the intricate dynamics between water, production, and urban development. For my design assignment, I aim to propose a new climate-resilient and productive system for Cồn Khương, which can potentially serve as a model for other parts of the Mekong Delta. In terms of multidisciplinary collaboration, this system would act as a design framework, integrating various interventions into a cohesive whole. This would be achieved by summarizing the key concepts, strategies, and tools, and showing how they are implemented spatially

- **Interpretation main question:**

  *T*he first sub-research question dives more into the climate-related impact on the productive landscape of Mekong Delta, aiming at identifying the environmental challenges and proposing adaptive measures for agriculture and aquaculture sectors.

  The second sub-research question aligns closely with the main research question's emphasis on leveraging traditional knowledge; it also addresses the integration of traditional and modern methods in solving environmental challenges.

- **Sub questions:**

  What specific environmental challenges related to climate change are affecting the agricultural and aquacultural productivity of the Mekong Delta, and what adaptive measures can be implemented to mitigate these impacts?

  How can traditional water management practices in the Mekong Delta be effectively integrated with modern technological solutions to enhance resilience against climate change?

3.2. Objective

The goal of the project is to perform a novel design tank to envisage new systemic and innovative ways of living with water and inclusive forms of production to foster food security. This will be achieved by detailing spatial and technical solutions based on local and traditional construction methods, food production techniques and water and sediment management measures.

3.2.1. From vision to feasibility

To achieve the goal of the project, a novel design tank needs to be performed. chapter 4 presents the vision for the design and explores various opportunities, found during fieldwork (section 3.4), to address the environmental and socio-economic challenges of the Mekong Delta. By creating a vision rooted in five core design values - sustainability, multi-purpose functionality, flexibility, systemic thinking, and design with nature — the chapter outlines a paradigm for creating resilient, adaptive, and forward-thinking solutions. In chapter 5, the implementation of the vision is presented. This chapter illustrates how the previously presented design values and solutions can be integrated as a whole. By using the Cồn Khương Island as a case study, various cross sections are presented to illustrate how the vision can be used to design a future where the Mekong Delta can sustainably and resiliently coexist with water in the future.

The coming three chapters hereafter are dedicated to the feasibility of the design which is proposed in order to answer the main research question of this project. The feasibility is divided into three categories in which different sub-research questions are answered. The answers to the sub-research questions ultimately contribute to answering the main question of the report. chapter 8 is dedicated to the socio-economical side of the design solution proposed and focuses on the stakeholders and governance. chapter 6 delves into the technical feasibility of the soft dykes which are proposed, keeping the vision in mind. Lastly, chapter 7 is focused on the technical feasibility of implementing a new type of floating structure which uses the design values.

3.3. Methods

Several methods will be used to answer the research question such as, research by design, workshops, fieldwork and more technical tools like Qgis and Python.

3.3.1. Research by design

The project is an interdisciplinary project (see 3.1.1). An interdisciplinary method is 'research by design'. The research by design process alternates between interdisciplinary and disciplinary phases (Figure 3.1). In the interdisciplinary phase, knowledge and options within all disciplines are explored. In the disciplinary phase, choices are made on the basis of the conditions set by the other disciplines. The understanding of the capacities and constraints of each discipline is part of the design process.

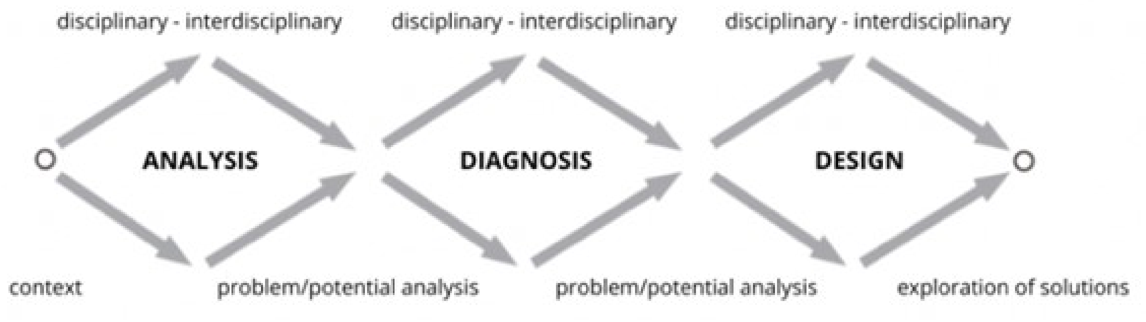


Figure 3.1: Interdisciplinary research by design process (DeltaFuturesIab, 2024)

Research by design is an approach to integrate engineering into urban planning and design. With research by design, different scenarios can be designed by thinking beyond the boundaries of the reality. The approach is used to investigate potential futures. Therefore the design process, as well as governance processes and products, need to be innovative. This can be achieved by creating a framework of understanding using the scoping method. The deliverable of research by design will be context and options for new futures (Dutton, 2000).

3.3.2. Workshop

Unlike traditional research methods that might rely on observation, experimentation, or theoretical analysis, research by design integrates creative practice directly into the research process. To get more familiar with the research by design method, a workshop with lectures and fieldwork was organised. The workshop stimulated combining and integrating knowledge of the different disciplines for the vision of the project and it contributed to setup the interdisciplinary approach.

3.3.3. Fieldwork

The fieldwork activities during the workshop gave insight into the current situation of the Vietnamese way of living. To asses the current state of Cần Thơ, tools like photographing, drawings and small interviews where used during the fieldwork. After the fieldwork, the outcome was reflected, elaborated and presented, where (online) data was linked to the fieldwork findings and ideas.

3.3.4. Other methods

Next to the fieldwork, online methods will be used as well. Implementation of the vision will be investigated with QGis. Technical and environmental models will be made using Python. Finally, literature studies and reference projects are used for the analysis.

3.4. Review fieldwork week

The first fieldwork with Dinh Diep Anh Tuan, a lecturer affiliated with the Dragon Institute, took place at four different locations in Cần Thơ. The Dragon Institute is a research center focused on climate change based in Cần Thơ, and we collaborated closely with them during the first workshop week. Their expertise and local knowledge, particularly through the guidance of Dinh Diep Anh Tuan and the other lecturers, greatly enriched the understanding of the climate challenges and opportunities in the region. This collaboration was instrumental in shaping the design.

Figure 3.2: Group photo of the fieldwork activity (27 August 2024)

At each location there was a structure or design solution that provided a solution to deal with high water levels. The advantage of visiting all these projects was to get an understanding of what is currently possible, what the limitations are of existing projects and obtaining inspiration. Another benefit of doing the fieldwork visits was observing the current threats or problems in the region.

1. Cai Khe Boat Lock project: The sluice gate with 3 lock valves is built in 2023 to regulate the water. It is able to keep water out either from the side facing the river or the seaside due to the tidal differences. The sluice is built in 2023 for a design life of 20 years, which was considerd to be rather short giving the future enviromental threats it needs to face. Additionally a big problem the sluice is facing, is the large amount of waste that passes the valves, this seems to present an opportunity to do something about.

Figure 3.3: Cai Khe Boat Lock and the waste problem (27 August 2024)

2. Dyke work: The flood prevention route is a multipurpose solution to living with water. In this project, infrastructure is combined with a flood prevention construction of about 1 meter high. Also other water infiltration systems were seen in the surrounding, like water-permeable tiles. These observations gave insight to possible solutions to deal with high water levels.

(a) Water-permeable Tiles

(b) Flood prevention dyke

Figure 3.4: Fieldwork activity to the Dyke Work in Cần Thơ (fieldwork 27 August 2024)

To review this fieldwork, a primarily design was made using a multipurpose road. The sketch allowed envisioning what a future scenario might look like where infrastructure is not only limited to functioning as transport route, but also as safeguard for residential areas.

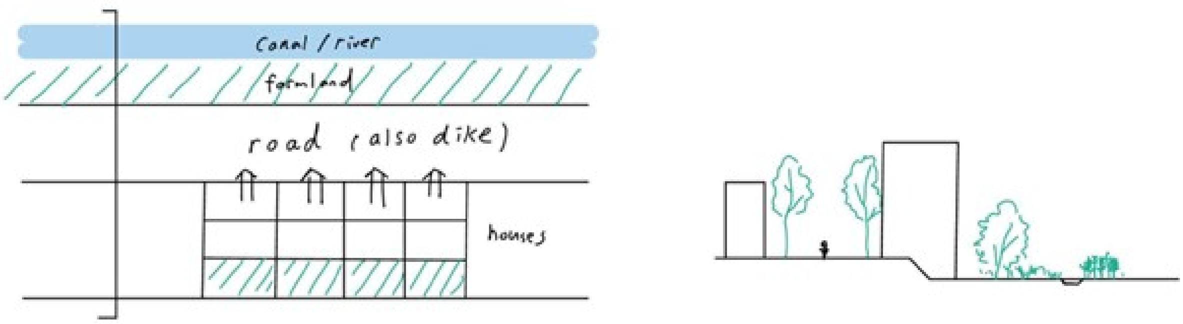


Figure 3.5: Dyke road design for flood prevention (by all authors, 2024).

3.Thoi Nhut Residential Area 2: This park serves as a public space for people to meet eachother and do leisurley activities. Furthermore, the park also doubles as a large pluvial retention area in the urban fabric. Dinh Diep Anh Tuan, the lecturer from the Dragon Insitute, also explained that the community is working together to keep it a lively park without much waste. This presented an interesting opportunity to think about future solutions where design solutions are not only practical but also serve as a tool to increase the sense of community.

(a) Woman using the park to fish

(b) Further ellaboration about the park by Diep Dinh

Figure 3.6: Fieldwork activity to the in Cần Thơ (fieldwork 27 August 2024)

Unfortunately, a lot of waste was seen, but almost no bins. The waste was even blocking a sewage pit, which is contradictory with the purpose of the green infrastructure, since this is also an important drainage system. Once again, pollution posed itself as a threat again and something to deal with in the future.

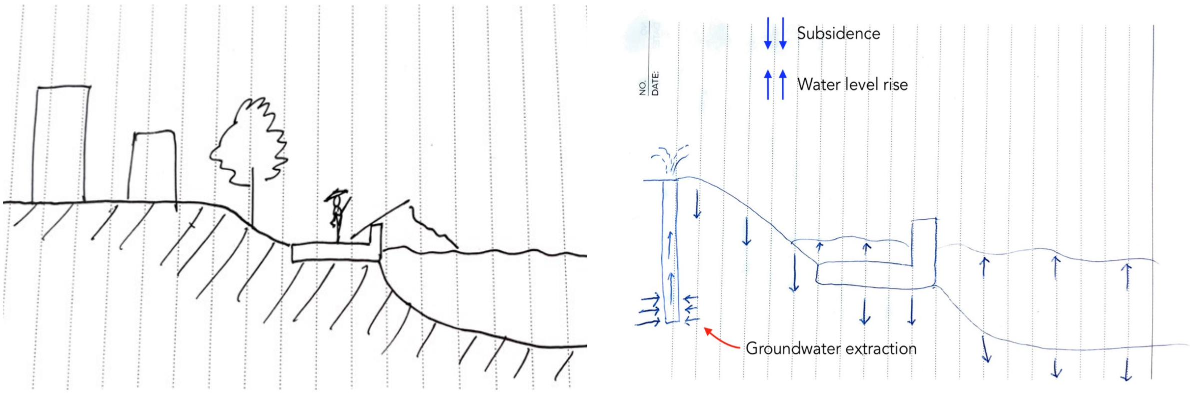
(a) Waste in the park

(b) Waste in the sewage pit

Figure 3.7: Fieldwork activity to the Dyke Work in Cần Thơ (fieldwork 27 August 2024)

Bung Xang lake project: The surface water regulation is built in 2018 for water reserves and regulation of water to prevent flooding in Cần Thơ. The goal of the project was to make the city greener, cleaner and more beautiful. The fieldwork visit showed us that the lake does functions as a drainage system. Also it is used for fishing, but the expected goal to make a greener and cleaner city has not been achieved (see Figure 3.8). The banks of the Bung Xang lake project presented an interesting opportunity to redesign the lake bank in such a way that it can be used for recrational use as well, under the condition that it gets designed in a clever way that it deals with groundwater table forces and other governing forces involved in settlement.

Figure 3.8: Surface water regulation lake (fieldwork 27 August 2024)



(a) Sketch of fishing in the lake

(b) Sketch of possible loads

Figure 3.9: Fieldwork activity to the Dyke Work in Cần Thơ (fieldwork 27 August 2024)

The second fieldwork with a local guide was the visit to Con Son Island. First, there was a stop at a floating fish farm. The owner of the fish farm was available to answer questions, which brought us some useful information. This is how we found out that they are connected to the electricity grid, have their own solar panel and have a water purification system. Also, the floating fish farm presented an interesting possibility for the future to be able to live on water given high water scenarios.

(a) The floating fish farm

(b) Interview with the owner of the floating fish farm

Figure 3.10: Fieldwork activity to the Floating Fish Farm in Cần Thơ (fieldwork 29 August 2024)

Next, the fieldwork continued to the Con Son Island itself. The island consist of a rural area where a couple of families live with the water. Although they have found a viable way to live with the water, the impact of climate change will impact the island. Problems like sliding and salinity can cause failure of structures. Another interesting observation on the island was the succesfull use of irrigation canals to let the water into the island giving the river more room and using the channels as a means for transport by boat. Figures 3.11b and 3.11a presents the identification of these problems.

(a) Salt affecting the foundation pile

(b) Erosion that causes land sliding under a structure

Figure 3.11: Fieldwork activity to the Con Son Island in Cần Thơ (fieldwork 29 August 2024)

The third fieldwork activity was an excursion to the Cần Thơ Floating Market. This field trip activity was interesting for the students of the Masters Floating and Offshore Structures and Structural Engineering. Unfortunately, there where no locals with knowledge about the floating structures. However, it did provide insight in the methods already applied to live on water and showed that the Vietnamese are already very successful at living on water.

(a) Construction floating pontoon

(b) Heavy oven on floating structure

Figure 3.12: Fieldwork activity to floating market Cần Thơ (fieldwork 31 August 2024)

Furthermore, an Ocean Clean Up machine was spotted on the river during the commute back to the jetty. Suggesting that external organizations involved in sustainability are already present in Vietnam, offering an interesting opportunity to expand this.

Figure 3.13: Ocean Clean Up (fieldwork 31 August 2024)

Finally, a fieldwork trip was made to the Cồn Khương Island by ourselves. During the visit, the first thing which struck us was the extreme inequalities present on the island. Some houses almost looked like castles, while other houses were constructed from plastic tarps and corrugated sheets. It was noted that the wealthy areas could be easily accessed by asphalt roads and sometimes by boat, while the poorer areas often were only accessible through dirt paths surrounded by thick vegetation. On the main street on the island, many Korean restaurants were present and on the northeast side of the island some resorts were located.

Figure 3.14: Extreme difference in wealth on the island

It became evident to us that the island was not very organised from an urban planning perspective. Maintenance for infrastructure looked neglected and a lot of waste was present on public places. Two bridges are connected to the mainland, but only one could be used for the public, which is the bridge located on the southwest. It is unclear why the bridge on the northwest is not accessible to the public.

In terms of flood barriers, it was observed that the more urbanised areas were protected by concrete dykes, while the less developed areas still had natural barriers protecting them from the river, which makes these areas more prone to flooding. Furthermore, many aquaculture sites were present on the island, while not many agricultural land was identified. The agricultural sites looked liked they were once being used with a clear plan, but now most of them looked neglected. Interestingly, no rice cultivation was found on the island either.

3.5. Timeline

The first week of the program is an intens workshopweek where a lot of fieldwork is done. In the later stages of the project the development of the initial design and sub-research questions is worked out. Figure3.15 presents a simplification of the timeline. For a more extended version of the timeline, information can be found in the appendix **??**.

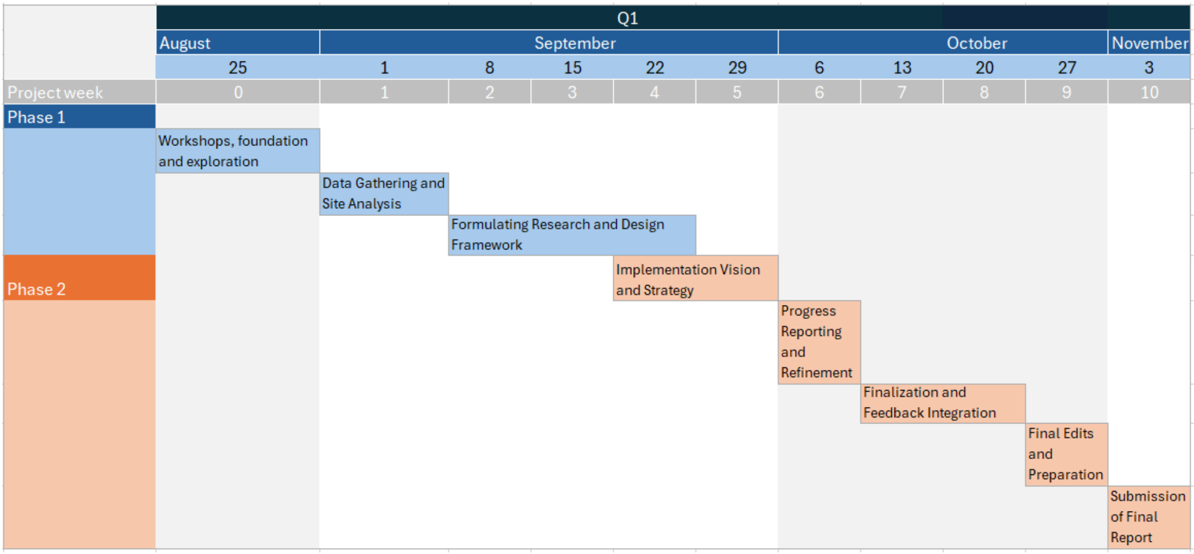


Figure 3.15: Timeline project

4

Vision

This chapter presents the vision for the design and explores various opportunities, found during field-work which align with the vision, to address the environmental and socio-economic challenges of the Mekong Delta. By creating a vision rooted in five core design values — sustainability, multi-purpose functionality, flexibility, systemic thinking, and design with nature — the chapter outlines a paradigm for creating resilient, adaptive, and forward-thinking solutions. These principles serve as a guide for reshaping the region's urban, social, and geographical landscape, aiming to ensure that the Mekong Delta sustainably and resiliently can coexist with water in the future.

4.1. Vision

As discussed before, the Mekong Delta is a labyrinthine network of waterways and fertile alluvial plains, home to 18 million people. As the region responsible for producing more than half of Vietnam's rice, it is often called the country's "rice bowl." For centuries, the people of the delta have lived in harmony with water, nurtured by the river and the land. At the same time, they have also depended on the extraction of natural resources from the delta to support their livelihoods.

In creating the vision it is crucial to take the environmental threats of chapter 2 in to account like: sea level rise, increased tidal activity, declining fluvial sediment, and human impact from upstream developments etc. Addressing this multitude of anthropogenic activities necessitates a comprehensive and collaborative approach to ensure the long-term resilience of the Mekong River Delta. Also, it is essential to shift from a defensive stance to one that works with nature.

This *research-through-design* project explores a high flood risk scenario through the lenses of Landscape Architecture, Civil Engineering, and Applied Earth Sciences. A new "living system" for the delta is proposed, using spatial planning, technical design, and policy strategies. This vision offers a potential pathway toward a resilient and productive future for the Mekong Delta in the face of climate change.

The Mekong River splits into nine arms where it meets the sea, commonly referred to in Vietnamese folk tales as the "nine-tailed dragon". By utilizing this vast network of rivers, canals, and wetlands as an ecological backbone, the Mekong Delta can enhance its resilience while restoring and protecting natural ecosystems. This approach would foster sustainable livelihoods and help the region adapt to climate change by working in harmony with its natural water dynamics (see Figure 4.1).

In the case study of Cồn Khương, an island located in Cần Thơ, the largest city in the Mekong Delta, several hypotheses will be tested within an urbanized context: What if there were more "room for the river"? How could floating structures contribute to resilience in coastal areas? And how can traditional practices be effectively integrated with modern technological solutions? This interdisciplinary design experiment has the potential to serve as a model for sustainable development across the entire Mekong Delta.

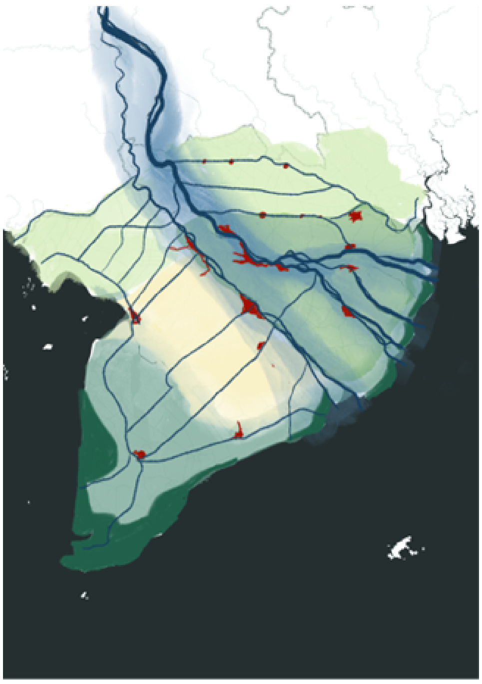


Figure 4.1: Vision Mekong delta 2075

4.2. Design values

The vision requires that the Mekong Delta needs innovative design solutions to reshape its urban fabric, socio-economic landscape and geographical landscape in order to ensure that the Mekong Delta can sustainably and resiliently coexist with water in the future. The vision is centered around five design values: sustainability, multi-purpose functionality, flexibility, systemic thinking and design with nature. These values serve as a guiding framework for proposing effective solutions specific for the region's unique context.

Design with nature

'As we begin to understand the true complexity and holistic nature of the earth system, and begin to appreciate humanity's impact within it, we can build a new identity for society as a constructive part of nature. This is ethical. This is optimistic. This is a necessity.' (McHarg, 1969)

Building upon Ian McHarg's pioneering ideas in ecological planning and design, it becomes clear that any future development must prioritise the integration of natural processes, materials, and landscapes. McHarg's work suggests to think beyond traditional, anthropocentric design approaches and instead adopt a methodology that respects and utilizes the existing ecological systems. This involves a deep engagement with the local environment, understanding how natural ecosystems function, and recognizing their invaluable contributions to human well-being.

Considering the environmental threats and the importance of the Mekong Delta, the application of McHarg's ideas becomes even more critical. By leveraging natural processes in the design of urban and agricultural systems, it is possible to create solutions that not only mitigate environmental risks but also enhance the resilience of the local communities. Furthermore, the valuation and preservation of existing nature is one of the core drivers in ecological development. (Wu et al., 2020)

For instance, incorporating wetlands and other natural landscapes into urban planning can serve as a buffer against flooding, while simultaneously providing habitats for wildlife and maintaining biodiversity. Using local materials and traditional ecological knowledge, one could create sustainable structures that minimize environmental footprints and reflect the cultural identity of the Mekong Delta (see Figure 4.2). By fostering a sense of stewardship and sustainable practices within the community, it becomes possible to empower individuals to take an active role in preserving their environment. stability against climate change and environmental degradation.

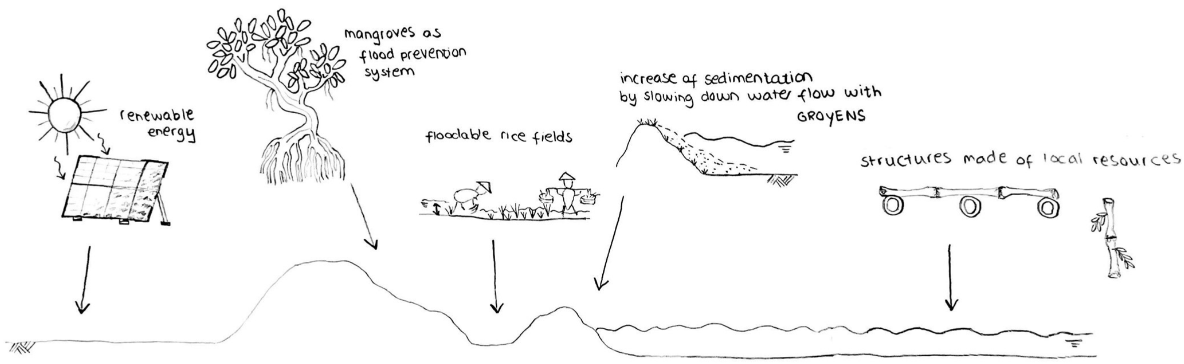


Figure 4.2: Design with nature in a cross-section. The mangrove denotes the melaleuca forests (by all authors, 2024).

Sustainability
As an integral part of the vision sustainability will be a core design value which aligns with the agenda for sustainable development from the United Nations which is a plan of action for people, planet and prosperity. The sustainable development goals demonstrate the scale and ambition, and will stimulate action in areas of critical importance for humanity and the planet, like the Mekong Delta (United Nations & Affairs, 2015). Therefore sustainability is extremely important for the project by focusing on integrat-

ing practices that ensure environmental protection, economic growth, and social equity, allowing the Mekong Delta to thrive amidst its ecological vulnerabilities, see Figure 4.3.

Sustainability serves as another core value in the vision for future development, ensuring that all design initiatives are rooted in principles that honour and protect our planet's resources while promoting human well-being and longevity. This aligns with the United Nations' Agenda for Sustainable Development, an extensive framework that aims to address the connected challenges planet earth is facing.

Considering the environmental threats the Mekong Delta is facing it is important to adopt sustainability as a core design value, a shift in focus can take place towards integrating practices that create a balance between environmental protection, economic development, and social equity (Fauzi et al., 2018)

For instance, eco-sensitive agricultural practices can enhance productivity while preserving vital ecosystems. This approach promotes economic growth that aligns with ecological preservation, ensuring that the agricultural activities in the Mekong Delta do not deplete the resources on which they depend.

Economic growth can also be fostered through sustainable tourism initiatives that celebrate the unique cultural and natural assets of the Mekong Delta (Florek, 2011). By promoting community-based tourism that engages local communities and educates visitors about the region's ecology and heritage, we can create new revenue streams that support local economies while also creating awareness among visitors. This ensures that the benefits of development are equitably shared, aligning with the principles of social equity inherent in the SDGs.

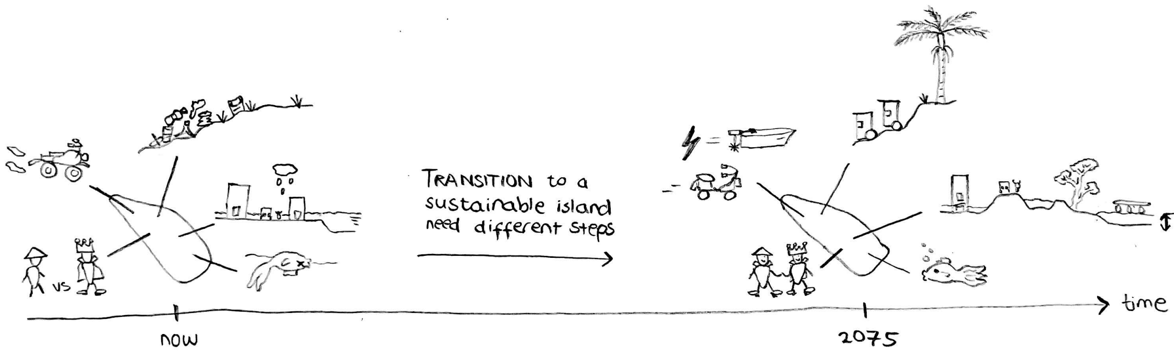


Figure 4.3: Sustainable island on a timeline (by all authors, 2024).

Multi-purpose
To maximize the effectiveness of strategies and design solutions in addressing the complex challenges faced by regions like the Mekong Delta, it is increasingly important to emphasize the creation of infrastructure and systems that fulfil multiple functions simultaneously. This approach not only optimizes the use of limited land and resources but also enhances the region's resilience in the face of pressing challenges such as climate change and economic development.

The implementation of multi-purpose design as a core value within the development vision gives several benefits. One key advantage is the versatility of structures and systems that are designed to serve multiple functions at once. For instance, a stormwater management system that doubles as a public park can provide essential flood mitigation services while also offering residents a recreational space. This dual functionality ensures that the infrastructure remains relevant and useful, even as the urban fabric evolves.

Moreover, the efficient use of resources is enabled through multipurpose design. By integrating various functions into a single solution, we can reduce the need for separate, dedicated infrastructures, minimising land disruption and lowering the overall resource footprint. An example is shown in Figure 4.4, where a various functions are given to one pontoon design.

Furthermore, multi-purpose design can significantly reduce costs and time in the development process. When infrastructure can serve several functions, it decreases the necessity for redundant structures, thereby lowering both initial capital expenditures and ongoing maintenance costs.

This approach also opens avenues for stakeholder collaboration and engagement in the design process. Engaging community members in the creation of multipurpose infrastructure allows for a greater understanding of local needs and preferences, ultimately resulting in designs that reflect the unique cultural, social, and environmental aspects of the Mekong Delta. By promoting inclusive practices in the planning stages, it becomes possible to ensure that a diverse range of voices contributes to the vision, ultimately enhancing the success and multi-purposed nature of design solutions.

Finally, implementing multipurpose design can act as a catalyst for innovation. It encourages designers, engineers, and planners to think creatively about how to solve problems in ways that may not have been previously considered.

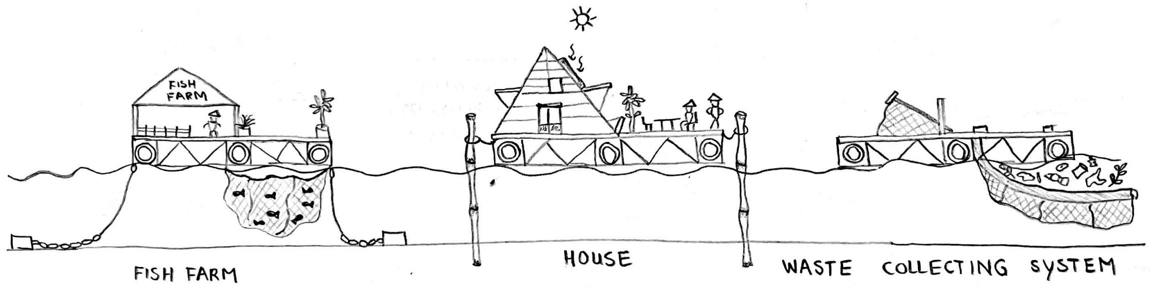


Figure 4.4: Multi-purpose implementation of a pontoon (by all authors, 2024).

Flexibility
The urban landscape can be understood as a complex system composed of multiple interconnected subsystems, each with its own distinct dynamics and rate of change (Meyer & Nijhuis, 2013). These subsystems—such as transportation networks, ecological systems, economic structures, and social interactions—operate at different paces, making the urban environment dynamic and unpredictable. As a result, the interactions between these subsystems create a need for adaptive design solutions that can flexibly respond to evolving conditions and future uncertainties.

In the context of increasing challenges like climate change, rapid urbanization, and fluctuating socio-economic conditions, it is essential that design strategies are resilient and forward-looking (National Academies of Sciences & Medicine, 1999). Flexible design aims to integrate flexibility and robustness, allowing urban spaces to evolve and remain functional even as demands shift. These solutions are not static; they are designed to accommodate changes in environmental conditions, such as rising sea levels, extreme weather events, and shifting resource availability, while also accounting for socio-economic transformations like population growth, technological advancements, and economic changes.

By incorporating flexibility into the design process, urban planners and engineers can create environments that are both resilient and sustainable. This ensures that the spaces remain effective and livable across a variety of future scenarios (see Figure 4.5), providing long-term value to communities while mitigating risks. The focus on adaptability also emphasizes the importance of continuous monitoring and adjustments, making urban design a dynamic, ongoing process rather than a one-time intervention (Meyer & Nijhuis, 2013). In this way, adaptive urban design fosters more resilient cities capable of thriving in an era of uncertainty and rapid change.

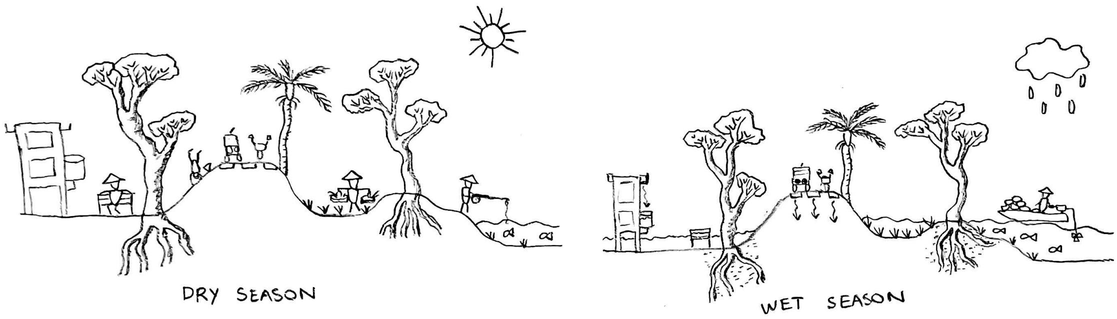


Figure 4.5: The flexibility of an area of the island in different seasons (by all authors, 2024).

Systemic thinking

Systemic thinking is a design approach that emphasizes the understanding of interconnectedness and interdependence among various factors within a system. In the context of urban design and engineering, it involves recognizing that environmental, social, and economic elements do not exist in isolation but are part of a larger, dynamic system. This approach encourages designers to think beyond isolated issues or "boxed problems" and consider the broader context in which these elements interact. One of the key principles of systemic thinking is the recognition of different scales within a system. Whether considering the neighbourhood, city, or regional level, designers are required to think about how changes at one scale affect others (Hartung & Hillmert, n.d.).

For example, changes in urban infrastructure impact local ecosystems, social dynamics, and even economic patterns. By applying this perspective of systemic thinking design solutions become aligned with the complexity and connectedness of real-world problems. In this approach, identifying how different components interact is crucial.

Instead of focusing on isolated threats or problems, systemic thinking looks at the root causes of issues and the system as a whole. This enables designers to develop solutions that address long-standing, complex challenges by improving the functioning of the entire system rather than applying temporary or 'boxed' solutions.

To effectively apply systemic thinking, it is essential to analyse the different problems within the system. Understanding these complex interactions allows designers to create solutions that are aware of the context they are placed in, see Figure 4.6].

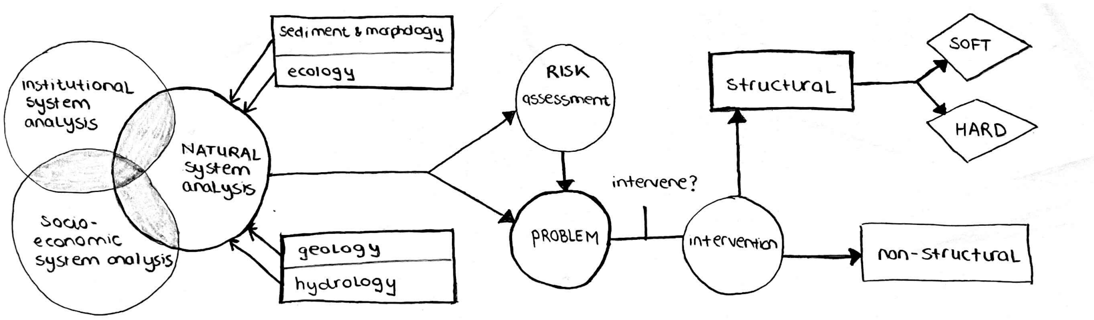


Figure 4.6: Systemic thinking (by all authors, 2024).

4.3. Design principles

By embedding these design values into the vision, we aim to create a transformative approach that can be applied across different scales within the Mekong Delta. The goal is to develop design solutions that are in line with the vision and will allow for coexistence with water and the surrounding environment. Through various fieldwork visits and literature reviews conducted during the initial workshop week, a range of opportunities have been identified that align with each of these values, which gives insight into how the vision can be translated into real-world design solutions.

Design with Nature

1. Reforestation: Planting forests to serve as natural buffers against storm surges and coastal erosion while supporting biodiversity and local fisheries.
2. Green Infrastructure in Urban Areas: Implementing permeable pavements and green roofs in cities like Cần Thơ to manage stormwater, reduce urban heat, and enhance biodiversity.
3. Native Plant Landscaping: Utilizing native species in green infrastructure projects to minimize maintenance needs and improve resilience.
4. Cleansing river water through natural methods: No further subsidence within the Mekong delta due to groundwater extraction.

Sustainable

1. Organic Farming: Adoption of organic practices by farmers to protect soil health and access higher-value markets.
2. Eco-Friendly Aquaculture: Integration of multi-trophic aquaculture to mimic natural ecosystems, promoting sustainability and reducing environmental impact.
3. Renewable Energy Projects: Investing in solar and wind energy projects such as Bac Lieu Wind Farm to reduce reliance on fossil fuels.

Multipurpose

1. Multipurpose Dykes: Designing dykes that act as flood protection while functioning as transportation routes and agricultural support structures.
2. Rice-Shrimp Farming Systems: Combining rice cultivation and shrimp farming to maximize land use and income during different seasons.
3. Community Centers: Building community centers that serve as disaster shelters during emergencies and hubs for education and training in sustainable practices.

Flexible

1. Floating Agriculture: Cultivating floating rice varieties that adapt to seasonal flooding and changing water levels.
2. Stilt Houses with Adjustable Heights: Creating modern stilt houses that can be easily raised or lowered depending on flood levels.
3. Community-Managed Irrigation: Implementing flexible irrigation systems that can be adapted by communities based on real-time water availability.

Systemic thinking

1. Integrated Water Resource Management (IWRM): Coordinating agricultural, urban, and ecological water needs to balance competing demands while preserving natural ecosystems.
2. Agroecological Practices: Employing systems thinking in farming to integrate pest management, crop rotation, and livestock to enhance sustainability and resilience.
3. Sponge City Concepts: Incorporating natural processes into urban planning for effective stormwater management and flood mitigation through green spaces and drainage systems.

These concise examples illustrate how each design value can be applied effectively within the context of the Mekong Delta's unique challenges and resources.

5

Design & Implementation

In this chapter the implementation of the vision is presented. This chapter illustrates how the previously presented design values and solutions can be integrated as a whole. Firstly, a case study is identified to show on a manageable size how the vision would be used to design a future plan. Secondly, a visionary map is presented and explained. Lastly, various cross sections are presented to once again illustrate how the vision can be used to design a future where the Mekong Delta can sustainably and resiliently coexist with water in the future.

5.1. Case study justification

To effectively answer the research question proposed in the problem statement, a specific location within the Delta that exemplifies these intricate problems needs to be chosen. The goal here is to find a location that depicts the socioeconomic dynamics and traditional practices of the area, as well as the various environmental problems the Mekong Delta faces, discussed in section 2.1.

Many areas within the Mekong Delta were discussed, but the island of Cồn Khương stands out as the most suitable location for the case study to address the research question. The island is particularly interesting because of its unique geographic features that make the island vulnerable to the effects of the environmental challenges, discussed in 2. Because of its proximity to the Hau River and its low elevation, the island is directly affected by land subsidence, riverbank erosion, and floods on a smaller scale, really underscoring the urgency of these issues. Its location inside the river makes it extra vulnerable to abrupt changes in water levels and land stability. The inadequate infrastructure on the island makes it difficult to handle the immediate effects of these environmental stresses. Unlike mainland areas that might have more time to adjust to environmental changes, the island is on the front lines of erosion and seawater intrusion, making the island the perfect case study for understanding how these dynamics affect the environment and the way of life for the inhabitants.

Figure 5.1: Location island in Mekong Delta

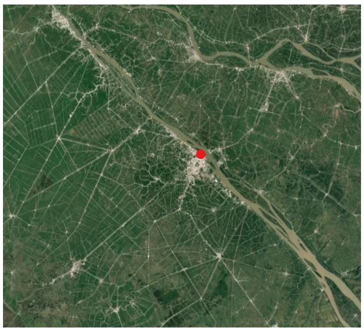


Figure 5.2: Location island in the Region

Figure 5.3: Location island in Cần Thơ

The island serves, therefore, as a sample of the broader challenges facing the Mekong Delta, which are not all environmental problems but are much more extensive. This was also clear after the site visit to the island as Cồn Khương Island presents a stark disparity between richness and poverty, reflecting larger socioeconomic divisions in the Mekong Delta. The conflict between the islands' current socioeconomic structure and the new urban planning ideas targeting affluent populations is a key aspect of the island's development. Current plans, such as the construction of luxury resorts such as the Cồn Khương resort, and commercial buildings like the Misa Commercial and Office Building prioritize wealthy investors and visitors over the needs of the community, potentially exacerbating already-existing disparities (Vietnam.vn, 2024). Though these investments provide the possibility of short-term economic growth, these changes pose a challenge to the traditional way of life on the island, mostly based on agriculture and aquaculture.

The field observations, furthermore, showed the struggle of inhabitants with basic infrastructure. The current urbanisation approach could lead to an increase in the socioeconomic gap, further isolating people. The vision for the island must, therefore, address the poverty and, apart from the environmental challenges, be just and fair. The partial development status of the island provides the opportunity for implementing change before irreversible damage occurs. This reflects the wider vision that accounts for the environmental, economic, and social dimensions.

Figure 5.4: Fieldwork observations island (by all authors, 2024).

To conclude, because of its size, Cồn Khương provides a manageable case study for investigating the relationship between urbanisation, agriculture, and the environmental challenges in the Mekong Delta. Its location, at the intersection of traditional agriculture, and the rapidly urbanising Cần Thơ city, makes the island interesting for also addressing environmental degradation issues, such as waste management and pollution, which end up in the Mekong River.

5.2. Implementation of the vision

In section 4.3 the 5 design values around the vision are stated. This section gives a possible implementation of the values in the design using the case study. The concepts are answers to the main research question: 'How can the Mekong Delta coexist with water in the future in a sustainable and resilient way, leveraging traditional knowledge and practices to address future environmental and socio-economic challenges, by taking the island Cồn Khương as a case study?.'

For the design of the island a strategy toolbox has been made which relates the different types of threats, discussed in chapter 2-Problem Analysis, to the vision and design principles of chapter 4-Vision. The strategy toolbox is applicable in different places of the Mekong Delta as well, making it scalable and flexible.

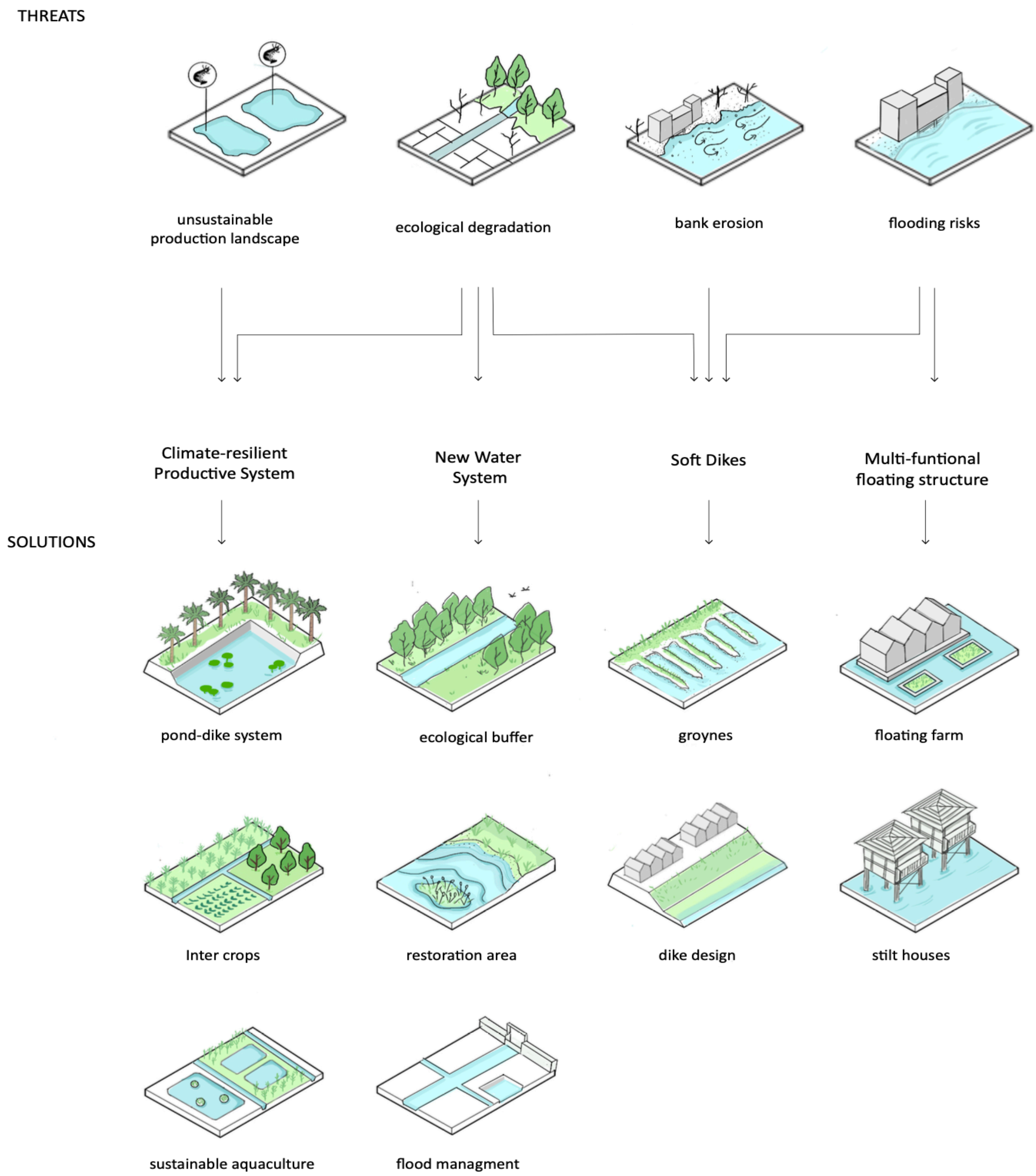


Figure 5.5: Design toolbox (by all authors, 2024).

5.2.1. A Visionary map for Cồn Khương's Future

To articulate the vision for the Cồn Khương case study, a conceptual map was developed. In urban planning and landscape architecture, a masterplan is typically used to outline future development in a very exact and predetermined way, showing zones for residential, commercial, and other land uses. However, for this vision, a traditional masterplan would be too rigid and prescriptive. Instead, the approach focuses on flexibility, illustrating possibilities within urban development rather than dictating a fixed outcome. This vision serves as a framework, providing guidelines for planning that can later be translated into practical engineering solutions without imposing a strict blueprint.

The project draws inspiration from Plan Ooievaar. Plan Ooievaar is a spatial development vision from 1986 that proposed a new approach to planning the Dutch river area (Archined, 2022). The plan used a rough sketch to depict how the Dutch river landscape might evolve (see appendix G). Unlike a detailed, fixed blueprint, it provided an open and adaptable impression of future development possibilities. Before developing a design for the island, the process began with analysing the existing map to identify urban zones. The idea is to respect these existing zones. Subsequently, flood maps were developed based on different IPCC scenarios (see Figure 5.2) to understand the different potential impacts. For more detailed information, refer to chapter 12.The analysis identified two major zones on the island that are prone to flooding. Additionally, it revealed that the urban center, or "urban heart," will remain unflooded (see Figure 5.7).

Figure 5.6: Flood scenarios for 2080 in Cồn Khương under the SSP2-4.5, SSP3-7.0, and SSP5-8.5 scenarios, not taking into account subsidence.

The urban heart remains unflooded primarily due to hard-edged infrastructure like concrete dikes. To protect this urban center along the river's edges, hard concrete dikes are proposed. The flood-prone zones, which are currently predominantly agricultural and aqua-agricultural, have fewer residents directly affected by flooding risks. These flood prone zones formed the basis for the adapted impression of the Ooievaar Plan for Cồn Khương (see Figure 5.8).

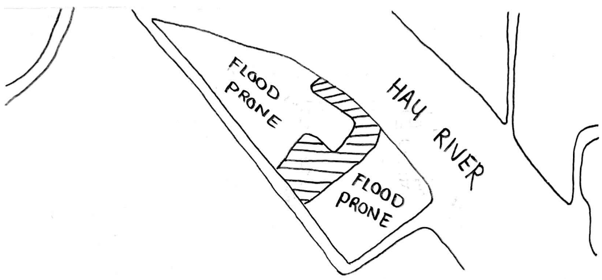


Figure 5.7: Urban Heart and Flood-Prone Zones (by all authors, 2024).

Figure 5.8: A design of Cồn Khương Island. With 1) Soft Dike, 2) Floating Farm, 3) Sustainable Aquaculture, 4) Sustainable Aquaculture, 5) Water Corridor, 6) Mixed Crops, 7) Urban Heart and 8) Adaptive residential (by all authors, 2024).

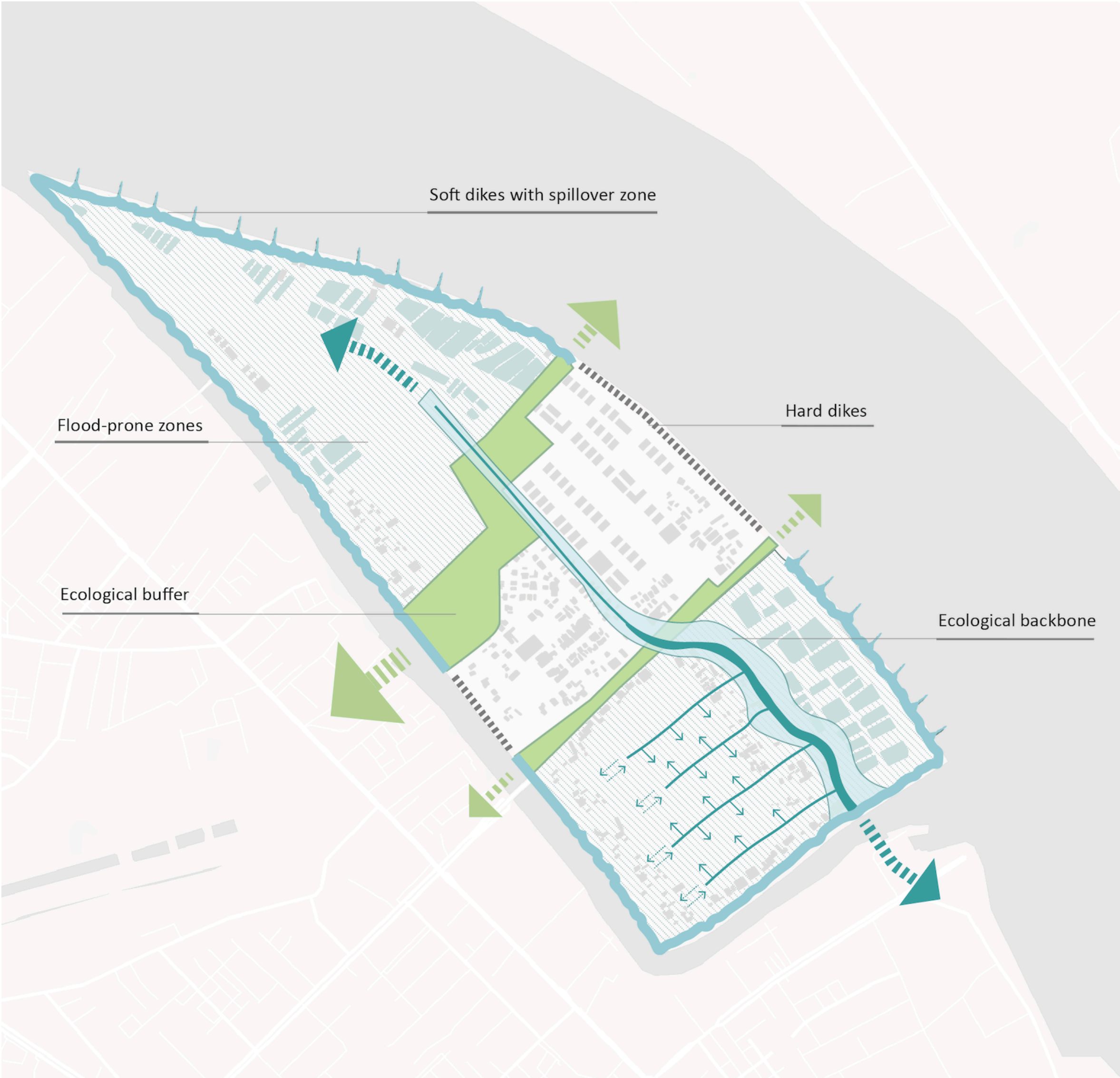


Figure 5.9: A visionary map for Cồn Khương Island (by all authors, 2024).

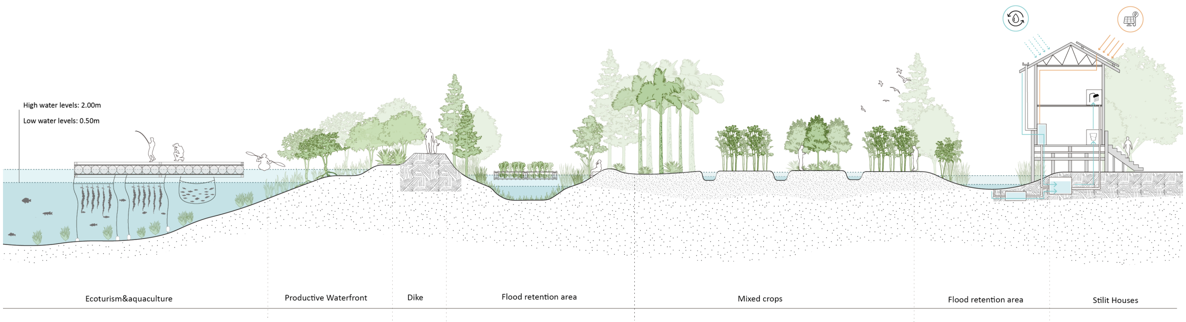


Figure 5.10: A holistic section of the island (by all authors, 2024).

The island is designed in a smart and adaptive manner to coexist with water. To achieve this, soft dikes with spillover zones are proposed around the agricultural and aquacultural areas, while hard dikes would protect the edges of the urban center. This strategy not only safeguards the urban core but also allows for potential urban expansion within the center. In addition, the inland edges of the urban center require protection against water. To ensure cohesion between different zones—urban, agricultural, and aquacultural—an ecological buffer is proposed. This buffer acts as a natural barrier, offering protection from water while creating a smooth, permeable transition between the zones. It also mitigates the risk of fragmentation, maintaining a harmonious relationship between urban and rural areas. Within the flood-prone zones, the inclusion of residential areas remains essential. These residential areas, however, must be designed with adaptability and flexibility in mind, given the flood risks associated with their locations.

An additional element of the design is the introduction of an ecological backbone, centered on an extended canal system. This canal, adapted from an underutilized existing waterway, is extended with minimal disruption to existing infrastructure and urban design, so that current locations of settlements are respected. It functions as a water retention and regulation system, with smaller attached canals dedicated to the irrigation of adaptive agricultural areas. This backbone not only serves as an essential water management tool but also reinforces the ecological balance between the various zones, contributing to the overall sustainability of the landscape. More about the water management of the island design is presented in section 5.4. In the following section, we will explore the intersections of the Design map of the Island, using design values and the strategy toolbox as guiding principles.

5.2.2. Intersections of the design

During the workshop week, the first iteration of the case study design was presented, translating the vision into the 'Ooievaarplan' presented earlier and into three cross sections that illustrate how the island could evolve in the future. Each cross section represents a different transition from the river into the island.

The first cross section highlights the transition from river to agricultural land, where design solutions are presented which provide resilience against flooding and environmental challenges. The second cross section showcases the transition from river to aquaculture, highlighting sustainable food production in harmony with the natural water systems. The third cross section illustrates another facet of the future vision, reinforcing the idea of integrated, adaptive strategies for land and water management.

These cross sections demonstrate how the proposed design solutions are interconnected, reflecting a systemic approach. They illustrate how the current situation can adapt and evolve, by applying a paradigm that envisions a future where the Mekong Delta can sustainably coexist with water.

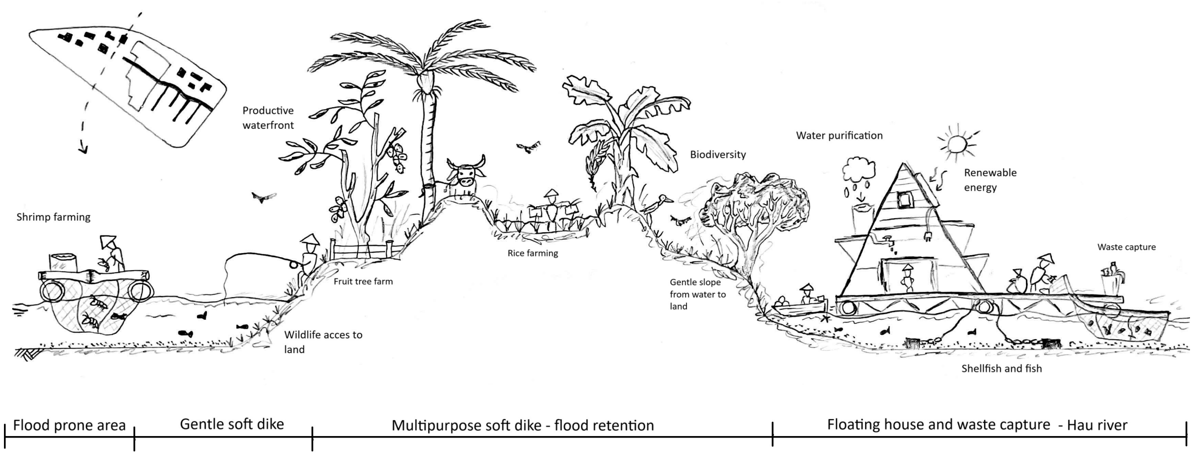


Figure 5.11: Transition river to agricultural land - Concept 1 (by all authors, 2024).

In the first cross-section, the transition from river to island is designed with the vision in mind. This begins with the introduction of dykes fortified by natural growth such as melaleuca, shrubs, and orchard trees, which play a critical role in preventing riverbank erosion. The deep-rooted vegetation hodls on to the soil, while the addition of orchard trees on these dykes serves multiple functions: enhancing the landscape's productivity by providing fruit and resources while also maintaining the ecological balance and increasing biodiversity.

On the river itself eco-tourism can take place. This sustainable tourism model allows Vietnam to continue benefiting from the significant revenue generated annually, but now with the added benefit of promoting environmental awareness. Visitors can experience the natural beauty of the region while supporting conservation efforts, creating a greater appreciation for the Mekong Delta's ecosystem and way of life.

In response to the increased flood risks that challenge the island's current agricultural practices, a new spill-over zone is introduced where flexible, adaptive agriculture can thrive. One example is floating rice fields, which not only withstand flooding but also turn a current vulnerability into an opportunity for growth. The island's existing water infrastructure, including canals, will be upgraded to increase flood capacity, creating a more resilient system capable of managing extreme weather conditions.

Sustainability extends to waste management as well, in the canals waste collection will take place. Collected waste can be recycled and reused, tackling pollution through a systemic, circular approach. Additionally, the future vision includes floating houses on these canals, integrated with aquaculture, which is already a traditional way of life for many in the Mekong Delta. This housing solution supports both livelihood and food security, relating to one of the core design values flexibility .

At a broader typology level, these homes are designed to harness solar energy, utilising the high average sun hours in Vietnam to provide clean, renewable power. This design aims at energy independence and sustainability, aligning with global trends in green energy solutions. Another advantage is that working with solar energy is a known solution and method for Vietnamese people who are unable to connect to the existing energy grid, if there is any at all.

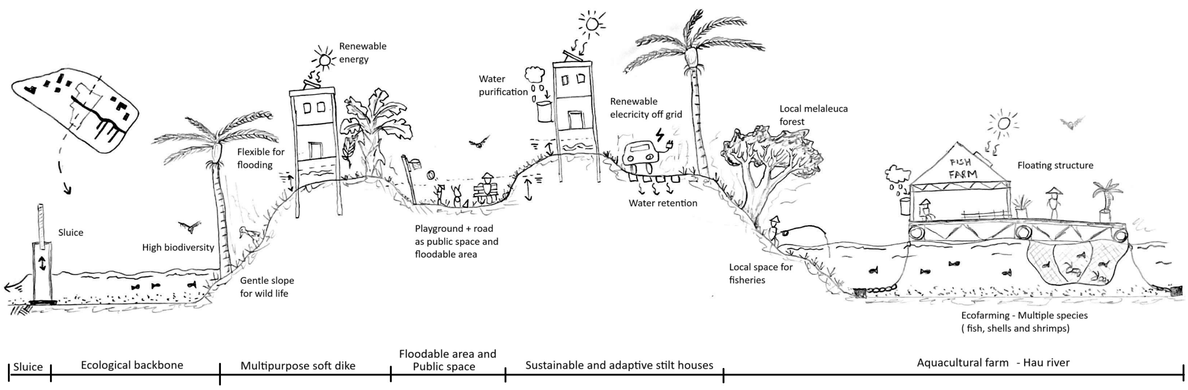


Figure 5.12: Transition river to agricultural land - Concept 2 (by all authors, 2024).

The second cross-section illustrates the conceptual transition from a river environment to an urban area. Building on the principles outlined in Concept 1, this design features soft dykes with natural vegetation. To maintain a fluid boundary between the river and the urban area, water adaptation strategies should extend into the urban area. Therefore, housing structures must be designed to accommodate fluctuating water levels.

The water-adaptive houses could be either floating or built on stilts with adjustable heights. These innovative and sustainable designs would allow the buildings to be raised or lowered in response to flood conditions, enabling the urban area to flexibly interact with incoming water.

Additionally, local infrastructure, ecosystems, and community systems must be integrated into the water management strategy, reflecting a systemic approach to design. For instance, integrating flood mitigation and drainage systems within both infrastructure and housing can enhance storm water management. Implementing local water treatment systems for each house (as illustrated in **??**) not only supports water adaptation but also enables the house to function as a local reservoir for drinking water, thereby promoting multi functionality.

Further enhancing sustainability, houses could be equipped with solar panels. By harnessing solar energy, these homes contribute to sustainable living and reduce reliance on nonrenewable resources, creating a harmonious integration of nature and technology within the community.

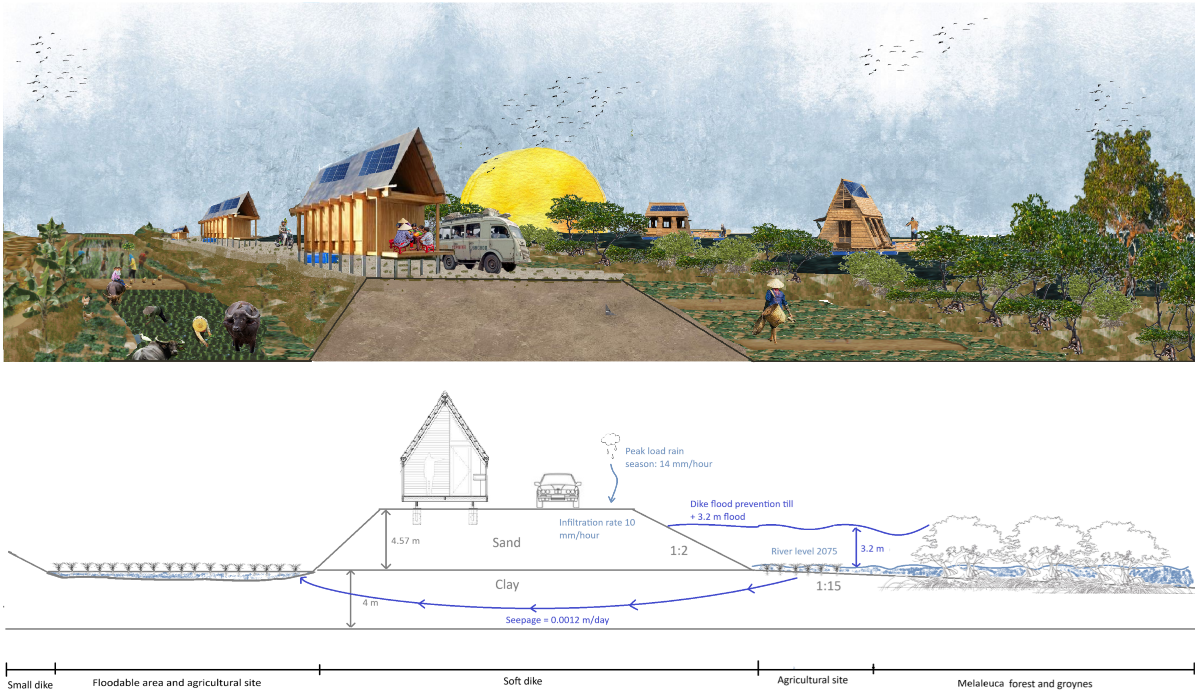


Figure 5.13: Collage and section soft dike (by all authors, 2024).

5.2.3. Conclusion

The design for Cồn Khương presents a forward-thinking approach that balances urban development with ecological preservation and redesign, addressing both current and future challenges of the Mekong Delta. By adopting adaptable solutions such as soft dikes, floating rice fields, and water-adaptive housing, the design aims to answer the question: 'How can the Mekong Delta coexist with water in by 2075 in a sustainable and resilient way, leveraging traditional knowledge and practices to address future environmental and socio-economic challenges, by taking the island Cồn Khương as a case study?'

It also integrates sustainable practices like eco-tourism, solar energy, and circular waste management to enhance local livelihoods while fostering environmental stewardship, which will be further elaborated in the next sections.

This design offers flexibility, allowing for future adjustments as environmental conditions evolve. It emphasizes the need for a systemic approach where natural, urban, and agricultural areas coexist harmoniously, ensuring that the Mekong Delta remains a vibrant, sustainable landscape. The project's core principles provide a framework for long-term resilience, ensuring that future development can thrive in harmony with the delta's unique environmental conditions.

Ultimately, this design serves as a model for sustainable urban and landscape planning, offering a flexible yet strategic path toward a resilient future for the Mekong Delta.

5.3. Water management stratgey on the Cồn Khương Island

One of the main problems stated in chapter 2 is the increased flood risk and extreme drought. This means that there is a surplus of water which could desirably be held onto and used for in the dry season. Therefore, when designing the island a new water infrastructure has been created which allows for better water management by utilising the increased and controllable water capacity of the ecological backbone. Furthermore, small scale solutions are also proposed to be implemented to be able to adapt to the increasing environmental threats.

5.3.1. Large scale design structure

The ecological backbone, supported by the connecting irrigation canals, is designed to enhance the flexibility and multi-purpose functionality of the existing canal system. By adapting the infrastructure, it becomes more capable of managing both extreme high-water scenarios, such as floods, and drought conditions. This improved system allows for better water regulation and distribution, reducing the risks posed by climate extremes. The controlled flow of water can help prevent overflows during heavy rainfall while ensuring adequate water supply during dry periods, addressing the increasing challenges of climate change.

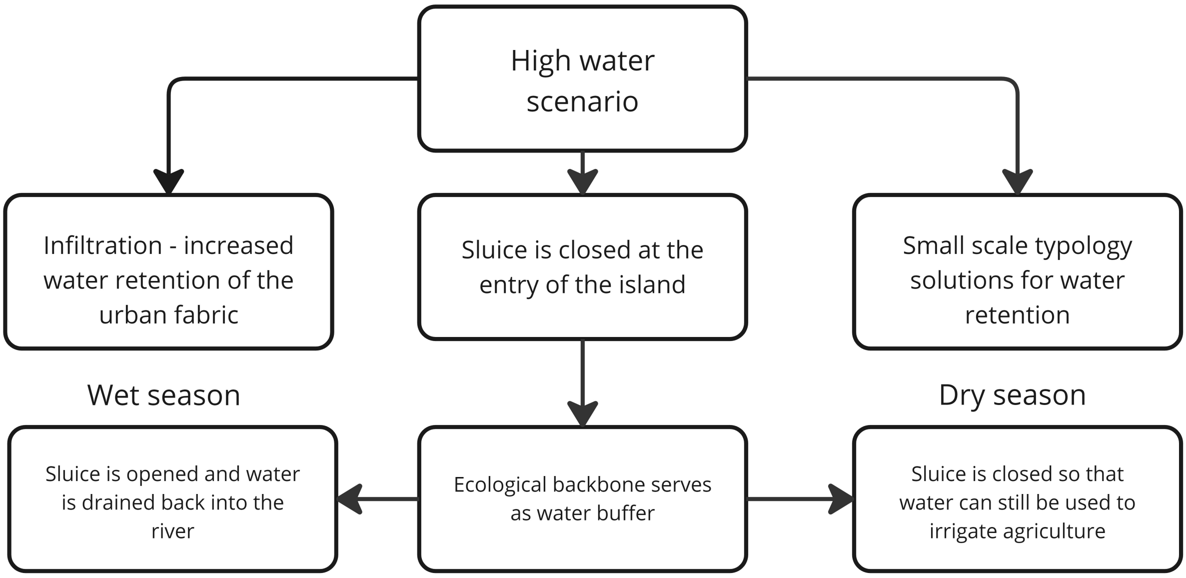


Figure 5.14: Water system diagram (by all authors, 2024).

In addition to the large-scale improvements in water management, smaller, localized solutions have also been implemented. For instance, the use of stone tiles with holes, strategically placed throughout urban and agricultural landscapes, facilitates the natural infiltration of rainwater into the ground. This not only aids in groundwater recharge but also helps to increase surface water runoff.

One of the most notable aspects of this approach is its scalability and adaptability. The design principles applied to this system are not restricted to a specific region but can be expanded and implemented throughout the entire Mekong Delta. The modular nature of these solutions makes it possible to tailor them to local conditions, whether urban, rural, or agricultural, thereby creating a sustainable and resilient water management system.

The new water infrastructure design takes a systemic approach, integrating ecological, social, and economic needs. It does not just the efficient use of water but also the restoration of natural ecosystems by maintaining wetlands and floodplains, which serve as natural buffers during floods. In the following schematic, the design illustrates how these interconnected solutions work together to create a more resilient water infrastructure. The network of irrigation canals, ecological features, and water-absorbing surfaces combines to form a comprehensive system that supports agriculture, urban living, and ecosystem health in an integrated manner. This design aims to create a sustainable, balanced interaction between human activities and the natural environment, laying the groundwork for sustainable development throughout the delta.

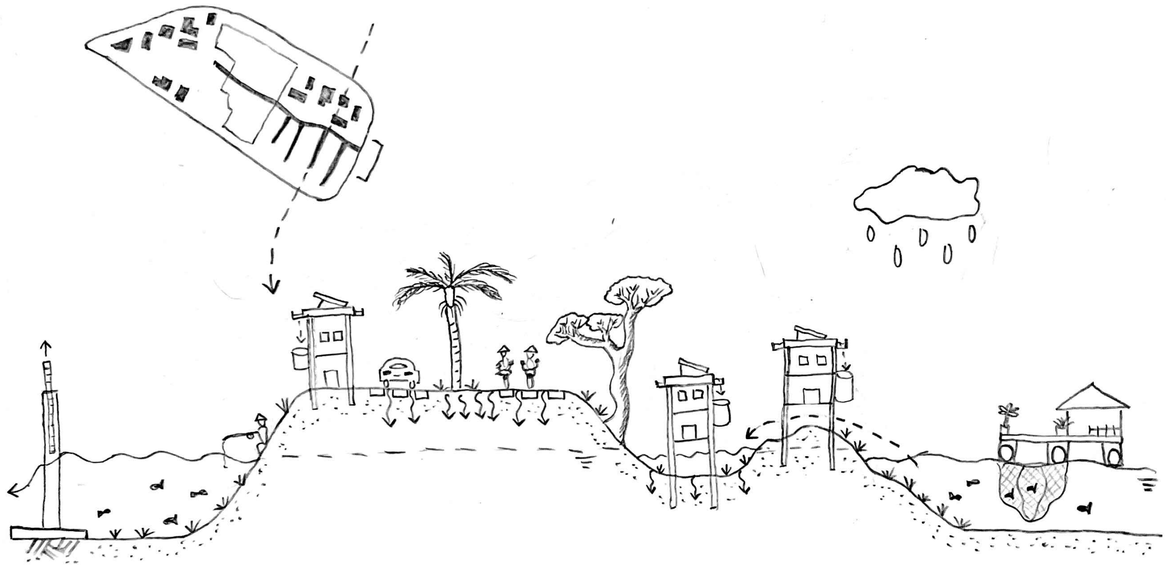


Figure 5.15: Water system cross section (by all authors, 2024).

5.3.2. Small scale design solutions

Besides the ecological backbone and the connecting irrigation canals as a large scale solution for the water management of the island, smaller adaptations in the design have also been implemented. These are discussed in the section beneath. Important to note again is that the proposed small scale solutions are able to implemented in other places in the Mekong Delta as well.

Water retention

One of the problems noted in the workshop week was the lack of water retention in the streets. A lot of pavement and non-porous media were used in the design of streets and other public spaces. Therefore, in the future, the roads should be able to retain more water during the wet season. A viable solution is having tiles which still keep their function as hardened top layer and are multi-purpose due to their ability to still let water through. The smaller built up areas of the island where traffic moves slowly are very suitable to be transformed. Furthermore, a more natural middle barrier is proposed with greenery. A big advantage of working with these tiles and types of pavements is that it is a known method and design solution already observed during the fieldtrip.

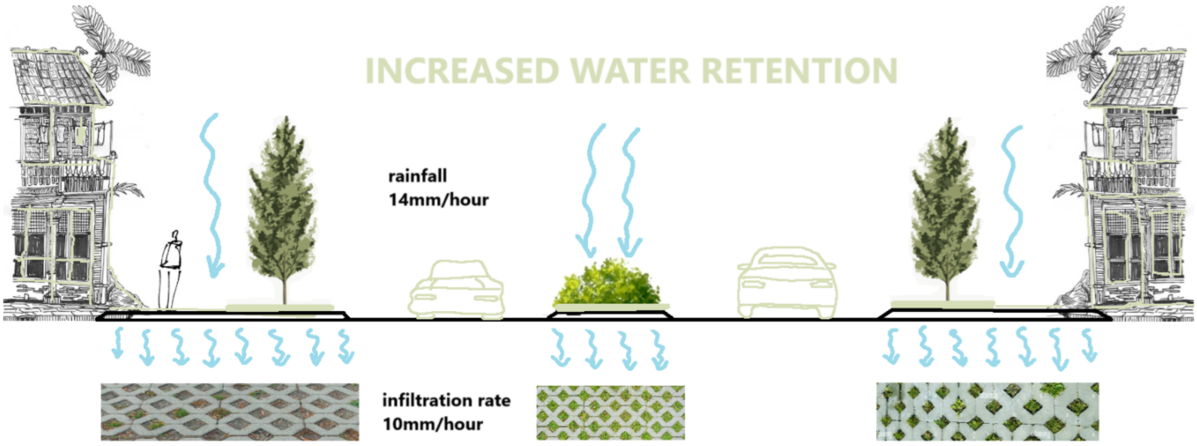


Figure 5.16: Redesign pavements (by all authors, 2024).

Water adapted infrastructure

Another problem to prevent flooding in some areas is heightening the roads in such a way that they serve as a dyke. The roads can therefore become part of the water management strategy of the island, making this design solution both multipurpose and systemic. In the design of the island, the main road serves as a suitable candidate to increase the height of. During the wet season the heightened road can serve as an extra buffer to keep water in the designated areas of the island where adapted agriculture takes place.

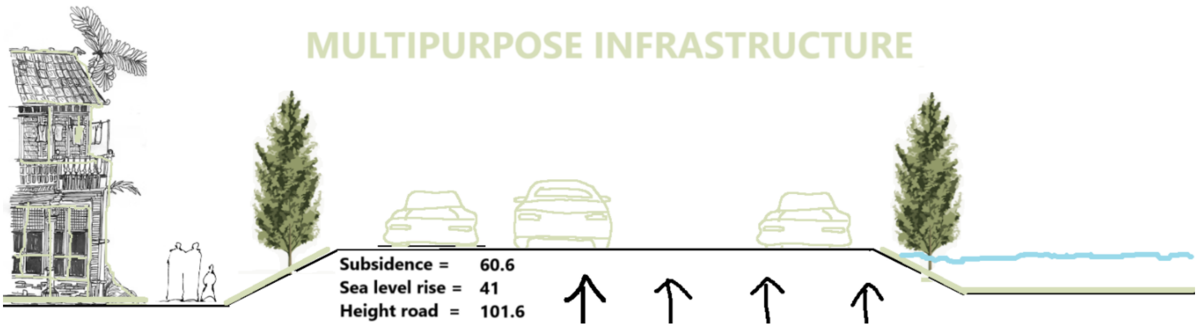


Figure 5.17: Multipurpose road and dyke (by all authors, 2024).

Typology solutions

Besides redesigning the island in public places there are also design solutions to deal with water at a typology level which will enable home owners to also deal with the imbalance in supply and demand of water bewtween the wet season and dry season. Rather than immediately redirecting the pluvial water from the roof to the sewer systems or back into the streets, it would be more desirable to have a buffer where this water can be stored for future use in the dry season. By storing the rainwater in a large tank, this water can be used again at later moments during the dry season for different purposes, watering plants, flushing toilets, etc. Since the installation of a gutter on the side of the existing houses with a pipe directing the water into a tank is a very low cost and low maintenance design solution this can also be quickly implemented and once again everywhere else in the Mekong as well.

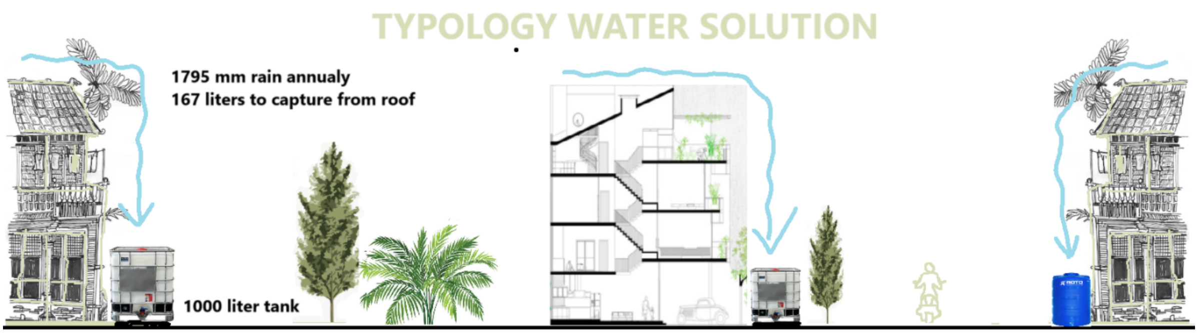


Figure 5.18: Water storage at typology level (by all authors, 2024).

Green infrastructure

Another small scale design implementation which will allow the Mekong Delta to live with water is the incorporation of more flora in the urban fabric. During the wet season the increased flora will allow for more absorption of water and during the dry season the effects of the urban heat island effect are reduced by plants. Besides the technical advantages of the park also doubles as a comfortable recreational part in the city. Furthermore, the increase in biodiversity and added greenery aligns with the design values of sustainability and design with nature. Another advantage about these parks is that observations were made during the fieldtrip that these parks are kept clean due to the increased sense of community and pride of a nicely maintained high value public place which can be shared and enjoyed by everyone in the comunnity.

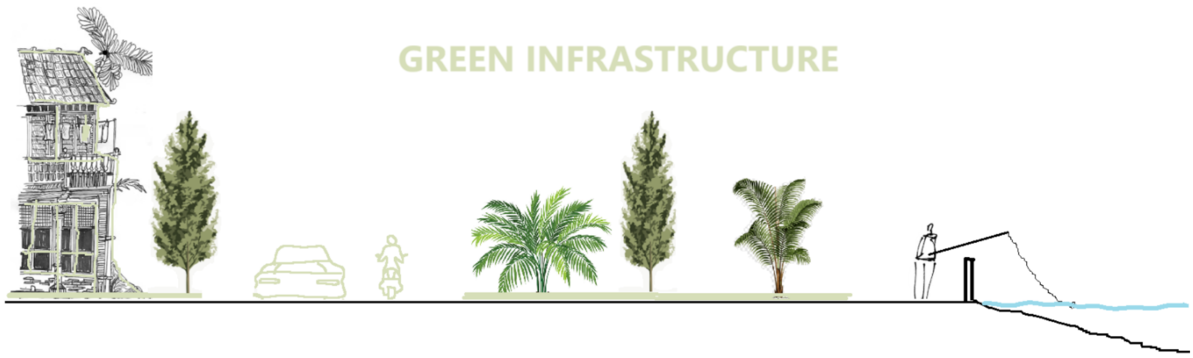


Figure 5.19: Green parks (by all authors, 2024)

5.3.3. Conclusion

Overall in order to address the challenges of increased water during the wet season and drought during the dry season, systemic and scalable water management solutions are essential. Large-scale ecological backbones and irrigation canals can control water flow and storage, while smaller-scale solutions like permeable pavements and green infrastructure enhance water retention and absorption. It is important to think about multiprupose design solutions like roads can serve dual purposes as both transportation routes and acting as dykes during floods. Additionally, rainwater storage at the household level provides an effective and easy way to reuse water during dry periods. Implementing these strategies systemically will create resilient systems adaptable to future environmental uncertainties.

5.4. Agricultural strategy

Aligned with the "Design with Nature" principle, the irrigation canals connecting Cồn Khương Island have been re-envisioned as an ecological backbone, where the existing canal system has been expanded into a linear artificial wetland designed to fulfill multiple roles. This wetland serves as a multifunctional infrastructure element, supporting ecological protection, flood retention, and agricultural irrigation. Currently, the region's mono-varietal, triple rice cropping system extends into the floodplain, exacerbating ecological degradation in the delta and highlighting the urgent need for a shift towards a climate-resilient, productive system. This project proposes a transition to a more diversified and ecologically integrated agricultural model, introducing the dike-pond system, see **??**. This is a traditional circular agricultural approach adapted to optimize the ecological value of Cồn Khương's existing fish ponds. By alternating dikes and ponds, the system creates a relationship between aquaculture and crop cultivation. Nutrient-rich pond water irrigates the fields, while dikes offer natural flood protection and help control erosion, thus preserving the soil and maintaining a balance between land and water use. This method is particularly suitable for the dynamic conditions on the island, as it can adapt to seasonal high tides, brackish water incursions, and erosive forces. Furthermore, fish ponds within this system support the reintroduction of native fish species, enhancing biodiversity and reducing the ecological impact of monoculture.

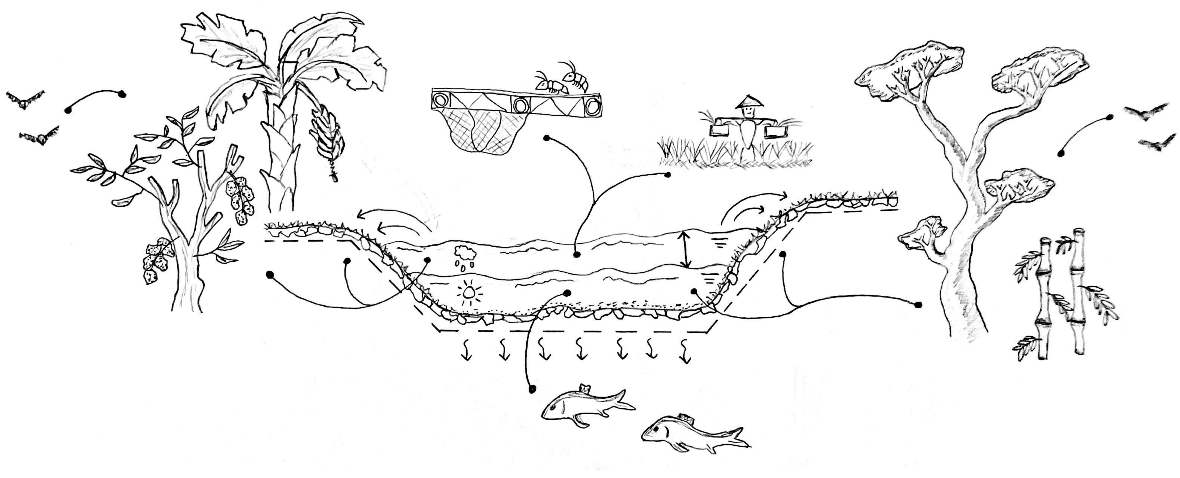


Figure 5.20: Dike-pond system (by all authors, 2024)

To address the challenges posed by seasonal flooding and the need for diverse crop production, the project incorporates a floating agricultural system built from recycled, locally sourced materials, such as bamboo and natural fibers. This floating system provides a flexible, resilient platform for cultivating aquatic and semi-aquatic crops which thrive in flooded conditions. With the ability to float and adjust to changing water levels, this system not only maximizes agricultural productivity but also provides local farmers with a diversified crop base, reducing dependence on the mono-cropping of rice and increasing resilience to climate impacts. The floating agricultural model is an adaptation that aligns with the dynamics of the delta, offering a solution to deal with the discrepancies between the wet season and dry season.

5.4.1. Conclusion

Together, these strategies—the artificial wetlands, dike-pond system, floating agriculture, work together in building a resilient productive agricultural land on Cồn Khương Island. By blending traditional techniques with innovative ecological solutions, the project not only imporves the island's agricultural adaptability but also provides a scalable model for sustainable land-use practices in the Mekong Delta's transitional fresh-brackish zones. These efforts aim to create a sustainable agricultural model that is resilient to climate impacts, productive, and ecologically integrated.

5.5. Energy and waste strategy

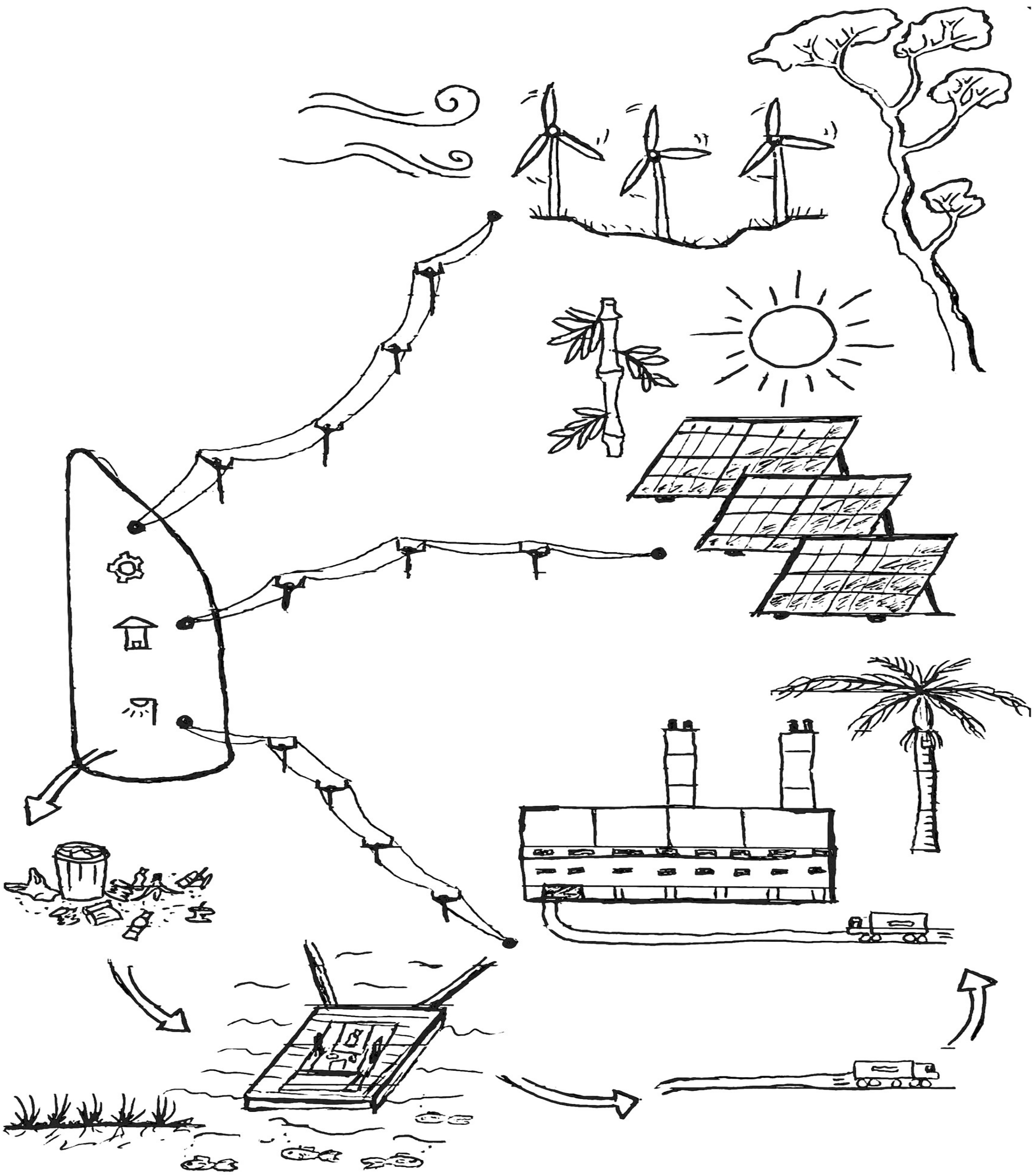


Figure 5.21: Renewable energy resources for the Island (large scale) (by all authors, 2024).

According to chapter 2 one of the causes of the large environmental threats the island is facing, is due to climate change. Energy is at the heart of the climate challenge, but also the key to the solution. To avoid worse impacts of climate change, emissions need to be reduced. Transition to clean energy is the pathway to a healthy livable planet and to a resilient and sustainable living on the island. Renewable energy is cheaper, healthier, creates jobs and makes economic sense and is therefore part of the vision of the island. Grid power plant solutions, like wind farms, solar panel parks and waste-to-energy, are large scale solutions. The resources for these renewable energy solutions are present in large quantities in Vietnam. To ensure green energy in the future on the island, all of these solutions need to be implemented to tackle the influence of the seasonality in the region. In high wind seasons, the wind farms will deliver more green energy to the grid for example. For a reliable energy supply, the waste-to-energy plants are integrated in the design, since it can deliver energy consistently. Renewable energy systems can also be implemented on smaller scale on the island, see subsection 7.9.4.

Additionally, to accommodate the increase in renewable energy, Vietnam's government is actively working on grid infrastructure improvements. Recent investments and international collaborations are aimed at addressing these issues and ensuring future growth (EnergyTrackerAsia, 2024).

5.5.1. Wind energy

The ambitious targets that Vietnam set to achieve its commitment to transition to net-zero by 2050, lead to innovation on both onshore and offshore wind energy. The target is to increase to 91 [GW] by 2050. To build large-scale offshore wind farms, partnership with countries like Japan and Singapore are required. Also an implementation plan and detailed regulatory framework is needed to turn the targets into reality. Second, for onshore wind energy, new policies like competitive bidding and transitional pricing have been introduced (VIR, 2024). These changes are challenging for developers due to lower tariffs and complex regulation, see chapter 8. In conclusion, Vietnam has significant potential for floating offshore wind energy, which will contribute to a sustainable renewable energy capacity in the long term. In Figure 5.22 locations for onshore and offshore wind energy farms are shown, based on the wind potential concentration. As seen in the figure, potential locations for wind energy are near the Mekong Delta. For a proper transmission to the grid, a transformer is needed to increase voltage for the transmission to the sub station. From the substation the voltage increases for transmission over a long distance to the island. A high-voltage pylon network is then needed to provide green energy to the island for industry and households.

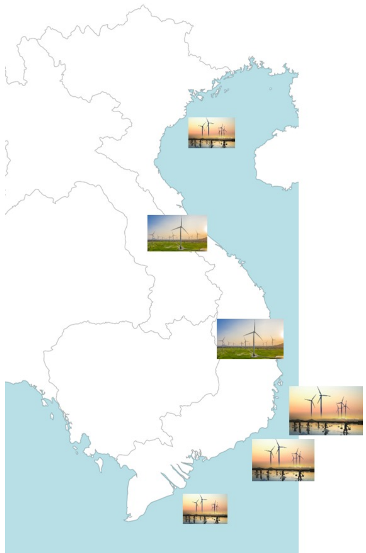


Figure 5.22: Onshore and offshore wind power locations in Vietnam (by all authors, 2024).

5.5.2. Solar energy

Also in solar energy Vietnam is developing significantly. Solar panels are already an existing solution to generate power in the region of Cần Thơ, so knowledge about the renewable energy source is already there. Further innovations of solar energy are interesting for the island, because it is located in the Mekong Delta, where the solar potential concentration is high. Challenges in solar energy innovations are on both technological and infrastructure sides. The key development is the integration of *agrivoltaics*. *Agrivoltaics* combines solar energy with agricultural use of land. This development will help to protect agricultural resources, particularly in the Mekong Delta, which is crucial for the country's food security (Stimson, 2024). Agrivoltaics will contribute to a systemic and sustainable solution for the vision. Another innovation are the floating solar projects. An advantage is that floating solar parks avoid the need for land use (EnergyTrackerAsia, 2024). In Figure 5.23 locations for agrivoltaics and floating solar parks are shown, based on the solar potential concentration. The pontoons of chapter 7 can be used as foundation for these floating solar parks.

Figure 5.23: Agrivoltaics and floating solar park locations in Vietnam (by all authors, 2024).

5.5.3. Waste-to-energy (WtE)

Developments in waste-to-energy (WtE) innovations in Vietnam are driven by goals like waste reduction and transition to cleaner energy. Projects to reduce emissions and improve waste management infrastructure are already implemented in different regions. So is the Bac Ninh's WtE plant (located in Hanoi) one of the most advanced ones in Vietnam. The plant treat 500 tonnes of waste daily and generate around 92 [MWh] of clean energy per year. Also in the Mekong Delta region a WtE plant is operating: the Cần Thơ WtE plant. Every day the plant processes around 400 tonnes of waste (VNS, 2024). For the vision, waste collecting systems play a large role to tackle the waste issues in the Mekong Delta. The pontoon (see chapter 7 for more elaboration) can be used as foundation for a waste collecting system. In this way the residents of the island can easily collect waste (mainly plastic) from the water Figure 5.24.

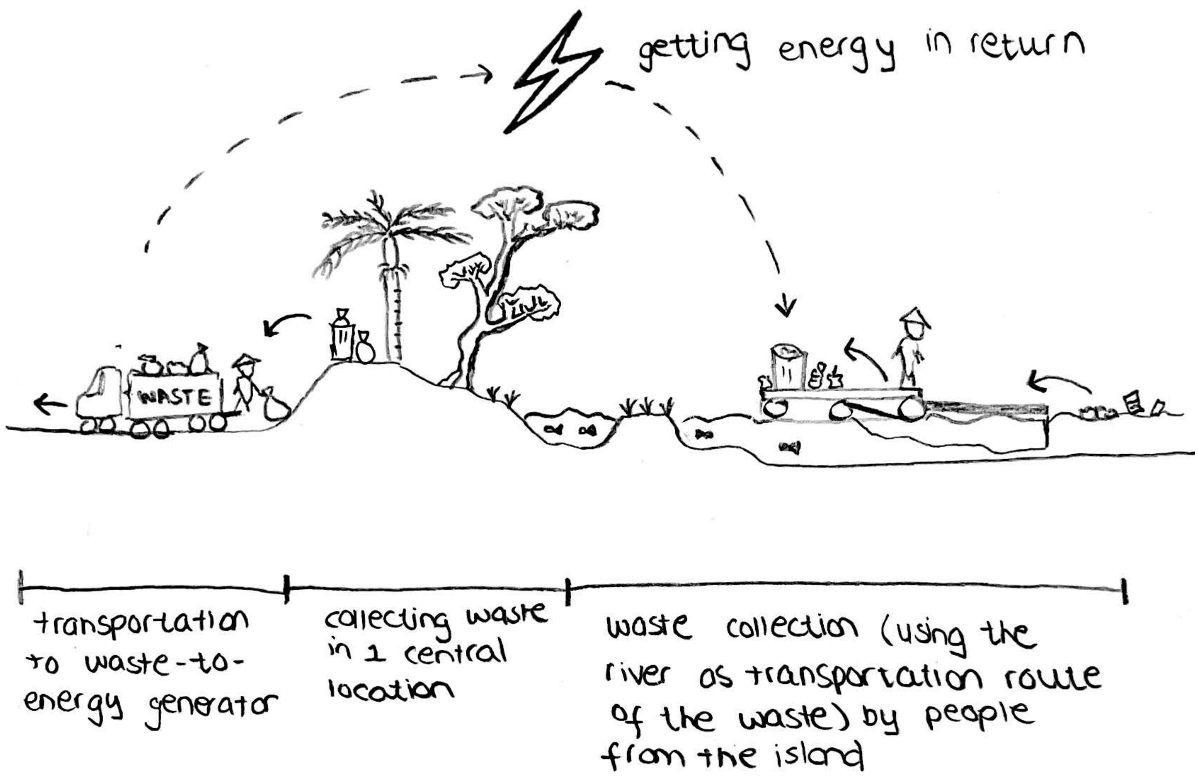


Figure 5.24: Waste collecting system for the island (by all authors, 2024).

5.5.4. Conclusion

Overall, the energy and waste design for Cồn Khương Island shows a sustainable approach that integrates renewable energy sources—such as wind, solar, and waste-to-energy in a systemic way aimed at addressing climate change, pollution and energy demand. The implementation of large-scale solutions like wind farms and solar parks, combined by innovative concepts such as agrivoltaics and waste collection systems provides cleaner energy but also improves overall quality of life for residents.

Furthermore, the strategies developed for Cồn Khương Island are not exclusive, they can be replicated throughout the Mekong Delta. The abundance of natural resources and the pressing need for sustainable practices in the region create a unique opportunity to implement similar renewable energy initiatives and waste management systems in various localities. This systemic approach offers a blueprint for ensuring environmental wellness and economic growth across the broader Mekong Delta, providing a design for a clean, resilient, and sustainable future.

" Do you know that feeling? That there isn't enough space for you. That you're constantly pushing yourself back to let others go first. Not being able to be yourself and holding your breath for the sake of your surroundings isn't pleasant. I can tell you that from experience. I'm at many places around the world. Some places where I feel my freedom and can be myself without restraint. In many other places, I have to adapt. A little adaptation is fine, but not if it comes at the cost of who you are as a person. There was one such place where I truly couldn't be myself anymore. And that was in the Mekong Delta. I was held within rigid boundaries and couldn't move freely. But the people, they took notice of me. And that's why now I take them into account. I carry them on my back. Provide them with everything they need. I try to be my purest self, so that in return, they continue to give me space. It's a good deal.

There's this island in Can Tho. It's like a playground for me there. I can enter the ride through the rooftops and flow into a tank. There, I am completely purified and come out fresh and clean from the tap. There are also water parks that I have to share with the residents. Sometimes, I get to show off my little tricks, and other times, I watch the children playing, the neighborhood ladies sharing the latest gossip, the young families with their cheerful toddlers. I enjoy it. I am in the ecological buffer zones and wetlands. But I know I shouldn't be everywhere. I can also be dangerous. Then I can't keep pretending to be something I'm not. Then I pull trees from the ground, roots and all. I wash away pieces of land. I flatten houses. Or I cause accidents on the roads. But on this island, I can disappear into the paths as my solid form under the sun. I reunite with myself underground and emerge again via the roots of all the nature that thrives on this wonderful island. The roots of nature also create a resilient island. I can grasp around as much as I want, but the defenses are stronger. I can race across the entire island, under houses, over rice fields. And still ensure a good, healthy harvest.

On this island, I feel happy and free. Almost like a love-struck teenager. I do everything for the people of this island. I collect waste for them, bring it to a convenient place for recycling. I make sure I flow, so they can use my movement to generate energy. I provide as much food and nutrients as I can. And I carry everything they could want on my back: a well-insulated house, a profitable fishing business. Ultimately, I hope it balances out against what they give me: myself. "

6

Soft dykes feasibility

In this chapter a design, supported with calculations, will be given for soft dikes on the Cồn Khương island. A conceptional implementation of groynes will also be provided. The design for the soft dike will be based on data for subsidence and sea-level rise (see chapter 12), elevation profiles, bathymetry and wave profiles, while also taking the design values, as stated in section 4.3, into account. The design will be made in a fit-for-purpose fashion, which will be applied to specific areas of the island for which flood adaption, by means of soft dikes, would be crucial. It is important to understand that the soft dikes will not particularly serve for flood protection of the hinterland, but mostly for accommodation space for housing of the local people (mostly farmers), transportation and to enhance biodiversity, as forests attract wildlife. This chapter answers the research question: *How would a soft dike look like on Cồn Khương island?*

6.1. Location

Below, one could find how a section could look like on the rural side of the Cồn Khương island Figure 6.1. Figure 6.2 highlights the locations where the soft dikes could be applied.

Figure 6.1: A section of the a soft dike (by all authors, 2024).

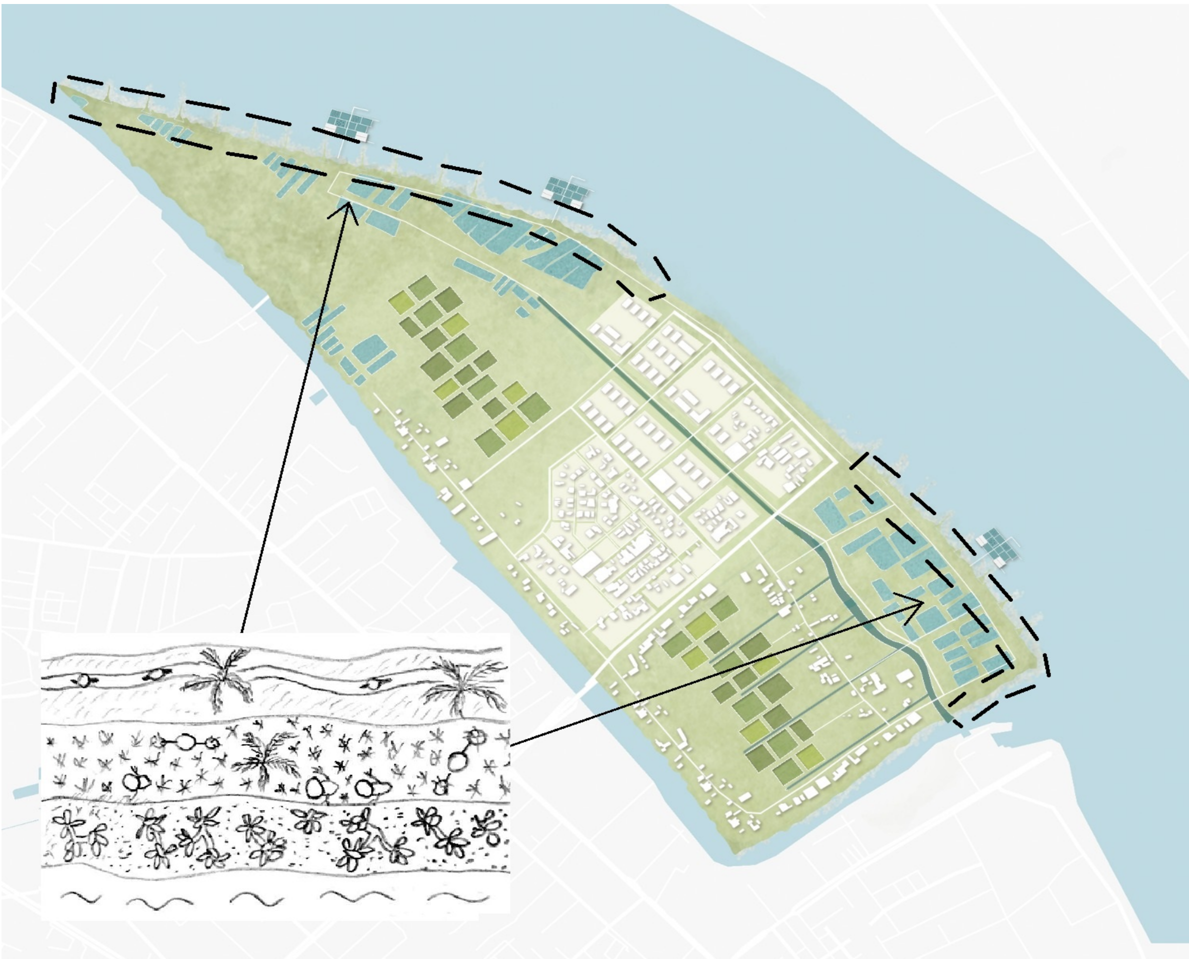


Figure 6.2: A design of Cồn Khương Island in 2075 with the locations for the soft dikes and groynes highlighted (by all authors, 2024). The locations for the soft dikes are based on the risk areas as presented in chapter 12.

6.2. Design Requirements

As stated, the soft dike for the island will not necessarily serve as protection for the hinterland, but will serve as accommodation space for housing, as a location for roads and for a place for nature. This is because the island will be able to be (partly) flooded, as explained in chapter 4 . For the construction, as many natural materials as possible will be used. The 'soft' in 'soft dikes' will be the trees planted on top of the dike. These trees will be able to increase the stability of the dike, trap sediments and reduce the impact of waves on the dike, while enhancing biodiversity. Unlike traditional 'hard' dikes made of concrete and rocks, the soft dike will be designed to blend in the with environment. 'Soft' also means that there will be no hard boundary, so areas will overlap instead of being separated by a hard barrier.

Design with Nature, *Multipurpose* and *Systemic Thinking* are the three design values which are most applicable for the construction of soft dikes. Below an explanation will given in how the three design values will come back in the design of the soft dikes, which is explained below:

- **Design with Nature**
  By the use of natural materials for the construction of the soft dike, and by using vegetation on the outside of the dike for the entrapment of sediments, one can design with nature.
  Another aspect of designing for which 'design with nature' could be applied is for the construction of potential groynes. groynes are structures built perpendicular to the riverbank, extending into the river to alter the flow of water. Their first purpose is to prevent bank erosion, by slowing down the water near the riverbank. Their second purpose is for ship transport. They help maintain a clear and stable channel for navigation by directing the water flow towards the center of the river, keeping it deep enough for boats to pass. This is caused by a decrease in flow near the banks, which leads to an increase in flow in the middle of the river, by using conservation of momentum. A decrease in flow at the banks leads to an increase of sedimentation, while an increase in the middle of the river leads to an increase of erosion of the riverbed, leading to a deeper river. At last, the island will be allowed to flood, which makes the design done *with* nature, instead of against nature.
- **Multipurpose**
  The soft dyke will serve the following purposes:
  - Accommodation space for housing As most of the island be be below sea level in 2075 (see chapter 12), houses will be have to be located on higher elevated locations, or be able to float. Stilted and floating houses will be discussed in chapter 7.
  - A grid for road transportation Many locations on the island will be unavailable for transportation during floods, so it would be wise to design the island in such a way that most of the island be accessible to a certain degree during flooding. The soft dikes are therefore the perfect locations for a transportation grid around the island, since no flooding will be taking place here, due to its higher elevation.
  - Room for nature The soft dike will host small melaleuca ecosystems, which will serve as a hub for biodiversity, enabling restoration of the local species. This could be useful for local sustainable fishery. The melaleuca trees will also increase sedimentation rates and reduce the impact of waves, which both increase the stability of the dike.
- **Systematic Thinking**

  The melaleuca trees planted on the soft dike play a crucial role in stabilizing the structure through their root systems, which prevent erosion and buffer the dike against wave action. Systemic thinking emphasizes that the dike's success is intertwined with the health of the melaleuca forest ecosystem. This means considering water salinity, tidal flows, and other conditions that support forest growth.

  Melaleuca forests are furthermore known to sequester large amounts of carbon. A systemic approach would evaluate how incorporating melaleuca forests into the dike can contribute to climate change mitigation strategies, and how that fits within broader regional or national climate policies. Melaleuca forests also can provide economic benefits to local communities through fishing, tourism, or timber. When applying systemic thinking, it's important to consider how the dike's construction and the health of the melaleuca forests will affect local livelihoods and ensure that community needs are integrated into the project.

A soft dike with melaleuca trees is more dynamic and changes over time. Systemic thinking emphasizes the need for an adaptive management strategy that monitors the growth of the forests and the integrity of the dike, making adjustments as necessary.

6.2.1. Failure Modes

The failure modes which are most relevant to consider for the soft dike are *B, C, E, F, G, H and J*, and are therefore considered risks, as explained in Table 6.1. To quantify these risks, calculations will be performed on the design of the soft dike, which will take local conditions into account.

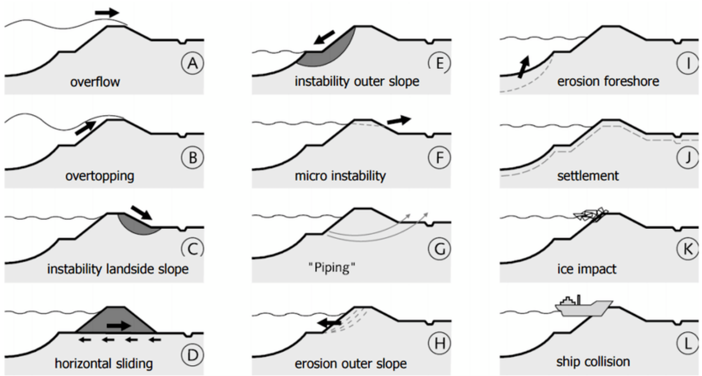


Figure 6.3: All failure modes for a dike.(TAW, 1998)

Failure Mode	Deemed Relevant?	Explanation
A	No	The soft dike will be designed in such a way that it will be located too high for overflow.
B	Yes	To determine the height of the dike, calculations for overtopping will be performed.
C	Yes	Liquefaction of the dike could cause instability.
D	No	It is assumed that the friction of the dike with the subsurface will be too great for sliding to occur.
E	Yes	Liquefaction of the dike could cause instability
F	Yes	By choosing the right material for the soft dike, and choosing the right dike cover, micro instability will be accounted for.
G	Yes	As water will be located higher than the hinterland, piping could be a problem, which could lead to liquefaction. Calculations for be done for this.
H	Yes	By means of construction of groynes parallel to the flow of the river, erosion of the soft dike will be limited. Forest and grass planting will also help reduce erosion.
I	No	The construction of groynes will significantly limit the amount of erosion of the foreshore.
J	Yes	The settlement is calculated in chapter 12.
K	No	Ice will not be able to form in the climate of the Mekong delta.
L	No	It is assumed that no major ship collisions will take place.

Table 6.1

6.3. Materials

Using sustainable materials helps reduce the ecological footprint of dike construction and ensures long-term environmental benefits. Key materials include:

- **Bio-based Geotextiles** Made from natural fibers such as jute or coir, these geotextiles stabilize the soil and prevent erosion during the forest establishment. Over time, they biodegrade without releasing harmful chemicals into the environment, aligning with ecological goals.
- **Recycled Aggregates** Materials like crushed concrete and reclaimed asphalt can be reused in the core or foundation of the dike, reducing the need for new raw material extraction and landfill waste.
- **Eco-friendly Concrete** Where concrete is required (e.g., for groynes), using low-carbon concrete made from recycled aggregates or cement alternatives (like fly ash or ground granulated blast furnace slag) minimizes CO_2 emissions during production.
- **Timber from Sustainable Sources** Timber elements, such as piles or platforms along the dike, can be sourced from certified sustainable forests. Bamboo is another renewable option, given its rapid growth and strength.

Using sustainable materials in soft dikes with forest and incorporating groynes represents a forward-thinking approach to riverbank management. By blending natural elements with sustainable infrastructure, this method addresses environmental challenges such as erosion, flooding, and climate change while enhancing biodiversity and ecosystem health. However, the success of these projects relies on thoughtful design, monitoring, and the careful selection of materials that align with ecological and community needs. Through a combination of nature-based solutions and sustainable construction practices, soft dikes can offer resilient and environmentally friendly riverbank protection for the future.

6.4. LCA

The Life Cycle Assessment (LCA) framework evaluates the environmental impact of a project throughout its life stages - from material sourcing, construction, and operation to end-of-life management. This LCA will assess the ecological, economic, and social impacts of building a soft dike in the Mekong Delta with a floodable hinterland, balancing flood protection, agricultural sustainability, and ecosystem restoration. The design includes:

- **Soft Dike** Integrated with melaleuca forests to control erosion and wave energy.
- **Groynes** To stabilize sediment, reduce wave energy and act as anchors for floating houses.
- A **floodable hinterland** to regulate water levels and support sustainable agriculture.

6.4.1. Goal and Scope Definition

- **System Boundary**: The assessment covers the entire life cycle:
  - **Material Extraction**: Sourcing sustainable geotextiles, aggregates, and timber.
  - **Construction**: Transport, installation, and planting of melaleuca forests.
  - **Operation & Maintenance**: Monitoring sedimentation and managing controlled flooding.
  - **End of Life**: Decommissioning and reuse of materials.
- **Functional Unit**: Protection of the hinterland over a lifespan of 50 years.
- **Impact Categories Considered:**
  - Global Warming Potential (GWP)
  - Water Use and Pollution
  - Biodiversity Conservation
  - Economic and Social Impact

6.4.2. Inventory Analysis

A detailed inventory of materials, activities, energy use and emissions is essential to evaluate the environmental burden:

Phase	Inputs	Outputs
Material Extraction	Bio-based geotextiles, recycled aggregates, sustainable wood, steel supports	CO2 emissions from processing and transport
Construction	Heavy machinery for dike, groins, and floating platforms; planting forests	Noise pollution, CO2 emissions
Operation & Maintenance	Monitoring water levels, replanting forests, sediment management	Water pollution form runoff, habitat creation
Floating Housing	Installation and upkeep of floating house attachments on kroynes	Minimal emissions, potential waste from human activity
End of Life	Decommissioning, reuse of wood and other materials	Waste management, emissions from equipment

Table 6.2: Inventory analysis

6.4.3. Impact Analysis

- **Global Warming Potential (GWP)**
  Using recycling materials and bio-based components reduces emissions. The planted melaleuca forests can sequester CO_2, helping offset construction emissions within the first decade.
- **Water Use and Pollution**
  The floodable hinterland minimizes salinity buildup and supports sustainable agri- and aquaculture. However, careful management is needed to monitor water pollution from agricultural runoff and human activities on the floating houses. Melaleuca forests act as natural filters, improving water quality by trapping sediments and excess nutrients.
- **Biodiversity Conservation**
  Melaleuca forests provide essential habitats for fish nurseries and migratory birds, promoting biodiversity. Groynes stabilize sediment, creating favorable conditions for further ecosystem restoration. Floating houses can facilitate ecotourism, generating economic benefits and awareness for conservation efforts.
- **Economic and Social impact**
  Floating houses offer new economic opportunities through tourism and aquaculture, increasing community resilience. Controlled flooding supports agriculture and fish farming. However, some communities may need temporary relocation, requiring participatory planning and social support.

6.4.4. Interpretation and Recommendations

Key findings:

- **Carbon Sequestration vs. Emissions**
  Melaleuca forests can offset the dike's construction emissions.
- **Water Quality Management**
  Sensors could be required to monitor water quality and manage agricultural runoff.
- **Social Impact**
  Community engagement is essential to minimize relocation challenges.

Recommendations:

- **Maximize Recycled and Bio-Based Materials**
  Use recycled aggregates and sustainable materials wherever possible to reduce the carbon footprint.
- **Monitor Water Quality with Sensors**
  Ensure floating house installations and agricultural practices do not introduce pollutants into the

water.

- **Adaptive Design**
  Ensure groynes and floating houses can adjust to changing flood levels.
- **Community Involvement** Engange local communities early in the design and planning phases to foster ownership and cooperation.

6.4.5. Summary Table and Conclusion

Impact Category	Impact Level	Mitigation Strategy
Carbon Footprint	Medium	Use recycled materials, promote melaleuca forests growth
Water Use & Pollution	Medium	Monitor water quality, manage human and agricultural runoff
Biodiversity Conservation	High Positive	Enhance habitats with forests, capture sediment with groynes
Economic Impact	Positive	Floating houses support tourism and aquaculture
Social Impact	Mixed	Engage communities, provide relocation support where necessary

Table 6.3: LCA Summary Table

The soft dike system, with groynes supporting floating houses and a floodable hinterland, presents a sustainable approach to flood management in the Mekong Delta. This hybrid solution offers ecological benefits through melaleuca forest restoration and biodiversity enhancement, while floating houses provide economic opportunities through tourism and aquaculture.

However, careful planning and community involvement are critical to address potential social challenges such as temporary relocation. With sustainable materials, adaptive management, and community participation, the project enhances the region's resilience to climate change and supports long-term sustainable development.

This LCA outlines the environmental, social, and economic impacts of the soft dike with groynes and floating houses, emphasizing the balance between flood protection, ecological health, and community well-being.

6.5. Structural Design

To make sure that the design for the soft dike is technically feasible, a technical design for the dike will be made. This will be done based on data found in literature.

Parameter	Value	Unit	Meaning
ξ	2.86	[-]	Breaker parameter 1
s_m	3.06 * 10^{-2}	[-]	Breaker parameter 2
α	26.57	[°]	Angle Talud
β	65	[°]	Incidence angle wave
r_{db}	0.997	[-]	Reductionfactor
H_{0m}	0.9	[m]	Significant wave height
T	4.3	[s]	Period of wave
H_{berm}	1	[m]	Height of bank
L_{berm}	55.60	[m]	Lenght of bank
L_0	46.70	[m]	Deepwater wavelength
B	52	[m]	Width of bank
γ_β	0.857	[-]	Reductionfactor for angle of waves
γ_f	0.8	[-]	Reductionfactor for roughness of forest talud
γ_b	1	[-]	Reductionfactor for presence of bank
$R_{2\%}$	2.07	[m]	Design requirement with 2% spill
d_b	2	[m]	Difference between height bank and mean water level
g	10	[m/s^2]	Gravitational acceleration

Table 6.4: An oversight of the values and meaning of the relevant parameters for the design of the soft dike. β was obtained from (**EsurfdataCanTho**). T and H_{0m} were obtained from (Nguyen-Xuan et al., 2022). L_0 was obtained from Equation 7.1. All other parameter values were determined using the formulas provided in this chapter.

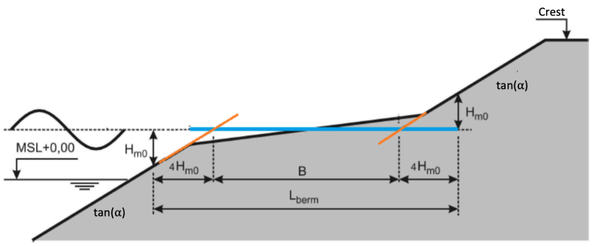


Figure 6.4: A schematic overview of the slope of the dike.

6.5.1. Failure mode B: Overtopping

Failure mode B could be a problem for the design of the dike, as it could flood houses on the dike, and could lead to other failure modes, such as instability of the outer and inner slope. Spilling of the hinterland is not seen as a problem, as this is allowed to flood. Overtopping is mainly caused by the:

- wavelength and waveperiod.
- geometry of the slope of the dike. Here, the slope is that water-facing side of the dike.
- roughness of the slope. This is influenced by the presence of the melaleuca forest.

Only 2% of the waves is allowed to overtop the dike (**dike_overtopping**).

The length of the berm, L_{berm}, is determined the following way:

$$L_{berm} = B + 2\frac{H_{m0}}{tan(\alpha)} \tag{6.1}$$

L_{wave} is determined by:

$$L_{wave} = \frac{gT^2}{2\pi} \tag{6.2}$$

To see with which types of waves one has to deal with as shown in Figure 6.5, one has to do the following calculation:

$$\xi_m = \frac{tan\alpha}{\sqrt{s_m}} \tag{6.3}$$

with,

$$s_m = \frac{2\pi H_{m0}}{gT_m^2} \tag{6.4}$$

After determining ξ_m, the following applies:

- *spilling*: at a very gentle slope.
- *plunging*: strong turbulence and dissipation (0.5 < ξ_m < 1.8)
- *collapsing* transition between plunging and surging.
- *surging*: little breaking of waves, much reflection (ξ > 1.8)

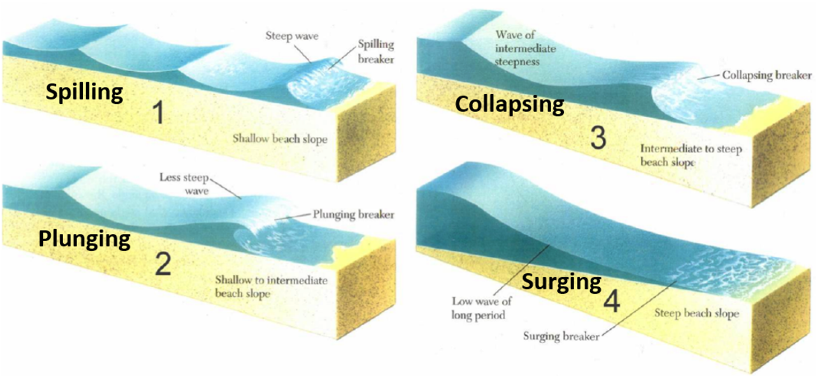


Figure 6.5: The our different type of waves

As the ξ_m is equal 2.84, the dike has to be designed for surging waves

Note that for the total height, the crest has to be located 0.5 [m] higher, due to a factor of safety which has to be added.

The reductionfactor of the berm can be calculated by:

$$\gamma_b = max\left\{1 - \frac{B}{L_{berm}}(1 - r_{db}) \ ; \ 0.6\right\} \tag{6.5}$$

$$r_{db} = \begin{cases} 0.5 - 0.5cos(\pi \frac{d_b}{R_{u,2\%}}) & \text{if berm above water level} \\ 0.5 - 0.5cos(\pi \frac{d_b}{2H_{m0}}) & \text{if berm below water level} \end{cases} \tag{6.6}$$

The reductionfactor for the wind direction can be calculated by:

$$\gamma_\beta = \begin{cases} 1 - 0.0022|\beta| & \text{if } 0^\circ \leqslant |\beta| \leqslant 80^\circ \\ 0.824 & \text{if } 80^\circ < |\beta| \end{cases} \tag{6.7}$$

The height for the dike can now be calculated using the lower formula as $\gamma_b\xi$ > 1.77:

$$R_{u,2\%} = \begin{cases} 1.75H_{m0}\gamma_\beta\gamma_f(\gamma_b\xi_m) & \text{if } 0.5 \leqslant (\gamma_b\xi_m) \leqslant 1.77 \\ H_{m0}\gamma_\beta\gamma_{f,surging}(4.3 - \frac{1.6}{\sqrt{\gamma_b\xi_m}}) & \text{if } (\gamma_b\xi) > 1.77 \end{cases} \tag{6.8}$$

The total height for the dike is calculated by:

$$Height\ of\ Crest = MWL + H_{hightide} + R_{2\%} + 0.5 \tag{6.9}$$

Which results in a minimal total height of of 0 + 2 + 2.07 + 0.5 = 4.57 meters above the mean water level of the river.

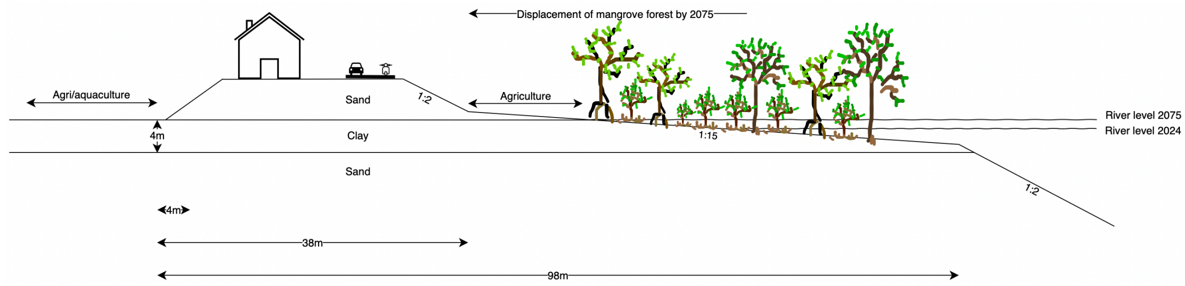


Figure 6.6: The conceptual design for the soft dike. The melaleuca forest can be easily recognized, as well as the multipurpose aspect of the dike (by all authors, 2024).

6.5.2. Failure mode G: Piping

When the water level is higher than the level of the hinterland, piping (seepage) can occur. This means that the hinterland will flood, which is not necessarily bad, since the hinterland is allowed to flood. Piping does however often cause failure of the dike, as the hydrostratic pressure will be greater than the overburden pressure. This means that the pressure of the the pore water exerts a higher pressure on the grains than the grains on the pore water. To check whether piping will take place, a calculation will be performed, based on the design presented earlier.

Boundary conditions:

- Pressure head, h, at ground level is equal to 0 [m].
- Hydraulic conductivity, k, is equal 3 * 10^{-8} [m/s] for the clay layer.
- The volumetric weight, γ_w, is equal to 18 [kN/m^3] for the clay layer.
- The clay layer is underlain by a highly permeable sand.

To get a feeling for the amount of seepage taking place, a calculation can be performed to quantify the seepage:

$$h_0 = z + \frac{p}{\gamma_w} \tag{6.10}$$

which results in a pressure head at the base of the clay layer of 2 [m]. As the pressure head at ground level is equal to 0 meters, the pressure head gradient, dh/dz, will be equal to -0.5.

The seepage, q, is given by:

$$q = -ki = -k\frac{dh}{dz} \tag{6.11}$$

This results in a seepage of 0.0012 [m/day]. By making the simplification that the whole island experiences the same seepage rate, the total seepage rate could be calculated:

$$Total\ seepage\ rate = qA \tag{6.12}$$

by using an island cover of 2.90 [km^2], the total seepage rate of the island will be equal to 3370 [km^3/day].

To see at which flood level liquefaction of the dike would occur, one could perform a calculation. Liquefaction occurs when the effective stress is equal to zero. The total stress that clay layer exerts on the layer below is equal to 18 * 4 = 72 [kN/m^2]. This means that the power pressure as the base of the layer should also be equal to 72 [kN/m^3]. This is equal to 72/10 = 7.2 [m] of water. 7.2 - 4 gives a 3.2 [m] head, which is means that the river could flood up to 3.2 [m] relative to the mean river level in 2075. When this threshold is met, liquefaction will cause failure of the embankment. The rest of the embankment is largely redundant in this scenario.

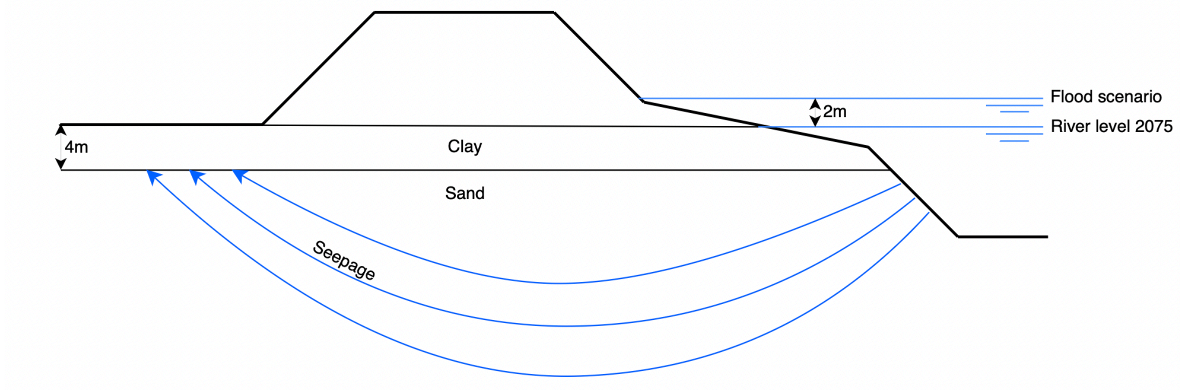


Figure 6.7: A schematic oversight of seepage of the dike (by all authors, 2024).

6.5.3. Conclusion

In this chapter a design was presented for a soft dike on the Cồn Khương island. This design gives an answer on the research question: *How would a soft dykes look like on Cồn Khương island*. It was found that melaleuca forest could reduce the impact of waves on the dike, as well as to trap sediments. The addition of groynes support the entrapment of sediments needed for the growth of the forest on the talud of the dike.

The choice of materials could thereby reduce the environmental footprint for the construction of the soft dike. To make sure that design of the soft dike meets the goals as formulated in the vision (section 4.3), a LCA was made to outline the environmental, social and economic impact of the construction.

The soft dike will be a multi-purpose solution for current and future environmental threats on the island, which incorporates infrastructure, accommodates (dry) housing, and enhances biodiversity.

7

Floating Structures feasibility

This chapter answers the following sub-research question: 'How can we build a modular floating pontoon with local construction methods and materials to facilitate living on water in the year 2075?'.

The chapter begins by outlining the design requirements, including vertical deflection limits, pontoon size, design life, and ultimate service load (USL). Consideration is also given to factors like wobbling tolerances and the weight capacity of the platform, ensuring stability and usability in varying conditions. The chapter then examines the forces acting on the platform, including environmental loads such as wind, waves, and currents, which directly influence the pontoon's structural performance. Material selection is guided by a Multi-Criteria Decision Analysis (MCDA), incorporating Life Cycle Assessment (LCA) to ensure durability, cost-efficiency, and environmental sustainability. Attention is also given to the design of the structure, which prioritizes flexibility and ease of repair, ensuring that the pontoon can be maintained with minimal downtime. The mooring system is analysed in detail, considering different mooring designs to keep the pontoon secure under varying load conditions. Both structural and offshore analyses are conducted to evaluate the pontoon's behaviour under static and dynamic forces. Finally, the chapter discusses potential design reiterations based on the outcomes of these analyses, allowing for adjustments that optimize performance and ensure compliance with the defined design criteria.

7.1. Location

The design of the pontoon can be implemented along the outer edges of Cồn Khương Island, specifically in areas highlighted with green markings on the image below. This location is advantageous for several reasons. Firstly, there is not a lot of space available for the installation of the pontoons, ensuring that they can be deployed without overcrowding the area. Additionally, this location is useful for efficient trash collection systems, which is one of problems identified in chapter 2.

Moreover, the outer edges of Cồn Khương Island are particularly susceptible to flooding and elevated water levels, making it an ideal site for the pontoons. By positioning the pontoons here, we can mitigate potential risks associated with high water events and provide a safe and accessible platform for various activities. Furthermore, the design allows the pontoons to be securely anchored to potential groynes, ensuring their stability and resilience against strong currents and tides.

The pontoon has been engineered to adapt to a range of environmental conditions, with calculations conducted to account for extreme scenarios that may arise in the Mekong Delta. This adaptability means that the pontoons can be deployed not only on Cồn Khương Island but also across various locations within the Mekong Delta region. The flexibility of the design ensures that these structures can serve multiple purposes, from recreational use to facilitating ecological conservation efforts and also providing a sustainable solution to address the challenges posed by climate change and rising water levels.

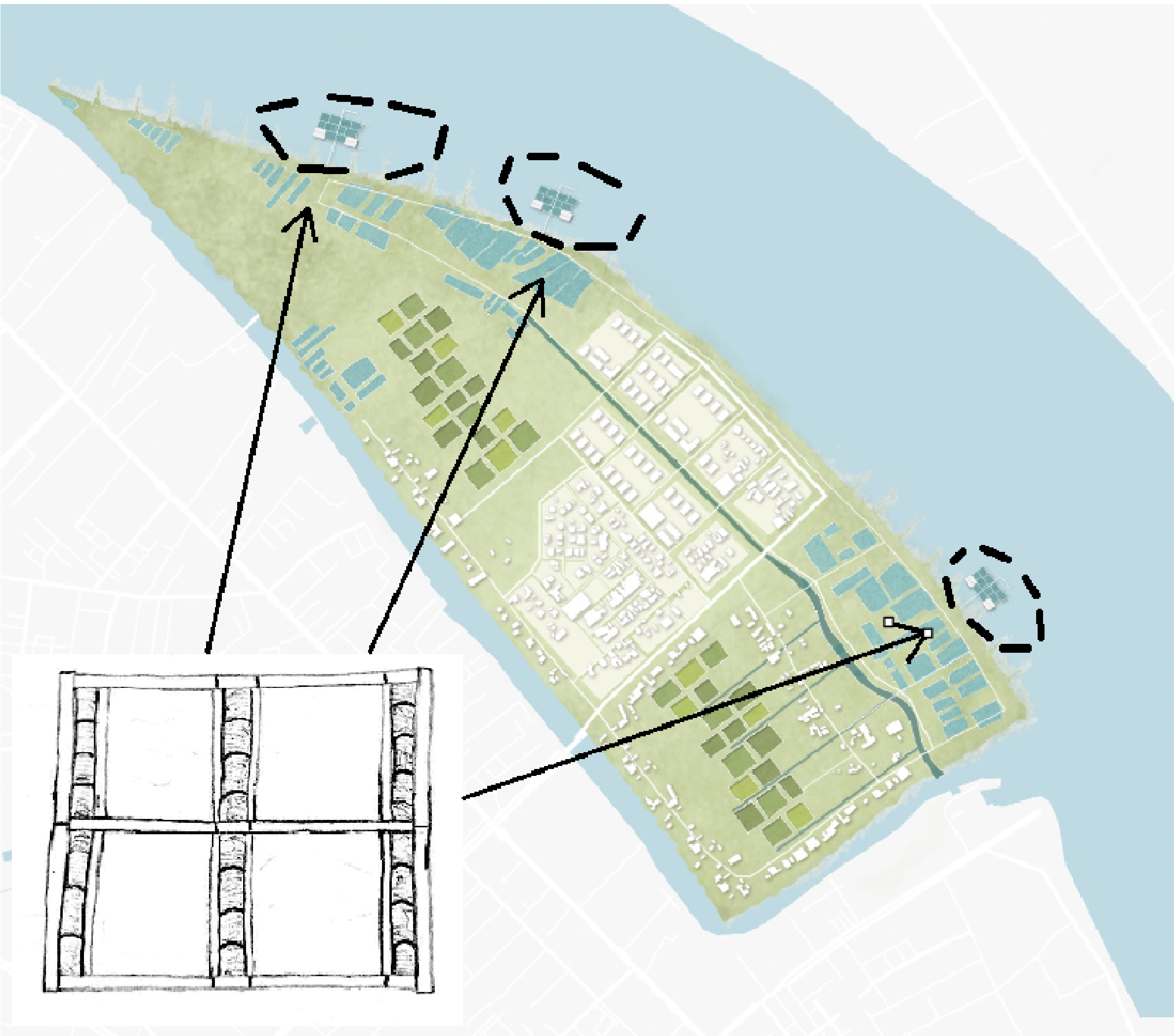


Figure 7.1: Location around Cồn Khương island (by all authors, 2024).

7.2. Design requirements

Establishing design requirements for a pontoon involves considering various factors to ensure it meets its intended function and needs. The pontoon will be designed using the vision, presented in chapter 4, as a guideline. Furthermore, the design will have to fulfil social, technical and practical requirements such as the desired size of a dwelling and manufacturability.

With regards to the vision, the pontoon must be systemic in such a way that more pontoons can be connected to each other and flexible in the sense that it is easy to assemble, disassemble, repair or maintain. Additionally, the pontoon will be multi-purpose so that it can be used for householding, agricultural purposes and/or fish farming. Furthermore, the pontoon will be designed using natural materials from the region as much as possible. Lastly, sustainability will be taken into account as an integral aspect during the whole design process.

When designing the pontoon it is important to consider the people who will use it. In Vietnam the average household consists of 3.8 people according to Global Data Lab, 2023. Furthermore, in line with the National Housing development strategy (E.Baochinhphu, 2022), the goals is that the average Vietnamese dwelling in a rural area will need a surface area of 26 square metres. Therefore, the aim is to design the pontoon with a surface area of at least 100m2, so that future families who build a dwelling on the pontoon can live comfortably.

Besides the size of the pontoon, another important factor to consider is the fact that a common practice for people who live on water is to make use of fish farming as their livelihood (D. T. Nguyen et al., 2018). This means that the pontoon needs to be designed in such a way that it can be used for fish farming. This means that a net can be attached beneath the pontoon and that a large enough feeding hole can easily be made in the deck. Considering the fact that the pontoon will be used and built by locals it is desirable to be able to have a lightweight design which can be made on the riverbank or shore right next to the location where the pontoon will be in the water and can also be easily transported on land if necessary.

Furthermore, the pontoon may not tilt too much to ensure comfort. Therefore the design of pontoons intended for human habitation, it's essential to maintain an allowable tilt (roll or heel) that ensures comfort and stability. Based on studies and design practices in marine architecture:

- A tilt of 3 degrees or less is generally considered acceptable for human comfort, particularly for long-term use, such as living on the structure . This level of tilt is common in floating platforms and ensures that occupants do not feel disoriented or uncomfortable (Splinter et al., 2017).
- In more dynamic conditions (e.g., from wave action or uneven weight distribution), tilts up to 5-7 degrees can be tolerated temporarily without significantly compromising comfort, though it may be noticeable (Splinter et al., 2017).

These figures align with design criteria for floating walkways and pontoons, where safety and comfort thresholds are set based on human postural stability and the platform's motion response under typical condition

With regards to the design life, the aim is to design a pontoon which will have a lifespan of 50 years. In offshore engineering a typical lifespan is usually 25-30 years (Animah and Shafiee, 2018). It was decided however, to increase this lifespan up to 50 years since the pontoon can also be used for residential purposes.

Strength requirements will also be imposed on the design. The materials chosen for the design may not exceed their maximum strain or tension capacity, more about this will be discussed in the materials section 7.3 of this chapter. The strength capacity of the materials will be adjusted with safety factors from the Eurocode .

Lastly, the capacity of a single pontoon needs to be able to float a dwelling of considerable size. The average house in Vietnam is constructed with relatively light materials like corrugated steel, local timber and plastic panels (Teutonico et al., 2006). Furthermore, if a mooring line is used to keep the pontoon in place, the pontoon will also need to be able to withstand the forces of the mooring line. The required capacity of a pontoon has therefore been established at 3500 kg, this will allow for more than enough materials and objects to be placed on the pontoon and leave some margin for the forces of a possible mooring line.

Here is a brief summary of the design requirements for the pontoon:

Systemic and Flexible Design:

- Must be systemic to allow connection with other pontoons.
- Easy to assemble, disassemble, repair, or maintain.
- Multi-purpose use for householding, agriculture, and fish farming.

Material Use and Sustainability:

- Use natural materials from the local region where possible.
- Sustainable materials to align with environmental and social goals.

Size Requirements:

- Minimum surface area of 100 m² to accommodate a typical Vietnamese household (3.8 people).
- Comply with the National Housing Development Strategy and ensure enough space for comfort (26 m² per person).

Fish Farming Adaptations:

- Design must allow attachment of a net underneath for fish farming.
- Include provisions for a feeding hole on the deck.

Lightweight and Portable:

- Must be lightweight to facilitate construction on the shore and easy transport if necessary.

Tilt and Stability:

- Maintain an allowable tilt of 3 degrees or less for comfort (Splinter et al., 2017).
- Temporary tilt up to 5-7 degrees may be tolerated under dynamic conditions.

Design Life:

- Target lifespan of 50 years, longer than typical offshore structures (25-30 years) (Animah and Shafiee, 2018).

Strength and Safety:

- Materials should not exceed their strain or tension capacity.
- Apply safety factors from Eurocode for material strength considerations.

Load Capacity:

- Pontoon must support a total weight of 3500 kg, enough for a dwelling and additional loads like mooring forces (Teutonico et al., 2006).

Mooring System:

- Design should account for the forces from mooring lines, ensuring structural integrity while keeping the pontoon in place.

7.3. Materials

The materials that will be used for the main structural/floating component will be chosen through a multi criteria analysis with criteria such as sustainability, availability and material properties. The amount of material will be minimised due to practical, financial and sustainable reasons. In this report, financing is not the main focus point.

To narrow down the wide range of possible construction materials, a selection has been made based on the project's vision, the preference for using local materials and techniques, insights from fieldwork and literature review. The following potential materials for the main floating body of the pontoon have been identified and will be further analysed in this chapter: bamboo, plastic drums, jackfruit, timber, styrofoam and melaleuca timber.

Bamboo
From several sightings, two interviews and literature research it became apparent that Bamboo used to be a very common construction material for floating structures. Nowadays, according to the owner of the floating fish farm, bamboo has been slowly replaced by large, blue, plastic drums due to the reduced maintenance required. However, considering the vision, bamboo is a very suitable material to reconsider. 'Bamboo can grow naturally without the use of pesticides as it is not eaten by insects. A wonderful bacterium is found in bamboo, called bamboo kun. The products of bamboo fibre are ecofriendly and biodegradable having anti-bacterial properties. Bamboo has a higher specific tensile strength than the synthetic fibres. The main properties of bamboo are their light weightiness and high tensile strength' (Gutu, 2023).

Plastic drums
As mentioned before, the use of plastic drums has become very common in the Mekong Delta to build floating structures with. These drums are oftentimes bonded together with a timber frame on top. It is assumed, by the observations made in the fieldwork week, that the drums used are 220 litre drums which are 581 mm wide and 935 mm high. Although the use of plastic is not considered to be sustainable, it is important to also consider the lifespan of materials, the required maintenance and their potential to be reused. Furthermore, the plastic drum is commonly used which aligns with the preference to use materials which are already known and used by locals.

Melaleuca timber
Based on various literature, Melaleuca timber has also been identified as a suitable construction material to consider in the MCDA. Of all the advantages of Melaleuca forests, the most important benefit seems to be their environmental protection function (Trung, n.d.). In addition to its ability to contribute to climate protection Melaleuca forests also play a critical role in regulation of water levels: Melaleuca forests preserve a remarkable amount of water in the rainy season and in turn, provide an important source of ground water (fresh water) during the dry season, thus being a primary water source for daily life and agriculture production in adjacent areas (Trung, n.d.).

Jackfruit timber
Another suitable locally grown type of tree which can be used for timber is the Jackfruit tree. 'Jackfruit trees can be planted in poor soils and marginal lands, and they have a year-round availability due to the flexibility of crop planting and harvesting. Because of its low environmental requirements and labor costs, jackfruit has become the fastest growing and most common fruit tree in tropical and subtropical regions' (Abedin et al., 2021). This is why the jackfruit tree can grow in the region of the Mekong Delta and can be used as construction material.

Styrofoam
Another material which is often used by the locals and has a low degradation rate (Nhaima Atiq et al., 2017) is styrofoam. At various instances during the fieldwork trip, styrofoam has been observed as a construction material for floating structures. Considering styrofoam's very low density, costs, insulation properties and durability (Nhaima Atiq et al., 2017). However, just like the plastic drums, the material itself is not necessarily considered to be sustainable. Furthermore, one of the design requirements is that the pontoon can easily be made on the shore and transported by locals themselves into position. This is another reason why styrofoam is a potential construction material to use for the pontoon as the main floating body.

7.4. LCA & MCDA

In this section the Life-cycle assesment (LCA) and Multi-criteria design analaysis (MCDA) are presented. The LCA is done before the MCDA to assess which criteria are relevant.

7.4.1. Life-cycle assessment

A life cycle analysis is made to be aware of how various approaches and stages are incorporated in the design. The LCA helps identify opportunities to reduce resource consumption, minimise waste, lower greenhouse gas emissions, and increase safety awareness throughout the structure's life-cycle. Within the life-cycle assessment, the following stages are considered: procurement and material supply chain, fabrication, transport, installation, operation management and decommissioning (see Figure 7.2).

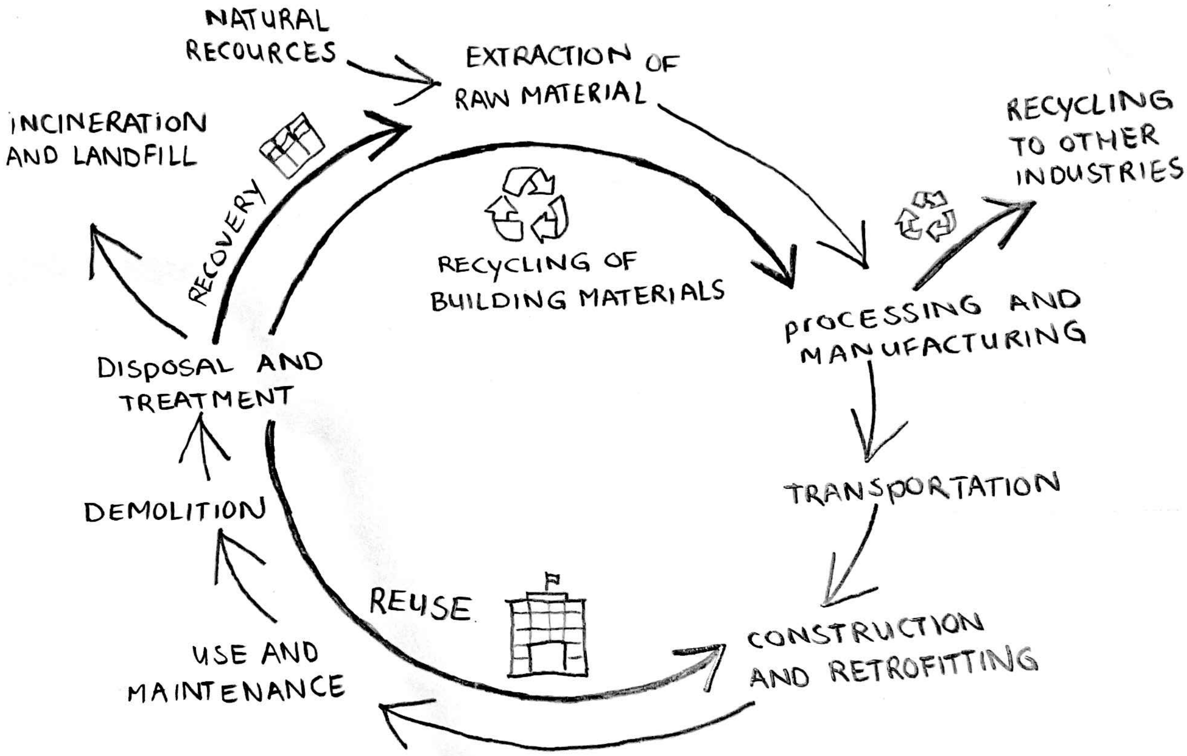


Figure 7.2: Stages of the life-cycle assessment (by all authors, 2024).

Procurement and material supply chain

The procurement phase emphasises sourcing materials that are both environmentally sustainable and locally available to reduce transportation emissions. The 2075 design will incorporate sustainable practices, utilising natural resources or recycled building materials. This approach requires a strong understanding of material properties and application methods (OE44097, 2023-2024).

Vietnam is highly dependent on imports of raw materials from China. Also, Vietnam's reliance on Chinese imports of half-fabricated products results in longer production times and higher logistics costs. Additionally, uneven production capacities at various stages highlight the need for more focus on educating its workforce. By improving skills, Vietnam can attract foreign companies to shift more upstream manufacturing activities and thereby reduce dependence on imports from China (ARCGroup, 2023).

Fabrication

The pontoon will measure approximately 10m by 10m. Constructing the structure on land is a straightforward and practical approach, but it requires a sufficient area to build on. Some components can however be prefabricated, while others will be built on-site to reduce construction time and lower production costs (OE44097, 2023-2024).

Considering transportation, it's important to note that only 20% of Vietnam's roads are paved with medium to low quality materials. This results in cracks and uneven surfaces. There is a vision for 2050 to expand the existing national road network, because road transport is very important for the logistic sector. This vision can be incorporated into the report's vision for 2075.

Apart from transportation infrastructure, key technical elements for fabrication include electricity supply, water supply, and waste treatment systems. It's crucial that local factories have access to all utilities to run operations in order to supply materials for the pontoon (ARCGroup, 2023).

Installation

If the pontoon is constructed on-site, it must be moved to the waterside and launched into the water using a dedicated system, which requires a strong quay. If the pontoon is fabricated somewhere else, it will need to be transported by ship. In this case, installation methods include lifting the pontoon into place or floating it to the operation site. A simple and efficient installation method can improve the feasibility of the design and eliminate the necessity of having a very strong quay. For example think of installation in sections or as a single unit. Note that it is important to consider environmental conditions during installation, using a 1 year return period.

Figure 7.3: Installation of a fixed house (fieldwork 27 August 2024)

Once the pontoon is at the operation site, if needed the mooring system can be installed. The number of mooring lines required will depend on the horizontal stability of the structure. If technically possible, fewer lines are preferable to reduce installation time and costs, as mooring line installation is labour-intensive (OE44097, 2023-2024).

Operation management

To ensure sustainability, the design must be maintainable during operation. Therefore in the design phase can already be thought of easily maintainable or repairable systems, or the design can include easily repairable systems where components can be quickly connected and disconnected. Additionally, other mechanical and instrumentation systems, such as ventilation, ballast systems, corrosion protection, firefighting, and drainage systems, can be integrated (OE44097, 2023-2024). These systems can be for example designed with nature.

Figure 7.4: Operation phase of a floating fish farm (fieldwork 29 August 2024)

In addition to monitoring systems for the structure, it's also important to predict changes during extreme conditions. This monitoring can help mitigate the impact of harsh environmental events. Also, the new 2023 Housing Law provides house ownership development, operation management and use; housing transactions; and state management of housing in Vietnam (VLLF, 2024).

Decommissioning

One of the design values is sustainability, which is an important factor during the decommissioning phase. The impact on the environment after the pontoon's lifetime should be minimised. For this phase, the choice of material is important. The goal is to maximise the reuse of as many elements as possible. An appropriate method should be employed to facilitate this process (OE44097, 2023-2024).

The goal for 2025 in Vietnam is to eliminate all dilapidated houses across the country. This is part of the National Target Program for Sustainable Poverty Reduction from 2021 to 2025 (VLLF, 2024). It is a step towards a sustainable decommissioning phase. For the decommissioning phase of the pontoon, strategies for reuse, reduce, renew, recycle and/or redesign must already be considered in the design.

7.4.2. Multi-criteria design analysis

In order to determine which material is most suitable, a multi-criteria design analysis is performed. The criteria are determined through the performed LCA (subsection 7.4.1) and also by the design requirements presented earlier in section 7.2. In Table 7.1, all criteria and corresponding units are presented. The values are afterwards normalised with a value between 0 and 1. Lastly, the criteria are also given a weight. This is done because some criteria are considered to be more important than others.

One of the criteria, which is manufacturability, does not have a metric or actual value. Based on literature research the materials have been given a score between 0 and 100 to assess how convenient the material is for manufacturing. It is important to note that although literature research can reveal how pliable a material is or how easy it is to drill in a material, the rating is still relatively subjective and relies on the individual experience and preference to work with a certain material.

Furthermore, the values of the last criteria have been inversed. This is done because a higher score in this case means it is less preferred, by inversing the values we circumvent this problem.

-	Bamboo	Plastic drums	Melaleuca timber	Jackfruit timber	Styrofoam
Density kg/m3	650	189	780	700	38
Tensile strength n/mm2	160	56	106	123	0.7
Compression strength n/mm2	60	90	52	76	1.02
Degradation time years	4	450	10	12	500
Float capacity kg per m3	350	998	220	300	962
Manufacturability	80	90	78	70	80
Weight per kg float capacity	0.00123	47.61	0.1	0.1	2.105

Table 7.1: MCDA table

-	Bamboo	Plastic drums	Melaleuca timber	Jackfruit timber	Styrofoam
Density kg/m³	0.344	1.000	0.413	0.370	0.020
Tensile strength n/mm²	1.000	0.350	0.663	0.769	0.004
Compression strength n/mm²	1.000	1.500	0.867	1.267	0.017
Degradation time years	0.008	0.900	0.020	0.024	0.000016
Float capacity kg per m³	0.364	1.000	0.220	0.301	0.001022
Manufacturability	1.000	1.125	0.975	0.875	1.000
Weight per kg float capacity	0.00003	1	0.0021	0.0021	0.044

Table 7.2: Normalised MCDA table

	Bamboo	Plastic drums	Melaleuca timber	Jackfruit timber	Styrofoam
Density kg/m³	0.516	2.000	0.619	0.555	0.030
Tensile strength n/mm²	1.500	0.700	1.326	1.538	0.0048
Compression strength n/mm²	2.000	3.000	1.734	1.5204	0.0204
Degradation time years	0.0096	1.08	0.024	0.0288	0.0000192
Float capacity kg per m³	0.4368	1.200	0.264	0.3612	0.0012264
Manufacturability	1.000	1.125	0.975	0.875	1.000
Weight per kg float capacity	0.0015	0.05	0.000105	0.000105	0.0022
Cumulative score	**5.4639**	**9.155**	**4.9409**	**4.574**	**1.063**

Table 7.3: Weighted and normalised MCDA table

Due to the large float capacity, the relatively decent strength properties and the very long degradation time, the plastic drums are the best material according to the MCDA.

7.5. MetRiver Data

This section refers to the combined effects of meteorological (weather) and river conditions on offshore structures and operations. These conditions have a significant impact on the design of an offshore structure for ensuring safety and efficiency. The Metriver conditions include a variety of environmental variables, such as water depth, wind speed, wave height, currents and tides. These conditions can be highly variable depending on the location, time of the year and up-to-date information. For this report and the design of pontoons for the Cồn Khương Island of Cần Thơ, no exact datasets are available. Information is therefore gathered from literature research instead of more precise prediction models.

7.5.1. Wind speed & Direction

The design of the pontoon consists of floaters, therefore it is necessary to collect wind data. For the real life situation, wind speeds at 10 [m] height gives a good representation. In Figure 7.5 wind data of 3 months for Cần Thơ and its average is plotted. The average wind speed from this plot is 11 [m/s].

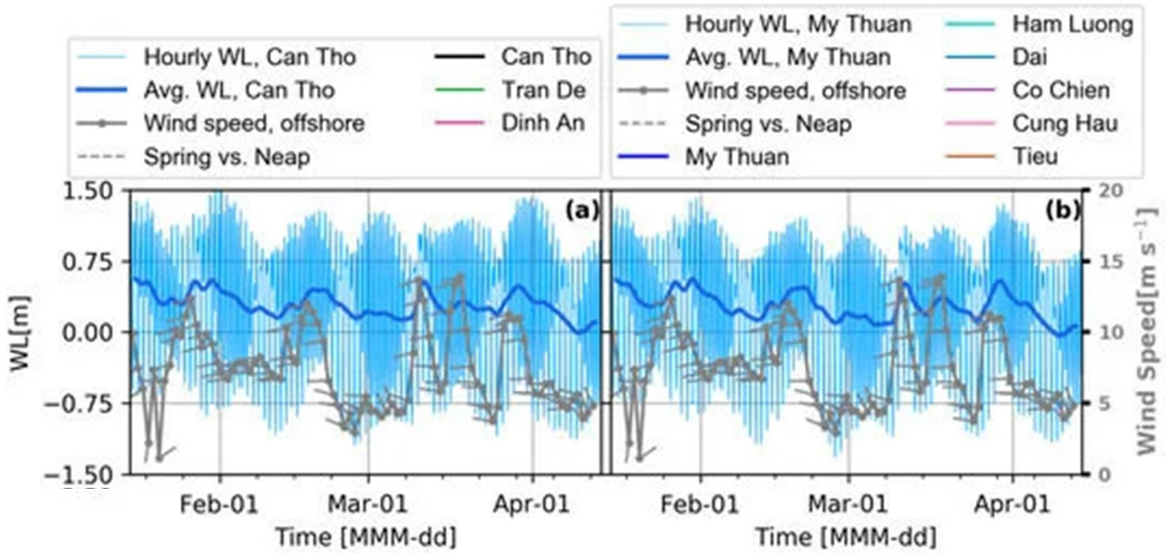


Figure 7.5: Wind speed and direction for Cần Thơ (left) (**EsurfdataCanTho**)

Figure 7.5 shows the result of an Extreme Value Analysis (EVA) conducted using data from Copernicus. Additionally, a plotted set of wind data from 2024 is available, Figure 7.6. This dataset cannot be used for predictions with EVA, as it is only available in a figure. Nevertheless, the data can be evaluated using a Peak Over Threshold (POT) approach.

POT is a technique to sample extremes. It consists of selecting the excesses over a defined threshold with a minimum time between them. Two parameters are therefore important: the threshold and declustring time (the minimum distance between two extreme observations). For this time series the threshold $th = 11[m/s]$ and declustring time $dl = 72[h]$. The declustring time is chosen to be 72 hours, because this is an acceptable value for windstorm data (since this allows storms to be decoupled and only assigning one value for each such event). In Figure 7.6 the application of this method is shown. In the period from January till March a concentration of extremes can be seen. This means that there were several storms (with high wind speeds).

The extreme values for the given threshold are visually identified and stored in a list. The process of the best fitting distribution for the extreme values is done using Python. The magnitude of the wind speed can then be identified for the given return period of 50 years. The best fitted distribution is the Gamma 3P. Compared to the other distributions, Gamma 3P returns a relatively high value for the expected wind speed of 11.5 [m/s]. To assure safety, this value is chosen to be designed for.

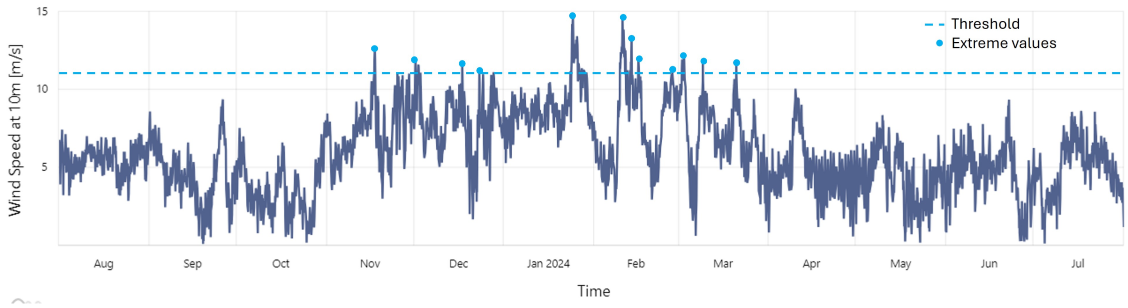


Figure 7.6: Peak over threshold plot of the yearly wind speed in Cần Thơ in 2024

Figure 7.5 and Figure 7.7 shows that the most common wind direction is from the West.

Figure 7.7: Wind direction in Cần Thơ

7.5.2. Wave height, Period & Direction

To identify the hydrodynamic loading on the floating pontoon, a reliable prediction of the expected wave height, period and direction is needed. Waves can be generated by wind and swell. A short fetch length will result in a lower height of the wind waves. Assumed is that the spread of the wind waves will be high and will only contribute to low wave height and small wave periods, since Cần Thơ is located 80 [km] inland. So the focus will lie on small wind generated waves, since high swell waves will not occur in the Hau river at the level of Cần Thơ.

Datasets for waves in the Hau river in Cần Thơ are not available. A study 'Hydrodynamic Modelling of New Segment Channel to Navigation Channel in Hau River, Vietnam' gives data (of an offshore station at the Hau river estaury) about wave height and wave period during a period from 1999 to 2008. The wave heigth ranges from 0.88 to 3.58 [m] and the wave period ranges from 4.3 to 9.6 [s] in dry season. The mean wave height and wave period in flood season is 1.29 [m] and 5.8 [s] respectively (Nguyen-Xuan et al., 2022). Assumed is a wave height of 0.9 [m] and a wave period of 4.3 [s], since Cần Thơ is located 80 [km] inland. These values are very conservative, but will take future extreme weather events into account.

The depth of the Hau river in Cần Thơ is 10 to 16 [m], for calculation for the pontoon, a river depth of 12 [m] is assumed (since the floating structures will be implemented near the river shore) (Nguyen-Xuan et al., 2022).

7.5.3. Tidal information

Still the physical processes governing tidal and subtidal (averaged over a tidal cycle) flow are not fully understood yet. However, it is important to understand these processes, especially for identifying current forces and for the freshwater distribution in the system. The Corpernicus tool gives the tidal information of Cần Thơ, see Figure 7.8.

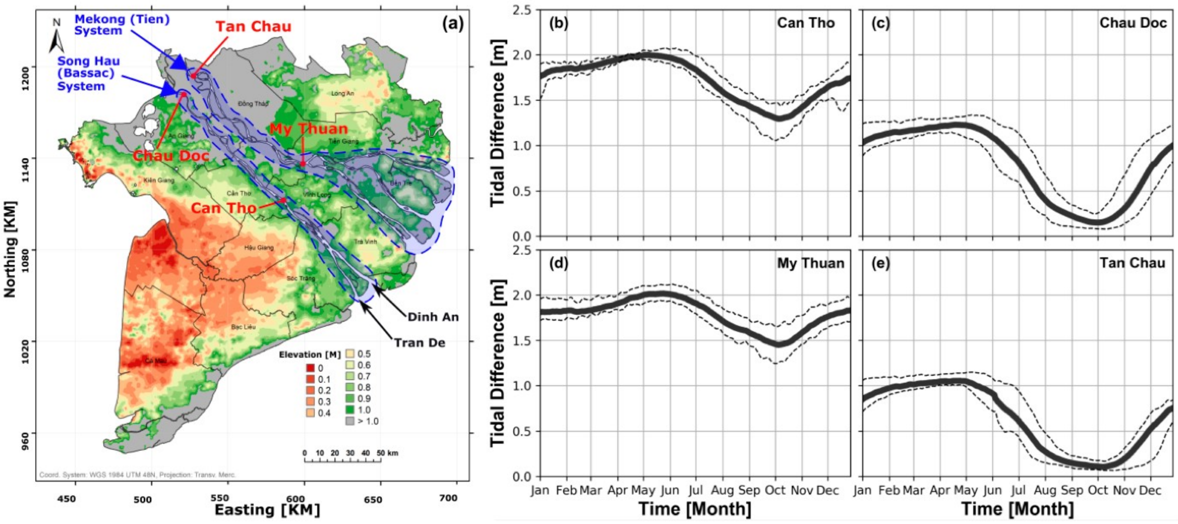


Figure 7.8: Tide chart and curves for Cần Thơ (b) in 2024 (**EsurfdataCanTho**)

From Figure 7.8, the maximum tide height is 2.1 [m]. Note that for 2075 an extreme scenario result in a sea level rise of 51 [cm] chapter 12.

The influence of the tidal regimes result in a current speed in the river. For the current speed at Cần Thơ, data of 2011 and 2020 is used. Simulations and observations established that the mean current speed is 0.8 [m/s] in 2011 (Pham-Van & Hai, 2016). By comparing simulations and monitored data in 2020, a mean current speed of 0.78 [m/s] was conducted (Vu et al., 2024). Based on these two datasets a current speed of 0.8 [m/s] is assumed.

7.5.4. Result and evaluation

Note that the data is found with literature research and not by using (actual) datasets. Assumptions are made to get a first thought about dimensions and loading.

Condition	Parameter	Value	Unit
Wind	Speed	11.5	[m/s]
	Direction	West	[-]
Waves	Height	0.9	[m]
	Period	4.3	[s]
Tides	Height	2.1	[m]
	Current	0.8	[m/s]

Table 7.4: Loading conditions and their parameters

7.6. Structure design

In this section the design process of the structure is presented. The goal was to design the pontoon in such a way that it could effectively be build and easily repaired and maintained.

To design a floating platform capable of supporting a load of 3,500 kg on a 10x10 meter area, two drum configurations are evaluated: vertical and horizontal. Each drum has a float capacity of approximately 200 kg, displacing 220 liters of water for a total of 202kg of effective buoyancy, after accounting for its self-weight of 18 kg. To therefore safely accommodate the required load, a minimum of 18 drums is necessary.

As can be seen in the image below, several iterations were made before opting for the configuration to design the pontoon in such a way that there are 3 linear elements in which the drums are positioned and 3 trusses to stabilise in the opposite direction.

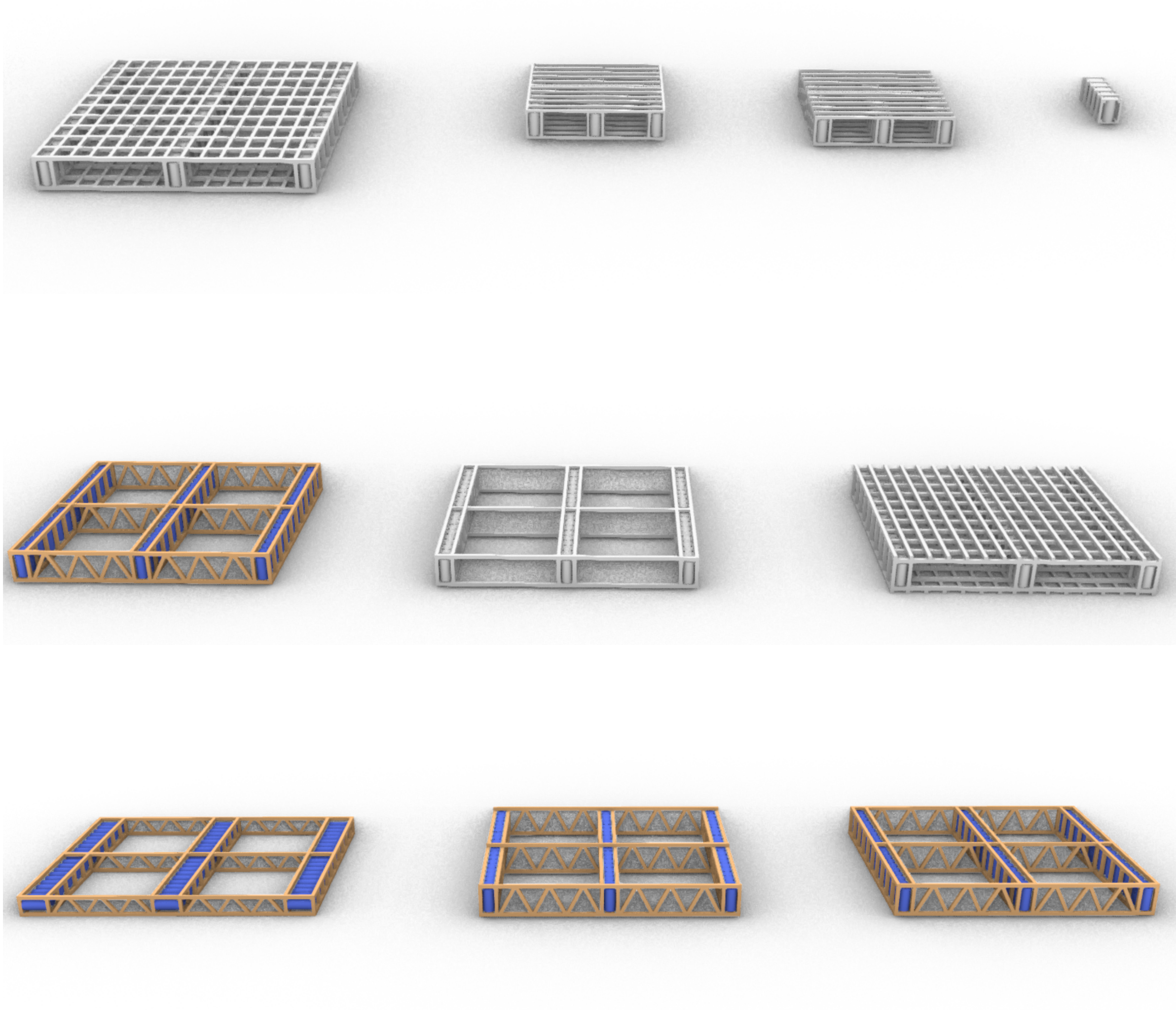


Figure 7.9: Design iterations pontoon (by all authors, 2024).

To optimize stability and support functionality, the drums will not only be positioned along the edges but also in the middle of the platform to limit the span. This configuration will also ensure a stable buoyant structure across its entire length, allowing for multipurpose use on the deck by being able to randomly place weight at a desired place.

By configurating the drums in 3 linear elements the amount of drag is also reduced when the pontoon is positioned in the direction of the current. Also considering the fact that fishing holes need to be made the pontoon can now be split up into 4 sections for fish farming. Trusses will be integrated to provide additional stability in the transverse direction. Furthermore, the design incorporates a 'sliding' or 'push trough' mechanism for drum repair.

In terms of drum orientation, vertical drums would allow for a denser configuration of four drums per square meter, totalling 400 drums and a buoyancy capacity of 80,000 kg. This method also facilitates easier access for repairs and storage, as the lids are accessible from the top. However, increased water resistance and reduced stability are potential drawbacks.

When opting for a horizontal drum configuration it is possible to have two drums per square meter, maximizing stability and reducing water resistance with a total capacity of 40,000 kg. Nevertheless, this configuration offers fewer drums, which could limit storage options and impact buoyancy.

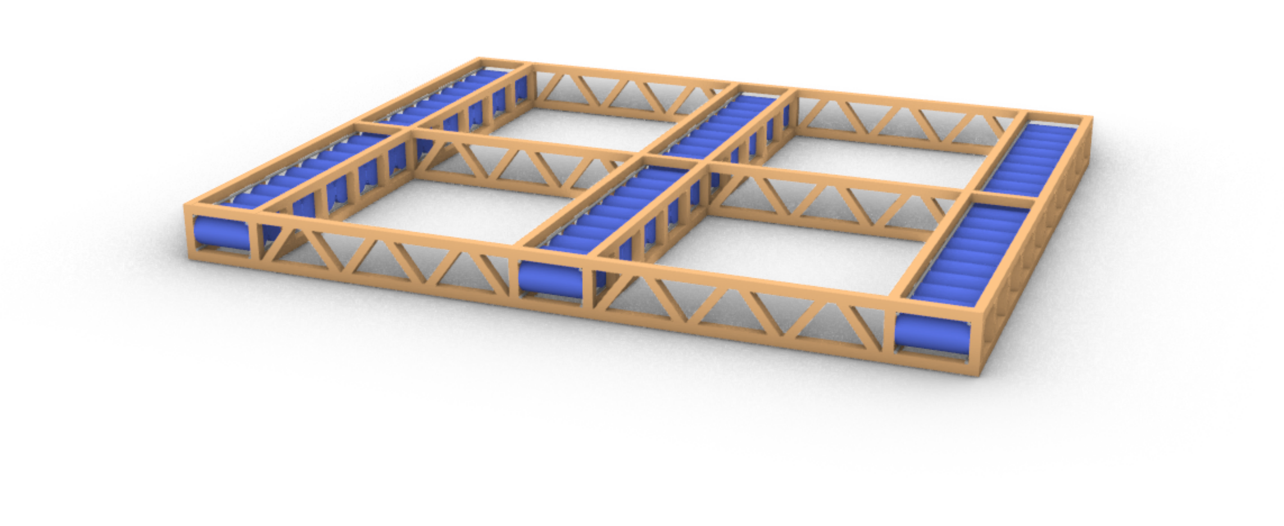


Figure 7.10: Horizontal configuration (by all authors, 2024).

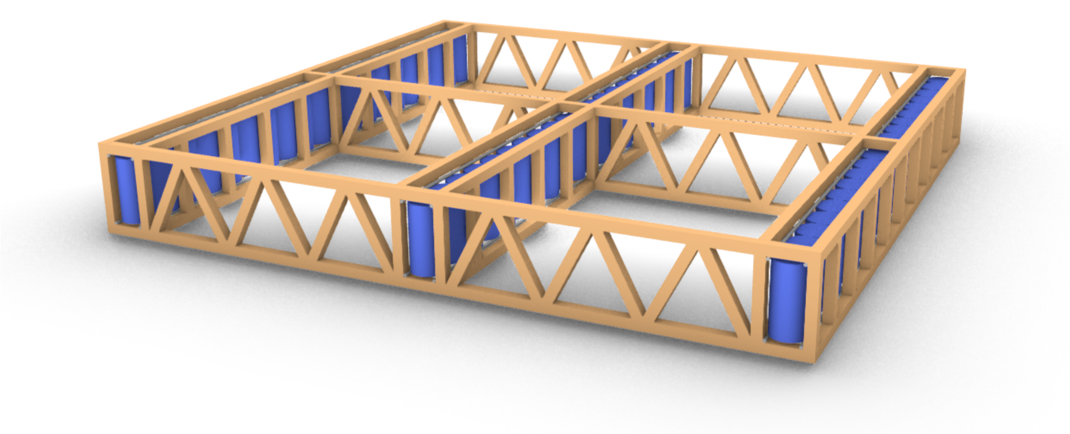


Figure 7.11: Vertical configuration (by all authors, 2024).

7.6.1. Horizontal load analysis

Hydrodynamic loads

The combination of current, wind and wave loads causes horizontal loads on the pontoon. Due to currents and waves, drag and inertia loads acting on the pontoon. The environmental loading regime is used to determine whether inertia, drag or both are normative, Figure 7.12.

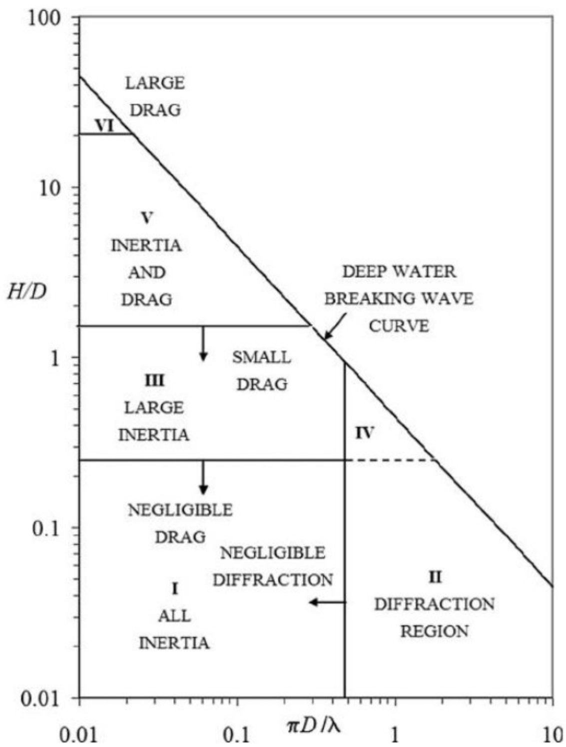


Figure 7.12: Environmental loading regimes

The determination of the forcing regime is based on the ratios of:

$$\frac{H}{D} and \frac{\pi D}{\lambda} \tag{7.1}$$

With:

- H = 0.9 [m]: wave height
- D = 0.5 [m]: diameter of plastic drum
- λ = 46.7 [m]: wave length based on airy wave theory for shallow water, $\lambda = T\sqrt{gd}$
- T = 4.3 [s]: wave period
- d = 12 [m]: depth

Following the necessary steps in the process, the combination of these parameters gives an all inertia forcing (Region I). The forcing on the pontoon can then be determined using the Morison equation.

$$f = \frac{\rho\pi}{4} C_m D^2 \dot{u} + \frac{1}{2}\rho C_D D u^2$$

With:

- ρ = 1000 g/m^3: water density
- C_D = 1: drag coefficient
- C_m = 1 + C_a with C_a = 1: inertia coefficient
- D = 0.5 [m]: diameter of the plastic drum
- u = u_{wave} + $u_{current}$: speed of the water at depth of the structure
- $u_{current}$ = 0.8 [m/s]: current velocity

$$u_{wave} = \frac{H}{2}\omega e^{-kz}$$
$$\dot{u} = \frac{H}{2}\omega^2 e^{-kz}$$

With:

- k = $\frac{2\pi}{\lambda}$: wave number
- z = 0.75 [m]: depth of pontoon
- $\omega = \frac{2\pi}{T}$: angular frequency

By applying the Morison equation a load of $f = 0.7[kN/m]$ is found. For this load a shelter coefficient of 2.0 is applied to account for the three tubes next to each other. Both, wave and current loading, are taken into account instead of only current (static) loading. Therefore the design load is very conservative.

Wind loads
Based on the general wind load equation, the wind load can be calculated.

$$F = \frac{1}{2}\rho u_{wind}^2 C_D D$$

With:

- ρ = 1.225 kg/m^3: air density
- u_{wind} = 11.5 [m/s]: wind velocity
- C_D = 1.0: drag coefficient
- D = 0.5 [m]: diameter of plastic drum

From the formula the wind load per unit length in vertical direction is 0.04 [kN/m]. For calculation of only the single pontoon this load will be neglected, since the area the wind is acting on is very small. However, for calculations of the pontoon with a house on top, the wind load should be taken into account.

7.7. Mooring Analysis

A system must applied to resist the horizontal hydrodynamic and wind loads. A mooring system, with the design values in mind, is a flexible system that is usable for different water levels.

A mooring system is applied to limit the motions and structural displacements. The catenary mooring system is the most widely used system and is often used in shallow to medium water depth. As shown in Figure 7.13, the mooring line of the catenary system is lying on the seabed in the static equilibrium position. The mooring forms a catenary shape due to the self-weight of the line which generates resistance to dynamic motions and structural displacements (Ma et al., 2019).

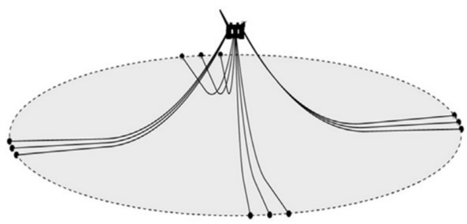


Figure 7.13: Catenary mooring system

Next, a spread mooring system is used, because it is simple and economical compared to a single-point mooring system. The spread of the mooring lines depends on a number of factors, such as design, installation, environmental conditions, mooring material and costs. In the equal spread design, all mooring lines are spread symmetrically with a uniform spread angle to simplify the design and installation (Ma et al., 2019).

7.7.1. Anchor system

The second step is to identify a suitable anchor system. There are different anchor systems for different loading and soil conditions, see Figure 7.14. For a catenary mooring system the anchor need to be designed for horizontal loads.

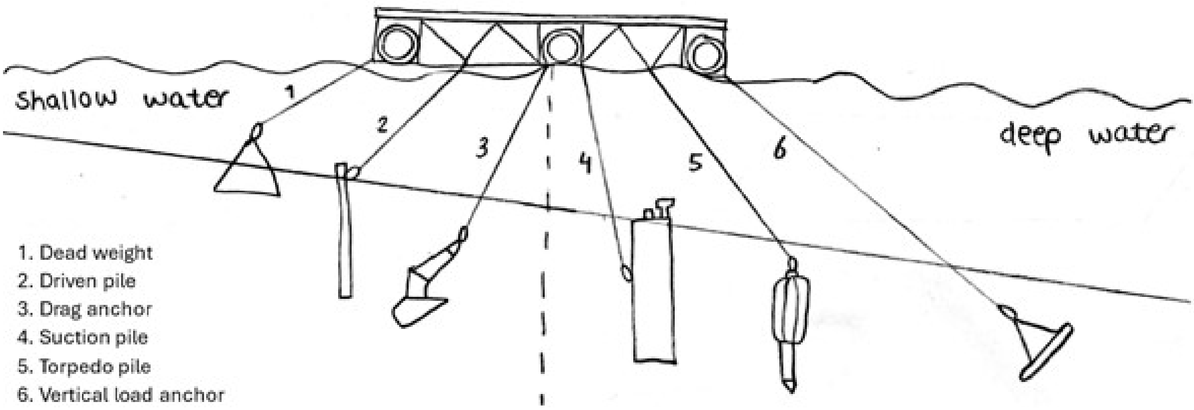


Figure 7.14: Different anchor types for shallow and deep waters (by all authors, 2024).

For the shallow water condition, common anchor types are: dead weight anchor, driven pile anchor and drag embedment anchor (DEA). There are two anchor design considerations: the structural design (including maximum loads and fatigue damage over lifetime) and the geotechnical design (including site investigation, soil characterization and foundation assessment).

Comparing the three anchor types, DEAs are less expensive and more efficient than driven piles in terms of the ratio of load capacity to anchor weight. DEAs in soft clay leads to increased DEA load capacity, because soft clay profiles typically exhibit increasing strength with depth. Second, gravity installed anchors are used in situations where penetration into the riverbed is not possible (Ma et al., 2019). In conclusion, DEA anchors will be used if anchors are needed in the design of the floating pontoon.

7.7.2. Mooring line composition

A chain, wire rope, synthetic fiber rope or a combination of these can be used as mooring line. In shallow water, most of the time a simple and effective "all-chain" design is used, Figure 7.18. Chain is sturdy, has a good resistance to riverbed erosion and provides added capacity to the anchor (Ma et al., 2019). Therefore the chain is more sustainable in operation phase than the synthetic fiber rope or the wire rope.

Figure 7.15: Chain mooring line

7.8. Finite element model

The frame was analyzed using Abaqus under a static distributed load simulating a weight reaching the ultimate limit state of the material. In the analysis, three linear elements of the frame were assigned appropriate boundary conditions to reflect the floating force exerted by the plastic drums integrated into the structure. The results indicate that the trusses are sufficiently robust to support the 3500 kg design requirement, ensuring that the frame, as a whole, maintains its structural integrity under the applied conditions. Overall, the analysis confirms that the design is capable of withstanding the specified load without compromising performance.

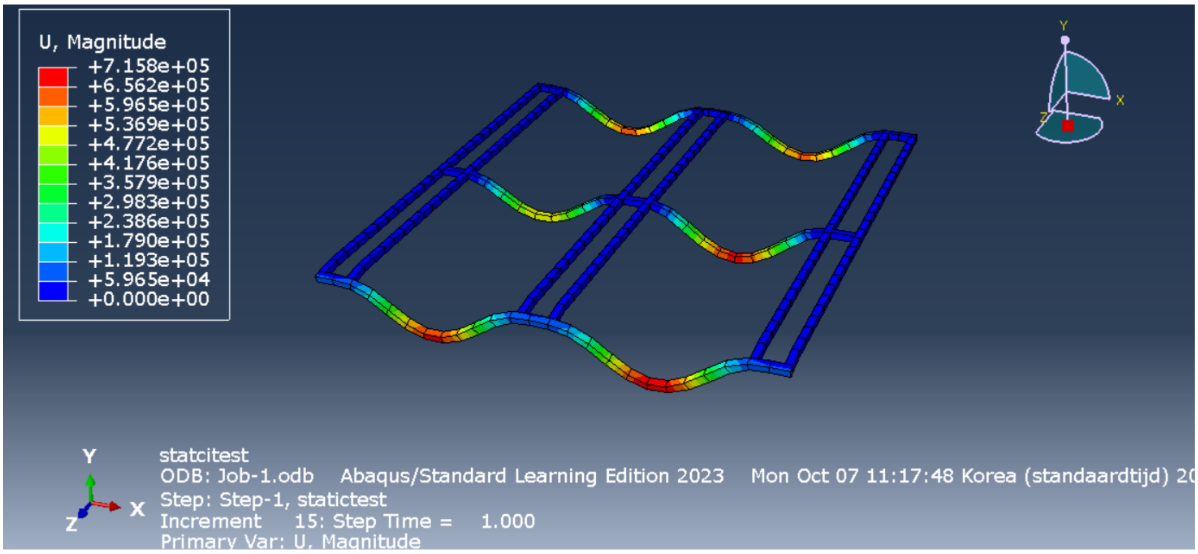


Figure 7.16: Extreme displacement distributed load

The frame was analyzed in Abaqus with a point load applied at the center, simulating a concentrated weight reaching ULS of the frame again. This analysis aimed to assess the effects of heavily concentrated loading conditions on the structure. The results indicate that while the trusses are designed to be strong enough to support the 3500 kg load, the concentrated nature of the load may lead to higher stress concentrations in the vicinity of the application point. However, the overall structural integrity of the frame remains intact, demonstrating that the design can effectively handle localized loads without significant risk of failure.

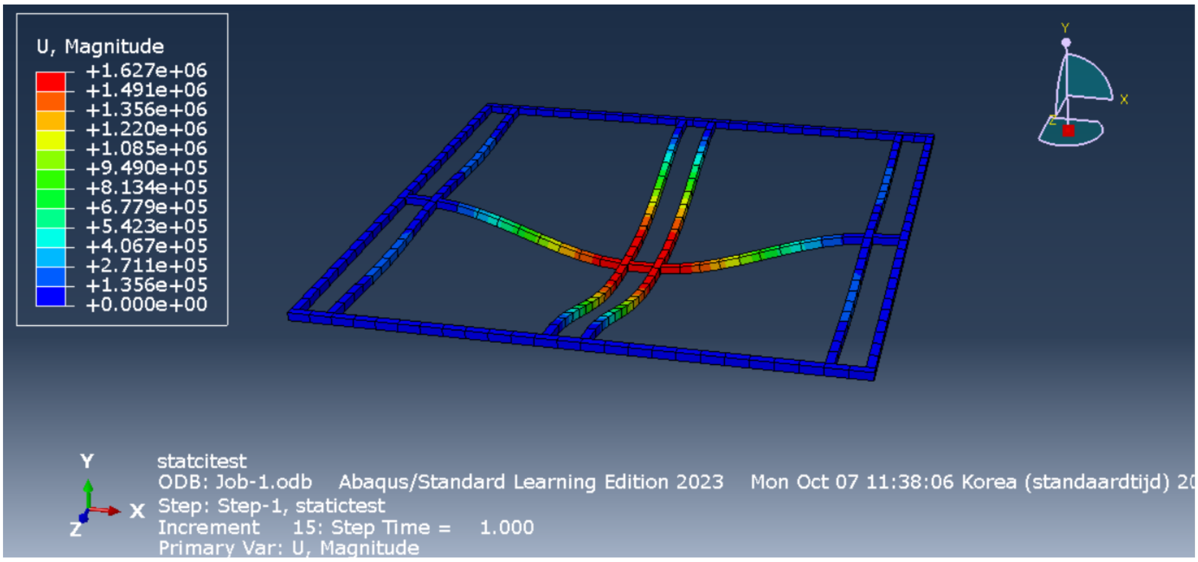


Figure 7.17: Extreme displacement point load

Lastly the dynamic loading scenario, representing the Morrison force due to river conditions, the results from Abaqus suggest that the frame design may need additional bracing to ensure the tilt criteria are met. Strengthening the frame with extra bracing would help distribute the forces more evenly and reduce the risk of tilting or excessive deflection under these variable loads.

The recommendation would be to conduct further dynamic analysis to identify the optimal locations and configurations for the added bracing, ensuring that the frame can endure both static and dynamic loads effectively. This is beyond the scope of this subresearch question however.

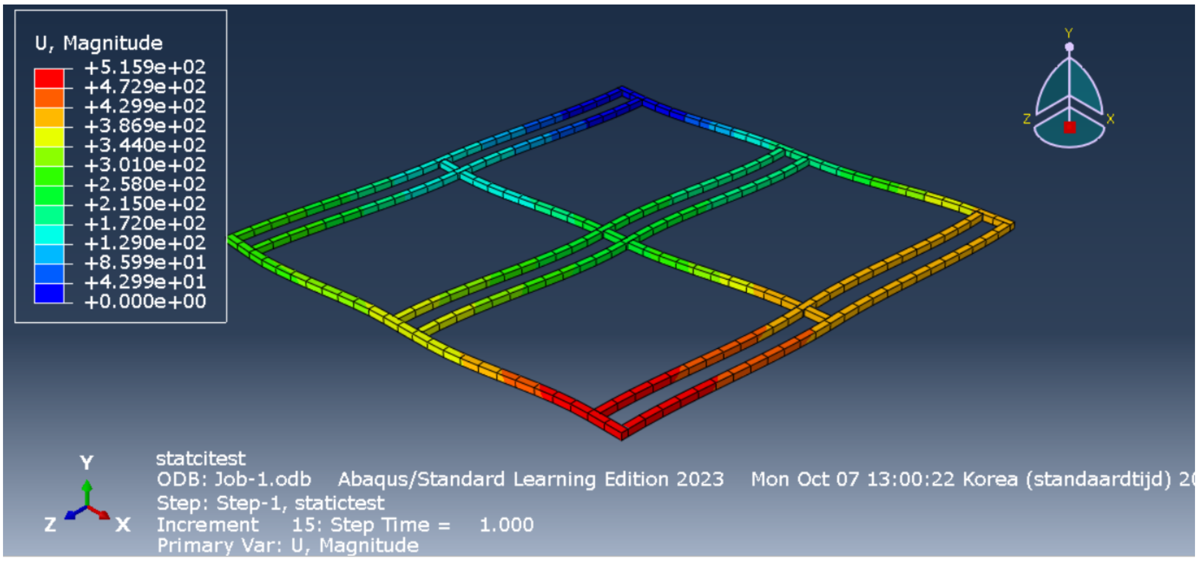


Figure 7.18: Dynamic loading

7.9. Multipurpose use of the pontoon

The pontoon is flexible to use. The multipurpose of the floating foundation will contribute to a systemic design where agriculture, community and environment are integrated in one design.

7.9.1. Floating house

The pontoon can be used as foundation for a floating house. Vietnamese architecture studio and H&P Architects have designed a floating bamboo house (Figure 7.19). It is a residential design model to support livelihoods that are living in the Mekong Delta. The design is based on traditional Vietnamese communal structures, called *Rong*. A *Rong* is a type of communal house found in villages of ethnic minorities in Vietnam's central highlands. The use of wood and bamboo architecture encapsulates the cultural hearts of the locals. The house itself is designed such that it is multipurpose as well. It can be used for different activities like hosting community ceremonies, administrative events or as a space where bachelors could spend the night (STIRworld, 2023). This bamboo house is an example of a sustainable structure, with a long-lasting nature, that can be built on the pontoon.

(a) Views of the house

(b) Climate-resilient floating bamboo home

Figure 7.19: Floating house (STIRworld, 2023)

7.9.2. Floating waste system

During the field trip, a lot of waste was seen on the island and in the river. In Vietnam, waste pollution is a huge problem. That is why the pontoon can also be a foundation for a waste collecting system. Besides, waste will be stuck between the floating structures, what can cause issues regarding technical life time of the structure and the livability on the water. The main waste source in the Mekong river is plastic. A waste collecting system like in Figure 7.20 can be built on the pontoon. It uses a boom system that feeds floating garbage to a meshed net. This net needs to be emptied 2 to 4 times on a weekly basis. The design of this system is made such that it is easy to handle and robust enough to withstand river conditions (safety4sea, 2019).

Figure 7.20: Waste collector to address pollution in rivers

7.9.3. Floating agriculture

Floating agriculture is a method used to grow food in areas that are extended to frequent or prolonged flooding. Floating beds made of rotting vegetation can act as compost for crops. The practice is similar to hydroponic agriculture and no additional chemicals are required. The practice helps mitigate land loss through flooding, by allowing cultivation of these areas to continue (UNctcn, 2010). Next to agriculture, the pontoon can be used as fish farm. In Cần Thơ, fish rafts has increased significantly since 2000 and become economically interesting. A raft with fish can have an area of 60-100 m^2. Fish that is raised in floating rafts are all catfish varieties, mainly for export to Europe and North America. Households in the Cần Thơ river that are in the fish farming industry earn a very high income for the family (Vemong, 2020).

7.9.4. Integration of renewable energy

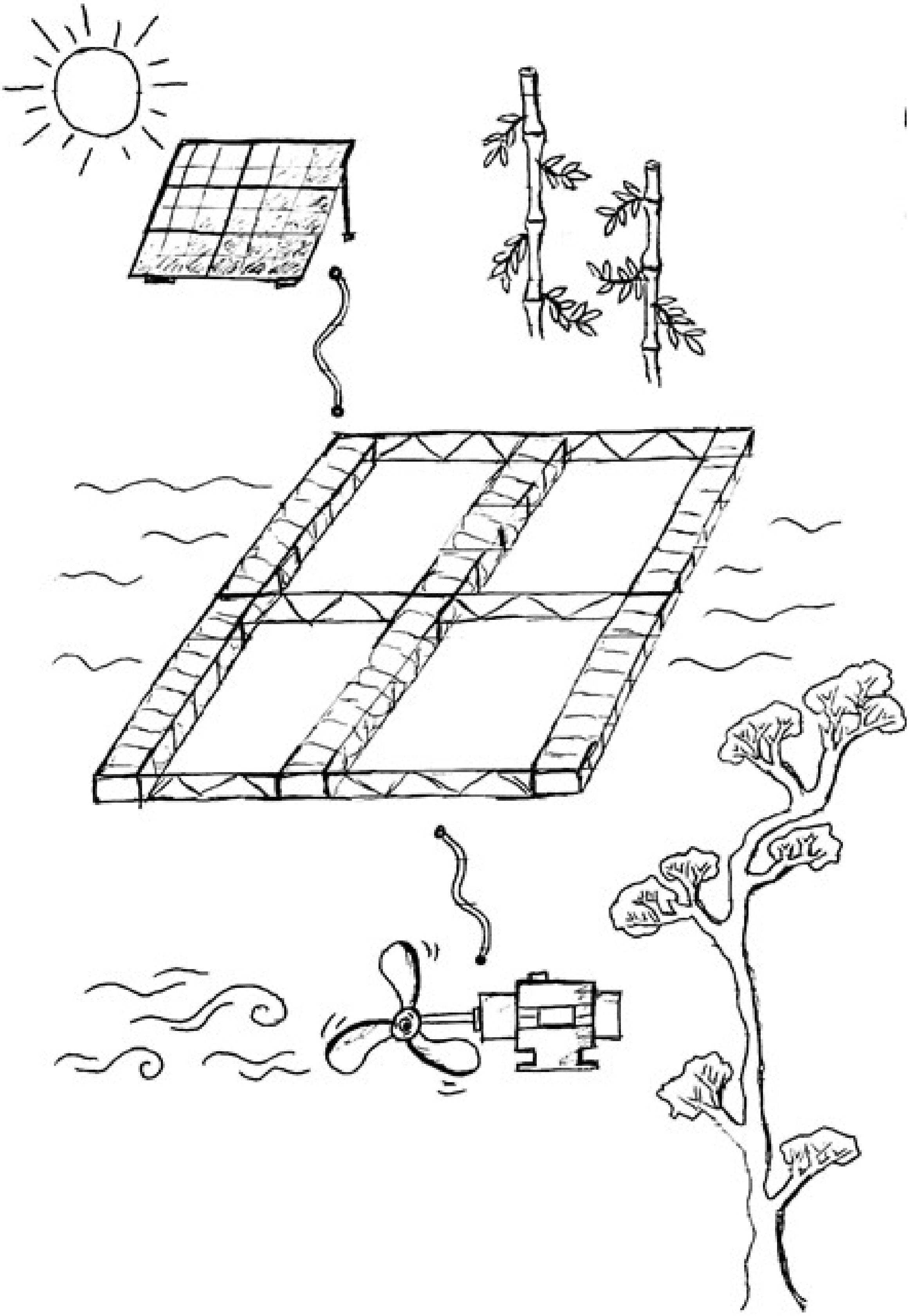


Figure 7.21: Renewable energy systems for the pontoon (by all authors, 2024).

The design for the island is a small scale scope. For a bigger scale of renewable energy design, the large wind resources in Vietnam can be used for generating wind energy. However, this is out of the scope of the project, so the focus will lie on small scale energy generation. Small scale integration of windmills is not practical due to the costs, aerodynamic noises, structural issues and turbulence caused by neighbouring structures (Calautit & Johnstone, 2023).

The waste that will be collected by the waste system can be used in large scale to generate electricity. Effective waste processing for energy generation will help ensure energy security, reduce environmental pollution, and contribute to efficient land use and green sustainable economic development. The use of landfill gas for energy generation is a highly regarded project due to the dual benefit of reusing waste to produce electricity. It is being tested in Hanoi to lead the transformation of other waste facilities throughout Vietnam (C40cities, 2019).

Due to the large amount of sun hours in Vietnam, the country has a high installed solar energy capacity. However, solar power expansion causes grid issues. Vietnam has to fix its grid issue before it can upscale the renewable energy. The ambitious government targets and relatively flexible terms and policies for easing project financing gives opportunities (EnergytrackerAsia, 2024). However, on small scale, solar panels can be installed. An integrated design of a solar panel with a house, fish farm or waste system can give opportunities to be independent and self-sufficient. This contributes to the ability to implement the vision on a larger scale.

Finally, a hydro turbine generator can be an alternative. It is, like the wind turbine, a complex system, but requires very minimum resources to generate maximum electricity. Another advantage is that the environmental resource, tides, are very consistent. Further research into hydro generators for small-scale use under pontoons in the Mekong river near the island is necessary.

7.9.5. Conclusion

The proposed modular floating pontoon offers a flexible and sustainable solution to address the challenges faced by communities living in the Mekong Delta, particularly in the context of rising water levels and the other environmental threats discussed in chapter 2 regarding the sub-research quesiton: How can we build a modular floating pontoon with local construction methods and materials to facilitate living on water in the year 2075?

By effectively integrating local materials such as bamboo and melaleuca timber, construction methods like working with timber, and using the design principles, this pontoon can serve multiple purposes like housing, fish farming, waste management, and agriculture and therefore contribute to facilitate living on water in the year 2075.

Furthermore, the consideration of renewable energy integration, such as solar panels and hydro turbine generators, enhances the pontoon's potential for energy independence and environmental sustainability in order to succesfully facilitate living on water in the future. The analysis of material selection through Multi-Criteria Decision Analysis (MCDA) and Life Cycle Assessment (LCA) ensures that the chosen materials not only meet structural and functional requirements but also align with sustainability goals. Furthermore, the consideration of environmental loading conditions and structural design confirms that the pontoon can withstand local hydrodynamic forces and provide a safe and stable pontoon for multi-purpose use which will last far into the future.

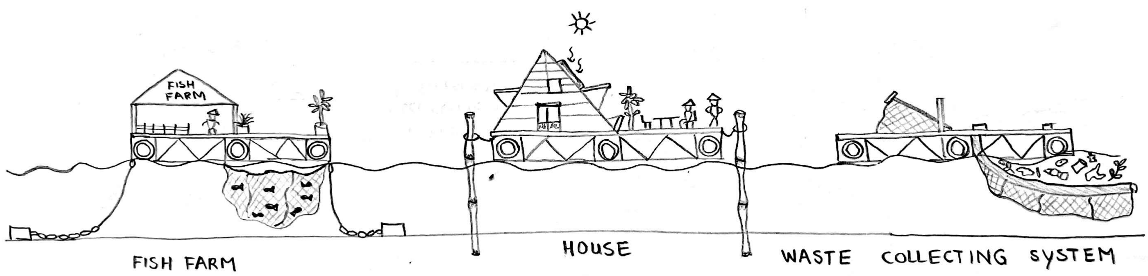


Figure 7.22: Multipurpose implementation of the pontoon (by all authors, 2024).

8

Socio-economical feasibility

The Mekong Delta has various stakeholders, each with different roles and interests tightly linked by natural and human factors. Stakeholders include those involved in the development and execution of projects, those impacted by these developments, and the legal and regulatory bodies in charge of the area. Furthermore, the populations living in the Delta are also affected by environmental problems, discussed in chapter 2. These stakeholders' interests often diverge due to their differing backgrounds, priorities and vulnerabilities.

In this chapter, the key stakeholders in the Mekong Delta, specifically focusing on the Cần Thơ area, are identified and elaborated. This covers government organisations and developers, but also local communities that are significantly affected by these developments. To evaluate the issues, it will be essential to comprehend their differing problem perceptions about development, land use, and environmental dangers. A network analysis will be carried out to map out the relationships between these stakeholders, showing the interdependence and power dynamics at play. Furthermore, it is essential to gain a comprehensive understanding of how environmental and socioeconomic factors intersect in this region for a future vision.

8.1. Relevant stakeholders

As mentioned in the introduction of this chapter, the first thing done is to map all relevant stakeholders. The stakeholders listed below are all integral to addressing the future challenges in the area. The stakeholders are subdivided into four groups; governmental authorities; international organizations and donors; the private sector; and community stakeholders.

Figure 8.1: Stakeholders (by all authors, 2024)

8.1.1. Governmental authorities

Governmental authorities largely shape the rules, laws, and frameworks governing the Mekong Delta's water management and climate resilience. Among these stakeholders are national and municipal governments, ministries, and regulatory agencies in charge of infrastructure development, national resource management, and urban planning. Their actions are essential to guaranteeing the long-term viability of water management plans and the coordination of regional objectives with national aims.

Table 8.1: Governmental Authorities in the Mekong Delta

Stakeholder	Role
Central Government of Vietnam	Responsible for managing and overseeing land, water resources, geology, the environment, climate change, and marine and island resource protection. It implements laws, policies, and strategies in these areas, ensuring sustainable resource use and environmental protection.
Ministry of Natural Resources and Environment (MONRE)	Manages land, water resources, and environmental protection while implementing national policies on climate adaptation.
Ministry of Agriculture and Rural Development (MARD)	Oversees agriculture, forestry, and rural development nationwide, ensuring sustainable practices and food security.
Mekong River Commission (MRC)	Regional organization that oversees the Mekong River Basin's transboundary water management.
Vietnamese Institute for Urban and Rural Planning (VIUP)	Supports government management in urban planning and infrastructure with a focus on climate change and heritage conservation.
Department of Urban Planning and Architecture, Cần Thơ	Provides design and consultancy services in urban and rural planning.
Department of Planning and Investment (DPI)	Oversees development and approval of infrastructure projects in the Mekong Delta.
Cần Thơ City People's Committee	Manages infrastructure development and environmental management at the local level.

8.1.2. International organisations and donors

International organisations and donors supply crucial financial, technical, or strategic support. Access to these stakeholders is important for local stakeholders to gain global knowledge and resources, as these organisations can help introduce new technology or effective governance models worldwide.

Table 8.2: International Organizations and Donors in the Mekong Delta

Stakeholder	Role
World Bank	Significant financial supporter of large-scale sustainability and climate resilience projects in the region.
Dutch Government	Strategic partner providing technical expertise in water management and delta planning.
International Union for Conservation of Nature (IUCN)	Collaborates with local governments to promote sustainable water retention strategies and flood-based livelihood models.
WWF, IUCN, and Oxfam	International NGOs focusing on climate resilience and sustainable agriculture in the Mekong Delta.

8.1.3. Private sector

The third group is the private sector, this sector plays a dual role in the Mekong Delta's future. On the one hand, they promote infrastructural development and economic growth, especially in sectors like urbanisation and tourism. However, occasionally, for some stakeholders, their emphasis on profit conflicts with long-term sustainability objectives. Effective stakeholder involvement is necessary to coordinate their efforts with more comprehensive water management and climate resilience policies.

Table 8.3: Private Sector in the Mekong Delta

Stakeholder	
Financial Institutions and Banks	Provide loans or funding for water management projects and infrastructure investments.
Tourism	Contributes to the economy through leisure activities in Cần Thơ and the Mekong Delta.
Shipping companies or maritime transport operators	Facilitate the movement of goods and people via the Mekong Delta's extensive river network.
Private Investors	Engage in CSR activities and collaborate with organizations to support sustainable water management projects.
Real Estate Developers (e.g., Cồn Khương Resort, Misa Commercial and Office Building)	Drive urbanization and shape the socioeconomic structure of the region.
Infrastructure Developers and Contractors	Involved in constructing critical water management infrastructure.

8.1.4. Community stakeholders

The fourth group is the community stakeholders. This group plays a central role in the environmental challenges, as they are directly affected by changes in flood risk, agricultural viability and urban development. Those whose lives and well-being depend on efficient and sustainable water management practices include the residents, farmers, fishers, and local businesses. Their involvement in decision-making, traditional knowledge and acceptance to change are essential to the effectiveness of new practices.

Table 8.4: Community Stakeholders in the Mekong Delta

Stakeholder	**Role**
Mekong Delta Development Research Institute, Cần Thơ University	Conducts research on sustainable water management and flood adaptation strategies.
Residents	Directly affected by water management policies and infrastructure, crucial for community-level adaptations.
Agricultural farmers	Rely on predictable water management for irrigation and flood protection.
Aquacultural farmers	Depend on stable water quality and levels for fish farming.
Local businesses	Drive economic growth and provide goods and services that support local communities.
Fishermen	Rely on healthy aquatic ecosystems for their livelihoods.

8.2. Interests and goals

The different stakeholders have now been identified, their goals and interests, however, differ greatly from one another. All above-mentioned groups, be they governmental, corporate, or community-based, have different views on water management, urban development, and sustainability initiatives which results in unique goals and interests. Understanding these is crucial for creating a comprehensive framework for stakeholder engagement, as they will shape the decision-making processes and potential conflicts. In this section, therefore, each stakeholder's primary goal and long-term interests are outlined, serving as a basis for identifying areas of potential cooperation and conflicts. The interests and goals of the stakeholders are shown in Table 8.5 and Table 8.6.

Table 8.5: Stakeholders in the Mekong Delta (Part 1)

Stakeholder	Interest	Goal
Central Government of Vietnam	Policy-making on national level	Achieve sustainable economic growth, enhance climate resilience, and improve urban infrastructure to support the livelihoods of the population by 2075.
Ministry of Natural Resources and Environment (MONRE)	Sustainable management of natural resources	Protect land and water resources, reduce environmental degradation, and enhance national policies for climate adaptation by 2075.
Ministry of Agriculture and Rural Development (MARD)	Agricultural sustainability and food security	Develop resilient agricultural practices that withstand climate impacts and ensure food security for the population while promoting rural development by 2075.
Mekong River Commission (MRC)	Transboundary water management	Promote and coordinate sustainable management and development of water and related resources for countries' mutual benefit and people's well-being.
Vietnamese Institute for Urban and Rural Planning (VIUP)	Urban and regional planning	Make strategies for sustainable urban and rural development that combine traditional knowledge and modern practices.
Department of Urban Planning and Architecture, Cần Thơ	Local urban development and management	Reduce flood risks and enhance livability for residents by implementing effective sustainable urban planning.
Department of Planning and Investment (DPI)	Infrastructure development and project approval	Facilitate funding for infrastructure projects that will increase economic growth, with a focus on sustainability.
Cần Thơ City People's Committee	Local governance and community welfare	Enhance local resilience to environmental threats through effective governance and community involvement.
World Bank	Funding and supporting sustainable project developments	Drive large-scale investments in climate resilience and sustainable infrastructure projects.
Dutch Government	Technical expertise in water management	Collaborate on innovative water management solutions to enhance resilience in the Mekong Delta.
International Union for Conservation of Nature (IUCN)	Sustainable practices and conservation of biodiversity	Promote policies and practices that protect biodiversity and ecosystems while fostering sustainable livelihoods.
WWF, IUCN, and Oxfam	Climate resilience and sustainable agri- and aquaculture	Advocate for community-based approaches that enhance climate resilience and ensure food security through sustainable practices by 2075.
Financial Institutions and Banks	Investments in sustainable projects	Identify and fund innovative projects that yield high financial returns.
Tourism	Economic growth through (eco)tourism	Drive visitor numbers and revenue. Promote sustainable tourism that protects the environment for ecotourism.
Shipping companies or maritime transport operators	Efficient logistics and transport via waterways	Maximize operational efficiency and profitability while ensuring reliable transportation of goods within the Mekong Delta.
Private Investors	Profitable investment opportunities	Seek high returns on investments.

Table 8.6: Stakeholders in the Mekong Delta (Part 2)

Stakeholder	Interest	Goal
Residents	Well-being and safety in their communities	Ensure safe living conditions and increased livability, with active participation in decision-making.
Agricultural farmers	Farmland and economic viability	Maximize crop yields and profitability while ensuring access to reliable water resources for irrigation.
Aquacultural farmers	Available water for aquaculture and economic viability	Maximize output and profitability.
Local businesses	Economic viability and profitability	Focus on maximizing profits, which may result in prioritizing short-term financial outcomes over sustainable practices.
Fishermen	Available water for fishing practices and economic viability	Economic viability through fishing by maintaining access to abundant fish stocks and clean water.
Real Estate Developers (e.g., Cồn Khương Resort, Misa Commercial and Office Building)	Urban development and infrastructure	Focus on profitable development projects that meet market demands with a high return on investment.
Infrastructure Developers and Contractors	Construction and maintenance of infrastructure	Build resilient infrastructure that supports flood control and water management.
Mekong Delta Development Research Institute, Cần Thơ University	Research on the Mekong Delta and sustainable practices	Contribute to sustainable rural development and increased livability of inhabitants in the Mekong region through education, research and development collaborations.

8.3. Power-Interest matrix

To further map and classify the different stakeholders at play, a power-interest matrix is constructed. This tool, introduced by Mendelow (1991), analyses each stakeholder based on two areas; power and interest. In the case of the Mekong Delta's future and the island of Cồn Khương, these include the following two:

- Power axis: Represents the stakeholders' ability to influence decision-making processes, implement policies, or allocate resources.
- Interest axis: Reflects the extent to which stakeholders are affected by or invested in the outcomes of the water management strategies, ranging from those directly impacted by the flooding to those more focused on infrastructure projects and economic growth.

The power-interest matrix has four different quadrants, each corresponding to four primary stakeholder classifications. These stakeholders, with their predefined approach, are:

- Crowd: Monitor
- Subjects: Maintain confidence
- Context settlers: Keep informed
- Players: Collaborate with

These predefined approaches can be further defined and adjusted to develop strategies that engage stakeholders effectively. This will ensure that their interests are considered in the governance framework for sustainable and resilient water management in Cần Thơ and the broader Mekong Delta. The four predefined approaches are discussed here, section 8.4 goes into more detail, by defining strategies for the five policy and management categories. First, the power interest matrix is shown in Figure 8.2.

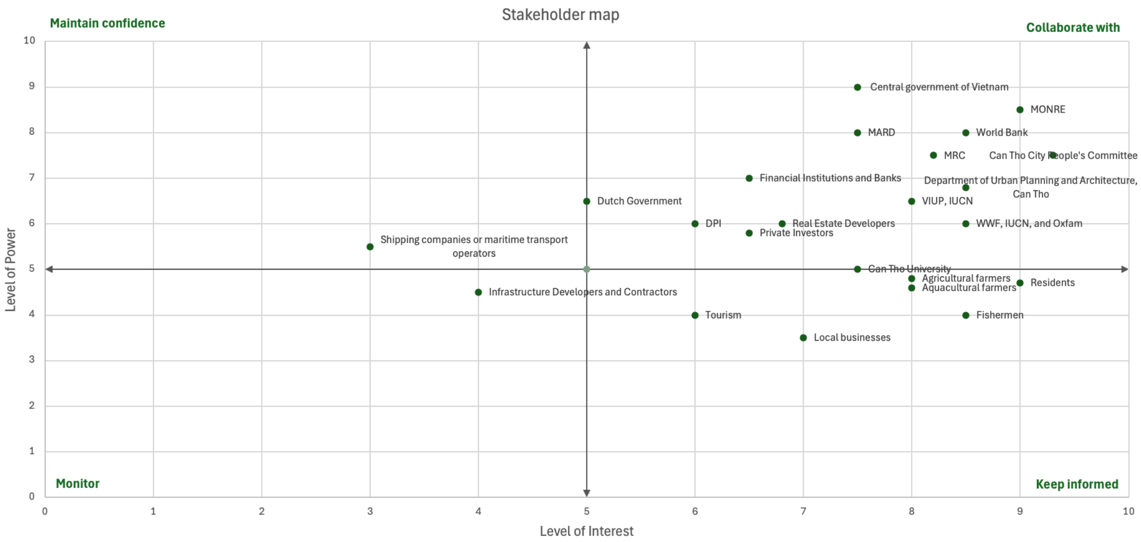


Figure 8.2: Power-Interest matrix (by all authors, 2024)

Governmental authorities take the lead in the collaborative process to develop a resilient and sustainable Cồn Khương island, as they further engage other important stakeholders that need collaborating with. Important is that, when looking at the power-interest matrix, the four quadrants' borders are not rigid. Many stakeholders influence one another, and for this reason, positions may overlap or change over time. This also results in stakeholders closely located to the boundaries being subject to a more nuanced strategy. Although the government sets the general direction, the approach described is not strictly top-down; rather, it encourages collaboration between the private sector, NGOs, and local stakeholders. Governmental authorities set the general direction and enable different engagement strategies.

Crowd: Monitor

The first group in the power-interest matrix is the crowd. This group has limited power, but also its direct interest in long-term resilience planning is limited. The focus of the government here is to monitor and provide basic updates. The main goal is to passively inform them without spending too many resources, this will help maintain social stability and prevent misinformation during environmental transitions. The government uses passive channels like the internet and community notice boards to provide the necessary information. This information about flood preparedness and risks could be made available via information pamphlets in tourism centres, community centres and local markets.

Subjects: Maintain confidence

This group has a lower interest in resilience initiatives and the island's future vision. However, their influence over economic and infrastructure development makes maintaining their confidence very important. Frequent briefings, offering updates on resilience measures, future projects, and the vision for the island, will be held, where their financial advantages are especially discussed, to maintain their confidence. By involving these stakeholders in discussions about particular infrastructure projects, it is possible to better connect their goals with the objectives, thus preventing potential resistance and promoting a collaborative environment (Ansell & Gash, 2008). An annual consultation between the government and the shipping companies can be held to discuss how suggested implementations on the island impact the waterways and how it could enhance operational efficiency and safety for the companies.

Context settlers: Keep informed

The context settlers quadrant covers the stakeholders with low power, but high interest. On the island of Cồn Khương this group includes the residents, agricultural farmers, and local NGOs. Since the residents and the local farmers have a lot of important insights and a huge stake in the outcomes of the implementations, it is necessary to keep these stakeholders informed and offer them learning opportunities. Here, community meetings, workshops together with Cần Thơ Univeristy, and feedback sessions asking for suggestions on the project and vision, help achieve this. By informing these context settlers in the planning process, the government can build the necessary trust, while fostering a sense of ownership among these stakeholders. This will enhance the overall effectiveness of the initiatives and the future vision for the island. Furthermore, it will not only improve local resilience but also enable the government to gather data on local practices and challenges, creating adaptability (Reed, 2008).

Players: Collaborate with

Finally, the fourth quadrant and group of the power-interest matrix are the players. This group includes stakeholders with both high power and high interest and also represents the most stakeholders in the context of Cồn Khương island. Stakeholders in this group include governmental and local organisations, major investors, and influential NGOs. The government should prioritize collaborating with these stakeholders by actively involving them in the decision-making process. There are many ways of doing this, from collaborative planning sessions to strategic partnerships and co-funded projects that use their resources and expertise. Regular reporting from each of the stakeholders on their progress will ensure a shared responsibility for these projects, which increases the adaptive capacity and enhances accountability (Nonet et al., 2022). For example, the Cần Thơ City People's Committee could organize summits with the MONRE, MARD, MRC, and NGOs to review the progress made and adjust plans according to new policies and research. In conclusion, collaborating with these stakeholders ensures that the strategy and vision are comprehensive and effective and that it will align with both economic and environmental objectives.

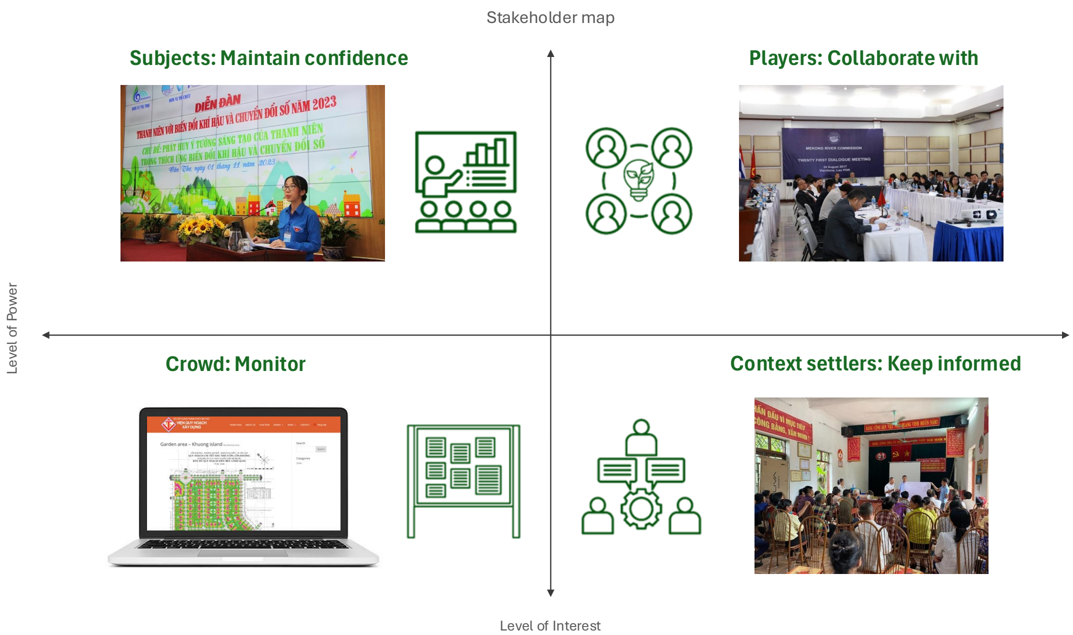


Figure 8.3: Different predefined approaches (by all authors, 2024).

8.4. Stakeholder management

Interconnected Stakeholder Dynamics in Policy and Management

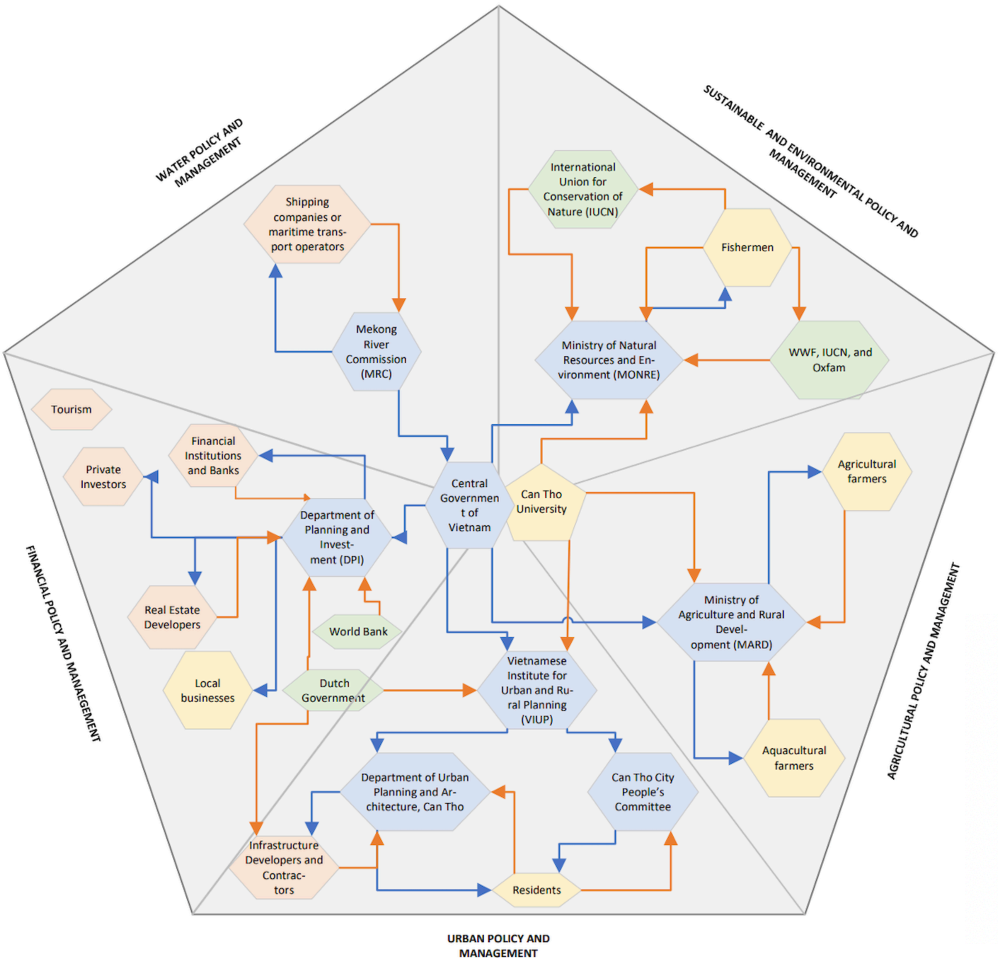
Effective policy-making is not a straightforward process; it involves the interaction of multiple stakeholders, each with its objectives, constraints, and areas of influence. For policies to be truly effective, they must not only be well-designed at the top level but also take into account the diverse roles and needs of the stakeholders affected by them (Luu et al., 2022). These stakeholders, ranging from governmental authorities to local communities, play a critical role in shaping how policies are implemented, adapted, and ultimately succeed in meeting their goals. To illustrate how these stakeholders should interact in policy-making and management, an organizational diagram is provided to show the interconnectedness and dynamics involved.

Understanding the dynamics between stakeholders is crucial because each one operates within a distinct management category. These categories determine how stakeholders are influenced by and contribute to policy decisions. Within the diagram, each stakeholder is categorized into one of the five policy and management categories:

1. Urban Policy and Management
2. Financial Policy and Management
3. Water Policy and Management
4. Sustainable and Environmental Policy and Management
5. Agricultural Policy and Management

The aim of this categorization is to provide a simplified overview of how each stakeholder interacts with and is influenced by policies within a particular management field or category. While this approach offers a general perspective, it is important to acknowledge that stakeholders often fit multiple management categories and may have overlapping roles that are not always clearly defined. For example, Cần Thơ University and the central government occupy central positions in the diagram as they engage with multiple management and policy categories.

Each stakeholder is further classified into one of four roles: governmental authorities, international organizations and donors, private sector, or community. These roles reflect their function within the larger system. Figure 8.4 shows the management categories to which these stakeholders belong and the roles they fulfill. The interactions regarding policy between stakeholders are shown by the orange and blue arrows (see Figure 8.4). In the following subsections, a more detailed explanation of the diagram follows by zooming in on different policy and management categories.



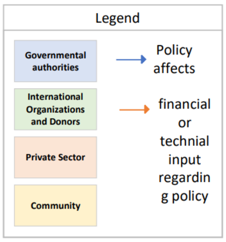


Figure 8.4: Stakeholder engagement framework (by all authors, 2024).

Agricultural policy and management In the context of agricultural policy and management, the figure demonstrates that the Central Government (CG) policy directly influences the Ministry of Agriculture and Rural Development (MARD). MARD's policymaking is shaped by decisions made at the CG level and, in turn, impacts the livelihoods of agricultural and aquacultural farmers (see Figure X). However, this interaction is not a strictly top-down approach, where policies are dictated by higher authorities without consultation from those directly affected.

A purely top-down approach is undesirable because it risks overlooking local needs, challenges, and specific circumstances that practitioners, such as farmers, are most familiar with. Relying solely on higher-level policy decisions could lead to the implementation of solutions that are not fully grounded in the realities of day-to-day agricultural practices, potentially making them less effective or even harmful in addressing the actual issues faced by farmers.

Therefore, MARD should receive valuable technical input from both farmers and institutions like Cần Thơ University. Farmers, as practitioners, have firsthand knowledge of the challenges they encounter, allowing them to provide critical insights into priority areas that need policy attention. Their practical experiences are crucial in shaping policies that are responsive to real-world agricultural challenges.

Moreover, Cần Thơ University, as a leading research institution, plays a crucial role by researching the latest technological advancements, innovations, and sustainable practices. This research helps to inform MARD and other stakeholders about potential solutions and policy directions that could foster sustainable agricultural development. The combination of practical input from farmers and scientific input from academic institutions helps ensure that policies are not only informed by empirical evidence but are also aligned with the needs and challenges of those most directly involved in the sector.

Sustainable and Environmental management Another example can be seen in sustainable and environmental management (see Figure 8.4, where the policies of the Ministry of Natural Resources and Environment (MONRE) impact fishermen. This makes it essential for the government to consider input from fishermen and the university (shown by the orange arrows) when developing policies.

International organizations and donors, such as WWF and IUCN, also play a crucial role. Table 6.5 shows that their goal is to "advocate for community-based approaches that enhance climate resilience and ensure food security through sustainable practices by 2075." These organizations often represent community interests and receive input from fishermen (orange arrow) to reflect their needs.

These organizations possess valuable knowledge because of their global expertise in climate resilience, biodiversity, and sustainable practices. They have worked in diverse regions, allowing them to apply international best practices to local challenges. Additionally, they conduct and support research on sustainable solutions, which provides MONRE with data-driven insights. By combining scientific knowledge with their experience working directly with local communities, these organizations understand both the environmental and socio-economic impacts of policies. This helps MONRE design strategies that not only protect natural resources but are also practical for those who rely on them, ensuring more effective and sustainable outcomes.

Interconnected Stakeholder Dynamics in Policy and Management Systems

To better understand how this stakeholder diagram works as a system, Figure 8.5 provides an overview of the relationships between policy and management for various stakeholders. Specialized governmental authorities, ministries, and departments are often influenced by overarching authorities. These might be national bodies, like the central government, or international authorities, such as the Mekong River Commission. The goals and interests of these higher-level authorities shape the policies of specialized bodies, which then create policies to manage specific areas.

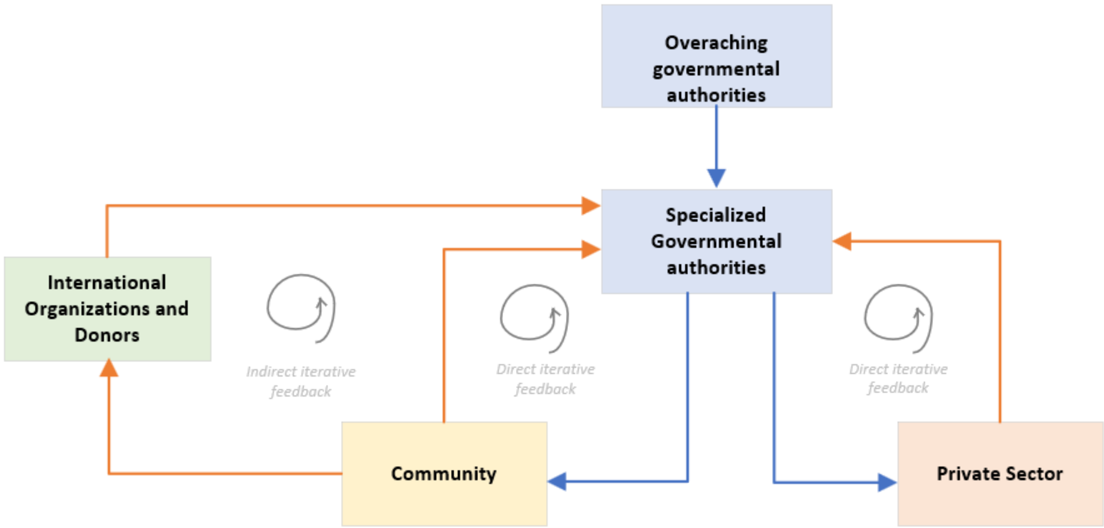


Figure 8.5: Interconnected Stakeholder Dynamics in Policy and Management Systems (by all authors, 2024).

These policies made by specialized governmental authorities, directly impact local communities and the private sector. However, for these policies to be effective in practice, cooperation between these parties is essential. Without clear communication, policies might not address real needs or may conflict with local interests. A continuous, two-way feedback loop is important to make sure that both sides, specialized governmental authorities and the communities or private sector they affect, discuss their goals, needs, and constraints. For example, a specialized authority might want to respond to community needs but has to adjust its plans to match the broader policies set by the central government or other higher-level bodies.

International organizations and donors play a crucial role in this system, often representing the needs of local communities in the policy-making process. As seen in the example of "sustainable and environmental management," community needs may not always be communicated directly but instead come through international organizations that advocate for these needs. This creates an indirect feedback loop where local interests are represented in higher-level policy decisions.

When all these connections are made, we can see that these separate entities form part of a larger, interconnected system. This system becomes complex because of the different needs, limitations, and challenges each party faces. For example, policies that meet the needs of one group might create problems for another, and limited financial resources can make it hard to find solutions that work for everyone. Additionally, in unstable or corrupt policy environments, conflicting interests and inefficiencies can make the process even more complicated.

8.5. Stakeholder management strategy for governmental authorities in practice - Cồn Khương Island

The following chapter focuses on stakeholder management in the context of Cồn Khương Island's sustainable development, particularly regarding water management, urban planning, agriculture, environmental protection, and financial strategies. It examines the diverse stakeholders involved; governmental authorities, International Organizations and Donors, private sector entities and local communities and maps their power, interests, and roles within this complex system. Through an analysis of their goals, the chapter highlights the dynamics of collaboration, outlining how each group influences decision-making processes and contributes to long-term development objectives. By providing a detailed overview of each stakeholder's position, the chapter aims to identify areas for cooperation, ultimately offering a framework for effective stakeholder engagement.

8.5.1. Urban Policy and Management

Governmental authorities – Players (collaborate with)

The Central Government of Vietnam holds the most power (P = 9) due to its ability to set national policies, though its interest in Cồn Khương Island is somewhat lower (I = 7.5) as it is just one of many national projects. This positions the Central Government as the strategic overseer, providing the overall framework while relying on local authorities for execution. Governmental authorities always directly or indirectly *collaborate with* one another.

The Vietnamese Institute for Urban and Rural Planning (VIUP) (P = 6.5, I = 8) plays a crucial advisory role, translating national goals from the *Central Government* into policy-relevant for local authorities like *The Cần Thơ City People's Committee* and *the Department of Urban Planning and Architecture, Cần Thơ*. VIUP ensures that urban planning is both technically feasible and aligned with national standards Governmental authorities always directly or indirectly *collaborate with* one another.

The Cần Thơ City People's Committee (P = 7.5, I = 9.3) and the **Department of Urban Planning and Architecture, Cần Thơ** (P = 6.8, I = 8) are key local authorities responsible for translating national policies into local urban development initiatives. With the People's Committee holding slightly more power and higher interest due to its direct governance role, both bodies collaborate to ensure that urban development aligns with local needs and priorities. Their combined efforts ensure the effective adaptation and implementation of national policies at the local level, focusing on practical execution and community impact. Governmental authorities always directly or indirectly *collaborate with* one another.

Private Sector – *Context settlers* (monitor)

Infrastructure developers and contractors (P = 4.5, I = 4) have a more limited role in urban policy-making. Their influence is primarily focused on the execution and construction phases, and their interest in the broader urban planning strategy is relatively low. However, for the *Department of Urban Planning and Architecture, Cần Thơ, monitoring* their activities are essential to ensure that infrastructure development aligns with the urban policies set by governmental authorities.

Communities - Context settlers: keep informed - Players: collaborate with

Cần Thơ University (P = 5, I = 7.5) holds moderate power due to its research capabilities and advisory role. Its high interest comes from its involvement in sustainability and urban development projects that impact the region. The *Cần Thơ City People's Committee* should *collaborate with* the university to integrate its scientific insights, particularly in areas like flood resilience and sustainable urban planning. The university's role is to provide evidence-based recommendations, though it does not directly influence policy decisions.

Local residents (P = 4.7, I = 9) have lower power, as they cannot directly shape urban policies, but their high interest reflects the significant impact these developments will have on their daily lives. *The People's Committee* must ensure residents *keep informed* through public consultations and open channels for feedback, ensuring their concerns and needs are considered in the planning process. While residents have less influence, engaging them is vital to fostering public support and aligning policies with community welfare.

8.5.2. Agricultural Policy and Management

Governmental authorities – Players (collaborate with)

The Central Government of Vietnam (P = 9, I = 7.5) retains significant power in agricultural policy, particularly through national programs and regulations that guide agricultural and rural development across the country. However, as with urban policy, its interest in Cồn Khương Island is relatively lower due to competing national priorities. The Central Government sets broad directives, while local bodies are responsible for execution. Governmental authorities always directly or indirectly *collaborate with* one another.

The Ministry of Agriculture and Rural Development (MARD) (P = 8, I = 7.5) plays a critical role in developing policies related to agriculture and aquaculture. Its power is slightly lower than that of the Central Government, but it has direct authority over agricultural practices, rural development programs, and food security. MARD's high interest stems from its focus on ensuring the agricultural sustainability of the Mekong Delta region, which is vital for Vietnam's food production and economic stability. They work closely with local communities (*Cần Thơ University, Agricultural and Aquacultural farmers*) to adapt national agricultural policies to local needs. Governmental authorities always directly or indirectly *collaborate with* one another.

Communities – Context settlers: Keep informed / Players: Collaborate with

Cần Thơ University (P = 5, I = 7.5) holds moderate power due to its expertise in agricultural research, particularly in areas like soil science, water management, and sustainable farming techniques. Their high interest reflects their academic involvement in research projects that address the environmental and socio-economic challenges faced by the region. They should be *collaborate with* and *keep informed* by *MARD* to ensure that agricultural policies are informed by scientific research and best practices. While the university provides valuable insights, its role remains advisory.

Agricultural and aquacultural farmers (P = 4.8, I = 8) have relatively low power in policy-making but are directly impacted by agricultural policies. Their high interest stems from their reliance on these policies to sustain their livelihoods. Agricultural farmers depend on access to land, water, and resources, while aquacultural farmers are particularly concerned with water management, fishery regulations, and climate resilience. It is crucial for *MARD* that these groups *keep informed* and engaged through consultations, ensuring their practical needs and concerns are integrated into policy decisions.

Figure 8.6: Collage, goals and interest engagement of stakeholders, agricultural and aquacultural farmers, healthy productive landscape (by all authors, 2024).

8.5.3. Sustainable and Environmental Policy and Management

Governmental authorities – Players (collaborate with)

The Central Government of Vietnam (P = 9, I = 7.5) holds significant power over environmental policies, acting as the primary overseer of national sustainability strategies. Although the Central Government's interest in Cồn Khương Island is somewhat lower compared to other national projects, it remains essential in setting broad environmental directives. Governmental authorities always directly or indirectly *collaborate with* one another.

The Ministry of Natural Resources and Environment (MONRE) (P = 8.5, I = 9) plays a pivotal role in managing Vietnam's natural resources and implementing environmental protection measures. MONRE has high power and interest due to its responsibility for addressing key environmental issues such as climate change, water management, and biodiversity conservation in the Mekong Delta. As the primary governmental body responsible for environmental policies, MONRE should *collaborate with international organizations*, and *communities* to ensure that sustainability objectives are met and adapted to the specific needs of Cồn Khương Island. Governmental authorities always directly or indirectly *collaborate with* one another.

International Organizations and Donors – Players (collaborate with)

International Union for Conservation of Nature (IUCN) (P = 6.5, I = 8) and **World Wide Fund for Nature (WWF), and Oxfam** (P = 6, I = 8.5) play a crucial role in supporting sustainability and environmental protection initiatives in the Mekong Delta. While their power is moderate, their high interest comes from the global importance of the region's biodiversity and its vulnerability to climate change. These organizations provide critical research, funding, and conservation programs. Therefore MONRE should *collaborate with* to align Vietnam's environmental policies with international standards and foster resilience against climate-related risks.

Communities – *Context settlers* (keep informed) / *Players* (collaborate with)

Cần Thơ University (P = 5, I = 7.5) holds moderate power through its academic expertise in environmental science, particularly in the areas of climate resilience, water management, and ecological conservation. With a high interest in sustainable development projects that impact the region, the university should be both *collaborate with* and *keep informed* by *MONRE* and international organizations. The university provides scientific insights and data essential for shaping environmental policies, although its role remains primarily advisory.

Fishermen(P = 4, I = 8.5) represent a community group with lower power but high interest in environmental policies, particularly those affecting water quality, fishery regulations, and biodiversity. As their livelihoods are directly impacted by sustainable fishing practices and environmental conservation, *MONRE* must *keep informed* through consultations and public engagement. Their feedback and practical knowledge are critical to ensuring policies align with the ecological and socio-economic realities of the local fishing industry.

Figure 8.7: Collage, goals and interest engagement of stakeholders, fishermen and aquaculture, floating structure on the Hau river (by all authors, 2024).

8.5.4. Water Policy and Management

Governmental Authorities – *Players* (collaborate with)

The Central Government of Vietnam (P = 9, I = 7.5) holds significant power over water policy, acting as the strategic decision-maker responsible for national water resource management. While its interest in Cồn Khương Island is somewhat lower than in other national projects, the Central Government plays a crucial role in setting water management policies and coordinating with both local and international stakeholders to ensure that water resources are sustainably managed across the country. Governmental authorities always directly or indirectly *collaborate with* one another.

The Mekong River Commission (MRC) (P = 7.5, I = 8.2) is a key regional body responsible for coordinating water management and development across the Mekong Basin. The MRC has substantial influence over cross-border water management strategies and policies due to its role in fostering collaboration among Mekong countries. Its high interest stems from the ecological and economic importance of water resources in the region. As a governmental authority with regional reach, *the Central Government* should *collaborate with* MRC to ensure that policies align with transnational water management frameworks and address challenges such as climate change, water scarcity, and flood risk.

Private Sector – *Context settlers* (maintain confidence)

Shipping companies or maritime transport operators (P = 5.5, I = 3) play a role in the Mekong Delta's water management due to their reliance on water transport routes for trade and logistics. However, their power is moderate, and their interest is relatively low compared to other stakeholders, as their primary concern is maintaining navigable waterways rather than the broader environmental and policy aspects of water management. It is essential for the *Central Government* and *MRC* to *maintain confidence* with these companies to ensure the smooth operation of trade routes while balancing environmental and water resource needs.

Figure 8.8: Collage, goals and interest engagement of stakeholders, shipping companies or maritime transport operators (by all authors, 2024).

8.5.5. Financial Policy and Management

Governmental Authorities – Players (collaborate with)

The Central Government of Vietnam (P = 9, I = 7.5) holds the highest power in shaping financial policies at the national level, including budget allocation and investment planning for projects like Cồn Khương Island. While its interest in the project is relatively lower than for other national initiatives, its role remains crucial in establishing frameworks and ensuring fiscal responsibility across the country. Governmental authorities always directly or indirectly *collaborate with* one another.

The Department of Planning and Investment (DPI) (P = 7, I = 6) is a key governmental body that collaborate with the *Central Government* to manage and implement financial strategies at the regional and local levels. DPI plays a critical role in attracting investments and managing funds for infrastructure and development projects in Cồn Khương Island. While its power is lower than the Central Government's, its interest in the project is focused on regional development and ensuring the effective use of funds.

International Organizations and Donors – *Players* (collaborate with / maintain confidence)

The World Bank (P = 8, I = 8.5) is a major international financial institution providing funding, technical assistance, and strategic advice to Vietnam for large-scale development projects. Its high power comes from its financial resources, and its strong interest stems from the global development impact of sustainable financial planning in regions like the Mekong Delta. For *DPI collaboration with* the World Bank is essential to ensure proper financial structuring and sustainability.

The Dutch Government (P = 6.5, I = 5) also plays a role in providing support through funding and partnerships, particularly in areas related to water management and sustainable development. Though its power is moderate, for *DPI maintaining confidence and collaborate with* the Dutch Government is important due to their expertise in flood resilience and sustainable development. The lower interest reflects the fact that the project is one of many international collaborations they are involved in.

Private Sector – *Players* (collaborate with) *Context settlers* (keep informed, monitor)

Private investors and **Real estate developers** (P = 5.8-6, I = 6.5-6.8) are significant players in the financial landscape of Cồn Khương Island. They hold moderate power due to their financial contributions and development initiatives, particularly in tourism, housing, and commercial infrastructure. Their interest is relatively high as these developments directly impact their investments and profits. It is essential for governmental authorities, particularly *DPI* but also *VIUP* and *the Department of Urban Planning and Architecture, Cần Thơ*, to *collaborate with* these stakeholders to ensure that developments align with local regulations and sustainable development goals. Engaging them early in the process can help align financial and planning incentives with public interests, ensuring a balanced approach to development.

Tourism operators (P = 4, I = 6) are key stakeholders in the private sector, although their power is lower compared to other sectors. Their interest lies in ensuring the policies support tourism infrastructure, which is vital for the island's economic growth. While they should be keep informed , by *DPI* , their direct influence on policy-making is minimal.

Financial institutions and banks (P = 7, I = 6.8) play a critical role in providing loans, capital investment, and financial services for development projects. They have significant power in financing, and for *DPI*, collaborate with them is crucial to ensuring that financial risks are mitigated and that funds are efficiently managed.

Communities – *Context settlers* (keep informed)

Local businesses (P = 7, I = 5) have moderate power due to their influence on the local economy, but their interest in financial policy is relatively lower, focusing more on how policies impact their day-to-day operations. Local businesses should be *keep informed* by *DPI so that* essential for building local support and ensuring that financial policies do not negatively impact the existing business environment.

8.6. Up-scaling of management strategy over the Mekong Delta

This section builds on the stakeholder engagement and management strategies that have been discussed in the last sections. As these were all specific to Cồn Khương island, this section will explore the scalability of these frameworks to the wider Mekong Delta region. This will be done using the Multi-level Perspective (MLP) framework, where Cồn Khương will serve as a niche innovation, showing how the vision for the island can impact wider practices and regimes.

The framework used, the Multi-Level Perspective (MLP) framework, focuses on interactions across three levels: niches, regimes, and landscapes. It is used to understand how large-scale systemic transitions happen across society (Geels et al., 2017).
At the **niche level**, innovations and novel practices emerge in small environments, allowing experimentation without direct competition from established regimes (Smith & Raven, 2012). Cồn Khương island can be viewed as a niche where innovative resilience and water management strategies are designed and implemented on a small scale, while mostly being shielded from larger socio-political pressures.
The **socio-technical regime** level represents the current dominant practices, policies, and infrastructures that represent daily life and governance. In the Mekong Delta, traditional agriculture, water management, and socioeconomic norms that define how people interact with their environment are all part of this regime. Regimes are generally resistant to change, but they can adapt under pressure from niche innovations and landscape shifts (Geels & Schot, 2007).
The final level is the **socio-technical landscap**e level. This is the broader, slow-changing external environment, consisting of broad external forces such as climate change, economic globalization and political shifts, all of which apply pressure on the regime (Geels & Schot, 2007). By using this pressure they create windows of opportunity for niche innovations. In the Mekong Delta, rising sea levels, and increased flooding, among other environmental threats, are driving the need for systemic adaptation.

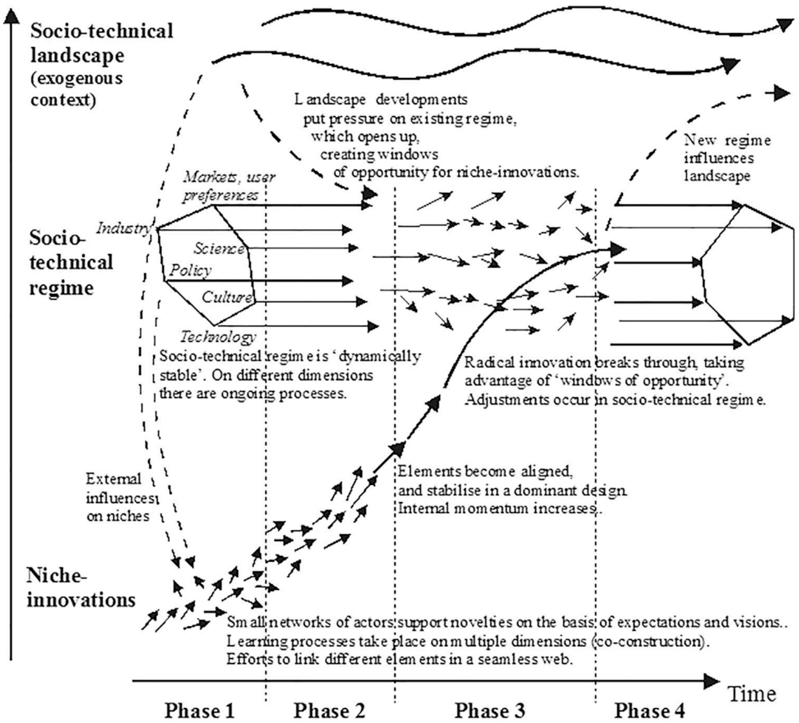


Figure 8.9: MLP Framework (Geels et al., 2017)

Figure 8.9 shows the MLP framework. In this framework, the three levels are arranged vertically, with niches at the bottom representing less structured environments where radical innovations emerge. The middle level represents the socio-technical regime, which is the stable configuration of existing systems.

Finally, the socio-technical landscape at the top represents broader external influences. Furthermore, the framework shows arrows indicating influence and movement, these will be discussed when the framework is applied to the project.

Niche innovations on Cồn Khương island

In the context of the Mekong Delta, Cồn Khương Island serves as a niche innovation. These niche innovations are the new adaptive strategies happening on Cồn Khương Island such as the development of floating structures, incorporating renewable energy (like waste-to-energy systems), and implementing soft dike designs. These new ideas are shielded from the limitations of the dominant socio-technical regime, enabling room for testing. Achieving success at this local level with flood-adaptive infrastructure and nature-based water management is essential for scaling the vision. Here, involving local communities, government stakeholders, and construction management experts guarantees the solutions are contextually viable (Loorbach et al., 2008). This provides the practical and social foundations necessary for further expansion.

The scaling of these niche innovations begins when the socio-technical system of the Mekong Delta, which includes local governments, policies, agricultural systems, and flood control technologies, faces growing pressure from environmental, economic, and social external forces, known as the landscape level (Kemp et al., 2007). In the Mekong Delta, climate change is the main landscape pressure, intensifying forces like sea-level rise, increased storm frequencies and intensity and salinity intrusion, among others, discussed in chapter 2. This also adds to social challenges such as the displacement of communities due to the inhabitable land caused by rising water levels (Minderhoud et al., 2019). Furthermore, international funding and growing political commitment to climate resilience and sustainability are creating a more favourable environment for niche innovations. The regime, which currently relies on hard-engineered solutions like dikes and levees, will face difficulties when these challenges accelerate. While effective in the short term, these hard-engineered solutions often need ongoing maintenance and significant financial investments, and they also cannot adapt to the changing environmental conditions caused by climate change and the other elements at play. This also holds for the dominant rice monoculture in the regime, which depends on traditional irrigation systems which are less adaptable to changing environmental conditions. Here, the proven innovations from Cồn Khương are being recognized as viable alternatives to the existing, more rigid, infrastructure.

Phased expansion and scaling of innovations

This process is very much a phased process. During the first phase, the innovations will be expanded to other vulnerable areas in Cần Thơ City that face similar flooding challenges. This gradual expansion, supported by data from Cồn Khương, allows stakeholders to see the immediate benefits of these innovations in various scenarios. Providing stakeholders with real data on how adaptable floating structures function in regions prone to seasonal floods or constant inundation is crucial for demonstrating the scalability of these innovations. During this stage, financial support from local governments and international organizations is crucial to make sure communities and stakeholders have the necessary resources to carry out these innovations.

The next phase is the further expansion of these solutions into the wider area of the Mekong Delta, such as regions with high agricultural dependency, and those most at risk for threats like salinity intrusion and floods. Implementing niche innovations like floating farms or adaptive renewable energy systems can enhance resilience in these areas and create economic benefits. During this phase, policy adjustments and stakeholder engagement strategies will need to ensure that agricultural communities are assisted in shifting to adaptive methods, such as floating farms, by providing training and technological resources (Geels et al., 2017). It is important to note, however, that despite the clear benefits, the scaling may face barriers. Institutional inertia, as established systems and regulations may resist change, may occur (Teisman, 2000). Additionally, it will be crucial to secure long-term financial support to ensure the successful expansion of these innovations across the delta. To mitigate these barriers, targeted policy changes and increased cooperation with local and international stakeholders will be required to streamline regulatory processes and guarantee long-term financial investments in adaptive solutions.

Transitioning to a new regime

As the effects of climate change become more severe, the pressure from the landscape on the socio-technical regime grows, accelerating the need for regime actors (such as local governments, industry, and agriculture) to reconsider the established practices and transition to adaptive solutions. This is the critical window of opportunity in transition management where the niche innovations from Cồn Khương start to break through at a larger scale.

In the third phase, regional governments, industries, and international organizations start establishing the scaling process, implementing the innovations as common solutions across the delta. By now, the implementations started on Cồn Khương not only offer local flood protection but also contribute to large-scale resilience strategies. Soft dikes, for instance, are integrated into national flood management policies and floating housing and agriculture are seen as the default infrastructure in the most vulnerable regions of the delta.

The innovations have now formed the basis of the new socio-technical regime for the Mekong Delta. This regime will be characterized by more sustainable, adaptive infrastructures, such as floating houses and renewable energy systems, and nature-based solutions like soft dikes. Over time, these solutions will influence the broader landscape, by providing a model for resilience and sustainability in delta regions worldwide, demonstrating how adaptive innovations can meet the specific needs of communities and address worldwide environmental challenges.

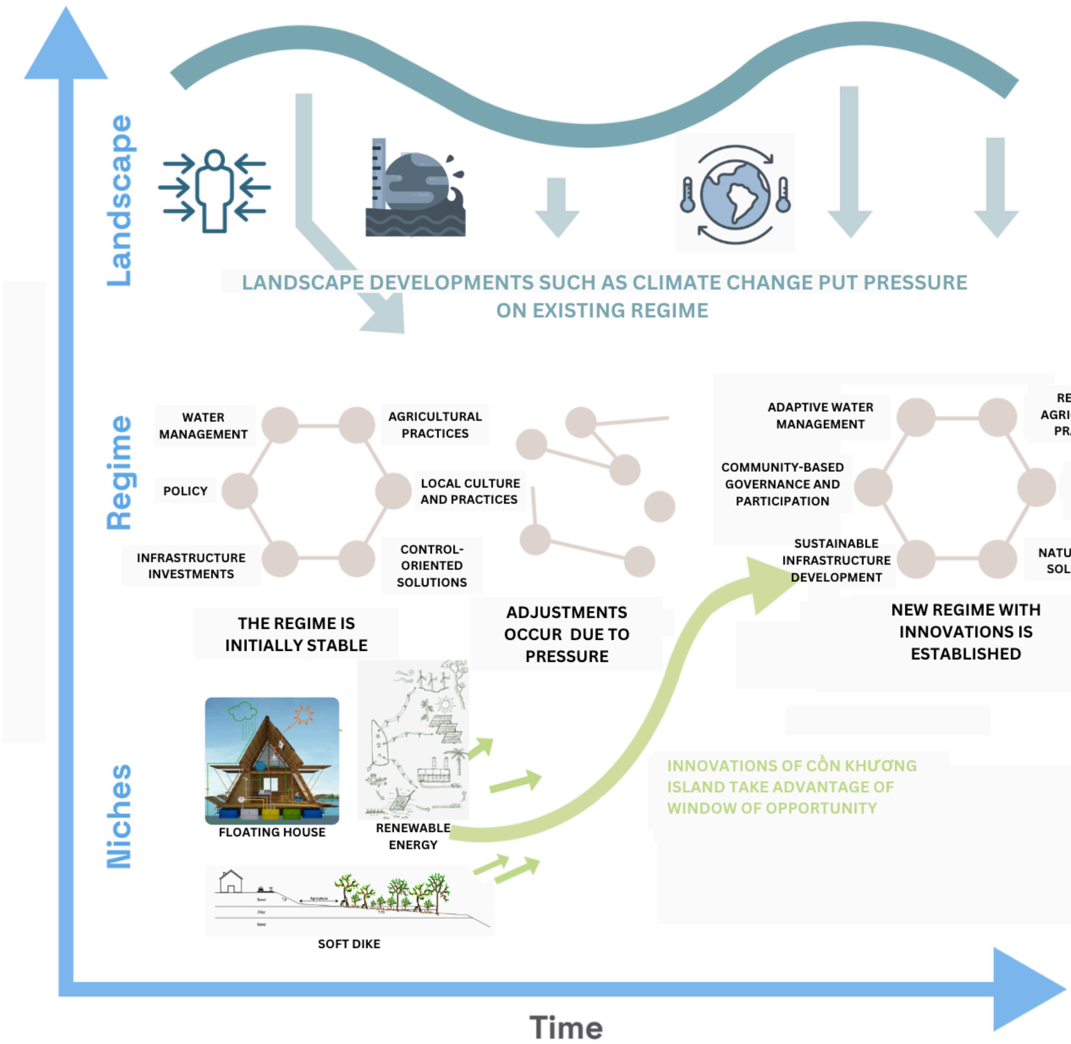


Figure 8.10: MLP Framework (by all authors, 2024).

As shown in Figure 8.10, the transition of the Mekong Delta's socio-technical regime follows the Multi-Level Perspective (MLP) framework. The landscape pressures, such as climate change, sea-level rise, and the growing need for sustainability, among others discussed, exert a growing stress on the existing regime. This existing regime relies on hard-engineered solutions and traditional (agricultural) practices.

This pressure from the landscape causes the regime to be unstable, creating a window of opportunity for the niche innovations developed on Cồn Khương Island to scale and influence the broader regime. Eventually, this new regime, including innovations, becomes stable and starts influencing the broader landscape.

8.7. Conclusion

This chapter addressed the following sub-research question: What framework can be developed to effectively engage stakeholders in Cần Thơ for future water management scenarios, while ensuring the scalability of this strategy in the Mekong Delta? This was done by conducting a detailed stakeholder analysis on Cồn Khương Island. This analysis highlights the importance of engaging a wide range of interconnected stakeholders who are essential to creating scalable and sustainable strategies within the Mekong Delta. Key stakeholders include governmental organizations like the Central Government and the Ministry of Natural Resources and Environment (MONRE) and international stakeholders, however, their effectiveness relies on collaboration with the local stakeholders, as was visible on islands like Con Son. Since each group has different levels of influence and interest, tailored engagement strategies are necessary for them to be successful. This strategy encourages sector-specific strategies that engage both high-power stakeholders, such as governmental bodies and environmental organizations, and high-interest groups like local communities, which are directly affected by these policies.

The management strategies designed emphasize an organized approach across sectors, including agriculture, urban development, environmental protection, water management, and finance. These strategies define clear roles for each stakeholder, with governmental authorities providing strategic oversight and regional actors handling local implementation. This creates consistency across sectors and ensures that policies are developed systematically and adapted to regional needs. Because of the Mekong Delta's vulnerability to climate risk, biodiversity loss, and economic instability, each sector's strategy integrates sustainability as a key focus. Here, the financial sector is important because it supplies the required funds, with support from institutions like the World Bank and private investors who help sustain development projects by aligning financial incentives with environmental goals. Moreover, Cần Thơ University acts as a crucial bridge by offering scientific and technical insights, ensuring that policy decisions are informed by evidence and suited to regional contexts. This structured framework of sector-specific strategies creates a balanced and adaptable management approach that takes into account both the high-level policy goals, as well as, the practical needs of local communities.

This management framework developed on Cồn Khương Island shows significant scalability potential across the Mekong Delta, embodying the MLP framework's vision of transitioning towards resilient, adaptable policies that satisfy local demands while adhering to international sustainability goals. By using sector-specific frameworks, a power-interest alignment strategy that allows for regional adaptation, and a multi-tiered governance structure, this system may be expanded. Adaptable engagement methods, supported by long-term funding from local governments and international donors, offer a vision for regional implementation that can be tailored to various areas across the delta.

This management strategy creates a strong foundation for sustainable development in the Mekong Delta, balancing national priorities with local needs. As a scalable model, it has the potential to promote adaptation and resilience throughout the area in the face of evolving environmental and socio-economic challenges.

9

Discussion

This report presents a design for Cồn Khương Island in 2075, developed in response to current and future environmental threats and socio-economic challenges in the area. Addressing these issues requires a paradigm shift from traditional, hard-engineered solutions to a more integrated and adaptive approach. This could have benefits for the environment, while also saving expenses.

Currently considerable research is available on climate resilience in river deltas. However, significant gaps remain in holistic, nature-inclusive strategies. Research has namely often focused on engineered solutions like dykes and seawalls, which mitigate immediate flood risks but often overlook long-term ecological impacts and socio-economic sustainability. Few studies effectively integrate traditional water management practices with modern techniques, leaving an opportunity for community-based, adaptable approaches that align with local environmental and social dynamics. This project seeks to fill that gap by proposing a resilience framework for Cồn Khương Island centered on five key design values: sustainability, multi-purpose functionality, flexibility, systemic thinking, and design with nature. Each value contributes to a holistic strategy that acknowledges the intricate socio-environmental dynamics of the Mekong Delta, ensuring long-term adaptability and sustainability.

To realize a holistic design, a vision was created to realize a resilient and sustainable island in the Mekong Delta in 2075. This vision accepts flooding of the island, and therefore embraces adaptation, instead of mitigation. Fieldwork and collaborative design with local stakeholders revealed that combining traditional and adaptive measures offers effective flood mitigation while supporting community resilience. The vision indicates that multi-purpose ideas, such as dyke roads and retention parks, enhances flood resilience and promotes social engagement by providing communal spaces. Additionally, flexible solutions like floating agriculture and stilt housing accommodate seasonal flooding, preserving livelihoods without necessitating relocation. Restoring melaleuca forests and wetlands emerged as a critical nature-based strategy, buffering against riverbank erosion and enhancing biodiversity. The emphasis on natural solutions, supported by community input, provides an actionable framework for future spatial planning on the island, which, as noted by local students, is currently lacking in Cần Thơ.

Comparing these findings with existing literature highlights several unique contributions. Many studies recommend large-scale relocation to mitigate flood risks, yet this study advocates for adaptive, on-site solutions. These findings align with approaches observed in other delta regions, such as the Mississippi Delta, where community-focused adaptive structures have proven effective in balancing ecological and economic resilience (Meyer & Nijhuis, 2013). This report gives a direction for further design on the island and aims to make it an integrated whole, providing a sustainable model that could serve as a source of inspiration for future development in Cồn Khương, as well as Cần Thơ and the Mekong Delta as a whole.

There are however some limitations regarding usability of this report. The input parameters used in the engineering solutions (i.e. for wind, waves, subsidence, water-level rise) are based on values found in literature, due to a lack of available datasets. These literature-based values were often determined for nearby locations or areas, but not specific to the Cồn Khương island. By doing measurements on the island itself, one could yield more accurate parameters, resulting in designs which are more fit-for-purpose. Additionally, because the design is based on observed and well-documented issues rather than firsthand, daily exposure to the Mekong Delta's evolving problems, it may not fully encapsulate the nuanced local challenges experienced by local citizens. Our results are however based on the environmental problems, like waste and flooding, observed in the one-week fieldwork. Another limitation is that economic considerations, such as funding and financial support for these constructions, were outside the project's scope, which could affect implementation feasibility. Furthermore, a lack of detailed, publicly accessible information on current urban developments in Cần Thơ and the Mekong Delta restricts the ability to incorporate ongoing government plans into the design fully.

While the resilience framework developed for Cồn Khương Island offers valuable insights, its direct applicability to rural regions in the Mekong Delta is limited. One significant limitation is the difference in infrastructure and resource availability between Cần Thơ and rural regions. Cần Thơ, as a more urbanized and economically active center, has access to resources and technical expertise that may not be readily available in less developed areas. Implementing solutions like multi-purpose dykes or floating agriculture in rural settings could face logistical challenges due to limited funding, lack of technical capacity, and reduced government support. Cultural factors also play a role, as rural populations may be more resistant to new technologies or external interventions, favoring time-tested practices that may not align with the adaptive solutions proposed in this study. However, beyond cultural and financial limitations, the underlying principles of the framework — sustainability, multi-functionality, flexibility, systemic thinking, and design with nature — are broadly relevant and can guide resilience planning in rural areas. A translation of policy from the national government towards smaller-scale local municipalities could also be hard. For instance, private property owners on the Cồn Khương island, could be hard to get on board for the design presented in this report.

To make the results as presented in this report more useful, future research could be conducted. This future research should focus on bridging the gap between the conceptual design in this report and the practical implementation (i.e. in-depth technical design, identify construction companies, quantify costs, involvement of stakeholders, legal framework, etc). Creating a phased timeline could clarify which elements of the design should be prioritized, leading to an urban planning outline. The stakeholder engagement would also be very important in this urban planning outline. Furthermore, detailed environmental modeling across different areas of the Mekong Delta is essential to assess the scalability of these adaptive measures and test their performance under various climate scenarios. Expanding the research scope to include long-term monitoring and incorporating more precise, field-collected data (i.e. soil type, local subsidence, river data) would further validate the resilience of multi-purpose, flexible infrastructure. Additionally, conducting economic analyses could strengthen cost-benefit assessments for both nature-based and traditional approaches. Engaging local residents through interviews and fostering partnerships with local governments would also provide insights into community needs and encourage collaborative implementation. Such partnerships could improve the potential for practical impact, facilitating cooperation and policy support for adaptive solutions.

This report offers a comprehensive, adaptable framework for enhancing resilience and living with water in the Mekong Delta by integrating traditional knowledge and nature-based solutions with proven engineering principles. Through systemic thinking and flexible design, it proposes a sustainable path that balances ecological integrity with socio-economic stability. Although limitations in data and scope affect the precision of the design, the report's recommendations provide valuable direction for future research and development. As climate change continues to challenge delta regions worldwide, this project offers a promising model for sustainable resilience, demonstrating the potential of harmonizing natural and engineered solutions to protect vulnerable communities.

10

Conclusion

Main research question:

How can the Mekong Delta coexist with water in the future in a sustainable and resilient way, leveraging traditional knowledge and practices to address future environmental and socio-economic challenges, by taking the island Cồn Khương as a case study?

In order for the Mekong Delta to coexist with water in the future in a sustainable and resilient way, it is important that a paradigm shift takes place by rethinking the purpose, scope and relationship of design solutions which are implemented in order to deal with the environmental threats the Mekong Delta is facing. In this report the vision is therefore centered around 5 core design values which are: flexible, multipurpose, sustainable, design with nature and systemic.

In the future it is important to embrace water rather than focusing on keeping the water outside. By adapting to the water, through rethinking agriculture, typology and urban design to be a flexible and sustainable system which responds and adapts during rising water levels rather than remaining static and susceptible to the negative consequences.

Central to this objective are the core design values which aim at flexible, multipurpose , sustainable, designed with nature, systemic solutions that embrace water rather than attemt to exclude it. This includes soft dykes that facilitate flood management while supporting agricultural practices, modular floating pontoons crafted from locally sourced materials like bamboo and melaleuca timber, which enable communities to live sustainably on water and governmental frameworks which allow to successfully implement solutions and cooperate with one another in the future.

Sub-research question:

'What framework can be developed to effectively engage stakeholders in Cần Thơ for future water management scenarios, while ensuring the scalability of this strategy in the Mekong Delta?'

To ensure successful implementation, a comprehensive stakeholder management strategy is essential. This involves a detailed stakeholder analysis conducted on Cồn Khương Island and the Mekong Delta as a whole that informs a scalable framework for engaging various parties in Cần Thơ. It recognizes the importance of collaboration among governmental organizations, local communities, and international stakeholders, ensuring that management strategies for water resources are tailored to local needs while accomodating broader Mekong Delta goals.

Sub-research question:

'How would a soft dykes look like on Cồn Khương island?'

For resilient soft dykes on Cồn Khương Island, an emphasis on flexibility and ecological integration leads to structures that not only protect against flooding but also enhance the ecological value of the landscape. Similarly, modular floating pontoons provide an innovative solution for living on water, incorporating renewable energy sources and sustainable practices that address future environmental challenges.

Sub-research question:

'How can we build a modular floating pontoon with local construction methods and materials to facilitate living on water in the year 2075?'.

In order to have floating structures to facilitate adaptability to rising water levels it is important to focus on existing materials and methods which are present in the surrounding area. By working with Bamboo and plastic drums it becomes economically viable to realise these pontoons and accessible to fabricate them. Providing a manageable size and considering different loading conditions it can serve several purposes and realigns with the necessity of having flexible and multi-purpose design solutions.

Ultimately, the combination of these design solutions based on the vision is one of many ways in which the future Mekong Delta can aim to be a dynamic, adaptive system capable of thriving in harmony with rising water levels rather than against it. This case study and paradigm shift offers a path towards a resilient future, serving as a model for the broader region's sustainable development in which the Mekong Delta can successfully coexist with water in the future in a sustainable and resilient way, leveraging traditional knowledge and practices to address future environmental and socio-economic challenges.

11

Reflection

This multidisciplinary project and honours program has been an extraordinary opportunity and wonderful learning journey. Working across different fields from civil engineering to architecture, we aimed to explore sustainable, water-resilient designs. Each step, from fieldwork to workshops, has deepened our appreciation for the complex relationship between communities and their environment, raising questions, inspiring creativity, and sometimes evoking frustration.

Arriving in Cần Thơ, we were warmly welcomed by the university, setting the stage for the transformative experiences that followed. At Cần Thơ University, local experts from the DRAGON institute shared insights that expanded our understanding of its urban environment and the Mekong delta. Throughout centuries, the people of the Mekong Delta have adapted to life with water. Observing this, particularly on the field trip to the aquacultural farm, was enlightening. During our visit of this fish farm, the owner asked, ”*What do you think we could improve?*” It was a moment that left us without a clear answer; the fishery already utilized solar energy, managed contamination risks, and minimized plastic waste and was able to withstand the floodings. This exchange led us to question our role: *Were we truly here to impart knowledge, or rather to learn from those already living resiliently with water*?

This question echoed on Con Son Island, where we observed farmers adapting their practices to the seasonality of water, harmonizing with nature in ways urban areas struggled with. The sight of these resilient agricultural practices became a fundamental inspiration for our design, creating realisations about adaptability and interdependence. We began to wonder*: What do these communities understand about water that cities overlook*?

The fieldwork was essential, not only for its content but for the perspective it offered: We come as outsiders, as ‘high educated engineers’, yet it is us who must learn. At Cần Thơ University, local experts shared knowledge about their adaptive practices. This learning extended beyond technicalities, it shaped our design values, helping us see our design role as part of a more extensive dialogue with local expertise.

Our group, primarily composed of civil engineering students, faced a challenge when introduced to the discipline of design. Initially, accustomed to finding direct solutions, we struggled with the open process and exploratory nature of design thinking. Time and again, we circled back to the question: *What are we truly trying to show*? *What is design*?

Our instructor’s response, “*I teach design, and even I don’t know what design is*,” lingered in our minds. Gradually, we understood that our discomfort was part of the process, as was embracing ambiguity. This mindset shift enabled us to conceptualize a vision, translating it into design. Following our final presentation after the fieldwork and university lectures in week 1, we each resumed work within our disciplines, which allowed for deeper exploration within our own domain, social aspects for CME students, technical calculations for engineers, and visionary elements for the architecture students.

However, eventually we realized that staying within our disciplines limited the cohesive vision we were building. As we drifted back into familiar comfortable roles, we questioned: *What is the value of a* *multidisciplinary project if we each work independently?* To create a strong design, we needed to cross these boundaries again. This integration highlighted the beauty of diverse approaches. The architectural idea of an ecological backbone, for instance, gained strength when supported by engineering calculations and environmental assessments. Similarly, we saw that without considering the social context of stakeholders, even the best engineering solutions could miss the mark.

This journey of working across disciplines required embracing discomfort, admitting our knowledge gaps, and learning through collaboration. Reflecting on the farmers' ease around water, we saw parallels with our process: Perhaps, like water, design is not meant to be controlled but rather navigated together. The farmers didn't view water as an enemy; they adapted to it and even used it for their own interest. Similarly, we learned that embracing diverse perspectives, even those we struggled to understand, could reveal unexpected insights and enrich our work.

In reflecting on this journey, we found ourselves repeatedly asking: *What is design?* Nature revealed one answer: a process built on integration and adaptability, where each part supports the whole. Observing the farmers' relationship with water, we saw that design thrives when it harmonizes with its environment, evolving naturally over time. But in asking this question, we also learned that design doesn't need to answer everything. In fact, designing often brings forth more questions than we started with. By allowing uncertainty to exist, leaving some questions open, as farmers leave water to flow, design can unfold and adapt through interaction with its context. This insight into letting go of fixed answers is a lasting lesson we take forward.

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12

Appendix A: Flooding Simulation

In order to come up with a design for Con Khuon island in 2075, one has to find out which areas on the island are most prone to flooding. By doing this, one can create a design based on science. As we are only interested in which parts of the island will be flooded, no advanced tools will have to be used for the flood simulation, which means that simple web-apps will suffice. The software that will be used are Climate Central (Climate-Central, 2024) and FastFlood (The-FastFlood-Team, 2024). This chapter aims to answer: *Which locations are most prone to flooding on the Cồn Khương island?*

Before these software are used, one has to find out which scenarios should be tested for. Question that should be answered are:

1. What is the sea level in 2075?
2. How much subsidence will take place between 2024 and 2075?

However, before going deeper into the these questions, one first should know the elevation profile of the island. This is given in Figure 12.1. The elevation of the river is 0 meters.

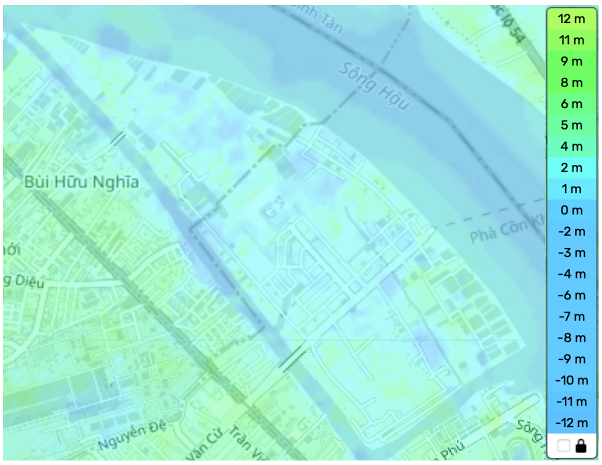


Figure 12.1: An elevation map of the Cồn Khương island in Cần Thơ City. The highest point is located at 6m above sea-level, and the lowest point at -1m below sea-level. The map was created in 'Topographic-map' (Author, 2024).

12.1. Sea-level rise

To find out what the sea-level will be in 2075, one has to take several scenarios into account, which are based on scientific literature. These scenarios are the scenarios given in the IPCC report of 2021

(Masson-Delmotte & Zhai, 2021). This will be the *SSP1-2.6*, *SSP2-4.5*, *SSP3-7.0* and *SSP5-8.5* scenario. Each of these scenarios will lead to different amount of sea-level rise. The projections are based on median projections of global and regional sea level rise, relative to a 1996-2014 baseline. Below, a more elaborate explanations follows for the scenarios. Since this chapter focuses on background data needed for the design of the island, it was decided to put this chapter as a appendix in this report.

1. SSP1-2.6 stays below 2.0°C warming relative to 1850-1900 (median) with implied net zero emissions in the second half of the century.
2. SSP2-4.5 is approximately in line with the upper end of aggregate Nationally Determined Contribution (NDC) emission levels by 2030. SR1.5 assessed temperature projections for NDCs to be between 2.7 and 3.4°C by 2100, corresponding to the upper half of projected warming under SSP2-4.5. New or updated NDCs by the end of 2020 did not significantly change the emissions projections up to 2030, although more countries adopted 2050 net zero targets in line with SSP1-1.9 or SSP1-2.6. The SSP2-4.5 scenario deviates mildly from a 'no-additional- climate-policy' reference scenario, resulting in a best-estimate warming around 2.7°C by the end of the 21st century relative to 1850-1900.
3. SSP3-7.0 is a medium to high reference scenario resulting from no additional climate policy under the SSP3 socioeconomic development narrative. SSP3-7.0 has particularly high non-CO2 emissions, including high aerosols emissions.
4. SSP5-8.5 is a high reference scenario with no additional climate policy. Emission levels as high as SSP5-8.5 are not obtained by Integrated Assessment Models (IAMs) under any of the SSPs other than the fossil fueled SSP5 socioeconomic development pathway.

For each of these scenarios, the sea-level rise was determined near Vung Tau, as shown in Figure 12.2. In 2075, the sea-level rise corresponds to 0.32, 0.37, 0.41 and 0.46 meters respectively for scenario SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5. The sea-level rise is relative to the sea-level in 2014

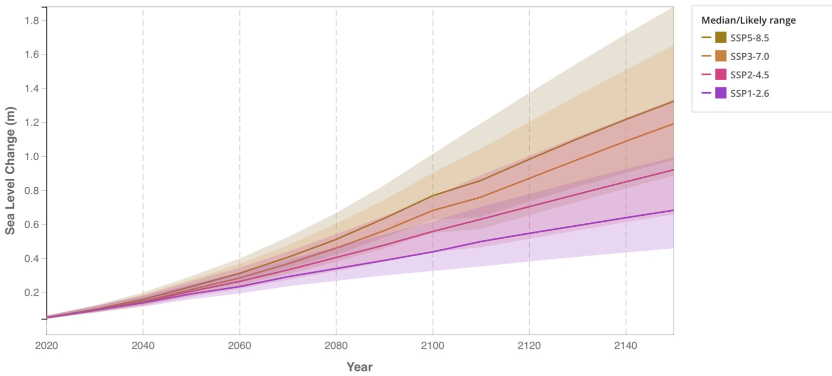


Figure 12.2: A plot of the sea-level rise relative to the sea-level in 2014 for the four different IPCC scenario at Vung Tau, which is located adjacent to the Mekong delta. This plot was made in the Sea Level Projection Tool (NASA, 2024).

12.2. Subsidence

Due to groundwater extraction and natural compaction, subsidence in currently taking place in the Mekong delta. This makes the delta prone to flooding, saline intrusion and coastal erosion, which threatens agriculture, infrastructure and the livelihoods of millions of lives. As stated in the problem analysis, the mean elevation of the Mekong delta was at 0.8m meters above sea level in 2019 (Minderhoud et al., 2019). As sea sea level is rising as well, the consequence of subsidence will only become more severe.

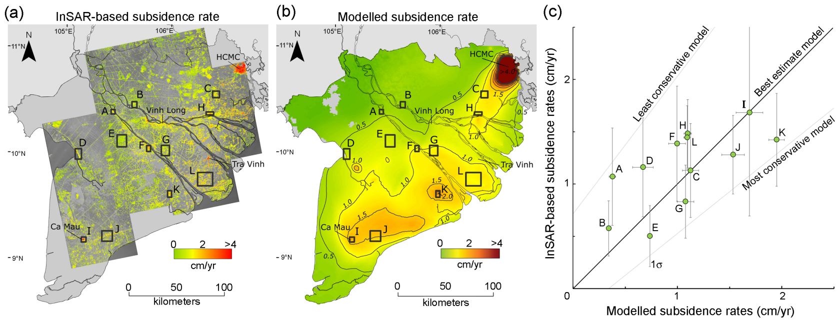


Figure 12.3: (a) InSAR-measured subsidence. Rectangles show selected subsets for comparison. Region F denotes Cần Thơ City. (b) Modelled subsidence of the best estimate model. (c) Fit between modelled subsidence rates and InSAR measurements for the selected subsets showing average values (green dots) with one standard deviation (Minderhoud et al., 2019).

Figure 12.3 shows the subsidence rate in the Mekong delta for 2019. The subsidence around Cần Thơ City is here determined to be around 1.1 cm per year. If one was to linearly extrapolate this number towards 2075, the total subsidence would be 66 centimeters. This would severely increase the likelihood of flooding.

According to more a more accurate study (Takagi et al., 2016), the average subsidence in Cần Thơ City was equal to 17.1 mm yr^{-1} from 1993-2013, which is close to an average subsidence rate of 16 mm yr^{-1} for 2006-2010 measured using InSAR (Interferometric Synthetic Aperture Radar) found by (L. Erban et al., 2014). The first number, 17.1 mm yr^{-1}, will be used for the simulation, because it represents an average taken over a higher number of years.

For the flood simulation, the following four scenarios will be tested, which are summarized in the table below:

Scenario	Average subsidence (cm yr^{-1})	Total subsidence by 2075 (cm)
Same extraction	1.71	106
Phase out 2075	0.993	60.6
Phase out 2050	0.698	42.6
Zero extraction	0.475	29.0

Table 12.1: Four different scenario's for subsidence. The first scenario corresponds to an extraction rate equal to a the historical average as mentioned earlier. The second scenario corresponds to a linear phase out by 2075. The third scenario corresponds to a linear phase out by 2050, and an extraction rate of zero by 2050. The fourth scenario corresponds to an immediate cease of groundwater extraction in 2025. All scenarios start at 2024.

Note that the subsidence rates in Table 12.1 take natural compaction into account, which accounts for around 2 mm yr^{-1}, which means that 1.51 cm yr^{-1} of subsidence occurs due to groundwater extraction (Minderhoud et al., 2019).

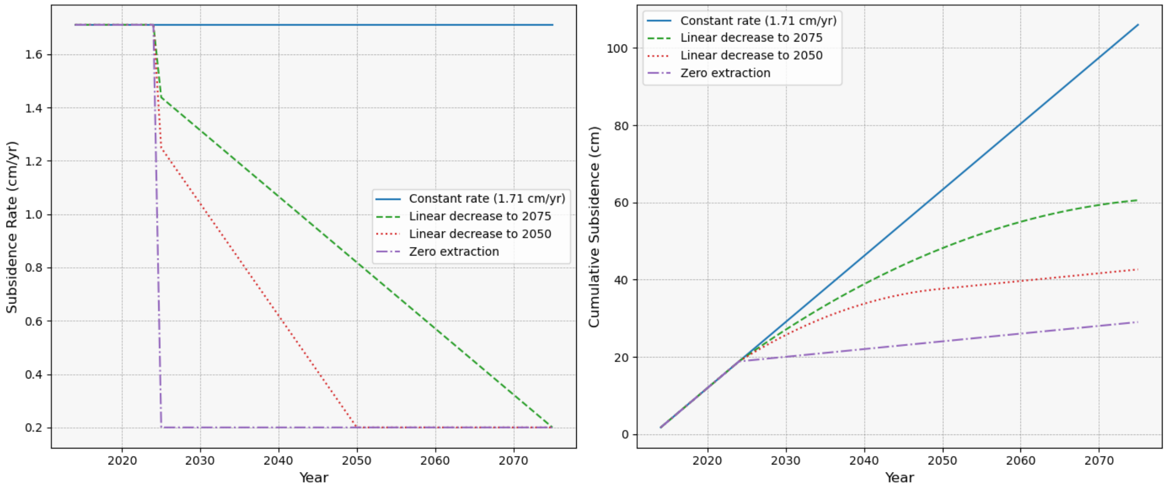


Figure 12.4: subsidence rates (left) and cumulative subsidence (right) over time for the different scenarios.

12.3. Model

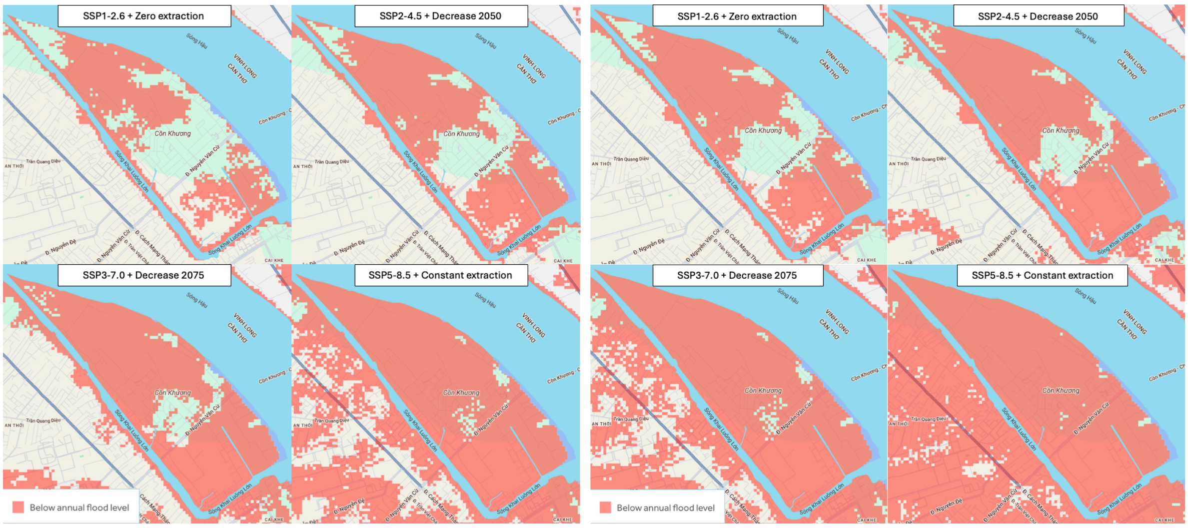
In the model, the four climate scenarios and four subsidence scenarios will be merged to obtain four combined scenarios. The magnitude of a climate scenario is coupled with a subsidence scenario of corresponding magnitude. The results should be interpreted simply as possible realities in the future, and serve as an indication for the design of the Cồn Khương island. No discrimination between scenarios in terms of probability exists in the results. The model software uses the following assumptions:

- The flooding of the island is caused by river flooding due to sea-level rise and storm surges. For the latter, results from a model by (Dullaart et al., 2021) was used. The water level at Cần Thơ is namely heavily influenced by the sea level at the delta mouth.
- No pluvial flooding is taken into account.
- No river flooding due to extreme upstream rainfall is taken into account.

In Figure 12.5, one can observe the flood model for the Cồn Khương island. A return period of 1 year and a return period of 50 years was used. When a return period of one year is used, an annual flood is statistically expected to occur once a year(>95% of the times), but some year might have more incidents, and others might have none. From these figures it can clearly be concluded that flooding forms a major risk in the future, and flood resilience should be one of the core topics within its design.

Scenario	Sea-level rise (cm)	Cumulative subsidence (cm)	Total relative change (cm)
SSP5-8.5 + Constant extraction	46	106	152
SSP3-7.0 + Phase out 2075	41	60.6	101.6
SSP2-4.5 + Phase out 2050	37	42.6	79.6
SSP1-2.6 + Zero extraction	32	29.0	61.0

Table 12.2



(a) return period of 1 year

(b) return period of 50 years

Figure 12.5: Eight different flood scenarios in 2080 in Cồn Khương, based on the *SSP1-2.6*, *SSP2-4.5*, *SSP3-7.0* and *SSP5-8.5* scenarios of the IPCC in 2077. The area highlighted in red denotes area which will be flooded due to sea level rise as well as the added height of local flood due to storm surges. An annual flood is statistically expected to occur once a year, but some year might have more incidents, and others might have none.