Mangroves in motion: Investigating the impact of the Hai Phong Masterplan

A case study in the Do Son area

CEGM3000: Multidisciplinary Project

D. Janssen, H. Kapper, L. Smulders, P. Prins, B. Krans, S. Lagerwey

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D. Janssen, H. Kapper, L. Smulders, P. Prins, B. Krans, S. Lagerwey

Student Name	Student Number
Donna Janssen	4716701
Hannah Kapper	4891325
Lisa Smulders	4678796
Pepijn Prins	4588118
Berend Krans	4489365
Stijn Lagerwey	4554132

Supervisors Thuy Loi: Lê Hài Trung, Nguyễn Thị Thế Nguyên
Supervisors TU Delft: Cong Mai Van, Erik-Jan Houwing
Project Duration: September, 2023 - November, 2023
Faculty: Faculty of Civil Engineering & Geosciences, Delft

TU Delft

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Preface

This report presents the findings of a 10-week study conducted in Vietnam, focusing on the hydraulic, socio-economic, and environmental impact of the implementation of the Hai Phong Masterplan on the existing mangrove systems.

This multidisciplinary project was made possible by the long-term collaboration between TU Delft and Thuy Loi University. During this multidisciplinary project, six students from different master directions—Hydraulic Engineering (Pepijn Prins and Berend Krans), Construction Management and Engineering (Stijn Lagerwey, Donna Janssen, and Hannah Kapper), Biochemical Engineering (Lisa Smulders)—conducted this research.

From Thuy Loi University, we received excellent supervision during the project period. We would like to sincerely express our gratitude and thanks to Dr. Trung, not only for guiding us in the right direction with the helpful tips, but also for showing us around in Vietnam.

We would also like to express our gratitude to Lindsey Schwidder for facilitating this collaboration and giving us this opportunity. Also, special thanks to everyone in Vietnam who helped us with guidance and assistance.

Lastly, special thanks are given to our TU Delft supervisors, Dr. Ir. Cong Mai Van, and Dr. Ir. Erik-Jan Houwing, for taking the time to provide us with insights and guidance.

Stijn Lagerwey, Hannah Kapper, Berend Krans, Donna Janssen, Lisa Smulders and Pepijn Prins

Hanoi, Wednesday 1th November, 2023

Summary

The Hai Phong region is undergoing transformative changes through a Masterplan aimed at enhancing financial stability and improving the quality of life for the local community. A significant component of this Masterplan involves the construction of two new port terminals close to the mangroves of Do Son, a small town southeast of Hai Phong.

Mangroves are beneficial in multiple facets. They act as a natural barrier, protecting coastlines from erosion, storm surges, and tsunamis. Additionally, mangroves contribute to water quality by filtering pollutants and trapping sediments, improving overall aquatic ecosystems. Furthermore, they provide crucial habitat for various species, supporting biodiversity and serving as nurseries for many marine organisms that benefit the local community.

This research investigates the potential implications of the Masterplan using the following research question:

What are the potential effects of the Hai Phong Masterplan on the mangrove ecosystems and the local community?

Conducted by a multidisciplinary team of six students, this research involved interviews with professionals, locals, and governmental organisations, extensive literature review, and field trips.

It was concluded from this research that the construction of the port terminals have far-reaching consequences. In the mangrove area in Bang La (area A), the port terminal will have a sheltering effect over the mangrove area. This will cause sedimentation to occur and thus accretion. Also, it is also expected that the water quality will degrade further due to increased anthropogenic activity in combination with the poor sewage system present. The mangrove area in Ngoc Hai (area B) is expected to have little direct changes.

The local community in Do Son shows varied awareness and support for the Masterplan, with stronger support in mangrove area A. Economic benefits, such as increased tourism, drive positive attitudes. However, there is a notable lack of awareness in area B. The willingness to participate is influenced by economic incentives, and effective communication is crucial for shaping community perspectives.

With regards to the further execution of the Masterplan it is recommended to incorporate effective waste management, revise reafforestation plans to meet legal obligations, and engage key environmental stakeholders.

For further research, it is recommended to conduct measurements over a more extended period of time to better understand the dynamics of the area. Additionally, more detailed research is needed to substantiate assumptions.

Contents

1
Introduction

This research proposal is written as part of a multidisciplinary research project in Hanoi, Vietnam. The project team consists of six TU Delft master students with backgrounds in different engineering disciplines, including Hydraulic Engineering, Biochemical Engineering and Construction Management Engineering. The research project is executed in collaboration with Thuy Loi University and is supervised by professors from both universities.

Research subject and scope

The research subject concerns the 2050 Masterplan of the city Hai Phong. With an estimated population of 4.5 million in 2050, the historic port town of Hai Phong is the third largest city in Vietnam. To capture upcoming external and internal opportunities, a team of consultants proposed to strengthen the city's industrial and economic growth by strategically defining two development belts and three green corridors. The vision is to transform Hai Phong from an industrial port city to a global maritime center, and from an industrial town to a waterfront service-oriented urban area that attracts talent, entrepreneurs and tourists from around the globe.

This research will focus on the area of Do Son, which is a small town southeast of Hai Phong. Do Son is a small peninsula founded by a mountain chain of dozens of hilltops from 25 to 130 m in height to form a dragon shape of 5 km in length heading to the open sea. Around Do Son there are many mangrove forests located. Mangrove forests represent a critical resource for Vietnam, offering a wide range of ecological diversity, economic potential, and serving as a natural barrier against coastal erosion and storm surges. However, the mangroves face significant disturbances due to various human activities related to the Masterplan. Comprehensive understanding with regard to the different aspects of the Masterplan of Hai Phong is crucial for its success.

Problem definition

This research will focus on the insufficient knowledge regarding the potential impacts of the Masterplan on the mangrove ecosystems in the Do Son area. Failure to address the potential impacts of the Masterplan on the vital mangrove ecosystems could lead to their degradation or complete disappearance, which would have devastating consequences. The complete disappearance of the mangrove forests in Do Son would not only result in the loss of ecological diversity but also expose the region to increased risks of coastal erosion, storm surges, and the loss of livelihoods for local communities dependent on these resources. Furthermore, the continued degradation of mangroves could exacerbate climate change and have long-term socio-economic impacts. Therefore, understanding and mitigating the threats to these ecosystems is of utmost importance for the well-being of the region and its sustainable development.

Currently, there is a notable lack of a comprehensive understanding of the potential effects of the Masterplan. Closing this knowledge gap is crucial to ensuring the sustainable development of the region. To achieve this, it is vital to gain insights from hydraulic, environmental, and socio-economic perspectives and recognize the interconnectedness of these disciplines. Figure 1.1 illustrates the strong coherence and influences between the hydraulic, socio-economic, and environmental effects of the Masterplan.

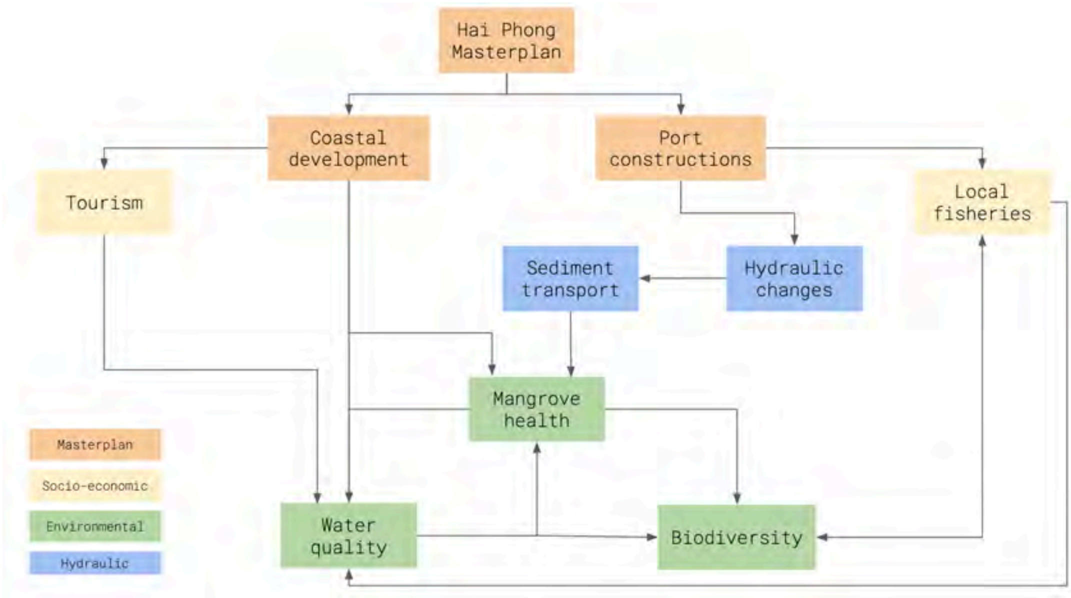


Figure 1.1: Schematisation of the research system.

Research questions

In order to conduct this comprehensive research the following main research questions and corresponding sub research questions are formulated as followed:

The main research question: *"What are the potential effects of the Hai Phong Masterplan on the mangrove ecosystems and the local community in Do Son?"*

This question will be answered using the following sub research questions:

- "What are the ecosystem services of the mangroves in Do Son?"
- "What are the potential environmental and hydraulic effects of the Hai Phong Masterplan on the mangrove ecosystems?"
- "What is the attitude of the local community towards the Masterplan and the mangrove ecosystems?"

Goals and objectives

The purpose of this study is to assess the current situation in the Do Son area and provide a forecast of the area's future situation after the implementation of the Hai Phong Masterplan. The current and future situation will be assessed from hydraulic, environmental, and socio-economic aspects. A literature study will be performed to understand the role of the mangrove ecosystems and the services they provide to the environment and the local community. Moreover, interviews will be conducted with different people from the local community to identify their dependencies on the mangroves and their perceptions on the implementation of the Masterplan. Data from measure stations in the area will be used to understand the current hydraulic conditions, and water quality measurements will be performed to assess the current quality of the mangrove environment. These findings will be used to describe the current situation and possible effects caused by the implementation of the Masterplan. Finally, recommendations will be provided to mitigate any expected negative effects of the Masterplan on the study area.

The research consists of two field trips to the study area. The aim of the first field trip is to get a good understanding of the study area. The information gathered during this trip is used to develop methods to analyse the environmental, socio-economic, and hydraulic impact of the Masterplan. During the second field trip, the data for the analyses will be collected.

In appendix A, the research plan is depicted in a schematised figure.

2
Background

2.1. Mangroves in Vietnam

Mangrove forests can be found along the entire coastline of Vietnam, as shown in figure 2.1. Two globally important river deltas are located in Vietnam, the Red River Delta in the north and Mekong River Delta in the south, both of which have extensive mangrove ecosystems (Veettil et al., 2019). Mangrove forests in Vietnam can be divided into four zones. The study area of this research is part of zone 2 (northern delta), from Do Son cape to the Lach River mouth with 7000 ha of mangrove forest (Hong, 1984). The northern delta has suitable soil and hydraulic conditions for mangrove vegetation, primarily attributed to the alluvial deposits from the Red and Thai Binh rivers. However, this region is vulnerable to strong winds and tidal currents (Veettil et al., 2019). Mangrove ecosystems are constantly changing. They can spread to new areas quickly, but they can also be affected by natural forces like storms and erosion. Human activities, like clearing mangroves and altering coastlines for a long time, have made these changes even more significant (Leal & Spalding, 2022).

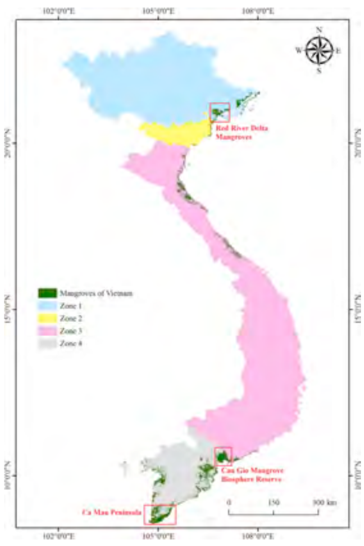
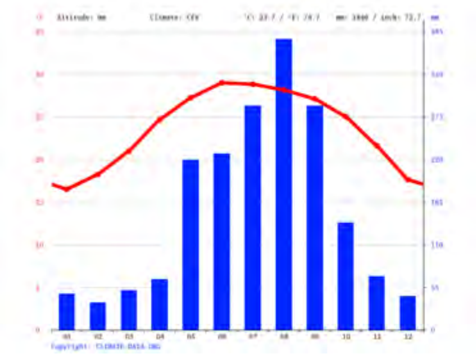


Figure 2.1: Mangrove distribution and zones in Vietnam (Veettil et al., 2019).

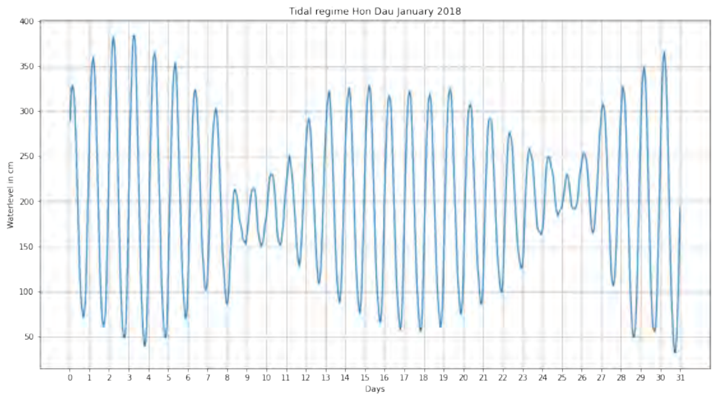
2.2. Study area description

Do Son is an urban coastal district of Hai Phong City. It is located 22 km outside of the city on the shore of the Gulf of Tonkin. The district has a total area of 42.37 km^2. The district is subdivided into seven wards, of which three of them contain mangroves: Bàng La, Ngọc Xuyên and Ngọc Hải. The climate in Do son is determined by a humid subtropical climate. During winter, from November to April, the temperature is mild with little precipitation. The average temperature in Hai Phong is 23.7 degrees Celsius. The annual precipitation is 1846 mm. The monthly temperature and precipitation is plotted in figure 2.2(a) (CLIMATE-DATA.org, 2023). During summer, from May to October, the climate is hot with a high level of precipitation, resulting in elevated humidity. The area is characterized by a diurnal tidal regime with a spring/neap cycle of 14 days as seen in figure 2.2(b). The maximum tidal range is 4.0 meters (K.-C. Nguyen et al., 2012). Do Son is characterised as a meso diurnal, tide-dominated area with a form factor of 18.9. In fact, according to D.S. van Maren, it is a one of a kind.

In march 2023, the Do Son district counted 51,417 inhabitants (Socialist Republic of Vietnam, 2023). Do Son beach is a popular destination for both tourists and local people to relax, participate in water activities and eat seafood. It is easy to reach from Hai Phong city by car and public transportation. According to the Head of the Department of Tourism, Culture and Information, Do Son welcomed 2.67 million domestic and international tourists from the beginning of the year to the end of September, far exceeding the annual target for 2023 (Vietnam.vn, 2023).



((a)) Monthly temperature (red) and precipitation (blue) (Climate-data.org, 2023).



((b)) Tidal regime Hon Dau.

2.2.1. Mangrove characteristics

To describe and visualize the mangrove areas in Do Son, data from the Global Mangrove Watch (GMW) is used (Bunting et al., 2018). The GMW is an initiative convened by Aberystwyth University, soloEO, The Nature Conservancy and Wetlands International. It aims to provide geospatial data information from 1996 up to 2020 about mangroves extend and changes throughout the entire world. The mangroves in Do Son are distributed within location A and B. The extent of the mangrove forests in these locations in 2020 are displayed in figure 2.3. In table 2.1 several mangrove characteristics of locations A and B are displayed based on the data from the GMW.

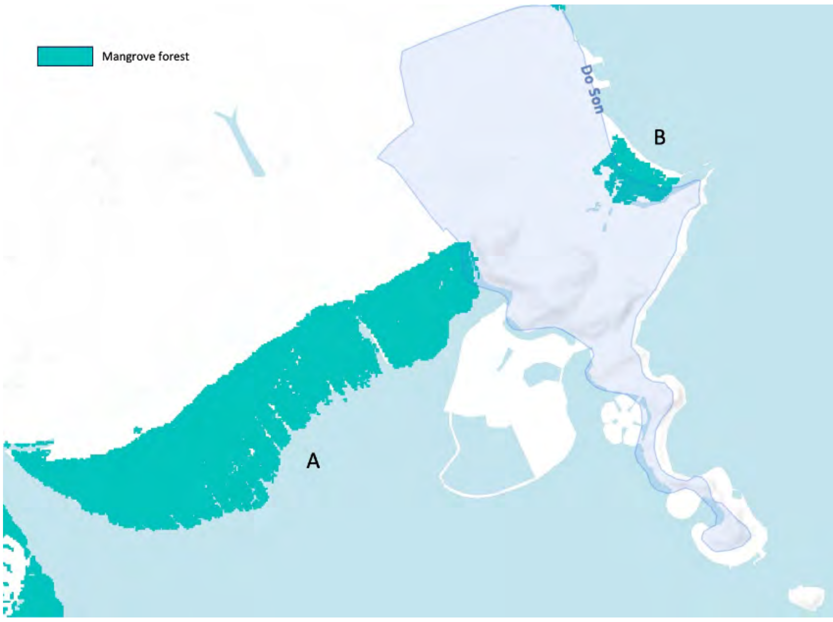


Figure 2.3: Spatial mangrove extent in Do Son.

Table 2.1: Mangrove characteristics

	Location A	Location B
Hectares (ha)	908.91	56.45
Mean mangrove above-ground biomass density (tons/ha)	79.11	84.94
Mean mangrove maximum canopy height (m)	5.13	6.15
Organic carbon stored (Mt CO_2e)	5.16	0.18
Net increase 1996-2020 (ha)	256.26	2.6

As indicated in table 2.1, there has been noticeable growth in the mangrove forests since 1997. This can be primarily attributed to the restoration efforts from the Japanese Red Cross (JRC), which were part of a national mangrove plantation program to reduce poverty and promote fixed cultivation and sedentarization (Dat & Yoshino, 2013).

Moreover, as described before mangrove forests play a crucial role in mitigating climate change due to their unique ability to capture and store significant amounts of carbon dioxide (CO_2) from the atmosphere. This process is essential in the fight against global warming, and the numbers in the table indicate that the mangroves in Do Son store 5.34 Mt CO_2e within their biomass and soils. This carbon sequestration function effectively reduces the concentration of greenhouse gases in the atmosphere, thus helping to mitigate climate change.

The species richness of trees is another important component of mangrove ecosystems. According to the biodiversity research of Nguyen Hoang Tiep in Hai Phong province, the following mangrove species are dominant in the mangrove forests in Do Son and cover about 68% of the area: Sonneratia caseolaris, Kandelia obovata and Avicennia marina (Hoàng Tiệp, 2020).

2.2.2. Mangrove restoration efforts

Since 1997, the Japanese Red Cross Society (JRCS) has collaborated with the Vietnam Red Cross Society (VRCS) on initiatives to promote afforestation of mangroves, along with a range of environmental protection efforts, spanning approximately 10,408 hectares across Vietnam. Throughout the entire project, local communities were directly engaged and provided active support in the restoration of the mangrove forest (Japanese Red Cross Society, 2016). Hai Phong is one of eight coastal provinces selected as target areas for mangrove plantation projects sponsored by the JRCS. In the period of 1997-2015, 360 ha of forest has been planted in the Bang La commune and 450 ha in the Dai Hop commune as part of the community-based 'Mangrove Plantation and Disaster Risk Reduction' (MP/-DRR) project. Effective coastal management policies have been implemented in both the Dai Hop and Bang La communities since 1998, led by the Red Cross branch of Hai Phong city. As a result, there has been a significant increase in mangrove growth during this period (Anh & Hoa, 2017). To assess the protective impact of the mangrove forests planted during the MP/DRR project, two level 9 typhoons that hit Do Son before and after 835 ha of mangrove trees were planted. The first typhoon caused substantial damage to the sea-dyke for a 3 km stretch, which cost 300,000 US dollars to repair, whereas the second typhoon caused no damage to the same dyke due to protection by the mangrove forests. The ecological benefits of the MP/DRR project were estimated at 549,450 tonnes of CO_2 captured by the mangrove forests planted during the 17-year implementation of the project (International Federation of Red Cross and Red Crescent Societies, 2011).

2.2.3. Hydraulic conditions

The main rivers in the estuary of the Hai Phong area are branches of the Red River; the Van Uc River, the Lach Tray River, Bang Dang River, and the Cam River. These rivers bring large amounts of sediments into the estuary, causing hotspots of erosion and accretion. According to (K.-C. Nguyen et al., 2012), the Hai Phong access channels experience continuously morphological changes. It was measured that the discharge of the Cam River lies between 100 - 1,000 m^3/s, depending on the dry season or the wet season. The averaged sediment concentration is 200 mg/L. The maximum depth in the rivers, estuary and nearshore has changed from 11-14 meters in 1934 to 3-10 meters currently. This has caused the access channels to be dredged annually. For the Do Son study area, only the Lach Tray River and the Van Uc River are considered. The discharges of the rivers causes brackish water to flow out of the bay during ebb, while salt water enters the bay during flood. The wind and wave characteristics changes throughout the seasons. According to (Duy Vinh, n.d.), during winter season the main wind direction are North and Northeast and during summer season the main wind directions are South and Southeast. In 2022, the main wave directions are East and Northeast during winter, with an average wave height between 0.3 - 0.75 meters per month. During summer, the main wave direction is South and Southeast with an average wave height between 0.7 - 1.2 meters per month ("Hon Dau Station", 2023). The bathymetry of the relevant area is described as shallow and lightly sloping. The sediment mean diameter and sedimentation rates at area B were measured from 1935 to 2008 by (Dang Hoai et al., 2013). The results are depicted in table 2.2 and table 2.3

	size [mm]
Min	0.008
Max	0.057
Avg	0.024
Std	0.015

Table 2.2: Sediment properties location B

	rates [cm/year]
Min	0.26
Max	15.00
Avg	1.40
Std	4.01

Table 2.3: Sedimentation rates location B

2.2.4. Coastal measures

The coastal defence structures of the Do Son area can be divided into hard measures and soft measures. An overview of the measures can be found in figure 2.4. The hard measures of the coastline defence consist of two sea dikes, located at Bang La (dike no. 1) and Ngoc Xuyen (dike no. 2). Both dikes are made of sand/clay, concrete walls and blocks for the slope, which are now overgrown with vegetation.

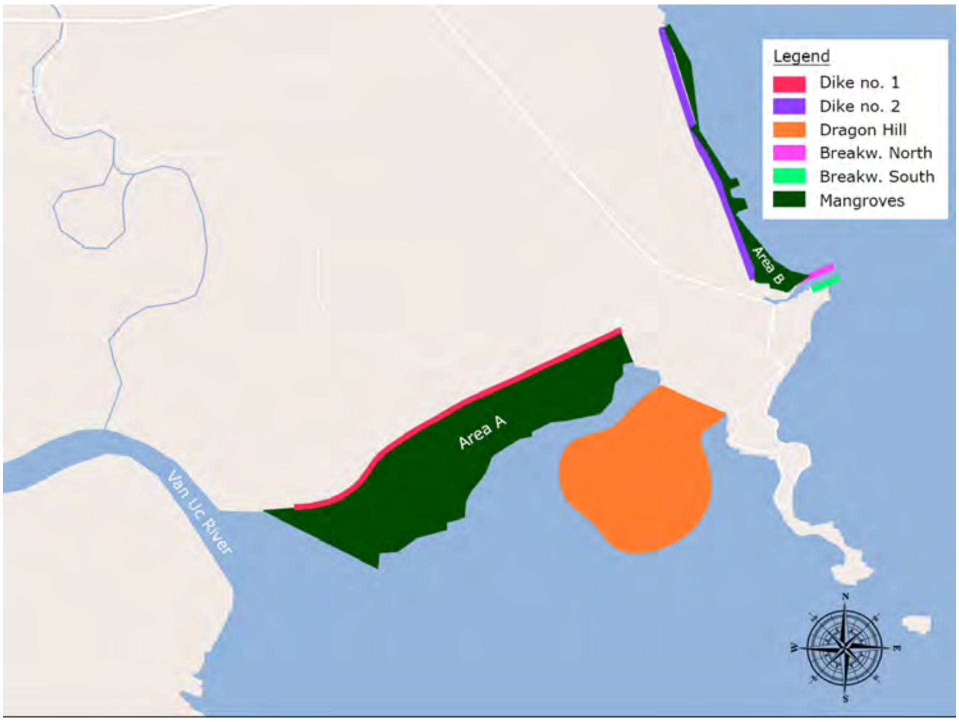


Figure 2.4: Overview of the hard and soft measures in the area of Do Son.

The port located south of mangrove area B is protected by two parallel breakwaters. The southern breakwater is a rubble-mound breakwater (appendix C) of 240 meters long, 25 meters wide with a maximum height of 1.5 meters. The breakwater is made out of two layers of stone, and tetrapods. The base layer is made out of LMA 60-300 stones, while the filter layer is made out of LMA 5-40 stones. Seen in figure 2.6. Its function lies in sheltering the port entrance against incoming waves, especially during summer as there are higher waves. In figure 2.5 it can be seen that the breakwater is not significantly high enough to meet the standards for wave overtopping. The tetrapods are placed along both sides of the breakwater. However, the legs of the tetrapods are made too thin, which caused them to break under wave loading, as seen in figure 2.7.

Figure 2.5: Southern breakwater at Ngoc Hai under wave loading from East direction (moving right to left) and high tide, overtopping does occur.

Figure 2.6: Stone sizes and tetrapods of the Southern breakwater.

Figure 2.7: Broken tetrapods of the Southern breakwater.

The northern breakwater is a monolithic vertically composite breakwater (appendix C) and is approximately 780 meters long, 0.90 meters wide and 0.90 meters high. From figure 2.8, it can be seen that waves caused a lot of damage in the form of holes and even completely broken parts; figure 2.9.
The first layer of this breakwater is made of stones with a diameter of 1.5-3 cm. It is assumed that another layer is placed on top in a later stadium, since shearing of the 2 layers occurred, which can be seen in figure 2.10. This layer contains rocks of . This breakwater has two functions. Firstly, it protects the port from the northern waves. Secondly, it can be assumed that it has been placed to stop the sediment coming from the Lach Uyen River. This resulted in accretion on the updrift side of the breakwater. This mechanism made it possible for the mangroves in area B to expand, as they are protected against erosion and high waves from the south.

Figure 2.8: Holes in the Northern breakwater at Ngọc Hải.

Figure 2.9: Broken parts of the Northern breakwater at Ngọc Hải.

Figure 2.10: Shearing of 2 rock layers, Northern breakwater at Ngọc Hải.

To further improve the coastal defence, two T-groynes were placed between 2010-2013 in mangrove area B. The body of the groynes is approx. 250 meters long, with a perpendicular arm of approx. 165 meters. The groynes are made of concrete blocks, which are 1.0 meter wide. The groynes were placed to disrupt the alongshore sediment transport, resulting in accumulation at the updrift side. The soft coastal defence exists mainly out of mangrove forests. Landwards of the soft measures we find concrete dikes or flood walls. The mud flats next to and in front of the mangroves are also part of the soft coastal defence. The local government also placed soft measures at area B, which include a permeable breakwater, made out of bamboo sticks. The effect of these bamboo sticks, however, is small as the sticks deteriorate fast compared to the time needed to have a proper sedimentation effect.

2.3. Hai Phong Masterplan

To strengthen Hai Phong's industrial and economic growth, the central government developed a Masterplan for Hai Phong 2050 in collaboration with many other stakeholders. The vision of this plan is to transform Hai Phong from an industrial port city to a global maritime centre, and from an industrial town to a waterfront service-oriented urban area that attracts talent, entrepreneurs and tourists from around the globe. The two institutes that are of particular interest for this study are: Vietnam Institute for Urban and Rural Planning (VIUP) and the Ministry of Agriculture and Rural Development (MARD). VIUP is a public service unit under Ministry of Construction and is responsible for the design of the general Masterplan for Hai Phong 2050. The MARD is responsible for the action plan which is a more integrated plan involving many different perspectives, such as socio-economic and environmental.

In this Masterplan there are also plans included for Do Son. In figure 2.11 the plans for the focus area of this study can be found. The mangrove forests are marked in green with letters A and B. Area A is the south-west part of Do Son, which includes the mangrove forests in Bàng La and area B is the north-eastern part of Do Son, which includes the mangroves in Ngọc Hải and Ngọc Xuyên. The prospected ports are marked in pink and annotated with P1 and P2. These two new port terminals will take over the cargo activities that currently take place in the existing port in Hai Phong because it has reached its full capacity.

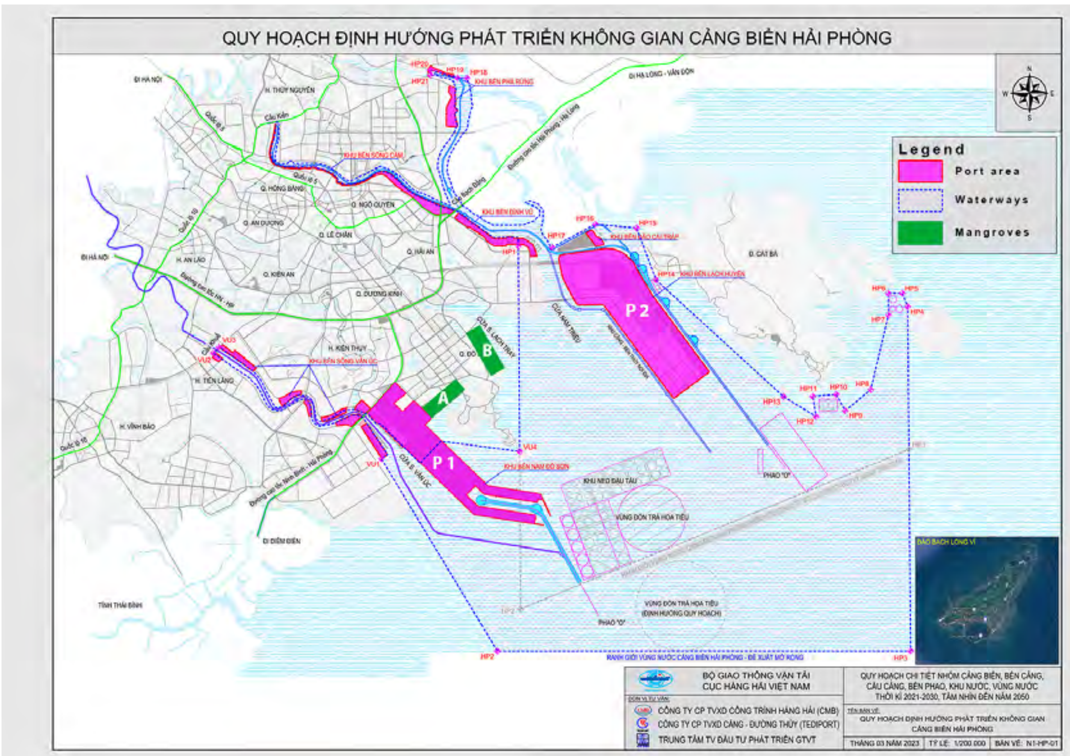


Figure 2.11: Project area, schematized mangrove areas A and B and prospecting harbours P1 and P2 (Boskalis 2023).

The Masterplan of Hai Phong contains two crucial aspects impacting Do Son. First of all, the construction of port terminals P1 and P2 (depicted in figure 2.11) will have have a significant impact. This study aims to increase the understanding of this impact. Secondly, the transformation of Do Son into a tourist destination will also have a big impact on the area. With a 125 km-long, flat coastline, the area holds significant tourism potential associated with the sea. Do Son, once a popular tourism destination in northern Vietnam, has faced challenges in developing high-standard resorts due to a lack of innovative ideas, promotion and investments. However, the new Dragon Hill resort project depicted in figure 2.12, located in the open sea, aims to become an appealing island destination, attracting tourists for longer stays and allowing them to explore the landscapes of Hai Phong (Tuoi Tre News, 2018). As depicted in figure 2.12, Dragon Hill will be accessible by two main roads that are connected to the mainland which should cover all the traffic to and from the island. By interviewing key stakeholders this study aims to get a better understanding of the socio-economic impact this Masterplan will have on the local community of Do Son and their perception and attitude towards the plans.

Figure 2.12: Dragon Hill resort in Do Son.

3
Literature review

3.1. Mangroves

A mangrove is a woody plant or plant community which lives in the area between the sea and the land. This shoreline, of most tropical and few subtropical countries, is flooded by tides for parts of time. Mangroves are unique ecosystems, as they have adapted to the characteristics of the transition zone between the ocean and land, in which only their tree species can survive. This transition zone deals with the daily rising and falling of the tide, which continuously influences the salinity amount and reduces the amount of oxygen in the soil (Miththapala, 2008).

Although it may seem that mangroves are fond of the saline as they live in the areas near the sea, the opposite is true. The salt water is actually a physiological stress factor for the mangroves. The only reason that they can be found along the seashore is that the flora and fauna of the mangroves have developed very distinct adaptations which allow them to survive in these unique circumstances of loose wet soils, saline habitats and periodic tidal submergence (Miththapala, 2008). This provides them with a competitive advantage over other plants.

3.1.1. Root structures

One of the most striking adaptations mangroves have made to their habitat are their root systems. There are four common types of breathing roots, which are depicted in figure 3.1. The pencil type as seen in Acivennia (1) and Sonneratia (3), the knee type, which grows upwards and then immediately downwards, as seen in Bruguiera (2), the stilt type with breathing pores as seen in Rhizophora (4) and lastly the ribbon or plank type, curving in a snake-like form (Miththapala, 2008).

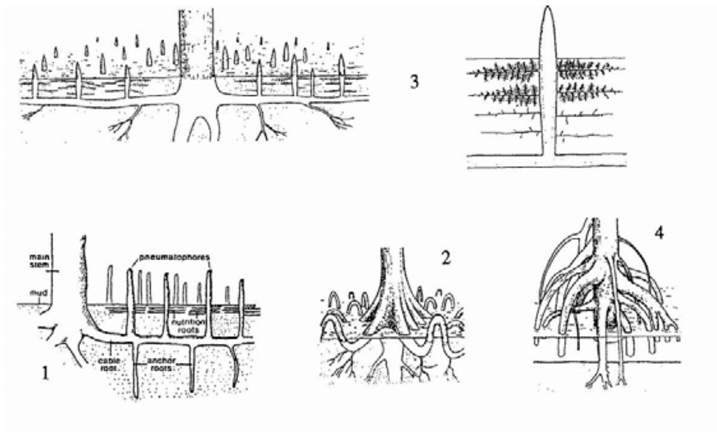


Figure 3.1: Typical root systems of Avicennia (1), Bruguiera (2), Sonneratia (3) and Rhizophora (4) (King & Clayton, 1981).

These root systems have different but closely associated parts with their own functions but can together be regarded as an integrated whole. The above-ground parts allows gas exchange through air holes or lenticels with below-ground parts (Marchand, 2008). This way oxygen can be supplied through air spaces to the underground roots in the oxygen-poor mud. The below-ground roots compromise the anchoring component and cable roots which unify the below- and above-ground roots forming a complete tree structure.

3.1.2. Salt coping mechanisms

Mangroves deploy a variety of means to cope with (high) salt concentrations of the seawater. Mangroves have the ability to obtain freshwater required for physiological processes from the soil surrounding the absorbing roots through salt exclusion. But this mechanism is not entirely sufficient as a little amount of salt is taken up by the tree and will accumulate. Salt in high concentrations in plant tissues is toxic and must be largely excluded. The mangroves exclude most of the salt in seawater. The way they do this differs between those that secrete salt (secreters) and those that do not (non-secreters). In salt secreters, such as Avicennia, the absorbed salt is primarily excreted via salt glands in the leaves. In non-secreters, such as Bruguiera, Rhizophora and Sonneratia, salt exclusion by the roots is more efficient (Marchand, 2008). An additional mechanism for the elimination of salt in all mangroves is simply by loss of parts, mainly being leaves.

3.1.3. Reproduction

Mangroves reproduce by flowering with pollination occurring via wind and insects. Once pollination occurs, the seeds remain attached to the parent tree. This way the seeds germinate into structures called propagules, ranging from 1 to 70 cm depending on the species see figure 3.2, before dropping into the waters below (Van der Stocken et al., 2019). This process is referred to as vivipary and helps them to grow rapidly upon falling to the soil below once they are ripe. When the propagules are dropped, the already-rooting seed will plant itself in the sediment, send up its first set of leaves and will grow into a new mangrove tree. The majority of floating propagules settle close to the parent tree, but long-distance dispersal is also possible. Floating mangrove propagules may remain viable for a month or longer (Simpson, 2019).

Figure 3.2: Propagule growing attached to the tree (Hillewaert, n.d.).

3.1.4. Growth conditions

To predict how well a mangrove forest will thrive, three hydrodynamic parameters are important. According to Marcel Marchang (Marchand, 2008), the water depth, inundation height and the frequency of inundation are crucial hydro dynamical factors. It was also mentioned that the inflow and outflow of the tidal wave needs to be present for the supply of sediment and nutrients. According to (D. A. Friess et al., 2012), it has been often demonstrated that there are certain thresholds for these key factors. As said in chapter 2, 2.2.1 the dominant species are: Sonneratia caseolaris, Kandelia obovata and Avicennia marina. Marcel Marchang (Marchand, 2008) found that the inundation class for S. caseolaris and A. marina is class I-IV. The inundation classes are found in Appendix D.

For the growth of the seedlings, it is important to avoid high energetic hydrodynamic environments as they cannot withstand the forces. This is one of the reasons that when mangrove trees are present, it does not mean that expansion is also possible. According to (Balke et al., 2011), a seedling needs to overcome three thresholds in order to grow. First, there needs to be a period of non inundation. Secondly, the roots need to grow long enough so they can overcome the hydrodynamic forces originating from the tidal currents and wave forces. Lastly, the roots need to be long enough to overcome the high energy events like typhoons.

To have mangrove growth, in most cases, accumulation is needed as mangroves are often squeezed by the sea and a sea dike (Phan & Stive, 2022). This is governed by two processes, the type of waves that arrive at the shore and the tidal wave bringing in the sediment. According to D.S. van Maren (Van Maren & Winterwerp, 2013), most sediment transport by the tidal waves occurs during the spring tide conditions. For both the onshore waves and the tidal waves, asymmetry is important for determining whether they are responsible for onshore or offshore sediment transport (Bosboom & Stive, 2023). It is also stated that in case only fine sediment particles are present, the suspended load is most dominant. According to D.S. van Maren, the most important factor is the lag effect. These are separated into scour lag and settling lag, which are a result of hydrodynamics and sediment properties (van Maren, 2023). It is mentioned that for tidal flats especially, the horizontal flow velocity decreases at the end of the basin causing a particle to settle. This is enhanced by mangroves as they reduce the flow velocity. However, a particle needs to have a critical shear stress that is high enough to not be resuspended into the water column.

3.1.5. Biodiversity

The biological environment of mangroves is a fascinating and diverse ecosystem that supports a wide range of plant and animal species. Insects, reptiles, amphibians, birds and mammals thrive in the habitat and contribute to its unique character by playing an evident role in functioning of the entire ecosystem of the mangroves. For example, crabs and mud lobsters are important in reworking the sediments among the mangroves as they mix the soils and change the surface characteristics (Marchand, 2008). Mud lobsters build large tunnelling burrows around mangroves which allow drainage, mixing, and aeration of the subsurface water in the mangroves, enhancing the growth and health of mangroves and other aquatic organisms.

3.2. Mangrove ecosystems services

Mangroves are amongst the one of the most productive ecosystems around the world. They have enormous ecological significance, both to the functioning of the natural environment as to humans. Besides hosting plant and animal life, mangrove forests serve multiple roles. They serve as carbon sink, help maintain water quality and offer protection against natural disasters for coastal areas. Additionally, mangroves create livelihood opportunities for coastal communities through activities such as aquaculture and ecotourism.

3.2.1. Environmental services

Mangrove ecosystems offer a wide range of environmental services, including carbon sequestration, the preservation of water quality and clarity, and the provision of habitat for marine life.

Carbon sequestration

Mangroves play a crucial role in mitigating the effects of greenhouse gases produced by human activities, such as industrial processes, agriculture and deforestation. This mitigation involves the conversion of atmospheric carbon dioxide (CO_2) into organic carbon through photosynthesis. This organic carbon, known as 'blue carbon' is partly stored in their above- and below-water biomass, in the form of roots, trunk and litter, that can be exported into the ocean through tides (Alongi, 2014). Additionally, carbon is accumulated in the soil by mangrove roots which trap additional suspended organic carbon in the water during tidal floodings. Due to waterlogging of the soils caused by tides, dead mangrove material decomposes very slowly. Mainly due to this hundreds or thousands of years process of carbon accumulation in the wet soil, mangroves are estimated to contain up to four times as much carbon compared to tropical rainforests (Leal & Spalding, 2022). Moreover, mangroves sequester carbon from the atmosphere at a ten times faster rate compared to tropical rain forests (National Oceanic and Atmospheric Administration, 2023). Due to the large amount of carbon stored in mangroves, current mangroves areas must be preserved in order to prevent the release of massive amounts of CO_2 back into the atmosphere and to maintain a valuable carbon sink for the future. Mangrove deforestation annually releases between 0.02 and 0.12 petagrams of carbon, contributing to around 10% of global deforestation emissions. This is significant considering that mangroves make up only 0.7% of the total area of tropical forests (Donato et al., 2011).

Water purification

Mangroves play a pivotal role in enhancing water quality within coastal areas, serving as nature's own water filtration systems for various contaminants, encompassing nitrogen, inorganic and organic pollutants. Strategically positioned at the interface of land and sea, they serve as highly efficient collectors of pollutants transported by the tidal flows, river discharges, and surface runoff. Due to their effective entrapment of suspended waste matter and their sediment's affinity for metal(loid)s and organic waste, mangroves can accumulate significant volumes of pollutants (Nguyễn et al., 2020). Moreover, mangroves function as long-term nitrogen sinks, offering a vital ecosystem service. Mangrove soils predominantly accumulate organic nitrogen derived from the decomposition of dead roots and litter, where it can be stored for decades. The growth of mangroves is significantly constrained by the availability of both nitrogen and phosphorous. Consequently, these ecosystems efficiently absorb and filter these nutrients from the surrounding water. Notably, net immobilization of ammonia (NH_4) stands as the highest ecosystem flux within the mangroves, highlighting their potential to treat wastewater from diverse sources, including aquaculture and sewage (Alongi, 2020; Ouyang and Guo, 2016).

Marine life habitat

Mangrove ecosystems provide habitats for indigenous animals and plants, serving as places for nesting, breeding, and nurturing. Above the water, the mangrove trees and canopy provide habitat for a wide range of species, including birds, insects, mammals and reptiles. Below the water, the roots are overgrown by epibonts such as tunicates, sponges, algae, and bivalves. The soft foundations in the mangroves forms habitat for various infaunal and epifaunal species, while the space between roots provides shelter, breeding ground and food for motile fauna such as prawns, crabs, fishes and mollusks (Nagelkerken et al., 2008). Mangroves provide nutrition directly through fallen leaves, fruits and hummus and indirectly through hummus-eating animals that function as prey for big fish and other predators (Nhung, 2004). Biodiversity is crucial for sustaining natural functioning ecosystems and offers economic and social advantages, as people depend on wildlife, plants and fisheries for their livelihoods. Biodiversity is threatened worldwide by various anthropogenic activities, such as loss of habitat and marine pollution. Carugati et. al studied the impact of mangrove destruction on biodiversity and ecosystem functioning by comparing undisturbed mangrove forests with disturbed ones. Meiofaunal biodiversity was used as an indicator of environmental changes. As habitants of the mangrove sediments, meiofaunal organisms play a crucial role in mangrove ecosystems in nutrient cycling, stimulating microbial activity and sustaining the food web. Benthic biomass and microbial carbon incorporation were used as indicators for ecosystem functioning. It was found that all indicators are lower in the disturbed mangroves, indicating that mangrove degration could have important consequences on ecosystem functioning (Carugati et al., 2018).

3.2.2. Commercial services

Due to the high biodiversity caused by the organic characteristics of the mangrove forests, the ecosystem itself provides multiple services such as commercial fishing, coastal aquaculture industries, timber production and non-timber production (Singh et al., 2010). These services create socio-economic values as job opportunities, food security and household income to the local communities in the mangrove areas (Hue & Scott, 2008). For this reason, mangrove forests are considered to enhance the economic and social stability of local communities (D. Friess et al., 2016).

In case of the fishery services, three broad classes mangrove-associated fisheries can be established; inshore, offshore and shrimp pond fisheries (Hutchison et al., 2014). Inshore mangrove fishing occurs in shallow coastal areas near mangrove forests, using small boats and traditional techniques to target smaller fish species, crabs and molluscs (Badola et al., 2012). On the other hand, offshore mangrove fishing operates in deeper waters beyond the coastal zone, employing larger vessels and specialised gear to catch larger, more commercially valuable species. At last, shrimp ponds within mangrove areas are aquaculture facilities located in or near coastal mangrove ecosystems. These ponds are specifically designed for cultivating shrimp species for commercial purposes (Le & Munekage, 2004). It's worth noting that besides the economical benefits shrimp pond farms in mangrove areas provide, they can also pose environmental risks if not managed properly (Hossain et al., 2013). Over-exploitation, habitat destruction, and pollution are potential negative impacts that need to be mitigated through sustainable aquaculture methods (Do & Thuy, 2022).

Beyond fisheries, mangrove forests yield both timber and non-timber resources that serve as essential commodities for the community. Timber parts from mangrove forests can be harvested and used for various purposes, including construction, furniture-making, and crafting (Adanguidi et al., 2020). In terms of non-timber resources, honey production, traditional medicine, and the sale of fruits and nuts in local markets offer several income sources for the local community which causes both timber and non-timber to contribute significantly to the economic stability within the mangrove forest areas.

3.2.3. Coastal protection

It is well known that mangroves have a positive effect on protecting the coastline. Wave attenuation was researched in a case study in southern Thailand (Horstman et al., 2014). It was found that the significant wave height was reduced by 30% for a transect of 98 meters up to 47% for a transect of 246 meters. The wave energy reduction was 60% and 71%, respectively. According to (Hashim et al., 2013), a mangrove forest in the Tong King delta, with a width of 1.5 kilometres with 6-year-old Kandelia Candel trees will result in a wave height reduction of 95% from open sea wave height to the coast. Mangroves are most effective in reducing wave energy for short waves, with a period of less than 10 seconds. The coverage of the vegetation zones on different heights is a key factor on how effective the wave dissipation by mangroves is (Mazda et al., 1997).

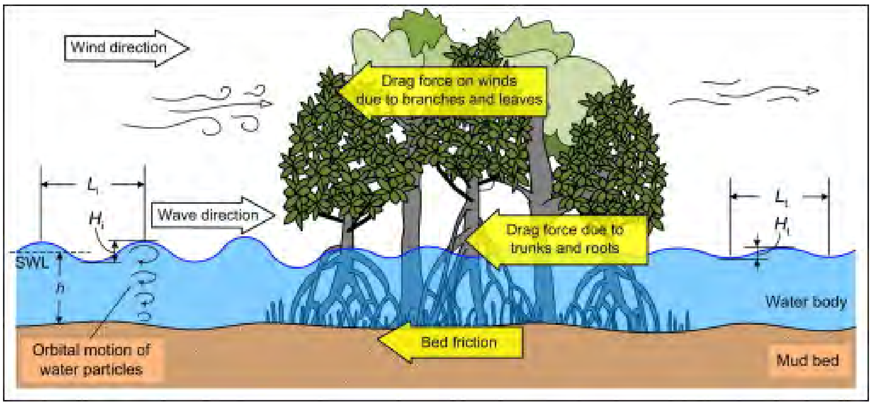


Figure 3.3: Schematisation hydrodynamic forces on mangroves (Esteban et al., 2015).

The energy reduction of the incoming waves is not only determined by the interaction between the waves and the trunks and roots, but also the bottom slope is a factor. According to Parvathy K.G., the reduction for mild slopes (1:80-1:40) is observed to be 93%-98%, 84% for 1:20 slope, and for steep slopes (1:10) 67%. The dissipation of wave energy by mangroves for different slopes can be assigned to different water depths, shoaling, breaking, and reflection phenomena for each slope (G & Bhaskaran, 2017).

The size of the sediment particles of the bed and the bed forms are affecting the bed roughness and bottom friction. The mud flats, where the mangroves are predominantly growing, can be typically considered as hydraulic smooth. The influence of currents on the bed shear stress in comparison with the wave impact is negligible according to S. Quartel et al. The resistance of the mangrove trees, as well as the bottom friction generate a drag force which leads to a reduction of the wave height. The drag force due to the presence of mangrove trees will be present over the full water column. S. Quartel et al found the wave height reduction was 5-7.5 times larger by mangroves than only by bottom friction (Quartel, Kroon, Augustinus, et al., 2007).

Mangrove forest also serve as effective measure for protection during typhoons. (Case study Vietnam, 2011 staat in MDP paper) examined the impact of two Catergory 9 typhoons in Do Son. The first typhoon occurred when the tidal flats were barren, it resulted in severe damage to the sea dike, causing 300,000 US dollars in repairs. However, when the second typhoon occurred and the tidal flats had been planted with mangroves, insignificant damage was caused to the sea dike. (Kandasamy Kathiresan, 2005) investigated the effect of mangroves with a Category 11 earthquake in India, 11 December 2004. This triggered a tsunami, which caused 2 million people homeless in different countries. It was shown that mangroves have the capacity to reduce the tsunami wave height and mitigate the salt intrusion into groundwater, causing drinking water to be available afterwards.

3.3. Anthropogenic effects on mangroves

It is common for mangrove areas to be located near anthropogenic activity, as mangroves offer multiple benefits to the local communities. However, degradation of mangroves is usually linked to higher human population densities. Coastal development plans, such as resorts, power plants, port facilities, dams and aquaculture ponds, pose a significant threat to mangrove ecosystems. Such coastal development invariably gives rise to serious problems, including soil erosion, pollution, and disrupted hydrology, which impede the existence of neighbouring mangrove forests. Moreover, coastal development frequently results in the blockage of rivers, causing changes in sediment deposition, infiltration, salinity levels, and temperature. These disturbances do not only affect the health of mangrove ecosystems itself, but also have broader implications for coastal biodiversity and ecosystem services. The degradation of mangroves jeopardises environmental sustainability, resulting in consequences such as loss of biodiversity and a rise in global warming (Akram et al., 2023).

As per the 2022 report from the Global Mangrove Alliance on the condition of global mangroves, there was a loss of 600 km^2 of mangroves from 2010 to 2020. It is estimated that 62% of this loss was driven by human activities, accounting for 373 $km^2$of mangroves. Southeast Asia has some of the highest loss rates in the world (Leal & Spalding, 2022). Of the mangrove species found in Vietam, *Aegiceras floridum* and *Sonneratia ovata* are declared a near-threatened species on the International Union for Conservation of Nature (IUCN) red list of mangrove plant species (Polidoro et al., 2010). The loss of biodiversity remains a substantial challenge, as even untouched mangroves are notably less diverse in species compared to other tropical ecosystems (Alongi, 2002). Mangrove restoration efforts often include fast-growing species like Rhizophora or Avicenna, overlooking rarer, slower-growing ones. As a result, restoring their full diversity is often difficult. In northern Vietnam, mangrove monocultures of *R. stylosa*, *K. candel*, or *S. caseolaris* are common. While these monocultures effectively reduce wave height, local residents have reported that they don’t provide suitable habitats for wild clams, crabs, and fisheries, potentially affecting local livelihoods and the success of mangrove restoration projects (Polidoro et al., 2010).

3.3.1. Hydrodynamic changes

Multiple studies have been conducted on the effects of anthropogenic activities altering hydrodynamic conditions on mangrove forests. For example, in Mangkang Kulon (N. Martuti, 2020), changes in erosion rates were monitored. It was concluded that after the construction of (port) buildings next to the mangroves, abrasion occurred. This was caused by the disruption of hydrodynamic conditions, especially the sediment transport. In Australia, the construction of a port also caused a disturbance to the hydrodynamics (Paling et al., 2003). After the construction, a nearby freshwater creek started eroding the coastline as the supply of sediment was interrupted.

A common misconception is that, for example, a detached breakwater has a positive influence on the growth of mangroves, as the reduce the waves and thus reduce the energetic hydrodynamic environment. However, as they trap the sediment, they can also limit the tidal range. On the long term, this will have a negative impact on the mangroves (van Maren, 2023).

3.3.2. Pollution

As a result of an increasing human population, the destruction of mangrove forests through activities such as industrial waste disposal, deforestation, agricultural expansion and timber harvesting has had harmfull effects on both the environment and the water quality within these ecosystems. Various sources of pollution and the destruction of mangrove forests diminish the quality of water. This decline in water quality poses a threat to aquatic organisms and the overall water ecosystem.

Human-induced pollution in mangrove ecosystems includes metal(loids), pesticides, nutrients (including sewage), and oil spills. According to Pham et. al, the primary sources of pollution in the Do Son area are fishing ports, iron and steel metallurgy industries, coastal industrial parks and economic zones, residential areas, agriculture and fisheries (Phạm, 2020). In the city of Hai Phong, the discharge of heavy metals and other hazardous waste materials originating from sources such as the cement plant, fish canneries, and plastic factories has inflicted significant harm upon the mangrove ecosystems situated at the estuaries of the Van Uc and Lach Tray Rivers (P. Hong & San, 1993).

Gandaseca et al. conducted a comparative analysis of water quality in disturbed and undisturbed mangrove areas in Indonesia. They assessed six key water parameters: pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (AN), and Total Suspended Solids (TSS), which collectively determined the Water Quality Index (WQI). Retnaningdyah et. al used a similar method to assess the health of mangrove ecosystems by examining water quality and analysing the relationship between human activities in the vicinity of the mangrove ecosystem and the state of water quality. It was found that increased human activities in the mangrove environment led to a decrease in water quality and that mangrove restoration efforts had a positive impact on water quality (Retnaningdyah et al., 2021).

Metalloids

Industrial wastes are the main source of metal(loid) pollution. However, heavy metals are typically attached to sediments and therefore generally do not pose a significant ecological threat to the mangroves (Hoff, 2002). Trapping suspended matter and sediments that carry metal(loid)s and organic waste from human activities is considered one of the important environmental services mangroves provide (Nguyễn et al., 2020). The mangroves act as natural filters, absorbing and accumulating pollutants in their bodies. They extract metalloids via various chemical reactions through their specialised root accumulation system (Maurya & Kumari, 2021). Nevertheless, the extensive accumulation of toxic metalloids in mangroves has not been thoroughly investigated and could potentially affect mangrove growth and respiration. Furthermore, the presence of toxic metalloids may also pose a threat to the animals inhabiting the mangrove ecosystem.

Nutrients and (in)organic waste

The periodic discharge of sewage, organic wastewater, and chemical pollution from ships, as well as the improper handling of waste, and accidental spills, can substantially impact mangrove ecosystems. The continually increasing population contributes to the release of sewage pollution into the estuaries housing the mangrove ecosystems. Many poor individuals and fishermen who reside in boats within these mangrove areas live in poor sanitary conditions (P. Hong & San, 1993). Improper sewage disposal results in elevated ammoniacal nitrogen levels in the water, which has potential negative effects on the health of mangroves. Excessive nutrient levels, as indicated by elevated ammonia, can disrupt the nutrient cycling within the mangrove ecosystem (N. Hershey, 2021). This can lead to imbalances in nutrient availability and utilisation, affecting the growth and health of mangrove vegetation. Moreover, oxidation of ammonia (NH_4) lowers the dissolved oxygen concentration in the water, fostering heightened algae production (Alongi, 2020). Excessive algae growth further depletes oxygen levels in the water, impeding the health of flaura and fauna in the mangrove ecosystem (Hoff, 2002). Algal mats covering the pneumatophores and leaves of mangroves disrupt respiration and photosynthetic processes in the mangroves (Sarkar, 2018). High levels of Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) exacerbate the issue, depleting oxygen levels in the water. Agriculture and aquaculture near urban areas, play a significant role in polluting mangroves, discharging organic residues into the rivers, ultimately reaching the mangroves by tides. This organic matter pollution will affect the ecosystem of aquatic organisms in the water. Each organism has a specific tolerance range to organic matter. Therefore, only types of organisms with high tolerance to organic matter will live

(Retnaningdyah et al., 2021). Additionally, toxic chemicals, such as pesticides and insecticides from agricultural runoff are transported into the mangrove ecosystem through rivers, affecting their health (P. Hong & San, 1993).

Oil
Oil pollution in the form of oil spills, slicks and tarballs is becoming an increasing threat to mangroves, particularly as the construction of the new port brings more ships in and out of the area. Oil cuts off the oxygen supply to the specialised root structures of the mangroves and has toxicological impacts on the trees, including both lethal and sub-lethal effects, such as yellowed leaves and defoliation. The coping mechanism that mangroves have developed that enables them to survive in a low-oxygen, high-salinity environment highly depends on the exchanges with water and air. Oil coatings can interfere with salt exchange on the leafs and roots of the mangroves (Hoff, 2002).

Plastic
The increasing global problem of marine litter, particularly plastics, poses a significant threat to mangrove ecosystems. The accumulation of non-biodegradable litter in coastal zones, if not properly managed, can harm mangrove forests, impacting the vital ecosystem services they offer. Furthermore, the impacts of plastic litter extend beyond the visible contamination, affecting biodiversity, habitats, and even biogeochemical cycles, with potential extensive consequences as ecosystems become less resilient to climate change and extreme weather events (Lincoln et al., 2022). A study by Martin et. al revealed that mangrove forests function as sinks for marine plastic litter and traps for land originated litter, with their aerial roots acting as sieves that retain large objects. It highlights the pressing need to reduce plastic pollution given its long-lasting presence in the environment (Martin et al., 2019). According to the Hai Phong Department of Agriculture and Rural Development plastic waste is believed to travel from multiple inland rivers to the sea. According to a local fisherman in Do Son, large amounts of trash are swept into the mangrove forests from several estuaries after heavy rain fall (VNExpress, 2019). This plastic has potential harmfull affects on the health of the mangroves. A field study assessing the impact of plastic waste on mangroves in Indonesia found that plastic is often trapped in the top layer of the sediment, where it becomes immobile and creates an anoxic environment for the roots. It was found that full plastic coverage of roots causes tree death, whereas mangroves that are partly buried are relatively resilient (Bijsterveldt et al., 2021).

3.3.3. Perception local communities

Just as in Do son, big coastal development projects around the world and unsustainable activities have become popular in mangrove forest areas these days, thus accelerating the deterioration of the ecosystem (Tengku et al., 2021). Multiple case-studies have tried to demonstrate the perception of local communities towards deforestation of mangroves caused by human intervention. Despite the fact that the socio-economic importance of the mangroves is well established, the attitude of local communities often cause conservation projects to fail (N. Hai et al., 2020). As these mangrove conservation projects require collaboration between community and third parties, perceptions of both policy makers and other stakeholders such as the land users themselves need to be taken into account (Thin et al., 2022). Different case-studies show this often leads to failure of conservation projects.

The study by Rahman and Zainora (2016) emphasises that public awareness in the forest of Kuala Selangor, Malaisia is crucial for mangrove conservation in order to improve the ecosystem as a whole. The authors state in their case-study that the lack of awareness leads to the deficit of information that is being received by the local community and therefore could be considered as the main problem of failed conservation projects. Public authorities, trying to manage mangrove forests in Kuala Selangor, are experiencing difficulties in implementation due to this lack of awareness. Local communities are using the forests as dump land for their garbage, illegally turning mangroves into shrimp ponds for conversion to agriculture and salt production, coastal industrialisation, conversion to aquaculture and others (Rahman & Zainora, 2016).

Similar to the cases in Do Son and Kuala Selangor, despite the protected status of the mangroves investigated in this case, activities such as a construction of a major port strongly affects the state of the mangrove forests. This case-study executed by Badola et al. (2012) emphasises the importance of understanding of the attitudes and perceptions of the local communities towards conserving the mangroves in the Bhitarkanika Area, India. In contrast of the case in Kuala Selangor, this study showed positive attitudes of local communities towards conservation of the mangrove forests. Mangrove functions, directly linked to the well-being of the local community, caused them to be willing to participate in conservation projects. However, the socio-economic characteristics are of great influence of the people's attitudes. Results show that in order to participate, the costs of the conservation of the mangroves to the local communities need to be lower than the benefits. This means, often in lower income levels, people find they need to compensate too much which causes the support for conservation to decrease.

As the mangrove forest ecosystem directly provides socio-economic benefits for the land users, such as farmers, fishermen and people living close to the mangroves, the local communities are highly depending on the conservation mangrove forest (Kuenzer & Vo, 2013). Therefore, in order to sustain local community support of mangrove conservation, understanding their attitudes and perceptions at different socio-economic levels is essential (Quartel, Kroon, Augustinus, et al., 2007).

This can help bring together the local communities, the people who make the rules, and others who care about mangroves. By doing this, we can make sure that making money and saving mangroves can go hand in hand, even when there are issues with development and bad practices near the coast.

Building upon the understanding of the perceptions of the local people and the impact on mangrove conservation discussed in the previous section, it is important to explore potential solutions. Payment mechanisms for environmental services (PFES) are promising ways to bridge the gap between local communities, policy makers, and other stakeholders. These mechanisms offer a way to protect the mangrove forests against the challenges posed by coastal development, through economic incentivisation. In a recent report, The Center for International Forestry Research (CIFOR) conducted an assessment of the feasibility of implementing payment mechanisms for mangrove ecosystem services in the Hai Phong region. The choice of Hai Phong as the study area is underpinned by its status as the largest seaport in Northern Vietnam, characterised by a wide array of stakeholders reliant on the environmental services provided by the mangrove ecosystem. Significantly, while the mangrove area in Hai Phong increased between 2007 and 2015, a concerning trend has emerged since 2016 with a reduction in the total area of mangrove forests. In the absence of effective measures, Hai Phong is at risk of losing its vital mangrove ecosystem, which would have adverse consequences on local communities' livelihoods. CIFOR has identified two environmental services warranting further exploration: clean water and heavy metal filtration, as well as carbon payments. These services have the widest range of potential buyers, and the collection of payments from service users, such as ports, can be included in the port fee collection system (Phạm, 2020). Such a carbon payment initiative is currently being piloted in the North region of Vietnam. The initiative is supported by the Forest Carbon Partnership Fund. It serves as a financial incentive to reward and assist forest owners and local communities, utilising funds generated from carbon emission reductions. These incentives are crucial in motivating ongoing efforts toward forest conservation and development. According to the Director of MARD, there is potential for extending a similar carbon credit program to regions with mangrove forests, primarily owing to their remarkable carbon-absorption capabilities (Kiem, 2023).

3.4. Stakeholder analysis

To answer the research question, it is important to identify the relevant stakeholders involved in the development of the Hai Phong Masterplan and its impact on the Do Son area. The research question "What are the potential effects of the Hai Phong Masterplan on the mangrove ecosystems and the local community in Do Son?" has several parts. In order to answer these questions, it is necessary to have a clear picture of what exactly the Masterplan entails, what the mangrove ecosystem in Do Son looks like, and how the local community interacts with the mangrove forests.

The stakeholders involved in the development of the Hai Phong Masterplan and its impact on the Do Son area can be visualised using a power-interest grid. In such a grid, a stakeholder's power is plotted on the x-axis, while its level of interest is plotted on the y-axis. Using these two indicators, four main groups of stakeholders can be distinguished: players, context setters, subjects and crowd (Bryson, 2004). In figure 3.4 the power-interest grid of this project is shown.

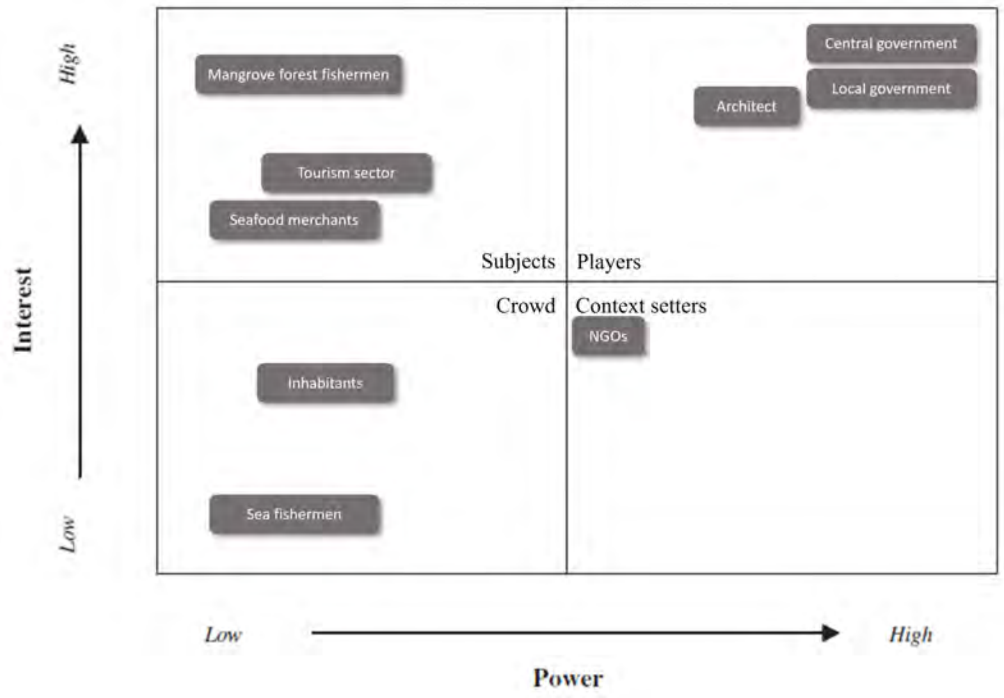


Figure 3.4: Stakeholder typification.

Players

Players are likely to be decision makers and have the greatest influence on the success of the project. These stakeholders need to be kept close in order to manage their expectations (Bryson, 2004). The stakeholder groups that are identified as players are the central government, the local government and the architect. The central government consists of several ministries. The ministries are some of the most powerful authorities in the central government, as they manage the local authorities. The central government also has a strong interest in the issue, as it is their duty to improve Vietnam's economy (VNA, 2023). Because of its power and interest, the central government is considered a key stakeholder. The ministries involved in the Hai Phong Masterplan are the Ministry of Agriculture and Rural Development (MARD) and the Ministry of Construction. As mentioned in section 2.3, the MARD is responsible for the action plan of the Masterplan and the Ministry of Construction is responsible for the design of the overall Masterplan for Hai Phong 2050. The local government is considered as an authority under the central government that provides public services directly to the people (Quang Huy, 2020). There are three levels of local government: provincial, district and commune (see figure 3.5). The provincial level consists of one of the five municipalities directly under the central government (Hanoi, Hai Phong, Da Nang, Ho Chi Minh City and Can Tho) and the provinces (Albrecht et al., 2010; Quang Huy, 2020). For the Hai Phong Masterplan, the provincial level of local government consists of the Hai Phong municipality and the Hai Phong city province. As the provincial level of local government has by far the most power, it is assumed that the local government in this project only consists of these two stakeholders. The local government makes decisions and has authority over public services, which gives them a lot of power (Albrecht et al., 2010). The local authorities also have a strong interest in developing both the municipality of Hai Phong and the Do Son area.

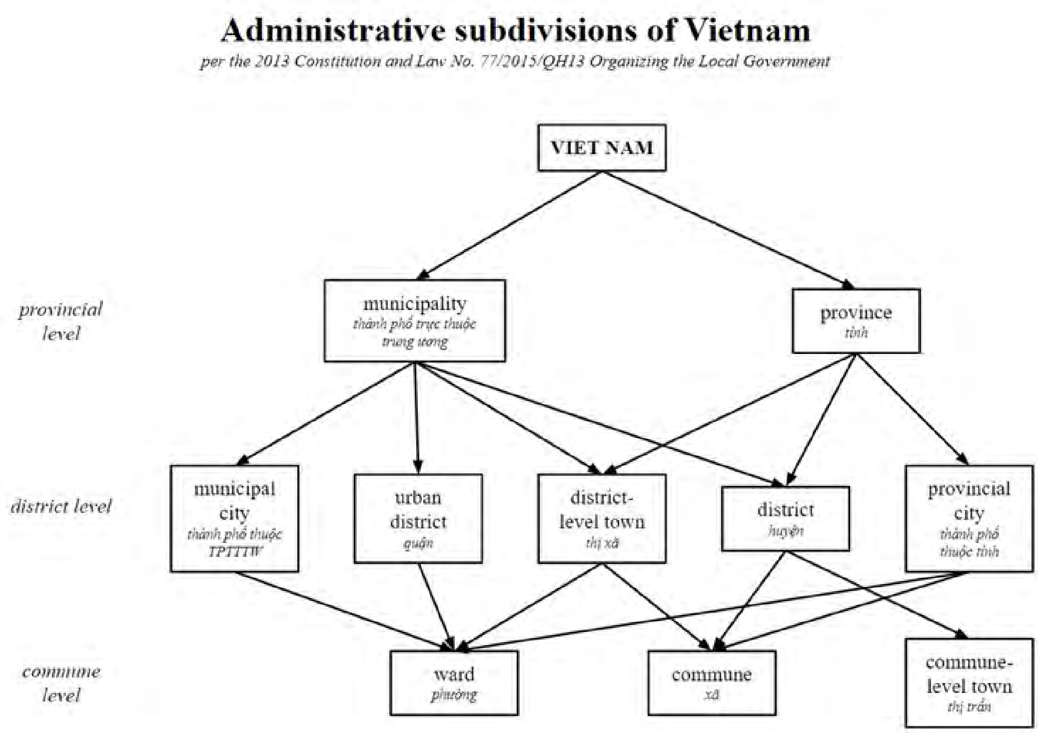


Figure 3.5: Administrative subdivisions of Vietnam since 2016 (Nguyen, M., 2023).

The architect of the Hai Phong Masterplan is VIUP, a company working under the Ministry of Agriculture and Rural Development, together with the local Department of Construction (see Appendix F.1). VIUP and the local Department of Construction worked together with the local government on the design and formulation of the Hai Phong Masterplan. VIUP can be subdivided into several departments. The two main departments involved in the design of the Masterplan are the architectural department and the environmental department. The architect has a high interest, as does the local government, but they have less power than the local government.

The three stakeholder groups described above are useful for gaining a better understanding of what exactly the Master Plan entails, which will give a better picture of the potential impacts on the mangroves and the Do Son area.

Context setters

Context setters are stakeholders who need to be kept informed about what is happening in the project, as they are a source of power. This type of stakeholder should be managed carefully, as they may use their power in a negative way if they are not satisfied (Bryson, 2004). An example of a context setter as stakeholder group are the NGOs. NGOs include environmental parties and corporations such as the Japanese Red Cross Society (JRCS) and the Vietnamese Red Cross Society (VRCS) (see section 2.2.2). As this stakeholder group is mainly involved in the conservation of natural areas, they have a certain interest in the project as it has the potential to affect the mangrove forests. And although they do not have much power in the decision-making process, they do have the power to restore mangrove forests that may be affected by the master plan. These stakeholders need to be kept informed about the plans.

As context setters need to be kept satisfied, it is important to know how the NGOs are included in the Masterplan and what their attitude is towards the plan and its impact. These insights are useful to get a comprehensive understanding of the implications of the Masterplan.

Subjects

Subjects need to be properly informed and talked to to ensure that no major problems arise (Bryson, 2004). As mentioned in section 3.3.3, the local community is highly dependent on the conservation of the mangrove forests. The local community can be subdivided in several stakeholder groups: mangrove fisherman, seafood merchants, inhabitants and sea fisherman. The mangrove fishermen are highly dependent on the mangroves and therefore have a high level of interest in the plans for Do Son, as they could have potential impacts on the mangrove forests that could potentially affect these fishermen. However, this stakeholder does not have much power, as the plans are made by the local government and the architect. The seafood merchants form another stakeholder group within the local community. This group comprises two types of sellers: those who vend fish caught in the mangroves and those who vend fish caught in the sea. Section F.2 states that VIUP's environmental department anticipates the disappearance of mangrove area A, but area B should remain unaffected as per the Hai Phong Masterplan. In section 3.3.3, it is noted that the local community, which includes seafood merchants, relies heavily on the mangrove forests. As this stakeholder comprises both seafood merchants from the mangroves and from the sea, their interest is balanced and given slightly less interest than that of the mangrove fisherman. Another group that is identified as subject is the tourism sector. As mentioned in section 2.3, the Hai Phong Masterplan was designed to strengthen Hai Phong's industrial and economic growth, by, among other things, increasing tourism in the area. A part of the Masterplan is the Dragon Hill resort in Do Son. This project is all about increasing tourism in Do Son and similarly in Hai Phong. As these plans are all about increasing tourism, the tourism sector has quite high interests in the plans. However, this stakeholder does not have much power and only needs to be informed about the plans in order to prepare for future activities.

Because subjects need to be properly informed to ensure that no major problems arise, it is important to know what the impacts are on these stakeholders with the implementation of the Masterplan.

Crowd

Crowd needs to be monitored, but no excessive effort is needed (Bryson, 2004). The stakeholder groups in this category are the inhabitants and the sea fisherman, which are the remaining groups that fall under the local community. The inhabitants are the people in Do Son that are not directly dependent on the services of the mangrove forests, such as shop owners, bar owners, schools, etc. The interest of this stakeholder lies mainly with the development of the area in terms of quality of life. The Masterplan may result in a better developed residential area, which may benefit the residents. However, because they are not directly dependent on the effects of the Masterplan, this stakeholder group has relatively little interest. They also have little power over the formulation of the plans. As the sea fisherman fish at sea, it is assumed that the implementation of the Masterplan will have a minimal impact on them. Therefore, their interest is quite low. And just like the other stakeholders who are part of the local community, their power is low.

Despite the low interest and power of the crowd, it is valuable to capture the attitudes of this type of stakeholder to explore how they look at the development of the Do Son area.

4 Methodology

4.1. Method hydraulic aspect

The hydraulic study aims to clarify the changes in hydrodynamics after the completion of the Masterplan in Do Son. This will be done in two parts. To analyse the changes in hydrodynamics, several techniques are used. First, multiple interviews with professionals are conducted. The professionals range from those who work in Vietnam at local companies to researchers with a history in the Hai Phong area. Secondly, data collection has a significant role in this research. Wind, wave and water level data is collected at the Hon Dau measuring station, located in the south of Do Son, see fig 4.1. This data is post-processed to give more clarity to the hydrodynamics. Wave roses are created by analysing the data sheets and, just like the water level data, it will be processed in Python. The schematism of how the processes influence each other is depicted in figure 4.2. The main focus lies on the influence of tidal currents and wave forces on sediment transport. This research will not address the changing tidal flat morphology, as time and resources are limited. The schematisation will be used to assess the impact of the Masterplan on the hydrodynamics. The remaining data is collected from papers. Numerous papers have been written about the state of the Gulf of Lokin. An effort has been made to select the important parameters needed to further understand the hydrodynamics of the area.

Figure 4.1: Location of Hon Dau measuring station.

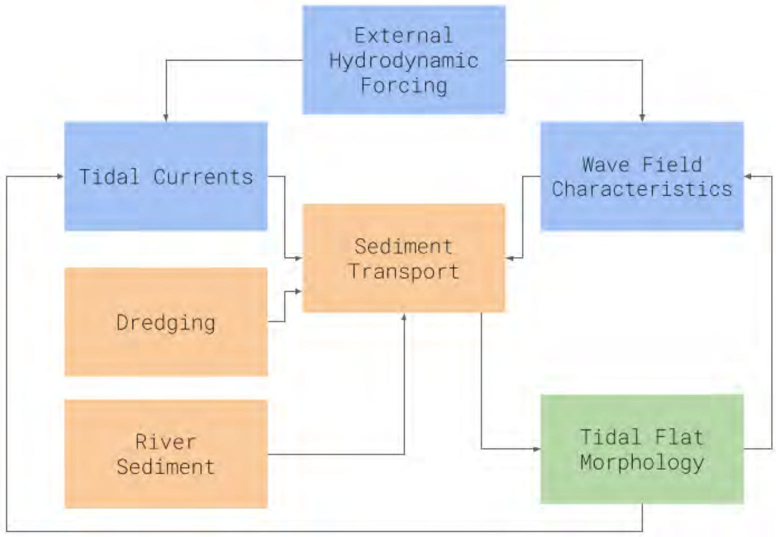


Figure 4.2: Hydraulic processes scheme.

4.1.1. Tidal prism

The water level data exists of hourly measurements for a time series of one year. In order to make use of the Navionics bathymetry chart, the Mean Lower Low tide (MLL tide from now on) needs to be calculated. MLL tide is the chart datum of the chart. This can then be compared to the Hon Dau station, where the chart datum is Vietnam's National Chart Datum. With the height difference between the mangrove areas and the measuring station known, the water level at the mangroves can be plotted. Since the Hon Dau measuring station is close to the mangrove areas, it is assumed that the water level rises simultaneously at both locations. With the water level plots, more insight is given into the inundation frequency and the inundation length of the mangrove areas.

Furthermore, with the help of the water level data, an estimation of cross-shore sediment transport is made. By analysing satellite images, the surface area is determined. In combination with the tidal range, the tidal prism can be calculated with equation 4.1. Whether the river discharge should be taken into account, is disputed (Academic Accelerator, n.d.). For this reason, the river discharge is calculated and checked how much the ratio is between the discharge and the tidal prism. It should be noted that the tidal range is taken from mean low water tide to mean high water tide. At the eastern side of mangrove area A, there is a river discharge. The discharge is regulated by a sluice gate which is only opened during low tide. This happens at a certain threshold, as the water level at the seaside should be lower than the water level in the river, to prevent saltwater intrusion into the river. The discharge is calculated with the Bernoulli equation, seen in equation 4.2. To use this equation, measurements of the water heights and width of the sluice gate were made during the field trip. With the calculated sediment amount, a sediment transport estimation can be made.

$$\text{Tidal Prism} = \text{Tidal Range} \times \text{Surface Area} + (\text{River Discharge}) \tag{4.1}$$

$$P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant} \tag{4.2}$$

Where:
P is the pressure,
ρ is the density of the fluid,
v is the velocity of the fluid,
g is the acceleration due to gravity,
h is the height above a reference point.

4.1.2. Wave analysis

The wave data is analysed by restructuring and processing Excel files with Python. For the wave data, two different data sets were obtained. The first originated at Hon Dau, close to the shore. The other wave data set originated from Bach Long, more than 100 kilometres to the southeast.

Firstly, unusable columns are deleted and put into data frames. Since the data is structured horizontally per year, it is restructured using the unstack function and merged to get a well-structured data frame with columns "direction", "height" and "month". NaN-values and inconsistency of the directions are removed by replacing text-values to the right directions in degrees. For 5 years of wave data (2018-2022), this resulted in 3408 and 3353 data records for Hon Dau and Bach Long respectively. The code can be found in Appendix B.0.2.

For plotting the wave data into roses, the Windrose function is used. The data is put in varying wave height bins: [0.50-0.75, 0.75-1.00, >1.5 meters]. The same bins are used for the 2 different measurement stations. This enables to make comparisons between the onshore and offshore wave conditions. For both locations, wave roses were made for all months and 2 seasons to compare the different conditions during the dry season (May-October) and the wet season (November-April).

The significant wave height is computed by taking the mean of highest one-third waves from the wave data for both data-sets of Hon Dau and Bach Long over the period 2018-2022. This is done by ordering the data-sets on wave-height. The used code can be found in Appendix B.

4.1.3. Long-shore sediment transport analysis

At mangrove area A, the assessment of long-shore sediment transport focuses on the upstream area of the T-groynes. The dimensions of the T-groynes were measured by a combination of inspecting satellite images and by collecting data during the field trip. Considering these dimensions and the duration since the T-groynes were constructed, it becomes possible to provide a rough estimate of the mean sediment transport and the alteration of the coastline. This will then be analysed by the different processes which influence sediment transport, including the tidal current, river current, and the incoming waves. An overview of the processes can be seen in figure 4.3

Figure 4.3: Overview of the bay where sedimentation occurs during tides. Source: Google Earth Pro.

4.2. Environmental impact analysis

The purposes of the environmental analysis is to evaluate the quality of the mangrove ecosystem through water quality measurements and analysing the relationship between surrounding human activities with water quality in mangrove ecosystem. In this study, the water quality status of the mangrove ecosystems at location A (Bàng La) and B (Ngọc Xuyên and Ngọc Hải) will be assessed to evaluate the impact of human activities and to assess the potential anthropogenic threats associated with the Hai Phong Masterplan. Water quality is a measure of water conditions seen from its physical, chemical, and biological characteristics. These analytical measurements will inform evidence-based recommendations aimed at preserving the ecological integrity of the mangrove ecosystems. Moreover, anthropogenic activities, such as industrial processes or shipping-related operations, can sometimes result in oil spills or contamination. Detecting the presence of oils helps in identifying potential sources of pollution and understanding their impact on the mangrove ecosystems.

4.2.1. Water quality parameters

To asses the current conditions of the mangrove ecosystem and the impact of human activities, six standard water quality parameters are measured in the mangroves at location A and B. These parameters include pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia (NH_4+), and total suspended solids (TSS).

pH

pH measures the acidity or alkalinity of a water sample. It quantifies the concentration of hydrogen ions (H+) in the solution. pH is important for aquatic ecosystems because it can affect the solubility and toxicity of various chemicals and the health of aquatic organisms.

Biochemical oxygen demand

BOD is the amount of oxygen necessary to oxidise biological components under standard conditions. It essentially measures the amount of oxygen needed by aerobic bacteria to remove waste organic matter from water. High BOD levels in water bodies can indicate pollution from organic materials and can lead to oxygen depletion, harming aquatic life.

Chemical oxygen demand

COD is a measure of the amount of oxygen that is consumed by reactions with chemicals in the water. It measures the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrate. COD is more inclusive than BOD, as it considers both biodegradable and non-biodegradable substances. It is used to assess the overall water quality and pollution levels, with higher COD values suggesting greater pollution.

Ammonia

Ammonia is a measure of the concentration of ammonia ions (NH_4+) in water. Elevated ammonia levels are often associated with pollution from sewage, agricultural runoff, wastewater, or industrial discharges. High ammonia concentrations can be toxic to aquatic organisms and indicate poor water quality.

Total suspended solids

TSS quantifies the amount of solid particles, both organic and inorganic, that are suspended in water. TSS can include silt, sediment, organic matter, and other particulate materials. High TSS levels can reduce water clarity, disrupt aquatic habitats, and carry pollutants, leading to degraded water quality.

4.2.2. Sampling areas

The mangroves in location A are adjacent to a sea dike, which is densely populated and where fishing activities take place in the mangrove forest. Moreover, the construction of the Dragon Hill Island resort takes place close the mangroves in location A, as seen in figure 5.17. The development of Dragon Hill Island is a crucial factor in Hai Phong's efforts to attract more tourists to the region. Samples at location A will be collected along the mangrove forest, extending from the coast to the sea, in order to compare regions with dense mangrove cover against those with lower density. The mangroves in location B are located next to the Ngọc Hải fishing port, where numerous fishing boats enter and leave the harbour during the day. In addition to water quality measurements, oil samples will be taken in location B, close to the Ngọc Hải fishing port and further away at the T-groyne, to assess the influence of the port activities on the mangrove forest. These results can be used as useful insights to assess the potential anthropogenic threats associated with the Hai Phong Masterplan.

Figure 4.4: Mangrove forest at location A in close proximity to land reclamation and building activities of Dragon Hill Island.

4.2.3. Sampling method and analysis

Samples will be collected in October 2023, during the high tide, using clean 1.5L plastic bottles and transported to the laboratory on ice and stored in a cool box until the analysis are performed. Laboratory analyses are conducted to determine the pH, BOD, COD, NH_4+ and TSS. In table 4.1 the parameters and their corresponding units and analysis methods are set out. In appendix E the laboratory analyses are explained in further detail. The values are individually compared to the limit values from the National Technical Regulations (QCVN 10:2023/BTNMT) on Marine Water Quality established by the Vietnamese Ministry of Natural Resources and Environment (Ministry of Natural Resources and Environment, 2023). The limit values can also be found in the table. Furthermore, to assess the impact of pollution on the health of the mangrove ecosystem, the forests will be visually inspected.

Table 4.1: Water quality parameters.

Parameters	Unit	QCVN limit	Method
pH	-	6.5 - 8.5	OHAUS Starter 5000 pH meter
BOD	mg/L	< 4	OxiTop
COD	mg/L	< 10	8000-Hach-USA
AN	mg/L	0.1	8038-Hach-USA
TSS	mg/L	50	630-Hach-USA
Oil	mg/L	5	SMEWW 5520.B

4.3. Socio-economic impact analysis method

The aim of the socio-economic analysis is to determine the socio-economic impacts of potential changes in the mangrove forests, caused by the Hai Phong Masterplan, on the local community. The method for this analysis consists of two parts: the data collection and the analysis of the data collected.

4.3.1. Data collection

In order to obtain the primary data needed for determining the impacts, multiple interviews will be conducted. For these interviews, two structures will be used: the semi-structured interview and the survey-structured interview.

Semi-structured interviews

Information of parties involved in the design of the Hai Phong Masterplan will be collected through semi-structured interviews. The semi-structured interview is a common research method in the social sciences (Hyman et al., 1955; Ruslin et al., 2022). It is based on the belief that respondents' perspectives are more likely to emerge in a moderately open-ended setting than in a standardised questionnaire format (Ruslin et al., 2022). Unlike structured interviews, which use a formalised, predetermined set of questions, semi-structured interviews offer flexibility, allowing new questions to emerge during the interview in response to respondent input. Typically, semi-structured interviews are organised around a topic guide, which consists of a pre-defined set of broad themes, usually numbered between 3 and 5 (Knott et al., 2022). Within each theme, a set of questions provides a framework for dialogue between the researcher and the interviewer. Based on the literature review, four themes were identified: economic, social, participation and awareness. Based on these themes, the questions used in the semi-structured interviews were drawn up.

For this study, a semi-structured interview will be conducted with the Vietnam Institute for Urban and Rural Planning (VIUP), a public service unit under the Ministry of Construction, which was the architect of the land-use plan of the Hai Phong Masterplan. The use of the semi-structured interview will serve as a tool to clarify the exact plans that will be implemented in the Do Son area, as it will reveal both the technical aspects of the Masterplan at a more detailed level, as well as a deeper understanding of people's experiences of the choices made in the design of the plan.

Survey-structured interviews

To gather perceptions of the local community, a survey-structured interview approach is selected. Participants will be selected based on their occupation and residential area and are asked to participate on site. The interview will be divided into two parts: open and closed questions. First, the participants are asked to answer the open questions regarding their personal characteristics, such as gender, age, occupation, monthly income, share of monthly income in the household, and the number of people in the household. This will be done in order to analyse causal relationships between socio-economic impacts and demographic characteristics of the participants.

This will be followed by a structured interview using a 17-item questionnaire to gather qualitative data that will provide insights into the local community's perceptions, beliefs and views on the socio-economic impacts of the mangrove forests. This approach is consistently used to capture the perspectives of the local community on the implementation of the Masterplan. For this study, the Likert scale will be used to format the questionnaires. Participants will rank the statements using a five-point scale ranging from ”strongly disagree” to ”strongly agree”. Like the four themes that were used in the semi-structured interviews, the statements used in the survey-structured interviews are derived from the same four themes.

As elaborated in the literature study, mangrove forests provide multiple services for the local community. As multiple studies show that people tend to be highly economically dependent on the mangrove forests, the first objective aims to get a good understanding of the people's economic perceptions and views. In addition, numerous case studies around the world show that lack of awareness makes it difficult for authorities to implement mangrove conservation projects. Therefore, the second objective contains statements with regards to the awareness of the local people towards the mangroves and the Masterplan. In addition to that, as these mangrove conservation projects require collaboration between local community and third parties, perceptions on the participation of the land users themselves need to be investigated. For this reason, the third objective consists of statements regarding the participation of the local community. Lastly, to get a good understanding of the social and cultural perspectives, the social aspect will be the fourth objective of the questionnaire. The final statements were formed based on the literature review and through the information obtained from the interview with VIUP. An overview of the statements is shown in table 4.2.

Table 4.2: Statements used in the survey-structured interviews.

No.	Statement	Category
1	I am dependent on the mangrove forest.	Economic
2	If the mangrove forest disappears, my income will disappear as well.	Economic
3	I want more tourism in the Do Son area.	Economic
4	I am aware of the fact that mangroves provide coastal defence.	Awareness
5	I am aware of the ecosystem services that mangrove provides for flora, fauna, and the climate.	Awareness
6	I am aware of the fact that mangroves provide economic benefits for the local community.	Awareness
7	I am willing to sacrifice part of my income to conserve the mangrove forest.	Participation
8	If I got offered a better paid job, I would switch jobs, regardless of the disappearance of mangroves.	Participation
9	I am aware of the effects of pollution in the mangroves.	Awareness
10	I am aware of the past conservation projects of Do Son's mangroves.	Awareness
11	I am aware of the new plans for Do Son.	Awareness
12	I feel that I have been included in the new plans for Do Son.	Participation
13	I am in favour of the new plans for Do Son.	Social
14	The new plans for Do Son will improve my quality of life in the Do Son Area.	Social
15	I think mangrove forests will disappear due to the new plans for Do Son.	Social
16	The new plans for Do Son will have long-term impacts on my cultural heritage and traditions of the Do Son Area.	Social
17	The new plans for Do Son will have a positive impact on my economic stability.	Economic

4.3.2. Analysis method

Once the results of the interviews have been collated, a statistical analysis is performed to identify patterns in the views expressed. The data analysis will be carried out using simple statistics in Excel software. This will be combined with qualitative analysis to address the research findings. Finally, the identified results are interpreted to enable the researchers to understand the range of perspectives within the group being studied.

4.3.3. Area description

Section 2.3 described the plans within the Hai Phong Masterplan and showed the two mangrove areas A and B in figure 2.11. This section also described that Dragon Hill will be accessible by two main roads. In figure 4.5 these two roads are depicted. The left-hand road does not currently have the capacity to handle the expected traffic. In addition, this road is currently very inaccessible. For this reason, the road will be resurfaced to improve access to the island. However, this work will require the demolition of some houses in area A. For this reason, mangrove area A has been divided into two areas: area A1 and area A2. Area A1 covers the area to be demolished, while area A2 reflects the mangroves adjacent to Bang La. People from each area will be interviewed for the survey-structured interviews in order to identify any potential differences in the socio-economic impact on the local community between the three areas.

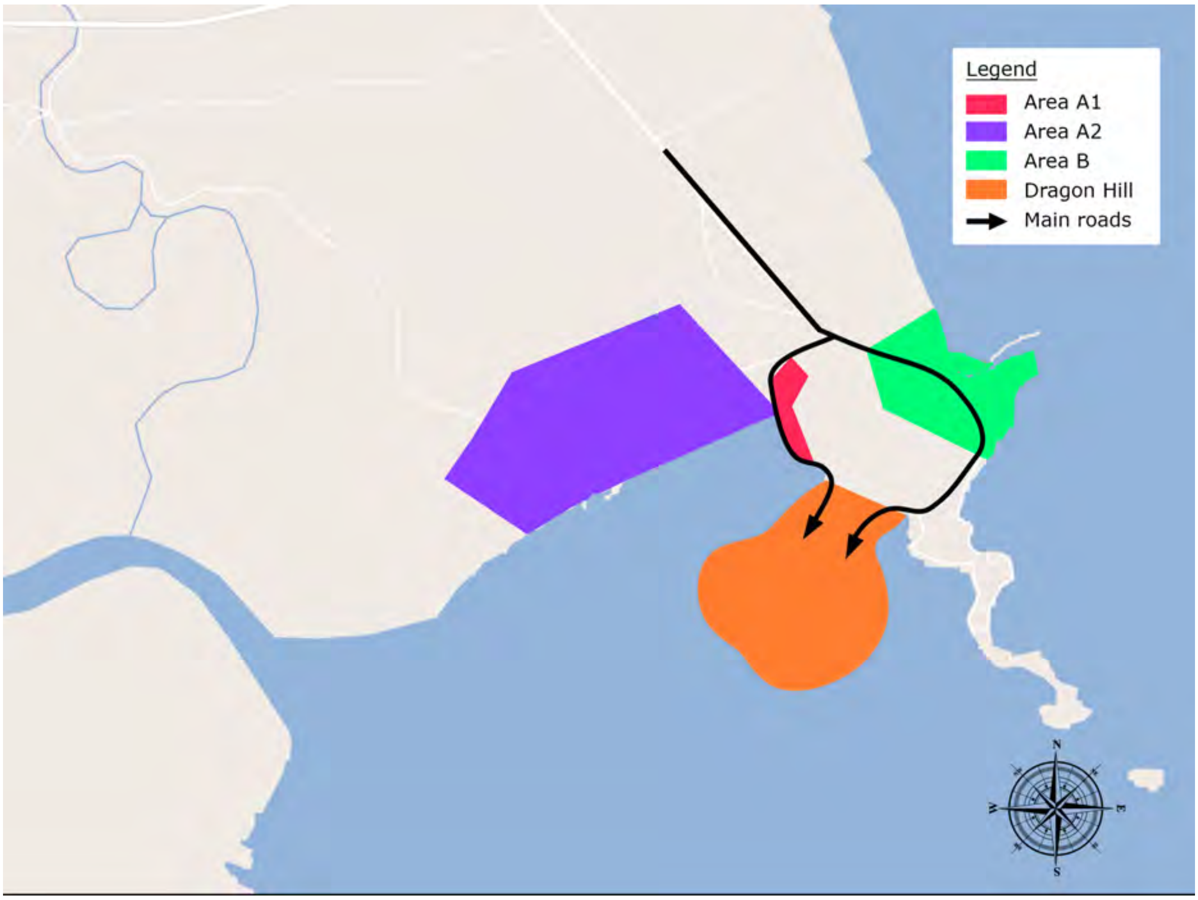


Figure 4.5: Area delineation with main roads to Dragon Hill island.

5 Results

5.1. Sediment transport results

5.1.1. Wave Analysis

Based on the computation method outlined in the section 4.1.2, the computed wave roses and seasonality in the study area are depicted in figure 5.1 to 5.6.

As shown in figure 5.1, the predominant annual wave direction for Hon Dau is East. There is also a significant contribution from the Southeast and a smaller contribution from the South direction. According to the data in figure 5.2 and figure 5.3 the Southeast contribution is mostly related to the summer season and the Eastern contribution to the winter season. Annually, the Eastern contribution (40%) from the winter season is relatively bigger than the Southeastern contribution (33%). The contribution of the Southern waves is 19%. The other 8% is from the remaining directions.

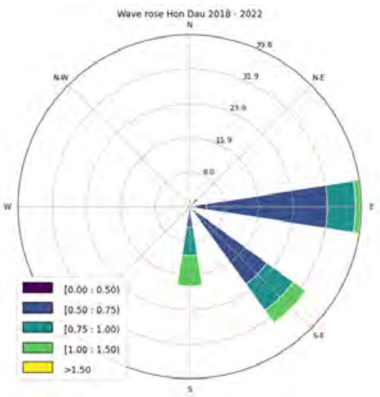


Figure 5.1: Wave rose Hon Dau 2018-2022.

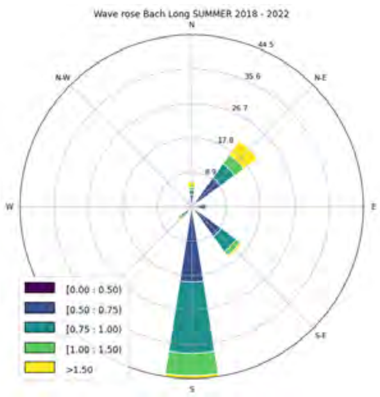


Figure 5.2: Wave rose Hon Dau 2018-2022 during the summer season.

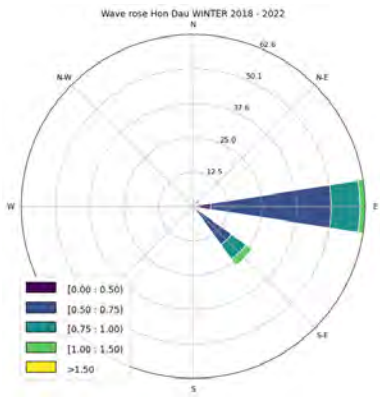


Figure 5.3: Wave rose Hon Dau 2018-2022 during the winter season.

The annual and seasonal wave directions of Bach long for the same time period (2018-2022) are depicted in figure 5.4 up to 5.6. Annually, the predominant direction is Northeast (46%) and the Southeast direction is the second most important one (26%). The Northeast wave direction is mostly found during the winter season figure 5.6 and the Southern wave direction follows from the summer season from figure 5.5. 12% Of the waves are coming from the South direction, while the remaining 16% are coming from the other wave directions.

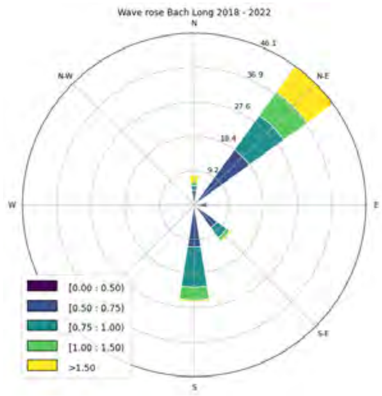


Figure 5.4: Wave rose Bach Long 2018-2022.

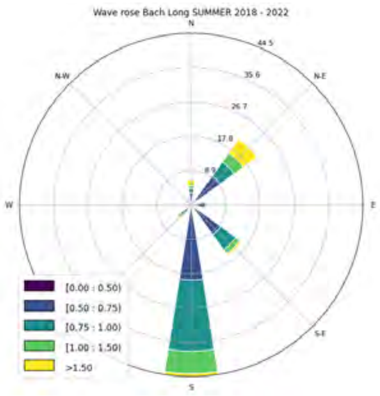


Figure 5.5: Wave rose Bach Long 2018-2022 during the summer season.

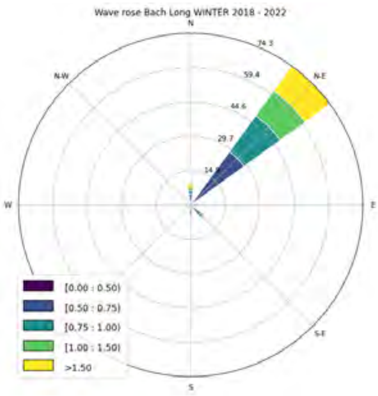


Figure 5.6: Wave rose Bach Long 2018-2022 during the winter season.

As mentioned in paragraph 4.1.2, the significant wave heights are computed by taking the mean value of the highest one-third of the ordered data points over 5 years per measuring location. The results for the mean annual significant wave heights for 2018-2022 are as follows:

- $H_{1/3,HonDau} = 0.91$ m
- $H_{1/3,BachLong} = 1.14$ m

5.1.2. Currents and waves

From earlier studies of current mechanisms, the influence on sedimentation by the Van Uc river is investigated. Figure 5.7 and 5.8 is used to determine how the currents of the river and the tide will change with the completion of port 1.

When comparing the flood currents during the wet season and the dry season, little difference can be noted. During both seasons, the flood current goes from the tip of the Do Son peninsula to the coast. The ebb current show more variation during the seasons. During the dry season, the current is deflected southwards, caused by the Coriolis effect. During the wet season, the Van Uc has a higher discharge due to the precipitation. The precipitation inland also causes more sediment to be suspended in the river discharge. The ebb current is higher and directed more along the coastline. This will bring the sediment from the Van Uc river to the mangrove area.

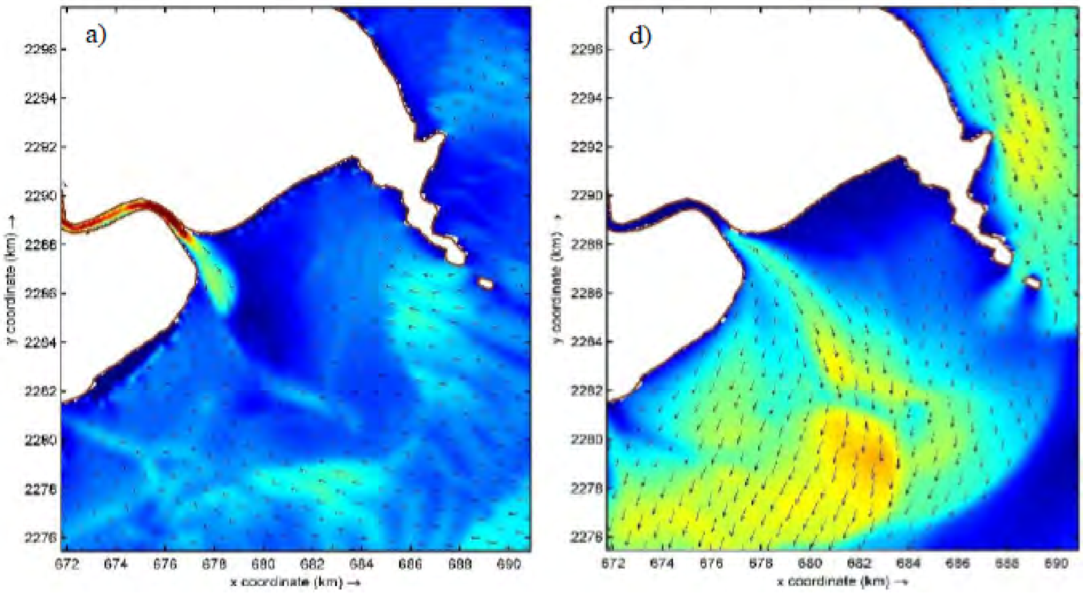


Figure 5.7: Flood current (left) and ebb current (right) at mangrove area A during dry season (N. M. Hai et al., 2019).

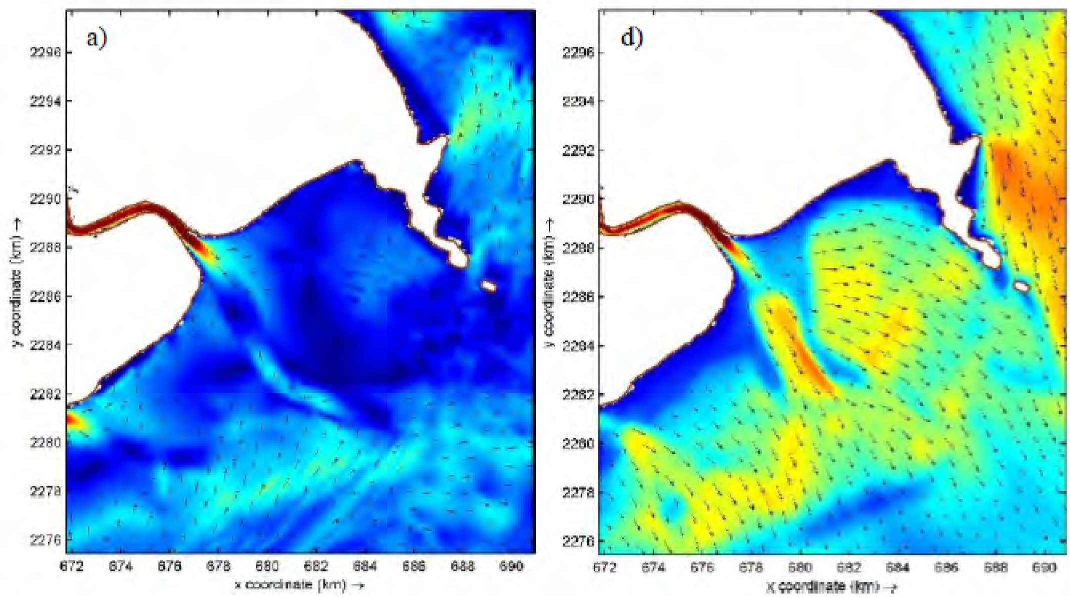


Figure 5.8: Flood current (left) and ebb current (right) at mangrove area A during wet season (N. M. Hai et al., 2019).

In figure 5.9 and figure 5.10, the main currents that influence the sediment transport are shown. The yellow arrow represents the river flow from the Van Uc river, which is coming from west of mangrove area A. The red arrows represents the direction, not the size, of the incoming and outgoing tidal current. Consequently, the blue arrow represent the curved direction of the predominant wave direction. For this schematisation, there is not differentiation between the wet and dry seasons. With the construction of the new port terminal, it becomes evident that the river current is cut off, and only the tidal and wave currents are the key factors in the sediment transport. In orange the reclamation of Dragon Hill is schematized. The construction of this area will cause more sheltering for mangrove area A, because incoming waves will more be blocked. This can be seen as a positive effect for sediment settling in the mangrove area.

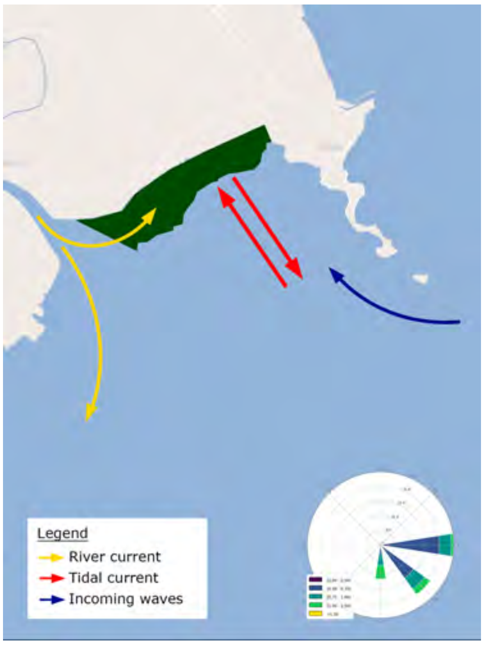


Figure 5.9: Mangrove area A, currents and incoming waves.

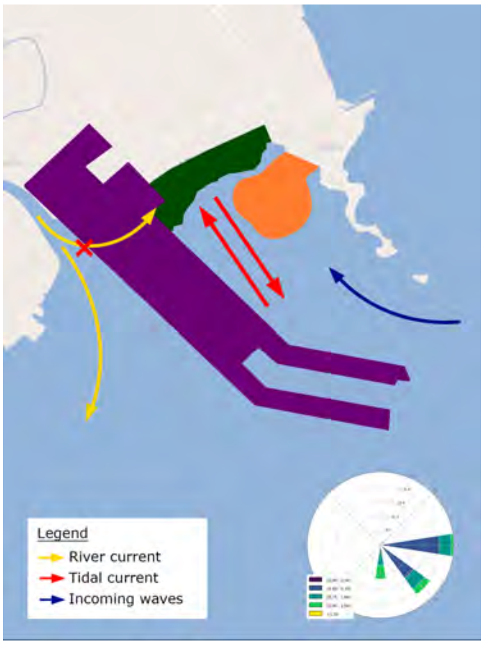


Figure 5.10: Mangrove area A, currents, waves Dragon Hill, and river cut-off after construction of Port 1.

In figure 5.11 and figure 5.12, the yellow arrow represents the Lach Tray river current. This current bends towards the south, a result of the Coriolis deflection southwards. The Lach Tray river is one of the many branches of the Red River all flowing from west to east. Due to the many outlets along the entire coastline, a southern current is present. The tidal current is also influenced by this southern flow, as indicated by the red arrow. It is chosen to depict the tidal current as a curved one-way direction rather than a two-way arrow as in the schematisation of mangrove area A. This is done to show that the main flow direction is to the south, which is supported the longshore sediment transport calculations for mangrove area B. The blue arrows represent the direction of the predominant wave direction, not the magnitude of the waves in the different scenarios.

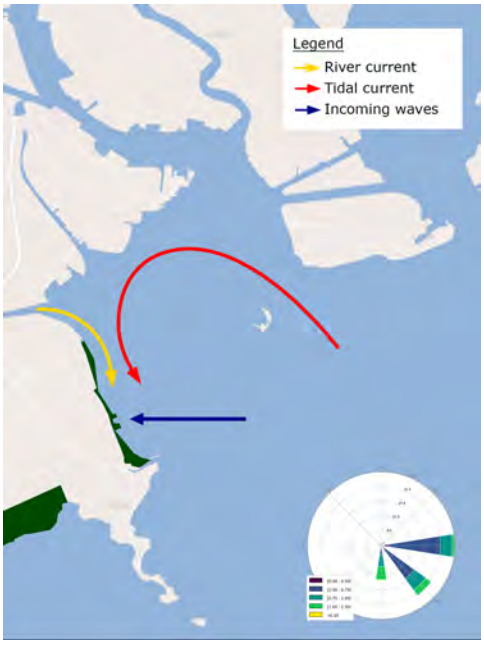


Figure 5.11: Mangrove area B, currents and incoming waves.

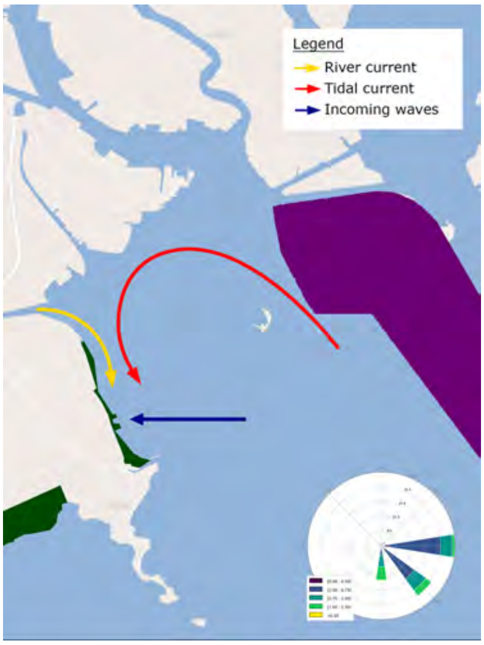


Figure 5.12: Mangrove area B, currents, waves and Port 2.

5.1.3. Water level

The results of the water level analyses are presented in this chapter. The water depths between Hon Dau measuring station and the mangrove areas were obtained using the Navionics map. The highest point for the mangrove areas was 0.9 meter and 1.2 meter above Mean Lower Low Tide (MLL tide) for area A and area B, respectively. The Hon Dau measures were conducted at 0.6 meter below MLL tide. The MLL tide is calculated by averaging the lowest low tides over a long period of time. This calculation was performed over the course of one year, resulting in a MLL tide of 105.57 cm above the measurement station's zero point. The results are shown in figure 5.13. To gain insight into the inundation periods of the mangrove, calculations were performed for five different bed levels: 0 cm, 30 cm, 60 cm, 90 cm, and 120 cm above MLL tide. For each bed level, the percentage of inundation per month and frequency of inundation times per month are shown in table 5.1. The frequency of inundations is determined by the number of occurrences, not the duration in days. This is evident in the case of mangroves at a bed level of 120 cm above MLL tide, because the frequency is lower compared to mangroves with a bed level of 90 cm above MLL tide. This can be seen at neap tide, where the mangrove remain exposed for multiple days.

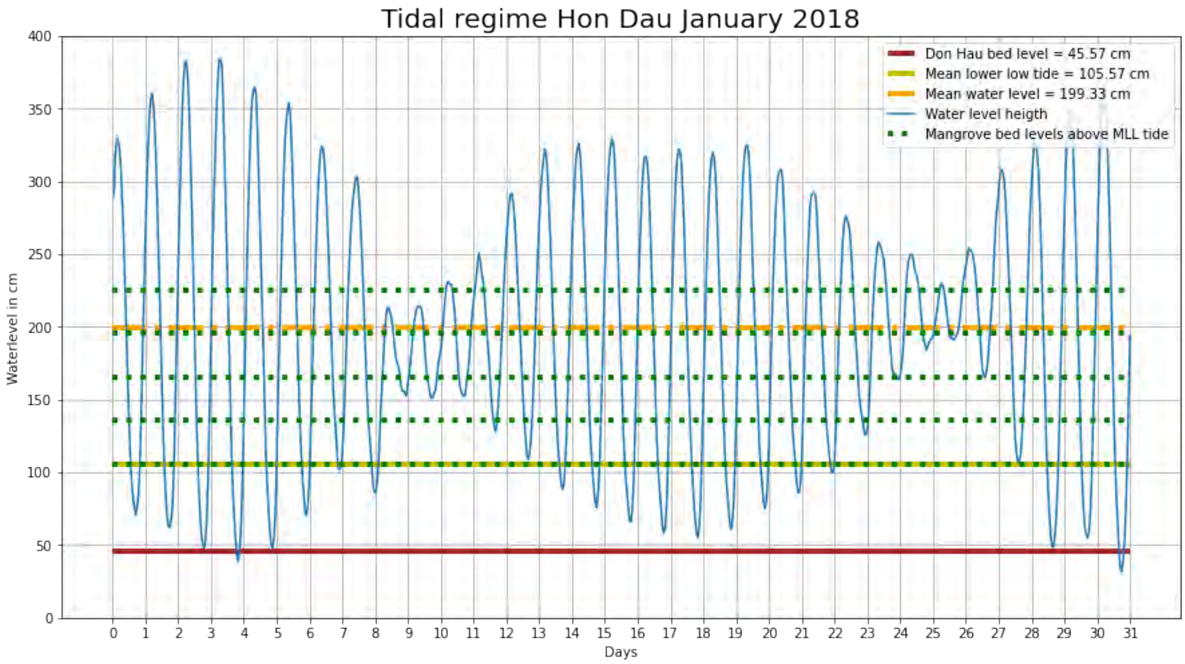


Figure 5.13: Water level plot in January.

Table 5.1: Percentage (top row) and frequency (bottom row) per month of inundation per month for different bed levels.

Month	0 cm	30 cm	60 cm	90 cm	120 cm
January	82.66 20	74.06 24	63.71 29	51.61 30	39.11 28
February	84.23 18	74.7 22	62.8 26	48.81 28	31.99 23
March	88.31 17	75.00 27	61.02 30	47.45 28	31.85 25
April	90.42 12	77.92 22	61.39 28	48.47 28	32.22 26
May	86.02 18	75.4 23	63.04 27	48.92 29	35.22 28
June	83.89 20	73.89 23	63.47 27	48.89 30	36.53 27
July	85.75 20	76.34 23	66.8 27	54.03 30	42.74 30
August	87.23 18	77.02 24	65.59 27	54.17 30	36.16 28
September	92.08 12	82.5 19	71.39 24	55.83 28	41.67 27
October	95.16 9	84.41 17	72.58 24	58.2 30	46.37 30
November	91.11 12	79.86 21	69.72 25	57.92 28	44.58 29
December	89.38 16	79.7 23	67.47 28	54.3 32	41.67 30

5.1.4. Tidal Prism area A

The tidal prism is calculated by multiplying the surface area and the tidal range. This is done for the mean tidal range. Consequently, the discharge during this tidal cycle of the river outlet is calculated. This done in order to check how much influence the discharge will have on tidal prism.
The tidal range (TR) is obtained from the water level from figure 5.13. The tidal range is calculated by subtracting the mean low water level of the mean maximum water level. The surface area is obtained using Google Earth Pro, where the new harbour is drawn into the figure, seen in figure 5.10. The surface area is then multiplied with the tidal range.

To determine whether the river has an influence on the tidal prism, the discharge needs to be calculated. During the second field trip, the sluice gates were closed because the water level at sea was higher. It was measured that the water level in the river was 210 cm relative to the zero point of the Hon Dau measuring station. The lowest water level for which the tidal range is calculated is 105.57 cm. It is assumed that the sluice gates only open when the water level at sea drops below 210 cm. With the python script in Appendix B Water Level script, each hour the water level is in between the 105.57 cm and 210 cm range, the discharge per hour is calculated. This resulted in a discharge of 5.7% per tidal prism, or a discharge of 2,531,074 m^3. For this reason, it has been chosen to neglect the river discharge for the calculations for simplicity.

In table 5.2, the assumptions for the calculations are given. The average sediment concentration was assumed from chapter 2. The $S_{\text{Van Uc River, annual}}$ is the total annual sediment mass out of the Van Uc River. In most systems, roughly 10^{-4} will settle of the total suspended sediment. As the new area will be sheltered against waves and tide current, it is assumed that between the $5 * 10^{-4}$ and $1 * 10^{-3}$ of the total suspended sediment will settle. (van Maren, B. personal communication, October 25, 2023). This assumption will be further discussed in chapter 6. The assumptions allows for the calculation of how much sediment will settle annually, which is done with formula 5.1, formula 5.1, and formula 5.3.

$$TP_{\text{mean}} = A_{\text{surface}} * TR_{\text{mean}} \tag{5.1}$$

$$S_{\text{sediment, annual}} = TP_{\text{mean}} * C_{\text{sediment, mean}} * 365 \tag{5.2}$$

$$S_{\text{sediment, annually settled}} = S_{\text{sediment, annual}} * Net_{\text{sedimentation}} \tag{5.3}$$

Table 5.2: Tidal prism assumptions.

$S_{\text{Van Uc River, annual}}$	5.1 MT
$A_{\text{Dragon Hill}}$	4,800,000 m^2
$C_{\text{sediment, mean}}$	200 mg/L
$Net_{\text{sedimentation}}$	$5 * 10^{-4}$ / $1 * 10^{-3}$ [-]

Table 5.3: Tidal prism results.

A_{surface}	22,960,095 m^2
TR_{mean}	1.934 m
TP_{mean}	44,404,823.73 m^3
$S_{\text{sediment, tidal cycle}}$	8.88 MT
$S_{\text{sediment, annual}}$	3,241.6 MT
$S_{\text{sediment, annually settled}}$	1.62 / 3.24 MT

An estimation is made for the amount of sediment that could potentially be transferred into the sheltered area. For the most conservative calculation, a lower limit is set at $5 * 10^{-4}$. since the sediment supply of the Van Uc river is cut off by the construction of port 1, the sediment must come from another source. This would be the mudflats on the upper shoreface. A rough estimation is made in order to check whether this sediment buffer is sufficient. This is done by calculating the area above MLL tide. This mudflat is assumed to be 1 meter thick. The results are given in table 5.4. As they sediment buffer is approximately an order of magnitude larger, it is considered sufficient.

Table 5.4: Calculation sediment capacity.

A_{mudflat}	33,170,000 m^2
$d_{\text{mud bed}}$	1 m
ρ_{sediment}	1200 kg/m^3
$V_{\text{sediment, buffer}}$	37.9 MT

5.1.5. Longshore sediment area B

The longshore sediment transport is determined by three main factors; the tidal current, the waves and the river discharge. An estimation of the direction and amount of sediment transport is made using the two T-groynes. From satellite images it is seen that the T-groynes were constructed somewhere between July 31 2010 and December 22 2013. The dimensions were measured during the field trip and validated by satellite imagery. The results are depicted in table 5.5. The T-groynes are identical in size.

Table 5.5: Dimensions of both T-groynes.

	Dimensions [m]
Length of body	250
Length of arm	80
Width of body	3
Width of arm	5

The next step was to determine the development of the coastline. By inspecting satellite images, a determination of the width of the progression is made. This can be seen in figure 5.14. The white line is the base line, dating from January 15 2014. The green line dates from August 1 2014. These dates had to be chosen, as this were the only satellite images during low tide. The T-groynes are exaggerated with red lines for clarity.

Figure 5.14: Coastline development area B.

Based on figure 5.14, the coastline south of the T-groynes, the progression has been measured at 10 places for the coast south and north of the T-groynes. The results of the measurements are depicted in table 5.6.

Table 5.6: Accretion of the coastline from 15/01/2014 to 01/08/2014.

Transect South	Progression [m]	**Transect North**	Progression [m]
1	95	**1**	191
2	118	**2**	177
3	102	**3**	137
4	87	**4**	119
5	65	**5**	102
6	63	**6**	115
7	25	**7**	151
8	55	**8**	80
9	40	**9**	47
10	34	**10**	42
Mean	68.4	**Mean**	116.1

Consequently, the coastline accretion between the groynes is measured. The coastline changes are heavily influenced by eddies, created by the currents. This causes that measurements to be taken differently. Here, the ratio between the original coastline and the new coastline is made in order to get an impression of the sedimentation volume. The frontal area has grown from 20,805 square meters to 58,745 square meters. This means an increase by 282%. The coastline before the T-groynes followed the white line along the sea dike, meaning a substantial increase of sedimentation.

In order to calculate the alongshore sediment transport rates, the single line theory is used. This means that the coast is seen as a single line, with constant hydraulic conditions. A schematisation is seen in figure 5.15. ΔY corresponds to the accretion, and d stands for the depth of closure. The depth of closure is defined as depth where the upper shoreface changes into the lower shoreface. For this area, is it taken at the depth were it can be assumed that the river causes constant depth by its erosion due to the outflow. This means that below the depth, no active changes are in place with respect to sedimentation. Seen in figure 5.16, the river maintains the depth at 0.1 meters below lower low tide. The depth of closure is taken at 1.0 meters as the coastline lies at +0.9 meters above lower low tide.

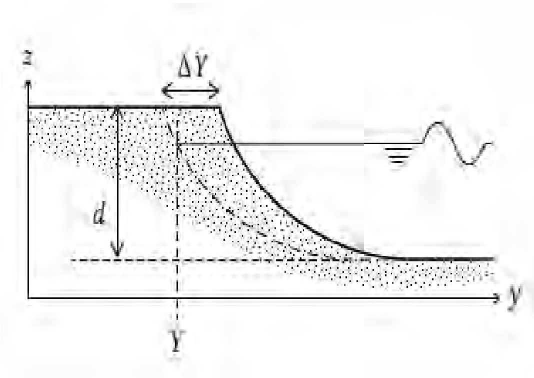


Figure 5.15: A schematisation of the single line theory (Coastal Engineering)

Figure 5.16: Navionics bathymetry map

With equation 5.4, the accredited volume of the tidal flat is calculated. Coastline south is the coastline south of the T-groynes and consequently, coastline north is the coastline north of the T-groynes. The results are depicted in table 5.7. These results are the net transport, during the period between the satellite images.

$$\Delta x \cdot \Delta Y \cdot d = V_{sediment} \tag{5.4}$$

Table 5.7: Results of sediment.

Coastline south		**Coastline north**	
$\triangle$**t**	17,107,200 s	$\triangle$**t**	17,107,200 s
$\triangle$**x**	2,196 m	$\triangle$**x**	1,233 m
$\triangle$**Y**	68.4 m	$\triangle$**Y**	116.1 m
d	1.0 m	**d**	1.0 m
$\mathbf{V}_{sediment,south}$	150,206.4 m^3	$\mathbf{V}_{sediment,north}$	143,151.3 m^3
$\mathbf{S}_{south}$	0.00878 m^3/s	$\mathbf{S}_{south}$	0.00837 m^3/s

5.2. Environmental impact

5.2.1. Visual Assessment

During the field study in Do Son, the mangroves in Bang La (location A) and Ngoc Hai (location B) were visually analysed to inspect their health and identify pollution sources. At location B, two distinct mangrove forests can be found, the forest at the T-groyne (figure 5.18) and the forest close to the Ngoc Hai fishing port (figure 5.19). Plastic waste was found in the mangroves at both study locations A and B as shown in figure 5.17 and 5.19. However, the amount of plastic waste was noticeably higher in the mangroves located next to the Ngoc Hai fishing port compared to the mangroves in Bang La and at the T-groyne, where less human activity occurs. Styrofoam cooling boxes made up the majority of the plastic waste that was discovered at the Ngoc Hai port. The fishermen who operate in Ngoc Hai preserve their caught fish in these cooling boxes, as shown in figure 5.20. Therefore, it is likely to assume that the Ngoc Hai port is the main source of plastic pollution in the mangroves at location B. Moreover, it was observed that coverage in plastic has a considerable negative impact on the health of the mangroves in Ngoc Hai. Figure 5.21 shows how the parts of the mangroves that are buried under the plastic had died, presumably due to suffocation as described in chapter 3.3.2. At Bang La, the mangroves were substantially less covered in plastic, as shown in figure 5.17. It was also found that the health of these mangroves was less adversely affected, as no dead roots were discovered at this location. According to the Vietnam Institute for Urban and Rural Planning, the area of the Ngoc Hai fishing port will be modernised in the Masterplan to attract more tourists to the port, including small dredging activities (Nguyen, V.D., personal communication, October 10, 2023). Without any specific considerations regarding plastic waste management it can be expected that this plastic pollution will increase due to the expanding port activities associated with the Masterplan.

Figure 5.17: Mangroves in Bang La (location A).

Figure 5.18: Mangroves at the T-groyne (location B).

Figure 5.19: Mangroves at the Ngoc Hai fishing port (location B).

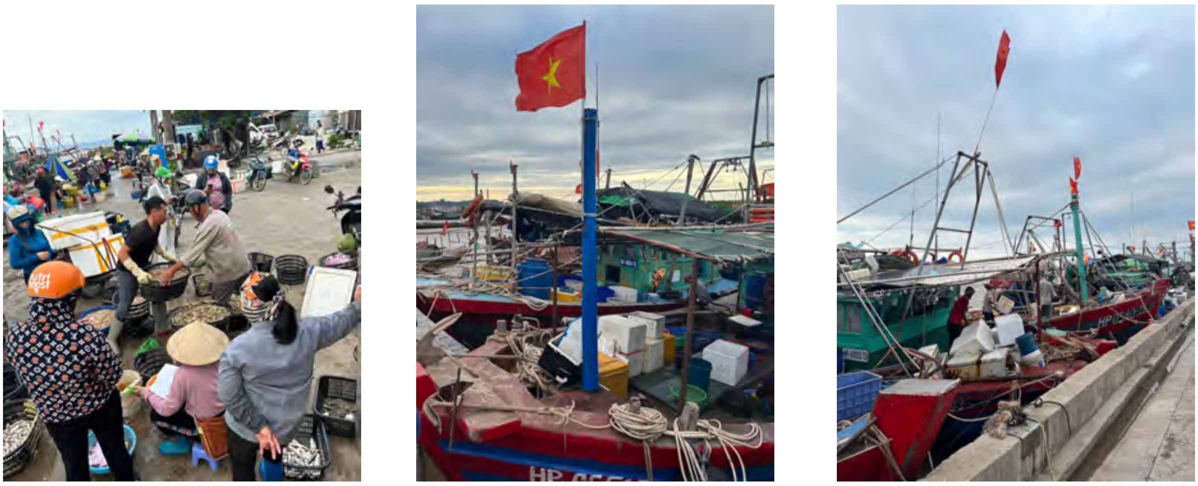


Figure 5.20: Styrofoam coolboxes used by the fisherman in the Ngoc Hai fishing port.

Figure 5.21: Dead mangroves buried under plastic waste at the Ngoc Hai fishing port.

5.2.2. Water quality measurements

Besides the visual observations, water samples were also taken during the field study as described in chapter 4 to assess the water quality of both mangrove areas. The sample locations and total amount had to be adjusted due to local authorities interference and other unexpected limitations. The exact samples taken at location B are depicted in figure 5.22. These samples were taken on October 11 2023, between 09:40 and 10:10 AM, during the high tide. The exact samples taken at location A are shown in figure 5.23 and were also taken on the same day during the high tide, between 2:15 and 3 PM.

Figure 5.22: Samples location B (Ngoc Xuyen & Ngoc Hai)

Figure 5.23: Samples location A (Bang La)

In tables 5.8 and 5.9 the exact sample results are presented as well as the Marine Water Quality limit values for each parameter, according to the technical regulations of QCVN 10:2023/BTNMT. The results are also graphically presented in figure 5.24.

Table 5.8: Water quality analysis results

	Location	pH	TSS (mg/L)	NH_4^+ (mg/L)	COD (mg/L)	BOD_5 (mg/L)
Sample 1	Ngoc Hai	7.7	880	1.24	31	17
Sample 2	Ngoc Hai	8.02	571	1.00	39	23
Sample 3	Ngoc Xuyen	7.9	444	1.16	46	28
Sample 4	Bang La	8.1	7	4.7	156	103
Sample 5	Bang La	8.1	14	3.79	111	70
Sample 6	Bang La	7.99	11	4.56	50	26
Sample 7	Bang La	8.06	10	4.31	46	31
Sample 8	Bang La	8	7	4.54	38	23
Sample 9	Bang La	8.04	7	4.62	37	26
Sample 10	Bang La	8.05	10	4.40	138	94
Sample 11	Bang La	8.1	9	4.45	99	65
Limit value	-	6.5-8.5	50	<0.1	<10	<4

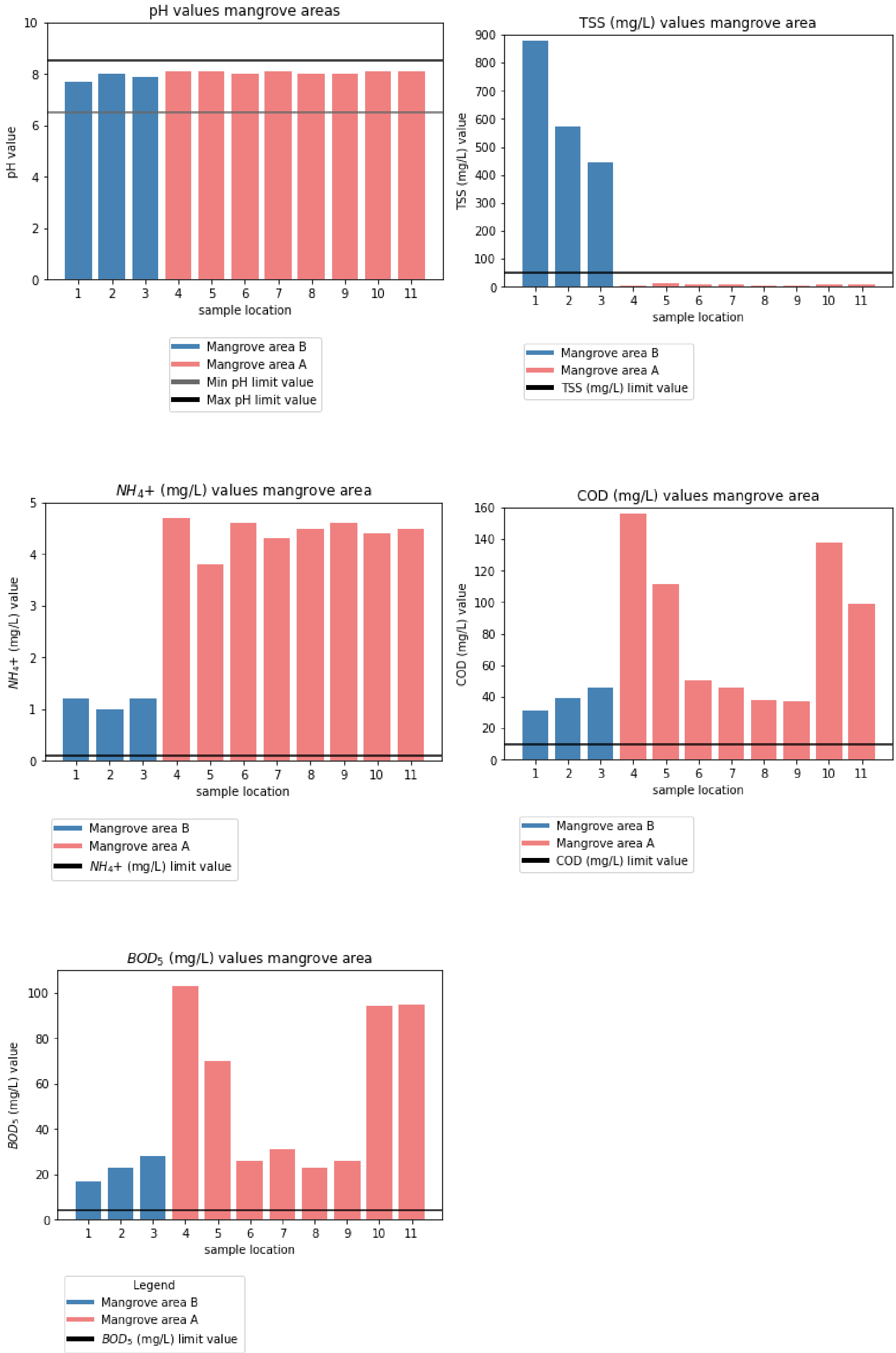


Figure 5.24: Water quality analysis results compared to limit values on Marine Water Quality (QCVN 10:2023/BTNMT)

pH

The pH values of area A and B range between 7.7 and 8.1. These are normal values according to Gandaseca et al. (2016) since the pH value of water may increase due to the mixing of estuaries water, with a pH generally ranging between 7.0 - 7.5, with sea water, of which the pH ranges between 8.1 - 8.3.

TSS

The TSS values in mangrove area B are significantly higher than mangrove area A. The reason behind this difference lies in the dynamics of sediment transport, see 5.11. In mangrove area B, the Lach Tray river current plays a vital role. This current carries a substantial amount of sediment into the area. However, the unique challenge here is that the tidal current pushes southward, preventing these sediments from settling on the coast. As a result, the TSS concentration in the water is higher.

On the contrary, mangrove area A experiences a different scenario. Here, the primary mechanism for sediment transport is driven by the tide. These tide pushes the sediment into the mangrove area, where it has ample time to settle (B. van Maren, personal communication, October 25, 2023). Consequently, this settling process results in lower TSS values in the water of mangrove area A.

Ammonia

The results from the samples collected in area A reveal significant higher concentrations of ammonia when compared with those in area B. This discrepancy in ammonia levels can be plausibly attributed to the domestic wastewater outflow from the homes that are located behind area A. Domestic wastewater discharge, if not properly treated, can lead to elevated ammonia concentrations in the surrounding area, affecting water quality. Mangrove area B faces lower ammonia levels because of the absence of residential homes near the mangroves.

COD & BOD

All sample results of the COD and BOD analysis significantly exceed the limit values. The high values of sample point 4 and 5 can be explained due to their locations close to the river water outlet at the sluice. As the water outlet flows into the sea, there is a dilution effect due to the mixing with seawater. This dilution can explain the decrease of the sample values as they progress towards the sea.

Oil and grease

In table 5.9 the results of the oil samples are listed. The sample locations are depicted in figure 5.23.

Table 5.9: Oil sample results

Sample	Oil and grease	Test method	Unit
1	2.2	SMEWW 5520.B: 2017	(mg/L)
2	2.2	SMEWW 5520.B: 2017	(mg/L)
3	2.5	SMEWW 5520.B: 2017	(mg/L)
Limit value	< 5	-	-

The analysis of oil samples indicate that the operations at the Ngoc Hai port have a minimal impact on mangrove area B as the sample results are below the limit values. These results can be explained through a combination of factors:

Sampling timing: In this case, the samples were specifically taken during high tide. High tide leads to a substantial inflow of seawater into the mangrove area, which, in turn, acts as a natural dilution factor.

Tidal currents: as seen in figure 5.11 there is a dominant current in the south east direction. These conditions play a pivotal role in dispersing the oil contamination in the opposite direction of mangrove area B.

With regards to the increased port activities associated with the Masterplan, this south eastern current and the location of the quay of terminal P2, see in figure 2.11, are of importance. Given that the quay is situated on the opposite side of the mangroves, namely the eastern side, and considering that the predominant southward current flows primarily seawards, the potential rise in oil levels within the water of the mangroves is expected to be minimal.

The data collected from the extensive assessment conducted at 11 sampling points clearly illustrates that the water quality heavily exceeds the standards limit values. This highlights the potentially adverse effects of various human activities associated with the development of Dragon Hill island as part of the Masterplan. It is reasonable to assume that these values will continue to exceed the limit values, as the Masterplan is being further implemented, in the near future if nothing is done. This expectation was also confirmed in an interview with the director at the Institute for Environmental Planning and Urban-Rural Infrastructure (Nguyen, V.D., personal communication, October 10, 2023). Because wastewater is not treated properly in Vietnam.

5.2.3. Expectations mangrove preservation

A case study by the International Federation of Red Cross and Red Crescent Societies revealed that the mangroves planted as part of the MP/DRR project have proven to protect dykes and coastal communes, and the initiative is seen as extremely efficient as it has provided benefits that much outweigh the costs. Mangrove afforestation is considered to be a comparably more effective method of protecting coastal communes compared to other methods, not only because it is less expensive but also because it provides immediate economic and ecological benefits, such as improved livelihoods and the mitigation of climate change.

The project evaluation also pointed out the need for increased cooperation between the VRCS, the MARD, and the Ministry of National Resources and Environment (MONRE) for long-term sustainability of the forests (International Federation of Red Cross and Red Crescent Societies, 2011). The lack of integration of the Mangrove Plantation and Disaster Risk Reduction (MP/DRR) project into the forestry management of the central government was also pointed out in another project evaluation carried out by the Asian Management and Development Institute (AMDI). One of the concerns was the absence of a clear exit strategy after the end of the MP/DRR project to ensure development and sustainability of the current mangroves. Moreover, the varying roles of the Red Cross in mangrove management at local, provincial and national level from one province to another results in a lack of linkage between the JRCS planted mangrove areas and government programmes. Currently the role of the Red Cross is more as a contractor for mangrove forest development instead of an equal partner (Chinh et al., 2015).

It was evident from the VIUP interviews that the central government places less importance on protecting the mangrove forests and more on promoting tourism and economic development. The two ports (P1 and P2) and the building of Dragon Hill Island are the primary means of doing this. According to the Deputy Director, the Masterplan's "nature preservation" plans include the protection of dykes and coastal communes against natural disasters, primarily through artificial measures, rather than natural ones. The protection of current mangrove forests was not brought up (Pham, 2023, October 2). Moreover, the director of VIUP's Environmental Planning and Urban-Rural Infrastructure department anticipates that the mangroves in location A will diminish and eventually disappear as a result of the construction of port 1 (V. Nguyen, 2023, October 2). As depicted in figure 5.10, part of the mangrove forest in area A will disappear due to overlapping parts with port 1. This means that the mangroves planted by the VRCS and JRCS during the MP/DRR project, which was implemented over the course of 17 years, will disappear.

However, article 21 of the Vietnamese Forestry Law states that project owners must plant replacement forests when forest areas are converted to areas for other purposes. These replacement forests must be equivalent to the forest area whose purpose is changed for planted forests and three times the size for natural forests (Socialist Republic of Vietnam, 2017). Therefore, if part of the mangroves in location A are destructed due to the construction of P1, more mangroves should be planted in another location. During the interviews with VIUP, it was pointed out by the Deputy Director that more mangroves will be planted alongside the coastline at location B (Pham, 2023, October 2). In the design plans that the Director showed, the mangrove forest in location B will be three times its current size. However, it is not clear how this will be accomplished. As the current velocity is too high for sufficient settlement of particles in area B, there is no opportunity for the mangrove forest to expand. Furthermore, the focus should be on maintaining and growing the existing mangroves rather than extending the mangroves to new areas previously un-planted with mangroves. Studies show that the survival rate of young mangrove stands in plantation projects varies, but can sometimes be extremely low. One of the main reasons is plantation in the wrong location, due to lack of documentation on long-term success (Marchand, 2008).

Despite the evidence-based effectiveness of mangrove afforestation, which prove the benefits outweighing the costs, there is a noticeable absence of its recognition and central management for these projects. Interviews with two representatives of VIUP indicate similar concerns for the mangroves areas in Do Son. There is lack of consensus on how ”nature preservation” is incorporated into the Masterplan and conflicting statements by experts regarding the future of mangrove forests are evident. Moreover, it seems that the key environmental stakeholders, such as the JRC, have not been adequately engaged in the Masterplan's design, which is crucial for effective management as indicated in previous mangrove project evaluations.

5.3. Socio-economic results

As described in the methodology section, survey-structured interviews are performed in order to obtain primary data needed to determine socio-economic impacts of mangrove forest on the local community in Do Son (see Appendix G for photos of the interviews). This section provides the results of these interviews and aims to analyse these results and determine possible causal relationships between socio-economic and demographic characteristics of the participants. First, an overview is provided on the characteristics of the participants. This is followed by a discussion of the four objectives of economic dependency, awareness, participation and perception of the local community. For each objective, the results are compared within the different areas (A1, A2 and B) in order to define relevant causal relationships. Findings derived from the interviews are sometimes substantiated through the explanations of the answers to certain statements. This is indicated by, as an example, ”(F.3.9; s9). This refers to statement 9 in Appendix F.3.9.

5.3.1. Socio-demographic characteristics participants

Participant's socio-demographic and economic variables are shown in table **??** and demonstrate a wide range of characteristics. The domination of male participants (10 out of 13) reflects the distribution of certain industries within the Do Son area, particularly in occupations related to the fishing business. The age distribution of participants is diverse, spanning across different generations, as displayed in table 5.10. The primary sources of income among participants were related to the fishing industry. A significant proportion identified as fishermen. Other sources of income included seafood merchants, a fish restaurant owner, and a grocery store worker. Additionally, a student participated in the study, offering an enlightening perspective as a member of the younger generation. Given the stakeholder groups identified in section **??**, occupations not directly related to the mangroves (the restaurant owner, the shop worker and the student) are grouped together as a representative group for the inhabitants as a stakeholder group. Participants were spread across different residential areas within the Do Son area, the number of representatives per area is displayed in table 5.10.

Table 5.10: Participants characteristics

Variable	Description	Number
Gender	Male	10
	Female	3
Age	18-29	2
	30-39	3
	40-49	5
	50+	3
Income source	Fisherman	8
	Seafood merchant	2
	Restaurant owner	1
	Grocery store worker	1
	Student	1
Area	B	6
	A1	3
	A2	4

5.3.2. Economic dependency

Figure 5.25 displays an overview of the results of the economic dependency. Two statements were relevant with regards to the economic dependency: statement 1 and 2. The figure clearly shows that for both statement 1 and 2 69% of the participants either agree or strongly agree. For both statements, these participants consist solely of fisherman, seafood merchants and the restaurant owner. The fisherman and the seafood merchants are directly dependent on the mangroves, as they earn their money by selling the fish that was caught in the mangroves. On the other side, for statement 1, 31% either disagrees or strongly disagrees and for statement 2, 23% disagrees and 8% is neutral. These people consist of sea fisherman, a store owner and a student. Since these fisherman get their fish from the sea, they or not economically dependent on the mangroves. The same goes for the shop worker and the student, they are not economically dependent on the mangrove forest's resources.

Table 5.11: Statements used for the economic dependency

Statements
1. I am dependent on the mangrove forest.
2. If the mangrove forest disappears, my income will disappear as well.

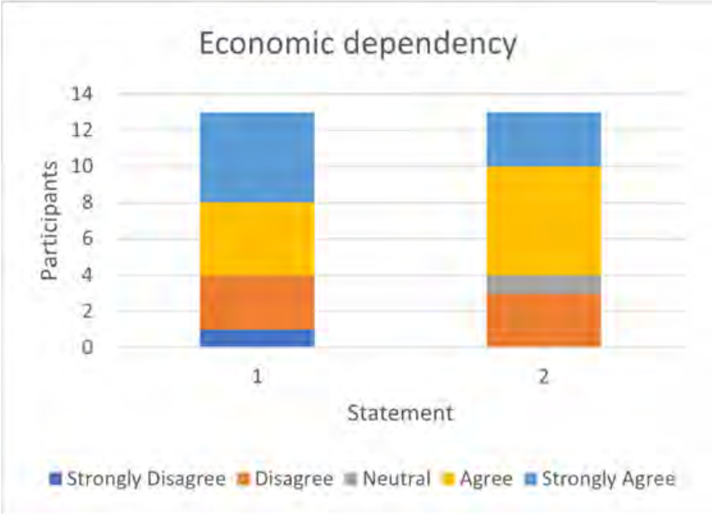


Figure 5.25: Results economic dependency

Figure 5.26 and 5.27 show the same results as figure 5.25, but subdivided per area. The first thing that is noticeable is that the participants from area A1 either agree or strongly agree with both statements, while the answers of the participants from area A2 and B are more divided. This can be explained by the occupations of the participants. Specifically, those from area A1 were solely mangrove fishermen, whereas individuals from areas A2 and B were a mix of mangrove and marine fishermen, alongside other professions.

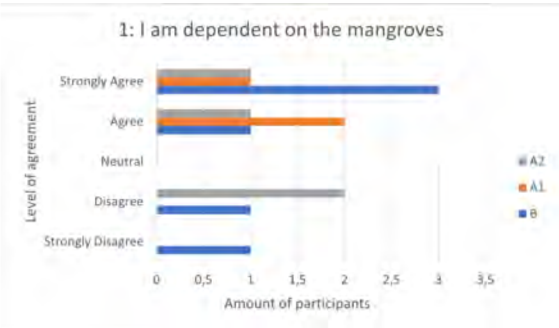


Figure 5.26: Results statement 1

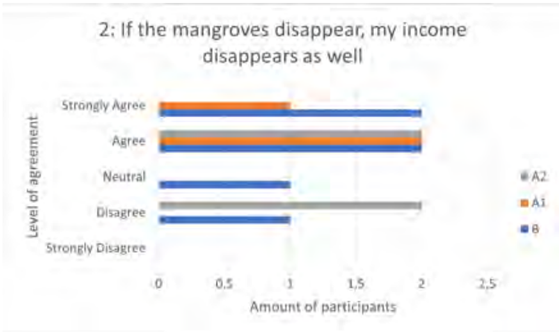


Figure 5.27: Results statement 2

The figures above show that the economic dependency of mangrove forests on the local community in Do Son is somewhat divided. The mangrove fishermen and the people who sell fish are highly reliant on the mangroves in both area A and area B, as their income is directly linked to the mangroves. Conversely, sea fishermen are not economically reliant on the mangroves, as are the other occupations that appeared among the participants. Since these occupations represent the inhabitants, it implies that the inhabitants are not reliant on the mangroves for their economic sustainability.

5.3.3. Awareness

Figure 5.28 shows the awareness of the local community. The results show a high level of awareness regarding the services provided by the mangrove forest.

Table 5.12: Statements used for the awareness

Statements
4. I am aware of the fact that mangroves provide coastal defence.
5. I am aware of the ecosystem services that mangrove provides for flora, fauna, and the climate.
6. I am aware of the fact that mangroves provide economic benefits for the local community.
9. I am aware of the effects of pollution in the mangroves.
10. I am aware of the past conservation projects of Do Sons mangroves.
11. I am aware of the new plans for Do Son.

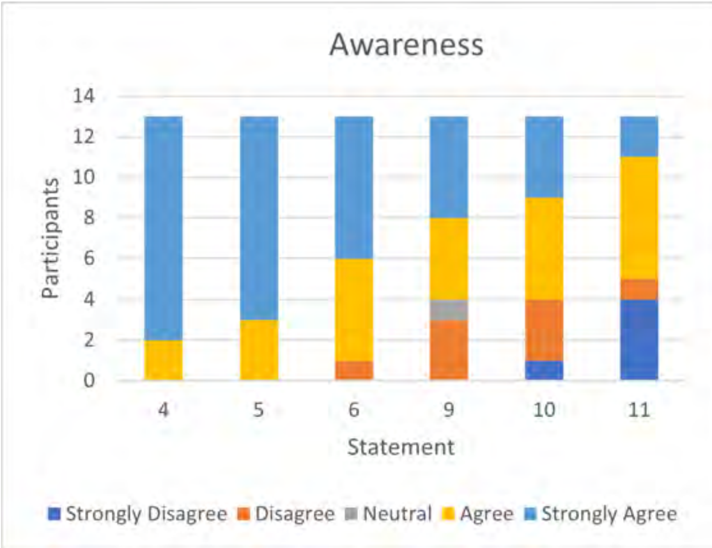


Figure 5.28: Results awareness participants

In addition, the majority of the participants are aware of the effects of pollution in the mangrove forest (4 out of 13 agree and 4 strongly agree with statement 9). As can be seen in figure 5.29, all participants in area A1 were aware of the effects, as were half of the participants in area A2. Participants from area B on the other hand were not very aware of the effects of pollution, only two participants indicated being aware of this. The difference between these areas could possibly be declared through a lack of information on pollution published by the government (F.3.9; s9). To confirm this, a correlation between statement 9 and 10 is investigated.

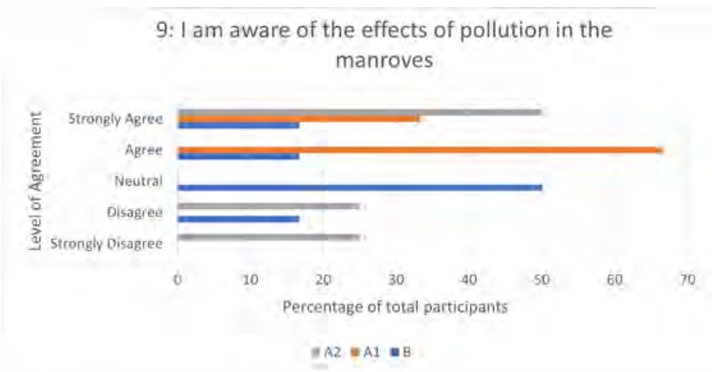


Figure 5.29: Results statement 9

Figure 5.30 shows how the participants' responses to statement 10 are broken down into the different areas. Similar to statement 9, the participants from area A1 are all aware of the past conservation projects, 50% of the people from area A2 are aware and only 33% of the participants from area B. Remarkable is that the group of participants that is not aware of the effects of pollution in the mangrove forest, is also not aware of the conservation projects in the area. This could indicate a correlation between the effectiveness of creating awareness of the effects of pollution, for example by informing local people through the Japanese Red Cross Society signs, and previous executed conservation projects (see figure G.1).

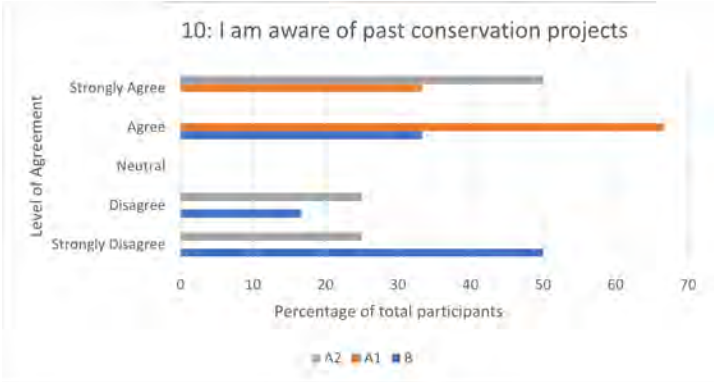


Figure 5.30: Results statement 10

As can be seen in figure 5.31, the awareness of the new plans of Do Son (statement 11) are quite divided across the different areas. Remarkable is that there is a clear difference between area A and B. 50% of the participants from area B strongly disagree on being aware of the new plans in Do Son. The remaining 50% state that they are aware, but only of the projects that are being executed at Dragon Hill. This means that none of the participants within area B is aware of the plans related to the construction of the ports. The reason for this lack of awareness is that the people in area B were not informed of such projects. They did not receive any information or support on future projects related to their area from the government. The participants located in area A, on the other hand, were informed a lot more, but still show a difference in awareness within the area as well. Participants from area A1 (67% strongly agree and 33% agree) were better informed than participants from area A2 (75% agree and 25% disagree) F.3.9; s11). The reason for this is that the participants from A1 were informed through megaphones located next to their houses. These announcements contained detailed information about the project (F.3.8; s11). The government announced the inhabitants located in area A1 that they will receive support once the plans were set into motion. This support includes new housing in Hai Phong City, new jobs to cover their former occupation, and financial support due to the disruptions in their lives. The participants from area A2 were also provided information about the project. They were informed via an announcement in the newspaper, which was, however, less detailed than the megaphone announcements (F.3.4 and F.3.5; s11). These observations are supported by what emerged in the interview with VIUP's environmental department (see Appendix F.2). In this interview, it emerged that "the legal requirements oblige us to consult with the local communities for stakeholder involvement". However, it was also mentioned that "the time we have is very constrained, so we are just concerned with the overall scale". It can be derived from this that the government chose to only inform the utmost necessary people with details of the plans, alias, the people form area A1. In addition, the participants in area A2 were not told that they would receive support from the government. These results indicate a correlation between the awareness of the project and the amount of information that is provided by the government across the three different areas.

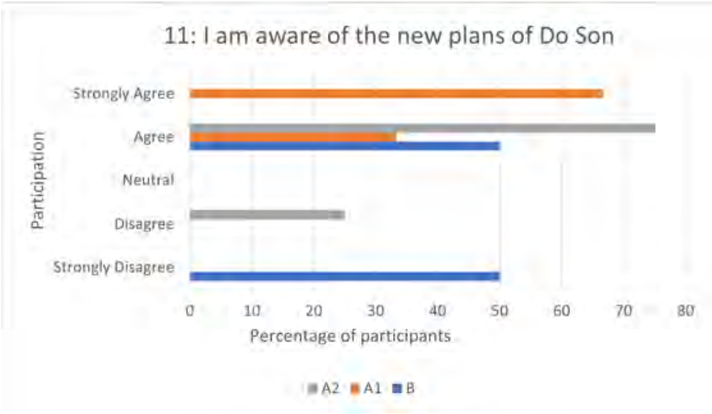


Figure 5.31: Results statement 11

5.3.4. Participation

Figure 5.32 shows the local community's view on participation. The vast majority of participants support the attraction of more tourists to the Do Son area. The main reason for this is that people tend to belief that attracting more tourist to the area will improve their economic stability as they would be able to sell more fish in markets, restaurants and stores. Another common reason for this support is that participants want to see Do Son again as the tourist centre of the Hai Phong area. According to the participants, Do Son used to be a big touristic destination with several historical and cultural attractions. Nowadays, the area is less popular anymore among tourist, due to the development of other touristic areas in Vietnam, causing the tourists to go to different areas. In order to show the beauty of Do Son again, and improve its inhabitants economic stability, people are willing to participate into projects that attract more tourists, such as the Dragon Hill project (F.3.6; s3 and F.3.13; s16). This is clearly reflected in the results of statement 3, where 12 out of 13 people either agree or strongly agree. The above reflects what emerged in the interview with VIUP's architectural department. In this interview it was mentioned that the aim of the plans is to make Do Son a tourist attraction again and boost economic development in the area (see Appendix F.1).

Table 5.13: Statements used for the participation

Statements
3. I want more tourism in the Do Son area.
8. If I got offered a better paid job, I would switch jobs, regardless of the disappearance of mangroves.
7. I am willing to sacrifice part of my income to conserve the mangrove forest.
12. I feel that I have been included in the new plans for Do Son.

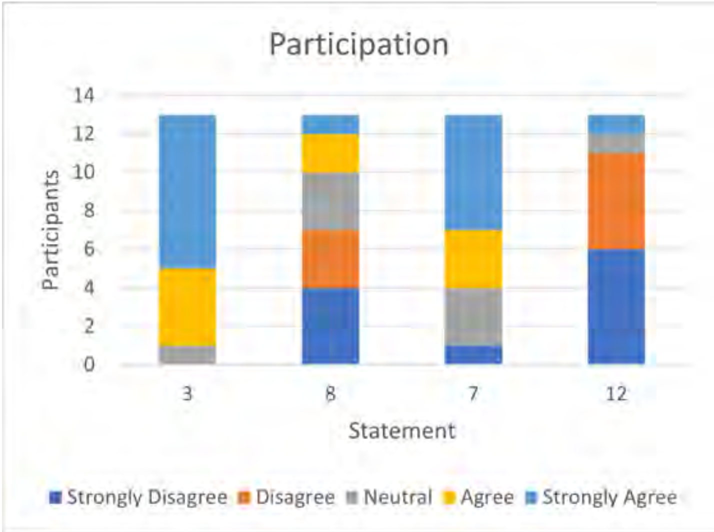


Figure 5.32: Results participation participants

To follow up on participation, analysing the results of statement 8 shows great division among the participants. 7 out of 13 participants are not willing to switch (strongly disagree or disagree) from their current occupation to a better paid job even though this means the mangrove forest will disappear. Three participants stay neutral as they consider both preserving the mangrove forest and ensuring economic stability to be highly important (F.3.6, F.3.10 and F.3.5; s7). 2 out of the 3 participants that either agree or strongly agree with this statement are from area A1. As mentioned in the previous section, the participants in A1 were better informed of the plans in Do Son, which causes their awareness to be higher compared to the other areas. They believe that the new plans, including their compensation, will have a positive impact on their economic stability and quality of life (F.3.8; s14 and s17, F.3.9; s14). As the government ensured they will get better jobs and receive financial support, they are more willing to participate even though this means the mangrove forest will disappear. The remaining participant from area A1, the one strongly disagreeing with statement 8, indicated that he would not switch to a better paid job different than being a fisherman as the fishing business is part of his family culture.

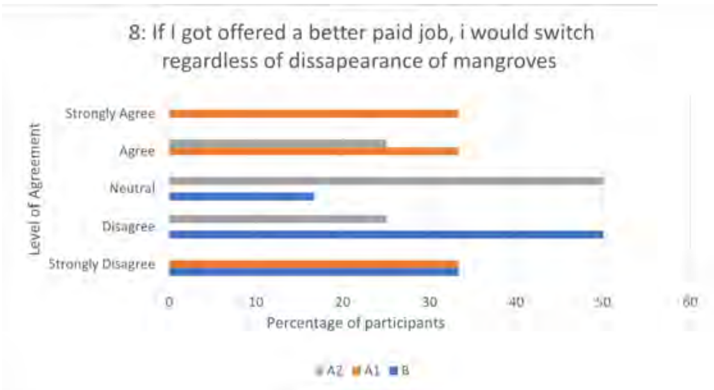


Figure 5.33: Results statement 8

Furthermore, looking at the results of statement 7, the willingness to pay for conserving the mangrove forest is quite high (3 out of 13 agree and 6 strongly agree). They would be willing to sacrifice a part of their income to preserve the mangrove forest, as they know their jobs and the protection of the land are very dependent on the services that the mangrove forests provide (F.3.9; s7 and s8). Comparing this to the results of statements 4, 5 and 6, a possible correlation can be established between the level of awareness of the mangrove services and willingness to sacrifice part of their income in order to preserve the forest.

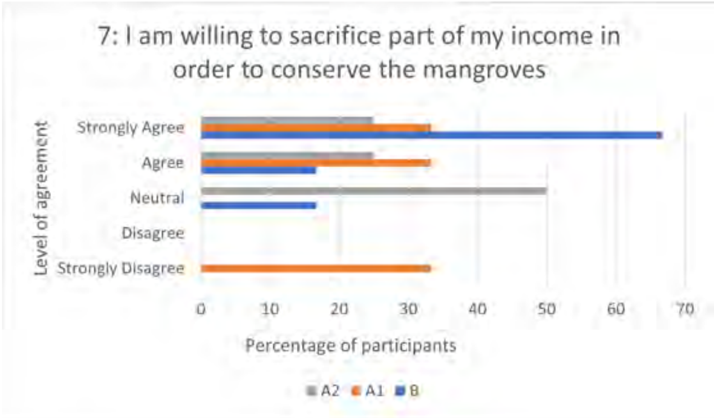


Figure 5.34: Results statement 7

Lastly, the local community almost unanimously stated that they did not feel included in the plans for Do Son. 11 out of the 13 participants stated that they did not feel included in the new plans of Do Son (7 strongly disagreed and 4 disagreed). The participants were not asked for their views on the plans and therefore did not feel included. The remaining participant who did feel included in the new plans of Do Son, indicated that he participated into a meeting with the governmental authorities. During this meeting he was asked for his opinion and view on the project and current situation.

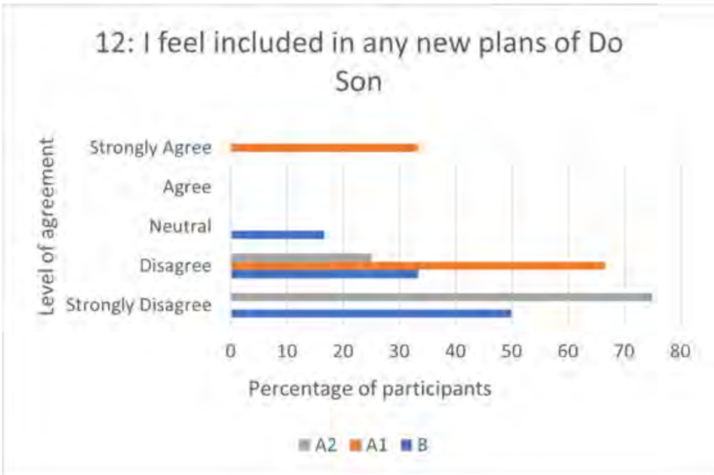


Figure 5.35: Results statement 12

5.3.5. Perception

Figure 5.36 shows the local community's perceptions towards the future plans in Do Son. The results from statements 13, 14 and 17 show no disagreement towards the new plans. Similarly, none believe that the new plans won't enhance their quality of life and economic stability. In relation to statement 15, the a slight majority (7 out of 13) agree on that the mangroves will be (partly) affected by the new plans. These observations are supported by what emerged in the interview with VIUP's environmental department, where it was mentioned that it was expected that mangrove area A would probably disappear due to the construction of the port in Do Son (P1) (see Appendix F.2). Four other participants, caused by a lack of information, maintain neutral. The remaining two participants think that the mangroves will remain untouched, either because the government's implementation of mangrove-related activities is unrealistic, or because they believe that public demonstrations will prevent the activities from being carried out (F.3.9; s15). Regarding the cultural heritage aspect, a large number of participants appear to be unaware of the cultural significance offered by the mangrove forest. This is confirmed by the vast majority of neutral responses (10 out of 13) to statement 16. Two of them disagreed as they explained that the cultural heritage is located in the temple on the top of the hill and won't be affected by the government plans (F.3.8; s16).

Table 5.14: Statements used for the perception

Statements
13. I am in favour of the new plans for Do Son.
14. The new plans for Do Son will improve my quality of life in the Do Son Area.
15. I think mangrove forests will disappear due to the new plans for Do Son.
16. The new plans will have long-term impacts on the area's cultural heritage and traditions.
17. The new plans for Do Son will have a positive impact on my economic stability.

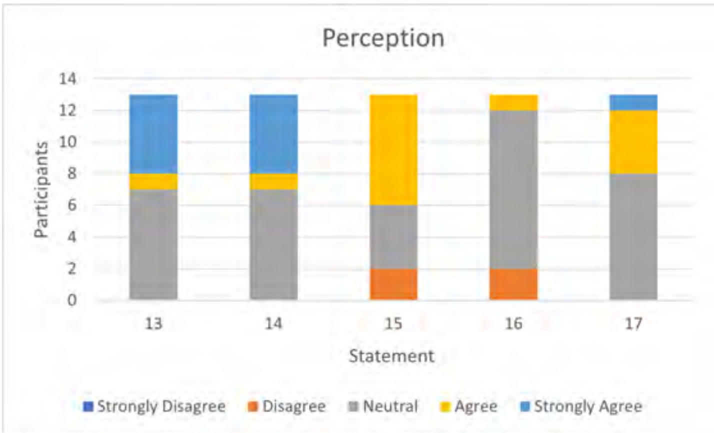


Figure 5.36: Results perception participants

In order to dive deeper into the perceptions of the local community, a comparative analysis of the participant's perceptions across different areas, supported by insights from statement 11, is conducted.

Area B

As presented figure 5.37, 67% of respondents in area B express a neutral standing towards their support for the new plans in Do Son (statement 13). A significant factor contributing to this neutrality is a lack of awareness, as 67% of the participants from area B strongly disagree with statement 11, indicating that they are unaware of the new plans. Among the remaining 33% who are aware of the plans, there is a unanimous agreement of being in favour. This suggests a strong correlation between awareness and support; when residents in area B are aware of the new plans, they tend to be in favour of those plans. The primary driving force behind this support is the belief that the new plans will attract more tourists to the Do Son Area, subsequently elevating their overall quality of life and economic stability. This perception is confirmed by the results of statement 14 and 17, which echoes these findings (F.3.9; s14). Conversely, respondents who are unaware of the plans predominantly adopt a neutral position. This indicates a prevailing optimism regarding the potential positive impacts of the new plans in area B on both personal well-being and the local economy.

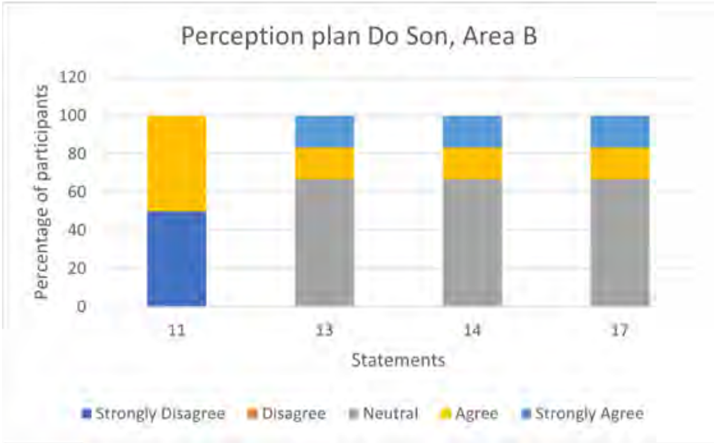


Figure 5.37: Results perception participants area B

Area A1 and A2

The perceptions towards the plans in area A1 and A2 are slightly different, as can be seen in figure 5.38 and 5.39. As mentioned before, people in these areas are better informed, causing the awareness of the new plans for Do Son (statement 11) to be higher in both area A1 and A2 compared to in area B. This results in a higher percentage of the participants to either being more in favour of the new plans (statement 13), with 67% strongly agreeing in A1, whereas in A2 50% strongly agrees, as to agree on an increase of their quality of life due to the new plans (statement 14), with 67% strongly agreeing in A1, and 50% agreeing in A2. This difference between A1 and A2, caused by the fact that participants from A1 are better informed, as discussed above, is also reflected in the results of statement 17.

As participants from A1 are aware of being compensated for moving to the city centre, they are more likely to agree that the new plans will have a positive impact on their economic stability. Important to note is that, just as in area B, there is a strong correlation between awareness and support; when participants are aware of the new plans in area A1 and A2, they tend to be in favour of those plans. If they are not aware of the new plans, participants express a neutral perception towards their support of the new plans, quality of life and impact on the economic stability.

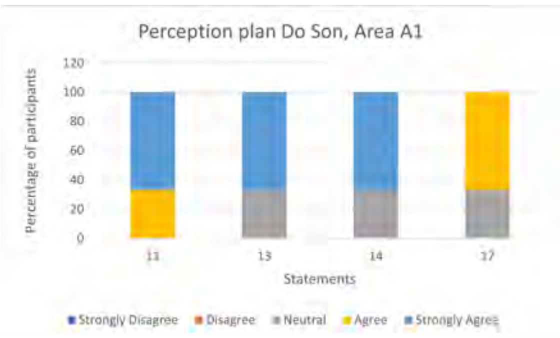


Figure 5.38: Results perception participants area A1

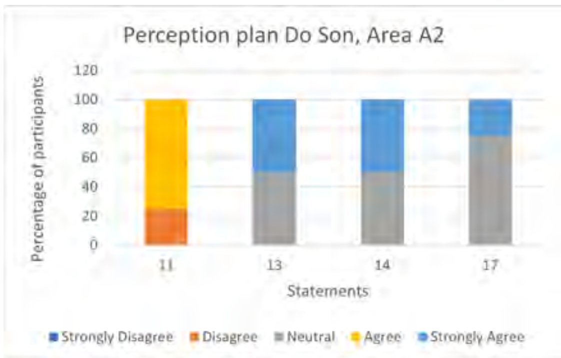


Figure 5.39: Results perception participants area A2

6
Conclusion

This study was conducted as part of a Multidisciplinary Project from the TU Delft in collaboration with Thuy Loi University in Hanoi. The goal of this research was to investigate the implications associated with the Hai Phong Masterplan on the mangroves and local community of Do Son, a small town south-east of Hai Phong.

The vision of the Hai Phong Masterplan is to transform Hai Phong from an industrial port city to a global maritime centre, and from an industrial town to a waterfront service-oriented urban area that attracts talent, entrepreneurs and tourists from around the globe making it the future ”gateway” of Vietnam to the world.

Comprehensive understanding with regard to the different aspects of the Masterplan of Hai Phong is crucial for its success. This research aims to support this. The findings of this study can be divided into two major components. First of all, it provides a comprehensive overview of the current situation in Do Son, with a focus on environmental, hydraulic, and socio-economic perspectives. Secondly, it provides insights on the expected implications associated with the further implementation of the Hai Phong Masterplan on the mangroves and local community of Do Son.

The study area was divided into two areas of interest: area A, the mangrove forest in Bang La, and B, the mangrove forest in Ngoc Hai, as depicted in figure 2.3 in chapter 2.

Assessment current situation

In this chapter, an assessment of the current situation of each mangrove area is given.

Mangrove area A

From the wave study analysis follows that the predominant offshore wave direction (NE) in Bach Long differs from the onshore direction in Hon Dau (E). The significant wave height is 0.23m lower in Hon Dau. As a consequence, the Do Son peninsula protects the area A against incoming waves from the east and south east. These waves diffract around the tip of the peninsula. Diffraction causes wave energy to disperse, resulting in a lower wave height. From figure 5.8, it is concluded that the area A has received its sediment during the wet season, brought by the ebb currents. The area is believed to be in equilibrium between the currents of the tide and the waves.

The sediment transport dynamics allow sediment in area A more time to settle compared to area B, leaving the water with lower TSS values. This contrast in settling process is also evident from the TSS values of the water samples, as the concentration in area A is notably lower than in area B.

The values of the other water quality parameters, pH, NH_4^+, COD and BOD_5, heavily exceed the standard limit values on Marine Water Quality (QCVN 10:2023/BTNMT), clearly illustrating the poor water quality conditions. This highlights the potentially adverse effects of various human activities around mangrove area A, such as the development of Dragon Hill island as part of the Masterplan. This poor water quality can have several negative effects on the mangrove ecosystem and the species that rely on the mangroves, as high levels of ammonia, BOD and COD can be toxic to flora and fauna. Elevated COD and BOD can deplete oxygen levels in the water, while excessive nutrient levels, as indicated by elevated ammonia, can disrupt the nutrient cycling within the mangrove ecosystem. This can lead to imbalances in nutrient availability and utilisation, affecting the growth and health of mangrove vegetation.

The findings from the survey-structured interview data show that the mangrove forests in Do Son offer crucial economic services to the local community. These services include fishing in the mangroves and selling fish on local markets, in grocery stores and in restaurants. These services generate job opportunities, food security and household income, enhancing their economic stability. 9 out of the 13 participants are dependent on these services and their income will disappear when the mangroves would disappear. In order to preserve these services, understanding their attitudes and perceptions is essential. With regards to the mangrove services (coastal defence, flora fauna and economic-benefits), results unanimously show a high level of awareness among the participants in all areas.

Regarding the effects of pollution, participants from area A, where billboards have been positioned as part of past conservation projects executed by the Japanese Red Cross Society, show higher levels of awareness (A1: 100%, A2: 50%) in comparison to their counterparts in area B (33%). Furthermore, the share of participants that was not aware of the effects of pollution also lacked awareness of the conservation projects in the area. Therefore, it can be concluded that creating awareness about past conservation projects, for example through billboards, causes an increase in the awareness of pollution.

This effect was also confirmed by the visual observations at the mangroves in area A. As they were substantially less covered in plastic, see figure 5.17, compared to the mangroves near the Ngoc Hai port in area B, see 5.19. It was also found that the health of these mangroves was less adversely affected, as almost no dead roots were discovered at the sampling locations.

Mangrove area B

The hydraulic conditions in mangrove area B have undergone changes over the years. Calculations of chapter 5.1.5 support the conclusion that significant sedimentation occurred due to the construction of the T-groynes. It is also concluded that, as the sediment source is the Lach Tray river located to the north of the area, the net flow direction is southward. This southward net-flow direction results from the higher velocities during ebb than flood, in combination with the Lach Tray river discharge. This flow velocity is too high in order to have more sedimentation. The waves counteract the sediment transport flows of the river and tidal current. Compared to area A, it can be concluded that the waves cause more erosion in area B.

This distinction is further substantiated by the TSS concentrations in the water samples collected from area B, where TSS levels are notably elevated compared to those in area A. As more sedimentation is impossible because of the flow velocity, there is a higher content of particulate matter in the water originating from rock and soil erosion. This results in higher TSS values.

Similar to area A, the values of the other water quality parameters, pH, NH_4^+, COD and BOD_5, heavily exceed the standard limit values on Marine Water Quality (QCVN 10:2023/BTNMT). This highlights poor water quality and the potentially adverse effects of various human activities associated with the fishing activities in the Ngoc Hai port near the mangroves of area B. In light of these potential adverse effects, it is crucial to address the sources of pollution and implement measures to improve water quality. This might involve stricter regulations in the Ngoc Hai fishing port, as well as broader efforts to reduce pollution.

As described before, the visual observations in area B showed noticeably higher amounts of plastic in the mangroves near the Ngoc Hai fishing port, with negative effects on the health of the mangroves. Styrofoam cooling boxes made up the majority of the plastic waste that was discovered near the port. It is likely to assume that the Ngoc Hai port is the main source of plastic pollution in the mangroves at location B, as the fishermen operating in the port preserve their caught fish in these cooling boxes.

The analysis of oil samples taken in area B indicate that the operations at the Ngoc Hai port have a minimal impact on the mangrove forests as the results are below the limit values. These results can be explained through a combination of two factors: sampling timing and tidal and river current. In this case, the samples were specifically taken during high tide. High tide leads to a substantial inflow of seawater into the mangrove area, which, in turn, acts as a natural dilution factor. Moreover, there is a dominant alongshore tidal and river current in the south direction, as seen in figure 5.11. These conditions play a pivotal role in dispersing the oil contamination in the opposite direction of mangrove area B.

Local community

In conclusion, the local community in Do Son show different levels of awareness regarding the Masterplan with residents in areas A1 and A2 being better informed through government channels. A notable correlation emerges, indicating that government provided information directly influences community awareness. Despite this awareness, the community predominantly expresses a positive attitude toward the proposed plans, primarily motivated by anticipated economic benefits, such as increased tourism and improved livelihoods. Concerning willingness to participate, there is a strong tendency among participants, especially in areas A1 and A2, to embrace the proposed changes, driven by potential positive economic outcomes. However, not everyone is willing to switch jobs, particularly if it entails the potential disappearance of the mangroves. Those that are willing to switch show a high willingness to pay for mangrove conservation, emphasising the perceived value of these ecosystems. Notably, those aware of receiving financial compensation express less willingness to sacrifice part of their income for conservation efforts, highlighting the influence of governmental support on community perspectives.

Expected implications associated with the Masterplan

With the completion of the Masterplan, it is evident that hydraulic, environmental and socio-economic changes will occur. In this chapter, an insight is given in the mechanism which drive the change.

Mangrove area A

For mangrove area A, the hydraulic system will be changed considerably. With the construction of port 1, the tidal currents are disrupted, mainly the ebb current during the wet season. It could be said that no sediment supply will be present after the completion of the port. However, it was found that sufficient sediment could be supplied by the tidal prism.

The order of magnitudes are calculated for the amount of sediment transported by the tidal current, for the amount of sediment that could settle in the mini estuary, and for the amount of sediment that is available in the system. In addition, since port 1 will now shelter the mini estuary from the south, large waves will not reach the mangrove area. Only the diffracted, and thus smaller waves will reach the mangroves. These waves are believed to cause an onshore sediment transport. Moreover, the reclamation of Dragon Hill will offer better protection to mangrove area A by blocking incoming waves. This improved sheltering effect is anticipated to have a positive impact on sediment settling. These calculations support the fact that although the Van Uc river sediment supply is distorted, sedimentation will occur. The rate of sedimentation is unknown, as more factors come into play. This would include typhoons, dredging works, and the rainwater outlets.

With regards to the water quality of the mangroves in area A, it is reasonable to anticipate that these values will continue to exceed the limit values in the future as the Masterplan is further implemented, mainly because of inadequate wastewater treatment in Vietnam. Additionally, the impact of residential areas in close proximity to the mangroves is evident, as indicated by elevated ammonia levels in the water quality samples of area A. Given the current development of residential buildings on Dragon Hill as part of the Masterplan, it is anticipated that this will further degrade the water quality. It is concerning to learn that a significant part of mangrove forest A will disappear due to the construction of port 1. Mangroves are essential ecosystems that provide numerous ecological and environmental benefits, including acting as natural water filters. They help improve water quality by trapping and removing contaminants, sediments, and pollutants from the water. It is expected that the destruction of the mangroves can lead to a further deterioration in water quality. To mitigate the negative effects on water quality and the environment, it’s essential to conduct comprehensive environmental impact assessments to understand the full extent of the project’s consequences.

Mangrove area B

With the construction of port 2, it is concluded that only the incoming waves at area B are subject to change. Just like the Lach Tray river current and sediment supply, the tide current and sediment supply will be negligibly influenced by the construction of port terminal 2. However, the incoming waves will have a smaller fetch, resulting in smaller waves reaching the shoreline. As the large wave are no longer present, less erosion will occur. However, as the tidal current remain unchanged, the flow velocities will still be too high for sedimentation.

These conditions play a crucial role in complying with the requirements of the Vietnamese Forestry Law. As the current plans suggest an expansion of area B three times to its current size as part of the legal reafforestation. However, the hydraulic conditions indicate that this would not be feasible.

With regards to the increased port activities associated with the Masterplan, the current and the location of the quay of terminal P2, are of importance. Given that the quay is situated on the opposite side of the mangroves, namely the eastern side, and considering that the predominant southward current flows primarily seawards, the potential rise in oil levels within the water of the mangroves is expected to be minimal.

However, as the Masterplan also encompasses the modernisation of the existing Ngoc Hai fishing port, it is foreseeable that the water quality in mangrove area B will deteriorate further, as current water samples have already exceeded the established limit values for Marine Water Quality.

Furthermore, in the context of plastic pollution, it can reasonably be anticipated that the expansion of the Ngoc Hai fishing port, coupled with the establishment of the newly constructed port, will lead to an increase in plastic pollution within the mangroves of area B. This escalation poses a significant threat to the health of the mangroves, as such pollution can suffocate their roots.

Local community

The impacts that the Masterplan has on the mangrove ecosystems as described above manifests itself in an effect on the local community. From section 6 it can be concluded that the community's attitude towards the Masterplan depends on their level of awareness, economic considerations, and the perceived benefits associated with the new plans. When people are better informed about the plans, they are more likely to believe the new plans will enhance their economic situation, thus resulting in a positive attitude towards the Masterplan.

6.0.1. Recommendations

As the water quality samples showed elevated ammonia levels, most often associated with pollution from sewage and wastewater, it is strongly recommended to treat wastewater associated with the construction activities of the Masterplan at the source. As the sewerage system in Vietnam is not yet completed or appropriate at many places, the water should be treated directly in order to prevent further deterioration of the water quality in the mangroves (V. Nguyen, 2023, October 2). Moreover, incorporating plastic waste management regulations and services in the Masterplan is vital to mitigate the risk of additional plastic waste accumulation in the mangroves, as a result of future expansions in fishing and tourism in Ngoc Hai, along with the establishment of the newly constructed port.

Additionally, the Masterplan's inclusion of mangrove preservation and reafforestation requires revision due to challenges posed by hydraulic conditions in area B. The current proposal, which envisions the expansion of the mangrove forest in area B, is hindered by insufficient settlement of sediment in this region. It is essential to revise these plans in order to align with the requirements stipulated in the Vietnamese Forestry Law. Moreover, it seems that key environmental stakeholders, such as the JRC and VRCS, from previous mangrove plantation programmes, were not involved in the design of the Masterplan. Given that the current design includes the deforestation of part of the mangroves planted in these previous programs, it is essential to involve them in the decision-making process to prevent potential conflicts.

In terms of the hydraulic considerations, it is recommended to improve both breakwaters at Ngoc Hai. For the Northern breakwater, it is advised to repair the holes and the sheared parts. Regarding the Southern breakwater it is advised to increase the rock classes and use bigger tetrapods. To protect the port entrance from (high) waves during high tide and the potential of sea level rise it is also advised to increase the height of the Southern breakwater.

7 Discussion

As previously mentioned in chapter 5, modifications were necessary for both the selection of water quality sampling locations and the total sample size due to unforeseen circumstances, including interference from local authorities and the availability of the dependency on local fishermen. These unanticipated limitations precluded the collection of samples from areas deeper within the mangroves, particularly beyond the vicinity of Dragon Hill.

To address this data gap and enhance future studies' comprehensiveness, it is strongly advised that periodic water quality monitoring initiatives be established in and near the mangrove areas. Expanding the scope of the study and accounting for variations in tidal patterns can mitigate the impact of tides on water quality data. This approach will yield a more comprehensive and reliable understanding of the environmental dynamics in the mangroves of Do Son. Moreover, these observations can be used for evidence-based decision-making and the implementation of necessary measures to rectify the concerning deviations from water quality standards and preserve the health of the mangroves.

One of the major limitations in the calculations was primarily the coarseness of the assumptions, the one-dimensional models, and the incomplete data. In order to make the calculations, simplification was done on multiple important factors. This mainly includes the sediment size, the available sediment volume that settles, and the flow velocities of the whole area. It is advised to further investigate these parameters, as well as the bathymetry. Using this new information, a three-dimensional model can be set up. In addition to this research, it might be interesting for following-up groups to investigate the impact of sea level rise, the development of subsidence, the improvement of the current hydraulic structures and the use of permeable hydraulic structures in the future. This was not incorporated in the scope of this project.

One of the factors that may have influenced the accuracy of the results from the semi-structured interviews is the size of the study group. Only 13 people took part in this study. A larger research group would reflect reality even better, making the results more reliable. In this study, the size of the research group was limited by two factors: the limited time for the field study, where the interviews were conducted, and frequent delays in the interviews. These delays were partly due to local authorities stopping the progress of some interviews or preventing some interviews from taking place. In order to obtain more presentable results, more time is needed for the field trip and documents that give permissions for retrieving certain interviews should be arranged in advance, reducing delays in the progress of conducting the interviews.

A second factor that may have affected the results is the language barrier between the researchers and the participants. Despite the fact that a translator was always present during the interviews, a lot of information was lost that was said during the interviews but not received by the researchers. This lost information could perhaps be valuable in gaining an even better understanding of the reasoning behind certain decisions made.

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A
Research approach

A.1. Research plan schematisation

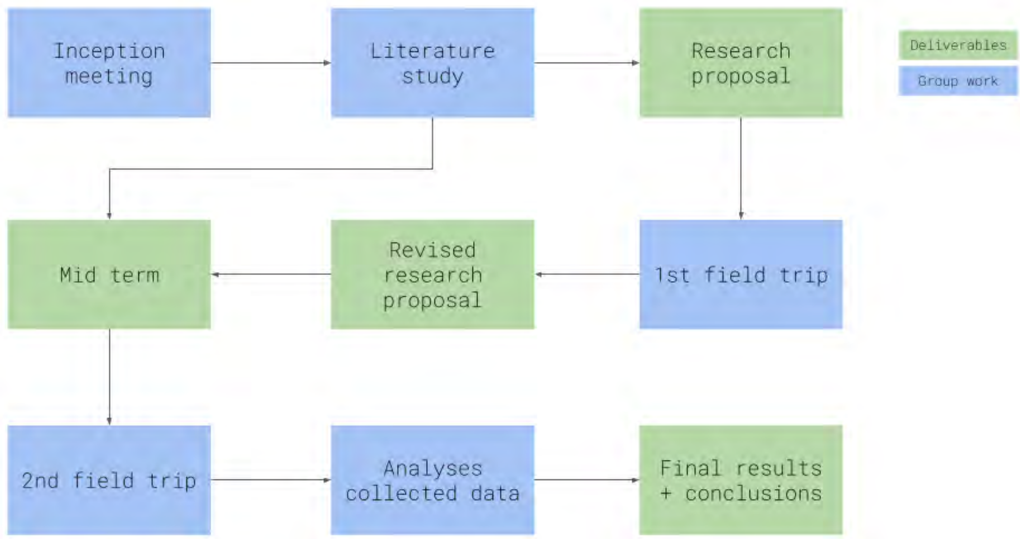

Figure A.1: Schematisation research plan

A.2. Task division

Table A.1: Distribution of the workload

Focus area	Student Name(s)
Environmental impact	Donna Janssen, Lisa Smulders
Hydraulic impact	Pepijn Prins, Berend Krans
Socio-economic impact	Stijn Lagerwey, Hannah Kapper

B

Python codes

B.0.1. Source Code Water Level

```
## Loading the data from CSV files
data_1 = pd.read_csv('Water_level_1.csv', sep=';', index_col=0, skiprows=[1])
data_2 = pd.read_csv('Water_level_2.csv', sep=';', index_col=0, skiprows=[1])
data_3 = pd.read_csv('Water_level_3.csv', sep=';', index_col=0, skiprows=[1])
data_4 = pd.read_csv('Water_level_4.csv', sep=';', index_col=0, skiprows=[1])
data_5 = pd.read_csv('Water_level_5.csv', sep=';', index_col=0, skiprows=[1])
data_6 = pd.read_csv('Water_level_6.csv', sep=';', index_col=0, skiprows=[1, 32])
data_7 = pd.read_csv('Water_level_7.csv', sep=';', index_col=0, skiprows=[1])
data_8 = pd.read_csv('Water_level_8.csv', sep=';', index_col=0, skiprows=[1])
data_9 = pd.read_csv('Water_level_9.csv', sep=';', index_col=0, skiprows=[1, 32])
data_10 = pd.read_csv('Water_level_10.csv', sep=';', index_col=0, skiprows=[1])
data_11 = pd.read_csv('Water_level_11.csv', sep=';', index_col=0, skiprows=[1, 32])
data_12 = pd.read_csv('Water_level_12.csv', sep=';', index_col=0, skiprows=[1])

## Filtering the data
data_1_adjusted = data_1.iloc[:, :-1]
data_2_adjusted = data_2.iloc[:, :-1]
data_3_adjusted = data_3.iloc[:, :-1]
data_4_adjusted = data_4.iloc[:, :-1]
data_5_adjusted = data_5.iloc[:, :-1]
data_6_adjusted = data_6.iloc[:, :-1]
data_7_adjusted = data_7.iloc[:, :-1]
data_8_adjusted = data_8.iloc[:, :-1]
data_9_adjusted = data_9.iloc[:, :-1]
data_10_adjusted = data_10.iloc[:, :-1]
data_11_adjusted = data_11.iloc[:, :-1]
data_12_adjusted = data_12.iloc[:, :-1]

## Converting the data from CSV file to an array for analysis
y_1 = pd.concat([data_1_adjusted.iloc[i] for i in range(len(data_1_adjusted))], axis=0)
    ## winter
y_2 = pd.concat([data_2_adjusted.iloc[i] for i in range(len(data_2_adjusted))], axis=0)
    ## winter
y_3 = pd.concat([data_3_adjusted.iloc[i] for i in range(len(data_3_adjusted))], axis=0)
    ## winter
y_4 = pd.concat([data_4_adjusted.iloc[i] for i in range(len(data_4_adjusted))], axis=0)
    ## winter
y_5 = pd.concat([data_5_adjusted.iloc[i] for i in range(len(data_5_adjusted))], axis=0)
    ## summer
y_6 = pd.concat([data_6_adjusted.iloc[i] for i in range(len(data_6_adjusted))], axis=0)
    ## summer
y_7 = pd.concat([data_7_adjusted.iloc[i] for i in range(len(data_7_adjusted))], axis=0)
    ## summer
y_8 = pd.concat([data_8_adjusted.iloc[i] for i in range(len(data_8_adjusted))], axis=0)
    ## summer
y_9 = pd.concat([data_9_adjusted.iloc[i] for i in range(len(data_9_adjusted))], axis=0)
    ## summer
y_10 = pd.concat([data_10_adjusted.iloc[i] for i in range(len(data_10_adjusted))], axis=0)
    ## summer
y_11 = pd.concat([data_11_adjusted.iloc[i] for i in range(len(data_11_adjusted))], axis=0)
    ## winter
```

```
y_12 = pd.concat([data_12_adjusted.iloc[i] for i in range(len(data_12_adjusted))], axis=0)    ## winter

## Clustering all data, summer data, and winter data
y_total = pd.concat([y_1, y_2, y_3, y_4, y_5, y_6, y_7, y_8, y_9, y_10, y_11, y_12], axis=0)
y_summer = pd.concat([y_5, y_6, y_7, y_8, y_9, y_10], axis=0)
y_winter = pd.concat([y_1, y_2, y_3, y_4, y_11, y_12], axis=0)
```

```
x_axis = np.arange(0, len(y_total), 1)
x_tick_positions = np.linspace(0, 8759, 12)
x_tick_labels = ['Jan', 'Feb', 'Mar', 'Apr', 'May', 'Jun', 'Jul', 'Aug', 'Sep', 'Oct', 'Nov', 'Dec']
days = 365
minimum_year = np.zeros(days)
maximum_year = np.zeros(days)

## Calculating the mimimum and maximum per day for the whole year:
for i in range(365):
    j = i * 24
    k = j + 24
    minimum_year[i] = np.min(y_total[j:k])
    maximum_year[i] = np.max(y_total[j:k])

## Calculating the mean tidal range and the Mean Lower Low Tide:
TR = np.mean(maximum_year) - np.mean(minimum_year)
MLL_tide = np.mean(minimum_year)
print(f'The Mean Lower Low Tide is: {MLL_tide:.2f} cm')
print(f'Tidal range: {TR:.2f} cm')
```

```
def inundation(data, TR, MLL_tide, plot, duration, WaterLevel):
    ## transform the data to be plotted per day and calculate the mean, minimum and, maximum water level
    ## Plotting the tidal level, mangrove level and bed level in one graph per month
    ## Returning percentage of inundation, the maximum tidal prism, and the number of times the mangroves are inundated
    if duration == 'year':
        y_inundation = data
    else:
        y_inundation = pd.concat([data.iloc[i] for i in range(len(data))], axis=0)

    mean = np.mean(y_inundation)
    minimum = np.zeros(len(data))
    maximum = np.max(y_inundation)

    for i in range(len(data)):
        minimum[i] = (np.min(data.iloc[i]))

    bed_level_Hon_Dau = MLL_tide - 60
    area = 27760095 #m2
    formatted_area = '{:,}'.format(area)
    tidal_range = (maximum - mean) / 100
    TR = TR / 100
    tidal_prism_mean = round(area * TR , 2)
    tidal_prism_max = round(area * tidal_range, 2)
    formatted_tidal_prism_mean = '{:,}'.format(tidal_prism_mean)
    formatted_tidal_prism_max = '{:,}'.format(tidal_prism_max)

    length = len(y_inundation)
    x1 = np.arange(1, length+1, 1)
    x_ticks_positions = np.linspace(0, length, 32)
    x_ticks = np.arange (0, 32, 1)

    count = 0
    mangrove_threshold = MLL_tide + WaterLevel
    for i in range(length):          ## Counting the hours that the waterlevel is higher than the mangrove bed
        if (y_inundation[i]) >= mangrove_threshold:
            count += 1

    crossings = 0
```

```python
    for i in range(1, length):      ## Counting the number of times the mangroves are inundated
        if y_inundation[i-1] < mangrove_threshold and y_inundation[i] >= mangrove_threshold:
            crossings += 1

    per_inun = (count / length) * 100

    ## Plotting all necessary features in figure
    if plot == True:
        print(f'Percentage␣inundation:␣{per_inun:.2f}␣%')
        print(f'Mean␣level␣of␣tidal␣range:␣{MLL_tide:.2f}␣cm')
        print(f'Mean␣tidal␣range␣of␣{TR:.2f}␣m␣')
        print(f'Maximum␣level␣of␣tidal␣range:␣{maximum:.2f}␣cm')
        print(f'Maximum␣tidal␣range␣of␣{tidal_range:.2f}␣m␣with␣an␣area␣of␣{formatted_area}␣m2')
        print(f'Mean␣tidal␣prism␣=␣{formatted_tidal_prism_mean}␣m^3␣per␣tidal␣cycle')
        print(f'Maximum␣tidal␣prism␣=␣{formatted_tidal_prism_max}␣m^3␣per␣spring␣tidal␣cycle')
        print(f'Bed␣level␣is␣at:␣{bed_level_Hon_Dau:.2f}␣cm')

        plt.figure(figsize=(15,8))
        plt.title(f'Tidal␣regime␣Hon␣Dau␣{duration}', fontsize=20)
        plt.xlabel('Days')
        plt.ylabel('Waterlevel␣in␣cm')
        plt.xticks(x_ticks_positions, x_ticks)

        plt.hlines(bed_level_Hon_Dau, 0, length, color='brown', linewidth=4 ,
                   label=f'Don␣Hau␣bed␣level␣=␣{bed_level_Hon_Dau:.2f}␣cm')
        plt.hlines(MLL_tide, 0, length, 'y', linewidth=4,
                   label=f'Mean␣lower␣low␣tide␣=␣{MLL_tide:.2f}␣cm')
        plt.hlines(mean, 0, length, 'orange', linestyles='-.', linewidth=4,
                   label=f'Mean␣water␣level␣=␣{mean:.2f}␣cm')
        plt.plot(x1, y_inundation, label='Water␣level␣heigth')
        plt.hlines(mangrove_threshold, 0, length, 'g', linewidth=4, linestyle='dotted',
                   label=f'Mangroves␣=␣{mangrove_threshold:.2f}␣cm')
        plt.hlines(y=MLL_tide +[30,60,90,120], xmin=0, xmax=length, colors='g', linewidth=4,
                   linestyle='dotted', label=f'Mangrove␣bed␣levels␣above␣MLL␣tide')
        plt.ylim(0, 400)
        plt.legend(loc = 'upper␣right')
        plt.grid()
        print(np.max(data));
    if plot == False:
        return per_inun, crossings, tidal_prism_mean
    return per_inun, crossings, tidal_prism_mean
```

```python
## Calculating the different inundation periods and frequency for different height of mangrove bed levels:
WL = [0, 30, 60, 90, 120]

ja = np.zeros((2, len(WL)))
fe = np.zeros((2, len(WL)))
ma = np.zeros((2, len(WL)))
ap = np.zeros((2, len(WL)))
my = np.zeros((2, len(WL)))
jn = np.zeros((2, len(WL)))
jl = np.zeros((2, len(WL)))
au = np.zeros((2, len(WL)))
se = np.zeros((2, len(WL)))
oc = np.zeros((2, len(WL)))
no = np.zeros((2, len(WL)))
de = np.zeros((2, len(WL)))

for index, i in enumerate(WL):
    for j in range(2):
        ja[j, index] = inundation(data_1_adjusted, TR, MLL_tide, False, 'January', i)[j]
        fe[j, index] = inundation(data_2_adjusted, TR, MLL_tide, False, 'February', i)[j]
        ma[j, index] = inundation(data_3_adjusted, TR, MLL_tide, False, 'March', i)[j]
        ap[j, index] = inundation(data_4_adjusted, TR, MLL_tide, False, 'April', i)[j]
        my[j, index] = inundation(data_5_adjusted, TR, MLL_tide, False, 'May', i)[j]
        jn[j, index] = inundation(data_6_adjusted, TR, MLL_tide, False, 'June', i)[j]
        jl[j, index] = inundation(data_7_adjusted, TR, MLL_tide, False, 'July', i)[j]
```

```
        au[j, index] = inundation(data_8_adjusted, TR, MLL_tide, False, 'August', i)[j]
        se[j, index] = inundation(data_9_adjusted, TR, MLL_tide, False, 'September', i)[j]
        oc[j, index] = inundation(data_10_adjusted, TR, MLL_tide, False, 'October', i)[j]
        no[j, index] = inundation(data_11_adjusted, TR, MLL_tide, False, 'November', i)[j]
        de[j, index] = inundation(data_12_adjusted, TR, MLL_tide, False, 'December', i)[j]
```

```
df_inundation = pd.DataFrame(np.concatenate([ja, fe, ma, ap, my, jn, jl, au, se, oc, no, de], axis=0))
x_tick_labels = ['Jan␣%', 'Jan␣#', 'Feb␣%', 'Feb␣#', 'Mar␣%', 'Mar␣#', 'Apr␣%', 'Apr␣#',
                 'May␣%', 'May␣#', 'Jun␣%', 'Jun␣#', 'Jul␣%', 'Jul␣#', 'Aug␣%', 'Aug␣#',
                 'Sep␣%', 'Sep␣#', 'Oct␣%', 'Oct␣#', 'Nov␣%', 'Nov␣#', 'Dec␣%', 'Dec␣#']
df_inundation.index = x_tick_labels
df_inundation.columns = ['0␣cm', '30␣cm', '60␣cm', '90␣cm', '120␣cm']
df_inundation = df_inundation.round(2)
```

```
def toricelli(h_1):
    ## Function to calculate the discharge of the river, depending on the water level:
    h_1 = h_1 / 100
    h_0 = 210 / 100
    dh = h_0 - h_1
    g = 9.81
    B = 4.5
    a_0 = B * h_0
    a_1 = B * h_1
    v_1 = np.sqrt((2 * g**2 * dh) / (1 - (a_1/a_0)**2))
    Q_1 = v_1 * B * h_1
    return Q_1

lower_limit = np.mean(minimum_year)
index_ans = [index for index, value in enumerate(y_total) if value < 210 and value > lower_limit]
value_ans = [value for index, value in enumerate(y_total) if value < 210 and value > lower_limit]

Q_river = np.zeros(len(index_ans))

## Loopt through each water level value for each hour the water level is within the range of influence on the tidal prism:
for i in range(len(index_ans)):
    Q_river[i] = toricelli(value_ans[i]) * 60 * 60

## Converting from discharge per year to per day:
Q_river_total = np.sum(Q_river) / 365
```

B.0.2. Source Code Wave Roses

```
from windrose import WindroseAxes
import numpy as np
import pandas as pd
import datetime

def dataframe(file, year):

    a_list = np.arange(1, 78)
    remove_idx = [12, 25, 38, 51, 64]
    columns_list = np.delete(a_list, remove_idx)

    # Load wave data from Excel file
    year = year

    df2 = pd.read_excel(f"{file}", usecols=columns_list, skiprows=5, sheet_name=str(year))
    df2 = df2.iloc[:-3]

    # Split the DataFrame into two separate DataFrames
    df2_1 = df2.iloc[:, ::2].copy()
    df2_2 = df2.iloc[:, 1::2].copy()

    # Concatenate the two split DataFrames vertically
    long_column = df2_1.unstack().reset_index(drop=True).to_frame()
    long_column2 = df2_2.unstack().reset_index(drop=True).to_frame()
```

```

    # Create a DataFrame with a date range for the entire year
    start_date = f"{year}-01-01 00:00:00"
    end_date = f"{year}-12-31 23:59:59"
    date_range = pd.date_range(start=start_date, end=end_date, freq="8H")
    months = pd.DataFrame({'Month': date_range.month})

    # Concatenate long_column and long_column2 horizontally to create df_merged
    df_merged = pd.concat([long_column, long_column2, months], axis=1)

    # Rename the columns
    df_merged.columns = ['direction', 'height', 'month']

    # Change directions to degrees
    df_merged = df_merged.replace({'N': 0, 'NE': 45, 'E': 90,'SE': 135, 'S': 180, 'SW': 225, 'W': 270, 'NW': 315,\
                              'E/NE': 67.5, 'SE/S': 157.5, 'SE/E': 112.5,'NE/E': 67.5, 'SE/NE': 90, 'SE/N': 225,\
                              'E/N': 45, 'S/SE': 157.5, 'E/SE': 112.5, 'S/E': 135, 'S/SW': 202.5, '0,54':0.54,\
                              '0,45': 0.45, 'NE/N': 22.5, 'SE/SW': 180, 'ENE': 67.5})

    # Drop NaN values, Max ưốHng, Ngày are dropped because empty cells
    df_merged = df_merged.dropna()
    df_merged = df_merged.drop(df_merged[df_merged['direction'] == '-'].index)
    df_merged = df_merged.drop(df_merged[df_merged['height'] == '-'].index)


    # Addressing winter and summer seasons
    df_merged['month'] = df_merged['month'].astype(int)
    df_merged['height'] = df_merged['height'].astype(float)

    return df_merged
```

In the following code, change the file-name and the area description to compute wave roses for Bach Long.

```
file = "wave-data-hon-dau-2002-2022.xlsx"
area = "Hon Dau"
bins = (0, 0.5, 0.75, 1.0, 1.5)

df = pd.DataFrame()
period = np.arange(2018, 2023)

for i in period:
    data = dataframe(file, i)
    df = pd.concat([df, data], axis=0)

df_summer = df[(df['month'] > 4) & (df['month'] < 11)]
df_winter = pd.concat([df[df['month'] < 5], df[df['month'] > 10]])
```

Plotting part:

```
ax = WindroseAxes.from_ax()
ax.bar(df.direction, df.height, normed=True, bins=bins, opening=0.8, edgecolor="white")
ax.set_legend(prop = { "size": 20 }, decimal_places=2)
ax.set_title(f'Wave rose {area} {period.min()} - {period.max()}');
```

```
ax = WindroseAxes.from_ax()
ax.bar(df_summer.direction, df_summer.height, normed=True, bins=bins, opening=0.8, edgecolor=
    "white")
ax.set_legend(prop = { "size": 20 }, decimal_places=2)
ax.set_title(f'Wave rose {area} SUMMER {period.min()} - {period.max()}');
```

```
ax = WindroseAxes.from_ax()
ax.bar(df_winter.direction, df_winter.height, normed=True, bins=bins, opening=0.8, edgecolor=
    "white")
ax.set_legend(prop = { "size": 20 }, decimal_places=2)
ax.set_title(f'Wave rose {area} WINTER {period.min()} - {period.max()}');
```

```python
import matplotlib.pyplot as plt

ax.bar(df.direction, df.height, normed=True, nsector=16, bins=bins)
table = ax._info["table"]

direction = ax._info["dir"]
wd_freq = np.sum(table, axis=0)

plt.bar(np.arange(16), wd_freq, align="center")
xlabels = (
    "N",
    "",
    "N-E",
    "",
    "E",
    "",
    "S-E",
    "",
    "S",
    "",
    "S-O",
    "",
    "O",
    "",
    "N-O",
    "",
)
xticks = np.arange(16)
plt.gca().set_xticks(xticks)
plt.gca().set_xticklabels(xlabels)
plt.xlabel('Wave Direction')
plt.ylabel('% of occurance')

formatted_table = [f'{number:.2f}' for number in wd_freq]

print(formatted_table)
```

```python
### Significant Wave Height

sorted_df = df.sort_values(by='height', ascending=False)

# Step 3: Calculate the index at which the 1/3 mark falls
one_third = len(sorted_df) // 3

# Step 4: Slice the dataframe to obtain the highest 1/3 of the data
highest_one_third = sorted_df.head(one_third)

# Print the result
print(f"The significant wave height for {area}: H_1/3 = {highest_one_third.height.mean():.2f}
    m")
```

C

Breakwater types

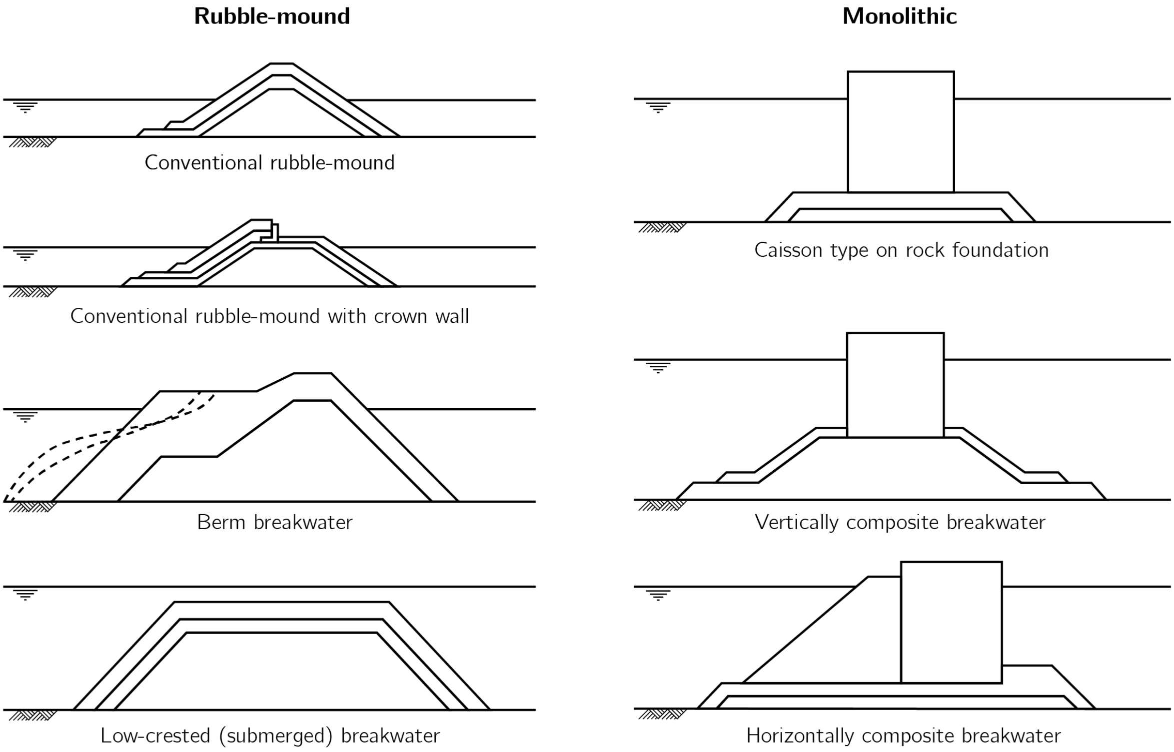

Figure C.1: Cross section of various types of breakwaters, Rubble mound types on the left and the monolithic types on the right. Redrawn from (Research & Information Association, 2007).

D

Inundation classes mangroves

Please have a look at the table on the next page.

Table 2 Mangrove flora and distribution in Vietnam (only true mangrove species listed)

Scientific name	**life form**	**inun-dation class**	**soil and position**	**Zone**			
				I	II	III	IV
ACANTHACEAE							
Acanthus ebracteatus	US	4-5	Loam, clay on river banks	+	+	+	+
A. ilicifolius	US	4-5	Loam, slit-clay with fine sand on river banks and estuaries	+	+	+	+
AVICENNIACEAE							
Avicennia alba	T	1-2	Deep mud, sea-face, river banks				+
A. lanata	T	2-3	Sandy mud			+	+
A. marina	T/ST	1-4	Deep sandy mud, sea face	+	+	+	+
A. officinalis	T/ST	2-4	Loam clay on river banks on degraded soil			+	+
BIGNONIACEAE							
Dolichandrone spathacea	T	4-5	Loam clay on river bank				+
COMBRETACEAE							
Lumnitzetra littorea	T	4-5	Loam firm mud, river banks			+	+
L. racemosa	T/ST	4-5	Clay, sandy loam, firm mud on river banks	+	+	+	+
EUPHORBIACEAE							
Excoecaria agallocha	ST/T	4-5	Clay, firm mud on river banks	+	+	+	+
MELIACEAE							
Xylocarpus granatum	T	2,3-5	Stiff mud on river banks, loam	+	+	+	+
X. moluccensis	T	4-5	Clay, river banks			+	+
MYRSINACEAE							
Aegiceras corniculatum	S	1-2-4	wet, sandy mud, sea face	+	+	+	+
A. floridum	ST	2				+	
PALMAE							
Nypa fructicans	P	3-5	River bank, low brackish water			+	+
Phoenix paludosa	P	5	Clay/loam, firm mud, degenerated soil			+	+
RHIZOPHORACEAE							
Brugiera gymnorrhiza	T	3-4	Loam, sandy mud, foot of limestone	+	+	+	+
B cylindrica	T	3-4	Firm mud, not far from sea				+
B. parviflora	T	2-3	Soft mud, along river banks				+
B. sexangula	T	3-4	Loam, river banks				+
Ceriops decandra	S/ST	3-5	Firm mud, river banks, land fringe				+
C. tagal		3-4	Quite firm mud, under Rhizo canopy			+	+
Kandelia candel	T/ST	2-4	Loam, sandy mud, river banks	+	+	+	+
Rhizhophora apiculata	T	2-4	Deep soft mud, river banks			+	+
R. mucronata	T	1-4	Deep soft mud, river banks, sandy mud			+	+
R. stylosa	T	2-4	Sandy shore, sandy mud & firm mud on river bank	+	+	+	+
RUBIACEAE							
Schyphiphora hydrophyllacea	ST	4-5	Sandy mud, river banks & clearings	+		+	+
SONNERATIACEAE							
Sonneratia alba	T	1-3	Deep soft mud, sea face			+	+
S. caseolaris	T	1-4	Soft sandy mud, river banks, estuary	+	+	+	+
S. ovata	T	4-5	Soft mud, salt water, islands				+
STERCULACEAE							
Heritiera litoralis	T	4-5	Sandy loam, river banks	+			+

Key life forms: T = tree; S Shrub; ST = Shrubby Tree. Source: (Hong & San 1993)

Inundation class:
1 = land flooded by all high tides
2 = land flooded by medium high tides
3 = land flooded my normal high tides
4 = land flooded by spring tides only
5 = land flooded by normal or equinoctial tides

Zones:
I = Northeast coast
II = North plain coast
III = Central coast
IV = South plain coast

E
Laboratory analysis water samples

In collaboration with the assistant of the laboratory at Thuy Loi University, Chị Liên, the water samples were analysed. In total 11 water samples were taken from the mangrove forests in Do Son. 3 of those were tested on oil containment at the ... institute and for the other XX samples analyses are performed to determine the pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia and total suspended solids (TSS) level of the water samples. As the samples were stored on ice in a cool box, the temperature of the samples was first increased to room temperature before starting the analysis.

Figure E.1: Performing laboratory analysis with Chị Liên

TSS

The sample analyses started with measuring the TSS. For this analysis the Hach DR 3900 and method 360-Hach-USA was used. This method of determining suspended solids is a simple, direct measurement which does not require the filtration or ignition/weighing steps. The test results as mg/L total suspended solids.

pH

pH is a measure of hydrogen ion concentration. pH is defined as the negative logarithm of the concentration of hydrogen ions in a substance, in moles per litre. To determine the pH of the samples, the OHAUS Starter 5000 pH meter was used.

BOD

The BOD value mainly represents the content of organic substances that are easily bio-transformed in wastewater. BOD is determined using the OxiTop method. The test results as mg/L, representing the amount of dissolved oxygen (DO) consumed by biological organisms when they decompose organic matter in water.

COD

The COD test is used widely to estimate the amount of organic matter in wastewater. The COD was measured using a Hach 45600-00 COD reactor following the method 8000-Hach-USA. The test results as mg/L, presenting the amount of oxygen consumed when the water sample is chemically oxidised.

NH_4+

Ammonia, NH_4+, is measured following the method 8038-Hach-USA.

Oil

For the oil measuring, the samples were analysed at the The Quality Assurance and Testing Center 1 in Hanoi. This was done because the laboratory of Thuy Loi did not have the resources itself to conduct the analysis. The analysis is conducted according to the standard method 5520 B: Partition-Gravimetric Method. Whereby dissolved or emulsified oil and grease is extracted from water by intimate contact with an extracting solvent.

F

Interviews

F.1. Transcript interview Pham Thi Nham

Deputy Director General at Vietnam Institute for Urban and Rural Planning (VIUP)

Date interview: 02-10-2023

Can you take us back to the beginning of this project, how did it start? Who was the client? And what were the initial parties involved?

Do Son used to be a very touristy area, but due to the development of other tourist areas in Vietnam Do Son became less attractive to tourists. With the new plans, we aim to make the area attractive for tourists again.

What was the role of VIUP in this process?

For the Masterplan of the province, VIUP needs to work with the local level of the Department of Construction, the province and the municipality. We work in terms of the urban development. My job was to design the actual plans, as the architect.

Do you have any documents or visuals that you can show us about the development of the plans in Do Son?

I can show you some old plans we designed. Here you can see that the Do Son port (P1) is almost 3 to 4 times smaller than they are now in the finalised plans. When we first designed this the government of Vietnam required that this port should be bigger, so we changed it.

With P1 becoming so much larger than initially designed, does the river on the left of the port need to be dredged?

No, the river does not need to be dredged. It is wide and deep enough for the traffic that will go through.

What is the name of the other port? And do they function together, or are they two separate ports?

P1 is named the Do Son port. P2 is the Le Quet port. They are two separate ports, but they are both used as cargo transportation ports.

Can you walk us through the plans of Do Son?

As the goal is to make Do Son a touristic destination again, the plans of Dragon Hill were introduced for Do Son, next to the Do Son port.

What is the destination plan for all the newly build houses on Dragon Hill?

These are both hotels for tourists and houses for new residents.

And in the plan it also says that you will turn the fishery port of Ngoi Hai into a tourist port? Can you explain how this will look like? Will the port be expanded? Will you have to dredge near the fishery port for this plan?

The local residents already use the fishing port for the local fish market. In order to attract more tourists to the port the area needs to be modernised. This includes small dredging activities.

And what are the expected influences on the local economy by the implementation of these plans in Do Son? And how did you determine these effects? Will they be measured?

We want to attract more tourists and stimulate the economic development.

On some documents we see "nature preservation". How is nature preservation included in the Masterplan? And how are mangroves included/involved/accounted for in this project? Are there any mangrove restoration efforts included?

Because the new plans of Do Son will attract new residents and more tourists, the local authorities want to improve the quality of the environment. They want to protect the environment from the water. One way they want to protect the environment is by building things like the two port terminals.

Does this take into account that one of the function of mangroves is that they act as natural coastal protectors?

The local government wants to keep the mangroves between the Do Son port and Dragon Hill area. But the local government is thinking about how to implement artificial security measures as well. For artificial measures, they need investors, so they are thinking about how to get those investors to invest, such as drawing up such plans as the new port.

On some documents we saw that the mangrove forest near Ngoc Hai will be 3 times its current size, how do you plan to accomplish this?

Some parts of the sea that are close to the mangrove areas are quite shallow. There is lot's of sand in these areas. New trees will be planted in the area next to mangrove area B. These plants are also planted in order to prevent the land behind it from flooding when there is a big storm coming from the sea.

What are the expected environmental effects of the execution of the plan? Effects such as on the water quality, biodiversity, health of mangroves etc?

As there is a potential violation of the environment of the area of Hai Phong, the local government tries to protect the area. They want to maintain and enlarge the mangroves and protect nature. They will do this together with the Department of environment and nature resources. They are specialised in maintaining the mangrove forests and they control and manage the area and the future plans. The department make sure there is a plan to manage and control the area to ensure nature preservation. But we don't know the plan ourselves.

How far along are you with the execution of the Masterplan? Do you have a planning we could see? When will you start with the construction of the ports?

The Masterplan is already finished. They are now executing it step by step. In 2050 the whole Masterplan will be finished.

Is there any data available for us to use for our research?

The government of Hai Phong will make actionplan within detail after the approval of the Masterplan. A useful contact to get the information in detail of the actionplan would be the Ministry of Agriculture and Rural Development.

F.2. Transcript interview Nguyen Viet Dung

Msc Director at Institute for Environmental Planning and Urban-Rural Infrastructure

Date interview: 02-10-2023

In what way will the construction of the port impact mangrove forest A?

I think mangrove forest A will disappear after the port in Do Son is build. There will be no sedimentation transport towards the mangroves anymore which they need to survive. I have already made an announcement about this with the government and the local authority, but they think the port is more *important. However, the mangrove on the left of terminal P1 will be conserved and play an important role in nature preservation.*

When you mentioned your concerns towards the government about the potential disappearing of mangrove forest A, did you also mention the impact this would have on the local community?

This is called a "Masterplan", so the level of concern is not on the local community. But the legal requirements oblige us to consult with the local communities for stakeholder involvement. But it is Masterplan, and it is a big one, so the time we have is very constrained. So, we are just concerned with the overall scale.

In some of the documents/maps of the Masterplan the term "Mangrove preservation" is included. How will this exactly be realised then?

That is just the view from an architect. But to be honest, from an environmentalist point of view, the mangroves will disappear. However, I don't think it will be that big of a problem. Since P1 will now serve as a coastal defence for the area behind the terminal instead of the mangroves.

If it is the case that mangrove forest A will disappear, do you think the local community will disadvantage from this? Such as fisheries for example? And what do you think this will do to the biodiversity?

No, I don't think so. They will just move their fishing activities to mangrove forest B. And for the biodiversity, maybe somehow. But the mangrove area on the left of terminal P1 is more important. This area is connected to the South and in the South we have Ramsar areas. Ramsar sites are classified under the Convention on Wetlands of International Importance. The mission of the Convention is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world".

Alright, thank you. And how do you think the construction of the port will influence mangrove forest B?

Mangrove forest B will not be impacted significantly by the building of the new port. Forest B will be ok.

How do you think that the construction activities on Dragon Hill will influence the water quality in the nearby area?

I think we need to treat wastewater at the source. This is the most important thing. Because in Vietnam, the sewerage system is not complete yet. We have some treatment facility, but the network is not appropriate. If this network would be complete and further developed sometime in the future, the environmental issues will be solved, I think.

However, for further details I think you should also talk to the Ministry of Agriculture and Rural Development in Hai Phong. Because they are responsible for the action plan of the Masterplan for Hai Phong and know a lot more about the details and the execution of the project. This is more of an integrated plan which involves many different perspectives, such as socio-economic and environmental.

F.3. Transcript interviews local community Do Son

F.3.1. Interviewee A

General questions

- Sex: female
- Age: 40
- Occupation: seafood merchant
- Monthly income: 10.000.00 VND (410 USD)
- Share of monthly income household: -
- Number of people in household: -
- Area: B

Statement 1 Strongly agree
I sell fish and shrimps that come from the mangroves, so I am strongly dependent.

Statement 2 Strongly agree
I won't be able to sell anything if the mangroves disappear as everything I sell comes from the mangroves, so I strongly agree.

Statement 3 Agree
If more tourists come to Do Son I will sell more fish, so I agree.

Statement 4 Strongly agree
I know that the mangrove forests protect the land from the sea when there is a storm.

Statement 5 Strongly agree
I know this because I sell many different things that come from the mangroves.

Statement 6 Strongly agree
I am one of these people, so yes, I know.

Statement 7 Strongly agree
If this means that I will eventually earn more money, then I strongly agree.

Statement 8 Strongly disagree
I would not do this.

Statement 9 Disagree
I know there is some pollution, but I don't know the effects of the pollution.

Statement 10 Agree
I know there have been some conservation projects.

Statement 11 Strongly disagree
I have no idea about the new plans for Do Son.

Statement 12 Strongly disagree
I have no idea about the plans, so I do not feel included.

Statement 13 Neutral
I don't know the plans, so I don't know.

Statement 14 Neutral
I don't know the plans, so I don't know.

Statement 15 Neutral
I don't know the plans, so I don't know.

Statement 16 Neutral
I don't know the plans, so I don't know.

Statement 17 Neutral
I don't know the plans, so I don't know.

F.3.2. Interviewee B

General questions

- Sex: male
- Age: 37
- Occupation: fisherman in mangroves
- Monthly income: 10.000.00 VND (410 USD)
- Share of monthly income household: 50%
- Number of people in household: 4
- Area: B

Statement 1 Strongly agree
I am a fisher in the mangroves, so I strongly depend on the mangroves.

Statement 2 Strongly agree
My income comes from selling the fish that I have caught, so when the mangroves disappear, my income will disappear as well.

Statement 3 Strongly agree
Yes, when there are more tourists in Do Son I will sell more fish, so I strongly agree with this.

Statement 4 Agree
I strongly agree with this.

Statement 5 Strongly agree
I fish in the mangroves, so I see a lot of the services the mangroves provide for the ecosystem there.

Statement 6 Strongly agree
I see a lot of fishers like me, that are dependent on the mangroves, so I strongly agree with this.

Statement 7 Strongly agree
I strongly agree with this.

Statement 8 Strongly disagree
No, I don't want the mangroves to disappear, so I would not switch jobs.

Statement 9 Neutral
I see pollution but do not know the effects.

Statement 10 Strongly disagree
No, I have no idea.

Statement 11 Strongly disagree
I have no idea about the new plans.

Statement 12 Strongly disagree
I don't know about any plans, so I do not feel included.

Statement 13 Neutral
I don't know the plans, so I don't know.

Statement 14 Neutral
I don't know the plans, so I don't know.

Statement 15 Neutral
I don't know the plans, so I don't know.

Statement 16 Neutral
I don't know the plans, so I don't know.

Statement 17 Neutral
I don't know the plans, so I don't know.

F.3.3. Interviewee C

General questions

- Sex: male
- Age: 47
- Occupation: owner restaurant
- Monthly income: -
- Share of monthly income household: 100%
- Number of people in household: 5
- Area: B

Statement 1 Strongly agree
Lots of the products I sell in my restaurant come from the mangroves, like the fish and the shrimps that are in the dishes.

Statement 2 Agree
My income will not disappear entirely, as I sell other things than fish as well, but it will indeed affect my income.

Statement 3 Strongly agree
I would really like to have more tourists in Do Son, so they will come and eat at my restaurant and I will earn more money.

Statement 4 Strongly agree
I know what the mangroves do for coastal defence.

Statement 5 Strongly agree
I know what the mangroves do for the ecosystems.

Statement 6 Strongly agree
I benefit from the mangroves, and I know that other restaurants and the fishers benefit from them as well, so I strongly agree.

Statement 7 Strongly agree
I strongly agree with this.

Statement 8 Disagree
I would not switch jobs.

Statement 9 Agree
I know the effects of pollution in the mangroves.

Statement 10 Agree
I know there have been some conservation projects of the mangroves in the past.

Statement 11 Strongly disagree
I don't know of any new plans for Do Son.

Statement 12 Strongly disagree
I don't know the plans, so I do not feel included.

Statement 13 Neutral
I don't know the plans, so I don't know.

Statement 14 Neutral
I don't know the plans, so I don't know.

Statement 15 Neutral
I don't know the plans, so I don't know.

Statement 16 Neutral
I don't know the plans, so I don't know.

Statement 17 Neutral
I don't know the plans, so I don't know.

F.3.4. Interviewee D

General questions

- Sex: male
- Age: 31
- Occupation: fisherman in mangroves
- Monthly income: 20.000.000 VND (820 USD)
- Share of monthly income household: 100%

- Number of people in household: 6
- Area: A

Statement 1 Agree
I fish in the mangroves, so I am dependent.

Statement 2 Agree
I sell my fish that I caught, so when the mangroves disappear, my income will disappear as well.

Statement 3 Neutral
I don't care about tourists.

Statement 4 Strongly agree
Yes, I am aware of this.

Statement 5 Strongly agree
Yes, I know the services the mangroves provide for the ecosystem.

Statement 6 Strongly agree
I, and other people I know, are economically depending on the mangroves, so I strongly agree.

Statement 7 Strongly agree
Yes, I would sacrifice a part of my income in order to conserve the mangroves.

Statement 8 Agree
I would switch jobs if it meant a higher income.

Statement 9 Disagree
I don't know the effects of pollution on the mangroves.

Statement 10 Strongly agree
I know there have been projects before.

Statement 11 Agree
I saw some information about new plans in the newspaper.

Statement 12 Strongly disagree
I do not feel included.

Statement 13 Neutral
I have no idea of the effects of the plans, so I don't know.

Statement 14 Neutral
I have no idea of the effects of the plans, so I don't know.

Statement 15 Agree
I think the mangroves will disappear. Someone told me about it and I looked it up on the internet, but I don't know if it is real or fake.

Statement 16 Neutral
I am not sure.

Statement 17 Neutral
I am not sure what the plans are, so I don't know what it will do to my economic situation.

F.3.5. Interviewee E

General questions

- Sex: male
- Age: -
- Occupation: fisherman in mangroves
- Monthly income: 20.000.000 VND (820 USD)
- Share of monthly income household: 100%

- Number of people in household: -
- Area: A

Statement 1 Strongly agree
I am a fisherman in the mangroves, so I am strongly dependent on the mangroves.

Statement 2 Agree
Yes, my income will disappear.

Statement 3 Agree
I want more tourism, because I want to sell more fish.

Statement 4 Strongly agree
Yes, I know this.

Statement 5 Strongly agree
I know the services the mangroves provide for the ecosystem.

Statement 6 Agree
I know that I and other fishers are economically dependent on the mangroves.

Statement 7 Neutral
I don't know if I would do this.

Statement 8 Neutral
I don't know what I would do.

Statement 9 Disagree
I don't know the effects of pollution.

Statement 10 Agree
Yes, i know there have been conservation projects in the past.

Statement 11 Agree
I saw some information about new plans in the newspaper.

Statement 12 Strongly disagree
Besides the bit of information in the newspaper I saw about that there are new plans, I don't know anything about the plans themselves, so I do not feel included.

Statement 13 Neutral
I have no idea of the effects of the plans, so I don't know.

Statement 14 Neutral
I have no idea of the effects of the plans, so I don't know.

Statement 15 Agree
I think the mangroves will disappear. Someone told me about it and I looked it up on the internet, but I don't know if it is real or fake.

Statement 16) Neutral
If the new plans cause the mangroves to disappear, I will have to find a new job, but I am not sure if this is the case, so I don't know.

Statement 17 Neutral
I am not sure what the plans are, so I don't know what it will do to my economic situation.

F.3.6. Interview F

General questions

- Sex: female
- Age: 50
- Occupation: seafood merchant
- Monthly income: 10.000.000 VND (410 USD)

- Share of monthly income household: 100%
- Number of people in household: 3
- Area: B

Statement 1 Agree
Fisherman catch fish in the mangrove forests. I buy this fish and sell it to my customers. This way I am dependent on the mangrove forest.

Statement 2 Agree
As the fisherman would not be able to catch fish anymore, I wouldn't be able to sell it to my customers.

Statement 3 Strongly agree
Two reasons; economic reason and cultural reason. I want more tourists in the Do Son Area as this would mean I can sell more fish to the people who visit Do Son. Besides that, I would like to show people how beautiful Do Son is. This way they would visit more and Do Son would become more popular.

Statement 4 Agree
I am aware that the mangrove forest protects us against storms and high water levels.

Statement 5 Strongly agree
I am aware that the mangrove forest protects us against storms and high water levels.

Statement 6 Agree
Yes, I am aware of the economic benefits for the local community due to the mangrove forest.

Statement 7 Neutral
Two sides. Yes I would like to preserve the mangrove forest as it is right now, but I also need to earn money to take care of my family.

Statement 8 Strongly agree
I love the mangroves and the fishery sector, I would never switch from a job even though it pays more money.

Statement 9 Neutral
No comments.

Statement 10 Strongly disagree
I have never heard of these projects.

Statement 11 Agree
I have heard of these projects but do not know the details.

Statement 12 Disagree
The Government never visited us to discuss the plans. We only heard information from the local community.

Statement 13 Agree
Attracting more tourists will increase stability within the Do Son Area and in the country. As I don't know the exact details I can only Agree. Perhaps if they elaborate more, I can give a more detailed answer.

Statement 14 Agree
I think the new plans will improve my quality of life. How much I don't know as I don't know details.

Statement 15 Agree
I think Government project always destroy part of the mangroves. Not everything, just a part.

Statement 16 Neutral
This I have no idea of.

Statement 17 Agree
Yes, I think the new plans will have a positive impact on my economic stability as it will attract more tourist.

F.3.7. Interview G

General questions

- Sex: male
- Age: 45
- Occupation: fisherman at sea
- Monthly income: 10.000.000 VND (410 USD)
- Share of monthly income household: 100%
- Number of people in household: 4
- Area: B

Statement 1 Strongly Disagree
I catch my fish on the sea, not in the mangroves.

Statement 2 Disagree
See previous answer.

Statement 3 Strongly agree
I want to improve the image of Do Son. If more tourists are coming to the area, they will enjoy the beauty of Do Son.

Statement 4 Strongly agree
I am aware that the mangrove forest protects us against storms and high water levels.

Statement 5 Agree
Yes I am aware.

Statement 6 Agree
Yes, I know that some people are highly dependent on the mangroves because they catch fish there.

Statement 7 Agree
The mangroves are part of the community and protects us against bad weather. Therefore I am willing to sacrifice part of my income to preserve the forest.

Statement 8 Disagree
No.

Statement 9 Neutral
No, I do not know the effects.

Statement 10 Disagree
I have never heard of these projects.

Statement 11 Agree
Yes, I am aware.

Statement 12 Disagree
No, they did not include us.

Statement 13 Neutral
As I don't know the plans, I can't chose sides for this question.

Statement 14 Neutral
See previous question.

Statement 15 Neutral
See previous question.

Statement 16 Neutral
See previous question.

Statement 17 Neutral
See previous question.

F.3.8. Interview H

General questions

- Sex: male
- Age: 45
- Occupation: fisherman in mangroves
- Monthly income: 10.000.000 VND (410 USD)
- Share of monthly income household: 100%
- Number of people in household: 3
- Area: A1

Statement 1 Agree
I catch part of my fish in the mangroves.

Statement 2 Agree
See previous answer.

Statement 3 Strongly agree
The economy will increase due to more tourists. Also more people will come to the area and enjoy its beaut.

Statement 4 Strongly agree
I am aware that the mangrove forest provide crucial services for the flora, fauna and climate"..

Statement 5 Agree
I am aware that the mangrove forest provide crucial services for the flora, fauna and climate"..

Statement 6 Agree
Yes, I am aware of the economic benefits for the local community due to the mangrove forest.

Statement 7 Agree
Yes, I am willing to sacrifice part of my income to conserve the forest.

Statement 8 Agree
I have heard of the projects. As I am very aware of the functions of the mangroves, I also know about its conservation projects.

Statement 9 Agree
Yes, I am aware.

Statement 10 Agree
I have heard of the projects. As I am very aware of the functions of the mangroves, I also know about its conservation projects.

Statement 11 Strongly agree
I have heard of the projects in detail. This part of the village is the place where one of the ports are going to be build. Everybody knows about the plan because the government announced these plans through the megaphones located outside their houses. The government is going to tear down our houses and build the port here. They provide new housing and jobs in the city for us. Besides that they give us financial support for starting a new life in the city.

Statement 12 Disagree
They only let us know through the megaphone. They never asked us about our opinions.

Statement 13 Strongly agree
I strongly agree.

Statement 14 Strongly agree
I think the new plans will improve my quality of life as I am one of the few people who is compensated for the new plans. I think if they provide al these compensations, my quality of life and my family's will improve overall.

Statement 15 Agree
I am sure a part of the forest will disappear. Not whole forest, just a part.

Statement 16 Disagree
The mangroves do not have big cultural value, the cultural heritage and traditions are more based on the hill, which will be untouched.

Statement 17 Agree
Partly. For the people like me who are being compensated, yes for sure. But a lot of people are indirect dependent on the mangroves such as fisherman. They depend on the mangroves but don't live at the location where the port itself is being build. These people are not going to be compensated but will experience a big change which will lead to a decrease of economic stability.

F.3.9. Interview I

General questions

- Sex: male
- Age: 62
- Occupation: fisherman in mangroves (retired)
- Monthly income: 10.000.000 VND (410 USD)
- Share of monthly income household: 100%
- Number of people in household: 4
- Area: A1

Statement 1 Agree
I used to catch part of my fish in the mangroves.

Statement 2 Agree
See previous answer.

Statement 3 Strongly agree
When the amount of tourist increases, people will earn more money which positively affects the stability in the area.

Statement 4 Strongly agree
I am aware that the mangrove forest provide crucial services for the flora, fauna and climate"..

Statement 5 Agree
I am aware that the mangrove forest provide crucial services for the flora, fauna and climate"..

Statement 6 Strongly agree
Yes, I am aware of the economic benefits for the local community due to the mangrove forest.

Statement 7 Strongly agree
Yes, I am willing to sacrifice part of my income to conserve the forest. I think when everybody sacrifice a small part, together we can prevent the mangrove forest from disappearing.

Statement 8 Strongly disagree
No, definitely not. If the mangroves disappear, the people will encounter big economical, ecological and coastal problems.

Statement 9 Agree
Yes, I am aware of the pollution but a lot of people are not. The reason for this is that the government does not provide any information about the effects of pollution.

Statement 10 Disagree
No, not aware.

Statement 11 Neutral
I know that there are plans, but I do not know any details. People living in the area that is going to be torn down know of the project. People not living in this area do not know this.

Statement 12 Disagree
No.

Statement 13 Neutral
Can't pick sides, do not know detail.

Statement 14 Neutral
I think the quality of life will increase for a small part of the local community. The rest will experience difficulties in regards to jobs, financial stability, coastal defence etc.

Statement 15 Disagree
No, if the government tries to tear down the mangroves, I am sure the local community will fight. Besides that, I cannot imagine the government has plans that involves the total disappearance of the forest.

Statement 16 Neutral
I don't know.

Statement 17 Neutral
I don't know.

F.3.10. Interview J

General questions

- Sex: female
- Age: 27
- Occupation: grocery store worker
- Monthly income: 7.000.000 VND (285 USD)
- Share of monthly income household: 50%
- Number of people in household: 4
- Area: A2

Statement 1 Disagree
Only a few of my products come from the mangroves, majority not.

Statement 2 Disagree
See previous answer.

Statement 3 Agree
More tourists means more people visiting my shop.

Statement 4 Strongly agree
I am aware that the mangrove forest provide crucial services for the flora, fauna and climate"..

Statement 5 Strongly agree
I am aware that the mangrove forest provide crucial services for the flora, fauna and climate"..

Statement 6 Strongly agree
Yes, I know lots of people that are 100

Statement 7 Neutral
No comments.

Statement 8 Neutral
I don't know.

Statement 9 Strongly agree
Yes, my mother organises yearly cleanup days to create awareness among the local community.

Statement 10 Disagree
No, not aware.

Statement 11 Disagree
I do not know.

Statement 12 Disagree
No.

Statement 13 Strongly agree
I am in favour of any new plans that increase tourism in the area .

Statement 14 Strongly agree
I think new plans that increase tourism has a positive effect on the local community.

Statement 15 Agree
Yes.

Statement 16 Disagree
I don't know.

Statement 17 Neutral
I don't know.

F.3.11. Interview K

General questions

- Sex: male
- Age: 67
- Occupation: fisherman at sea (retired)
- Monthly income: 10.000.000 VND (410 USD)
- Share of monthly income household: 100%
- Number of people in household: 4
- Area: A1

Statement 1 Disagree
I think people mostly work in the city.

Statement 2 Disagree
See previous answer.

Statement 3 Agree
More tourists means more money to earn.

Statement 4 Strongly agree
I am aware that the mangrove forest provide crucial services for the flora, fauna and climate"..

Statement 5 Strongly agree
I am aware that the mangrove forest provide crucial services for the flora, fauna and climate"..

Statement 6 Disagree
I think people mostly work in the city.

Statement 7 Agree
I think the coastal protected are very important. Everybody should sacrifice a part to protect the forest.

Statement 8 Disagree
See previous answer.

Statement 9 Strongly agree
Yes, I am aware **Statement 10** Strongly agree
Yes, I know of these projects.

Statement 11 Agree
I know of the plans in dragon hill, but I do not know any details of plans for the mangrove area.

Statement 12 Strongly disagree
No.

Statement 13 Strongly agree
I am in favour of any new plans that increase tourism in the area.

Statement 14 Strongly agree
I think new plans that increase tourism has a positive effect on the local community.

Statement 15 I don't think so as I am not aware of these cultural heritage
Yes.

Statement 16 Neutral
I don't think so as I am not aware of these cultural heritage.

Statement 17 Strongly agree
Yes, tourism is better for the area and the economic stability of the local community.

F.3.12. Interviewee L

General questions

- Sex: male
- Age: 41
- Occupation: fisherman in mangroves
- Monthly income: 20.000.000 VND (820 USD)
- Share of monthly income household: 67%
- Number of people in household: 5
- Area: A

Statement 1 Strongly agree
I only fish in the mangroves, so I am strongly dependent on them.

Statement 2 Strongly agree
I am completely dependent on the mangroves. I sell the fish I catch to people here, so I strongly agree.

Statement 3 Strongly agree
I want more tourists because it would mean that I will sell more fish.

Statement 4 Strongly agree
I am very aware of the functions of the mangroves. Every year there are a lot of storms and the mangroves protect the people from these storms.

Statement 5 Strongly agree
Because of the mangroves, the biodiversity is very high. For this reason we can do a lot of fishing.

Statement 6 Strongly agree
I am aware of this.

Statement 7 Strongly disagree
I would not sacrifie a part of my income.

Statement 8 Strongly agree
Yes, i would switch jobs if it meant that I would earn more money.

Statement 9 Strongly agree
Yes, I am aware of these effects.

Statement 10 Strongly agree
I know there have been conservation projects.

Statement 11 Strongly agree
Yes, I know the plans for Do Son.

Statement 12 Strongly agree
Yes I feel very included. I had a meeting with the local government about the project.

Statement 13 Strongly agree
Yes, I am very much in favour of the new plans. The projects will result in the development of Do Son and increase its economic situation. So the plans will definitely provide more income for the local community.

Statement 14 Strongly agree
I strongly agree with this.

Statement 15 Agree
Yes I think the mangroves will disappear, but they make room for new plans which will improve the economic situation in do Son.

Statement 16 Neutral
I am not sure.

Statement 17 Agree
Yes, I think the new plans for Do Son will have a positive impact on my economic stability.

F.3.13. Interviewee M

General questions

- Sex: male
- Age: 20
- Occupation: student
- Monthly income: 0
- Share of monthly income household: 0%
- Number of people in household: -
- Area: B

Statement 1 Disagree
I am a student, so I am not dependent on the mangroves.

Statement 2 I don't have a job yet, so I don't know.

Statement 3 Strongly agree
When more tourists come, it means my district's economy will improve, and the locality will develop more tourism.

Statement 4 Strongly agree
I know that the mangrove forests protect us from tropical storms.

Statement 5 Strongly agree
I know mangrove forests bring us many benefits in terms of scenery and seafood.

Statement 6 Agree
I know that some people depend on the mangroves as it is the source of their income.

Statement 7 Strongly agree
Mangrove forests are a part of my childhood, so I am willing to sacrifice a part of my income (later when I get a job) in order to conserve the mangrove forests.

Statement 8 Neutral
I don't have a job yet, so I don't know.

Statement 9 Strongly agree
I know the effects of pollution of the mangrove forests.

Statement 10 Agree
I know there have been some conservation projects in the past.

Statement 11 Agree
I know that there are new projects coming to Do Son.

Statement 12 Neutral
I know about the plans, but other than that I was not included.

Statement 13 Strongly agree
Mangrove forests bring us many benefits in terms of scenery, seafood, and protection from tropical storms and I think the new project offers suitable solutions such as planting more mangroves around new constructions that both increase aesthetics, are safer and more suitable for the people here. I am also ready to propagate to the people here about the benefits of new projects.

Statement 14 Strongly agree
The new project can bring many new job opportunities for people here, which can improve the quality of life.

Statement 15 Disagree
I don't think the mangroves will disappear. I think the government will have a plan for this.

Statement 16 Agree
I think it will have a positive impact. If many people come visit Do Son, for for example the bull fighting festival, more people will know Do Son and we will preserve and develop tourism.

Statement 17 Agree
I agree with this.

G

Photos of the interviews

Figure G.1: Information sign on the Japanese Red Cross Society's former conservation project in mangrove area A

Figure G.2: Interview with the restaurant owner

Figure G.3: Interview with local fisherman from area A1

Figure G.4: Interview with local fisherman from area A2