reclaiming mangroves of balikpapan bay:

designing socio-spatial strategies towards regenerative landscape

Graduation Project Report

Frithasya Purba | MSc Urbanism

MASTER THESIS - P5 REPORT
MSc Architecture, Urbanism, and Building Sciences - Track Urbanism
Faculty of Architecture, Urbanism, and Building Sciences
Delft University of Technology

Title
Reclaiming Mangroves of Balikpapan Bay:
Designing Socio-Spatial Strategies Towards Regenerative Landscape

Graduation Lab: Metropolitan Ecologies of Place

Author
Frithasya Jeniardina Purba
Student number: 5991617

Supervisors
First mentor: Steffen Nijhuis (Landscape Architecture)
Second mentor: Diego Sepulveda-Carmona (Spatial Planning & Strategy)

Acknowledgements

This report represents the culmination of a ten-month thesis research to complete my study at TU Delft. It is not only an extension of my thinking process but also a reflection of the support I have received from teachers, colleagues, friends, and family. I would like to express my heartfelt gratitude to these individuals.

First and foremost, to my family—especially my parents and grandmother—thank you for the trust and love that have sailed me far away from home to pursue my studies. Nothing I have achieved was without your blessings.

My utmost appreciation, needless to say, goes to both my mentors, Steffen and Diego. It would not have been such an exciting journey had I not joined Steffen's Landscape Architecture thesis group. It was an enriching experience of working on an interdisciplinary project that bridges urban planning and landscape study. I'm especially thankful to Steffen for his generous guidance, insightful feedback, and steady optimism throughout the process. To Diego, I'm sincerely grateful for the thoughtful ideas, warm encouragement, and consistent support that helped me believe in my work. His expertise in spatial governance was particularly valuable in shaping one of the most critical aspects of my project. I feel very fortunate to have had the opportunity to share the knowledge and culture from my home with both of my mentors.

To my friends—without whom starting a life far away abroad would have been much more difficult—thank you for the incredible support we have shared with each other. I am sincerely grateful to all my friends in the Indonesian community here, my Urbanism peers, my new teammates from Landscape Architecture, and my dearest friends in Indonesia who prove that friendship bonds know no distance.

My gratitude also goes to Universitas Mulawarman, our host and partner university, for supporting the fieldwork in East Kalimantan, Indonesia. Thank you to the teachers and new friends we met, for the warm welcome and guidance as we explored Kalimantan's forests and rivers.

Lastly, I am sincerely thankful to the institutions that made this journey possible through their generous support: LPDP (Endowment Fund for Education Agency) Indonesia, EFL Stichting, TU Delft Global Initiative, and Philip Spangenberg Travel Grant.

I am truly grateful for all the experiences, opportunities, and personal growth I've gained during my two years of studying at TU Delft.

Frithasya
Author

Contents

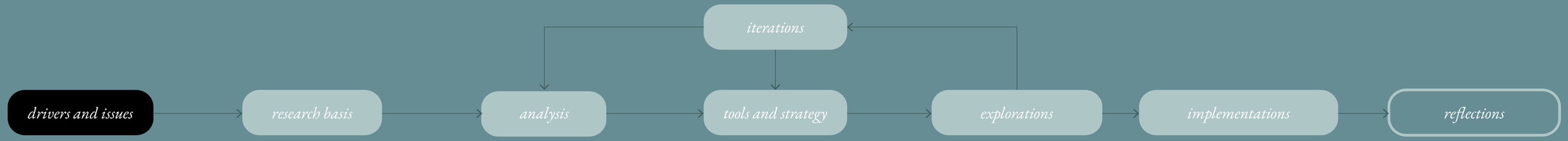
List of Figures

01

introduction

defining the problem

This chapter includes the Author's motivation, problem identification, and the proposed research questions to set a base for the research. The last part of this chapter provides report organisation explanation to understand the orders of the chapters of this report.



1.1. Fascination

The Author spent most of her lifetime living in Jakarta, Indonesia's current capital province located on Java Island, the world's most populated island since the 19th century. It is a congested city with all its wicked problems, where the residents are used to urban issues such as traffic congestion and flooding. Growing up, spending hours only to get to school was a routine for most of Jakarta's young population. In mid-2019, the present president at that time announced the plan to relocate the capital city and develop a new one in Kalimantan or Borneo Island to relieve pressure on the sinking Jakarta facing climate change's sea level rise. However, this decision left a big question mark. To most Indonesian people, Kalimantan was told to be the island of pristine forests—called the "country's lungs"—where Dayak indigenous communities of Borneo reside. Building a new capital city meant massive clearings of those forests, and replacements of the native people.

This graduation project allows an opportunity for the Author to delve deeper into the issue from the critical lens of landscape and urban design, development, and planning. Through the study, the Author found out that urban issues are complex and interrelated, often resulting from the dynamics of human-nature relations. The specific site chosen, Balikpapan Bay, was a region where complex dynamics happened, imposing different issues related to socioeconomic and ecology, such as biodiversity loss, climate vulnerability, and disruption of livelihoods of the local communities. Balikpapan Bay is one of the parts of Nusantara, the future new capital, where the bay ecosystem is also exposed to the impact of the existing and new urban developments. As an urbanism student, the Author is motivated by the study and aims for the project to explore strategies that integrate ecological preservation to guide urban development towards more social and ecologically inclusive urban environments.

Figure 1. Mangrove coexistence with human settlements and culture (Photograph by Author, 2025)

1.2. Problem Contextualisation

Mangroves of Indonesia

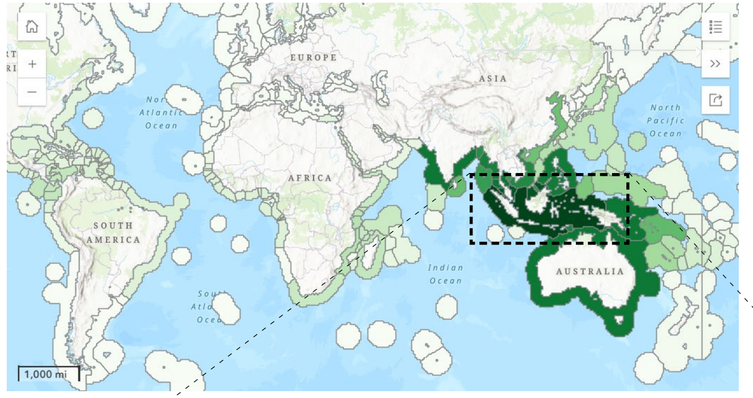


Figure 2. Global mangrove distribution map indicating darkest green color in Indonesia (Fair Carbon, 2023)

Indonesia is one of the world's great mangrove nations, covering 21% of the global total or over 3.000.000 hectares (Spalding et al., 2010) (refer to Figure 2. and Figure 3.). Mangrove forests are found throughout the country's coastlines with fringing, lagoonal, and deltaic formations, thriving in Indonesia's high precipitation level. Kalimantan—the Indonesian section of Borneo Island—is home to almost 30% of the mangrove forest (Noor et al., 2006).

Figure 3. The distribution map of mangroves in Indonesia (Adapted from Renggani et al., 2018)

The favourable environment for growing mangrove forests enriched Indonesia's variety of mangrove kinds. Of the world's 100 mangrove varieties, more than half exist in Indonesia (Warsidi & Endayani, 2017). The dominant species, *api-api* (*Avicennia sp.*) and *bakau* (*Rhizopora sp.*), benefit from the coast's brackish water and sandy-clay soil environment. Kalimantan coastlines offer biologically productive habitats, including estuaries, tidal wetlands, mangroves, and coral reefs.

Figure 4. Kalimantan mangrove and other wetland zone map (MacKinnon, 1997)

Mangroves and Biodiversity

The largest mangrove area in Borneo presents in East Kalimantan (MacKinnon, 1997; Spalding et al., 2010), covering more than 350.000 hectares (Asnaenie et. al, 2021 in Haydar, 2023). The mangrove forests in Kalimantan support a larger ecosystem of both marine and terrestrial species, especially in the semi-open waters of **Balikpapan Bay.** With a water surface of approximately 12.000 hectares (Nusantara Capital Authority, 2024), most of the bay's coastlines are covered by mangroves which serve as the habitats of a wide variety of animals and plants, including seagrass, coral reefs, saltwater crocodile, and the endangered endemic species of Irrawaddy dolphin and proboscis monkey. Located next to Balikpapan Bay, Sungai Wain Protected Forest is home to orangutans. These animals rely their survival on the mangrove ecosystem not only as their home but also as feeding and nursery grounds for their successions.

Figure 5. *Bekantan* monkey, an East Kalimantan endemic animals, in their mangrove tree habitat (elgiants, 2016)

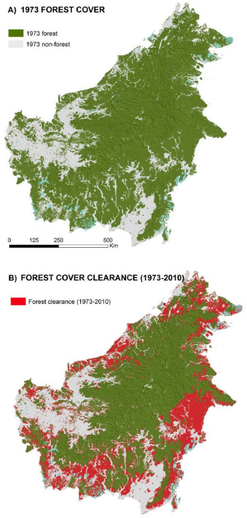


Figure 7. Borneo deforestation map, comparing forest coverage in 1973 and 2018 (Gaveau et al., 2014)

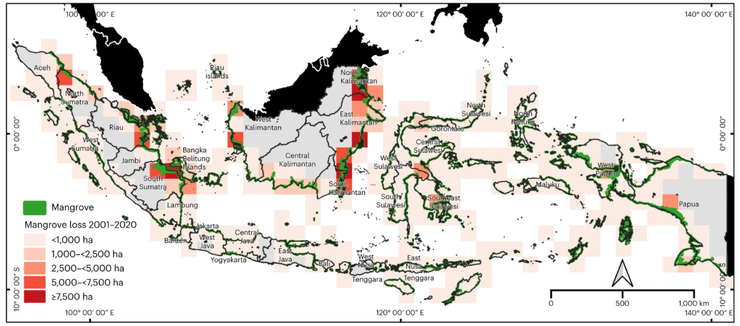


Figure 6. Mangrove loss map in Indonesia during 2001-2020 (Sasmito et al., 2023)

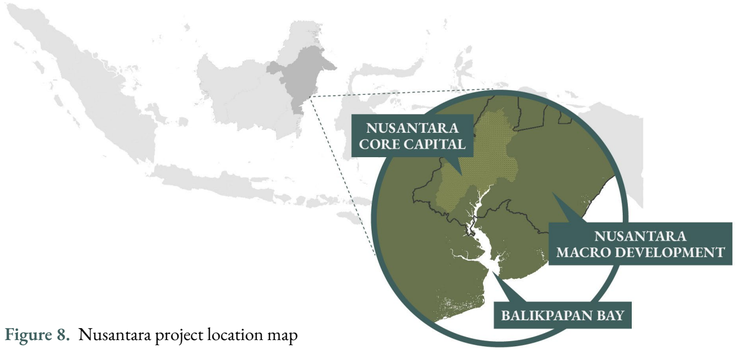


Figure 8. Nusantara project location map

Kalimantan coastal zones are also where the island's population resides and most developments are occurring (MacKinnon, 1997). Despite the rich wetlands ecosystem, during 2001-2020 Indonesia lost 6.500 hectares of mangrove forest annually (Sasmito et al., 2023) due to deforestation. More than 65% of Kalimantan's mangrove forest is presumably lost, primarily to land conversion for aquaculture, industry, and urban and rural development (Spalding et al., 2010).

In April 2018, an oil spill accident happened in the Balikpapan Bay area, causing heavy water pollution along almost 60 km of coastlines, affecting a massive loss of biodiversity and local fishermen's livelihood; with an estimated yearly economic loss of around 2.500.000 Euro (Oktawati et al., 2022). The following year, the Indonesian government decided to relocate the current capital city—Jakarta, located on Java Island—to Kalimantan Island, which was later called IKN or Nusantara, and was officially announced during the House of Representatives yearly meeting a day before the country's 74th Independence Day ceremony.

Nusantara plan is situated next to Balikpapan Bay, and consists of at least two main boundary scales: (1) the "core area" of 56.180 Ha and (2) the macro development area of 256.142 Ha (BAPPENAS, 2020). As construction began in 2022, Balikpapan Bay became the backbone for the new capital's construction logistics. Since then, it has intensified the socio-environmental degradation through forest clearing, increasing bay water pollution, and local population resettlement (Widadio & Budhi, 2024).

Figure 10. News on Nusantara capital development (Baraputri, 2022)

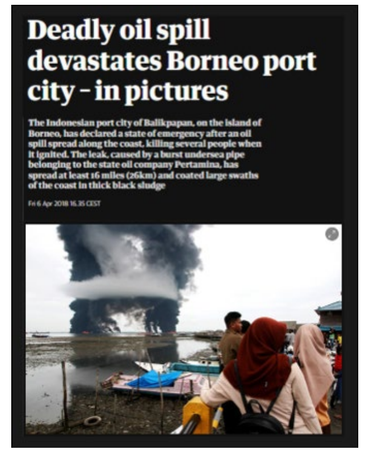


Figure 9. News on the oil spill accident in Balikpapan Bay (The Guardian, 2018)

Figure 11. Pipeline burst fire caused air pollution with thick black smoke (Photograph by Paksi Sandang Prabowo in The Guardian, 2018)

Figure 12. Oil spill polluted water extensively (Photograph by AFP in The Guardian, 2018)

Figure 13. Death of animals, including Irrawaddy dolphins due to the oil spill (Photograph by Anggi Praditha in The Guardian, 2018)

1.3. Problem Statement

Wetlands are among the world's most vital ecosystems, covering only 6% of the earth's land surface yet supporting 40% of its plant and animal species (Nations, n.d.). **Mangroves, as a wetland ecosystem, serve as natural defences against coastal storms and abrasion. They provide critical habitats for diverse marine and terrestrial species, acting as nurseries and feeding grounds.** Mangroves also play a vital role as the global blue carbon sinks, storing four times more carbon than terrestrial forests (Rani et al., 2023). For centuries, they have offered ecosystem services to humans, including supporting fishermen's livelihood productivity, serving as a tourism destination, and providing a spiritual space for some native communities. While both indigenous groups and modern societies view nature as a source of life, indigenous people have traditionally respected and protected it, whereas modern society often exploits it through urban expansion and infrastructure projects, placing less priority on conservation.

Indonesia is home to over 20% of the world's mangroves. However, economy-driven policies have led the country to lose 6,500 hectares of mangrove forests annually (Bunting et al., 2018). The primary driver is land conversion to meet the socio-economic demands of urban expansion, industry, aquaculture and plantations, leading to widespread environmental degradation. Over the past five years, the Indonesian government's plan to build a new capital city on Borneo Island has further amplified the environmental impact, where it could have served as an opportunity to pioneer a more sustainable and socially inclusive urban development model.

In Balikpapan Bay, which has been designated as one of the nature reserves within the new capital's development zone, water quality has deteriorated due to nearby industrial and urban activities. The degrading mangrove forests are losing their water filtration ability, resulting in biodiversity loss, including endangered species like the proboscis monkey and Irrawaddy dolphin (Baraputri, 2022). The coastal population loses houses to floods and abrasion, fishermen communities face threats to their livelihoods, and indigenous groups primarily lose their once-sacred lands. Ecologically, deforestation of the mangrove forests promotes carbon release into the atmosphere and exacerbates climate change. Further, it has reduced the region's ability to adapt to climate change, increasing vulnerability to coastal flooding and abrasion, risking infrastructure and leading to significant economic losses.

This situation calls for urgent action to regenerate the mangrove forests of the Balikpapan Bay area, intending to **foster a healthy ecosystem through landscape-based approaches that strengthen and support socioecological resilience** in the face of climate change. Strategy exploration of taking ecological rehabilitation into urban planning and design will be addressed through the lens of regenerative development that integrates ecosystem-based adaptation and adaptive capacity. The project aims to develop a spatial landscape framework to restore the damaged environment, counterbalance the economic needs, and guide future urban developments.

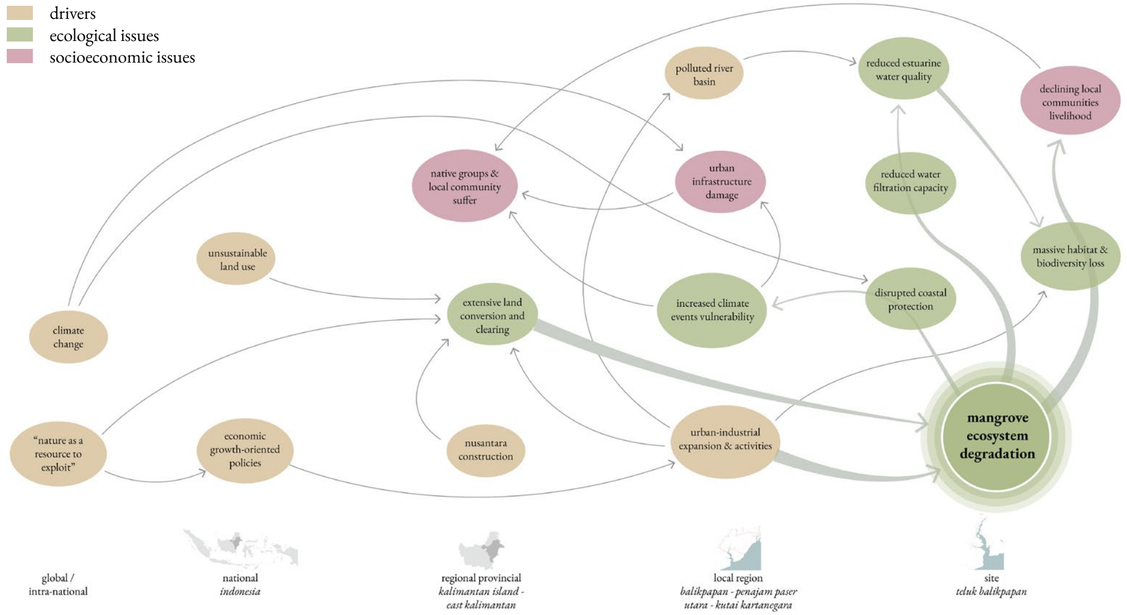


Figure 14. Complex and interrelated issues around mangrove ecosystem degradation in Balikpapan Bay, showing how an issue can be the cause or the impact of other issues in different scales

1.4. Research Questions

What **landscape-based socio-spatial strategies** can be applied to **regenerate the mangrove ecosystems in Balikpapan Bay** and **catalyse social-ecological resilience**?

Sub-Research Question 1:

What conditions enable mangrove ecosystems to thrive, and how do these reflect the current state of the mangrove ecosystem in Balikpapan Bay?

Sub-Research Question 2:

How do the challenges of mangrove ecosystem degradation in Balikpapan Bay impact the various actors and stakeholders involved?

Sub-Research Question 3:

How can regenerative principles address the issues imposed in the Balikpapan Bay region?

Sub-Research Question 4:

What socio-spatial framework and strategies can be applied to the issues imposed in the Balikpapan Bay region?

Sub-Research Question 5:

How can these regenerative socio-spatial strategies be put into realisation?

1.5. Scientific and Societal Relevance

Scientific relevance

As the pressure of climate change is increasing, the awareness of this wetland ecosystem's importance as our coastal forts is simultaneously escalating, initiating mangrove restoration projects globally. The Author takes on two reciprocal lenses to approach this. First, Indonesia covers a large part of the world's mangroves while also losing the forest significantly to socioeconomic developments. On the other hand, there are already several initiatives across the country to restore the mangrove forests, in which several of them needs more recognition. This thesis will try to complement and amplify previous studies about mangroves by also learning from previous projects, and provide a landscape-based approach to integrate them into socio-spatial strategies for mangrove regeneration. Second, this thesis will try to address multiple issues with an approach that considers context-based potentials. With the pressing context of the new capital city development close to the site, this thesis can be highly relevant through addressing contemporary issues and delivering a study on landscape-based frameworks to counterbalance socioeconomic development and environmental protection.

Societal relevance

Indonesia is a country with thousands of ethnicities, creating a rich cultural heritage that touches different aspects of life, including how humans interact with nature. It is undeniable that the human-nature relationship changes through decades and centuries, and heritage allows us to learn from their practices and approaches. In today's world, changing paradigms often put some groups on the vulnerable side and have their voices disregarded. This thesis will try to recognise different voices, from communities to large companies, and investigate the potential of working with the human-nature relationship through synergical strategies. Further, this thesis also aims to formulate implementable strategies through collaboration with different stakeholders while paying attention to the beneficial values for both the human and non-human stakeholders.

1.6. Report Organisations

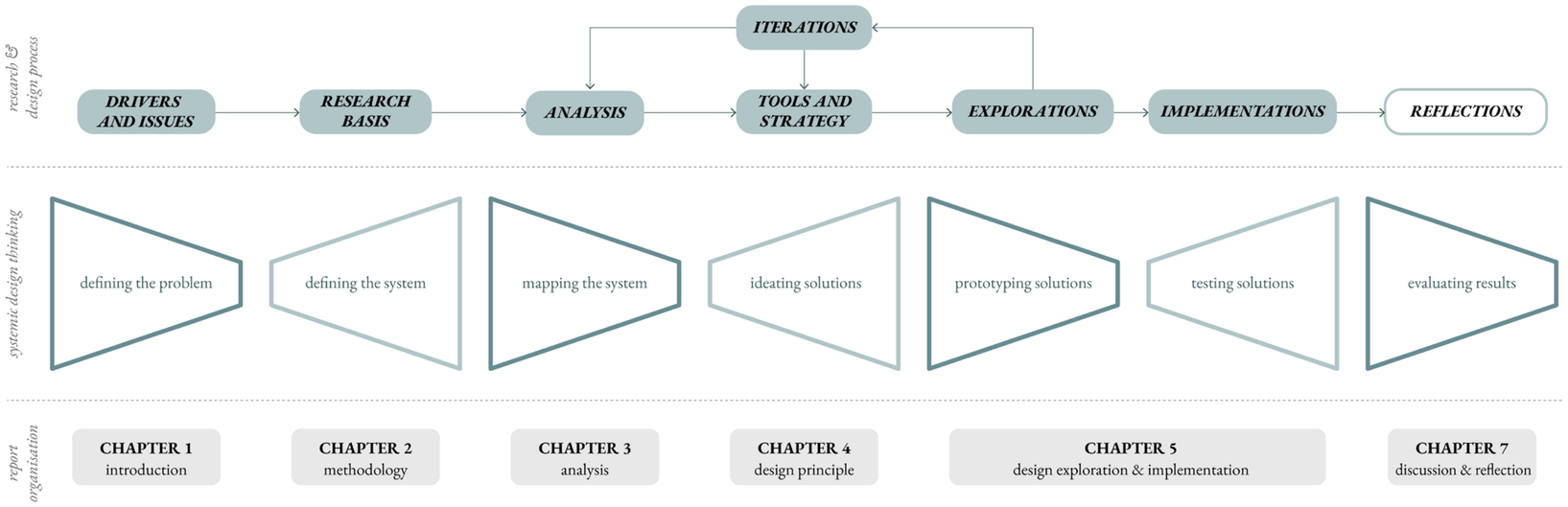


Figure 15. Report organisation diagram

The chapters in this research report is organised by adapting the schemes of *research through design process* from Landscape-based Urbanism (Nijhuis, 2022) and *systemic design thinking* (Ospina, 2019; Roggema, 2022; Wandl, 2024) from Research Development and Design. It follows the logic of research processes while having the design process as one of its main elements. The report will start with an introduction to the problem and the urgency and relevance of addressing the issues, followed by the analysis and design processes, and will end with a discussion and reflection chapter.

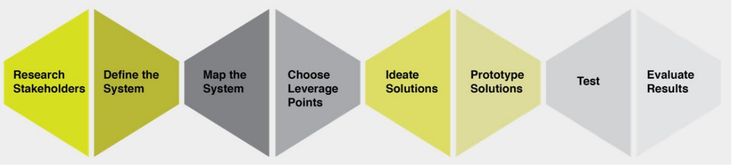


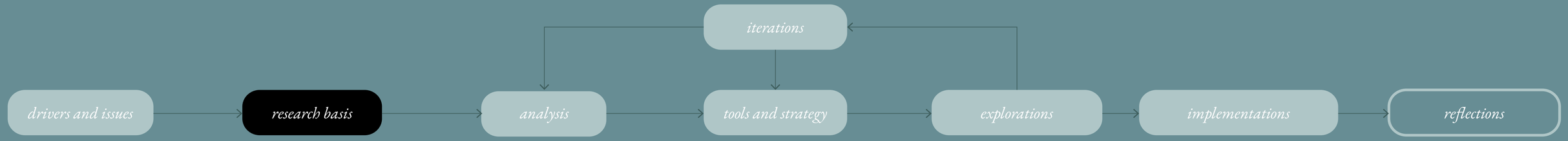
Figure 16. Design process of systemic design thinking (Ospina, 2019; Wandl, 2024)

02

methodology

defining the system

After defining the problem in the previous section, this chapter is intended to set a theoretical base for the study and investigate the methods for this research.



2.1. Theoretical Underpinning

The theoretical framework represents a scheme of theories used to build this research. The three theoretical bases—Landscape-based Urbanism, Regenerative Design and Development, and Ecosystem-based Adaptation—built the foundation to comprehend the issue and construct the project, in which the Author excerpted the central understanding of '*complex adaptive and dynamic system*' within the '*human-nature relation*'. Other approaches learnt from these theories include *research through design, layers approach, social-ecological resilience,* and *ecosystem services and biodiversity.*

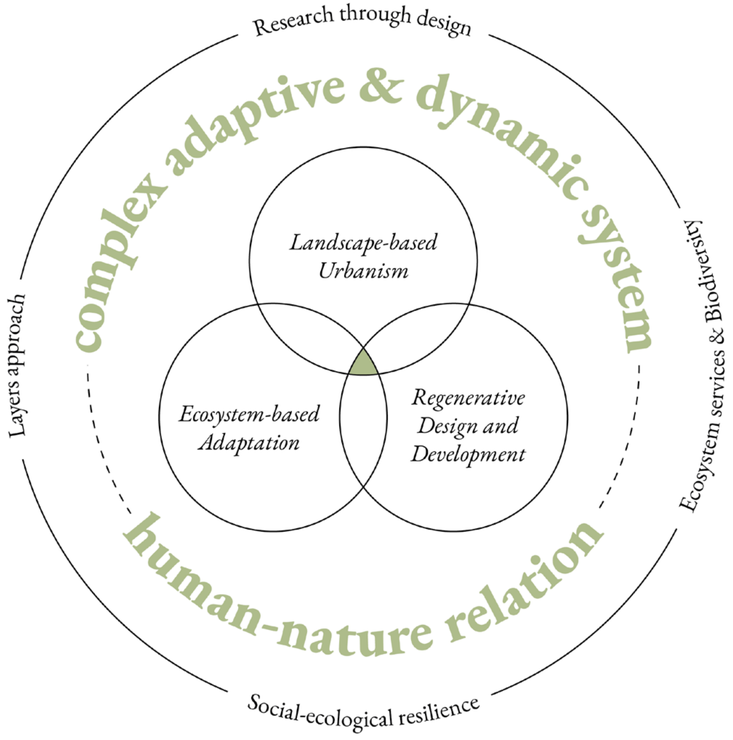


Figure 17. Theoretical Framework

A. Landscape-based Urbanism (LbU) and Research Through Design

In the present era of the Anthropocene (Crutzen, 2006 in Nijhuis, 2022), humans pose detrimental and irreversible impacts on the planet. The mechanistic worldview has been attributed to the exhaustion of the natural landscape, continually decreasing environmental carrying capacity and risk of worse damage and capital destruction (Planbureau voor de Leefomgeving, 2021 in Nijhuis, 2022).

The landscape-based approach puts landscape in the centre stage as a vital basis for human life and a living ecological system with logical interrelationships. The related **natural and social-cultural processes** become the foundation to guide spatial transformations and design future-proof urban environments (Nijhuis, 2024). Within its cores—**design with nature, people, and history**—this approach addresses multiscalar and interdisciplinary thinking, integrating learnings from history and vernacular practices to create synergies of human-nature systems. According to the "wedding cake model" by Stockholm Resilience Centre, the biosphere is considered the context for socioeconomic development, and the landscape is the point of departure of sustainable change (Nijhuis, 2024).

As a product of a cumulative process of changing, developing, and replacing structures over time, landscapes own rich history and typological variation (Sayer, 1925; Whittlesey, 1929; Bobic, 1990 in Nijhuis, 2022), shaping '**layers**' of different elements of structures and patterns and their relations and forming the landscape's character (du Plessis, 2022). Visualising these layers with maps (Nijhuis and Pouderoijen, 2014 in Nijhuis, 2022) can help to understand both the challenges and opportunities that may arise.

Design allows the application of these knowledge, as a vehicle to frame spatial problems and explore possibilities to generate solutions visually (Nijhuis et al., 2017). **Research through Design** demonstrates the co-evolution in research and design processes, where gaining understanding and generating design proposals go hand-in-hand. In design thinking, the design process is not linear; design explorations might generate new insights and require 'reframing' to lead to new solutions.

Figure 19. Wedding cake model by Stockholm Resilience Centre which put biosphere and related SDGs as a "point of departure" (Nijhuis, 2024)

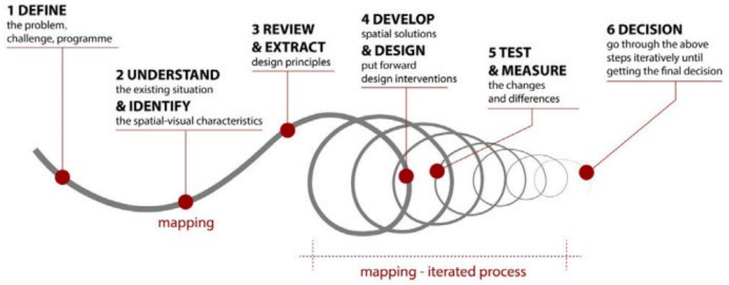


Figure 18. Non-linear design process diagram, including iteration process (du Plessis, 2022)

B. *Regenerative Development and Design*

According to IPBES, we have lost or will lose half of our biodiversity; and IPCC reports show our land use degrades large areas globally and worsens climate change (IPBES, 2019 and IPCC, 2019 in Roggema, 2022). Beyond the effort of balancing the system, regeneration of the living conditions is needed, where design can play a role. Regenerative paradigm emerged out of the transition from a 'mechanistic' to an 'ecological' or living systems worldview (Mang & Reed, 2012).

Regenerative design and development aims at **realigning human role** in the ecosystem, and goes beyond sustaining to create systems whose outcome **improves the health and resiliency of the system** itself (Roggema, 2022). The regenerative principles strive to bring new life, restore instead of taking out, and establish connections (du Plessis, 2021 in Roggema, 2022). Caniglia (2018 in Marshall & Twill, 2022) stated the three goals of regenerative processes: (1) to catalyse the health of human & nature through holistic design that includes community involvement, (2) to foster positive loops within the carrying capacity of human and natural resources, and (3) to be able to properly adapt by respect and consider the local context of economic, culture, and ecology.

Based on transformative resilience, the collapse of existing systems allows the opportunity to develop new relationships, values, and new systems by focusing on the potential and acknowledging living systems (du Plessis, 2022). According to Regenesis (Mang & Reed, 2012), regeneration concept expanded the "Levels of Work" framework by Charles Krone in 1970, which put 'improve' and 'regenerate' as "above the line work" for **living systems thinking.**

Figure 20. Ecologically responsible design paradigms (du Plessis, 2021 in Roggema, 2022)

C. *Ecosystem-based adaptation (EbA) as a nature-based solution*

Based on the two previous theoretical concepts, human footprints and its mechanistic worldview destroys our planet, especially on the event of climate change. There is an urgent need for environmental rehabilitation to increase our resiliency towards the changing climate, and putting focus on ecology can provide potential for low-cost and long-term solutions to protect lives, livelihoods, and infrastructure, while advancing the objectives of the UN's Sustainable Development Goals (UNDP, 2025). Ecosystem-based adaptation focuses on helping people to adapt to the impacts of climate change by utilising **biodiversity and ecosystem services**. It aims to **reduce vulnerability** and **increase resilience** (Colls et al., 2009).

In practice, ecosystem-based adaptation as a form of nature-based solution takes shape in restoring coastal habitats such as mangrove, or reforesting watersheds. According to Ecoshape, building with nature means to work with natural dynamics that are able to create an adaptive system under threats of climate change, and responds to place-specific context based on local knowledge (Ecoshape & Eekelen, 2020). The success of ecosystem-based adaptation, based on IUCN, depends on the recognition and involvement of traditional ecological knowledge to be included in the management strategies (Colls et al., 2009). Effective ecosystem management allows the approach to contribute not only to biodiversity but also to the local economy.

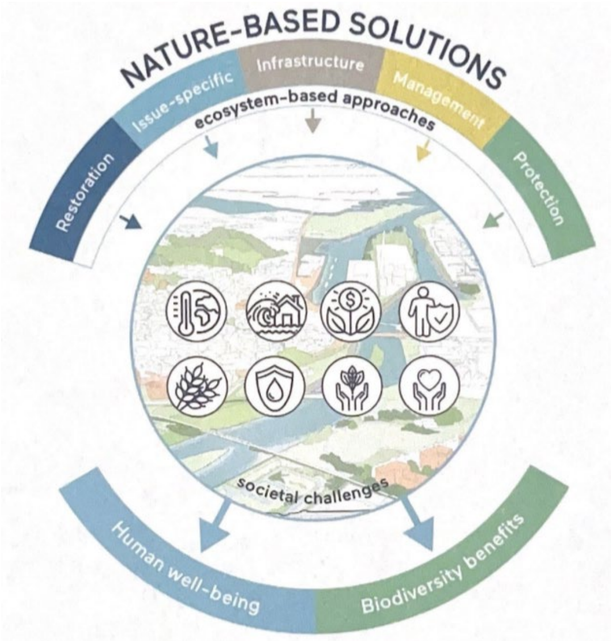


Figure 21. Ecosystem-based approach to apply nature-based solutions (Ecoshape & Eekelen, 2020)

2.2. Conceptual Framework

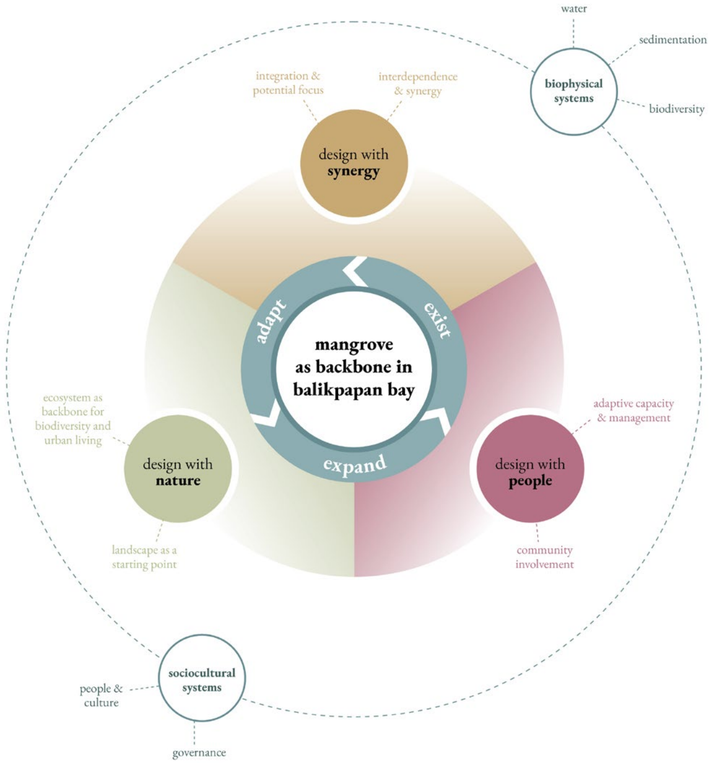


Figure 22. Conceptual framework

The three main ideas—*design with nature, design with people,* and *design with synergy*—are extracted from the theoretical studies that put emphasis on the relationship between human and natural systems which are apparent in patterns and have potentials and synergies. The central circle highlights the significance of mangrove ecosystems, in which they need the capacity to *adapt, exist,* and *expand* to ensure its quality as a 'backbone' in a bigger system. Furthermore, the biophysical environment and sociocultural elements are the sub-systems utilised to study the mangrove ecosystem.

Both illustrations on the following page depicted how human and its natural environment interacted through ages, especially in Balikpapan Bay.

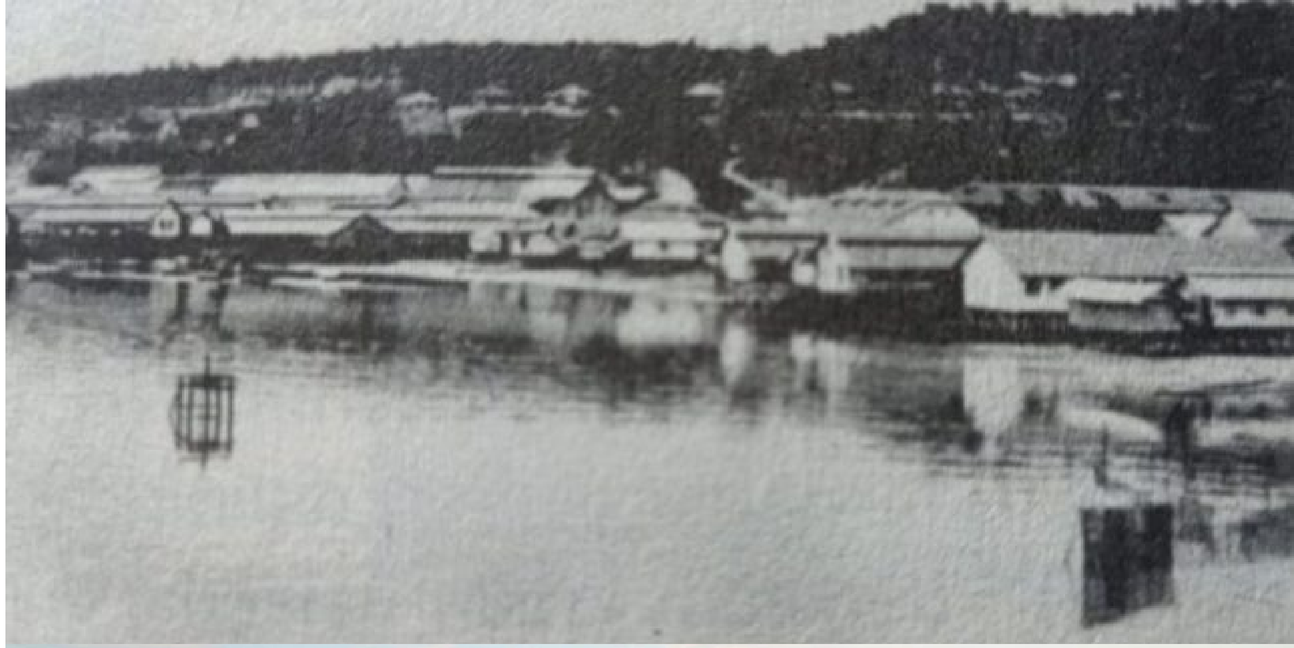


Figure 24. Left above – Old photographs of stilted-house settlements alongside Balikpapan Bay (Posted by M. Asran in beritakaltim.co, 2023)

Figure 23. Left below – Stilted-houses in Water Village Balikpapan (Photographed by Dewi in tripadvisor, 2016)

2.3. Methods

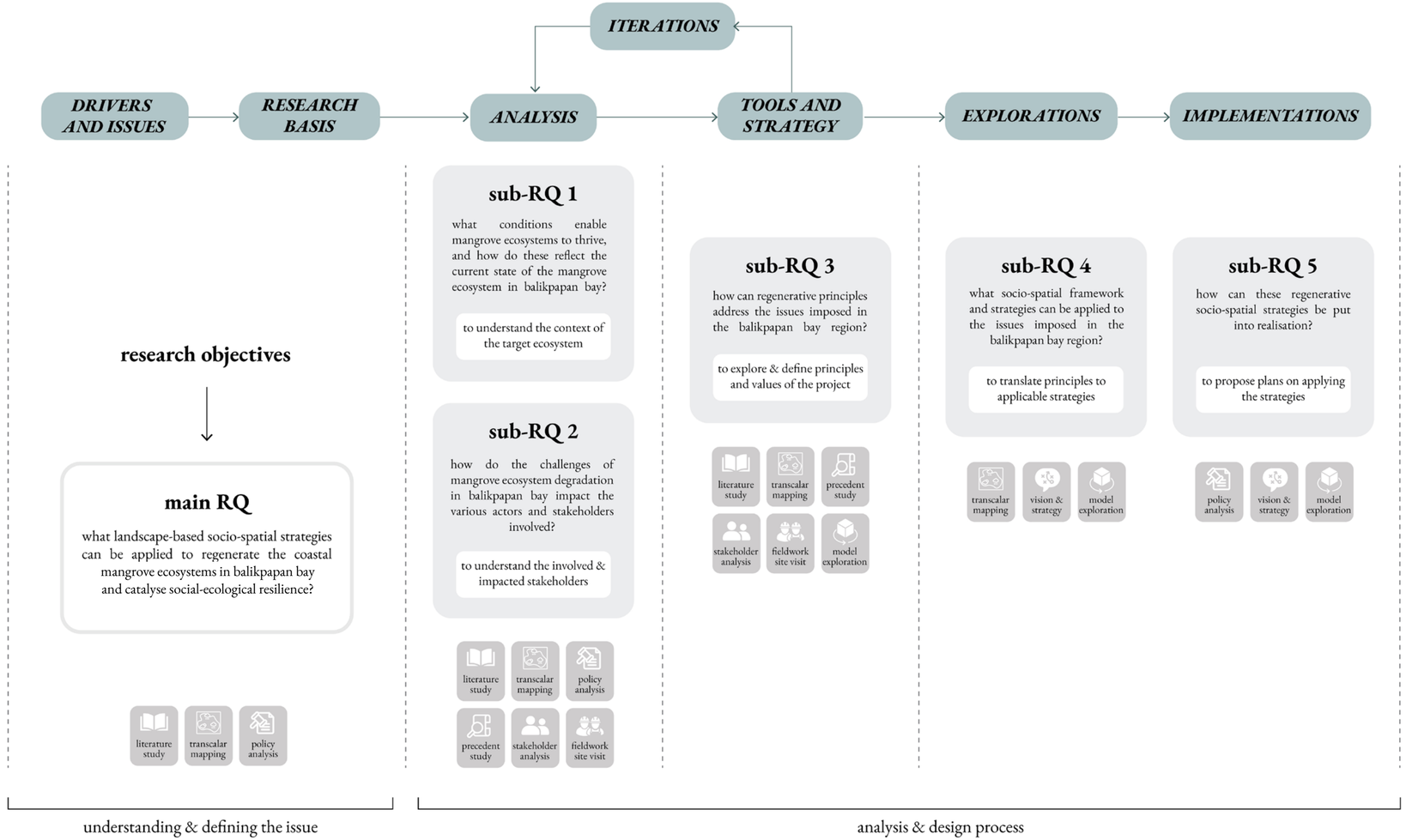


Figure 25. Research methods as tools to answer the sub-research questions

The methodology helps put order and organisation in the research. In this project, sets of methods facilitate the process of answering the research questions systematically. This research will examine the interrelationships between human, nature, and their synergies, through the context of the conditions, potentials, and risks; and use the results to build design assignments.

To initially build the research, a **literature study** is vital to set the ground for understanding the issues and the drivers, to put focus based on the context studied, and to support the knowledge gain for taking the next steps. As a part of the literature study, **precedent analysis** allows the Author to reflect on the ideas excerpted from the study and examine what has been applied, how it worked out, and what can be learned from it. **Policy analysis** includes a desk study to acknowledge both limitations and potential for the project. After generating the results, as part of the implementation process, policy analysis becomes the strategy to reflect on the existing regulations to propose new sets of policies in the project context.

The **survey** method, as a part of the co-creation strategy, will be conducted to complement the implementation process, with the target sample population being the local communities around the project's location. The target audiences will be decided through **stakeholder analysis**, which is vital to answering the research question about impacted actors and stakeholders.

Based on the "layers approach" from Landscape-based Urbanism (Nijhuis, 2024), unpacking the landscape in layers helps to grasp the systems and subsystems and their relationships. These layers are adapted into maps to facilitate visual thinking and communication through **transcalar mapping** to support the analysis and design processes. As a part of the Research through Design process, **vision and strategy formation** entails creating a long-term regional vision based on the knowledge of the human-nature systems by addressing the identified challenges and potentials to envision a desirable future (Nijhuis, 2022). Following the vision, **design models exploration** formulates the adaptation of the strategies into applicable design solutions in the local context. It is a powerful research method with which complex spatial challenges can be approached integrally (Nijhuis, 2022) to work across scales.

Fieldwork is an essential part of this research as a means to collect primary data through site visits, observation, and interviews, and provides a foundation or justification for the collected secondary data. Observation during site visits gives understanding of the area through experiences, and can be investigated with sensory experiences, space and scale, system and network, and culture and society observations (Rocco, 2023). The fieldwork trip was conducted in February 2025 to Kalimantan, Indonesia. The Author visited Balikpapan Bay and the surrounding area, including Balikpapan city, Samarinda city, Panajam city, and several nature reserve areas and native communities' villages.

2.4. Research Design

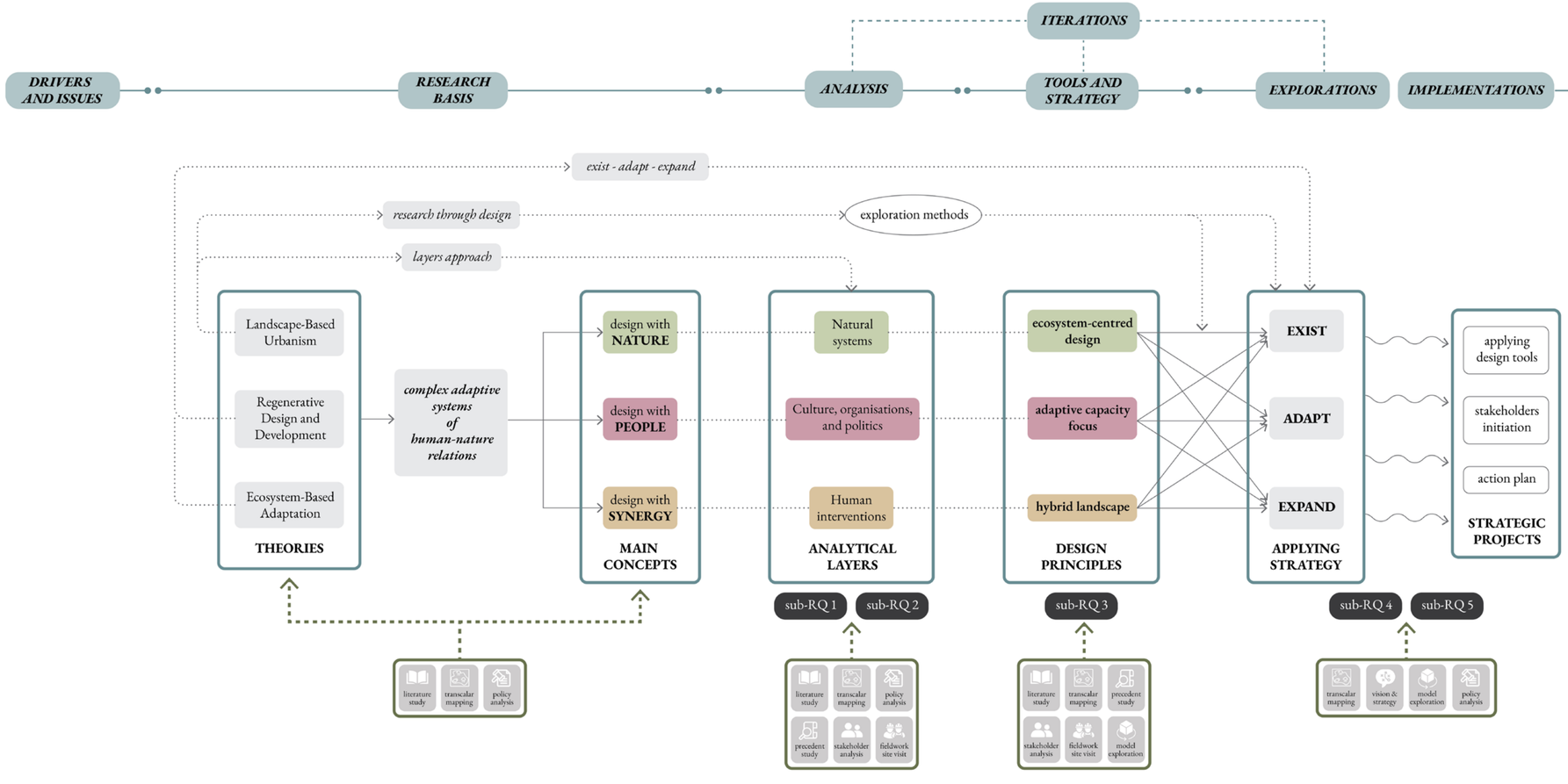


Figure 26. Research through design framework

This framework outlines the process of the research project, relating the theories, concepts, strategies and the methods used Identification of the issues at the start leads to the formulation of the problem statement, which then enters the analysis and design processes. Elements to be analysed are based on the conceptual framework (refer to Figure 22.) and put together in the analytical framework (refer to Figure 28.). The design processes consist of composing design principles and design model explorations. It is a non-linear process (*research through design*, refer to Figure 18.) where design iterations can happen, and insights from the exploration process might 'reframe' the result formulation. The following step of implementation consists of developing an action plan for strategic pilot projects and policy adaptations. The steps in analysis and design processes use the foundation and approach from the theoretical study.

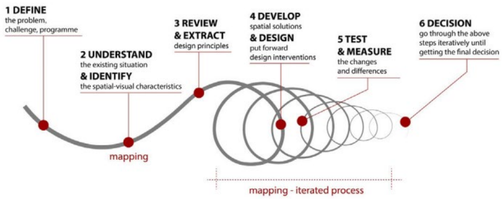


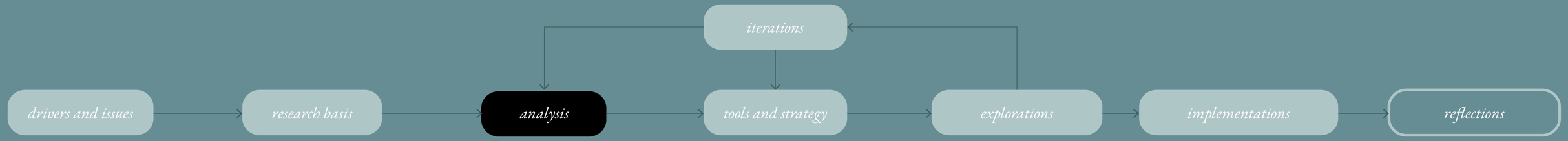
Figure 27. Design process diagram (refer to Figure 18.)

03

analysis

mapping the system

This chapter means to reveal the layers of the chosen issue, which systems and elements correlate to it, while relating it to the place-based specific contexts. Mapping method are mainly utilised to do the analysis process.



3.1. Unravelling the Layers

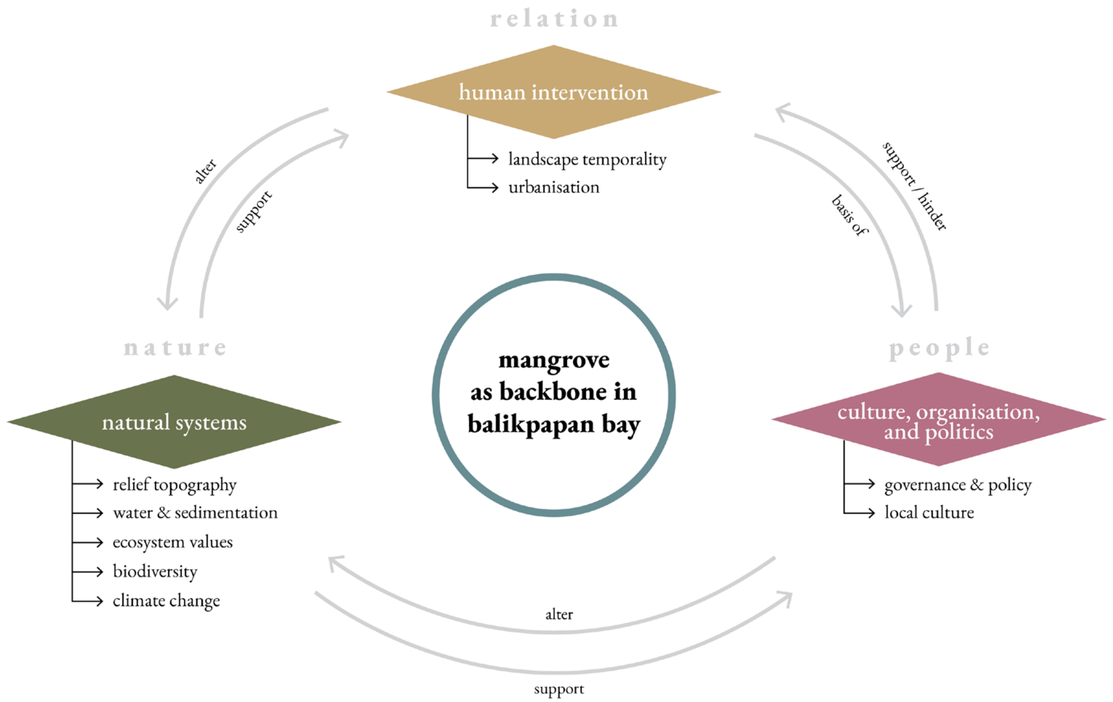


Figure 28. Analytical framework

Landscape-based Urbanism (Nijhuis, 2024) introduced the "layers approach" to understanding the networks of different sub-systems, including the **natural context, human interventions,** and **culture, organisation, and politics**. With these "complex dynamics of human-nature relation" understanding in mind, having the mangrove ecosystem at the centre stage as a backbone in Balikpapan bay requires a study of different elements constituting these sub-system layers. During the previous thinking process of the analytical elements, the Author introduced an interaction diagram between the ecological and socioeconomic elements, which were presented as *conditions, potentials,* or *risks and pressures* (see Figure x.)

Figure 29. Fishermen catching mudcrabs between the mangroves in Balikpapan bay (Photograph by Author, 2025)

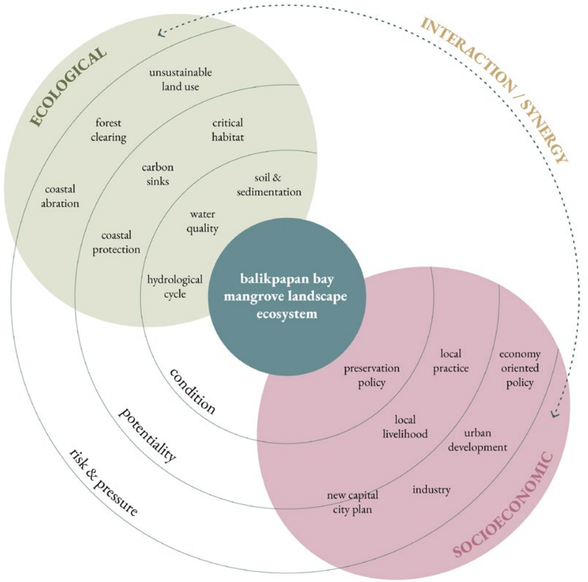


Figure 30. Drivers and issues presenting in ecological and socioeconomic layers, assessed on the context of conditions, potentials, and risks

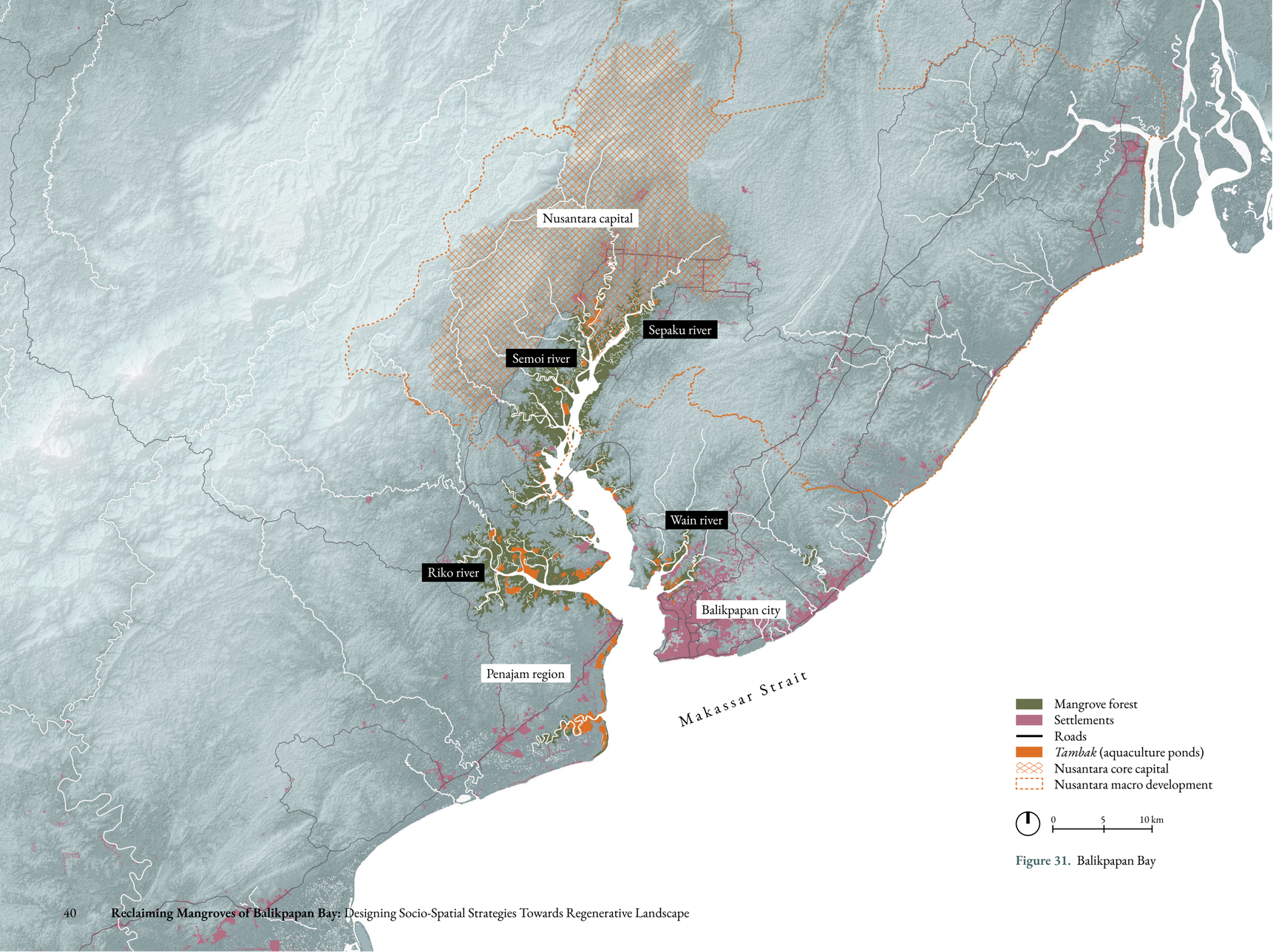


Figure 31. Balikpapan Bay

3.2. Balikpapan Bay

A. The urbanising coastal environment

Balikpapan Bay is a large estuarine located next to the heavily urbanised Balikpapan City. Boyd defined an *estuary* as the seaward portion of a drowned valley that constantly receives sedimentation from both river and sea (Boyd et al., 1992), simultaneously resulting in brackish water characteristics that differentiate them from other coastal environments. In Balikpapan Bay, daily tidal dynamics highly influence the supply of sediments in this embayed coast area.

As shown by history, humans naturally settle around water bodies, including coastal environments. From the older sultanate system before Indonesia was even established, the indigenous Dayak and Balik groups inhabited the bay's coasts, followed by rapid urbanisation started in the late 19th century when the Dutch built an oil well in a small village that later became Balikpapan City. Today, Balikpapan Bay is surrounded by urban developments and industrial activities alongside its coastlines.

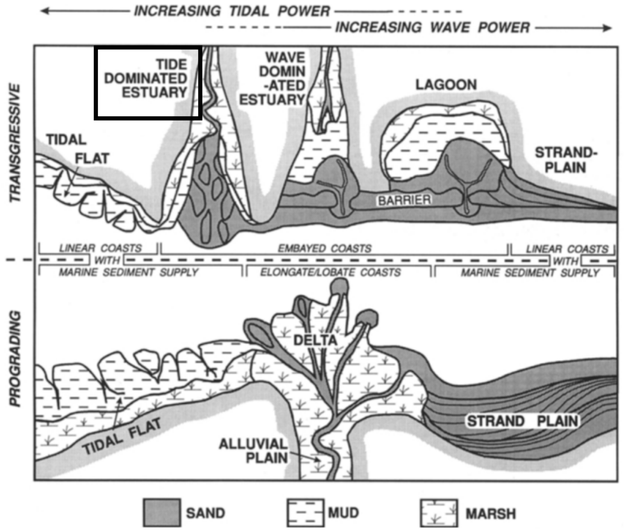


Figure 32. Coastal environment classification based on its process (Boyd et al., 1992)

B. Hydrological Flow

The water territorial of Balikpapan Bay stretch about 16,000 hectares. Balikpapan Bay collects freshwater discharge from four primary riverine sources: **Semoi River** and **Sepaku River** flowing from the **northern** part of the bay, **Riko River** water supplying from the west, and **Wain River** from the east and flowing alongside the heavily urbanised city region of Balikpapan. Balikpapan city is approximately 50.000 hectares in area, with a population of almost 750.000 in 2023 (BPS, 2023).

In the northern part of Balikpapan Bay (Figure x., Section A-A'), where the area overlaps with the macro development boundaries of Nusantara, the mangrove forests are still intact. Although the watersheds flow from upstream through plantation and urbanised areas with less water infiltration surfaces, the mangroves act as buffer zones to filter water and sediment discharged to the coastal water. Meanwhile, in the southern part of the bay (Figure x., Section B-B'), situated in the Balikpapan city boundaries, the mangrove belt was converted into industry and left no buffer zone for filtering the water discharge that streamed through more plantations and urbanised areas of the city. This condition also exacerbated the natural capacity of mangrove as a water filter for the marine water.

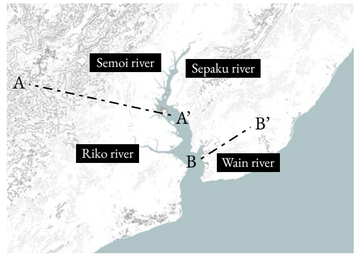


Figure 33. Section keymap

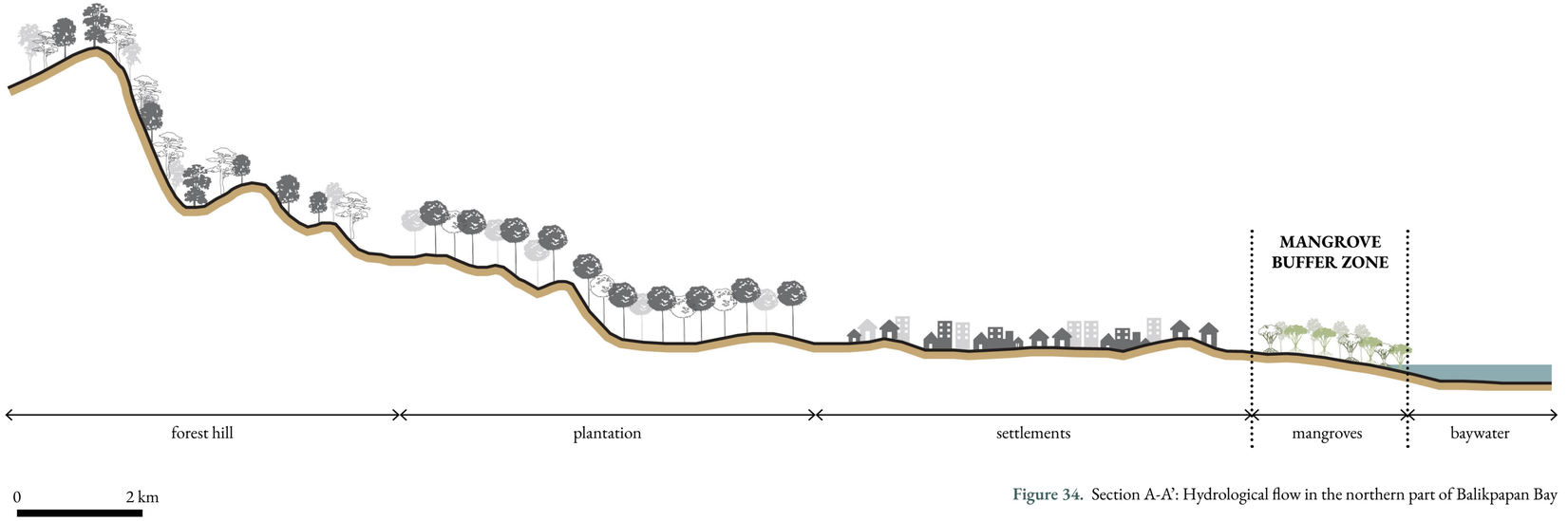


Figure 34. Section A-A': Hydrological flow in the northern part of Balikpapan Bay

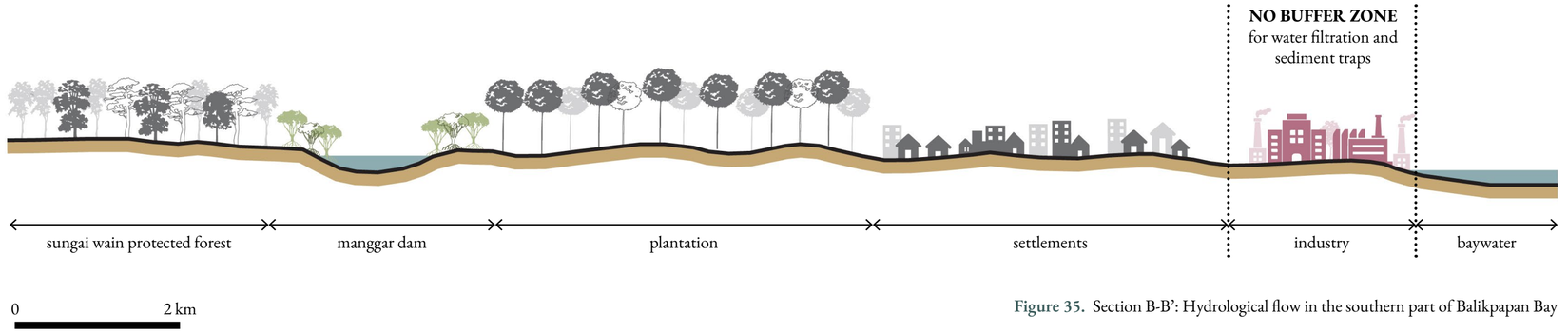


Figure 35. Section B-B': Hydrological flow in the southern part of Balikpapan Bay

C. Natural Ebb-Flow Tides and Sedimentations

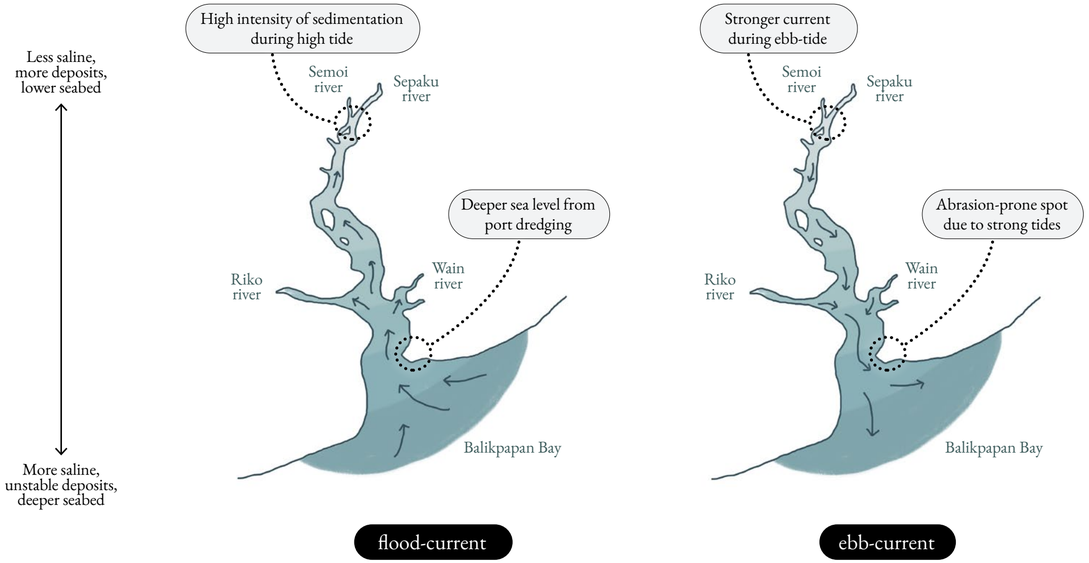


Figure 36. Ebb-flow tide and sediment flow processes linked with erosion risk

Balikpapan Bay shares the marine area with Makassar Strait, in which natural currents flow from the open ocean affect the water and sedimentation in the estuarine. The semi-enclosed waterbody characteristics keep water and sediments flow within the delta and the bay without flowing outwards to the strait. This means the deposited sediments have mostly stayed in the bay.

During both ebb and flow tides, Balikpapan city's coastline or the Port Semayang area holds the highest risk towards erosion (Harahap et al., 2021). The area has the deepest ocean floor in Balikpapan Bay, which influences the increasing rate of the current.

D. Biodiversity

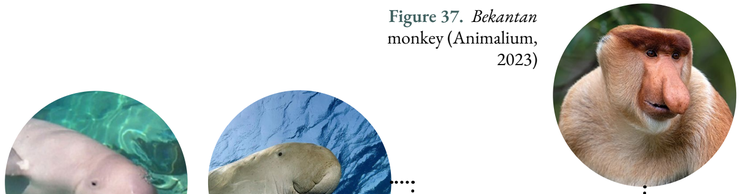


Figure 37. *Bekantan* monkey (Animalium, 2023)

Figure 38. *Pesut* (GIS Coastal, 2023)

Figure 39. *Dugong* (World Wildlife Fund, n.d.)

Balikpapan Bay's mangrove ecosystem attracts a rich biodiversity, including the endemic animals such as the *bekantan* (proboscis monkey) and *pesut* (Irrawaddy dolphins). The extensive mangrove forests linked to other thriving ecosystems, such as the underwater ecosystem beds of seagrass and coral reefs as home to various species of fish and other mammals, and different kinds of riverine and terrestrial forests as the habitat of crocodiles, leopards, monkeys, several bird species, and others.

Figure 40. Coral reefs (Pradana, 2024)

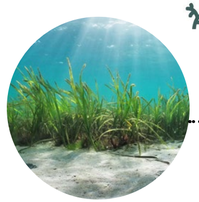


Figure 41. Seagrass beds (The Ocean Agency, n.d.)

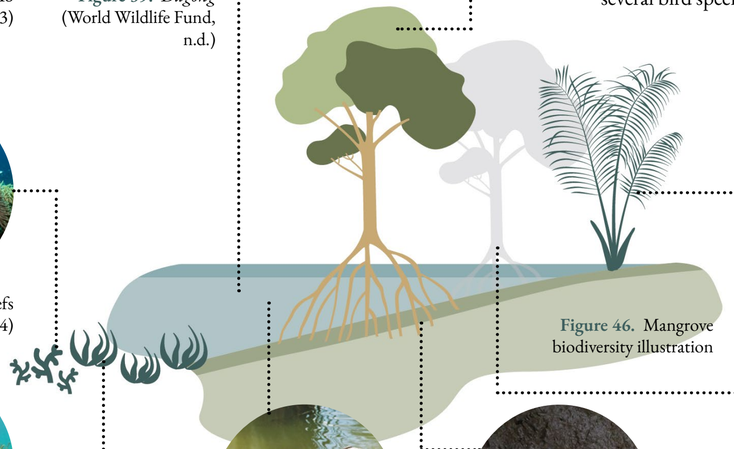


Figure 46. Mangrove biodiversity illustration

Figure 42. Saltwater crocodile (McPherson, 2024)

Figure 43. Mudcrab (Photograph by Robin Z., 2025)

Figure 44. Nypa f. (uforest, 2017)

Figure 45. Rhizopora m. (Photograph by Author, 2025)

3.3. Mangrove Ecosystem

A. Ecosystem values and services

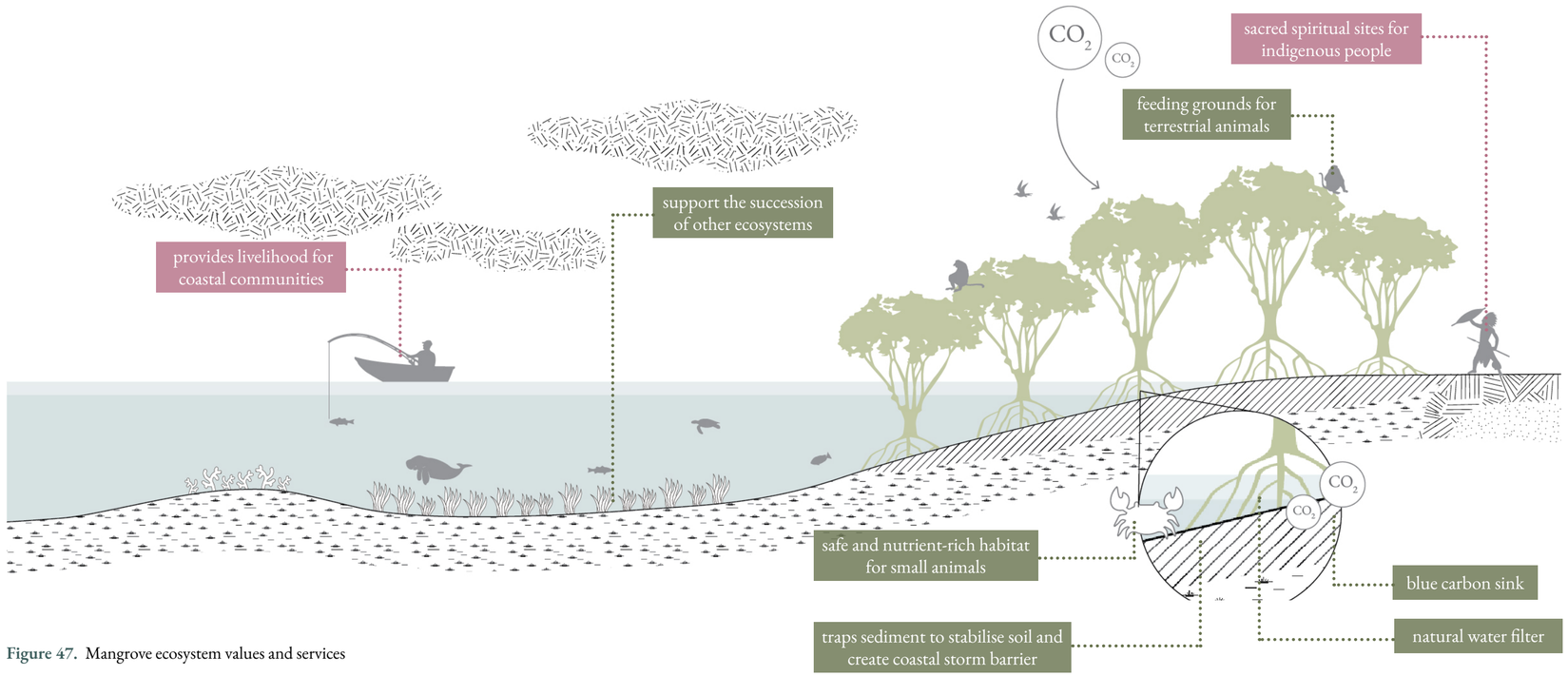


Figure 47. Mangrove ecosystem values and services

Mangrove forests are known as a productive wetland ecosystem, usually occupying intertidal zones (Chaudhuri & Choudhury, 1994; Kusmana, 2011a; Arfinati et al., 2021 in Haydar, 2023). They provide various ecosystem values and services that are identified into four major categories (Ecosystem Services, n.d.): supporting services, provisioning services, regulating services, and cultural services. Humans benefit from these services to maintain their well-being through obtaining the basic material of food, health, security, social, and cultural relations.

Regulating services. This ecosystem thrives along coastal brackish water, with complex root systems that trap sediment to stabilise the coastal soil and simultaneously attenuate waves to prevent risks of coastal flood and abrasion. It supports the regulation of climate, soil, and water. Given their high biomass and productivity, mangrove forests contribute to global models of carbon flows (Duarte et al, 2005; Alongi, 2009a in Spalding et al., 2010). As a blue carbon sink, mangroves sequester four times more and store ten times more carbon compared to terrestrial rainforests (Rani et al., 2023).

Provisioning services. Mangroves provide a critical habitat for marine animals to protect their juveniles from predators. At the same time, the small burrow crabs and shrimps support nutrient breakdown and transport, creating a natural water filter system. To humans, different parts of the mangrove provide food sources and raw materials. With the rich flora and fauna in this ecosystem, coastlines sprawled with mangrove forests are favourable for fishermen communities for livelihood and building settlements. They use timbers from the mangroves to build boats and houses or to transport them to the markets.

Supporting services. The existence of mangrove forests contributes to the sustenance of other ecosystem cycles. The nutrient-change process and water-filtration system support interlinking ecosystems of seagrass and coral reefs that provide critical habitats for other animals, such as fish, birds, monkeys, leopards, crocodiles, and turtles.

Cultural services. Mangrove areas provide opportunities for recreation, tourism, and educational purposes. For some native communities, mangrove forests are sacred due to their rich values. The Maridan and Balik indigenous people built ancestral tombs around these forests and used them as ritual sites. In the northern part of Balikpapan Bay, the Balik people protect a ritual site area where yellow-coloured mangroves grow, called *bakau lemit* or golden mangroves (AMAN, n.d.).

B. *Mangrove zonation and morphology adaptations*

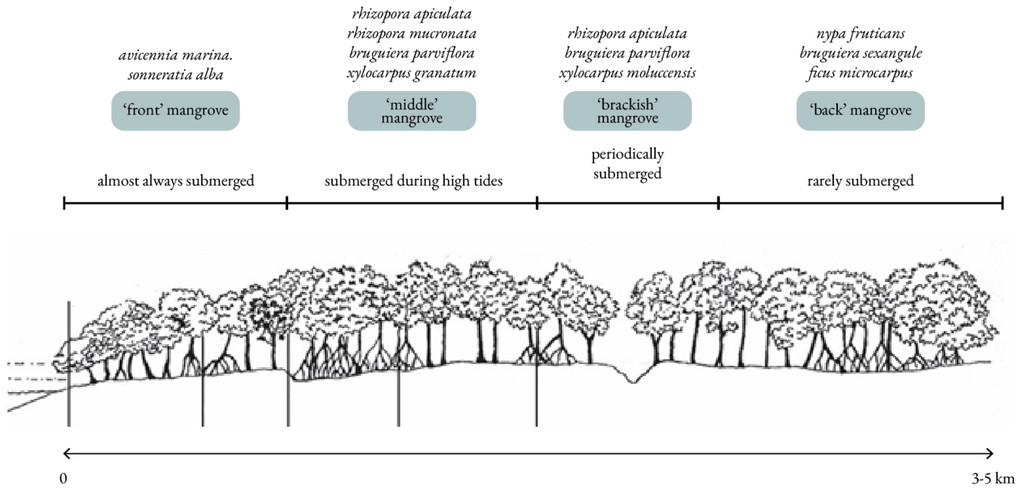


Figure 48. Mangrove zonation (Adapted from Noor et al., 2006)

Mangrove communities are never homogeneous; they show patterns of zonation in which the mangrove species' variations are determined by the structure and the adaptability to the environment that influences their survival and growth. Mangrove forests can be divided into four main zones: (1) 'front' or 'open' mangroves, situated in front of the open waters which require high adaptability towards tide flows and high salinity levels; (2) 'middle' mangroves; (3) 'brackish' mangroves, located in the mixed-water area of saline and freshwater; (4) 'back' or 'land' mangroves, where mangroves exist alongside other terrestrial forests (Noor et al., 2006). The species dominancy of each zone is indicated in Figure 33.

Indonesian people have different names in identifying mangrove trees. In Balikpapan Bay, the most dominant species are: (1) *Api-api* or Avicennia marina., often called "white" or "grey" mangrove due to its color, and can grow until 14 meters; (2) *Pedada* or Sonneratia alba, can grow until 15 m; (3) *Bakau minyak* or "red" mangrove or Rhizopora apiculata and *bakau hitam* or "red mangrove" or Rhizopora mucronata, can grow until 20-30 m; and (4) *Tanjang* or Bruguiera parviflora and Bruguira sexangula, can grow until 23 m (Haydar, 2023; Noor et al., 2006; Saenger, 2002; Spalding et al., 2010; Warsidi & Endayani, 2017).

The different conditions influence mangroves to adapt to their environment, which determines each species' different structure and morphology. The root systems of mangroves develop aerial roots to transport oxygen to waterlogged and anaerobic soils (Spalding et al., 2010) and take shapes in stilt roots, spike roots, knee roots, and buttress roots (refer to Figure 50.). To cope with salinity, mangroves actively exclude salt from their roots or leaves.

Establishing young mangroves in unstable substrates constantly washed by coastal currents affects a particular evolutionary way of reproduction. Most mangrove species are vivipary, in which the parent trees release fruits or propagules as young, growing plants, utilising the tides to float and disperse in water before settling in the watery soils. Some species, like *Avicennia sp.* and *Sonneratia sp.*, develop a condition of crypto vivipary, where the embryo remains inside the fruit wall until it breaks through when settled in. Besides its natural cycle, mangrove reproduction is done by humans in nurseries with seedling or wildling planting techniques before planting the young-adult trees in open waters.

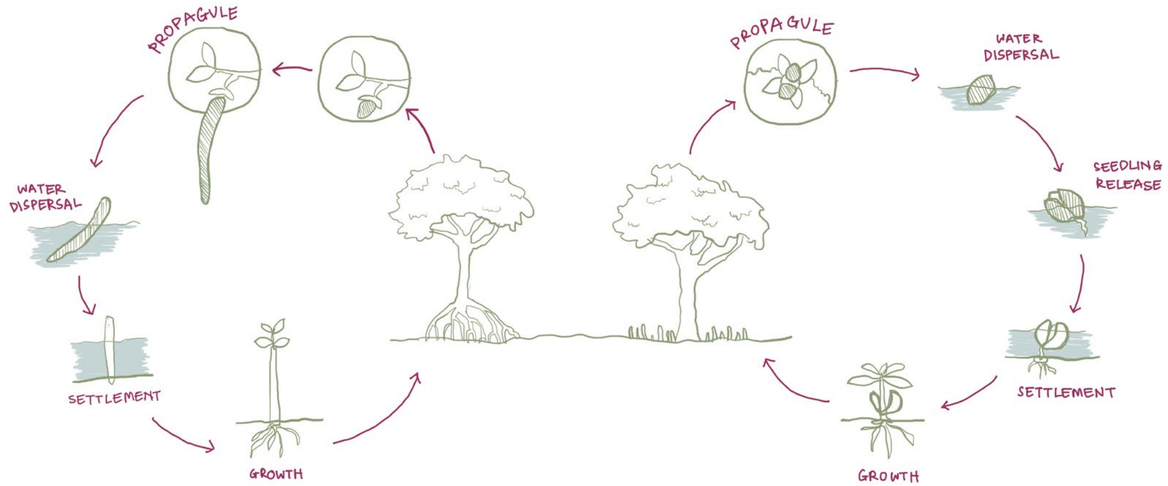


Figure 49. Mangrove life cycle

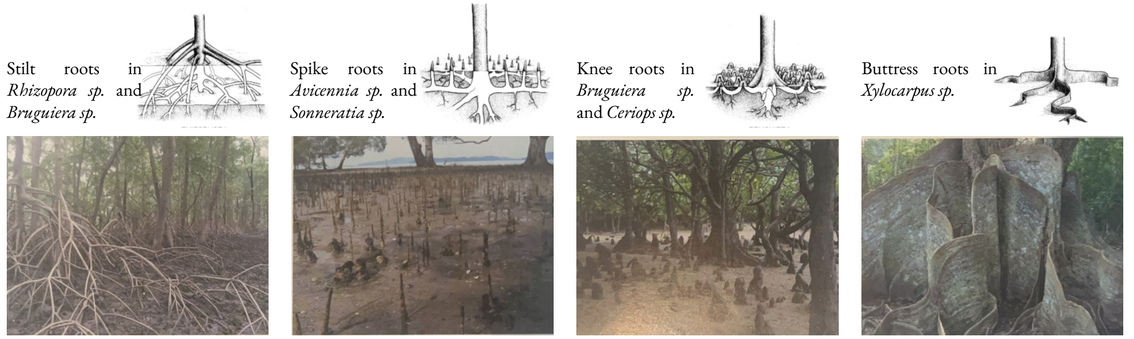


Figure 50. Mangrove root systems (MacKinnon, 1997; Spalding et al., 2010)

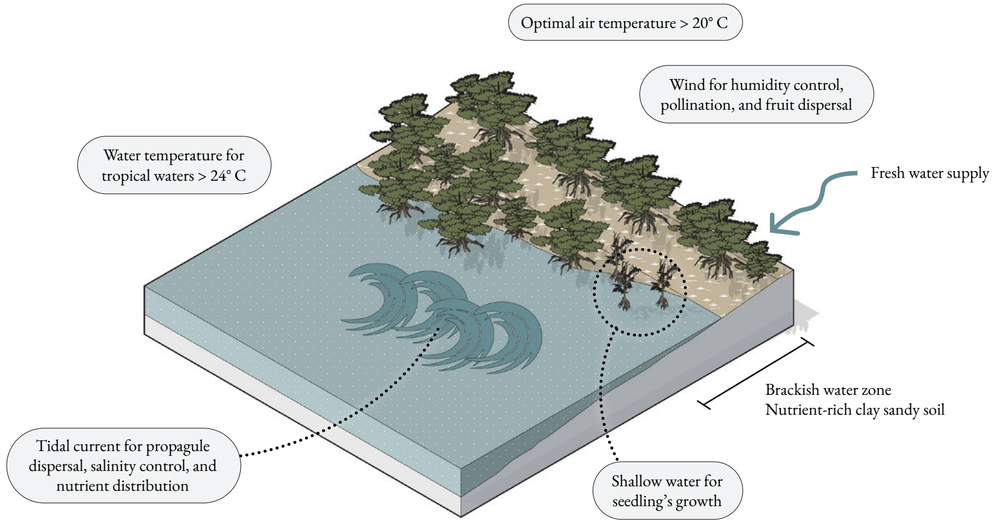


Figure 51. Biophysical conditions for mangrove ecosystem

Habitats of mangrove forests are intertidal zones bounded by harsh conditions of salinity and inundation. According to Spalding et al. (2010), they thrive in areas where seawater is diluted by mixed of rainfall, groundwater flows, and rivers, where mangroves can form extensive forests with canopy heights of 30 meters or more. Meanwhile, at other extreme where conditions are arid and exceedingly saline, trees can grow dwarf and only reach 1,5-3 meters in height.

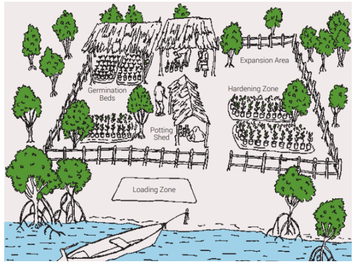


Figure 52. Mangrove planting in nurseries (The Nature Conservancy, 2020)

Figure 53. Exclusions of salt from leaves in Avicennia sp. (Spalding et al., 2010)

3.4. Climate Change Pressure

Climate change threatens coastal environments like Balikpapan Bay, as indicated by the sea level rise. This area becomes vulnerable as the bay area accommodates not only natural environments but also human settlements and economic activity centres. According to Sofian and Nahib (2010; in Triana & Wahyudi, 2020), sea level rise projection in Indonesia is estimated to reach 80 cm in 2100. However, when other factors such as the sea temperature rise are considered, the total rise in sea level can reach up to 1-2 meters by 2100 (Triana & Wahyudi, 2020). The rise of sea level can be influenced by a lot of factors and varies between areas. Based on another sea level study from 1993-2012, along the Balikpapan Bay coasts, the sea level rise rate is 5.4 mm/year (Putri et al., 2021).

Climate change causes uncertainties that result in extreme climate events. Coastal environments are prone to the risk of abrasion due to strong tides and currents, forcing the coastal communities to constantly adapt to the natural dynamics. Coastlines along Balikpapan use concrete breakwaters and seawalls; however, high tides and coastal floods destroyed these infrastructures, settlements, and other public facilities, constantly causing fear to the coastal communities (Ariyani et al., 2024).

Figure 54. Coastal infrastructure damage from coastal abrasion in Balikpapan (Ariyani et al., 2024)

3.5. Socioeconomic Pressures

Balikpapan bay extends between two major regions: Balikpapan City and Penajam Paser Utara Regency. Socioeconomic developments in both regions promote environmental degradation. According to a field survey report in 1999 (Malik et al., 1999), transportation, logistics, and construction activities around Balikpapan Bay were polluting the water.

Industry-led decision-making significantly affects the living and livelihood of the indigenous and local communities. The 2018's oil spill accident around Port Semayang impacted the decline of resources for fishermen, causing an estimated loss of 2.5 million euros that year (Oktawati et al., 2022). According to local fishermen, the increasing logistic traffic in the bay caused sonar pollution underwater, reducing the sight of pesut or porpoise (Baraputri, 2022). Following the Nusantara plan announcement in 2019, the residents of Sepaku villages—areas included in the new capital plan—were evicted from their houses and lands, despite Nusantara's concept of an "inclusive city" (Widadio & Budhi, 2024). The indigenous people's sacred spaces are also threatened; the bakau lemit or "golden mangrove" forest as the Paser and Balik indigenous groups' ritual site situated inside the Nusantara border face the challenge of destruction (Thalia, 2024).

Figure 56. Balikpapan Bay is located between two regions

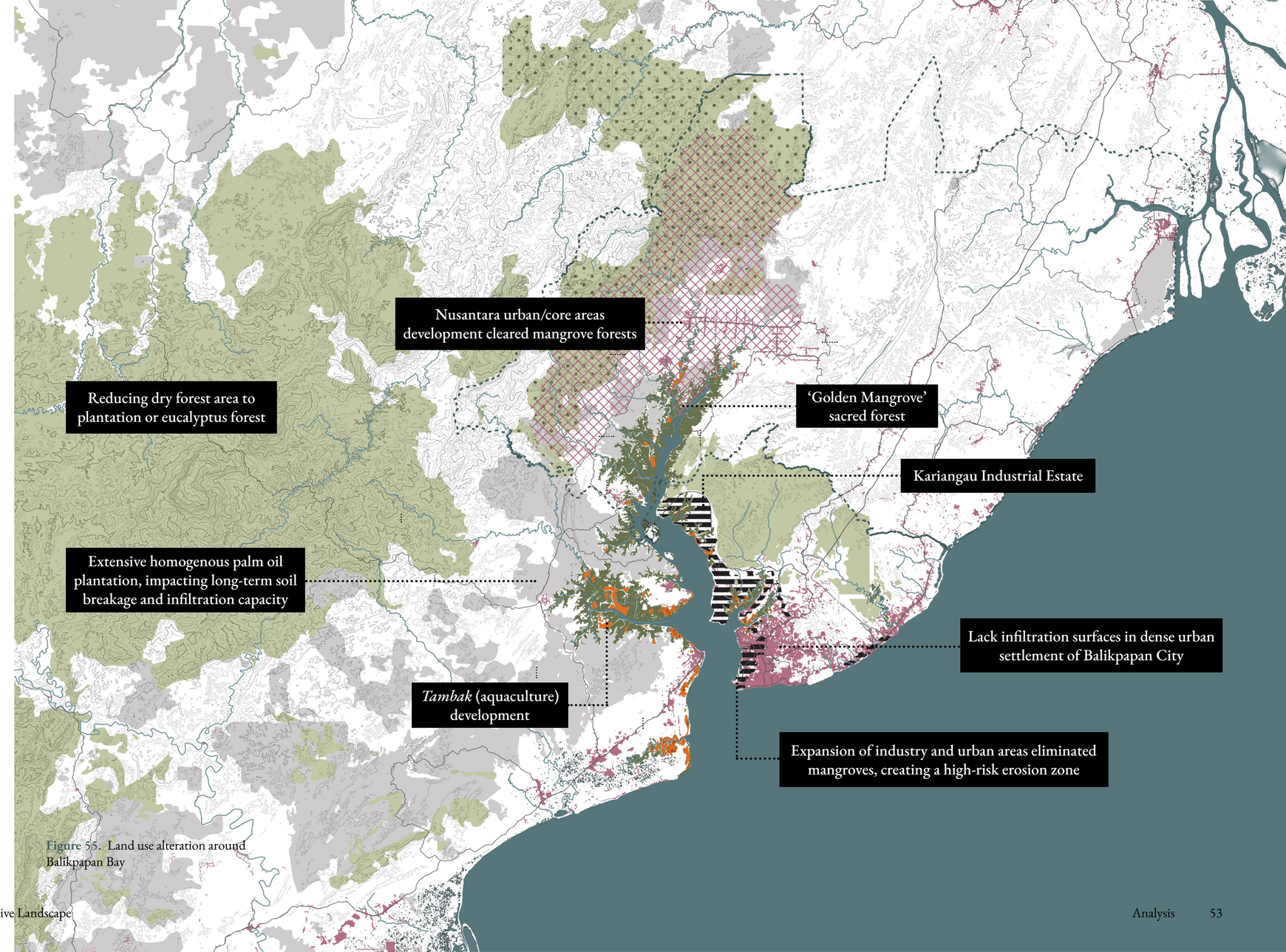


Figure 55. Land use alteration around Balikpapan Bay

A. Land use changes in PPU and Balikpapan

Extensive conversion of land use allows for more land clearing of the forests. In the current condition, the inland forests—the main promoters of hydrological health—have been largely converted into homogeneous palm oil plantations and eucalyptus forests. In some parts, the *tambak* or aquaculture practice rapidly grew and reduced the mangrove coverage.

Although Penajam Paser Utara (PPU) region is seven times larger, the development is currently not as prioritised compared to Balikpapan City. However, the land use change over the past decade needed attention, as almost half of the PPU area is included in the Nusantara New Capital development zone. According to a study (Permatasari et al., 2021), the largest land use cover in 2009 was the forest, while in 2020 more than 10% of the forests are shifted into plantations. In 2031, the study predicted a land use model which will have 55% plantations and 34% total of mangrove and inland forests.

Lack of mangroves means reduced natural capacity of flood prevention, increasing risk to coastal cities such as Balikpapan city. The current economy-driven policies have also enabled expansion of industries, with a new 5.000 hectares of designated area for Kariangau Industrial Estate (Saturi, 2012) next to Balikpapan City. Additionally, the construction of the Nusantara Capital intensifies the risk of environmental degradation along the bay with the upcoming development of new ports, airports, and urban areas.

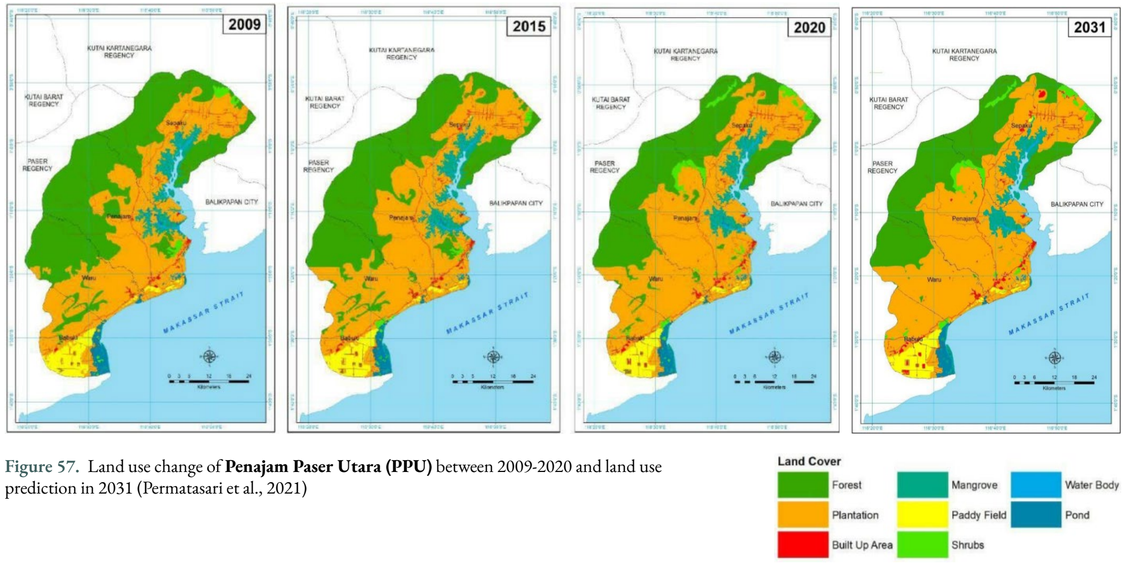


Figure 57. Land use change of **Penajam Paser Utara (PPU)** between 2009-2020 and land use prediction in 2031 (Permatasari et al., 2021)

Figure 58. Balikpapan RDMP (Refinery Development Master Plan) project in Balikpapan bay's coastline limits mangrove growth (Kompas.com, 2020)

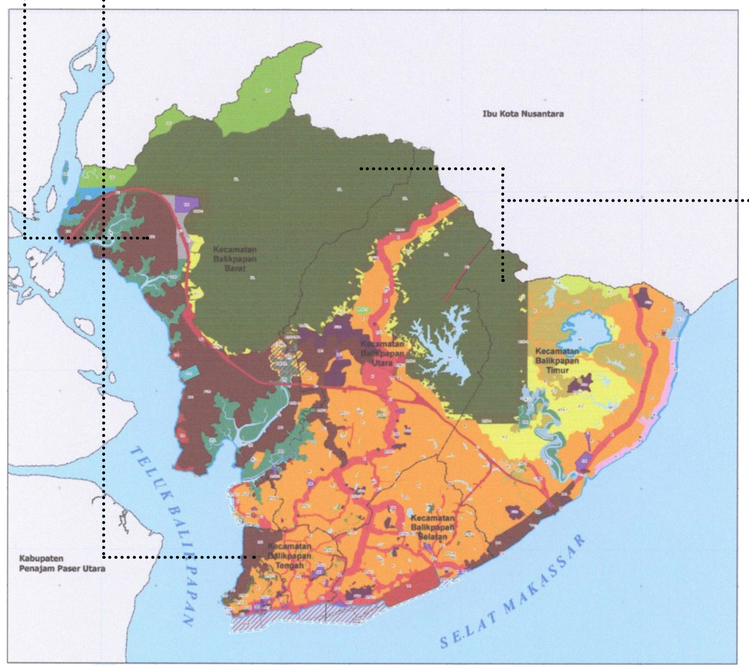


Figure 59. Regional 2024-2043 Spatial Plan of **Balikpapan City** (Municipal Government of Balikpapan, 2024)

Figure 60. Sungai Wain protected forest (Photography by Author, 2025)

B. The new capital city

The Nusantara new capital, located in East Kalimantan, was planned to reduce the socioeconomic and environmental burden on the overpopulated and sinking Jakarta, Indonesia's current capital city. The new capital is intended to promote distributive economic growth to other islands of Indonesia, which is now largely focused on Java island (BAPPENAS, 2020). The development of Nusantara will be included in the "Three City Ecosystem" along with the nearby Balikpapan and Samarinda cities, with their own regional roles. Therefore, networks between these cities will be improved by building new ports, airports, highways, and train rails.

Started in 2019, Nusantara construction is divided into phases, which will begin by developing the priority areas of governmental offices, followed by residential and facility areas, along with the development of the environmental protection zones. According to the Nusantara Biodiversity Management Plan (Nusantara Capital Authority, 2024), there are seven zones (refer to Figure 62.) with high biodiversity value within and around Nusantara boundaries as a part of the strategies in biodiversity conservation to realise the "Forest Smart City" concept of the new capital.

These concerns towards environmental protection hold a significant role in amplifying the potential of Nusantara as a leading and exemplary sustainable urban development. However, the construction of the new capital has so far led to environmental degradation—specifically in the Balikpapan Bay area, which is impacted by the pollution from industrial and logistic activities—and the removal of some local communities. Road development to connect the main hubs of Nusantara also threatens the mangrove forest around Balikpapan Bay.

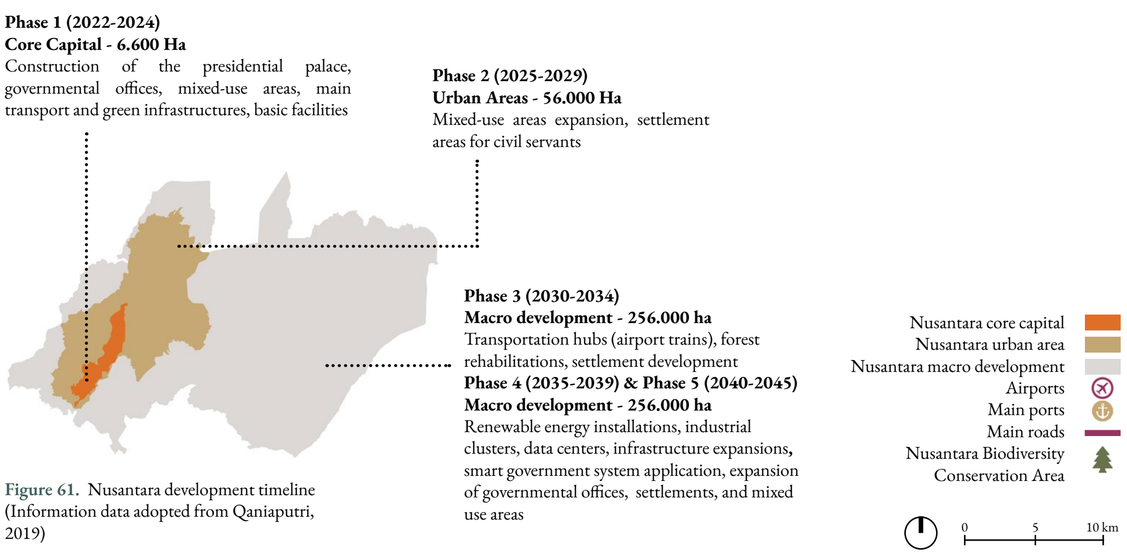


Figure 61. Nusantara development timeline (Information data adopted from Qaniaputri, 2019)

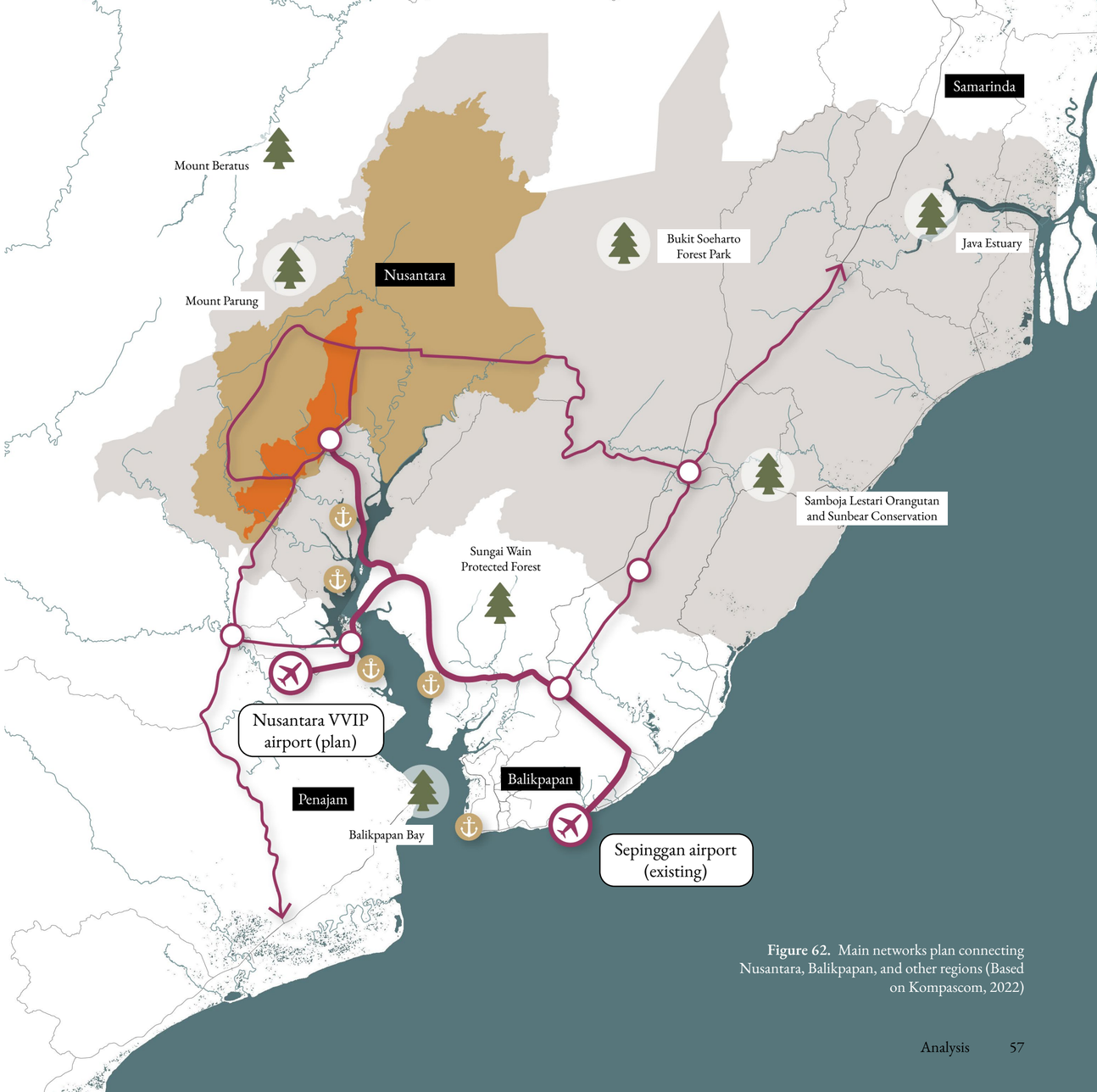


Figure 62. Main networks plan connecting Nusantara, Balikpapan, and other regions (Based on Kompascom, 2022)

3.6. People and Cultures Around Mangroves

Since Indonesia's older days, settlers inhabited Balikpapan Bay, leaving traces of history and cultures. There are still several native groups living around the forests, where several others have already merged with the local communities living close to the urban areas. As a productive ecosystem service resource, mangroves stimulate different livelihood activities, such as the fishermen communities. With the current declining state of the mangroves, local initiatives for restoring the forest are flourishing, mainly in Balikpapan City.

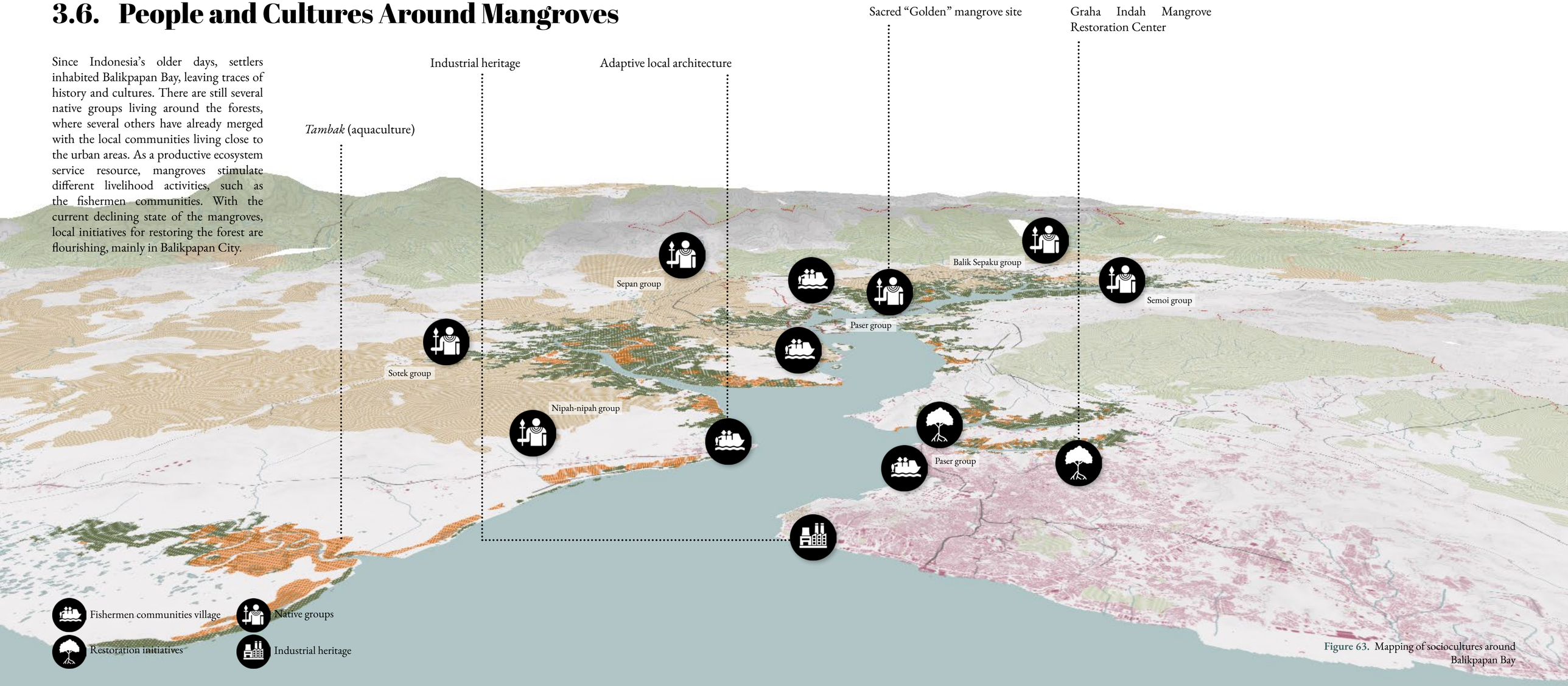


Figure 63. Mapping of sociocultures around Balikpapan Bay

A. Tambak (aquaculture)

Tambak or aquaculture is a widespread economic culture that cultivates fish, shrimp, or seaweed in constructed ponds. *Tambak* is closely related to coastal communities which benefit from brackish and saline ocean water. In Balikpapan bay, the ponds are as large as 2-10 hectares and monocultural, often taking the space of mangrove forests to utilise the natural tide flow for water supply of the traditional *tambak* system. At certain times during the early cultivation phase, fishermen also use the tide to bring the commodity (fish, shrimp, or crabs) into the ponds.

Based on the site visit to Delta Mahakam, the owners of large *tambak* ask fishermen to do the whole cultivation process, including the pond maintenance. After the harvesting period, yields will be given to the owner based on the initial agreement. Any excess results from the catch can be given to the workers. Around Balikpapan Bay, *tambak* takes up the total space of **2.300 hectares**, with almost 40% existing in the former mangrove forests area.

Figure 64. 12 hectares *tambak* pond in Delta Mahakam Samarinda (Photograph by Author, 2025)

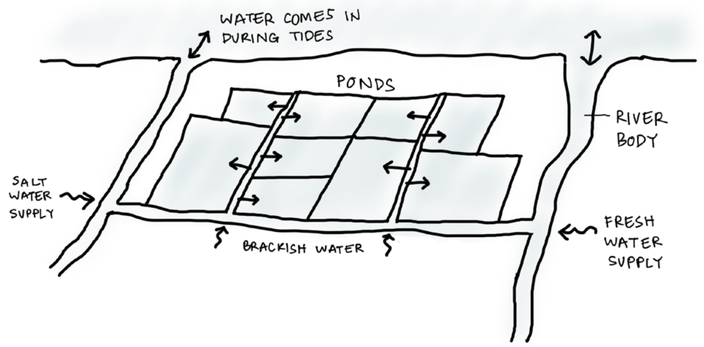


Figure 65. Above – Typical water supply system diagram in traditional *tambak*

Figure 66. Below – Mapping of *tambak* (orange shade) in Balikpapan Bay

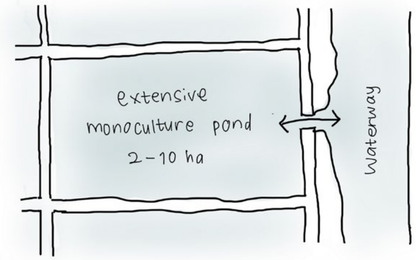


Figure 67. Typical typology of traditional *tambak*

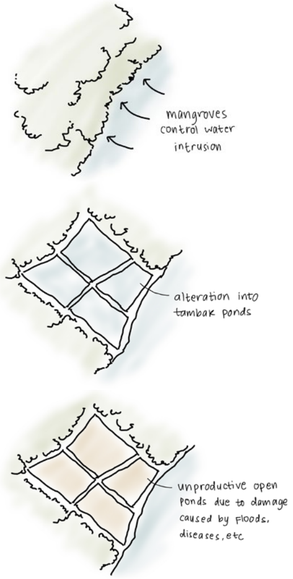


Figure 68. Alteration of mangroves into *tambak* ponds

In their natural state, mangroves have the natural capacity to attenuate waves and prevent coastal floods. *Tambak* requires space and forces the clearance of mangrove forest patches, further reducing their flood prevention capacity. After some time, these ponds can become unproductive due to damage from floods or diseases, leaving an abandoned empty space.

Several *tambak* in Delta Mahakam integrate mangrove planting within the ponds (refer to Figure 69.) to provide natural shade for the animals and to control water quality. However, without active periodical maintenance, fallen leaves from the trees cause eutrophication (nutrient excess), which makes the pond water toxic and reduces the commodity's productivity.

The *tambak* system profits from mangrove's "provisioning" **ecosystem services**. It depicts the "cultural" value of local coastal communities, but on the other hand weakens the "regulating" services of mangrove as a natural flood control.

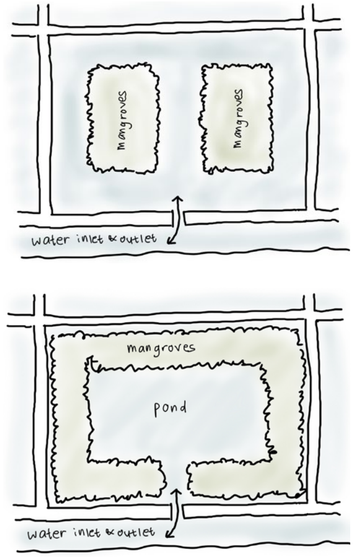


Figure 69. Diagram of mangrove planting inside the *tambak* ponds

Figure 70. Ecosystem services value in current situation

Figure 71. Sights of abandoned unproductive *tambak* in Balikpapan Bay (Google Earth, 2025)

B. *The indigenous forest*

The Dayak indigenous groups have long inhabited the forests around Balikpapan Bay. Today, they are threatened following the construction of the new capital, expansion of production forests, and other industrial development, putting pressure as they witnessed the removal of their sacred site (Widadio & Budhi, 2024). The native groups owned the **traditional ecological knowledge** to respect and protect nature's cycles. Shifting cultivation is a technique adapted from the traditional **swidden agriculture** practice, to cultivate a small patch of forests instead of extensive exploitation, and later reforest the cultivated area.

In Mentawir, the Paser indigenous people practice *bersoyong*, a ceremony to ask for their ancestors' permission to 'harvest' the *lati tuo* or old forest. For Maridan and Balik indigenous people, ancestral tombs were built around these forests and used as ritual sites. Mangrove forests, for some native groups in Balikpapan Bay, are sacred for their rich values. In the northern part of Balikpapan Bay, the Balik people protect a ritual site area where yellow-coloured mangroves grow, called *bakau lemit* or **golden mangrove** (Ayunda, 2025).

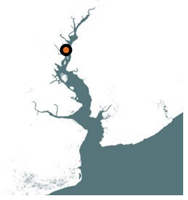


Figure 74. The 'golden' mangrove location

Figure 72. The 'golden' mangrove (Tempo & Paskalis, 2024)

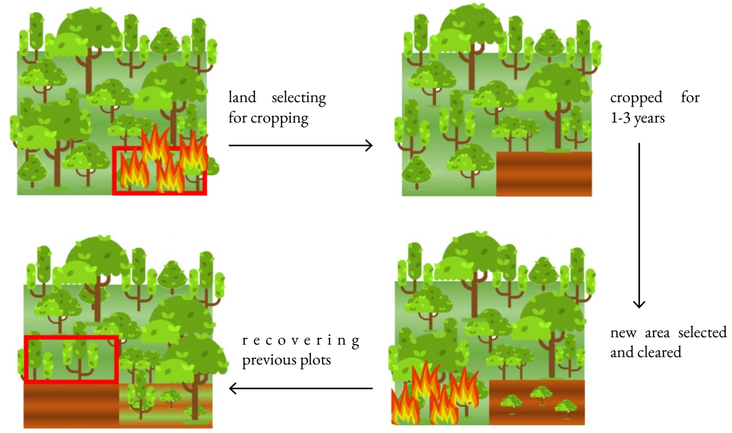


Figure 73. Traditional swidden agriculture practice (adapted from Morton, 2020)

C. *Local restoration initiatives*

Several mangrove restoration efforts have already been initiated to respond to the degradation of the mangrove forests in Balikpapan Bay. The initiatives came from local communities, private companies, NGOs, and others. In Balikpapan City, the Mangrove Center Graha Indah started small in 2001 and was initiated by a resident of a neighbourhood located next to the mangroves. Agus Bei, the owner, studied how mangrove live and grow, and experimented how mangrove can thrive, rooted from his concern about the declining mangrove in his neighborhood's 'backyard'. Since then, he **revitalised 150 hectares** worth of **one million mangrove trees**, received an environmental award from the government, and have collaborated with several national and global stakeholders not only for **restoration** projects, but also for **education and research.** Agus helped with restoration projects in different locations, including in the open coast area where simple planting will not work due to strong tides and certain techniques were needed. In the Mangrove Center, Agus provides educational and tourism services through boat trips throughout the mangrove forests. Simultaneously, the initiative helped with bringing back hundreds of *bekantan* monkey to their mangrove habitat.

Figure 75. The Mangrove Center Graha Indah location

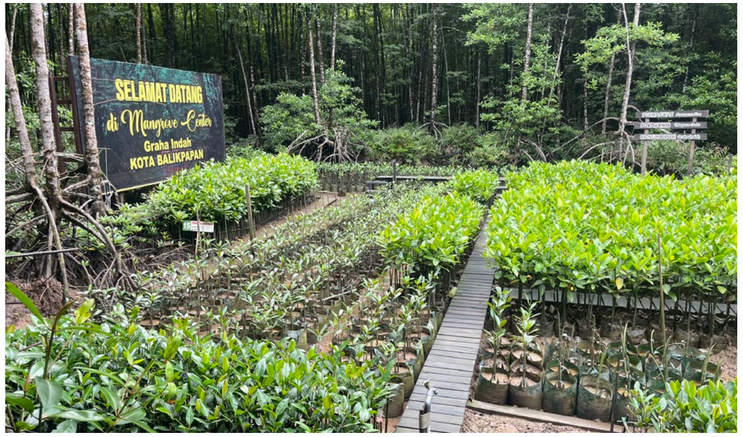


Figure 76. Nursery center of Mangrove Center Graha Indah (Photograph by Author, 2025)

Figure 77. Boat trips through the mangrove forests in Mangrove Center Graha Indah (Photograph by Robin Z., 2025)

D. The industrial heritage

1897 marked the first oil well establishment in Balikpapan City by the Dutch colonials, where the expansion of urban settlements followed afterwards and built the present 'Oil City'. The Mathilda well was closed only 6 years later. Still, it initiated the development of a large-scale oil extraction that yielded 32.618 oil barrels annually. Today, a national oil company owns the site and has expanded into crude refinery businesses. The site is now a national strategic asset with processing capacity up to 360.000 barrels per day (Brelsford, 2019).

The existence of a heritage with a cultural and economic value, in this case, impacted the mangrove forest's existence as the industrial expansion will perpetuate mangrove elimination and increase water and air pollution. The 2018 oil spill (refer to Figure 9.) happened in this area, killed several anis and heavily polluted the bay water, while the refinery is located only hundreds of meters from a nearby fishermen village. During the fieldwork, the Author visited the village and experienced the smell of smoke sourced from a nearby combustion chimney. According to one of the villagers, they are already used to the smoke, as there will be a worse smell when the company combusts their waste. As a part of the company's social responsibility project, mangrove restorations are done alongside the site's hard edges next to Balikpapan Bay, in collaboration with the local communities of the fishermen village.

Figure 78. Refinery Development Master Plan (RDMP) Project in Balikpapan (ESDM, 2024)

Figure 79. Mangrove restoration initiated by the oil company (Photograph by Robin Z., 2025)

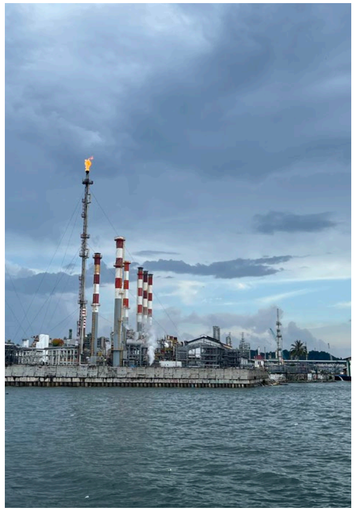


Figure 81. View from the fishermen village (Photograph by Author, 2025)

Figure 80. The refinery location

E. Adaptive local architecture

The local values in Kalimantan include its traditional architecture style of long houses (rumah lamin, rumah betang panjang, etc.), typically shaped as a large, elongated house and can be inhabited by 3-5 large families. Longhouses consisted of three main parts: 'above' (roof), 'middle' (body or house), and 'below' (footings or foundations); each as a depiction of the anatomy of head, body, and feet. The 'below' part is typically constructed of tall footing columns and leaves a hollow space under the house, typical for Indonesian vernacular architecture. In Kalimantan, the hollow underground serves a practical function of preventing wild animals from entering the house, or to adapt to flood risks. For coastal communities, stilted houses with long footings are built to float the houses above the water.

Figure 82. A modest house that adapted local architectural style inland (Photograph by Author, 2025)

Figure 83. Floating houses of coastal villages (Photograph by Robin Z., 2025)

Figure 84. Location of coastal communities with stilted houses

3.7. Stakeholder Analysis

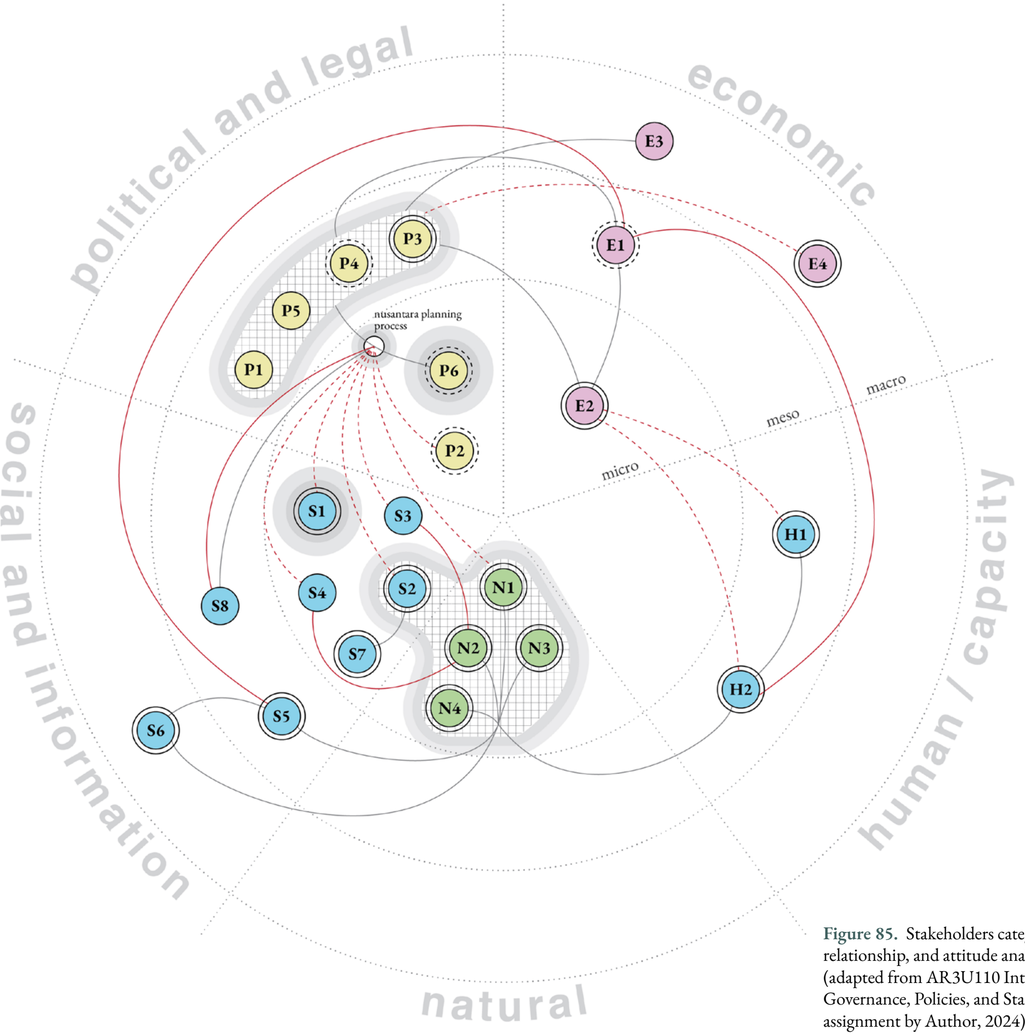


Figure 85. Stakeholders categorisation, relationship, and attitude analysis (adapted from AR3U110 Intensives: Governance, Policies, and Stakeholders assignment by Author, 2024)

Public sector
- P1 Ministry of National Development Planning
- P2 Provincial government of East Kalimantan
- P3 Ministry of Forestry
- P4 Ministry of Public Works and Housing
- P5 Ministry of Agrarian Affairs and Spatial Planning
- P6 Nusantara Authority

Private sector
- E1 National oil company, construction & logistic industry, plantation and *tambak* owners
- E2 Industrial planning consultants
- E3 Investors
- E4 Conservation trusts & foundation

Civil society
- S1 Coastal and fishermen communities
- S2 East Kalimantan native groups
- S3 Urban population
- S4 Rural population
- S5 Indonesian environmental NGO & advocates (WALHI, YKAN) as nature representatives
- S6 Global environmental NGO (WWF, IUCN, Mangrove Action Project)
- S7 Indonesian ethnic groups representatives
- S8 Media outlets
- H1 Research & academic institution
- H2 Landscape practitioner

Non-human
- N1 Mangrove forests
- N2 Balikpapan Bay
- N3 Animal & plants species
- N4 Forests

Relationship
- Collaboration
- Lack of connection
- Conflict
- Strong connection
- Significant stakeholders

Attitude
- Proponents
- Opponents
- Fence-sitters

A. Position and attitude

Socioeconomic pressures that threaten the survival of the mangrove forests are the result of the decision-making of different roles in society and have impacted a lot of other stakeholders including non-human ones. In this categorisation model, the stakeholders are mapped out based on the scale, their sectors, and how they relate. This diagram also informs the attitude of each stakeholder towards mangrove regeneration projects. The proponents supporting the project are either directly impacted by the cause, such as local fishermen communities or NGOs in similar fields. The opponents are parties that will risk losses from the project, such as the unsustainable business industry. The fence-sitters have no clear position towards the project.

Including the natural environment as a non-human stakeholder is essential in addressing climate change, promoting sustainability, and emphasising environmental protection. The indigenous groups have long recognised nature as a living entity and practised harmonious coexistence, therefore developing strong connections with nature. Local residents, such as those in coastal communities including the fishermen, also benefit from the ecosystem services of the mangroves for their livelihood. However, current developments and modern society often disregard the interests of nature and intensify natural degradation, including the Nusantara planning process cooperated by the Nusantara Authority and national ministries. Habitat loss also has severe consequences for both urban and rural populations, as displaced wildlife begins to enter human settlements and is often perceived as harmful. Further, humans then started to harm and hunt these animals.

Stakeholders in the public sector come from decision-making power, especially the ministries, with each possessing different interests. Some ministries have opposing attitudes due to concerns of limitation impacts on their project's timeframe. During 2020-2022, the number of Indonesians who disagreed with the capital relocation plan increased from 33.6% to 48.5% (Muhtadi, 2022). The media covers these dynamics of public opinion with various approaches from both supportive and opposing perspectives, creating either collaboration or tension with the governmental authorities. In the economic capital realm, private entities such as the oil company, different industries such as the plantation and *tambak* owners, favour economy-oriented policies but are in tension with sustainability-oriented practitioners, researchers, and NGOs.

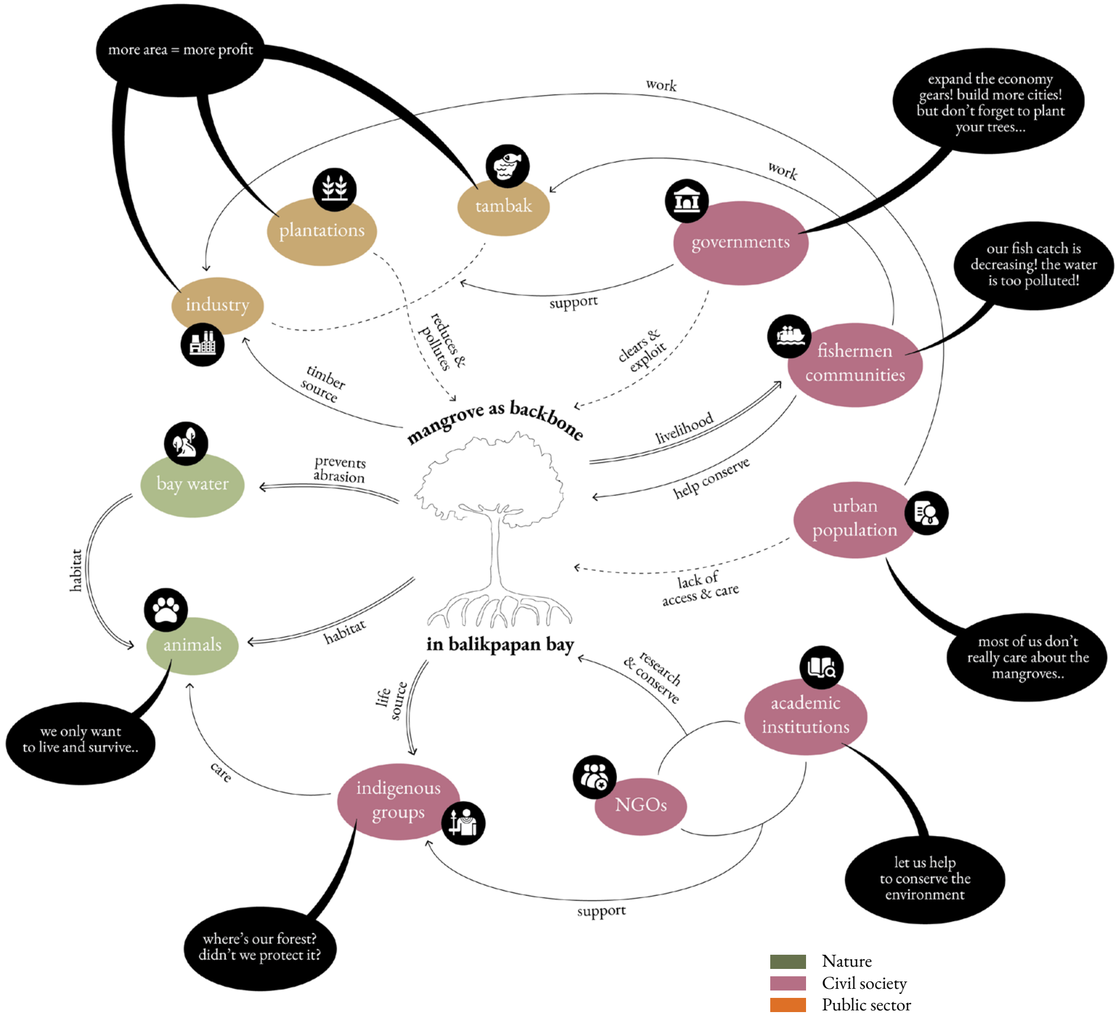


Figure 86. Stakeholders interests surrounding the mangroves

B. Different interests around the mangroves

Recognising different stakeholders, including the non-human ones, helps to understand different concerns and interests that impact the current state of the mangrove ecosystem in Balikpapan Bay. This diagram includes how each actors perceive the mangrove ecosystem, their relations, and their interests, based on the desk study and from interviews during the site visits fieldwork. For some actors, the mangrove ecosystem is a source of life, while others perceive it as an economic resource. Several actors did not interact directly with the mangroves, but their activities impact mangrove life. From the current policies study, including the spatial planning documents, governmental regulations are leaning towards economic growth. During 2020-2024, protected forest area in East Kalimantan reduced by 6%, while the total area designated for production forest was stable and occupied twice the amount area of the protected forest (BPS, 2022). The expansion of land use for economic purposes and industrial zones, including the plantation and *tambak*, perpetuated the reduction of the mangrove forests in Balikpapan Bay.

Figure 87. Different actors relationships with the mangroves. Top: saltwater crocodile sunbathing under mangrove trees (Photograph by Robin Z., 2025); Middle-upper: fishermen village within the mangroves (Photograph by Author, 2025), Middle-lower: altered mangrove into aquaculture (Photography by Robin Z., 2025); Bottom: oil well taking up mangrove forest space (Photograph by Author, 2025)

3.8. Analysis Conclusions

From the analysis process of unravelling the "layers" (refer to Figure 28.), there is a complex and dynamic system that entails the mangrove ecosystem in Balikpapan Bay, which growth and decline were results of various social-ecological relationships through years. Considering the different current mangrove states in Balikpapan Bay, there are three main zones determined by the alteration levels of the mangrove forest. Each of the zones poses challenges and potentials described in the following illustrations, where there are several typical issues happening in these zones.

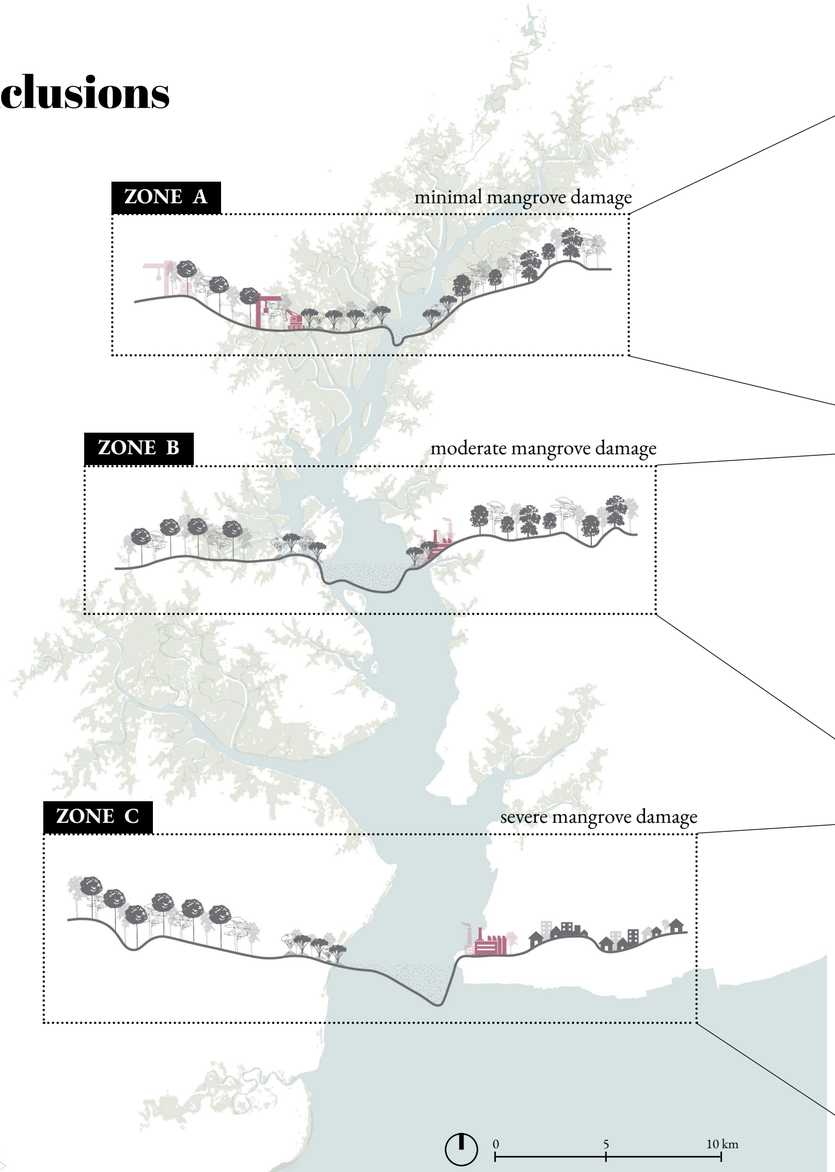


Figure 88. Conclusion map and sections of the analysis

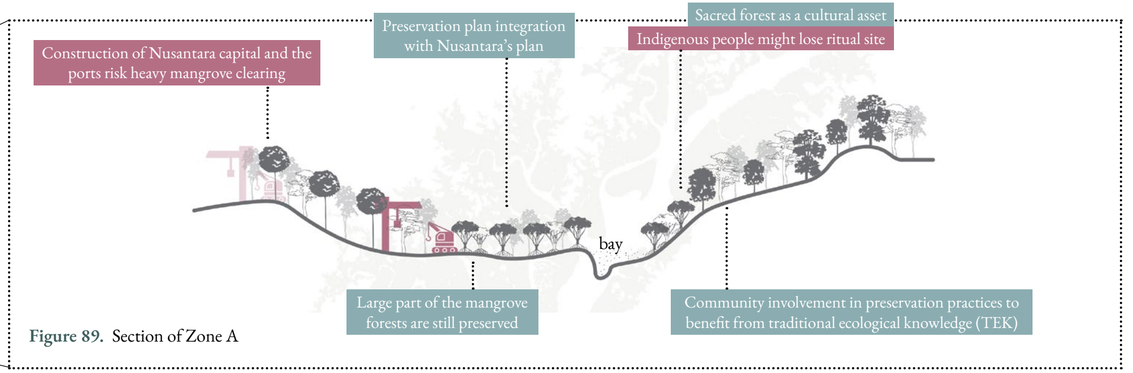


Figure 89. Section of Zone A

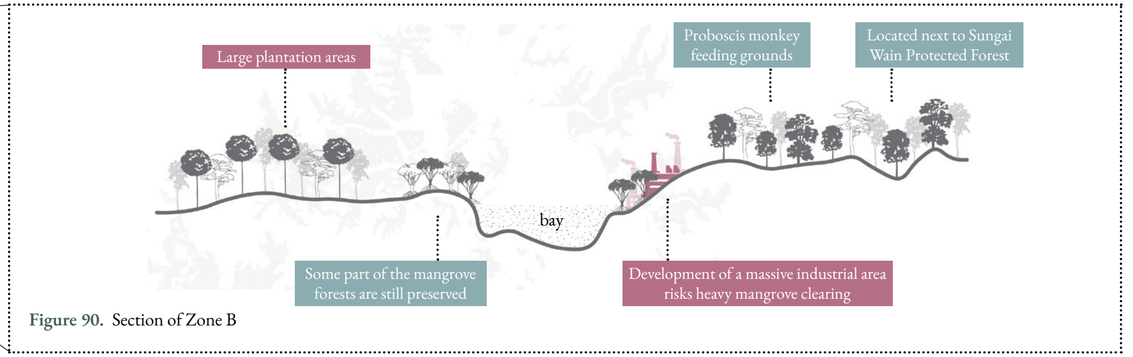


Figure 90. Section of Zone B

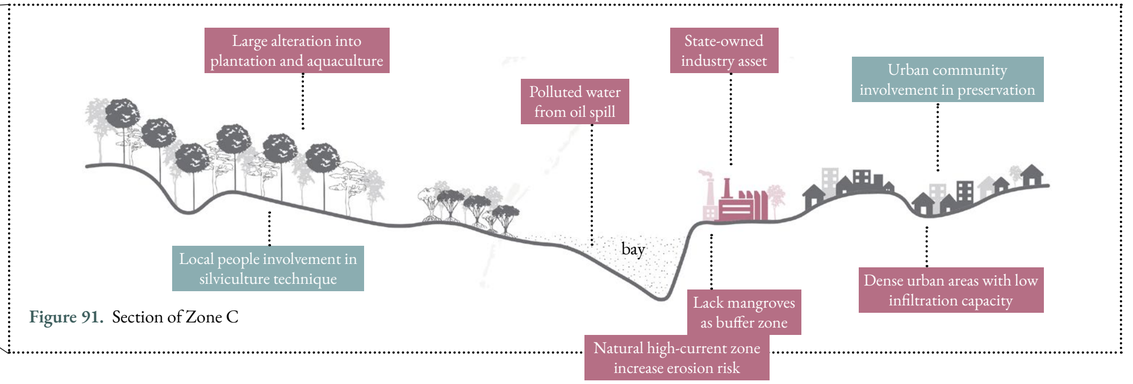


Figure 91. Section of Zone C

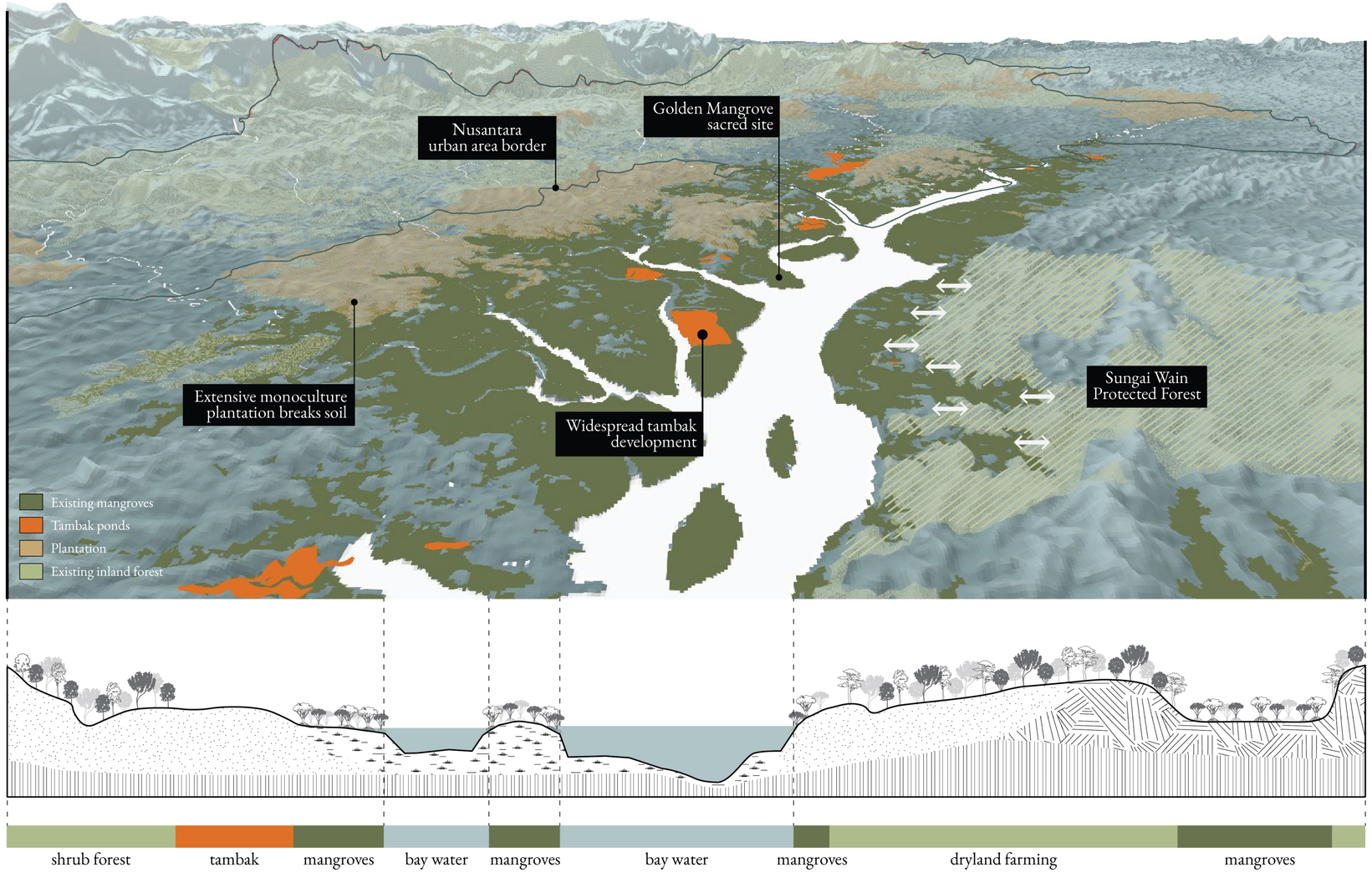


Figure 92. Mapping and section of Zone A

A. Current conditions in Zone A

The northern part of Balikpapan Bay is included in the Nusantara New Capital development, posing a threat to the mangrove forests due to heavy clearing for urban activities. Currently, with minimal damage, large parts of the mangrove forests are still preserved, but not without the upcoming challenges of the development of new settlement areas, transportation routes, ports, and others. In the current condition, Balikpapan Bay is the logistic route for containers bringing construction materials to Nusantara's new ports, which impacts the water quality and causes noise disturbance to nearby marine animals. Outside Nusantara, the inland forest suffers from degradation to make way for plantations. In some parts, around 136 out of 6.900 hectares (2%) of the mangroves are cut down to become *tambak* or aquaculture.

Close to one of Nusantara's ports is the Golden Mangrove site belongs to the Balik indigenous groups as their sacred forest. This area is vulnerable to being cut down due to its proximity to Nusantara's area. However, the sacred site delivers a significant cultural value that needs to be preserved, bringing a potential for reinforcing forest protection as a cultural asset in integration with Nusantara's development plan. The eastern side of this zone is adjacent to the Sungai Wain Protected Forest, in which inland forests can be a feeding ground extension for mangrove's animals, such as the *bekantan* monkey.

Figure 93. Right – Land clearing started to open areas for Nusantara development in Zone A (Google Earth,2024)

Figure 94. Below – Satellite view in Nusantara site in 2022 and 2024 (Novrian, 2024)

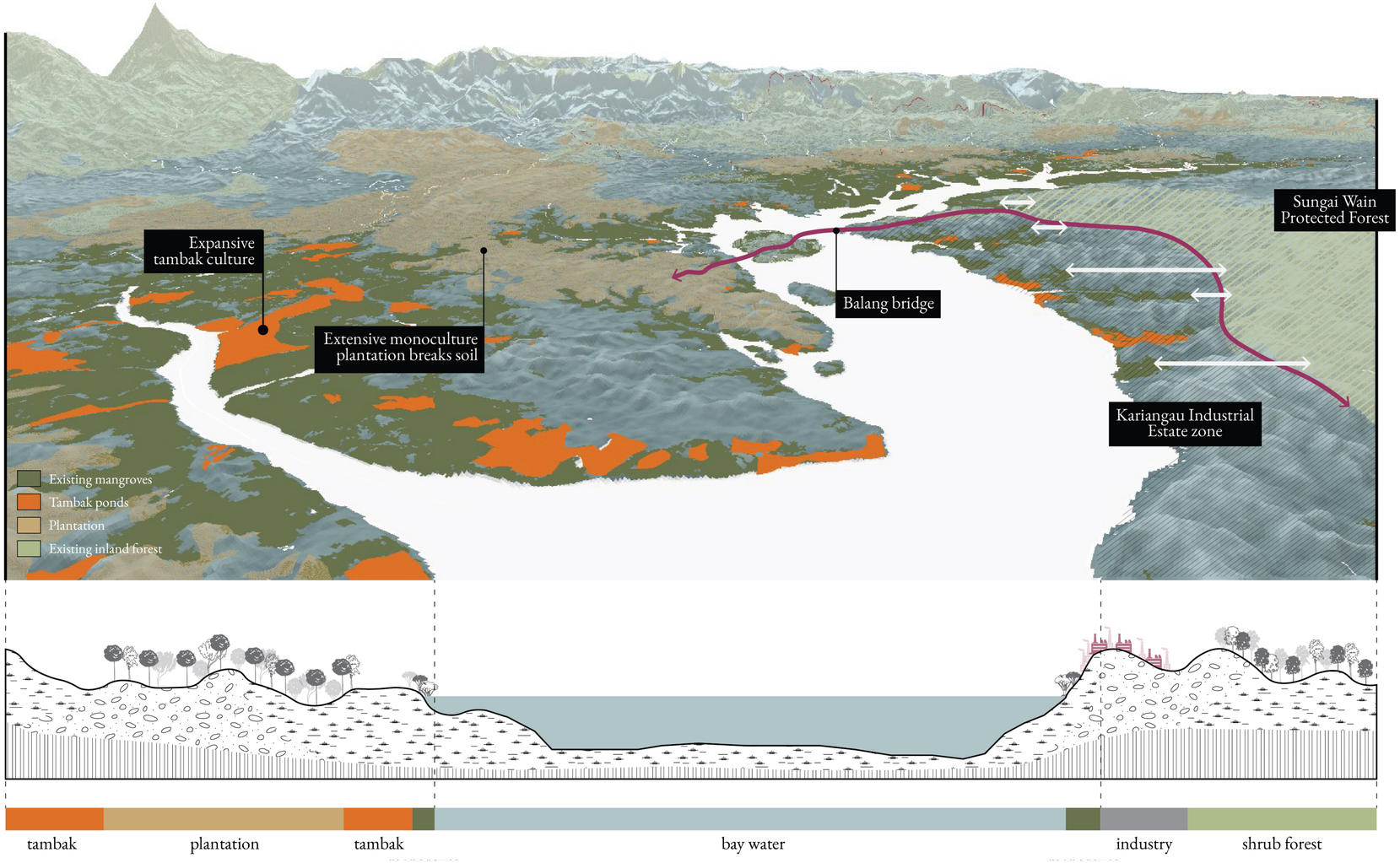


Figure 95. Mapping and section of Zone B

The middle part of Balikpapan Bay still has most of its mangrove intact. However, 7.7% (609 out of 7.900 ha) are shifted into *tambak* and the inland forests are already largely altered into plantations, considering this zone as an area with a moderate damage to the forests. The eastern part of this zone is currently a dedicated industrial zone called Kariangau Industrial Estate of 2721 hectares, targeting agro-industries, construction, oil, and gas companies, timber and manufacturing industries, and transportation industries (Mulyadi, 2019). In 2015, the 800-meter Balang bridge started building, aiming to connect Balikpapan, Penajam Paser Utara, and later to provide convenient access to Nusantara. However, the bridge's construction had contributed to mangrove clearance in that area. This demonstrates more upcoming challenges from the industrial zones to the existence of local mangrove forests.

On the other hand, the industrial zone and the connection roads are located next to the Sungai Wain Protected Forest. Similar to zone A, with a landscape-based approach, preservation of the mangrove forests can emphasise and go hand in hand with providing an ecological corridor to animal species living in the mangrove forests.

Figure 96. Right – Mangrove clearing for industrial roads construction in Kariangau Industrial Estate in Zone B (Google Earth, 2025)

C. Current conditions in Zone C

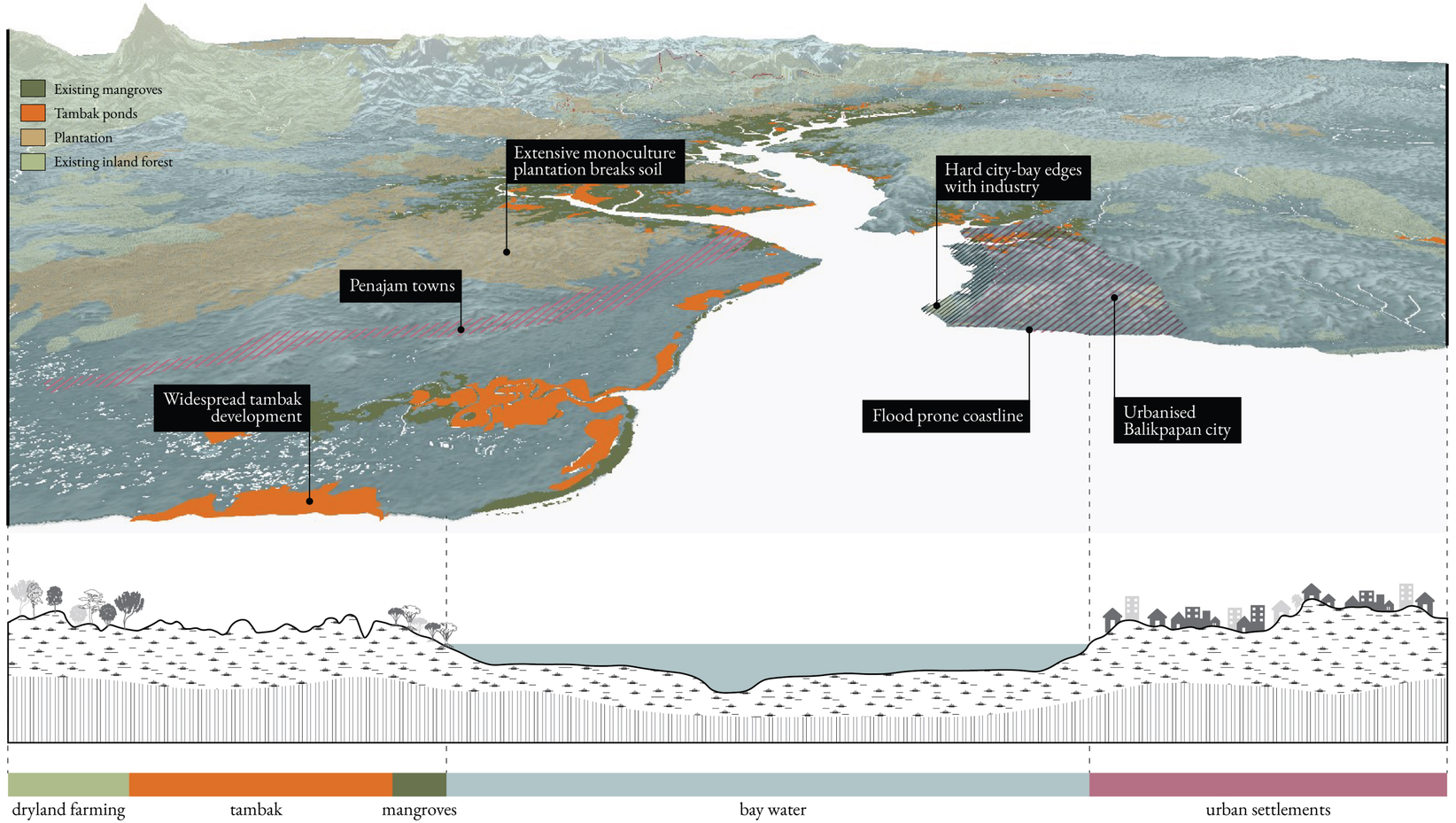


Figure 97. Mapping and section of Zone C

This zone has the most severe damage to the mangrove forests, with very little coverage on the coastlines of Ba-likpapan City, which is now mainly covered by industrial areas. Due to the strong natural current in this area, the Balikpapan coastlines are vulnerable to abrasion and coastal floods without the mangroves as a natural wave bar-rier. Polluted water from the city gets discharged directly to the bay without the natural water filter, while the industry occupying the coastline certainly contributed significantly to the polluted bay water. In the western side, with the growth of Penajam town and villages, large parts of the mangroves are altered into *tambak* with several fishermen communities living in this area. Out of only 770 ha of the mangroves here, 131.9 ha (17.1%) is becoming *tambak*.

However, the urban communities in Balikpapan City hold the potential to be collaborated into creating new restoration initiatives. Currently, there are already several small-scale restoration projects in different areas. The amount of existing *tambak* can be reused for mangrove regeneration sites.

Figure 99. Right above – Industry along Balikpapan City's coastline (Photograph by Author, 2025)

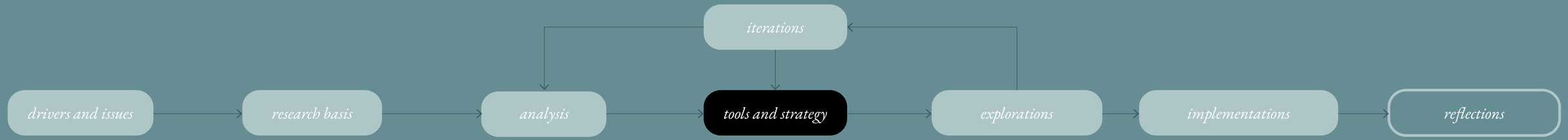
Figure 98. Right below – Failed seed mangrove cultivation due to water pollution from oil spill in Zone C (Anwar et al., 2021)

04

design principles

ideating solutions

After completing the analysis part of the research, the process continues to the design process. This chapter talks about the start of solutions ideation through creating sets of principles, followed by design tools to facilitate the implementation of the strategies. The second part of this chapter provides several best-case studies that helped in building this research and design project.



4.1. Design Principles

The Author proposes initial design principles to enter the design processes after analysis in this P2 report. This framework states five design principles formulated from ideas mentioned in the conceptual framework (refer to Figure 22.), and enriched with the analysis results that are based on the "layers" approach (refer to Analytical Framework in Figure 28.).

Ideas from the conceptual framework—design with nature, people, and synergy—suggested the human-nature relation in a complex dynamic system (refer to Theoretical Framework in Figure 17.), which, to make it work and achieve goals, needs to be addressed holistically and considered in a synergical system. The three over-arching design principles are extensions of the main concepts, and the following smaller design principles are translations into more context-based ideas, facilitating achieving the objective of shaping a regenerative mangrove landscape ecosystem.

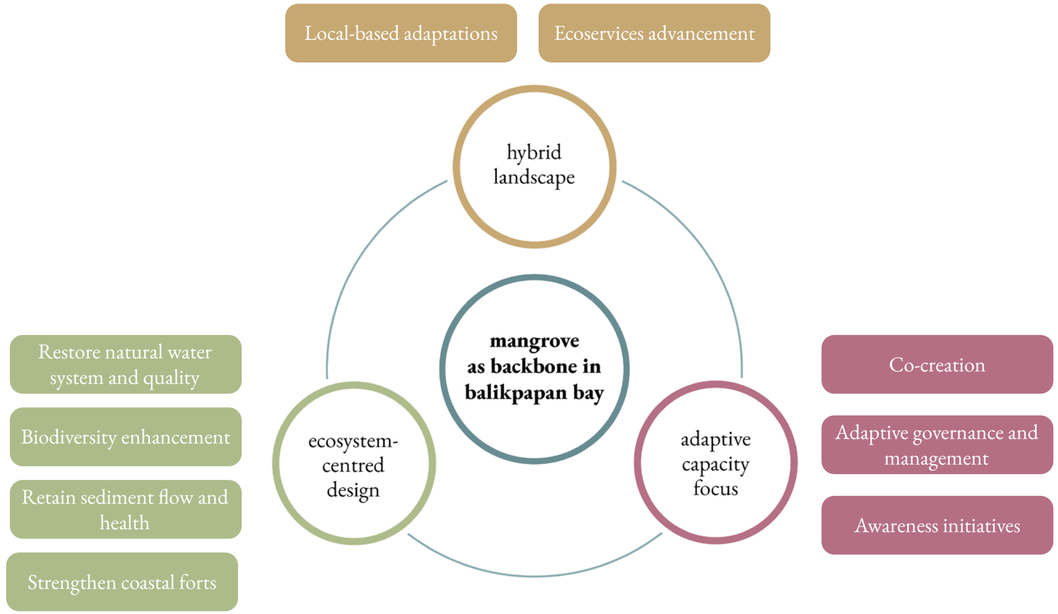


Figure 100. Design principles

4.2. Concrete Design Tools

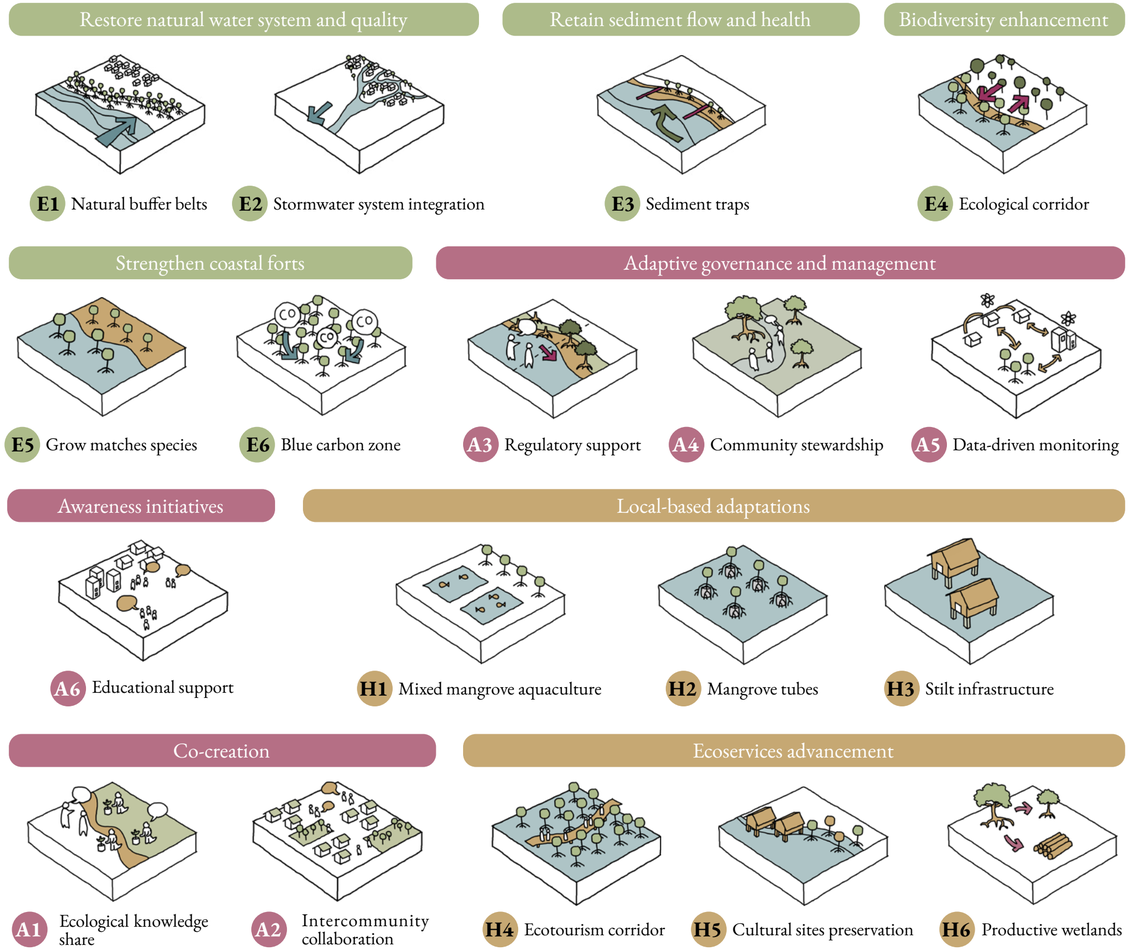


Figure 101. Design tools

4.3. Study on Best Practices

A. Bio-rights Building with Nature, Demak, Indonesia

Indonesia has been making a long effort towards mangrove restoration. However, according to statistics, 50% of mangrove restoration projects failed due to a lack of long-term monitoring strategies and sensitivity to project management and monitoring (Lovelock et al., 2022). In Demak, Wetlands International Indonesia collaborated with various stakeholders, including the Indonesian Ministry of Fisheries and the Ministry of Public Works, NGOs, and academic institutions for a **community-based ecological mangrove restoration (CBEMR)**. This low-lying coastal area has suffered from flooding, erosion, and land loss due to subsidence as one of the impacts of climate change and unsustainable practice of infrastructure and industrial expansion along the coastlines.

Ecological rehabilitation of the mangrove forests was combined with developing the local aquaculture technique or *tambak*, called **mixed mangrove aquaculture (MMA),** which generated new sources of income for the local economy. Young mangrove seedlings were cultivated in the fishponds and can be relocated later. To encourage the growth of new mangroves, sediment traps were set using permeable structures. In addition, adaptive capacity was established with training on the new techniques, incentives packages (Bio-rights) were offered to ensure participation, and monitoring was fostered to ensure long-term sustenance of the rehabilitation project (Astra et al., 2021; Lestari Sustainable Development Consultants Inc., 2021).

Figure 102. 2019 and 2021 project's progress (wetlandsglobal, 2021)

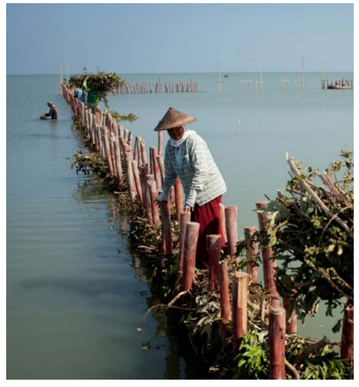


Figure 103. Left – Permeable structures for trapping sediments done by the local communities; Right – Growing mangroves within sediment accumulations behind permeable grids (World Bank, 2025)

B. A biophysical approach in Menabe, Mozambique

A mangrove restoration project in Madagascar's Menabe region had achieved an exceptional milestone with a seedling survival rate reaching 90%. This was a significant progress in which the previous project's success rate was below 10%. This improvement happened due to the adaptation of a biophysical approach—considering tidal patterns, soil composition, and other environmental factors—in other sites as temporary nurseries while rehabilitating the degraded coastal area; before planting the young plants back to the primary area. By implementing site-specific propagation and planting techniques, the initiative successfully cultivated and planted over 58,000 healthy mangrove seedlings.

The project, supported by the USDA Forest Service in partnership with the Malagasy government, USAID, and local communities, illustrates the transformative potential of combining instruments of scientific knowledge with active community participation. The success has inspired scaled-up efforts, including the SWIOFISH 2 project, which aims to restore 1,000 hectares of mangroves in the region (USDA Forest Service, 2023). The emphasis on community involvement enhanced the project's success and ensured its long-term sustainability. By aligning conservation goals with the needs of local populations, the initiative improved livelihoods through sustainable practices such as ecotourism and mangrove-based aquaculture. These initiatives highlight the essential role of mangroves in preserving coastal ecosystems, supporting biodiversity, and securing the socio-economic resilience of coastal communities.

Figure 104. Project collaboration (USDA Forest Service, 2023)

Figure 105. Mangrove seedlings in nurseries (USDA Forest Service, 2023)

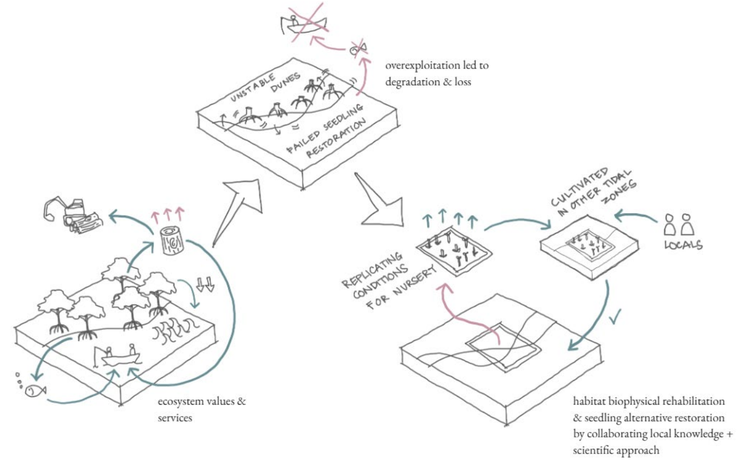


Figure 106. Restoration technique in Menabe, Mozambique by creating a temporary habitat (adapted from USDA Forest Service, 2023)

C. Restoration initiatives around Balikpapan and Samarinda

During the fieldwork, the Author visited several places around Balikpapan and Samarinda, which have done restoration efforts as exemplary projects. The projects were considering local context, including the biophysical conditions, the specific species, and the collaborators, therefore increasing the success probability.

In **Mangrove Center Graha Indah Balikpapan** (refer to Chapter 3.6), the initiative started by a community member in one of Balikpapan's neighbourhoods, and has been scaled up to 1 million mangrove trees. The owner developed specific place-based techniques for each restoration sites, including using concrete barrels *(buispot)* to support mangrove planting in high-tide areas and protect the propagules from being washed away, which the barrels can also function as tidal breakers. Every restoration project done has always involved local communities as the workers not only to ensure continuity of the project but also to open opportunities for local economy enhancement.

Figure 107. Above – ***Buispot*** technique of using concrete vases in high-tide areas (Photograph by Agus Bei, 2022)

Figure 108. Below – **Nursery** of young mangroves, from seedling, propagules, until becoming the juvenile trees are done insitu to ensure quality of the future trees (Photograph by Robin Z., 2025)

In Samarinda, Author visited Delta Mahakam and Sepatin Fishermen Village where collaborations are done between local communities, academic institutions, NGOs, and governmental bodies, setting an exemplary successful mangrove restoration project in Kalimantan. The partnership allows knowledge transfer between different bodies, including the local communities who owned the traditional ecological knowledge, and the technical biophysical requirement knowledge that can be provided with the help from the academic institutions. Supoprt from the government is also important to include the vital factor of the project's financial security. The project also emphasis the close relation between the mangrove to daily livelihoods for the local economy to highlight the importance of mangrove restoration, especially for the local communities.

Figure 109. Young mangrove trees of *Rhizopora mucronata* as the suitable species for restoration project in Delta Mahakam (Photography by Author, 2025)

Figure 110. Interactions as a knowledge transfer process between academic institution and village authorities during the fieldwork (Photograph by Author, 2025)

Figure 111. Integration of contextual local economy (making crab traps) to mangrove restoration in fishermen villages (Photograph by Author, 2025)

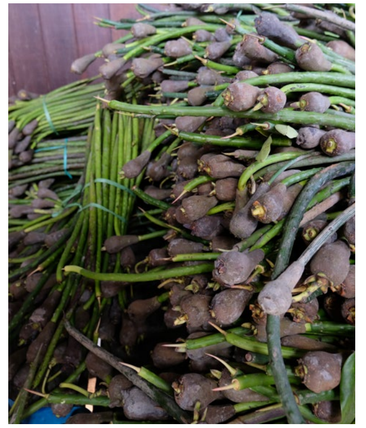
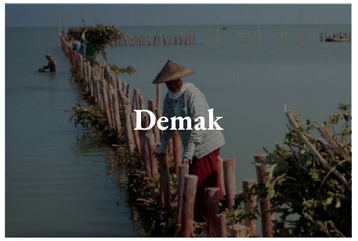


Figure 112. Selected harvest of mangrove propagules prepared for next plantings (Photograph by Author, 2025)

4.4. Connecting Key Takeaways to Strategies

The best practice study cases are chosen as successful mangrove restoration projects that aligns with the Design Principles of designing with people, with nature, and with the synergy between both to result in sustainable and long-term projects. The iteration process is demonstrated here, where the key takeaways from the study cases helped the Author to form the design strategies and tools, while the selection of the study cases was also based on the options of projects that were suitable with the design principles.

In principle, all of the case studies applied most of the design strategies. However, there are several characteristics in every project that the Author considered and listed as follows.



- H1 Mixed mangrove aquaculture
- A1 Ecological knowledge share
- A2 Intercommunity collaboration
- E3 Sediment traps

- A2 Intercommunity collaboration
- E5 Grow matches species
- A4 Community stewardship

- H2 Mangrove tubes
- A2 Intercommunity collaboration
- A6 Educational support

- A2 Intercommunity collaboration
- H6 Productive wetlands
- A4 Community stewardship

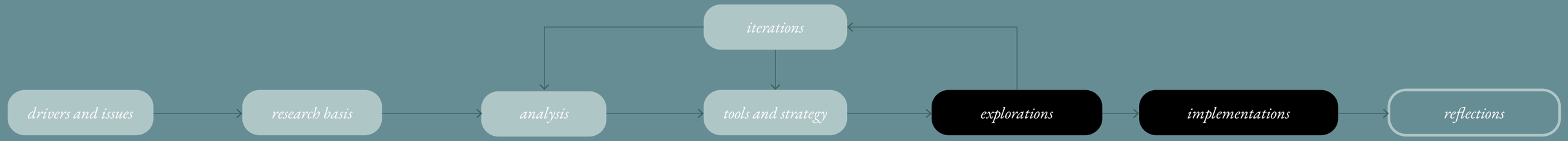
Figure 113. Young restorated mangrove trees with the matured trees in the back in Delta Mahakam (Photograph by Author, 2025)

05

design explorations and implementations

prototyping and testing solutions in strategic projects

This chapter provides the exploration phase of the project, combining spatial design and strategic planning in addressing complex and multiscale issues, and balancing different elements. Implementations of the solutions are explained through applicable project phases and engagement strategies.



5.1. Restoring Ecosystem Values and Services on a Regional Scale

Design explorations visualise spatial problems, and act as a vehicle to generate solutions, explore possibilities, and express cultural values (Nijhuis, 2022). The environmental degradation in Balikpapan Bay has led to the disturbance of the mangrove ecosystem services. In the analysis summary (refer to Chapter 3.8), different mangrove damage levels divided Balikpapan Bay into three main zones, which will guide the different focus goals formulations that are **"exist"**, **"adapt"**, and **"expand"**, by also considering the societal context.

The strategies of the focus goals are intended to be synergistic, while aiming to restore the ecosystem values and services of the mangroves. Zone C, with the most severe mangrove damage and little mangrove coverage, needs strategies to revive the mangrove ecosystem and focus on supporting the mangrove to **exist** first. Zone B, with moderate mangrove damage but facing future damage risk, requires the capacity to stabilise the ecosystem to be able to **adapt** to changes. Zone A, with the minimum damage where large parts of the forests are still intact and existing, focuses on strategies to maintain and **expand** the forests to improve resiliency towards future challenges.

The strategies of the focus goals are intended to be synergistic, while aiming to restore the ecosystem values and services of the mangrove ecosystem in the regional scale, such as regenerating the critical habitats, improving the coastal protection capacity, and supporting human socio-economic activities and well-being through accessible nature.

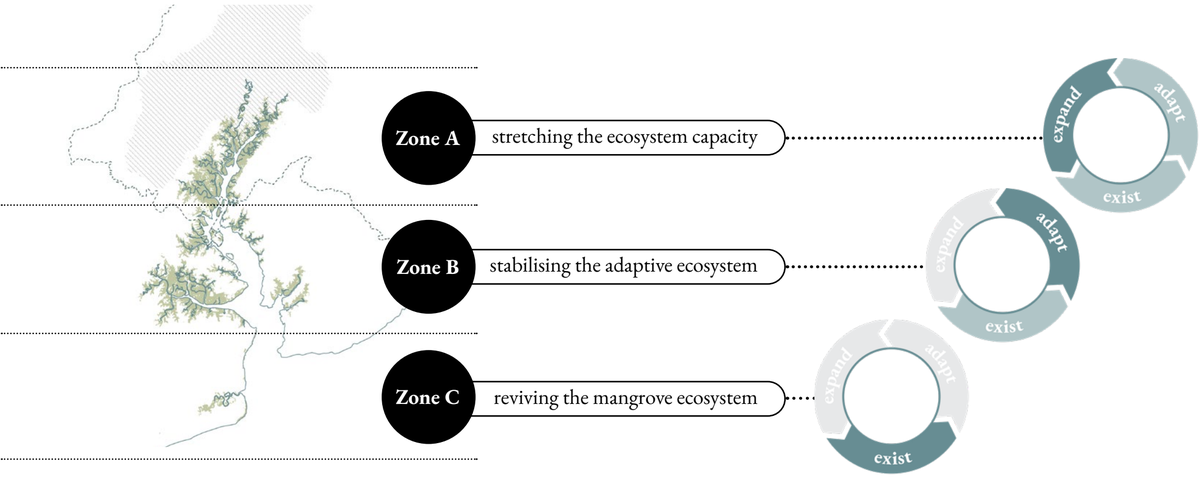


Figure 114. Alteration level zone division and the focus goals

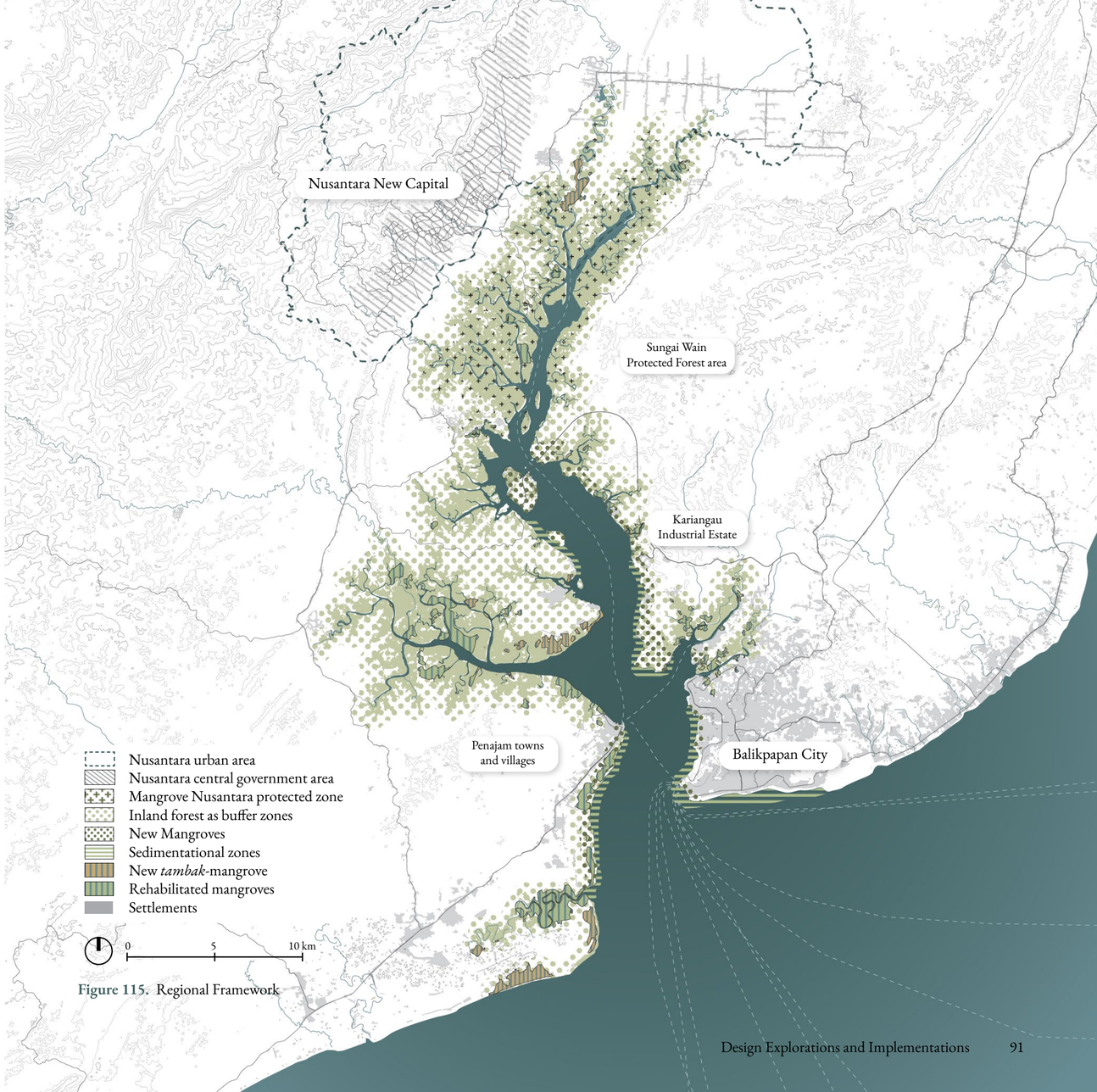
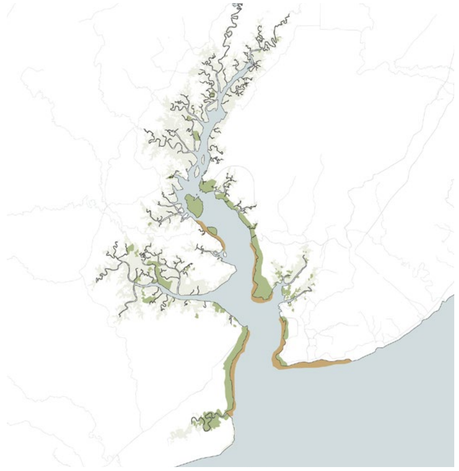
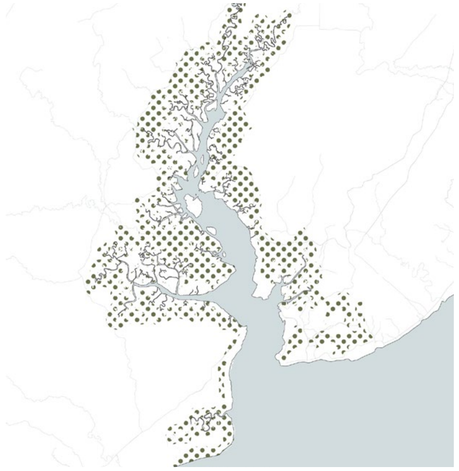
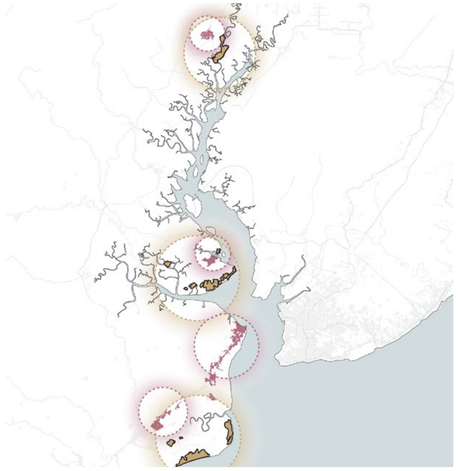


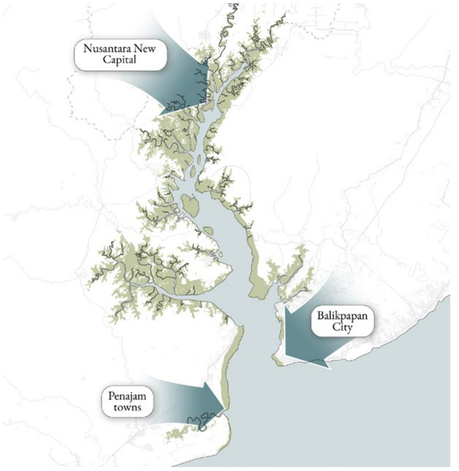
Figure 115. Regional Framework

Regional Goals









Ecological restoration

Within different mangrove damage levels, strategies are applied to revive, rehabilitate, and restore the forest loss. Measures are not limited to planting, but also focus on environmental rehabilitation to create the suitable biophysical requirements to support the natural regeneration of the mangroves. Besides restoring the mangrove forests, sedimentation zones are planned to prepare space for future seaward colonisation.

Habitat linkage

Rehabilitation of the bay water and mangroves restores the critical habitat of diverse marine and terrestrial animals. Reforesting the inland forests will simultaneously improve the inland habitats, mainly beneficial for different bird species and arboreal animals to expand the feeding grounds. Combining the natural capacity of both mangrove and inland forest allows better bay water quality.

Coastal protection zones

The new capital brings the opportunity to strengthen the policy reinforcement of core coastal protection zones, to protect intact mangrove forests around the development area and prevent future loss. As a possible priority project to integrate with the Nusantara planning, the effort can be amplified and replicated for other mangrove forests areas around Balikpapan Bay.

Nature-positive livelihood support

To overcome large mangrove loss to the aquaculture, different locations of existing *tambak* are assessed to optimise the economic development model, retaining ones closer to fishermen villages to support local-scale economy. A new *tambak* system is introduced to support mangrove restoration and eliminate future extensive clearing risk.

Human-nature reconnection

Shifting the perspective of seeing nature as an economic resource needs the measure of re-embracing the connection of people to nature. This means creating the blue-green networks between different forests to provide access from urban settlements to natural areas. Nusantara planning allows the opportunity for interaction space for urban people of native groups to co-exist.

Figure 116. Diagrams of regional goals

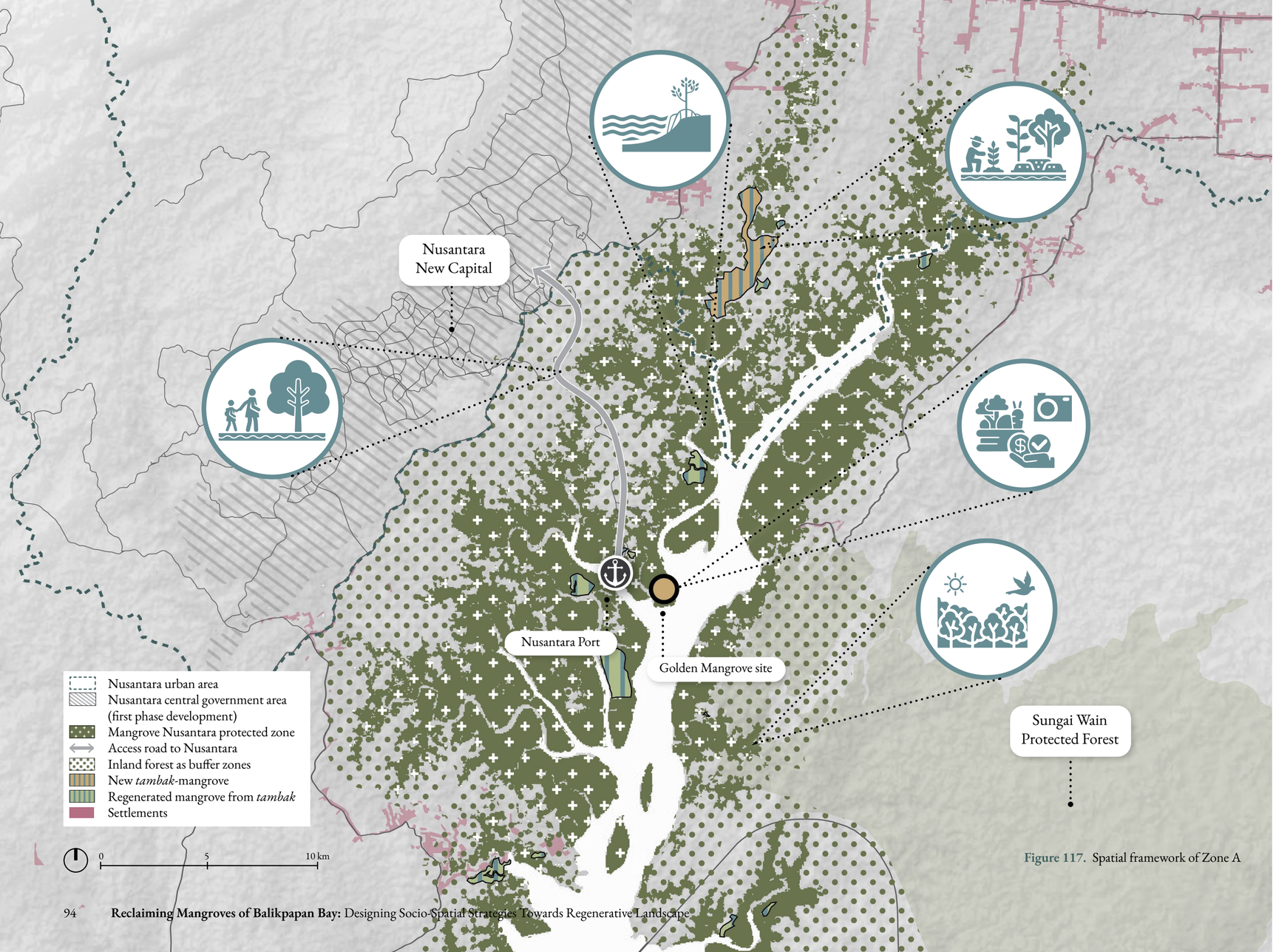
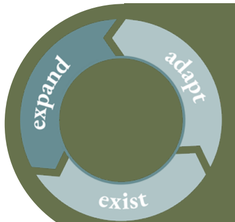


Figure 117. Spatial framework of Zone A



A. Design Principles in Zone A

Rehabilitated mangrove area: 296 ha

With minimal mangrove damage, this zone focuses on strategies to **safeguard intact mangroves, prevent future loss,** and **maintain the natural capacity** to be able to **expand** the ecosystem by also advocating a strong policy framework for coastal resilience, mainly in collaboration with Nusantara New Capital planning. The design principles are as follows:

Ecoservices advancement

The Golden Mangrove site, located next to Nusantara New Capital main port, needs to be acknowledged as a cultural significance that is vital to protect. Integrating the initiatives sees potential of collaboration between the new city authority and the native people, adding tourism corridor as the local economy generator.

Restore natural water system and quality

Mangrove protection strengthens its role as a natural buffer to protect the coastlines, and ensure better water quality discharged from the rivers to the bay.

Biodiversity enhancement

Ensuring a natural corridor between the mangroves and the protected forest, such as the Sungai Wain, supports rich biodiversity living, such as the bekantan monkey that constantly moves around these forests to nest, feed, and grow.

Strengthen coastal forts

Mangroves are among carbon intensive ecosystems that are productive for carbon sequestration. The average carbon stock in mangrove ecosystem in Kalimantan is 1.386,87 MgC/ha (Andari et al., 2023), therefore, in a fully regenerated condition, this zone serves 9,6 million MgC stock.

Urban-nature living

Advocating the integration of natural preservation to Nusantara's development boosts the project implementation priority, adds value to urban living with proximity to nature while simultaneously improving water quality flowing from riparian areas to the bay.

Core protection zones

Creating core protection zones to protect intact mangrove and prevent future loss as the part of Nusantara Biodiversity Management Plan (refer to Figure 62.).

Cultural asset protection

Mangrove rehabilitation as buffer belts for coastal resilience, while simultaneously protect cultural asset of local native groups through nature-positive ecotourism scheme to also support local economy and introduce native cultures.

Sustainable local economy

Sustainably transforming the current extensive *tambak* practices to support mangrove restoration and retain local economy resources for nearest community neighbourhoods.

Ecological corridors

Reforestation of inland forest within the minimum of 200-300 metres around the mangroves as urban buffers, improving ground infiltration, and providing eco-corridors for mangrove faunas.

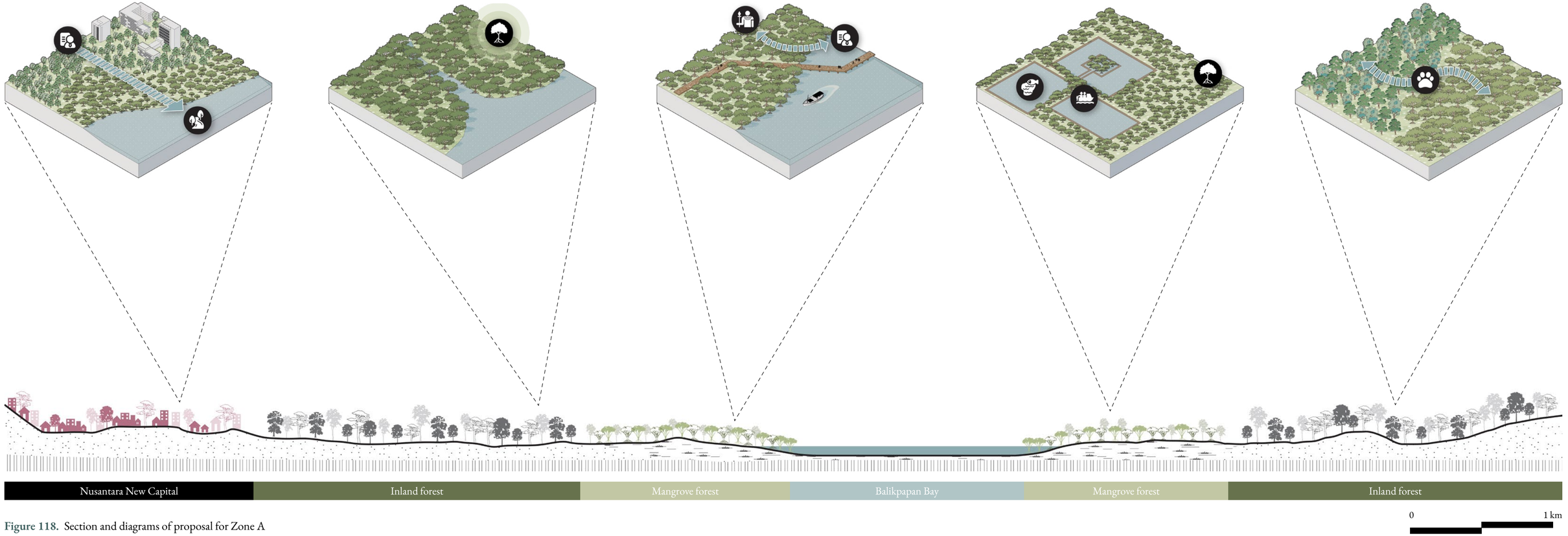
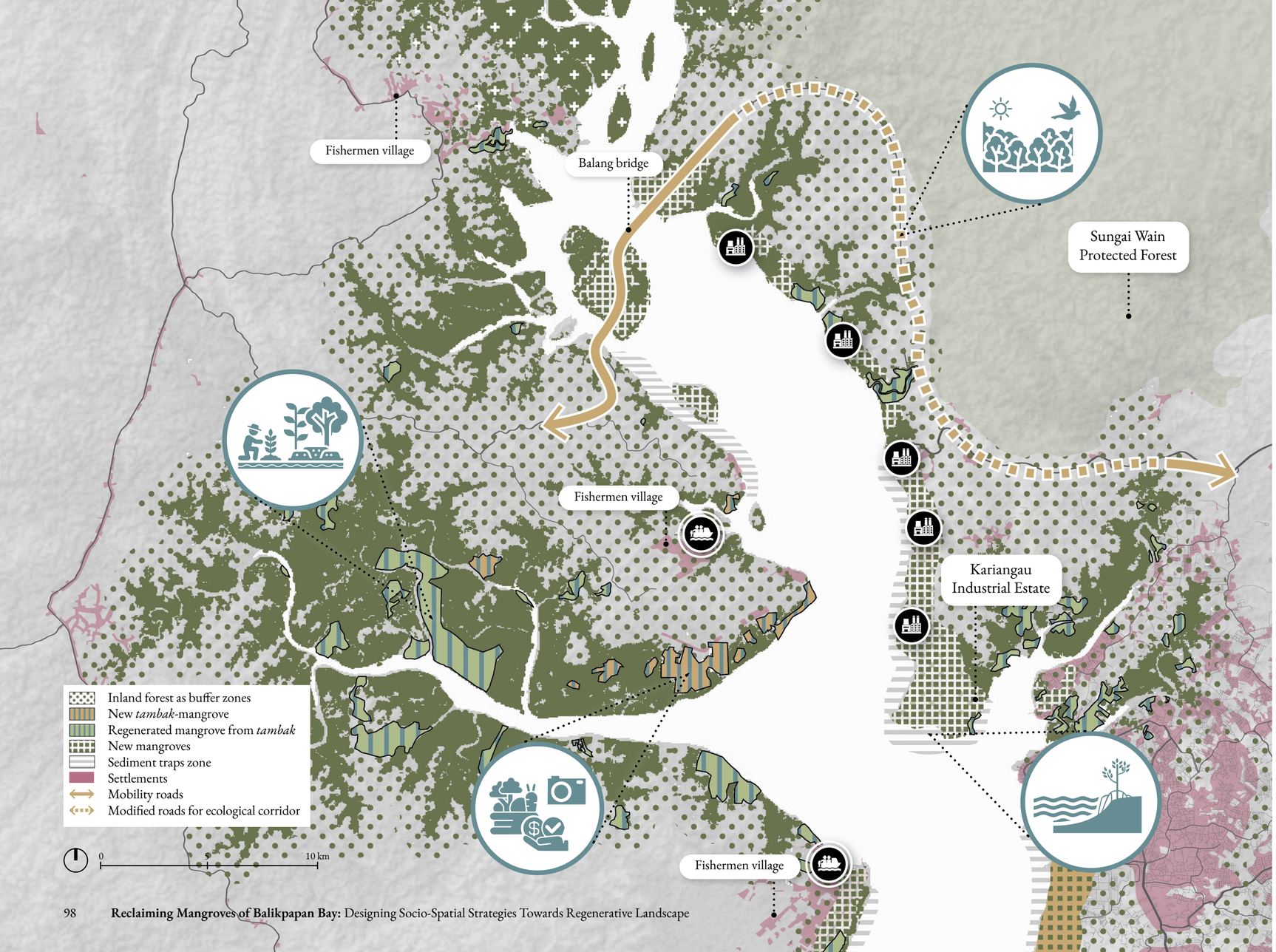
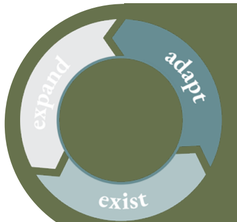


Figure 118. Section and diagrams of proposal for Zone A





B. Design Principles in Zone B

Rehabilitated mangrove area: 1223 ha

This zone includes the Kariangau Industrial Estate area and widespread *tambak* development as a challenge for mangrove degradation. Therefore, the measures are focused on stabilising the natural system for the mangrove to be able to **adapt** to future risks, while encouraging policy adaptation for non-extensive industrial areas. The design principles are as follows:

Retain sediment flow and health

To promote mangrove growth in some areas, engineering work with permeable structure helps to deposit sediments. The sediments will allow the growth of mangroves seawards. However, this strategy needs policy adaptation to prevent further loss to developing industries and regulate the waste management not to directly enter the bay water.

Biodiversity enhancement

The industrial zone is next to the Sungai Wain Protected Forest. With integrated industry and inland forest, the existing industrial road can be modified to allow movement of animals between these forests to expand ecological corridors.

Strengthen coastal forts

The blue carbon for carbon sequestration in this area, with the known average carbon stock in mangrove ecosystem in Kalimantan that are 1.386,87 MgC/ha (Andari et al., 2023), in a fully regenerated condition this zone serves 11 million Mg carbon stock.

Local-based adaptations

A new tambak system, mixed with mangrove, is introduced to regenerate large parts of the mangrove forests. The local coastal villages adopt the vernacular architecture of stilted buildings.

Figure 119. Spatial framework of Zone B

Setting the biophysical conditions

Transforming the widespread *tambak* ponds and ex-mining ash coal ponds for mangrove rehabilitation by primarily remediate the polluted water to create suitable biophysical conditions for natural mangrove growth.

Resilient coastal communities

Integrating mangrove into the *tambak* ponds to create new *tambak* mosaic system adds value to local economy diversification, while modifying the villages by adopting vernacular architecture of coastal buildings to support resilient communities.

Bio-engineering deposit support

Sediment catchment area, using bio-engineering solutions such as the permeable structures with local materials, support the natural regeneration for mangrove growth.

Eco-corridor in eco-industry

Regenerating the mangroves go together with inland forest protection to retain ecological corridors. In areas with limitation from industrial roads, modifications are needed to restore the continuous natural zones.

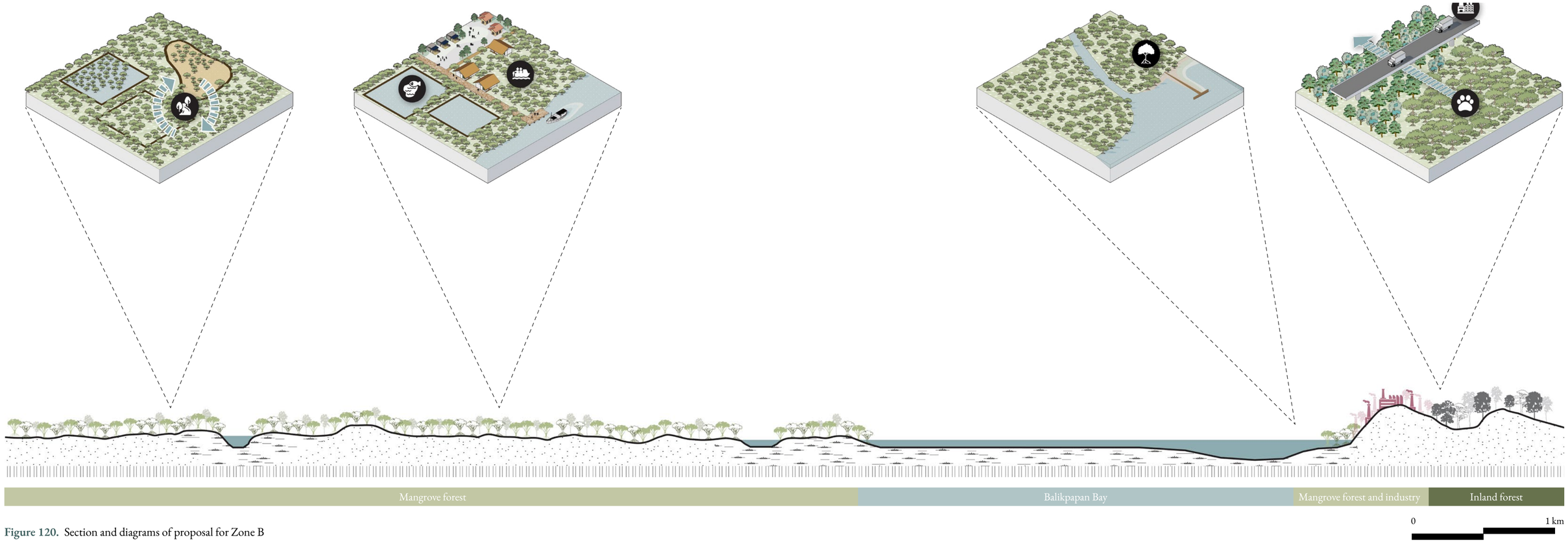


Figure 120. Section and diagrams of proposal for Zone B

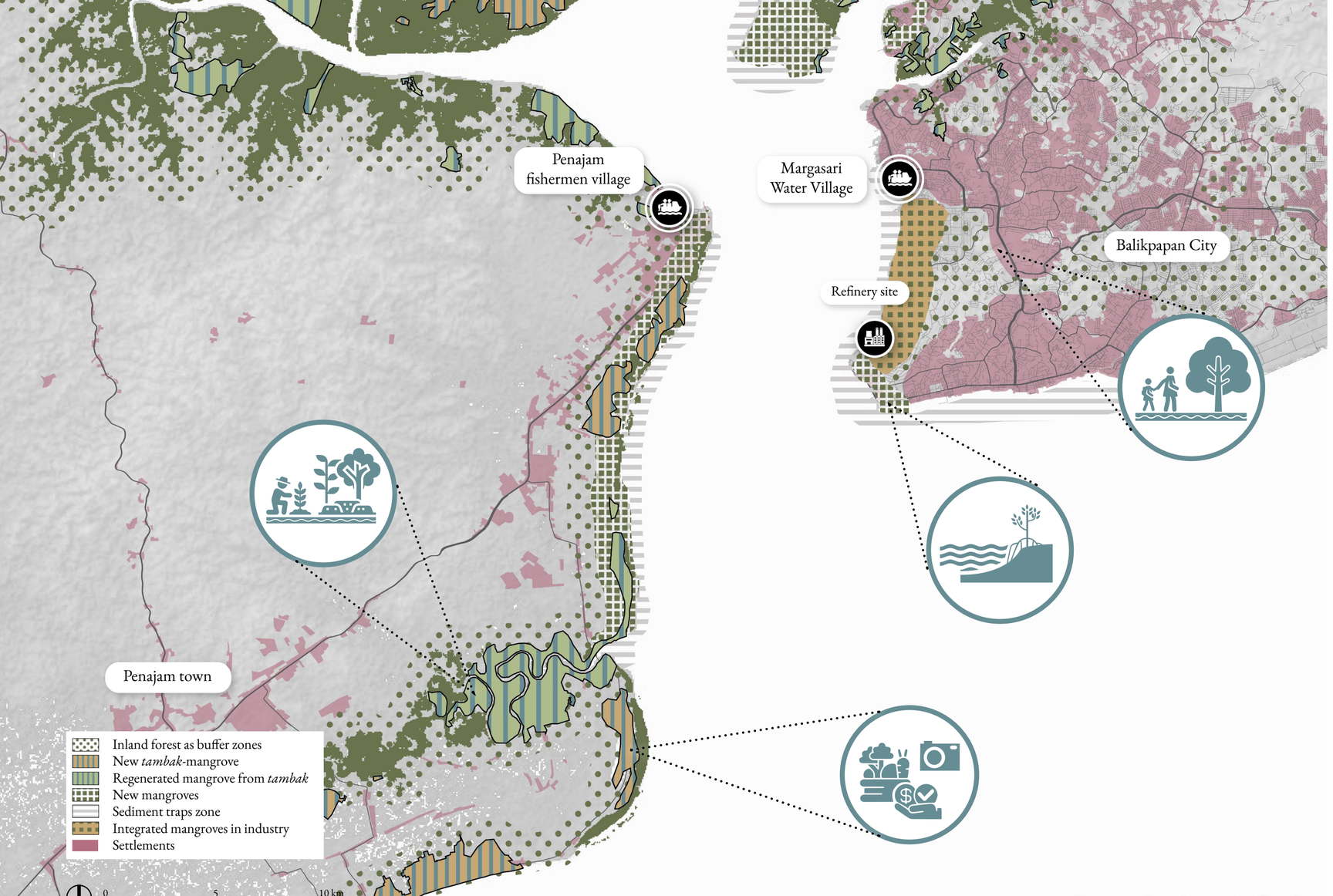
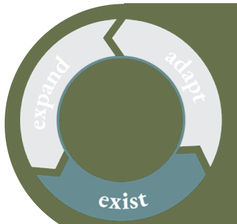


Figure 121. Spatial framework of Zone C



C. Design Principles in Zone C

Rehabilitated mangrove area: 781 ha

Zone C has the most distinguished properties where the mangrove loss is severe, suffering loss from different urban and rural activities, industrial works, and widespread *tambak* practices. Therefore, the strategy will be prioritised on helping the mangrove to **exist** first, focusing on the biophysical condition restoration to allow natural regeneration. The design principles are as follows:

Restore natural water system and quality

Regenerated mangroves will be natural buffers to prevent coastal floods as one of the issues in this zone. Therefore, integrating stormwater management in the city will also help with water infiltration and increase water quality. In the city's refinery site, mangroves are planted in the industrial complex to reduce the high risk of abrasion on this coastline.

Retain sediment flow and health

Permeable structures are applied along the coastlines to help with depositing more sediments to restore mangrove growth.

Local-based adaptations

The mixed mangrove *tambak* system is applied to regenerate the mangroves and reactivate unproductive ponds, with adaptation of stilted houses for the fishermen villages. Along the open sea coastlines, a local technique of *buispot* or mangrove tubes is applied to increase mangrove planting success.

Ecoservices advancement

Balikpapan city has already a lot of local mangrove restoration initiatives. It has the potential of integrating the ecotourism corridors, also with the existing fishermen Margasari Water Village and the old oil well, to add educational and promotional values while rehabilitating and preserving the mangroves.

Regenerating the buffer belts

Buffer belts regeneration to restore the natural capacity, especially for coastal protection in preventing floods and filtering water.

Local economy support

Using the new mosaic *tambak* system to restore the mangroves, while supporting local economy and fishermen communities by diversification and the opening of local fishermen market.

Adapting the local techniques

In the open coast area, new techniques learnt from the local 'expert' are applied to increase survival rate in stronger current zones.

Eco-oriented industry

Promoting sediment catches around the current industrial area to set the biophysical conditions, and later plant the mangroves to combine natural preservation with industrial activities.

Regaining access to nature

Reforesting the inland forest allows urban residents to regain access to nature, while simultaneously promotes ground infiltration for stormwater management to improve water quality flowing to the bay.

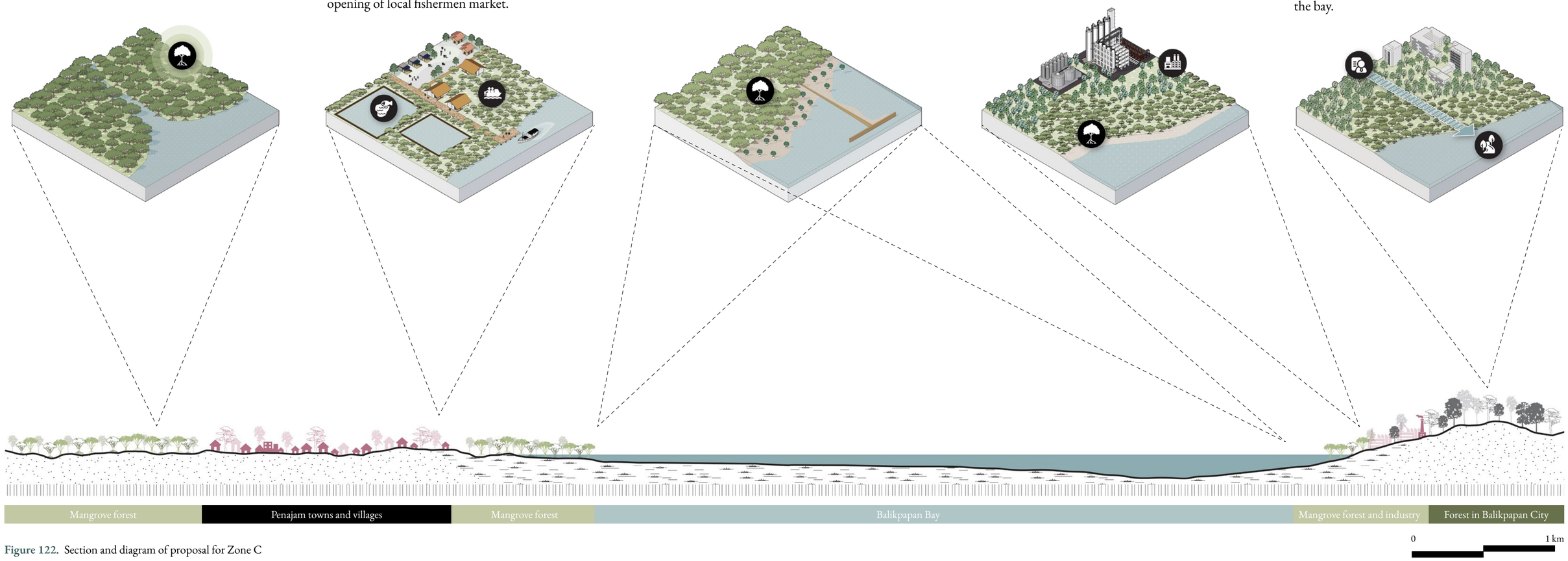


Figure 122. Section and diagram of proposal for Zone C

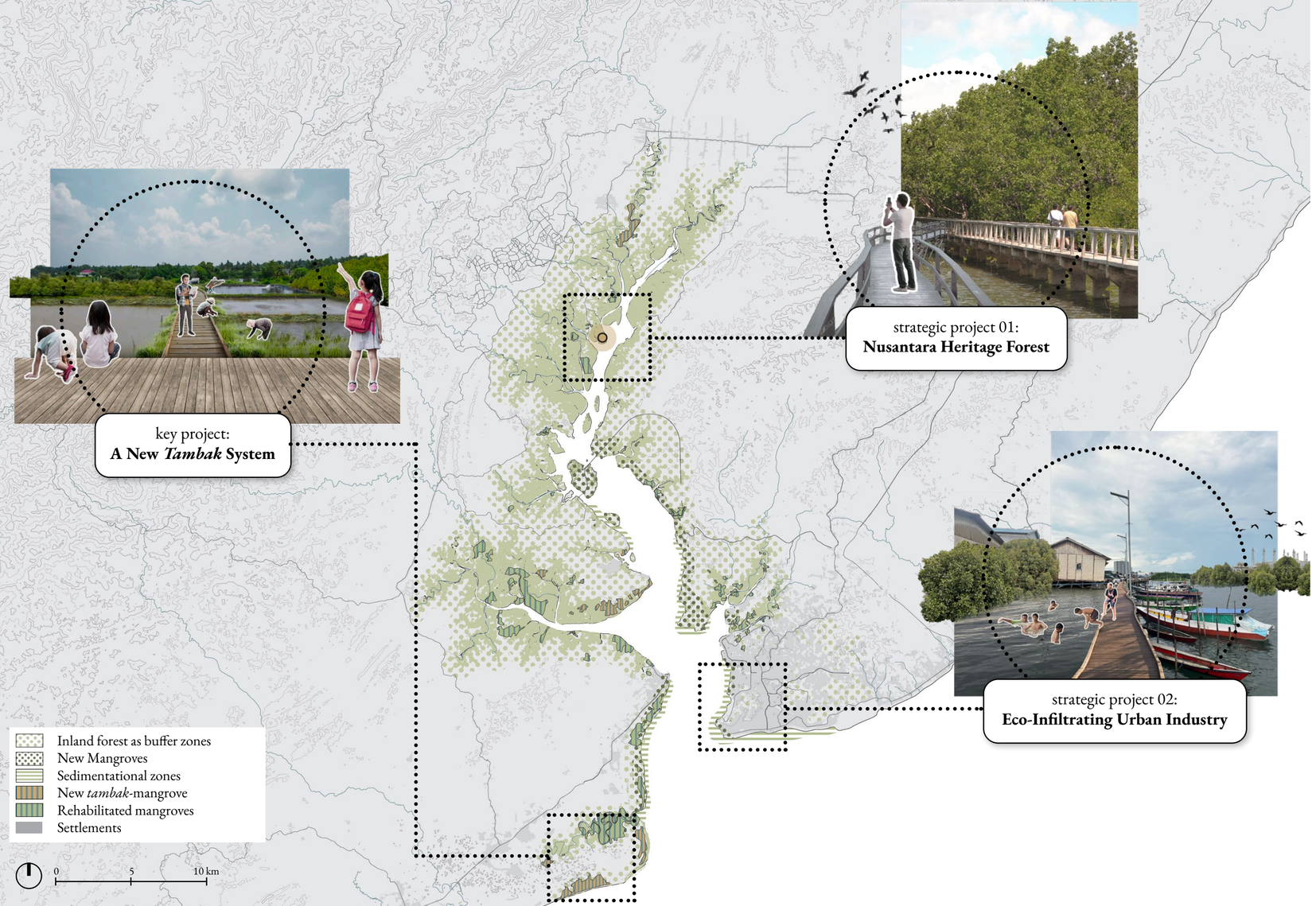


Figure 123. Strategic Projects Framework

5.2. Strategic Projects

To dive deeper into the application of different strategies and design tools, strategic projects are chosen to understand the implementation of various spatial strategies, which, in some cases, can be modified to fit the specific context of each location. The projects are considered strategic for possessing overlapping or predominant issues, making the site characteristic particularly complex. The strategic projects also represent the idea that design exploration methods can be used to address the problems on different scales. Further, each project will have socio-spatial operational strategies, including the governance of the actors as facilitators and caretakers of the nature-based solutions.

The first strategic project, **Nusantara Heritage Forest**, takes place in the northern part of the bay within the area intersected with the Nusantara New Capital development sites. It investigates the potential of collaboration and integration between city planning, ecological preservation, and local community engagement through a nature-positive ecotourism scheme to cover both environmental protection and economic support.

The second strategic project, **Eco-Infiltrating Urban Industry**, put focus on addressing the main socio-economic challenges to mangrove restoration where different interests applied. However, through a landscape-based approach, nature comes first to set the base for socio-economic interactions and guide further urban development, allowing possibilities to improve socio-ecological resilience in an urban setting.

The third strategic project is shown as a key project called **A New *Tambak* System**. This project is considered pivotal, where the *tambak*, as a challenge, is widespread and present everywhere, posing an issue to be addressed in a comprehensive manner. The *tambak*, as a system, includes several other sub-systems that interrelate with each other.

Each strategic project represents the three main zones. Therefore, the projects will also elaborate on different focus goals (refer to Figure 114.) to achieve, and the added value of ecosystem services it can serve.

A. Strategic Project 01: Nusantara Heritage Forest

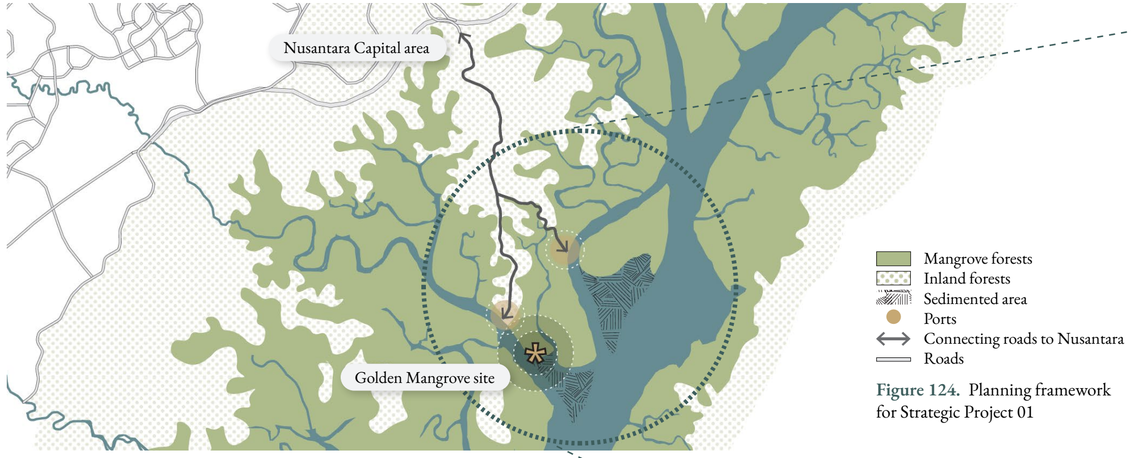


Figure 124. Planning framework for Strategic Project 01

Overview

The planning of Nusantara New Capital comes with socioecological trade-offs. Forests are cut down, biodiversity loses its habitat, while humans lose their homes, culture, and livelihoods. This strategic project aims to investigate the potential of local heritage to navigate the socioecological issues, while emphasising **Nusantara as a catalyst for socioenvironmental structural change.**

The Golden Mangrove spiritual site of Balik group becomes the departure point for protection zones as a cultural asset, supported by a nature-positive ecotourism scheme. The core protection zone strategy is amplified to other forests around Nusantara borders. The strategies are launched through collaboration with local people.

The Golden Mangrove story among the native people has embedded a deep cultural value as a rich heritage asset. Despite the risks, a large part of the mangrove area is still intact and provides its ecosystem services. The plan aims to amplify the cultural significance of this place and triggers a protection plan for the mangrove forests to also expand their ecosystem services.

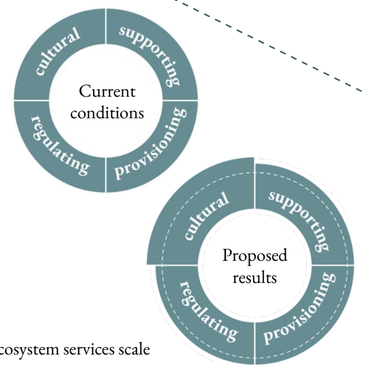


Figure 125. Ecosystem services scale

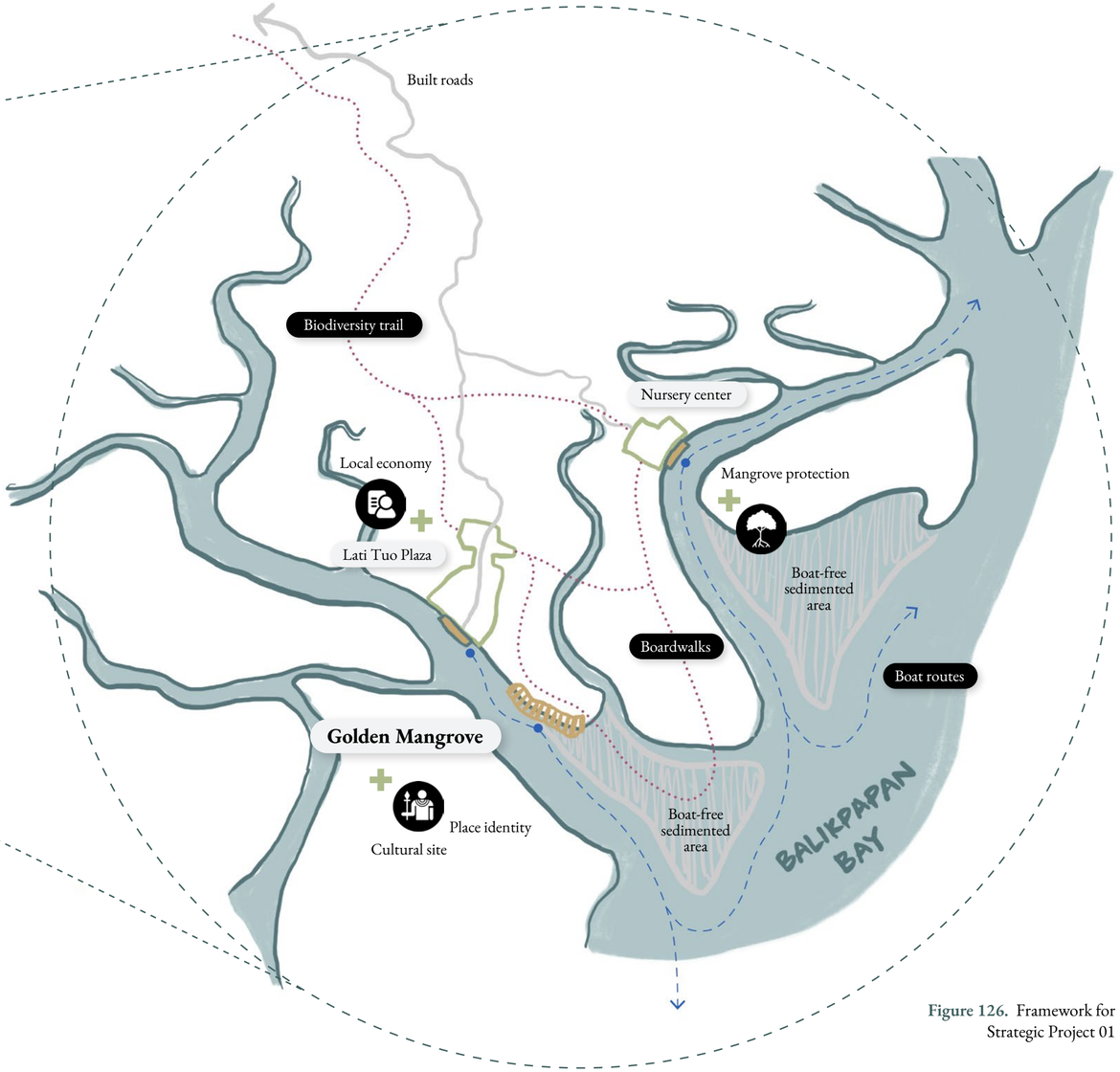


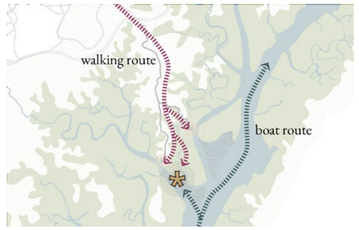
Figure 126. Framework for Strategic Project 01

Design Tools

Ecoservices advancement

H5 Cultural sites preservation

The acknowledgement of heritage means respecting the local culture, including the native people's sacred forest (*lati tuo*). The cultural site protection must be recognised as a national asset, while simultaneously protecting the mangroves to prevent future loss.



Ecoservices advancement

H4 Ecotourism corridor

Through a nature-positive tourism scheme, ecological preservation goes hand in hand with supporting the local economy and introducing local cultures. However, this case needs limitations on tourism development to avoid massive clearing for construction purposes.

Biodiversity enhancement

E4 Ecological corridor

Protecting the mangrove and inland forests safeguards the fauna corridors, ensuring green-blue networks from the Nusantara New Capital to the natural environment to allow accessible nature for the urban settlers.

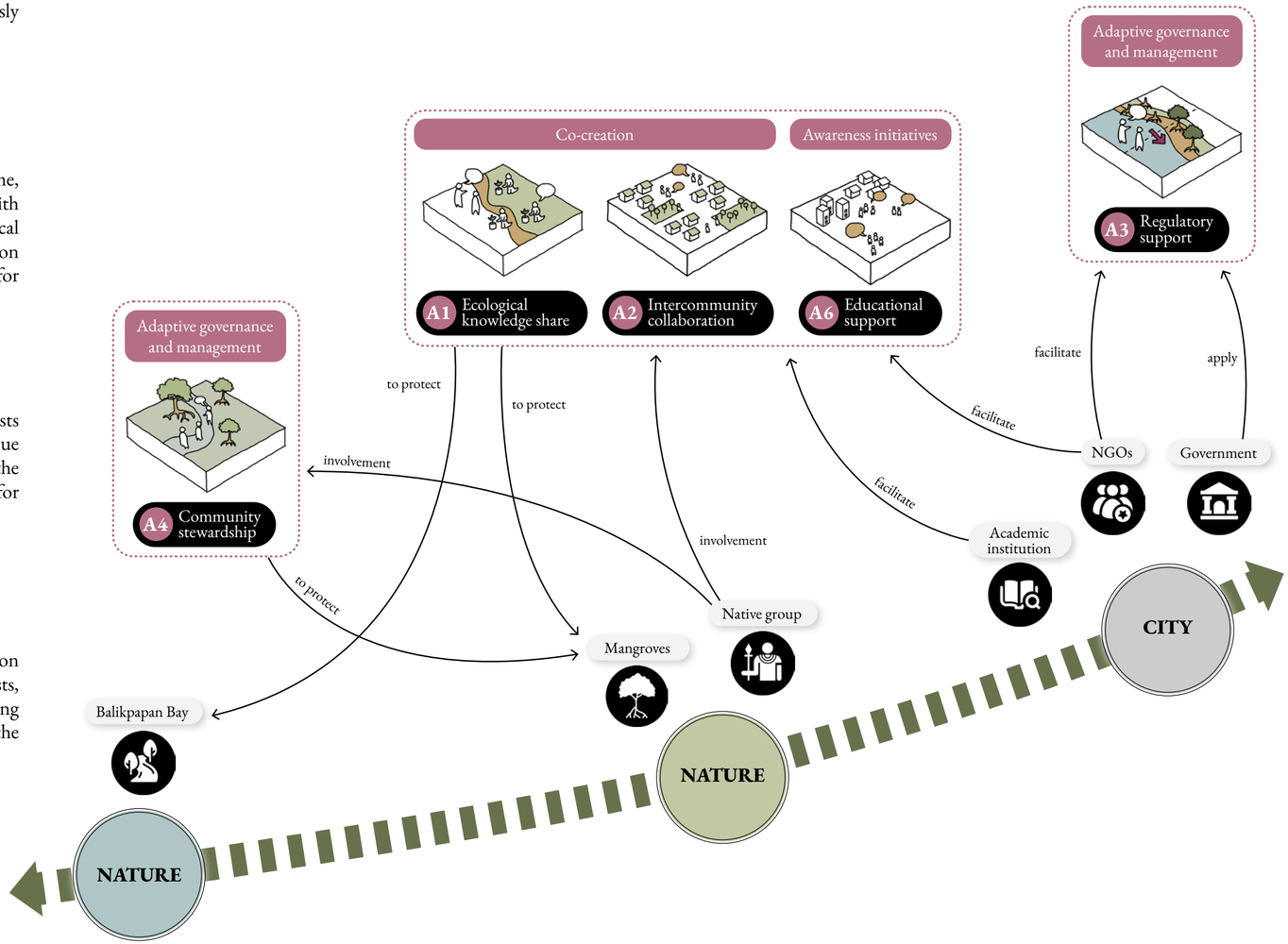
Restore natural water system and quality

E2 Stormwater system integration

Providing improved water infiltration integration from the Nusantara "forest city", to inland forests, and mangrove forests as natural filters in increasing the water quality discharged to the rivers and to the bay water.

Figure 127. Design tools

This strategic project, which aims to reconnect people to nature, involves different stakeholders to implement the strategies. As the plan deeply interrelates to Nusantara planning, acknowledgement and cooperation with the new capital authority and the national government are vital to encourage policy adaptation to implement the protection zones around the Golden Mangrove site, in which the dialogue can be facilitated by NGOs. Collaboration with the native Dayak group allows ecological knowledge transfer and strengthens community stewardship as the caretaker of the forests.



Nusantara New Capital

Forest trails

Mangrove boardwalks

Start point

Tropical rainforest walk

Dipterocarp forest

Hornbill

Sun bear

Nursery

Mangrove forest walk

Bekantan monkey

Gradients of mangrove species:
Nypa f. > *Sonneratia a.* > *Rhizopora m.*

Lati Tuo Plaza

Golden Mangrove boardwalk

Saltwater crocodile

Rhizopora m.

Bekantan monkey

Biodiversity Trail

The ecological corridors of the mangroves and inland forests create blue-green connections from the Nusantara New Capital to Balikpapan Bay. It provides an accessible nature to urban settlers, and a vast ground area for the various forest faunas to grow and look for food.

Integrating the idea of ecological corridor, cultural site preservation, and ecotourism, the biodiversity trail allows connections between the city and nature, providing people with the experience of walking through gradients of the inland and mangrove forests with vast array of biodiversity of flora and fauna. Additionally, this track delivers education by bringing people closer to nature.

The trail leads to the Golden Mangrove spot, discoverable by the boardwalk and modified boat routes. This emphasises the cultural value of the forest to support the protection of the native people's asset. In the Lati Tuo (means "old forest") Plaza, interaction spaces are provided to introduce ethnic cultures and boost local economy.

Figure 128. Biodiversity trail masterplan and visualisations

Lati Tuo Plaza

Collaboration with local people, especially the Balik native group, is facilitated through a cultural community center, providing a space for establishing potential local commerce, showcasing local ecological knowledge including boat-making, traditional-fishing, local crafts, clothes, and arts, and local restoration technique to be applied in the nearby Nursery Center. The community can earn income from different job creations to reduce reliance on unsustainable practices, such as logging, aquaculture, and others.

Generated revenues from the community-based ecotourism can be reinvested into the restoration projects for the mangrove nurseries, maintenance, and monitoring.

Figure 129. Lati Tuo Plaza visualisations

Figure 130. Activities in Lati Tuo Plaza by the native people (AI-generated image prompted by Author, 2025)

Aligning to Nusantara Plan

The Golden Mangrove zone preservation becomes the central strategy, ripples the impact to protect other mangrove areas and reforestation of the inland forests. An integrative and community-driven ecotourism scheme ensures environmental-based tourism and strengthens cultural identity. Instead of being seen as environmental threats, the existing Nusantara port and road constructions are integrated into the framework to connect the new capital and the heritage asset through roads, mangrove spots boat routes, and forest boardwalks.

Nusantara New Capital planning can become a pioneer in mangrove protection and rehabilitation plan while strengthening interaction with urban life and local community activities, stimulating more policy dialogues on environment-based decision making. Integrating the program to current construction can start immediately to prevent further large loss of the mangrove forest.

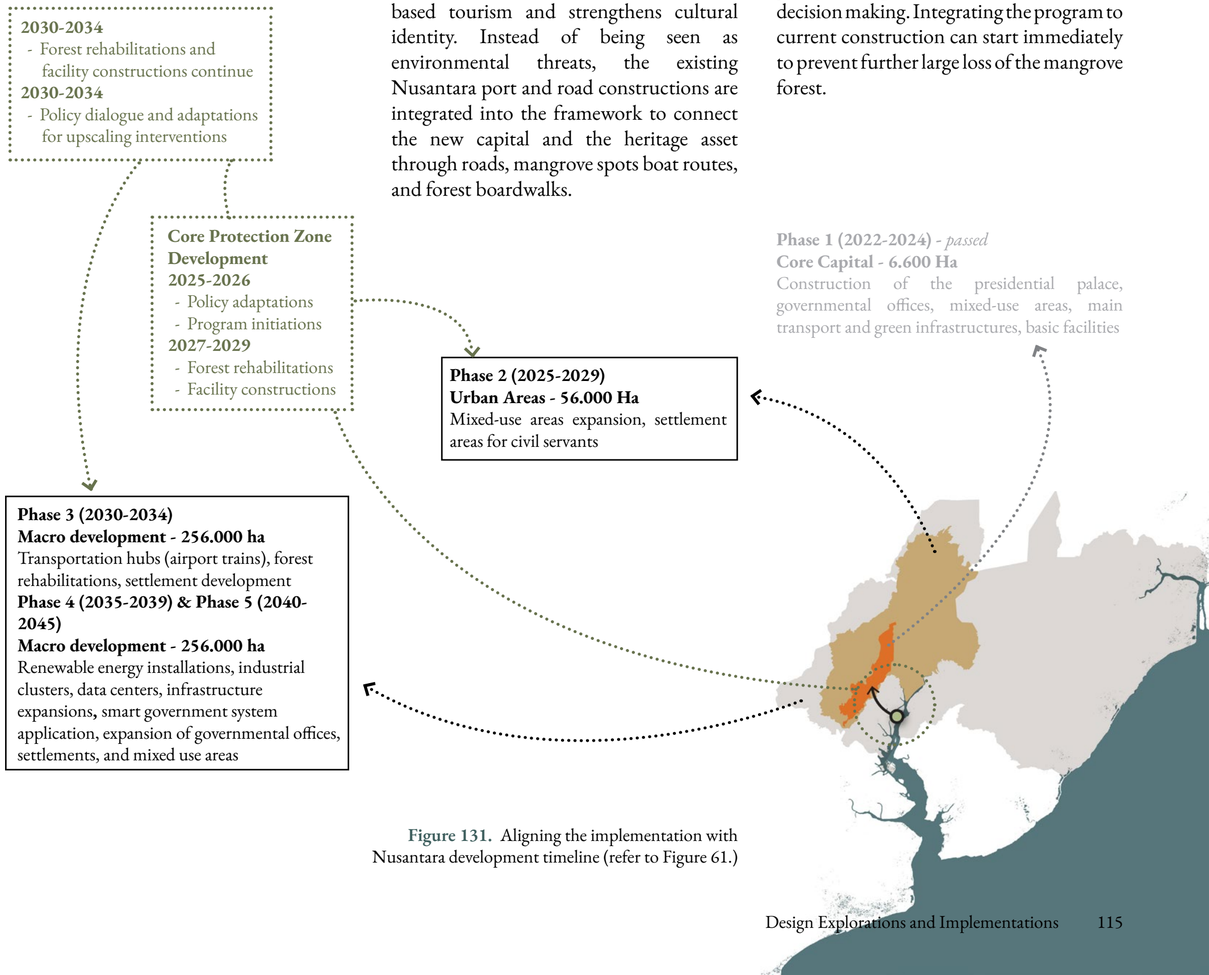


Figure 131. Aligning the implementation with Nusantara development timeline (refer to Figure 61.)

B. Strategic Project 02: Eco-Infiltrating Urban Industry

Overview

Balikpapan city's coastline that faces Balikpapan Bay is currently occupied by a state-owned refinery industry. Several socio-environmental impacts are showing up, including water pollution, reduced number of fish, disrupted local livelihood, and increasing risk of abrasion and coastal flooding when considering strong tides and other climate events. This strategic project aims to explore the application of landscape-based design tools to restore and infiltrate the mangrove forest into the city and industry development. Ultimately, it improves the ecosystem services values to regulate future climate events' risk, supports the sustenance of other biodiversity through new ecological corridors, and provides economic resources.

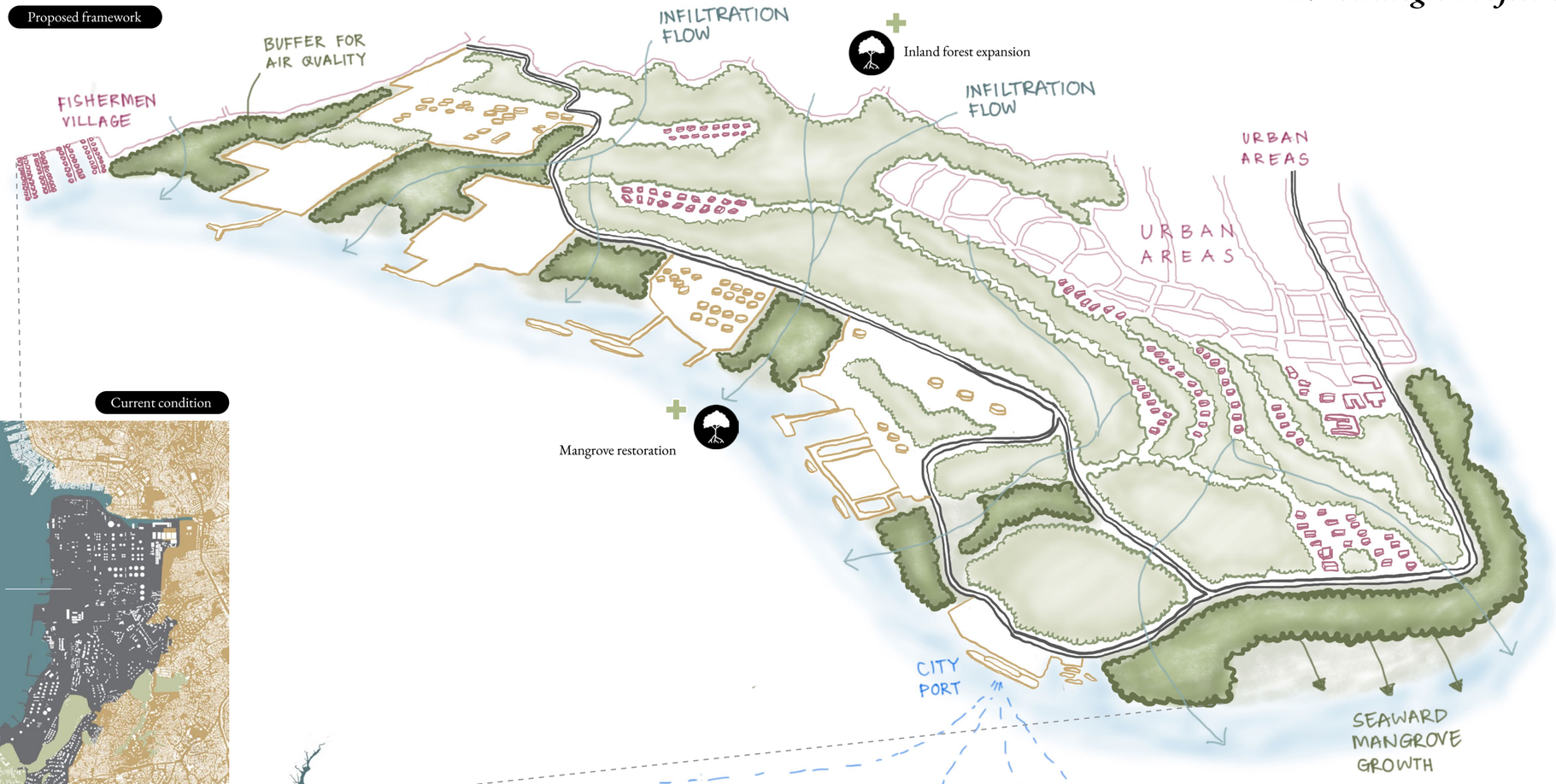


Figure 132. Above – Framework for Strategic Project 02

Figure 133. Left – Current situation map

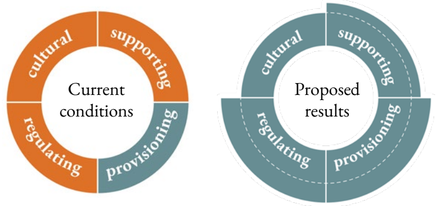


Figure 134. Ecosystem services scale

Design Tools

Polluted water can cause failures in mangrove plantings. Infiltrating mangroves into the industrial complex will require prior water remediation using plants with filtering capacity that are suitable in brackish water and occasional flooding, such as *krokot laut* (*Sesuvium p.*), *jeruju* (*Acanthus i.*), and *wlingi laut* (*Cyperus m.*). Some of these plants promote sediment capture, with help from a natural engineering tool to trap sediment using permeable structures. After the biophysical preparations are finished, mangrove planting can start. To ensure the water quality discharged from inland areas, green areas as infiltration surfaces in the city are expanded. Additionally, the inland forests support several mangrove animals, such as the migratory birds and primates, as ecological corridors.

The new mangroves act as buffer zones from the industry to nearby settlements, including the city and neighboring fishermen village that currently suffers from the air and water pollution caused by the industry. In the open-coast facing shorelines, strong currents become a challenge for mangrove planting. The *buispot* or mangrove tubes methods, learned from the local experts, are utilised to protect young trees from the strong tide and to also function as a breakwater. In the governance sense, these strategies that are related to a vital socioeconomic asset, need an adaptive management with the support from the government to implement transformative structural approaches.

Figure 135. Masterplan and Design Tools of Strategic Project 02

Learning the local knowledge

Despite the absence of mangroves along the city's coastline, some local restoration efforts are found across Balikpapan City. In the outer-fringe urban neighbourhood close to the riverine-mangrove areas, the Mangrove Center Graha Indah started around twenty years ago as an individual initiative to restore lost nearby forests, and today has successfully restored one million mangrove trees. The restoration processes followed the principles of place-specific context. Without prior proper scientific knowledge about ecological restoration, the initiator learned from years of hands-on experience of living around mangroves, resulting in unique approaches, methods, and techniques that were tailored based on the biophysical conditions of each site.

Mainly, mangrove lives on intertidal coasts with ebb-flow tide dynamics and rarely survives along open sea coastlines with stronger currents. Restoration efforts done by Mangrove Center Graha Indah investigated these conditions and utilised different methods. To help with depositing sediments as an important mangrove biophysical aspect, perpendicular bio-based permeable structures, using local materials, can be installed to trap the sediment grains along the coastline before planting young mangrove trees. To avoid young trees being washed away in strong-current areas, a hybrid bio-engineering approach using concrete vases—called *buispot*—helps to stabilise mangrove before growing the strong roots, while the concrete cylinders simultaneously act as breakwaters.

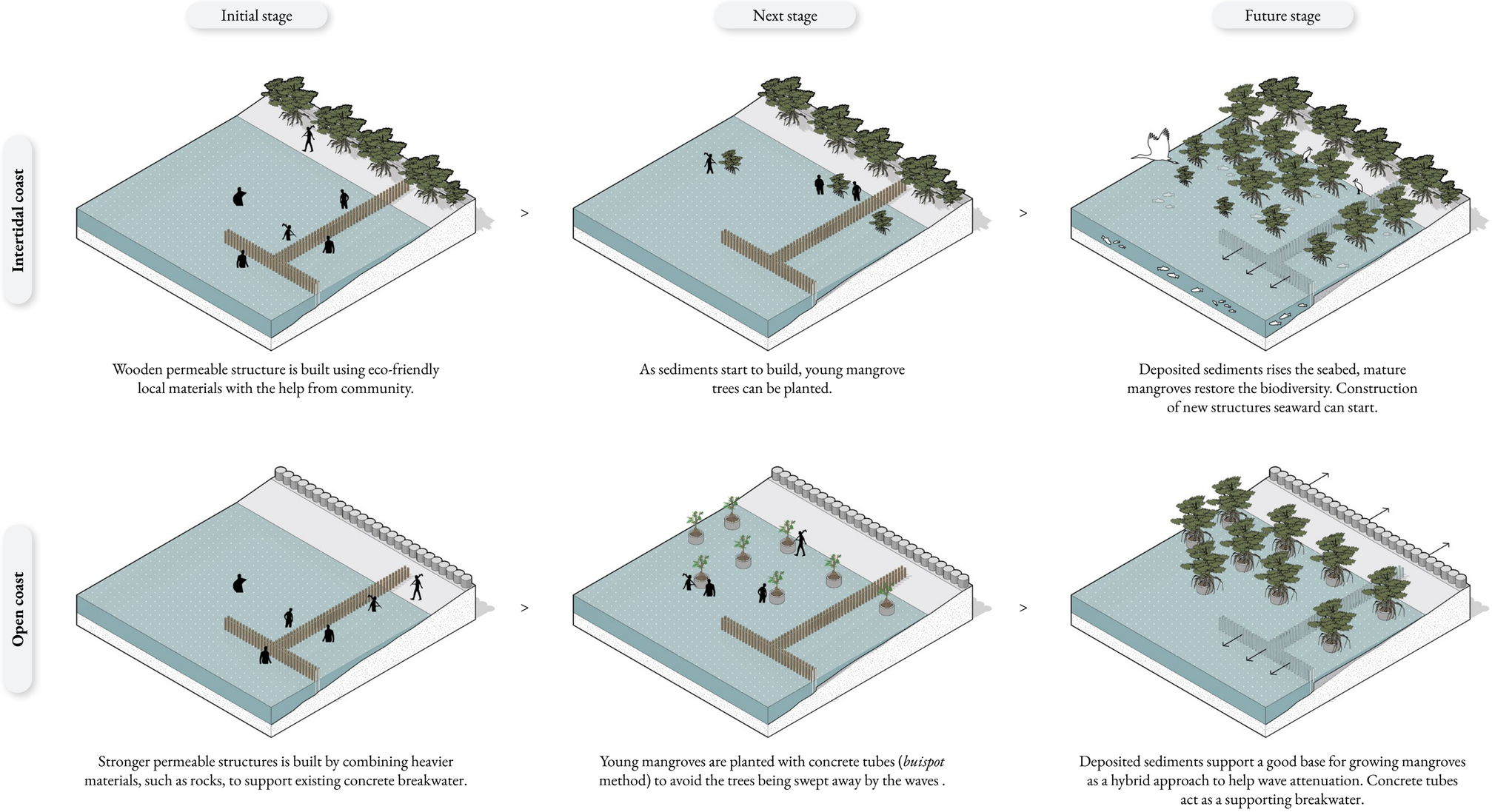


Figure 136. Diagrams of phases

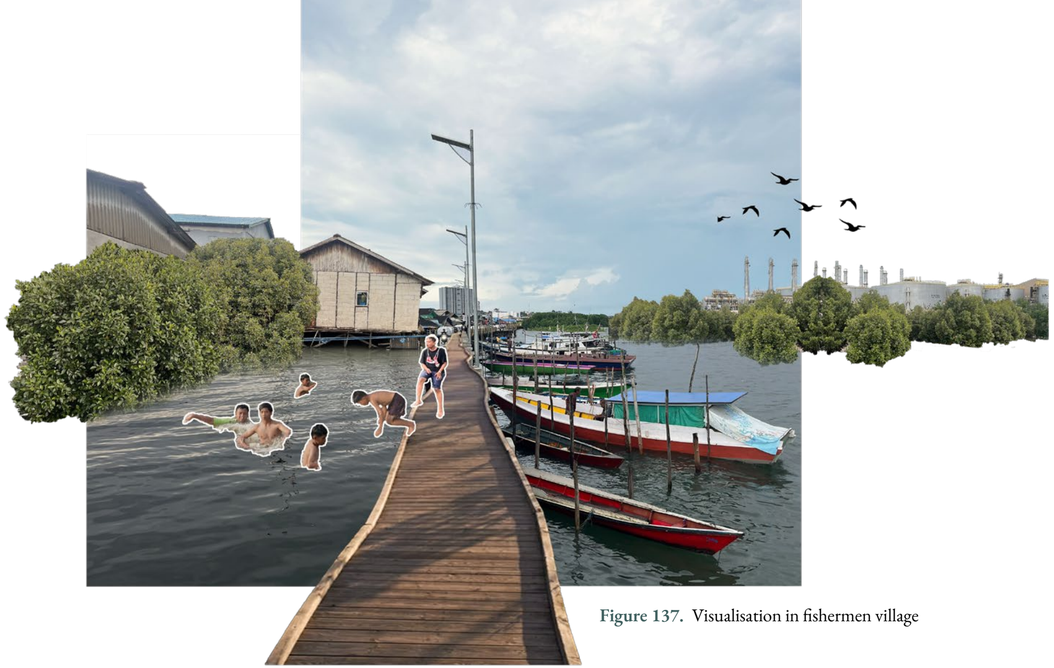


Figure 137. Visualisation in fishermen village

Figure 138. Visualisation of ecological corridors in industrial roads

Providing structural changes to a big socioeconomic activity allows transformation from a degrading environment into a regenerated ecosystem that delivers benefit to both natural cycles and sociocultural systems. Reflecting to the 2018's industrial oil spill accident that cause long-term water pollution and increasing mortality rate to both humans and animals, it is urgent to shift towards environment-based decision making through dialogues and advocacy for policy adaptations. The visualisation below illustrated the change from a damaged environment due to the heavy economic activity, to a rehabilitated ecosystem through partnerships with local stakeholders to restore biodiversity and support local economy.

There are already restoration initiatives supported by the industry company as CSR projects. However, results were not optimal. Mangrove growth will be slow without systemic changes regarding the industrial pollution, as low success rate occurs in a non-optimal biophysical conditions for planting.

The above visualisation shows the regenerated conditions of the mangrove that infiltrated the industry. This approach improves the mangrove's natural capacity on water filtration, increasing water quality within the industry's co-existence with nearby villages which daily life activities and livelihood deeply rely on the bay water and the mangrove ecosystem.

The upper-right visualisation shows potential of integrating ecological or wildlife corridors connecting the mangrove forest and inland forest, presenting above the existing industrial roads.

Figure 139. Visualisation of mangrove regeneration between industries

C. Key Project: A New Tambak System

Overview

The *tambak* culture reflects the human-nature interaction, connecting the biophysical (water, mangrove, biodiversity) and sociocultural (communities, business owners, economy, policy) sub-systems. In Balikpapan Bay, *tambak* has been a typical economic activity for decades. Despite providing valuable economic benefits, *tambak* practices have caused the loss of hectares of mangroves and reduced the natural capacity for disaster risk reduction.

In some areas, the *tambak* ponds exist around nearby villages, which are prone to coastal floods due to a lack of flood prevention capacity from the mangroves. This holds the potential to regenerate the mangrove forest by collaborating with local communities while still supporting the local economy.

The *tambak* case is considered as a key project due to the significance of the interrelation of different factors in this system, where the issue exists across Balikpapan Bay. Connecting to the focus goals, the case of *tambak* is suitable for the comprehensive implementation of the entire **exist – adapt – expand** strategy.

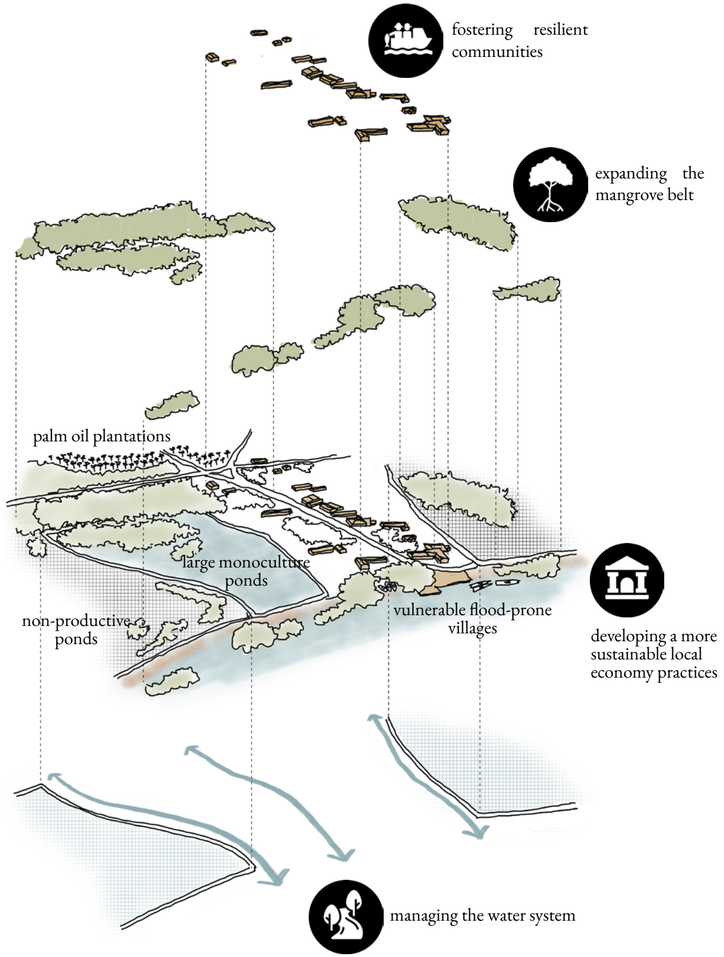


Figure 140. The sub-systems of *tambak*

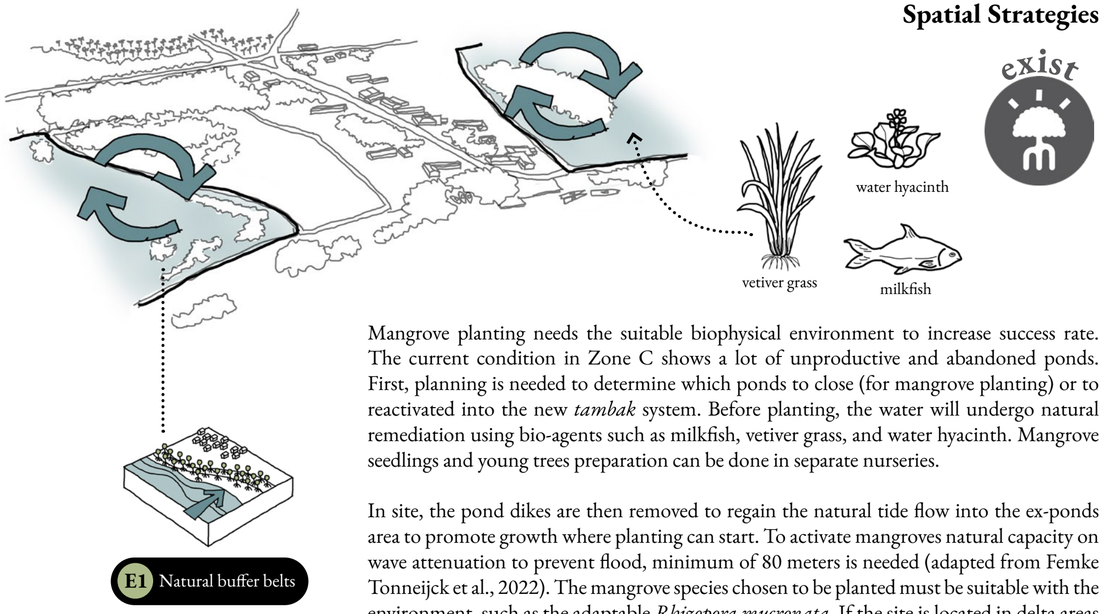


Figure 141. Diagrams of **exist** strategies

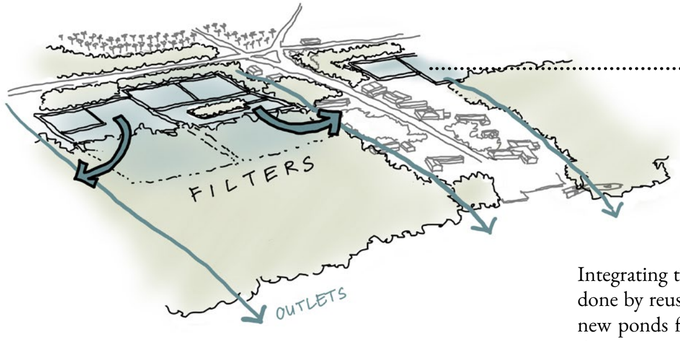
Mangrove planting needs the suitable biophysical environment to increase success rate. The current condition in Zone C shows a lot of unproductive and abandoned ponds. First, planning is needed to determine which ponds to close (for mangrove planting) or to reactivated into the new *tambak* system. Before planting, the water will undergo natural remediation using bio-agents such as milkfish, vetiver grass, and water hyacinth. Mangrove seedlings and young trees preparation can be done in separate nurseries.

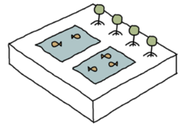
In site, the pond dikes are then removed to regain the natural tide flow into the ex-ponds area to promote growth where planting can start. To activate mangroves natural capacity on wave attenuation to prevent flood, minimum of 80 meters is needed (adapted from Femke Tonneijck et al., 2022). The mangrove species chosen to be planted must be suitable with the environment, such as the adaptable *Rhizopora mucronata*. If the site is located in delta areas with fresh water, the dominant species will be *Nypa fruticans*.

Figure 142. *Nypa f.* in fresh water area

Figure 143. *Rhizopora m.* in brackish water

adapt

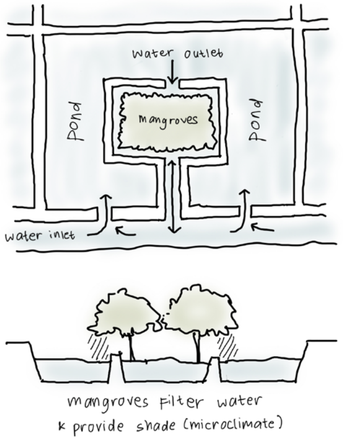




H1 Mixed mangrove aquaculture

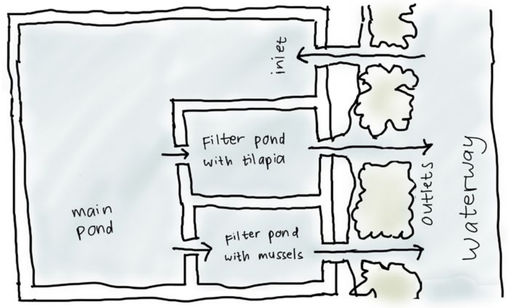
Integrating the new *tambak* system can be done by reusing existing ponds or creating new ponds farther from seaward to retain the mangrove buffers. Following diagrams show the scheme or variations of the ponds as part of design explorations.

Variations 01



Mangroves are planted within the ponds with smaller barrier to control the water quality. The pond animals will benefit from the tree shades controling microclimate, while the pond water will flow through and will be filtered by the mangroves without the eutrophication risks.

Variations 02



This variation makes use of the mangrove belts as the pond water's filter before entering the main waterway, and allowing economic diversification through services of different smaller ponds that can act as double-filtering agents. In this way, the *tambak* workers also receive additional economic value.

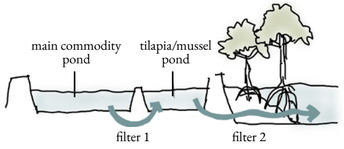
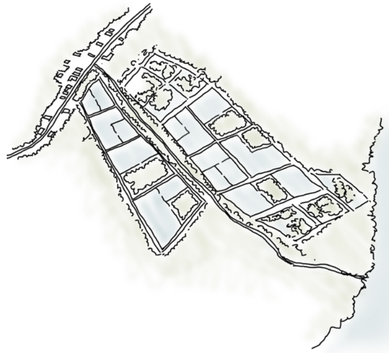


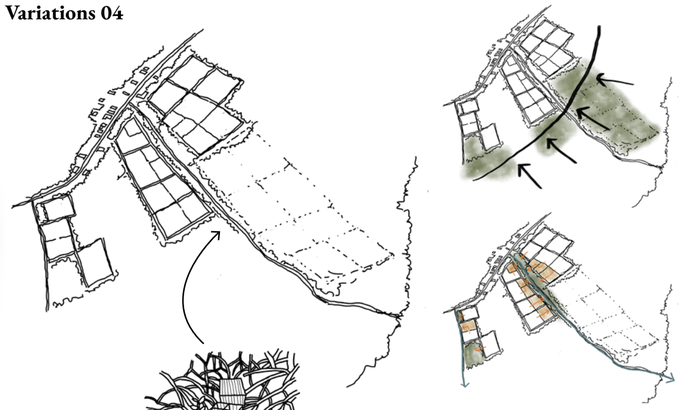
Figure 144. Diagrams of **adapt** strategies

Variations 03



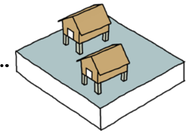
Combining different methods to modify existing *tambak* into smaller patches of ponds to diversify commodities and benefit from the mangrove belts as water filters flowing to the main waterways.

Variations 04

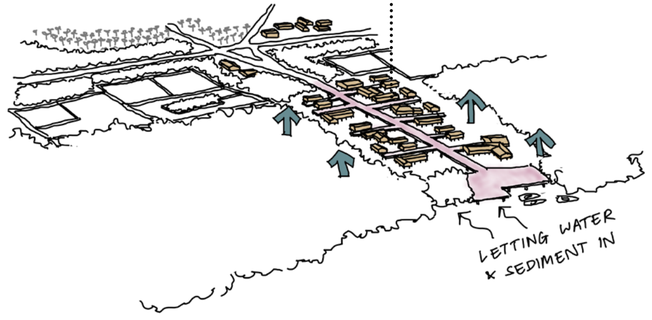


crab traps between mangrove roots

Ponds that are located closer to the seaward area can be closed to restore the mangrove belts and open smaller patches of ponds that combines filtering ponds. Diversification using smaller-scale, non-intensive, and non-extensive aquaculture practices, such as the 'crab cage culture', can be integrated between the mangrove roots without clearing the trees.



H3 Stilt infrastructure



During the process of growing matured trees, modification of the village can be done by adapting the stilt vernacular architecture that are suitable for coastal villages. This method adds resiliency to local infrastructures to withstand flood and sea level rise, but also allow more water and sediment deposit landward to support growth and succession of mangroves.

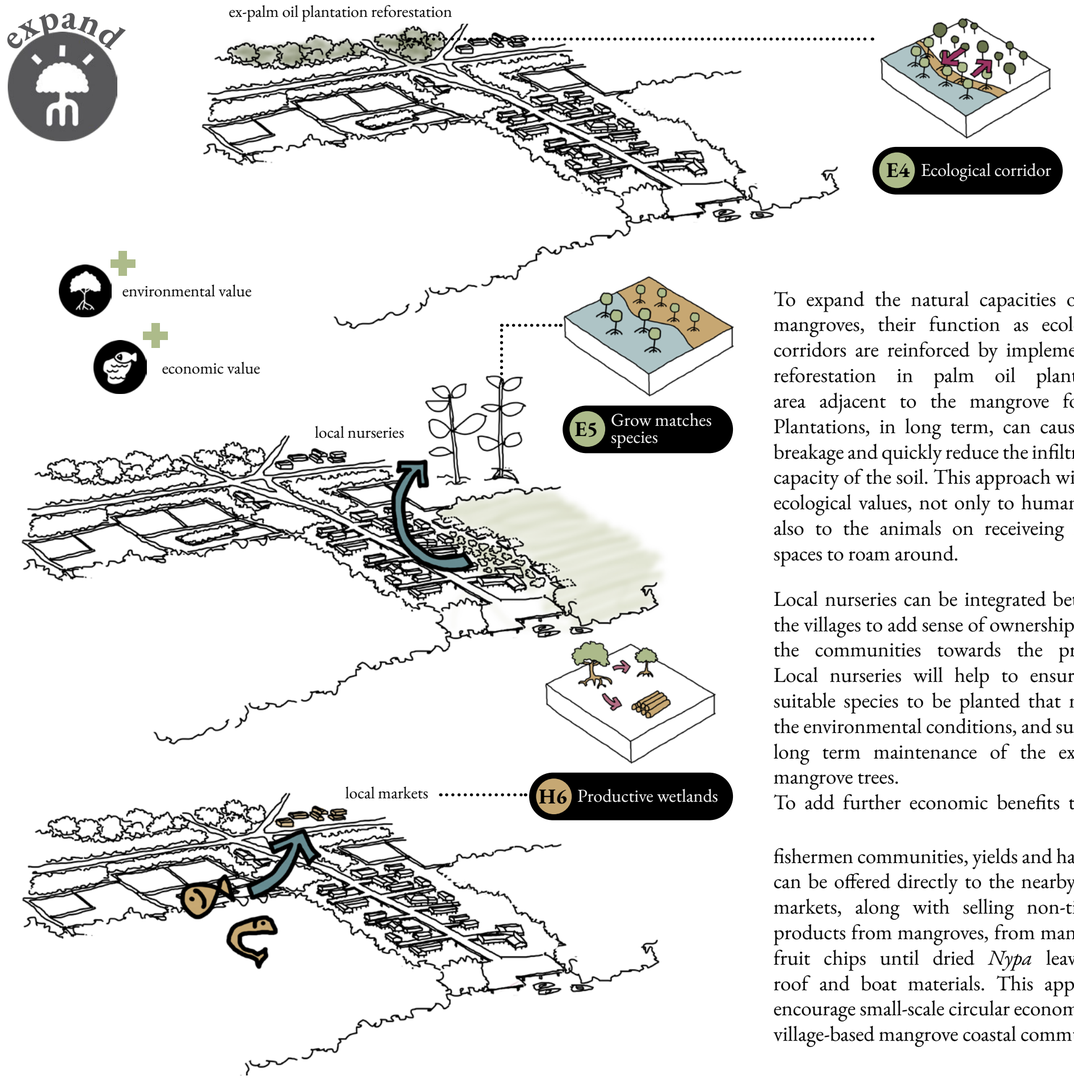


Figure 145. Diagrams of **expand** strategies

To expand the natural capacities of the mangroves, their function as ecological corridors are reinforced by implementing reforestation in palm oil plantation area adjacent to the mangrove forests. Plantations, in long term, can cause soil breakage and quickly reduce the infiltration capacity of the soil. This approach will add ecological values, not only to human, but also to the animals on receiveing larger spaces to roam around.

Local nurseries can be integrated between the villages to add sense of ownership from the communities towards the project. Local nurseries will help to ensure the suitable species to be planted that match the environmental conditions, and support long term maintenance of the existing mangrove trees.
To add further economic benefits to the

fishermen communities, yields and harvests can be offered directly to the nearby local markets, along with selling non-timber products from mangroves, from mangrove fruit chips until dried *Nypa* leaves as roof and boat materials. This approach encourage small-scale circular economy in a village-based mangrove coastal community.

The new *tambak* system allows the regeneration of a mangrove ecosystem that can exist, adapt, and expand, integrating not only ecological benefits but also socioeconomic benefits to the local fishermen villagers. Spatial modifications, integrating planning and design, support long-term mangrove growth in regenerating former polluted waters and non-productive ponds.

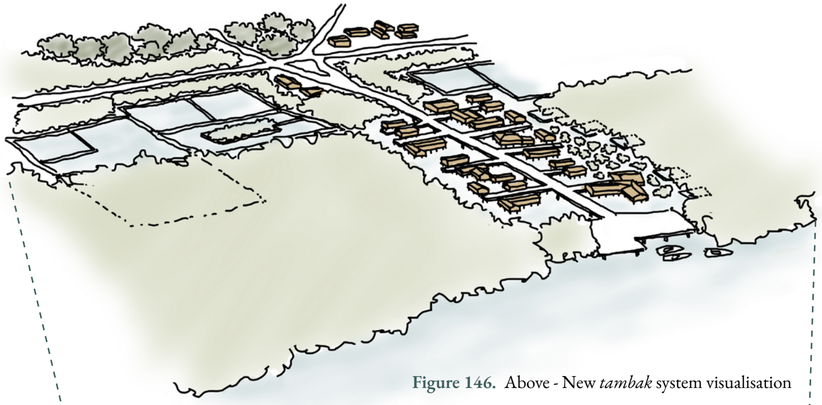


Figure 146. Above - New *tambak* system visualisation

Figure 147. Below - Project masterplan

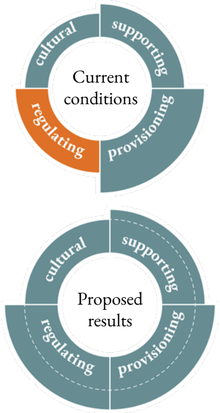


Figure 148. Ecosystem services scale

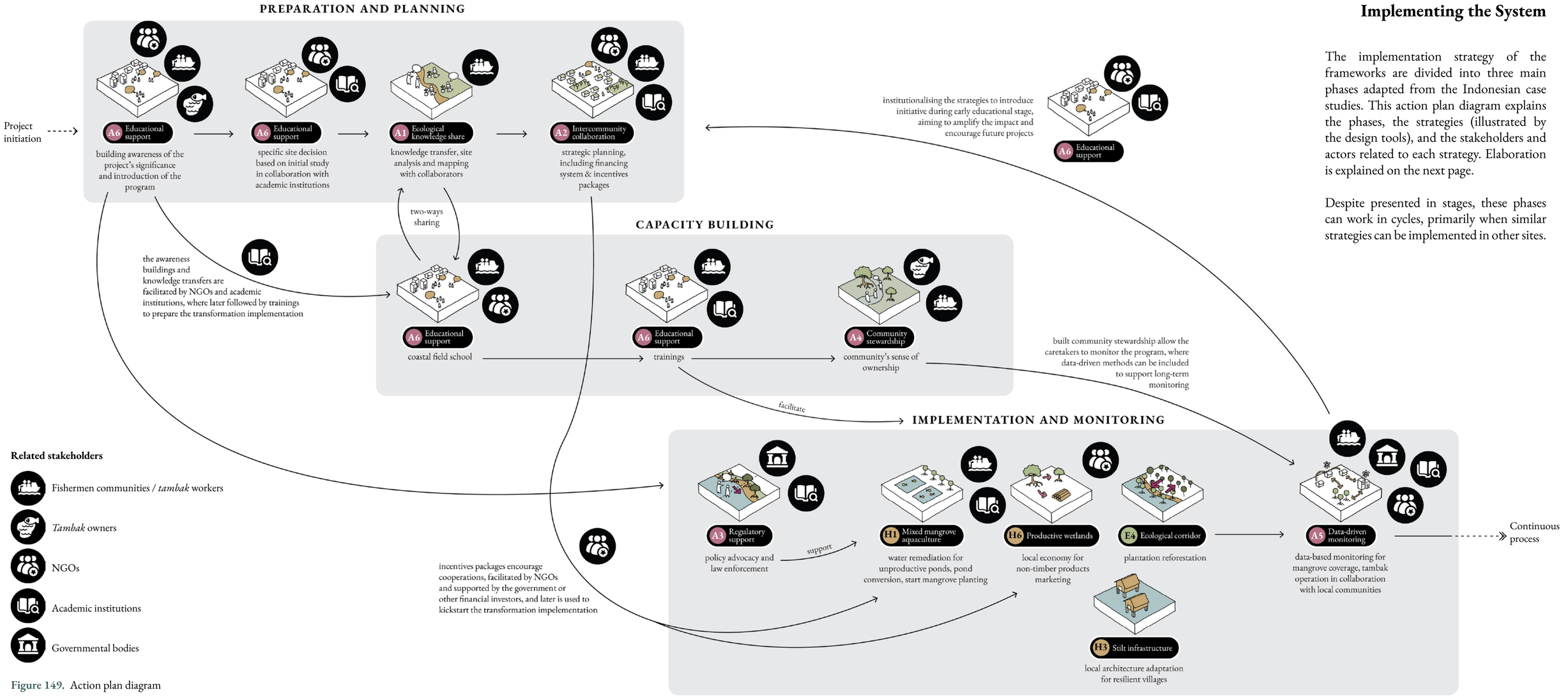


Figure 149. Action plan diagram

Implementing the System

The implementation strategy of the frameworks are divided into three main phases adapted from the Indonesian case studies. This action plan diagram explains the phases, the strategies (illustrated by the design tools), and the stakeholders and actors related to each strategy. Elaboration is explained on the next page.

Despite presented in stages, these phases can work in cycles, primarily when similar strategies can be implemented in other sites.

Mangrove restoration projects faced global failures due to the inability to understand the place-specific context properly. Based on the case studies, one of the challenges of similar projects was the unwillingness and refusal from the main stakeholders to cooperate, such as the *tambak* owners who disagreed to give up their ponds for mangrove regeneration. Therefore, at the beginning of the project, it is vital to build awareness of the project's significance and introduce the program to the *tambak* owners and the fishermen communities. In this preparation and planning phase, collaboration with NGOs will support the facilitation of the process. The next step will be the plan establishment, including the two-way knowledge transfer where the role of academic institutions will be needed. The goal of this phase is to formulate the strategic planning, including the program financing and incentives for the implementation phase.

The capacity building phase means to develop and strengthen the ability, skills, awareness, and initiatives of the local communities. The ecological knowledge transfer process in the previous phase initiated the coastal field school to facilitate training for the new *tambak* system and the mangrove restoration techniques. The training process aims to foster community stewardship towards the project.

Training kickstarts the implementation phase. However, the process of policy dialogues and advocacy with the governmental bodies, facilitated by NGOs and academic institutions, can start earlier. The transformation of the *tambak* and restoration of the mangrove forests can start, followed by plantation reforestation and stilted settlements renovation. This process requires the incentives launch to ensure participation, and monitoring from NGOs. The monitoring strategy comes after, encouraged by built community stewardship, and in collaboration with academic institutions and the government, can be done using data-driven monitoring.

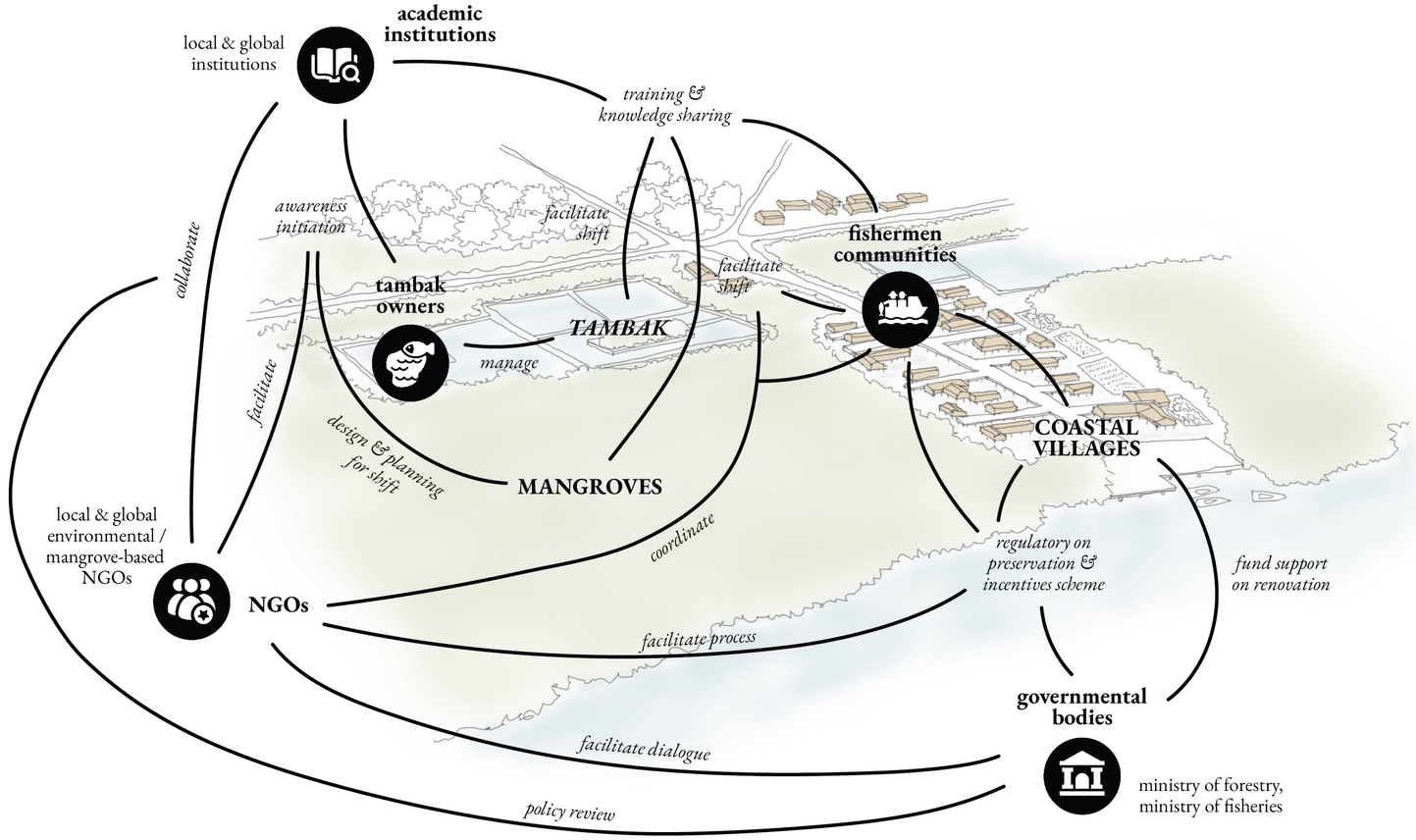


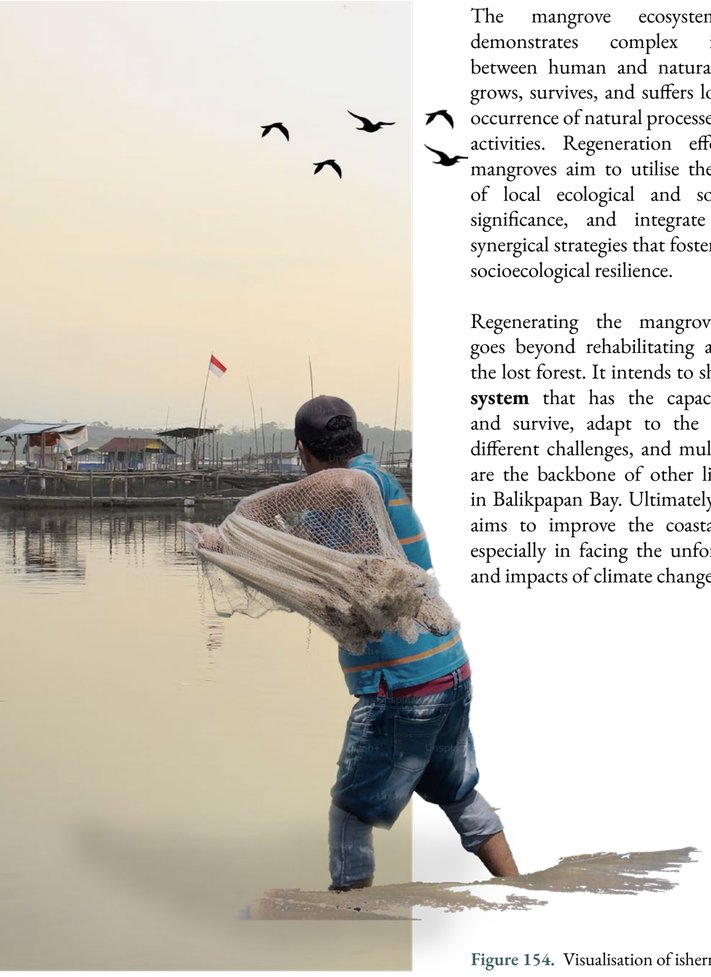
Figure 150. Stakeholders involvement in the action plan

Figure 151. Mangrove nurseries managed by villagers and local communities to ensure planting suitability and long-term monitoring and maintaining of the mangroves (AI-generated image prompted by Author, 2025)

Figure 152. Local market to support community's economy, selling tambak products and provide farm-to-table meals for visitors (AI-generated image prompted by Author, 2025)

Figure 153. Diversification of the existing tambak, using smaller non-extensive patches of ponds to integrate filtering ponds with tilapia, seaweed, etc. and mangrove forest as main water filte

5.3. A Living System in Balikpapan Bay



The mangrove ecosystem dynamic demonstrates complex interrelations between human and natural systems. It grows, survives, and suffers loss under the occurrence of natural processes and human activities. Regeneration efforts of the mangroves aim to utilise the potentiality of local ecological and socioeconomic significance, and integrate them into synergical strategies that foster the system's socioecological resilience.

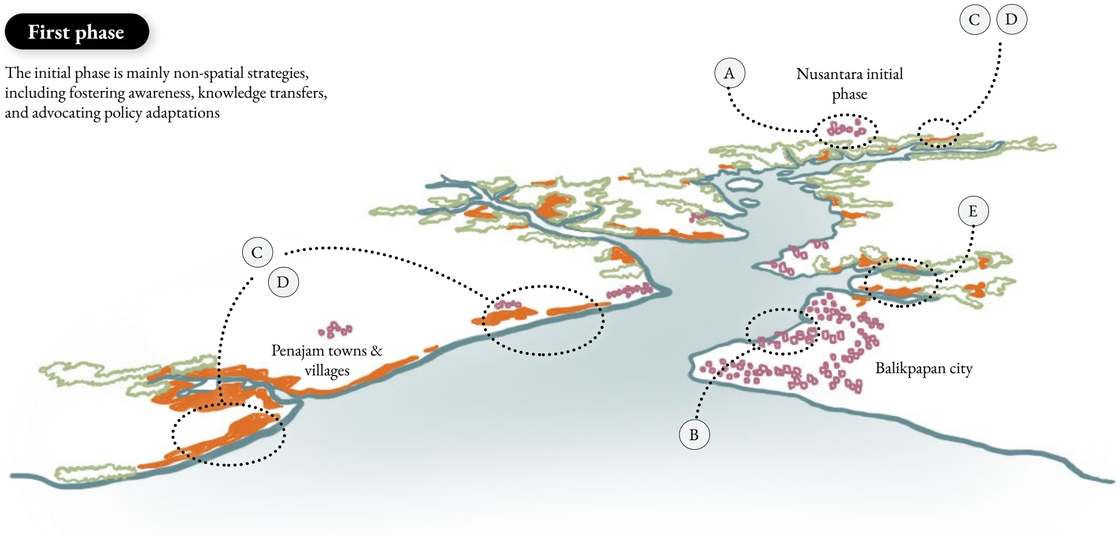
Regenerating the mangrove ecosystem goes beyond rehabilitating and restoring the lost forest. It intends to shape **a living system** that has the capacity to grow and survive, adapt to the dynamics of different challenges, and multiply, as they are the backbone of other living systems in Balikpapan Bay. Ultimately, this project aims to improve the coastal's resilience especially in facing the unforeseen events and impacts of climate change.

Despite occurring in specific locations, the three strategic projects' measures can be scaled up to different areas, considering the place-based context of ecological and socioeconomic aspects. The following drawings demonstrate the combination of different strategies, including the strategic projects, applied together as a growing system, where one site can trigger another site's strategy initiation which are closely linked with different actors related to each location. In general, the role of NGOs and academic institutions is vital as facilitators throughout all stages of the project, mainly to accommodate various kinds of collaborations between local communities, urban residents, and the government, and lastly to ensure monitoring from the caretakers of the projects. The socio-spatial strategies highlight the potential of human-nature interrelation as the synergical path to facilitate short-term strategies for long-term impacts.

Figure 154. Visualisation of ishermen activities

First phase

The initial phase is mainly non-spatial strategies, including fostering awareness, knowledge transfers, and advocating policy adaptations



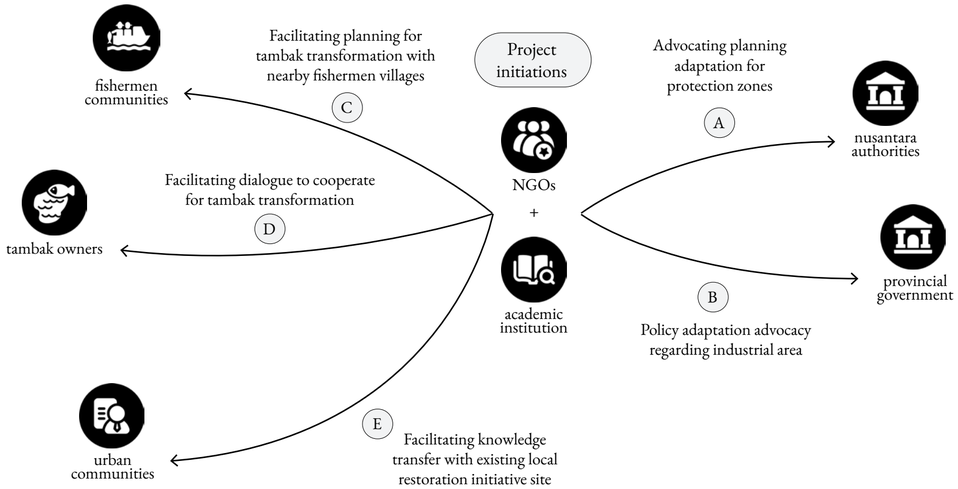
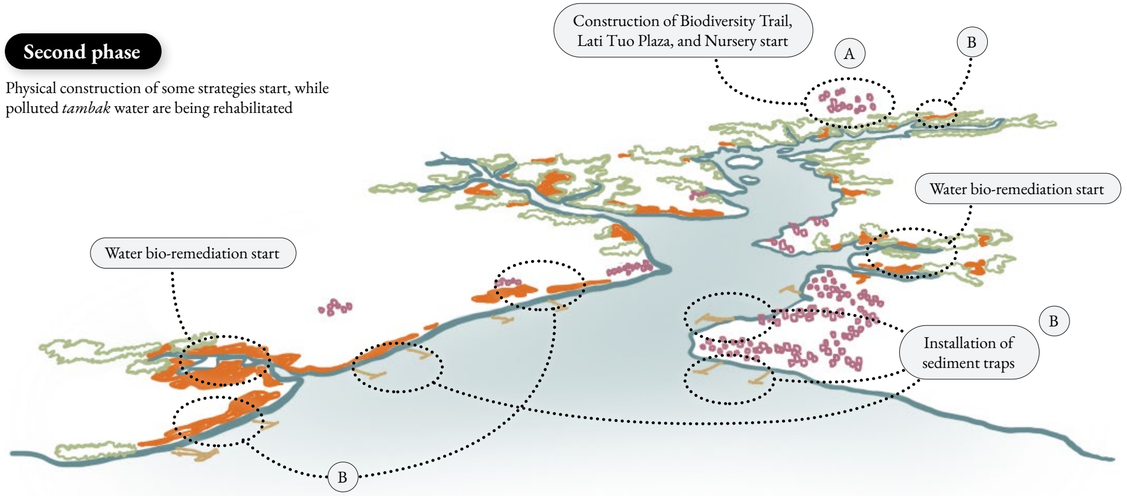


Figure 155. First phase of the growing system

Second phase

Physical construction of some strategies start, while polluted *tambak* water are being rehabilitated



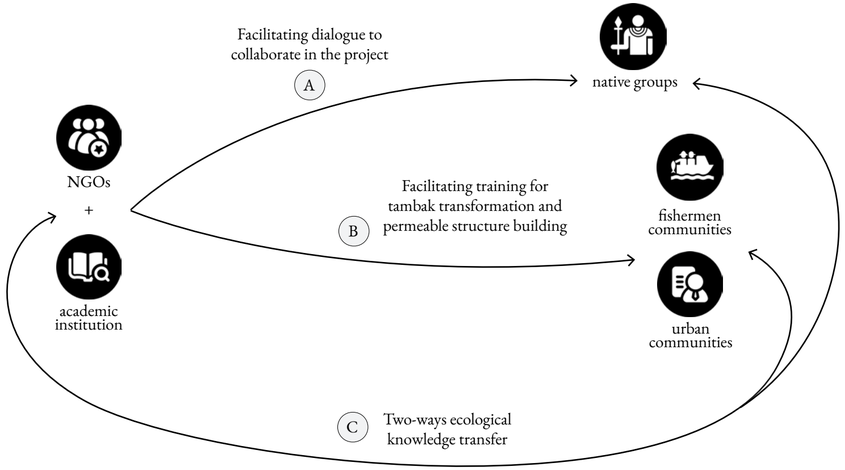
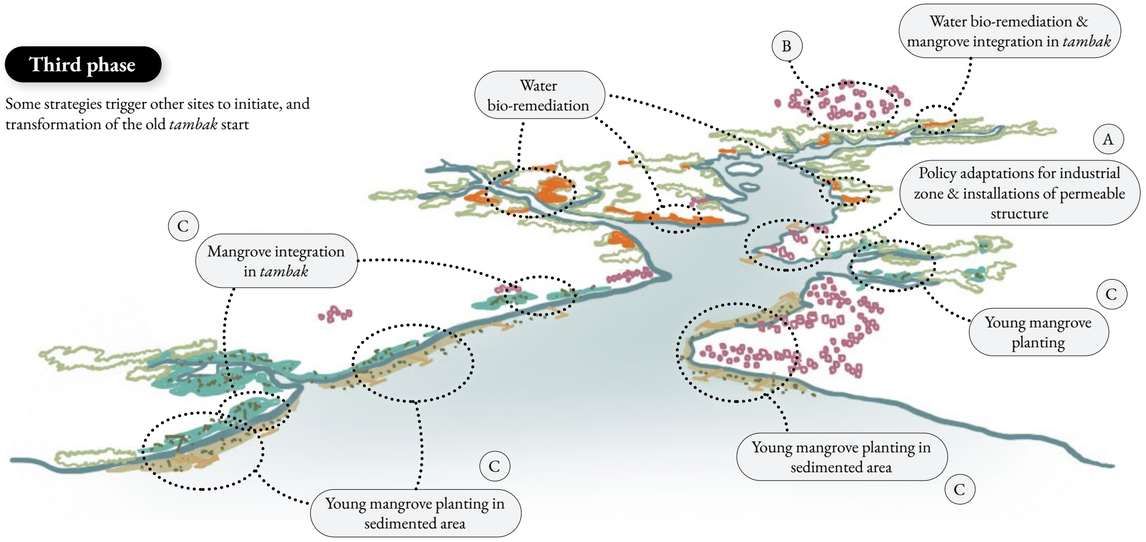


Figure 156. Second phase of the growing system

Third phase

Some strategies trigger other sites to initiate, and transformation of the old *tambak* start



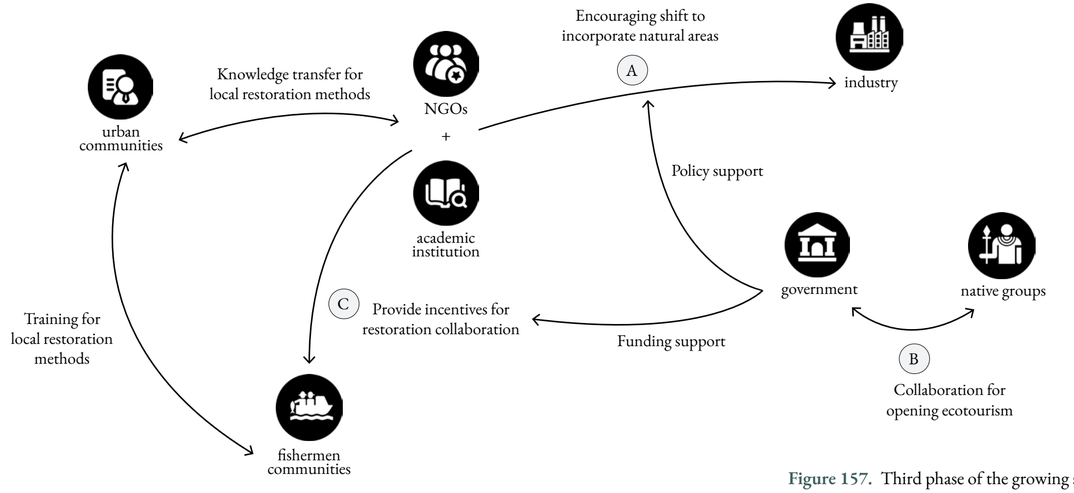
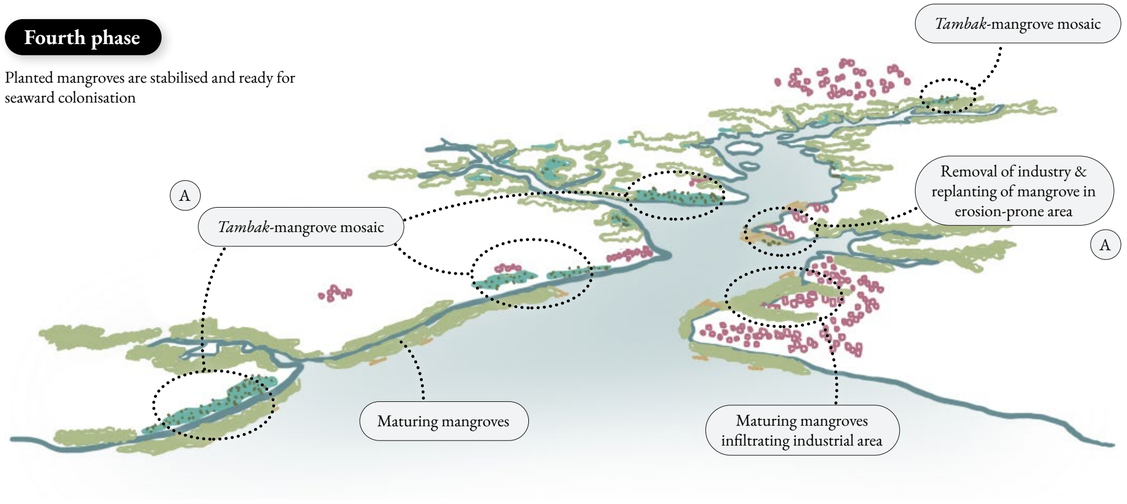


Figure 157. Third phase of the growing system

Fourth phase

Planted mangroves are stabilised and ready for seaward colonisation



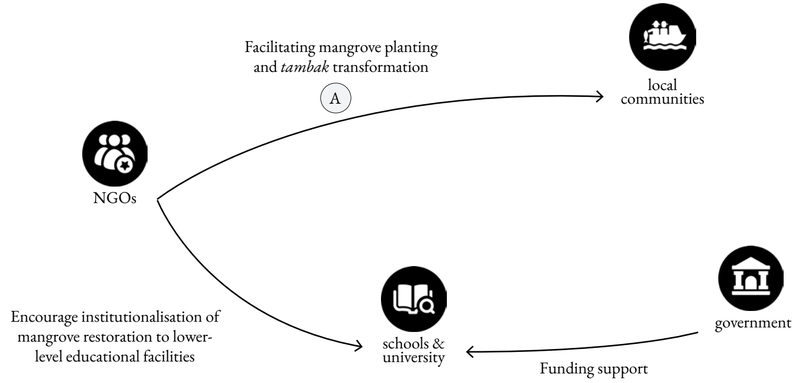
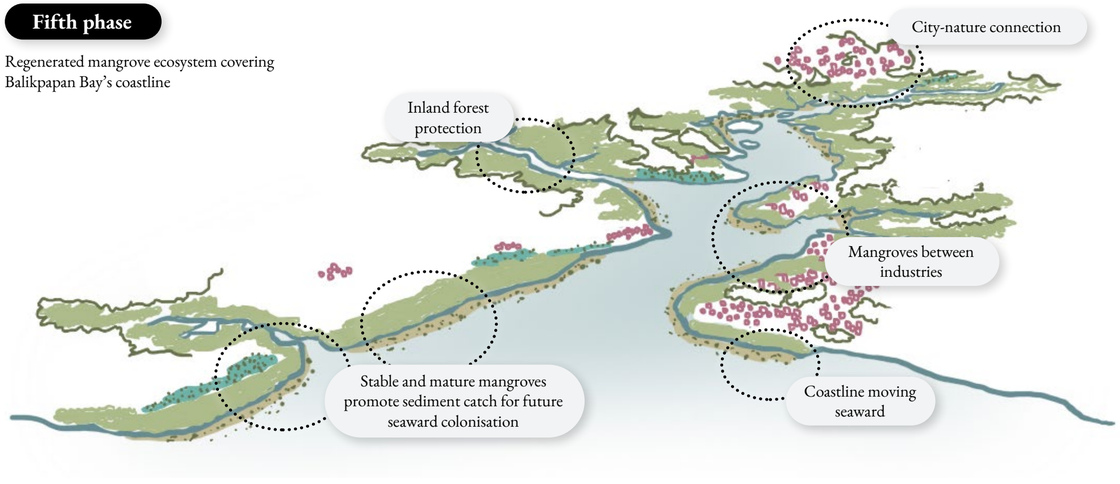


Figure 158. Fourth phase of the growing system

Fifth phase

Regenerated mangrove ecosystem covering Balikpapan Bay's coastline



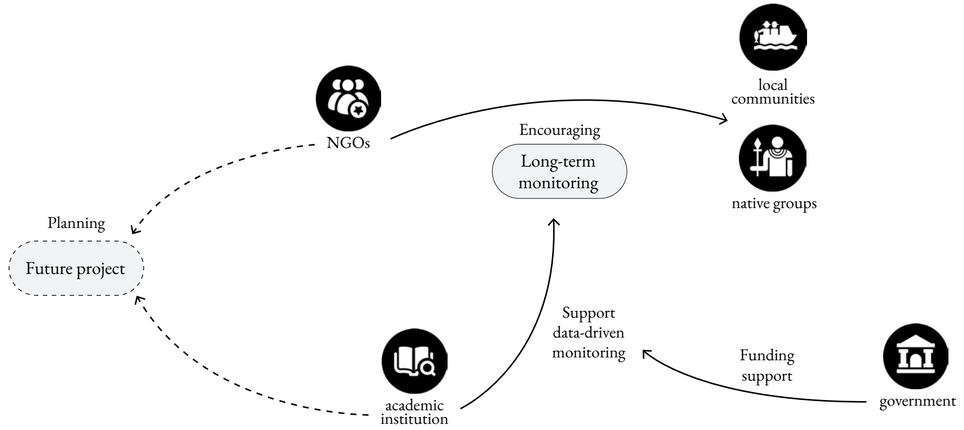


Figure 159. Fifth phase of the growing system

5.4. Initiating the Facilitators

In the AR3U110 Intensives: Governance, Policies, and Stakeholders course, the Author was challenged to think of the positioning of different stakeholders based on their sectors and attitudes (refer to Figure 86.), and power, and interest (refer to Figure 159.). The actors and stakeholders were elaborated, to think critically about the various interests that can arise in a project, and to further think about the different approaches to apply to each stakeholders. The diagram below explains positioning of the stakeholders in regards of their power and interest towards the project.

A. Power-interest matrix with attitude indications

Current situation

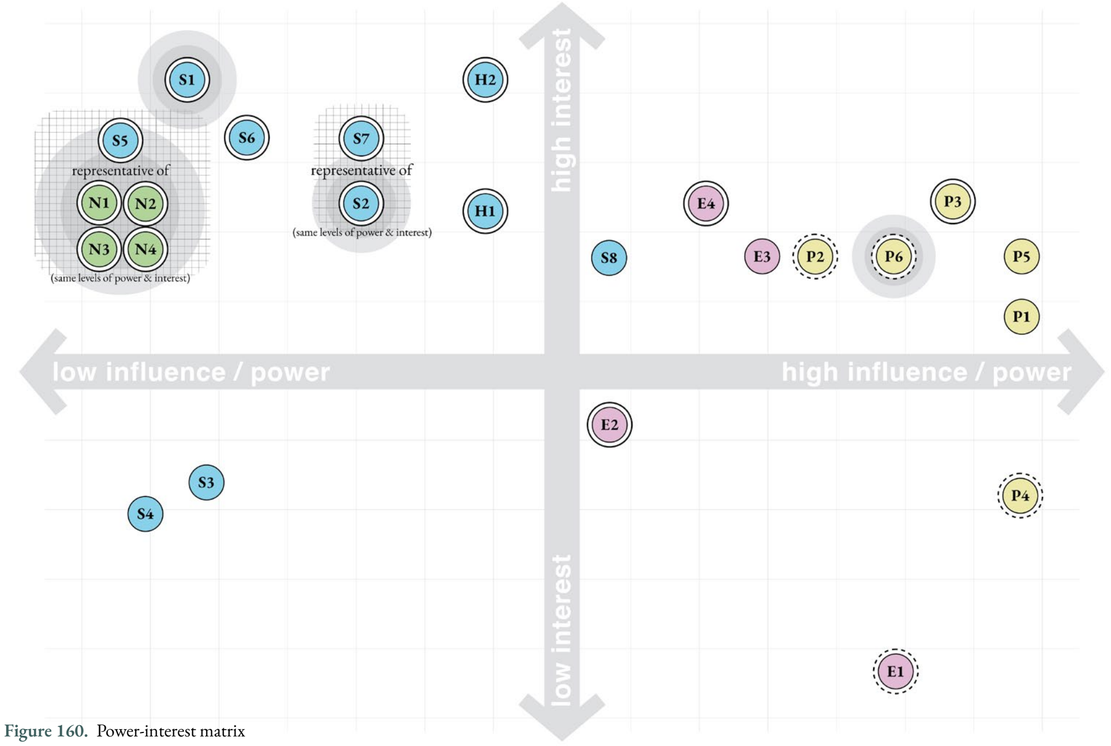
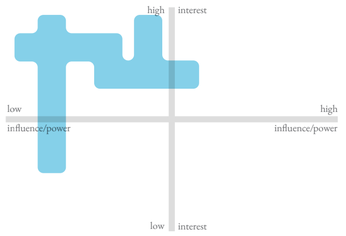


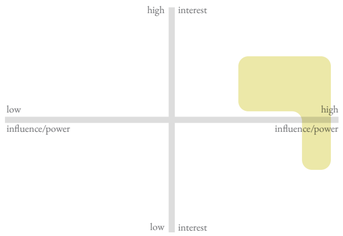
Figure 160. Power-interest matrix

Civil society



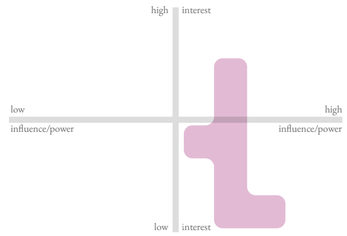
The stakeholders in this group is mostly in the high interest-low influencing power axis. The non-human nature and the native groups, is represented by related NGOs or advocate groups to amplify their voice. Urban and rural populations around the region have lower interest compared to local coastal communities as more vulnerable groups suffer direct impacts from environmental degradations.

Public



Stakeholders in this sector come from decision-making power, especially the ministries, with each possessing different interests. The Ministry of Forestry has a higher interest towards restoration projects but has lower decision-making power compared to the Ministry of National Development Planning, which focuses more on investments and economic strategic projects, and the Ministry of Public Works and Housing, which handles infrastructure projects. The two latter ministries have opposing attitudes due to project timeframe concerns.

Private



This stakeholder group has a higher influencing power compared to the civil society group. The refinery company and logistic industries have a considerably high power but very low interest towards restoration projects that can risk their business growth. With a similar low interest, *tambak* and plantation owners usually have weaker voices. However, groups with big capital for grants and funding are highly interested in and supported the project.

Figure 161. Above – Schematic diagram allocating different stakeholders sectors

Public sector

P1	Ministry of National Development Planning
P2	Provincial government of East Kalimantan
P3	Ministry of Forestry
P4	Ministry of Public Works and Housing
P5	Ministry of Agrarian Affairs and Spatial Planning
P6	Nusantara Authority

Private sector

E1	National oil company, construction & logistic industry, plantation and tambakowners
E2	Industrial planning consultants
E3	Investors
E4	Conservation trusts & foundation

Civil society

S1	Coastal and fishermen communities
S2	East Kalimantan native groups
S3	Urban population
S4	Rural population
S5	Indonesian environmental NGO & advocates (WALHI, YKAN) as nature representative
S6	Global environmental NGO (WWF, IUCN, Mangrove Action Project)
S7	Indonesian ethnic groups representatives
S8	Media outlets
H1	Research & academic institution
H2	Landscape practitioner

Non-human

N1	Mangrove forests
N2	Balikpapan Bay
N3	Plants & animals species
N4	Forests

Significant stakeholders

Attitude

- Proponents
- Opponents
- Fence-sitters

B. Moving the attitudes

Plan

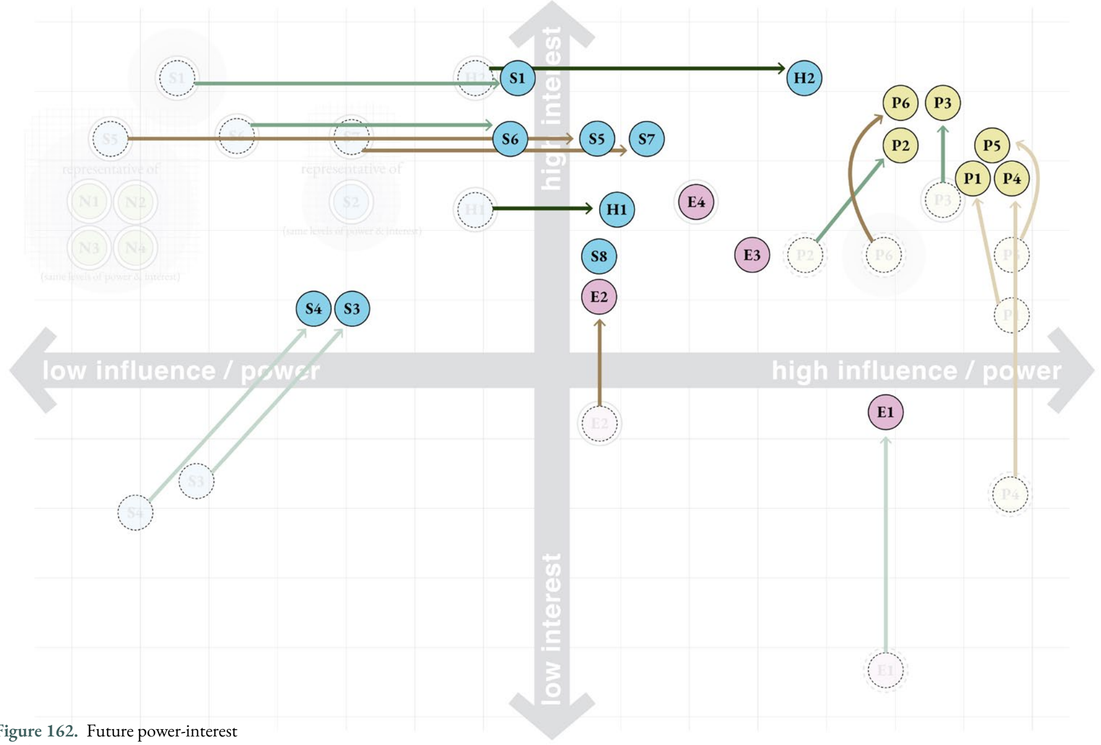
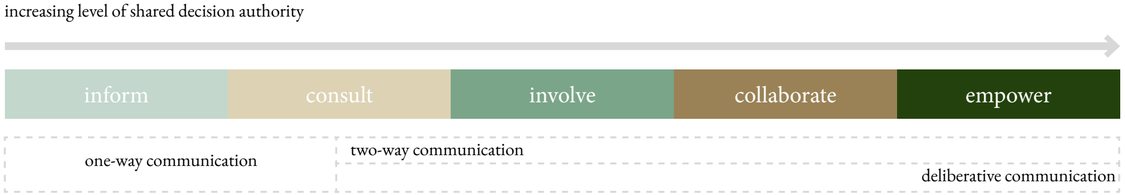


Figure 162. Future power-interest matrix

Recognising the voices of vulnerable and often disregarded groups, such as the native groups and coastal communities, is one of the main goal of the engagement strategy. The other goal is to increase the decision-makers' interest in shifting towards environmental protection approaches. By involving NGOs and global companies, this project fosters collaboration between public and private realms to ensure the success of the project.



The Spectrum of Public Participation (Spectrum of Public Participation, 2019) outlines five levels of participation, each representing a greater degree of public influence in decision-making. This framework helps community groups clarify and establish the public's role in democratic decision-making processes. The first degree of the participation strategy is **inform**. Informing stakeholders, such as the urban and rural population, and businesses related to this region, such as the refinery company, industries, and *tambak* and plantation owners aims to increase awareness of these parties of how vital environmental protections are. The **consult** engagement strategy for ministries that currently are more focused on economic development aims to convince the decision-maker of the project's importance and discuss integrating their views on the plan. Through the **involve** strategy, important roles with previously less power, such as the provincial government and the Ministry of Forestry with lower power compared to other ministries, and the local coastal communities, can be informed about the project, have their views considered in the planning process, and work directly with these stakeholders. The next strategy, **collaborate**, means to partner to a higher degree with the stakeholders with active involvement in decision-making. The project plans to collaborate with the related ministries, NGOs, and academic institutions. The highest degree of participation, **empower**, seeks to largely include the stakeholders in the planning process as equal decision-makers. This group belongs to research institutions and landscape-based practitioners that root decisions on sustainable considerations align with the project's objectives.

Public sector

- P1 Ministry of National Development Planning
- P2 Provincial government of East Kalimantan
- P3 Ministry of Forestry
- P4 Ministry of Public Works and Housing
- P5 Ministry of Agrarian Affairs and Spatial Planning
- P6 Nusantara Authority

Private sector

- E1 National oil company, construction & logistic industry, plantation and tambakowners
- E2 Industrial planning consultants
- E3 Investors
- E4 Conservation trusts & foundation

Non-human

- N1 Mangrove forests
- N2 Balikpapan Bay
- N3 Plants & animals species
- N4 Forests

Civil society

- S1 Coastal and fishermen communities
- S2 East Kalimantan native groups
- S3 Urban population
- S4 Rural population
- S5 Indonesian environmental NGO & advocates (WALHI, YKAN) as nature representative
- S6 Global environmental NGO (WWF, IUCN, Mangrove Action Project)
- S7 Indonesian ethnic groups representatives
- S8 Media outlets
- H1 Research & academic institution
- H2 Landscape practitioner

Inform
Consult
Involve
Collaborate
Empower

Figure 163. Different forms of public participations adapted from the Spectrum of Public Participation, 2017

C. *Engagement strategies in spatial context*

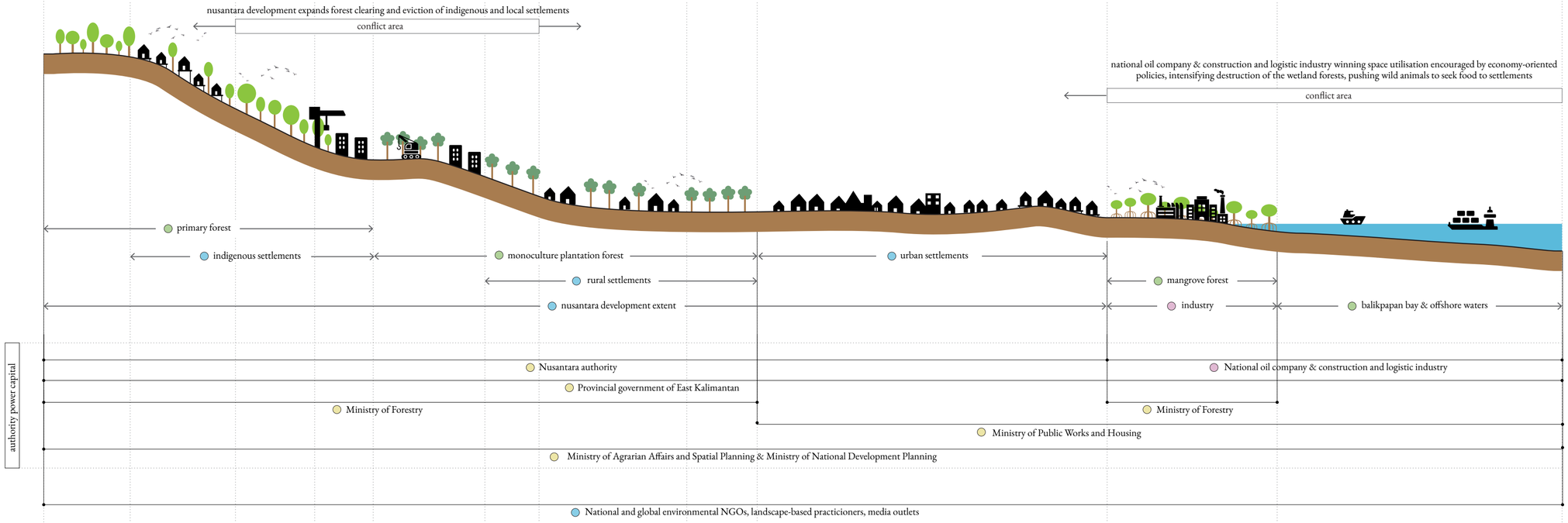


Figure 164. Sections showing stakeholders

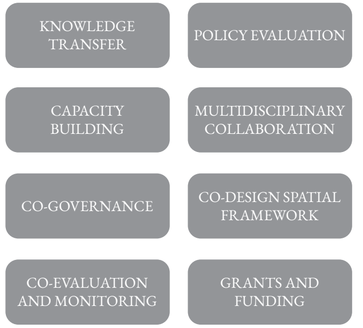
Figure 165. Keyplan for section

Empowering vulnerable stakeholder groups

The declining amount of mangrove forests and condition of Balikpapan Bay waters pose threats to the vulnerable groups of native people, local coastal communities, and the animals and plants relying their lives on resources in this region. To empower their voices, these groups can be represented through socio-environmental organizations. This approach draws inspiration from the Puhinui Stream Restoration project (Eke Panuku Development Auckland, 2017) as a study case in the Governance, Policies, and Stakeholders Intensive course, where the indigenous Māori group was appointed as a representative for the Puhinui River. The Māori people were heavily involved in the planning process as the river's 'guardians' within a co-governance model. The initiative brought together government councils, NGOs, local communities, and the Māori group to co-design a restoration framework rooted in Māori values of nature preservation. In Balikpapan Bay's context, science-based experts can engage in ecological knowledge exchange with coastal communities and native groups about nature, including the local practices. Community workshops will focus on building the capacity of these groups, enhancing their role in conservation efforts. Active involvement fosters a sense of ownership, enabling community-driven monitoring of restoration progress.

Fostering public-private-civic collaboration and partnerships

Current spatial planning policies prioritize economic growth. By incorporating input from communities, facilitated by NGOs, policy evaluations for government authorities aim to raise awareness and emphasize the importance of mangrove restoration in Balikpapan Bay, advocating for a shift away from unsustainable industrial expansion. Strong collaboration among diverse stakeholders enables a multifaceted approach to nature preservation, supports the development and implementation of effective restoration frameworks, improves access to funding opportunities, and sustains multidisciplinary monitoring and evaluation of the project.

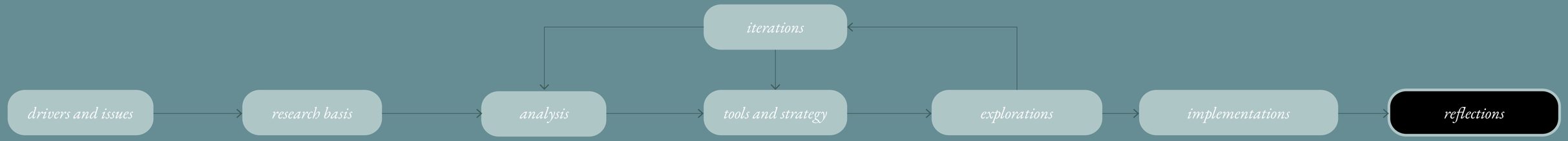


06

discussions and reflections

evaluating results

This chapter is intended to conclude the research and design project, as a means to reflect on the process, approaches, methods, and results proposed in this report.



6.1. Discussions

To conclude the research and design processes of this project, this section chapter is intended to answering research questions as follows:

Sub-Research Question 1: What conditions enable mangrove ecosystems to thrive, and how do these reflect the current state of the mangrove ecosystem in Balikpapan Bay?

Mangroves typically live in intertidal zones, but each mangrove species has different biophysical requirements that influence their survival and growth. Most of mangrove species occupy coastal areas with brackish water characteristics, while some others live in deltaic areas with fresh water, distinguishing the different water salinity level requirements needed between species. However, mangrove mainly needs healthy and nutrient-rich sedimentation that is deposited through the natural tide flow, where the tidal current also helps with seedlings and propagule dispersal and nutrient distribution. Mangrove ecosystems include other biodiversity that co-exist within an overlapping natural cycle and create a symbiotic relationship. For example, small animals that build burrows between the complex mangrove root systems, such as shrimp, mudcrab, and mudskipper, help to decompose fallen leaves to break down nutrients and avoid water eutrophication.

Balikpapan Bay supports almost 16.000 hectares of mangrove forests occupying its estuarine and deltaic zones. Native settlers built homes alongside the bay's coastlines since before the country was established, setting the foundation for the formation of some organic fishermen's villages, small towns landward, and the urbanised Balikpapan City that started with an oil-well excavation project. With the plan of moving the country's capital city, the northern part of the bay is now being developed for the construction of Nusantara New Capital. Balikpapan Bay, as a strong socioenvironmental structure, faces challenges from the socioeconomic development that impact the health of the mangrove ecosystem, including the water and sedimentation quality, and the removal of biodiverse habitats. The expansion of extensive industries—mainly oil and gas, and mining—triggered more urban development that together urged the clearing of mangrove areas, while the industrial activities significantly polluted Balikpapan Bay's water. With less water quality, mangroves are not able to grow well. In Balikpapan City, the industrial complex occupies almost the entire coastline with very little mangrove coverage. Combined with the impact of the strong natural tidal currents, Balikpapan City has a vulnerable coastline that is prone to abrasion and coastal flooding. Additionally, the other coastal mangrove areas are facing significant challenges due to large alterations for building *tambak* or aquaculture which is economically beneficial in the short term, and environmentally degrading in the long term.

Sub-Research Question 2: How do the challenges of mangrove ecosystem degradation in Balikpapan Bay impact the various actors and stakeholders involved?

Mangrove forest delivers an ample amount of ecosystem values and services, supporting the life of both human and non-human stakeholders through four main service categories: regulating, provisioning, supporting, and cultural services. Mangrove helps regulate wave and sedimentation dynamics to prevent coastal flooding and abrasion. As mentioned in the previous point, mangroves provide habitat to different marine and terrestrial animals, and provide food and livelihood resources for humans. Nutrient change and natural water filtration process in mangrove soil support other ecosystems' sustenance, such as seagrass and coral reef ecosystems. Lastly, some parts of Balikpapan Bay's mangroves are cultural sites for Kalimantan's ethnic groups.

The mangrove degradation in Balikpapan Bay has disturbed the ecosystem services for the different human and non-human stakeholders. Polluted water and frequent container ship traffic disrupted underwater animals, such as the endemic Irrawaddy dolphins which had reduced in number, according to local fishermen, due to the toxic water. For arboreal animals like the *bekantan* monkey, the decline means less habitat, fewer nests, and fewer spaces to roam around in. The declining number of fish also reduces fishermen's livelihood, while coastal flooding and abrasion caused by the lack of mangroves may destroy the local community's houses or even the city's infrastructure and cause economic loss. For the indigenous groups, industrial expansion causes the loss of culturally significant forests.

Sub-Research Question 3: How can regenerative principles address the issues imposed in the Balikpapan Bay region?

The analysis processes—covered in sub-research questions 1 and 2—justify the main themes used in the conceptual framework and derived from the theoretical study, which are: **Design with Nature, Design with People**, and **Design with Synergy** as a response to human-nature relations phenomena in complex-dynamic and interrelated systems. The design principles are based on the conceptual elements, and centred around creating a regenerative mangrove ecosystem landscape as a backbone in Balikpapan Bay, which are: **Ecosystem-Centred Design** that uses nature-based solutions, **Adaptive Capacity Focus** to build and foster the facilitators of the nature-based solutions, and **Hybrid Landscape** that looks into the synergy of different elements and its potentials. Environmentally, the principles aim to restore the natural water system and quality, enhance the biodiversity, retain the sediment flow and health, and strengthen the natural coastal fort capacity. Principles that focus on the people aim to do co-creation, apply adaptive governance and management, and foster awareness initiatives. Meanwhile, looking into the synergy potentials means doing local-based adaptations and advancing the ecosystem services.

Sub-Research Question 4: What socio-spatial framework and strategies can be applied to the issues imposed in the Balikpapan Bay region?

The design principles and sub-principles consist of several design tools to translate more abstract concepts into context-based ideas and concrete strategies. To restore the natural water system and quality, the design tools are: (E1) natural buffer belts, and (E2) stormwater system integration. To retain deposit flow and sediment health, the design tool is: (E3) deposit trap. To do biodiversity enhancement, the design tool is: (E4) ecological corridor. To strengthen coastal forts, the design tools are: (E5) grow matches species, and (56) blue carbon zone. To do co-creation, the design tools are: (A1) ecological knowledge share, and (A2) intercommunity collaboration. To do adaptive governance and management, the design tools are: (A3) regulatory support, (A4) community stewardship, and (A5) data-driven monitoring. To have awareness initiatives, the design tool is: (A6) educational support. To apply local-based adaptations, the design tools are: (H1) mixed-mangrove aquaculture, (H2) mangrove tubes, and (H3) stilt infrastructure. To do ecoservices advancement, the design tools are: (H4) ecotourism corridor, (H5) cultural sites preservation, and (H6) productive wetlands.

On the regional scale, the goals are to foster ecological restoration, expand habitat linkages, create coastal protection zones, promote nature-positive livelihood support, and stimulate human-nature reconnection. The strategies to achieve these goals are implementable through scales. On the zone scale, with different mangrove damage levels, each zone has different focuses from the exist-adapt-expand ideas. In this scale, mainly spatial strategies are implemented. The first zone (Zone A), located in the northern part of the bay, currently has

minimal mangrove damage, but with the risk posed by the Nusantara development. The strategies mainly aim to promote the expansion of the mangrove ecosystem and support the natural capacity to grow. The second zone (Zone B) is in the middle section where the industry is currently expanding. The strategies are focusing on stabilising the bay and mangrove system to withstand these challenges. The third zone (Zone C) is in the southern part of the bay with the most severe mangrove degradation mainly caused by the significant alteration into urban and industrial activities, including *tambak*, urban expansion of Balikpapan City, and the industrial complex on the city's coastline. With very low mangrove coverage, the strategies aim to restore the mangrove to exist first, and later prepare the capacity to also adapt and expand.

Applying the design tools on a smaller scale is demonstrated through strategic projects, which are chosen based on the particular issues happening in several sites that emphasise each site's significance. The first strategic project, Nusantara Heritage Forest, investigates the potential of an existing cultural site to trigger the creation of ecotourism tracks to simultaneously become core protection zones, in collaboration with the Nusantara New Capital authorities and the native group. The second strategic project, Eco-Infiltrating Urban Industry, taps into addressing the integration of natural space in industrial complexes to grow bigger socio-ecological impacts in an urban setting. The third strategic project is shown as a key project, called A New *Tambak* System. This project is substantial as it allows a holistic approach in addressing the *tambak* issue in which it includes several other sub-systems that interrelate each other.

Sub-Research Question 5: How can these regenerative socio-spatial strategies be put into realisation?

The strategic projects and the key project include the adaptive capacity tools to emphasise implementation strategies. Globally, most of the mangrove restoration projects failed due to the lack of considering place-specific context and the inclusion of suitable stakeholders as facilitators, managers, and future caretakers of the project. The strategies and design tools in this project are tailored to the ecological context of Balikpapan Bay and the societal context of Indonesian cultures. This method aims to fabricate measures that work out in Indonesia, based on a deeper study of different projects across the country. As mentioned before, restoration projects will fail without intercommunity collaborations. Therefore, initiating the project must start with dialogues with involved stakeholders, from communities, academic and research institutions, and NGOs, to build awareness of the project's significance to increase cooperation willingness. Adaptation in policy is also vital to accommodate by advocacy with business owners and governmental bodies to support environmental-based decision making. As the projects are commenced through collaborations, built stewardship from the community will ensure the long-term protection and monitoring of the projects.

Figure 165, Early stages of mangrove restoration: planting nursery-bred young trees to the natural tidal environment in Delta Mahakam (Photograph by Author, 2025)

6.2. Reflections

This reflection allows the Author to contemplate the research and design project. From a personal lens, this thesis project has been challenging in pushing the Author to constantly think of solutions that prioritise the natural environment in addressing complex issues. As mentioned in the very beginning of this report, the project provided an opportunity to look and examine—from a critical landscape and urbanism lens—about the new capital city establishment of the Author's home country. Through this lens, the Author gained an ample of new knowledge linking urbanism and landscape, mainly in formulating strategies to balance socioeconomic and ecological development, prioritising natural landscapes, and further maintaining healthy ecosystems that benefit humans.

Do we need mangroves, or do mangroves need us?

We can easily find thousands of articles explaining mangroves' importance to humankind, ecologically, socioculturally, or economically. However, the worldview of seeing nature as a resource threatens our coastal environment, as we witness a perpetual decline of our wetlands. Only when natural disasters destroyed the human-made mitigation infrastructures did we try to re-emphasise our dependency on nature. Unfortunately, thousands of euros spent on restoration projects worldwide have gone to waste as only 15-20% of mangrove restoration projects succeeded worldwide. To exist, mangroves sometimes need humans to set suitable habitat conditions before growing naturally. In other terms, replicating mangrove restoration projects must be place-specific.

To plan(t) or not to plan(t)?

As an intertidal zone species, mangroves can regenerate themselves with help from tidal and wind, but not without a suitable water and soil biophysical environment. However, place-specific does not only mean the mechanistic prerequisites and methods, but also the sociocultural context that needs to be weighed in. During the Author's fieldwork, encounters with local communities, fishermen, and villagers demonstrated the power of 'local experts'. With less technical knowledge, a lifetime experience of living with nature provided the ability to understand natural cycles and shape experimental techniques of nature preservation. Therefore, knowledge transfers between scientific understanding and local 'genius' are needed. This is where the importance of collaboration shows, as technical research is required to determine befitting planning and planting solutions, which will be implemented by the local communities later.

A planner and designer's perspective

In parts of Indonesia—where native culture prevails—forests are considered sacred. For the Dayak indigenous groups of Kalimantan, harvesting from the forest requires special timing depending on the ancestor spirits 'permission'. However, the industrial worldview shifted the perspective into perceiving nature as an economic resource and allowing the exploitation of these forests for more monetary benefits, eliminating these human-nature balance paradigms amid a contemporary world.

One of the restoration approaches of shifting the conventional *tambak* into a mixed mangrove aquaculture system requires a social engagement strategy that recognises the climate-related dynamics, and aims towards long-term co-management. Awareness building is needed first to train the workers to apply the new system later. Based on case studies and fieldwork interviews, this strategy often meets the challenge of disapproval from related stakeholders as they weigh the risk of economic loss. Therefore, adaptive capacity strategies are essential next to technical approaches to deliver suitable community engagement methods, with comprehensive educational support on ecological, sociocultural, and economic benefits of the restoration project to encourage full participation.

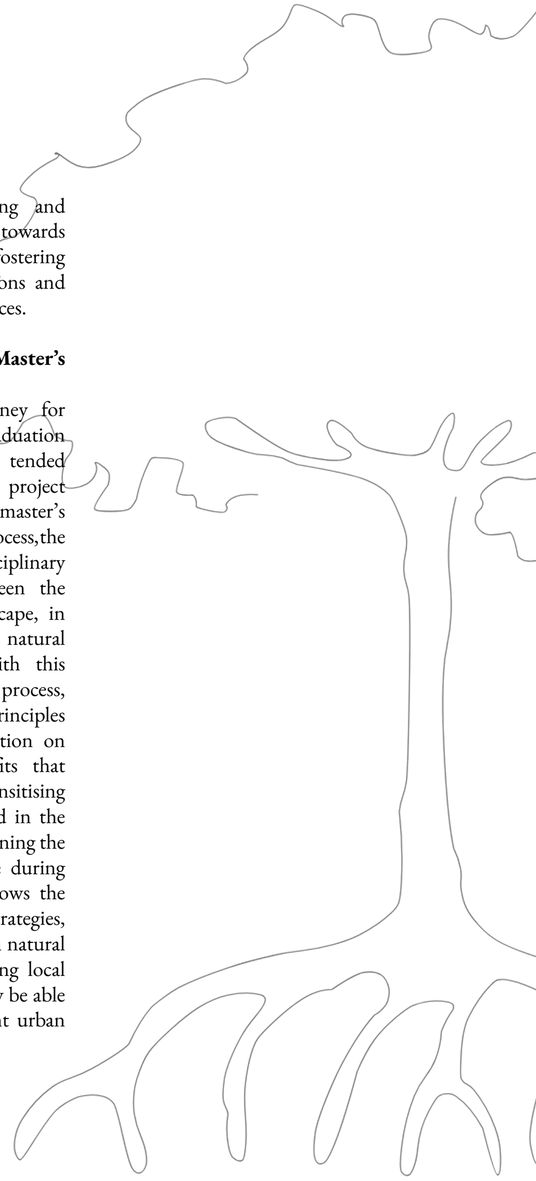
This research emphasised formulating socio-spatial strategies and frameworks to regenerate mangrove ecosystems and foster social-ecological resilience in adapting and mitigating climate change. The study was based on an in-depth analysis of ecological cycles around the mangrove ecosystem, their socioeconomic elements, and how they interact. It is found that the mangrove ecosystem works with several other sub-systems and, to and fro, impacts the health of the estuarine environment. Using the lens of having the landscape as a basis, complex issues can be approached by understanding existing patterns and networks, followed by utilising the knowledge to do multiscale and multidisciplinary design explorations as solutions.

Through design thinking in strategic projects, the author could comprehend and address multi-scale issues, shape suitable strategies, and explore design models to create possible outcomes. At the same time, the small-scale strategies allow detailed interventions that integrate implementation measures with involved stakeholders, which are then amplified into bigger-scale impacts. These methods recognise landscape as both the ecological and sociocultural processes, resulting in measures that can focus on nature-based solutions and their interoperability.

In conclusion, the human-nature relation identifies the complex adaptive system of the mangrove ecosystem in Balikpapan Bay. Sub-systems are interrelated, where each dynamics impact the other, sometimes leaving the natural environment and local communities in the most vulnerable category. This means reinforcing and recognising the local capacity towards creating socio-spatial strategies, fostering facilitators of nature-based solutions and 'guardians' of the ecosystemic services.

Relating the topics to the Master's programme

It has been a challenging journey for the Author to complete the graduation project. Midway, the research tended towards becoming a landscape project despite attending the Urbanism master's programme. However, later in the process, the Author acknowledged the interdisciplinary approaches that have always been the foundation for the work. Landscape, in its essence, is a system that relates natural and sociocultural processes. With this understanding, in the design process, the Author sought to apply principles and strategies that put prioritisation on nature while ensuring co-benefits that support human life. Meanwhile, sensitising local cultures had been embedded in the Author's way of thinking since learning the vernacular values of Architecture during bachelor's study. This project allows the Author to rethink urban-based strategies, towards aligning them deeper with natural cycles and processes by considering local sociocultural context, to ultimately be able to tailor a sustainable and resilient urban environment.



6.3. Future Research

This research was focused on investigating context-based socio-spatial strategies that are applicable in Indonesia, to regenerate the mangrove ecosystem amid different ecological and socioeconomic challenges. However, there are several limitations to this research that can be addressed in future research.

Mangroves have the natural capacity to prevent coastal flooding and attenuate strong waves as a case for disaster risk reduction. The threats from climate change might exacerbate the critical factor of sea level rise. A further study can investigate more deeply into the more detailed current sea level and the predicted sea level within a certain time frame, to formulate time-bound strategies that relate mangrove restoration with engineering-based solutions. As mangroves are the blue carbon instrument, the aspect of carbon-trading opportunity can also be included in the study.

Putting a further focus on the biophysical aspects, such as the sedimentation cycle, might be another interesting study, as mangrove growth relies on soil quality. Investigating different soil types adds context to suitably determine the specific mangrove species to plant, further increasing the success rate of restoration projects.

Lastly, stakeholders' involvement can be improved to achieve more organic and actor-based results. Time and resources were limited during the Author's fieldwork, where it was not possible to engage with different native groups as planned. Future research can involve more local communities and native groups in different areas and commence more community engagement through audience, workshop, or focus group discussions. This approach will enrich the traditional ecological knowledge as the local context.

Figure 166. Mangrove restoration visualisation (AI-generated image prompted by Author, 2025)

appendix

Bibliography

AMAN. (n.d.). Masyarakat Adat di Penajam Paser Utara Tergusur Oleh Pembangunan IKN. Retrieved January 18, 2025, from https://aman.or.id/story/masyarakat-adat-di-penajam-paser-utara-tergusur-oleh-pembangunan-ikn

Andari, L., Komara, L. L., & Kurniawan, N. P. (2023). Estimation of carbon stock at the mangrove forest of Sangkulirang District, East Kutai Regency, East Kalimantan Province. IOP Conference Series: Earth and Environmental Science, 1277(1), 012004. https://doi.org/10.1088/1755-1315/1277/1/012004

Animalium, R. (2023, January 5). Hidung Mancung Bekantan Bisa Pikat Lawan Jenis—Animalium. Animalium - Animal Science Center. https://animalium.id/2023/01/05/hidung-mancung-bekantan-bisa-pikat-lawan-jenis/

Ariyani, K., Rahmadi, R., & Anwar, Y. (2024). STRATEGI ADAPTASI MASYARAKAT TERHADAP RISIKO ABRASI PANTAI DI PESISIR KOTA BALIKPAPAN. 5(2).

Astra, A. S., Kuswantoro, & Priyanto, E. B. (2021, April 28). Mangrove green belt in Demak sees rapid mangrove recovery through fishpond conversion. Wetlands International. https://www.wetlands.org/mangrove-green-belt-in-demak-sees-rapid-mangrove-recovery-through-fishpond-conversion/

Ayunda, I. (2025). Masyarakat Adat di Penajam Paser Utara Tergusur Oleh Pembangunan IKN. https://aman.or.id/story/masyarakat-adat-di-penajam-paser-utara-tergusur-oleh-pembangunan-ikn

BAPPENAS. (2020). Naskah Akademik Rancangan Undang-Undang Tentang Ibu Kota Negara (p. 159).

Baraputri, V. (2022, September 7). IKN dan Teluk Balikpapan: Pesut pesisir 'tinggal kenangan' jika tidak diperhatikan nasibnya. BBC News Indonesia. https://www.bbc.com/indonesia/indonesia-62722490

Boyd, R., Dalrymple, R., & Zaitlin, B. A. (1992). Classification of clastic coastal depositional environments. Sedimentary Geology, 80(3–4), 139–150. https://doi.org/10.1016/0037-0738(92)90037-R

BPS. (2022). Luas Kawasan Hutan dan Konservasi Perairan¹ Menurut Kabupaten/Kota dan Fungsi Hutan di Provinsi Kalimantan Timur (ha), 2024—Tabel Statistik. https://kaltim.bps.go.id/id/statistics-table/3/Umpod09GaG5RbTlOYTJwaVFXWnJPRmQ1Wm1wMVp6MDkjMw==/luas-kawasan-hutan-dan-konservasi-perairansup-1-sup-menurut-kabupaten-kota-di-provinsi-kalimantan-timur--ribu-ha---2021.html?year=2021

BPS. (2023). Jumlah Penduduk Berdasarkan Kecamatan di Kota Balikpapan—Tabel Statistik—Badan Pusat Statistik Kota Balikpapan. https://balikpapankota.bps.go.id/id/statistics-table/2/MzEjMg==/jumlah-penduduk-berdasarkan-kecamatan-di-kota-balikpapan.html

Brelsford, R. (2019, September 17). Pertamina lets contract for Balikpapan refinery upgrade. Oil & Gas Journal. https://www.ogj.com/refining-processing/article/14040061/pertamina-lets-contract-for-balikpapan-refinery-upgrade

Bunting, P., Rosenqvist, A., Lucas, R. M., Rebelo, L.-M., Hilarides, L., Thomas, N., Hardy, A., Itoh, T., Shimada, M., & Finlayson, C. M. (2018). The Global Mangrove Watch—A New 2010 Global Baseline of Mangrove Extent. Remote Sensing, 10(10), 1669. https://doi.org/10.3390/rs10101669

Colls, A., Ash, N., & Ikkala, N. (2009). Ecosystem-based adaptation: A natural response to climate change. IUCN.

du Plessis, C. (2022). The City Sustainable, Resilient, Regenerative – A Rose by Any Other Name? In R. Roggema (Ed.), Design for Regenerative Cities and Landscapes (pp. 23–48). Springer International Publishing. https://doi.org/10.1007/978-3-030-97023-9_2#DOI

Ecoshape, & Eekelen, E. van. (2020). Building with Nature. Nai010 Publishers.

Ecosystem Services. (n.d.). National Wildlife Federation. Retrieved April 22, 2025, from https://www.nwf.org/Home/Educational-Resources/Wildlife-Guide/Understanding-Conservation/Ecosystem-Services

Eke Panuku Development Auckland,. (2017, March 15). Te Whakaoranga o te Puhinui—EkePanuku. https://www.ekepanuku.co.nz/projects/te-whakaoranga-o-te-puhinui/

ESDM. (2024). RDMP Kliang Balikpapan Targetkan TKDN 30-35%. ESDM. https://www.esdm.go.id/id/media-center/arsip-berita/rdmp-kliang-balikpapan-targetkan-tkdn-30-35

Fair Carbon. (2023). Mangrove Distribution Map—Fair Carbon. https://faircarbon.org/maps/mangrove-distribution-map

Forest Watch Indonesia. (2023, May 2). IKN dan Teluk Balikpapan. Forest Watch Indonesia. https://fwi.or.id/ikn-dan-teluk-balikpapan/

Gaveau, D. L. A., Sloan, S., Molidena, E., Yaen, H., Sheil, D., Abram, N. K., Ancrenaz, M., Nasi, R., Quinones, M., Wielaard, N., & Meijaard, E. (2014). Four Decades of Forest Persistence, Clearance and Logging on Borneo. PLoS ONE, 9(7), e101654. https://doi.org/10.1371/journal.pone.0101654

GIS Coastal. (2023). Climate Change and Challenges to the Mahakam Porpoise (Pesut Mahakam) Population in the Estuary: Supporting Ecosystem Sustainability | GIS Coastal Indonesia. https://gis-coastalindo.com/climate-change-and-challenges-to-the-mahakam-porpoise-pesut-mahakam-population-in-the-estuary-supporting-ecosystem-sustainability/

Harahap, R. G., Putri, D. L., & Nurmawati, N. (2021). Studi Laju Sedimentasi Teluk Balikpapan Menggunakan Model Hidrodinamika. Jurnal Ilmu Kelautan Kepulauan, 4(2). https://doi.org/10.33387/jikk.v4i2.3987

Haydar, M. H. (2023). Jenis-Jenis Tumbuhan Mangrove di Teluk Balikpapan dan Delta Mahakam, Kalimantan Timur. Universitas Gadjah Mada.

IUCN. (2017). Ecosystem-based Adaptation [Resource]. https://iucn.org/resources/issues-brief/ecosystem-based-adaptation

Kompas.com. (2020, May 28). Di Tengah Pandemi, Pertamina Tetap Tuntaskan Proyek Strategis Nasional RDMP Balikpapan. KOMPAS.com. https://biz.kompas.com/read/2020/05/28/211001128/di-tengah-pandemi-pertamina-tetap-tuntaskan-proyek-strategis-nasional-rdmp

Kompascom. (2022, June 14). Salah Satu Trase Jalan Tol IKN Dilelang, Pagu Dananya Rp 2,2 Triliun Halaman all. KOMPAS.com. https://www.kompas.com/properti/read/2022/06/14/180000521/salah-satu-trase-jalan-tol-ikn-dilelang-pagu-dananya-rp-22-triliun

Lestari Sustainable Development Consultants Inc. (2021). Assessment of the Biorights mechanism in Demak: A community incentive for sustainable development and mangrove conservation.

Lovelock, C. E., Barbier, E., & Duarte, C. M. (2022). Tackling the mangrove restoration challenge. PLOS Biology, 20(10), e3001836. https://doi.org/10.1371/journal.pbio.3001836

MacKinnon, K. (Ed.). (1997). The ecology of Kalimantan. Oxford Univ. Press.

Malik, R., Mochtar, M. Z., Dharmawan, A. S., Pirade, A., Farida HF, Kasmawaty, Yani, A., Mulyadi, A., & Mukti. (1999). Survey Identifikasi Isu dan Masalah di Teluk Balikpapan—Kotamadya Balikpapan (Proyek Pesisir Technical Report TE-99/05-I, Coastal Resources Center, University of Rhode Island, p. 42).

Mang, P., & Reed, B. (2012). Designing from place: A regenerative framework and methodology. Building Research & Information, 40(1), 23–38. https://doi.org/10.1080/09613218.2012.621341

Marshall, C., & Twill, J. (2022). Using Indigenous Knowledge in Climate Resistance Strategies for Future Urban Environments. In R. Roggema (Ed.), Design for Regenerative Cities and Landscapes (pp. 49–63). Springer International Publishing. https://doi.org/10.1007/978-3-030-97023-9_3

McPherson, S. (2024). Saltwater crocodile guide: Diet and where they live in the wild—Discover Wildlife. https://www.discoverwildlife.com/animal-facts/reptiles/facts-about-saltwater-crocodile

Morton, O. (2020, July 29). Economically viable forest restoration in shifting cultivation landscapes. Grantham Centre for Sustainable Futures. https://grantham.sheffield.ac.uk/forest-restoration-cultivation/

Mulyadi, H. (2019). DEVELOPMENT POLICY DIRECTIONS OF EAST KALIMANTAN.

Municipal Government of Balikpapan. (2024). Peraturan Daerah Kota Balikpapan Nomor 5 Tahun 2024 tentang Rencana Tata Ruang Wilayah Kota Balikpapan Tahun 2024-2043.

Nations, U. (n.d.). World Wetlands Day. United Nations; United Nations. Retrieved October 12, 2024, from https://www.un.org/en/observances/world-wetlands-day

Nijhuis, S. (2022). Landscape-Based Urbanism: Cultivating Urban Landscapes Through Design. In R. Roggema (Ed.), Design for Regenerative Cities and Landscapes (pp. 249–277). Springer International Publishing. https://doi.org/10.1007/978-3-030-97023-9_11

Nijhuis, S. (2024). Landscape Logic. JAP SAM BOOKS.

Nijhuis, S., Stolk, E., & Hoekstra, M. (2017). Teaching urbanism: The Delft approach. Proceedings of the Institution of Civil Engineers - Urban Design and Planning, 170(3), 96–106. https://doi.org/10.1680/jurdp.16.00013

Noor, Y. R., Khazali, M., & Suryadiputra, I. N. N. (2006). Panduan pengenalan mangrove di Indonesia. Ditjen PHKA : Wetlands International, Indonesia Programme.

Novrian, A. (2024). Deforestasi Hutan Kalimantan di Tengah Gemerlap Pembukaan IKN 17 Agustus 2024—Radar Malang. Deforestasi Hutan Kalimantan di Tengah Gemerlap Pembukaan IKN 17 Agustus 2024 - Radar Malang. https://radarmalang.jawapos.com/berita-terbaru/814950777/deforestasi-hutan-kalimantan-di-tengah-gemerlap-pembukaan-ikn-17-agustus-2024

Nusantara Capital Authority. (2024). Nusantara Biodiversity Management Master Plan. Nusantara Capital Authority.

Oktawati, N. O., Fadilah, A. N., & Saleha, Q. (2022). DAMPAK EKONOMI TUMPAHAN MINYAK DI TELUK BALIKPAPAN PADA PEMANFAATAN EKOSISTEM MANGROVE DI JENEBORA PENAJAM PASER UTARA. EnviroScienteae, 18(1), 77. https://doi.org/10.20527/es.v18i1.12981

Ospina, D. (2019). Beyond Design Thinking: The Systemic Design Thinking Framework. Medium. https://conductal.medium.com/beyond-design-thinking-the-systemic-design-thinking-framework-8d4952271222

Permatasari, R. J., Damayanti, A., Indra, T. L., & Dimyati, M. (2021). Prediction of land cover changes in Penajam Paser Utara Regency using cellular automata and markov model. IOP Conference Series: Earth and Environmental Science, 623(1), 012005. https://doi.org/10.1088/1755-1315/623/1/012005

Pradana, A. P. (2024). Kick of Koralestari Program in East Kalimantan: YKAN Supports the Establishment of UPTD-BLUD. Yayasan Konservasi Alam Nusantara (YKAN). https://www.ykan.or.id/en/publications/articles/press-release/ykan-support-the-establishment-of-uptd-blud/

Putri, M. R., Sari, T., Anwar, I. P., Mandang, I., Setiawan, A., & Tatipatta, W. M. (2021). Analysis of sea level changes in Balikpapan Bay as basic data for strategic planning the new capital city of Republic of Indonesia. Journal of Physics: Conference Series, 1763(1), 012043. https://doi.org/10.1088/1742-6596/1763/1/012043

Qaniaputri, E. D. (2019). Ibu Kota Pindah, Ini Timeline Hingga Komentar Masyarakat. http://www.esqnews.id/berita/ibu-kota-pindah-ini-timeline-hingga-komentar-masyarakat

Rani, V., Schwing, P. T., Jayachandran, P. R., Preethy, C. M., Sreelekshmi, S., Joseph, P., & Bijoy Nandan, S. (2023). Carbon stocks and sequestration rate in mangroves and its major influencing factors from highly urbanised port city, southern India. Journal of Environmental Management, 335, 117542. https://doi.org/10.1016/j.jenvman.2023.117542

Renggani, A., Guo, F., Wu, W., & Pavase, T. (2018). A Comparative Study on Mangrove Forests Between Indonesia and China. Indian Journal of Geo-Marine Sciences, 47.

Rocco, R. (2023). Methodology—Observation Techniques [Course lecture AR2U088 Research and Design Methodology for Urbanism, TU Delft Faculty of Architecture & the Built Environment].

Roggema, R. (Ed.). (2022). Design for Regenerative Cities and Landscapes: Rebalancing Human Impact and Natural Environment. Springer International Publishing. https://doi.org/10.1007/978-3-030-97023-9

Saenger, P. (2002). Mangrove Ecology, Silviculture and Conservation. Springer Netherlands. https://doi.org/10.1007/978-94-015-9962-7

Sasmito, S. D., Basyuni, M., Kridalaksana, A., Saragi-Sasmito, M. F., Lovelock, C. E., & Murdiyarso, D. (2023). Challenges and opportunities for achieving Sustainable Development Goals through restoration of Indonesia's mangroves. Nature Ecology & Evolution, 7(1), 62–70. https://doi.org/10.1038/s41559-022-01926-5

Saturi, S. (2012, July 24). Pengembangan Kawasan Industri Kariangau = Bencana Ekosistem Teluk Balikpapan (Bagian 1). Mongabay.Co.Id. https://www.mongabay.co.id/2012/07/24/pengembangan-kawasan-industri-kariangau-bencana-ekosistem-teluk-balikpapan-bagian-1/

Spalding, M., Kainuma, M., & Collins, L. (2010). World Atlas of Mangroves. Washington, DC : Earthscan.

Tempo, & Paskalis, Y. (2024, October 9). Kunci Enkripsi Cloudflare, Pohon Mangga, dan Bahaya SocialSpy WhatsApp dalam Top 3 Tekno. Tempo. https://dua.tempo.co/digital/kunci-enkripsi-cloudflare-pohon-mangga-dan-bahaya-socialspy-whatsapp-dalam-top-3-tekno--402

Thalia, Y. (2024). Bakau Kuning yang Sakral Terancam oleh Proyek Pelabuhan IKN. witness.com. https://witness.tempo.co/article/detail/9340/bakau-kuning-yang-sakral-terancam-oleh-proyek-pelabuhan-ikn.html

The Guardian. (2018). Deadly oil spill devastates Borneo port city – in pictures. The Guardian. http://www.theguardian.com/environment/gallery/2018/apr/06/deadly-oil-spill-devastates-balikpapan-borneo-port-city-in-pictures

The Nature Conservancy. (2020). Mangroves—The Nature Conservancy. https://www.natureprotects.org/posts/mangroves

The Ocean Agency. (n.d.). The Ocean Agency - The Magic of Seagrass: Seagrass is the ocean's wild savannah. Retrieved April 25, 2025, from https://theoceanagency.org/

Triana, K., & Wahyudi, A. J. (2020). Sea Level Rise in Indonesia: The Drivers and the Combined Impacts from Land Subsidence. ASEAN Journal on Science and Technology for Development, 37(3). https://doi.org/10.29037/ajstd.627

uforest. (2017). Nipah Palm—Nypa fruticans. https://uforest.org/Species/N/uforest.org/Species/N/Nypa_fruticans.php

UNDP. (2025). Ecosystem-Based Adaptation | UNDP Climate Change Adaptation. https://www.adaptation-undp.org/ecosystem-based-adaptation

USDA Forest Service. (2023). Mangrove Restoration Project Reaches 90 Percent Survival Rate and Becomes Model for Large-Scale Restoration Initiatives. https://www.forestlandscaperestoration.org/news/mangrove-restoration-project-reaches-90-percent-survival-rate/

Wandl, A. (2024, September 16). Designing with Flows -Systemic Design [Lecture for AR3U105 Graduation Orientation].

Warsidi, & Endayani, S. (2017). Komposisi Vegetasi Mangrove di Teluk Balikpapan Provinsi Kalimantan Timur. Jurnal AGRIFOR, XVI(1). https://doi.org/10.31293/AF.V16I1.2598

wetlandsglobal. (2021, April 28). Mangrove green belt in Demak sees rapid mangrove recovery through fishpond conversion. Wetlands International. https://www.wetlands.org/mangrove-green-belt-in-demak-sees-rapid-mangrove-recovery-through-fishpond-conversion/

Widadio, N. A., & Budhi, O. (2024, March 27). IKN: Masyarakat lokal "merasa terusir" saat Ibu Kota Nusantara digadang jadi 'magnet ekonomi baru'—'Kami tidak akan melihat kota itu.' BBC News Indonesia. https://www.bbc.com/indonesia/articles/cljl4lzw2dxo

World Bank. (2025). Building with nature [Text/HTML]. World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/en/559541527663917051

World Wildlife Fund. (n.d.). Dugong | Species | WWF. World Wildlife Fund. Retrieved January 15, 2025, from https://www.worldwildlife.org/species/dugong

Fieldwork Findings

Rainforest mini nursery in Nusantara

Nusantara Capital

Dipterocarp rainforest

Social engagement with local communities

Samarinda

Orangutan conservation

Samboja Lestari

Bukit Bangkirai

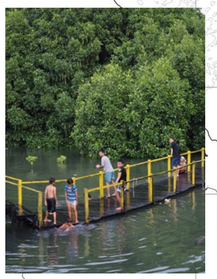
Mangroves in brackish to fresh water transition zone

Sungai Wain Forest

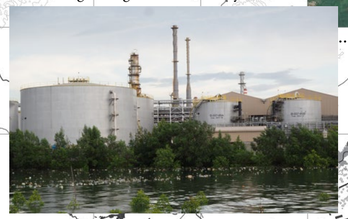
Mangrove Center Graha Indah

3 km

Community-based mangrove restoration initiatives



Water village living next to a refinery



Balikpapan City

10 km

Balikpapan Bay

Kalimantan, Indonesia

16.000 ha water surface, 16.800 ha mangrove cover