The Mekong Delta Digital Living Lab

Design, development, and framework for continued research and knowledge sharing to positively influence decision-making in the Mekong Delta

By:
Guusje Huijsmans
Mark Ketting
Maaike Krap
Famke Michielsen
Sem Roozendaal
Menne van der Spek
(MDP group 390)

Executive summary

The Mekong Delta is a densely populated and economically vital region in Vietnam. However, it faces severe coastal challenges threatening the livelihoods of the 20 million people living in the area. Mangrove deforestation, land subsidence, and sea level rise cause erosion and coastal retreat. To tackle these challenges, the Living Lab project combines long-term research, stakeholder engagement, and nature-based solutions to promote sustainable coastal management. However, research outcomes often remain fragmented and informing relevant stakeholders often proves difficult. This results in limited follow-up action taken.

This report introduces the Digital Living Lab, an online environment that makes complex research understandable and actionable for policymakers. It provides a theoretical background and translates technical information into clear insights that support decision-makers in choosing and implementing effective interventions. The platform follows a location-based storyline: content is organized per site and links drivers, processes, stakeholders, and interventions, emphasizing site-specific solutions and helping decision-makers weigh intervention options and long-term effects. The platform also features interactive maps displaying mangrove coverage over time, playing well into the visual and evidence-based orientation of decision-makers.

The research applies an interdisciplinary and iterative approach, combining different research methods. Literature analysis and interviews with experts and government representatives clarified the Vietnamese decision-making landscape. This revealed that most key choices occur informally, emphasizing the importance of concise, visually supported, and trustworthy information. The technical work focused on examining locations and human activities to identify drivers, processes, and interventions shaping each site. Also, mangrove loss and gain from 1988–2025 were mapped using satellite images and processed in Python and Google Earth Engine. For the website design, elements of the Double Diamond framework were combined with the design cycle of ideation. Iteration and evaluation, supported by user testing, ensure usability. By combining these different methods and backgrounds, the Digital Living Lab can act as a platform that contributes to evidence-based decision-making, leading to more strategic and sustainable solutions in Vietnamese water management.

To ensure this work continues beyond the project, a framework was developed as part of this research. The framework takes the form of a manual designed for future researchers to understand and extend the DLL independently. It contains three parts: a technical manual for maintaining and updating the mangrove maps, a design manual for structuring and building pages in Figma and Wix, and a content manual that guides what, where, and how to publish using an accessible flowchart.

The result of the project and its research is that a location-based storyline, supported by clear visuals and concise explanations, is effective for communicating long-term coastal dynamics to decision-makers in Vietnam. **The result of this work, the DLL website, can be accessed at: `livinglabmekongdelta.com`**

The DLL is the bridge between research and practical outcomes. Its impact must now be confirmed through direct validation with decision-makers themselves. The platform should be tested in meetings and workshops to evaluate how it supports understanding and decision-making. The mangrove maps must also be validated with field data to strengthen their technical reliability. Apart from these validations, future work should focus on completing and refining the website by making the DLL mobile-friendly and translating it into Vietnamese. Expanding the platform with new locations and additional layers of human activity will further enhance its relevance and reach. Together, these steps will ensure that the Digital Living Lab continues to develop as a credible, accessible, and practical tool for evidence-based decision-making in the Mekong Delta.

Preface

During our project, we collaborated with scientists from various Vietnamese universities and research institutions who obtained their PhD at Delft University, as part of a research project (the Mekong Living Lab) jointly executed with Delft University. The Living Lab has three physical locations in the Mekong Delta, where long-term research is carried out on coastal processes affecting mangrove forests. Our role in this project was to develop a digital platform designed to assist the Living Lab in explaining coastal processes and communicating research findings to a variety of stakeholders.

Our MDP group consists of six students from three faculties of Delft University of Technology; Civil Engineering, Industrial Design and Technology, Policy and Management. The project was carried out as part of the electives in the second year of our master's program. The electives were fulfilled in the form of the course CEGM3000: Multidisciplinary Project.

During the creation process, we combined our specific areas of expertise to develop a complete and comprehensible platform. The Civil Engineering students oversaw the contents displayed on the platform, The Policy students decided how this content was effectively translated and the design students developed the final platform. A specific challenge during our project was the constant communication needed to align everyone toward a common goal.

This report is written for members of the Living Lab, and tries to delve deeper into the reasoning behind specific choices made during the development of the platform.

Having said that, we would really like to sincerely thank our supervisors from Delft, Bas van Maren, Ellen Minkman and Arno van Leeuwen, for guiding us through challenges specific to each faculty.

We would also like to thank the members of the Living Lab, Phan Khanh Linh, Truong Hong Son, Phan Manh Hung, Dao Hoang Tung, Le Hai Trung, Thom Bogaard and Lindsey Schwidder, for introducing us to the Vietnamese culture and helping us on the way with our project. Also thank you for taking time for us every time we've had questions.

And last but not least, we would like to thank the organizations and people who made it possible for us to travel to Vietnam in the first place (Delta Futures Lab, Fast, Lamminga Fonds & Rijksdienst voor Ondernemend Nederland). Especially for this project, where we had to visit universities and institutions in the north, as well as in the south of Vietnam, the grants provided us with the means to travel and find accommodations.

Delta Futures Lab

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Contribution to the Living Lab Project

The Mekong Delta Living Lab Project is an open-air laboratory for coastal protection and nature-based solutions (NbS). The project focuses on the loss of the mangrove ecosystems, an essential part of the coastal protection [1]. The Living Lab is a collaboration between Delft University of Technology, Thuy Loi University and research institutes in the North and South of Vietnam, such as the Institute of Coastal and Offshore Engineering (ICOE). The project is financially supported by the Netherlands Enterprise Agency (RVO).

The core mission of the Living Lab project is to combine scientific research, community engagement, and NbS to find sustainable ways to protect the coastline and enhance climate resilience. To achieve this, the Living Lab tries to bridge the gap between laboratory theory and the complex realities of the field, providing evidence-based solutions for coastal management. On an operational level, the Living Lab serves two main functions:

1. Experiment & Research
2. Demonstration & Dissemination

The first function is conducting measurement campaigns, experiments, and research to address core scientific questions on coastal dynamics. The second function is disseminating research results, sharing knowledge, and demonstrating effective solutions to stakeholders and the community, which is the exact function the Digital Living Lab tries to fulfill.

The Digital Living Lab

The development of the Digital Living Lab makes the dissemination of findings easier on four aspects.

- It can make findings and information easily accessible.
- It can showcase and visualize long-term processes.
- It can showcase and visualize processes of multiple locations on a single platform.
- It can create a structured overview of all projects, data, and findings.

The Digital Living Lab does not only make the dissemination of knowledge easier, but also better understandable. By setting an elaborate theoretical background, coastal processes will be more comprehensible for relevant stakeholders. This makes new findings easier to communicate, and stakeholders more likely to act on them. Therefore, making information on these coastal processes better understandable and easier accessible, directly contributes to the core mission of the Living Lab project.

Contents

List of abbreviations

Abbreviation	Definition
AOI	Area Of Interest
DLL	Digital Living Lab
EIA	Environmental Impact Assessment
ICOE	Institute of Coastal and Offshore Engineering
LL	Living Lab
MAE/DAE	Ministry/Department of Agriculture and Environment
MARD/DARD	Ministry/Department of Agriculture and Rural Development
MKD	Mekong Delta
MOF/DOF	Ministry/Department of Finance
MONRE/DONRE	Ministry/Department of Natural Resources and Environment
MPI/DPI	Ministry/Department of Planning and Investments
MTIP	Medium Term Investment Plan
NbS	Nature-based Solutions
NDVI	Normalized Difference Vegetation Index
NIR	Near Infra Red
PNI	Projects of National Importance
RVO	Rijksdienst voor Ondernemend Nederland

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Introduction

1.1. Problem statement

1.1.1. Coastal problems in the Mekong Delta

Deltas like the Mekong are dynamic systems shaped by a balance between sediment supply by the river and erosive forces from the ocean, such as waves and tides. Mangrove forests are a crucial component of this balance: they act as natural shields, dissipating wave energy and capturing sediment [2]. However, many mangrove forests have been lost due to deforestation. In combination with land subsidence, reduced sediment supply from upstream, and rising sea levels, the Mekong Delta is under serious threat. Additional human activities, including aquaculture expansion and the construction of dikes, further constrain the ability of mangrove forests to survive.

The degradation of mangroves initiates a positive feedback loop, illustrated in Figure 1.1. Mangrove degradation leads to less wave damping, which increases erosion, resulting in further mangrove loss. Once the system is out of balance, the increased erosion process is difficult to stop. Over time, this process causes the coastline to retreat inland, endangering communities living in these coastal areas. Meanwhile, continued land subsidence and sea level rise cause the delta to sink below sea level, further accelerating the deterioration of mangrove forests.
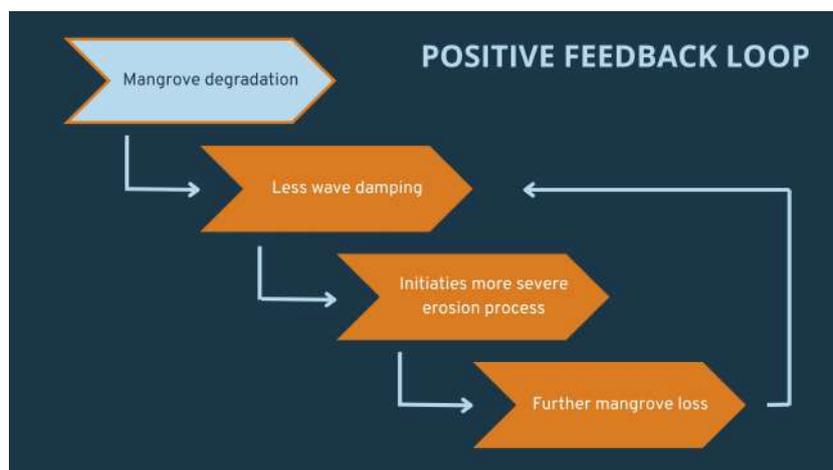
Figure 1.1: Visual showing the vicious cycle caused by mangrove deforestation.

To tackle this challenge, many coastal interventions have been carried out over the past decades, though their effectiveness has often remained limited [A.2]. Three main problems are identified in coastal protection strategies.

1. Because of the rate of deforestation, interventions need to be implemented quickly. Due to this time pressure, there is no opportunity to conduct thorough research on the long-term effects of these interventions [3][4].
2. Due to the complexity of the system, researchers still do not fully comprehend the quantitative mechanisms of coastal processes [5].
3. Limited budgets cause a lack of permanent measuring stations. This reduces the availability of relevant accurate data [2].

These challenges hinder decision-makers in implementing effective interventions, often leading them to act on inaccurate assumptions or incomplete data.

1.1.2. The Living Lab

To bridge the gap between scientific research and real world application, the Living Lab was created. It provides a place to perform research on coastal interventions, and also to demonstrate and share findings with various stakeholders. Mangrove restoration and coastal protection strategies should be based on evidence and not only on short-term gains. The Mekong Delta Living Lab thus advances scientific understanding and strengthens evidence-based decision-making. These are its two goals, and are defined as:

1. *Gaining better insight and knowledge through conducting of in-field measurement campaigns, long-term monitoring and a wide variety of research experiments;*
2. *Demonstrating and showcasing various lessons learned and potential (nature-based) solutions for coastal management in Vietnam*

1.1.3. Added value of the Digital Living Lab

The Living Lab in Vietnam aims to improve coastal protection and enhance mangrove forest development by doing on-site experiments and research. While the Living Lab provides good physical insights, it can be further strengthened by a complementary digital approach. A visualization of this approach is given in Figure 1.2.
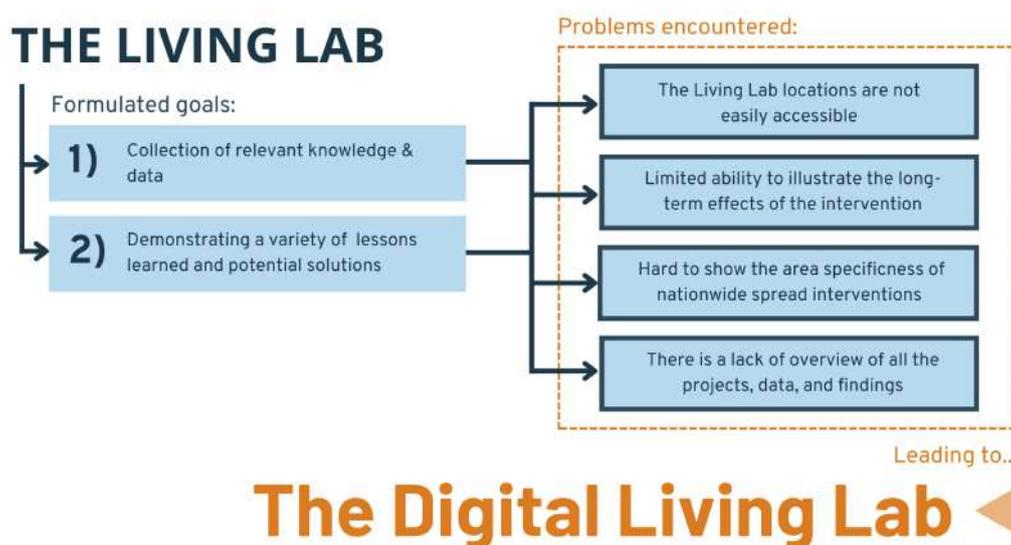
Figure 1.2: Visual showing the two primary goals of the Living Lab, the problems encountered and highlights the need for the DLL.

The Digital Living Lab (DLL) is an open online environment that integrates information on complex (bio)-physical and societal challenges over time. It serves as a collaborative platform for diverse stakeholders, supporting decision-making and bridging knowledge across sites and disciplines. As such, the DLL plays an important role in achieving the goals of the Living Lab by complementing physical experiments in the following ways:

- Accessibility: By making insights from the Living Lab digital, stakeholders can access findings from any location, expanding participation and collaboration.
- Spatial coverage: The DLL allows integration of data from multiple locations in the Mekong delta, providing a more wide spread perspective on how interventions affect mangrove forests and coastal protection.
- Long-term: By gathering long-term data and possible future scenarios, the DLL has the ability to visualize long-term effects of interventions, which are difficult to observe in a physical Living Lab.
- Knowledge integrations: The DLL organizes research and findings into a clear and accessible online storyline, connecting multiple projects and datasets into a narrative that supports the research and policy-making.

In this way, the Digital Living Lab serves as a parallel approach, complementing and enhancing the physical Living Lab, while making research outcomes more widely accessible, comprehensible, and applicable.

1.1.4. Final problem statement

The Mekong Delta faces significant environmental challenges, including erosion of the coast. Over the past years, extensive research has been conducted through the Living Lab to understand and address these threats. While these studies provide valuable insights, findings vary across locations and time periods, and integrating this knowledge into an overview remains challenging. The DLL complements the LL by shaping reserach findings into a clear, accessible, and interactive online platform. This

research focuses on developing an online platform that can act as a database to help researchers better communicate their findings by translating complex technical information into a clear storyline, enabling decision-makers to make better informed decisions.

1.2. Objective

1.2.1. Goal of the Digital Living Lab

The goal of the Digital Living Lab is to overcome current limitations by offering a comprehensive digital view of the system. To achieve this, the DLL should therefore:

- Provide the capability of containing all relevant information
- Allow to add new information that will be collected in years to come
- Be able to show information over a larger time period and scale
- Be comprehensive enough for the target group

At the same time, these requirements raise new questions. For instance: what exactly counts as relevant information, and who is considered the target group? Such definitions are not self-evident and strongly influence how the DLL should be designed and used. To address these uncertainties, research questions will be formulated.

1.3. Strategy

1.3.1. Research questions

The project is guided by one main research question, which answers questions needed for a good design and reaching of goals set for the Digital Living Lab. To make this research question comprehensive, it is divided into four sub-questions. Each sub-question is further detailed into a set of questions to make the research for this project more concrete. The main research question this report tries to answer is:

How can we develop a storyline-based framework for the Digital Living Lab that communicates the long-term impacts of drivers, processes and interventions in the Mekong Delta in a way that is understandable and actionable for decision-makers in Vietnam?

This main research question is divided into several sub-questions. First, it is necessary to understand the target group of the DLL and what information they need. After that, research will be done on how to make the information understandable and meaningful for this group. Finally, with this knowledge in place, the practical design and usability of the DLL can be addressed. The sub-questions shown on the next page address this procedure. Sub-questions:

1. Which storyline best communicates the long-term impacts of drivers, processes and interventions in the Mekong Delta?
    a. What kinds of interventions are applied in this/these location(s) and what is their function?
    b. Which processes and drivers influence the coastal area in this/these location(s)?
    c. Which interventions, processes and drivers provide the most relevant basis for a storyline that communicates long-term impacts in the MKD?
2. Who decides on the interventions in the MKD?
    a. What does the decision-making process look like?

    b. Who can influence the decision-making process?

    c. What values and interests are they motivated by?

3. How can information/data on the DLL be communicated in a way that is both understandable and actionable for decision-makers?

    a. Which forms of communication are most effective in Vietnamese culture?

    b. What types of information and data are essential to build and support the chosen storyline?

    c. How can the technical information/data be made understandable and actionable for decision-makers in Vietnam?

4. How can we develop a framework that makes the DLL accessible in use?

    a. How can the DLL be made convenient for decision-makers?

    b. How can the framework be developed so that researchers can continue contributing to the platform in the future?

1.4. A multidisciplinary approach

Three disciplines come together to address these research questions and develop a Digital Living Lab capable of effectively communicating information in a comprehensible way. It is essential that all technical information presented on the platform is accurate and that the underlying processes are clearly explained. Civil engineering experts (MSc Civil Engineering students specialized in Hydraulic & Offshore Structures and Hydraulic Engineering) explain and visualize these processes effectively.

In addition to technical specialists, policy experts (MSc students in Complex Systems Engineering and Management) are required to analyze the decision-making process to select an appropriate target group (decision-makers). It is crucial to know how to communicate with the target audience and to know what the decision-making process looks like, in order to determine when and how the digital living lab will be used. By tailoring the platform to these contexts, the website can effectively address the issues mentioned in Subsection 1.1.3 and offer optimal solutions, maximizing the chance of effective use.

Finally, designers (MSc students in Strategic Product Design) play a key role in developing the digital living lab. The platform must be visually engaging and capable of holding the visitor's attention so that they take the time to explore and absorb the information. It should also be user-friendly, allowing visitors to easily navigate the website.

By integrating expertise from these three fields, the digital living lab can be successfully developed and implemented.

1.5. Report Structure

This report is structured to address the research questions (Section 1.3.1) and to support the development of the DLL. Each chapter contributes to the overall goal, the research questions and the DLL as follows:

- Chapter 2: How to Influence Decision-Making in the Mekong Delta: Examines formal and informal decision-making processes, stakeholders, and their values. This chapter forms information for RQ2 by identifying the target audience for the DLL and understanding how decision-making can use the platform.
- Chapter 3: Storyline and Coastal System Understanding for the DLL: Focuses on the natural and human drivers, processes, and interventions in the Mekong Delta This chapter adresses RQ1 by giving basis for the storyline of Nha Mat and visualization in the DLL, which helps understanding the coastal system in the Mekong Delta.

- Chapter 4: Mangrove Coverage Maps: Gives the data collection, analysis, and visualization methods for the mangrove coverage maps. It gives input for RQ1 and RQ3, enabling the DLL to integrate spatial information to support better informed decision-making.
- Chapter 5: Website Design: Describes the design process for the DLL, including visual layout and user tests. This chapter focuses on RQ3 and RQ4 by translating research findings into a clear and accessible online platform for Vietnamese decision-makers.
- Chapter 6: DLL Framework: Presents the manual and frameworks for content integration, development of mangrove coverage maps, and website development. This ensures the DLL remains functional, maintainable, and expandable in the future.
- Chapters 7 & 8: Conclusion, Discussion, Recommendations: Summarizes the research outcomes, reflects on the effectiveness of the created DLL and provides recommendations of use and future improvement.

By integrating insights from these chapters, the DLL contributes to exploring interventions, understand long-term impacts and make informed decisions. The DLL can be accessed through: **livinglab-mekongdelta.com**.

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How to influence decision-making in the Mekong Delta

Coastal management in the Mekong Delta is both a social and technical challenge. Decisions on which interventions are implemented depend on multiple stakeholders, their values, and the institutions in which they operate. To design a Digital Living Lab that supports evidence-based decision-making, it is essential to understand these dynamics [6].

In this chapter, we are guided by research questions 2a-2c, as well as 3c (see Subsection 1.3.1). Understanding the decision-making landscape in Vietnam, will eventually lead to important design constraints for the DLL. In the next section, the importance of understanding these processes is explained. After that, research will be done on the structure of Vietnam's political structure, its decision-making processes and the actors involved. This research is divided in two parts: formal and informal. The formal research is done first and consists mainly of literary research. It gives the first insights in information needs of different actors. Then, in Section 2.3 the *in*formal processes are researched. Through interviews and literature research the informal structure of the governance and decision-making processes are mapped. The insights from both the formal and informal research will answer research questions 2a-2c and 3c. These will then be used to form a set of key takeaways that have implications for the design of the DLL, thereby answering research question 4a. These can be found in Section 2.4. Later, in Chapter 5, Section 5.4 the translation from these insights to design constraints for the DLL will be made, thereby addressing research question 4b.

2.1. The importance of understanding the decision-making landscape

To protect the Mekong Delta from stresses caused by human activities and natural processes, active interventions are needed, as natural recovery cannot counteract erosion, subsidence, and sea-level rise combined [7]. These measures, including dikes, polders and nature-based solutions (NbS), require significant investments, but don't generate immediate returns [2]. Therefore these projects must be coordinated and financed by Vietnamese governmental institutions. These institutions, thus have a crucial role in the protection of the MKD. Therefore, it is essential to understand the underlying factors and motivations that drive decision-makers in their choices.

Decision-makers often lack system insight and rely on experts. Misunderstanding these dynamics can cause decision makers to make decisions based on inaccurate assumptions, lowering the chance

of effective interventions [8]. The way experts share information with decision-makers is very important, since it can determine whether interventions are effective or not.

An example of a disaster caused by the miscommunication between experts and decision makers is the Formosa Steel Plant disaster. In 2016, the steel factory leaked toxic chemicals into the ocean in central Vietnam [9]. Although environmental experts quickly identified industrial pollution as the cause of mass fish deaths, their findings were poorly communicated and initially dismissed by authorities. This delay worsened the situation and eroded public trust in the Vietnamese government.

Findings from the Living Lab project can contribute to a better understanding of systems dynamics along the Vietnamese coast. Based on these findings, a strategy can be developed to enhance the long-term sustainability of the area. However, the Living Lab lacks the funding and authority to implement this strategy themselves. Therefore, improving the situation in the MKD inevitably requires cooperation with authorities. But how can this be done?

Research can only influence policy when it fits well with the environment in which decisions are made. There are however no universal methods to influence policy with research: impact depends on understanding how institutions actually work, and how to play into that. In Vietnam's system, this means knowing both formal and informal political structure and decision-making processes. Without this knowledge, even strong evidence remains unused. Researchers should therefore design their work and communication around how and when decision-makers absorb information [6].

2.2. Formal processes and stakeholders in Vietnamese decision-making

This section first explains the formal structure of the Vietnamese government, since understanding who the main actors are is essential. Next, the formal investment decision-making process is outlined to show how these actors interact. Lastly, the stakeholders involved in this process are identified, together with their information needs and values.

2.2.1. Formal political structure in Vietnam

Vietnam is a one-party state, the political system can roughly be divided in three parts: the Communist Party of Vietnam (CPV), the government and Vietnamese people, who are also represented through a body called the Vietnamese Fatherland Front (VFF) [10].

At the core of this system stands the CPV, which is recognized in Article 4 of the Constitution: *"The Communist Party of Vietnam ... is the leading force of the State and society."*[11] The CPV has over 5.1 million members operating in multiple layers [12]. Every five years, during the National Congress, new strategies and members for the high-layers are selected. At the National Party Congress, Party delegates elect the Central Committee, which in turn elects the Politburo and the General Secretary. Between congresses, the Politburo leads the Party and guides its internal affairs. These layers and the election process is summarized in the right pillar of Figure 2.1. Although the Party's leadership role is constitutionally recognized, it should operate as a distinct organization within the broader political system and not directly affect the state. Namely, in Article 6 of the constitution it is said that *"The people exercise the State power under the forms of direct democracy and of representative democracy through the National Assembly, the People's Councils and other State agencies"*. This, on paper, means that the people are the source of state power. This is however not the full picture, and will be further discussed in section 2.3.1. For now the focus lies on understanding the formal structures.

Alongside the Party, there is the civil actors in the structure: the Vietnamese people and the VFF. Citizens directly elect representatives for three levels: for the communal and provincial People's Councils and for the National Assembly. Before 2025 they also voted on the District-level People's Council, but

recent reforms removed these layers, this will be discussed in the next section.[13] Apart from citizens themselves, there is also the VFF. The VFF is a political organ that represents all Vietnamese, no matter their class, location or ethnicity. The VFF is, as defined in Article 9 of the Constitution as *"a political alliance and voluntary union of political and social organizations."*. Its main function is to promote a feeling of solidarity and unity among all Vietnamese people. It does this by gathering the public opinion, and giving feedback on laws and policies. It also screens and nominates candidates for the National Assembly and local councils, thereby ensuring everyone in Vietnam is represented enough in the government. The VFF is *"governed by the principles of democratic consensus"*[10]. It is however also tasked with implementing CPV guidelines, this hints towards at least some CPV influence over the VFF.

Formally, the National Assembly holds the highest authority in the State structure. It enacts laws, decides on national socio-economic plans, and elects the President, the Chairperson of the National Assembly, and the Prime Minister. It also approves the appointment of ministers that are recommended by the Prime Minister [10]. The Government, composed of ministries and headed by the Prime Minister, is responsible for implementing laws, managing the administration, and reporting back to the National Assembly.

At lower levels, the provincial and communal People's Councils exercise state power locally. They elect their respective People's Committees, which function as the executive organs of the councils. These committees organize and implement the councils' resolutions and ensure that policies and national plans are carried out locally. Vertical relations also exist between committees, as local plans and reports are submitted upward for approval, while national strategies and regulations are implemented downward through the hierarchy. These formal relations are summarized in Figure 2.1.[10]
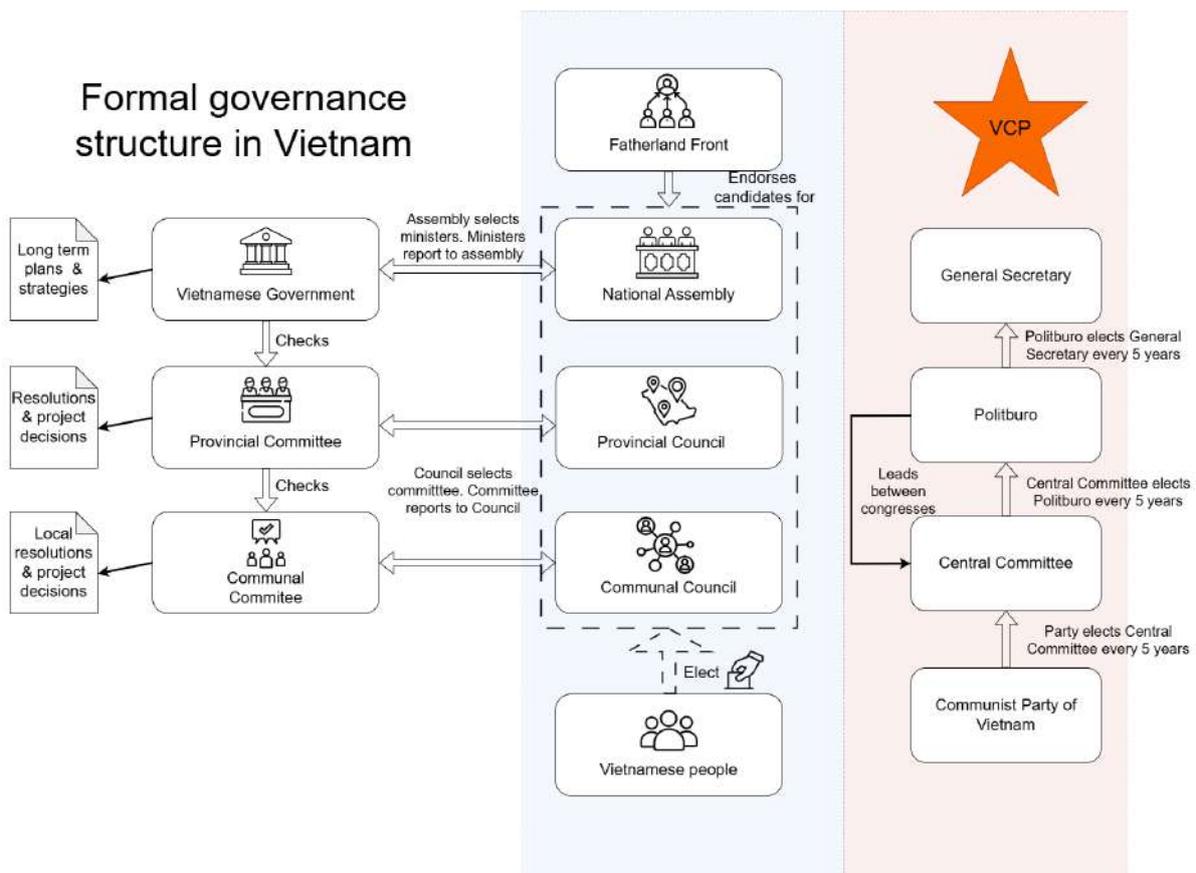

Figure 2.1: The formal governance structure in Vietnam. [11][A.1].

2.2.2. Vietnam's 2025 government reform

As of 2025, the Vietnamese government has undergone a significant reform [13]. The goal of the reform was to make the Vietnamese government more compact, efficient and effective [14]. The reforms include the merging of ministries (From 19 to 14), merging of provinces (from 63 to 34) and the removal of district-level governance [15]. This final aspect, has changed Vietnam from a former three-level governmental system into a two-level system. Tasks previously assigned to the district-level are mostly given to the commune-level. [16] The exact effects of the fusion of provinces and ministries are unknown and require further investigation. But these reforms could reshape decision-making processes in two ways.

Firstly, the merging of ministries and departments, directly influences the stakeholders involved in the decision-making process. Two ministries often involved in the construction of coastal interventions, the Ministry of Natural Resources and Environment (MONRE) and the Ministry of Agriculture and Rural Development (MARD), will merge as a result of the reform. This means that during the decision making process, these ministries did not have to be treated as two separate entities, simplifying the process. These ministries will now form a single stakeholder under the Ministry of Agriculture and Environment (MAE). [13] [15] [16]

Secondly, the merging of provinces can decentralize power, by delegating more authority to local governments. This decentralization of power is one of the main goals of this reform. As the Minister of Home Affairs Pham Thi Thanh Tra emphasized: *"Localities decide, localities act, and localities take responsibility"* [14]. This could be beneficial, since it might increase influence of local initiatives, like the Living Lab, on larger scales. In the Mekong Delta, where Bac Liêu has recently been merged with Cà Mau, the realization of smaller projects no longer requires engagement with multiple provincial institutions [16].

2.2.3. Investment decision-making in Vietnam

The construction of a coastal structure in Vietnam must follow a specific process [17] where different governmental parties are involved. To influence decisions on specific interventions, it is important to understand this process. However, the legal framework for public investment is currently regulated by eight different laws [3]. These laws, defining roles, powers and responsibilities, often overlap or conflict with each other [3]. This makes the decision-making process very complex and confusing. This chapter therefore presents a step-by-step overview of the general decision-making process in the Mekong Delta.

For an investment project in the Mekong Delta, two decision moments are identified [4]. The project begins with the conceptual phase that starts when a local problem is detected. In this phase, technical data is collected and community consultation is conducted. Based on the project category, responsibility for the project is assigned to the appropriate authority. After this, a pre-feasibility report is drafted and appraised, containing an estimation of aspects like: necessity, investment objectives, location, scale, costs and preliminary solutions [17]. Based on this report, an investment-policy decision is made. If the decision is positive, a feasibility report is drafted. This report contains technical information, selection of interventions and detailed costs. Parallel to the feasibility report, an Environmental Impact Assessment (EIA) is carried out, identifying and evaluating environmental and social impacts [18]. Based on the feasibility report and the EIA, the investment decision is made. If this is positive, the project needs to be included in the five-year Medium-Term Investment Plan (MTIP). After this, the project will be executed. An overview of this process can be seen in Figure 2.2.
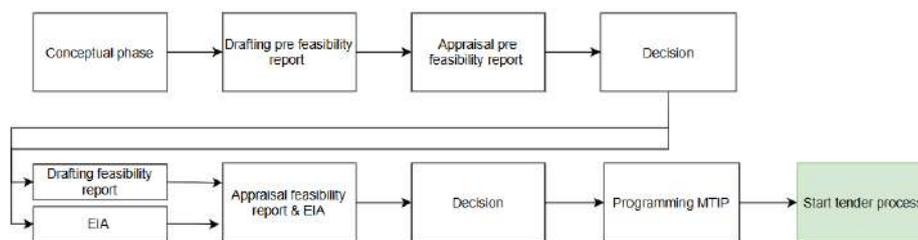
Figure 2.2: Steps of the Vietnamese public investment process [19][4].

Each investment project can be classified into four types of projects [17]. The cost of the project decides in which category it will fall. The lower the cost, the lower the level of importance of the project.

- Projects of National Importance (PNI)
- Group-A investment projects
- Group-B investment projects
- Group-C investment projects

The project category determines the government level that will be involved in the decision-making process. Table 2.1 shows the decision-makers and parties responsible for appraisal for each category. During the appraisal, a specific group checks whether the contents of the report are correct and complete. The appraisal of a report is usually carried out by a specific appraisal council, consisting of the responsible party shown in the table, together with experts. Mostly, these councils consist of proposing or technical line ministries. Proposing line ministries are responsible for initiating and submitting project proposals, while technical line ministries provide sector-specific expertise to review and evaluate those proposals.

Table 2.1: Decision-makers and appraisers in the Vietnamese investment process [4]

Project Category	Pre-Feasibility Study or Investment Intentions Report	Feasibility Study
Nationally Important Projects	**A:** State Appraisal Council **D:** National Assembly	**A:** State Appraisal Council **D:** Prime Minister
Category A	**A:** Inter-ministerial Council or Appraisal Leading Agency **D:** Prime Minister	**A:** Technical Line Ministries **D:** Proposing LM/Provinces
Category B	**A:** Proposing LM/Provinces **D:** Proposing LM/Provinces	**A:** Technical LM/Provinces **D:** Proposing LM/Provinces
Category C	**A:** Proposing LM/Provinces **D:** Proposing LM/Provinces	**A:** Technical LM/Provinces **D:** Proposing LM/Provinces

Notes: A = Appraiser; D = Decision-maker; LM = Line Ministry.

For the Living Lab, it is crucial to understand how this process applies specifically to the construction of coastal structures in the Mekong Delta. In Table 2.2 on the next page, the responsible party for each step in the decision making process can be seen.

In the conceptual phase, the appropriate ministry or department evaluates a specific problem in

an area and determines if an investment project is necessary. For projects regarding coastal structures in the MKD, this is the MAE or DAE. Also in this phase, the Ministry of Planning and Investment or the Provincial People's Committee, determines the projects' category and sets up an appraisal council. The composition of this council depends on the project category, and can be seen in Table 2.2. In general, the council consists of experts, researchers, local representatives and some committee members. Their knowledge level ranges from high school, for representatives, to university-level degrees for the others.

Table 2.2: Responsibilities in the decision-making process for investment projects in the Mekong Delta [19] [4] [17]

Project phase	Responsible party
Conceptual phase	Ministry of Planning & Investment or Provincial People's Committee or Ministry of Agriculture & Environment or Department of Agriculture & Environment
Drafting pre-feasibility report	Ministry/Department of Agriculture & Environment with external consultants
Appraising pre-feasibility report	PNI: State appraisal council Group-A: Inter-ministerial council of appraisal Group-B: Ministry/Department of Agriculture & Environment Group-C: Ministry/Department of Agriculture & Environment
Investment-policy decision	PNI: National Assembly Group-A: Prime Minister Group-B: Ministry/Department of Agriculture & Environment Group-C: Ministry/Department of Agriculture & Environment
Drafting feasibility report & EIA	Ministry/Department of Agriculture & Environment with external consultants
Appraising EIA	EIA appraisal council (established by Ministry/Department of Agriculture & Environment)
Appraising feasibility report	PNI: State appraisal council Group-A: Ministry/Department of Construction Group-B: Ministry/Department of Construction Group-C: Ministry/Department of Construction
Investment decision	PNI: Prime Minister Group-A: Prime Minister Group-B: Ministry/Department of Agriculture & Environment Group-C: Ministry/Department of Agriculture & Environment
Programming in MTIP Ministry/Department of Planning & Investment	Ministry/Department of Finance

Notes: PNI = Projects of National Importance; EIA = Environmental Impact Assessment; MTIP = Medium-Term Investment Plan

The MAE or DAE then usually outsources the writing of the pre-feasibility report. This report is evaluated by the appraisal council, created in the previous phase. If the council finds the report sufficient, it will be forwarded to the appropriate decision maker, depending on project type. A positive decision means that the project will go on to the next phase.

In this phase, two reports get drafted parallel to each other. Two different groups of external consultants

draft the Environmental Impact Assessment (EIA) and the feasibility report. The EIA will be evaluated by an EIA Appraisal Council. This council is appointed by the MAE/DAE; in coastal projects the EIA will therefore usually be approved. The appraisal of the feasibility report is dependent on the project type, but under Vietnam's investment law, it must be a council independent from the entity that prepared the report. For the coastal constructions in the MKD, this will typically be lead by the Ministry of Construction or the Department of Construction. After appraisal, the report will be forwarded, and the final decision will be made. If the decision-maker decides to go through with a project, it will be evaluated by the Ministry/Department of Finance and the Ministry/Department of Planning & Investment. If there is sufficient budget, the project will be programmed in the MTIP. After that, the tender process can start, deciding who will be responsible for the construction.

2.2.4. Stakeholders, values, and information needs

Since previous reports have already conducted extensive stakeholder analyses for the Living Lab, these will not be performed again [20] [21]. Instead, we build on these insights and focus on the values and information needs of the key stakeholders that can influence the decision-making processes described in the previous section; since these stakeholders By doing so, extra constraints on the information that should be on the DLL are found.

MAE and DAE

At both national and provincial level, the MAE/DAE are specialized bodies within the executive branch of the government (People's Committee) [22]. They formulate and implement policies on agriculture, forestry, fisheries, and environmental protection [23] [24] [25]. They are also tasked with the coordination of risk management regarding floods, droughts and land degradation, making them a very important stakeholder for living lab projects. They consult with experts and organizations to gather input for plans and align plans with the national strategies. After plans are approved, they are responsible for implementation. Because of these duties, their values are feasibility, compliance and effective governance.

From an information perspective, ministries and departments rely on legal and financial aspects to check alignment of projects with national and provincial plans. They also oversee climate adaptation and disaster risk management [26], which requires risk assessments and environmental and land-use data. Moreover, they need practical and technical information, which they get from advice form experts within their professional network as well as from (pre-)feasibility and EIA reports [A.3]. These typically include:

- Project objectives and expected socio-economic benefits,
- Technical specifications and design options,
- Cost estimates and financing sources,
- Environmental and social impact assessments,
- Land-use and resettlement requirements,
- Alignment with provincial and national plans.[22]

The Ministry/Department reviews these reports and makes a decision on the implementation of specific interventions. Because the members of these Ministries/Departments are not necessarily technical experts in these areas, they need this information to be presented in a way which is understandable for them.

National Assembly/People's Councils

The National Assembly and the People's Council represent the legislative branch of the state. They decide on investment plans and budget allocation of all policies in Vietnam. This power to decide on budget allocation between sectors, makes them a relevant stakeholder for the LL.

They are elected directly by the people, and in turn have the authority to elect and dismiss the People's Committees. The Council supervises the legality and implementation of the Committee's work [22]. In contrast to the Committee's executive role, the Council focuses on representation, budget allocation and oversight. Council members do not directly approve projects. Instead, they balance interests and allocate budgets accordingly [4]. They oversee the prosperity of their jurisdiction. Because of this, the Council needs a more holistic view of the region they oversee.

From an information perspective, Councils need concise and comprehensive evidence to allocate budgets efficiently. They do not formulate policy plans themselves, but they oversee detailed proposals and have the authority to approve or reject them through their budget allocations. After projects are completed, they also have to see whether goals are achieved. Based on this information, the Council adjusts future budgets or investment plans. In practice, they focus on visible benefits within their five-year term.

Experts (consultants and technical advisors)

Experts are approached by the government to help them solve specific problems. They can influence the process in the conceptual phase, where they're often invited for workshops or meetings, or they can be asked to draft official reports. Due to their technical expertise, they can translate scientific insights into decision documents such as (pre-)feasibility studies and EIA's. Their role is to deliver analyses that are feasible, timely, and actionable. This orients their values toward quality, applicability, efficiency, and methodological soundness that is sufficient for decision-making under deadlines. [A.4]

Because they must assemble complete reports quickly, experts need broad and cross-cutting information. They do not conduct field research themselves, but using up-to-date reports and interviews with researchers, they can gather sufficient information to base their advice on. Their broad information needs include relevant stakeholders, technical reports, financial estimates, legal and land-use constraints, and clear information on budget and project timeline benchmarks. With this information, they can bring stakeholders together and realize project execution. [A.4]

Researchers (Living Lab)

Researchers generate the empirical basis on which expert reports and policy choices are based. Their role is to seek the truth. They value transparency and validation. They want to know why decision-makers make the decisions they do. Scientists need to be heard; the knowledge they generate has to be applied in practice to make an impact. They contribute depth and precision within defined scopes and are careful to state uncertainty and limits of inference. This makes their work not directly applicable in decision-making, especially in complex systems like the MKD, where hard science cannot provide answers to questions decision-makers have.

Researchers need structured access to datasets and scientific work. To connect findings and expand system-wide knowledge of the MKD, proper tools and methods are essential. Centralized data storage and visualization are therefore needed. A Digital Living Lab can meet these needs by combining a research repository with visuals and short texts [A.1].

Locals (aquaculture farmers):

Local people are important to consider. This is mainly because of two reasons: First, they are the ones who experience the effects of coastal erosion and/or interventions. And second, they have influence over what *actually* happens in the Mekong Delta. Although local people are aware of basic governance structures, their knowledge is limited. Officials often interpret this limited knowledge as disinterest, resulting from their low education levels [27]. But in practice, their information needs are just outcome-oriented. This is because they mostly value protection of farmland, maintaining fish and shrimp yields, and reducing flood risk [27]. These people are not interested in abstract long-term policy goals [20].

In terms of formal decision-making power, local communities have almost no direct influence [20]. As mentioned in the previous section, elections hardly affect who is in government. Policy decisions are

driven by reports made by experts. Locals can affect and advice people making these reports through representatives of cooperatives, but decisions on these reports are mainly based on compliance with national investment plans.[A.1] [19] There is, however, growing governmental interest in integrating local knowledge into decision-making, providing an opening for the DLL to seize. By incorporating bottom-up insights, the DLL could support authorities in those decisions [A.5].

Despite little direct influence, communities may still exert indirect influence. For instance, if interventions or regulations interfere too heavily with their livelihoods, compliance is unlikely, reducing the effectiveness of policies in practice [28]. Moreover locals have a lot of tacit knowledge that has proved very valuable in the LL. Community participation is seen as crucial for gathering contextual information, ensuring social acceptance, and creating long-term sustainable solutions [20]. Thus, while local people lack formal decision-making power, their role in shaping outcomes on the ground remains significant. This underlines that farmers should be seen as an important stakeholder in the design of the Digital Living Lab. As noted by the previous MDP, *"farmers feel unheard"* and there is a *"need for a platform that ensures their voices are integrated"* [20].

Table 2.3 shows a clear picture of the stakeholders and their information needs. The needs are diverse, so the DLL must support different types of information and levels of detail for different goals. This mapping forms the basis for information that could be included in the DLL. This can be combined with the findings from Section 2.2.3 to a first "solution space" of what information to include on the DLL, where the information is used, and for who. The figure below summarizes this.

Next, we look at informal processes that shape how decisions are made in practice. These informal dynamics affect what information is most useful on the DLL and how it should be presented.

Table 2.3: Stakeholders, their values, and information needs relevant for the Digital Living Lab

Stakeholder	Values	Information needs
Ministry/Department of Agriculture & environment	Feasibility, compliance, Effective governance	Technical data, Legal Frameworks, Financial parameters, Environmental and land-use data, Expert advice, Risk assessments, Concise (pre-)feasibility reports
National assembly/People's Councils	Representation, Compliance, Prosperity	Elaborate policy plans, Holistic system view, Weighted costs & benefits
Experts (Consultants)	Technical quality, Applicability, Efficiency	Broad and up-to-date data, Cross-sector input, Benchmarks, Legal frameworks, Financial parameters, Broad stakeholder view
Researchers (Living Lab)	Truth, Transparency, Impact	System-wide datasets, Long-term monitoring
Locals	Safety, Livability	Practical outcomes, Effects on food yields, Floods

2.3. Informal processes and stakeholders in Vietnamese decision-making

From understanding the formal decision-making process, the general information needs for the DLL were found. These are however broad and non-specific. More detailed constraints and implications are therefore needed to make the DLL impactful.

Decision-making processes in practice rarely follow a standard procedure. Every phase in the process is therefore a bit different, and some phases turn out to be more important than others. Since the goal is to formulate a highly specific framework that makes the DLL convenient for decision-makers, these implications and constraints will be specified further by understanding the *informal* decision-making process as well.

These informal aspects are studied through interviews with experts in the field of Vietnamese decision-making, as well as literature research. In this section, the formal analysis of the previous section will be revised, taking the informal perspective into account. These informal aspects provide key findings that alter for whom the DLL should be made, and how information should be presented on there. The chapter concludes in the next section, where all these constraints & information are summarized by linking this policy research to design.

2.3.1. Informal government structure in Vietnam

The formal structure of the Vietnamese government sketched in Section 2.2 does not represent the full reality. For example, it is a public secret that, although the constitution emphasizes a democratic state, in practice elections and positions of ministers are heavily influenced by the CPV, if not determined completely. This became clear during a meeting where laughter followed a question about the meaning of voting in Vietnam; signaling that citizens recognize the symbolic nature of the electoral process.

In practice, the CPV maintains several direct channels of influence over the State and its key decisions. The Politburo and Central Committee decide who will occupy the highest positions within the National Assembly and the Government; President, Prime Minister, and the Chairperson of the National Assembly. On the lower levels, the Party's Organization Commission and Central Committee largely pre-determine the personnel of the provincial and communal councils before any public voting takes place. As a result, the representatives who will eventually function in the committees are highly filtered. Because of this filtering, it is difficult to bring alternative topics, like NbS for coastal protection, to light. Only in rare cases, where topics become national news, the CPV is directly informed and takes action. Elections do, however, have meaning and efforts have been made to improve them. This shows that there is willingness from the political elite to hear about what happens on the ground.[29]

The VFF is a political organ that represents all Vietnamese, through means of democracy. Its statutes however also say it implements the guidelines and policies of the CPV[11]. It does this by screening and nominating candidates for the National Assembly and local councils. Formally, this ensures everyone in Vietnam is represented enough in the government. Also, the VFF is *"governed by the principles of democratic consensus"*[10]. It runs however under CPV leadership; VFF leaders are chosen by the Central Committee. Although regulations require that the VFF be representative of Vietnam's diverse population, in practice it functions primarily as a rubber-stamping institution that legitimizes the CPV's predetermined choices rather than shaping them.[30] Because of this obsolete function, it is deemed effectively as an irrelevant organ in the informal political system. Whereas in the formal system, it had direct influence on the National Assembly. With these new findings in mind, it is merely a party that claims to represent the Vietnamese people without self-conceived influence.

The paragraphs above highlight the large amount of power that the political elite of the CPV holds. How does this elite form itself? In simplified terms, it reproduces itself through a self-selecting process that takes place every five years during the National Party Congress. In this congress, pre-selected

CPV delegates elect the Central Committee. The Committee then elects the Politburo and the General Secretary. These organs again oversee the nomination of new candidates for the next Central Committee, essentially completing the cycle. Although this description simplifies an internal process that involves more commissions and planning, it illustrates how leadership renewal in Vietnam appears more democratic than it really is [29]. This simplified cycle is shown in Figure 2.3.

Taken together, these dynamics transform the formal structure shown in Figure 2.1. Where the formal system places the Party as standing alongside the State, the informal structure reveals a clear hierarchy: the Party stands above the State, guiding its key institutions. Citizens are positioned below and hold limited or no real influence over who is in the government or committees and the resolutions and decisions they make. All above implications have been simplified and shown schematically in Figure 2.3.
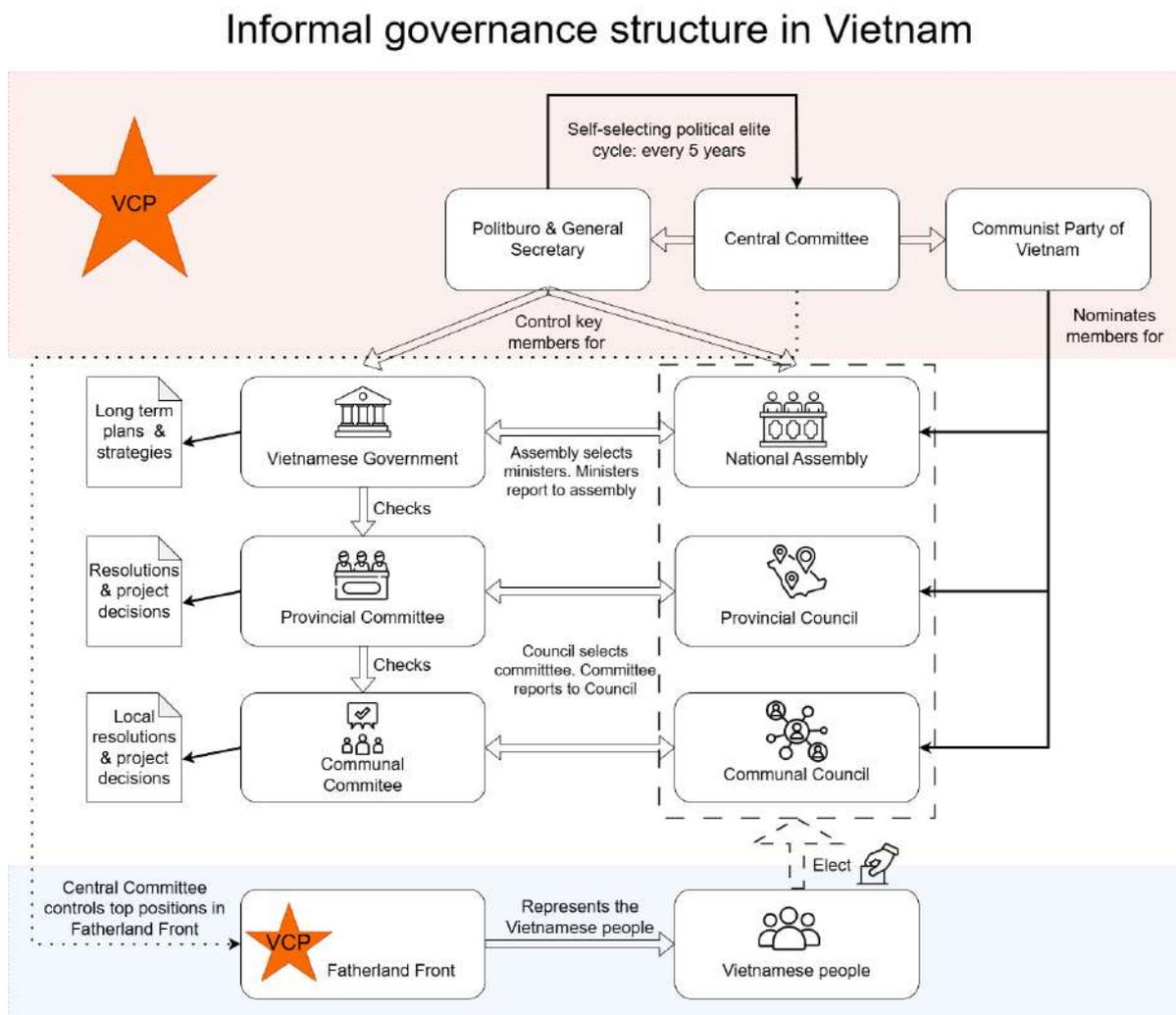
Figure 2.3: The informal governance structure in Vietnam, showing the practical influence of the Communist Party over State institutions and the limited role of citizens.

For the DLL, this political structure has several implications. The political elite of the CPV controls the general course of national plans and policies. Because of informal power relations, it is extremely difficult to influence these plans through formal methods such as elections or consultations. Influence can only

be achieved by working directly with CPV members or actors connected to the Party. There is, however, a small but growing interest in improving elections and using local experiences in policymaking. This provides limited, but relevant, opportunities for the DLL to connect on-the-ground knowledge to higher-level decision-making.

2.3.2. Decision-making process in practice

With the help of external pressure from private investors, like the World Bank, the Vietnamese government increasingly emphasizes the importance of citizen participation [A.4]. This also seems to have integrated into the decision-making process of public investments, like coastal structures. This process is modelled and explained extensively in section 2.2.3. The law on public investment, states that information on these investments must be publicly disclosed, ensuring transparency during the process. Additionally, the law intentionally allows for participation of civilians and community representatives at discussions and consultations related to these investments [17]. There are also laws that specifically assure transparency and public participation in Vietnamese governance. The Law on Access to Information states that the government has to provide information accurately, completely, timely, transparently, and easily accessible [31]. The Law on the Implementation of Grassroots Democracy focuses on participation under the motto: "People know, people discuss, people do, people supervise." [32].

However, recent studies show that Vietnamese governance is not doing well regarding transparency and public participation. According to the Public Administration Performance Index report [33], from 2023, Vietnamese provinces scored between *3.69* and *5.91* points on the 1-10 point scale for public participation, showing no increase compared to 2021. Provinces scored between *4.31* to *5.88* points for transparency, even showing significant decrease compared to 2021. And according to research, Vietnam's form of collaborative governance focuses on "appearing" participatory and inclusive, rather than actually trying to solve problems together [34].

The recent governmental reforms had the goal to decentralize power, enabling citizens to influence decision-making more effectively [14], but it's effect in practice is still unknown. This section tries to explain the gap between the participation oriented investment procedure, and the reality of limited participation.

Figure 2.2, shown in section 2.2.3, shows the formal decision-making process for public investments. The figure emphasizes the steps of the (pre-)feasibility reports, as these steps are elaborately addressed in Vietnam's law on public investment [17]. However, multiple interviews indicated that these steps are less significant than this law suggests. The majority of investment decisions are already made in the conceptual phase [A.1]. In most cases, the solution or intervention that will be implemented is selected in this phase as well [A.4]. This means that the conceptual phase is one of the most important steps in the decision-making process. Yet, no procedure has to be followed for this phase, giving decision-makers room to fill it however they please. It is therefore interesting to analyze what this conceptual phase looks like. Figure 2.4 on the next page shows our findings on the general course of the conceptual phase in the Mekong Delta. Since the conceptual phase is most important, and not yet highlighted, it will be discussed here. In appendix E, the course of all phases is explained in more detail.
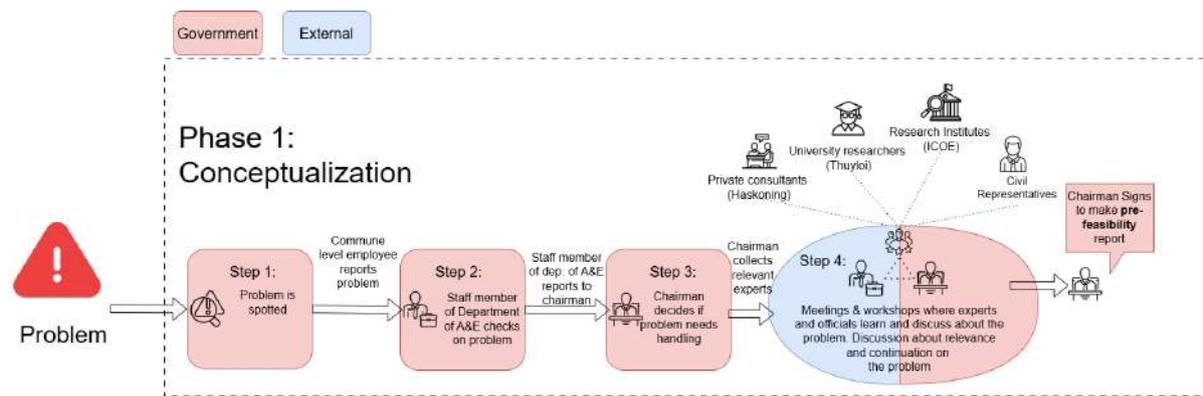
Figure 2.4: The general course of the conceptual phase in the Mekong Delta in detail. [A.1]

The very first step in the conceptualization phase happens when someone identifies a problem like erosion, irregular floods or mangrove loss. This can theoretically be a local resident, but according to an interview with a local fisherman from Vinh Chau, commune level governmental staff members regularly check the area themselves to spot problems [A.5]. Problems regarding coastal protection will be reported to a staff member of the DAE. Then, the DAE sends a team to investigate and report on the problem to the chairman of the DAE. The chairman then decides if it's necessary to act. If the problem is deemed serious enough, the chairman can invite relevant stakeholders to have a discussion about how the problem will be solved. These stakeholders can range from private consultancies, university researchers, research institutions and civil representatives. These conversations are informal, and consist of meetings, workshops and sharing of information through private communications [A.4]. A conversation with these varying stakeholders seems to enhance public participation and external expertise, but a couple of issues were identified.

First of all, there is no standard procedure for these meetings. This means that the group of invited stakeholders depends on the sitting chairman of the committee, who often invites people he already knows [A.3]. Therefore, not all relevant stakeholders who would like to have a say in the matter are invited to these meetings. They could, however, influence the decision-making process by invoking the Law on the Implementation of Grassroots Democracy, which provides a legal framework for participatory governance. However, this law and its contents remain largely unknown in Vietnam, with only between *14* and *46* percent of people across 61 provinces having heard of it [33].

Secondly, when stakeholders do get invited to these meetings, it is sometimes difficult for them to contribute to the conversation. Because these meetings are often held in a formal setting, it is difficult for participants lower in the hierarchy to voice opinions that are acknowledged or accepted by higher-ranking government officials [A.4]. This dynamic gets reinforced by the fact that in Vietnam, government officials are held personally accountable for their actions, making them cautious when it comes to listening to unfamiliar ideas or people, an insight that came from conversations with multiple experts.

In conclusion, the meetings and conversations in the conceptual phase do not necessarily contribute to enhanced public participation because not all relevant stakeholders who are eager to speak out get invited, or it is difficult for them to contribute to the conversation. When the chairman eventually signs off to start drafting the pre-feasibility report, the final intervention is already largely determined. From this moment, only technical reports will be drafted, leaving little room for conceptual thinking [A.4]. This means influencing decision-making will be much more difficult from this moment.

2.3.3. Stakeholder values in practice

In Section 2.2.4, relevant stakeholders that can influence the decision-making process were identified. However, after analyzing the Vietnamese government structure and investment decision-making process in practice, the stakeholder relationships and power dynamics look different than the theoretical case. From this analysis, two of the previously described stakeholders were found to hold the most power in the actual decision-making process.

The first important stakeholder to consider is the MAE or DAE. When it comes to investment decision-making, they have the final say in each step of the procedure [17] [A.1]. However, looking at the investment-decision making process in practice, the majority of decisions are actually taken in the conceptual phase. Taking this into account, the most powerful stakeholder in the process is the chairman of the DAE. This actor decides if the problem will be dealt with and authorizes the continuation of drafting the pre-feasibility report. Additionally, the group that will discuss which intervention will be implemented, is put together by the chairman as well [A.1].

Secondly, the experts advising the MAE/DAE are important to consider as well. The protection of the Vietnamese coast is a technical challenge. According to research, technocracy is a key feature of the Vietnamese water system [34]. This means that governance relies on expert-driven, top-down technical solutions, while local knowledge and deliberation is sidelined. Therefore, technical experts have a lot of influence in the decision-making process, as they are seen as the most capable stakeholders when dealing with these coastal challenges. However, after analysis, two types of experts could be identified: governmental experts and external experts. It is important to distinguish between these two types because they both play a role in the decision-making process, but they fulfill their roles in different ways. [A.1] [A.3] [A.4]

In conclusion, the chairman of the People's Committee, governmental experts and external experts arise as the three most powerful stakeholders in the investment decision-making process. This means that Table 2.3 needs to be revised to reflect the informal reality. The remainder of this section delves deeper into the values and information needs of these three actors. Figure 2.4 shows the values and information needs of the three most important identified actors.

Chairman of the People's Committee

The Chairman of the People's committee oversees all departments of the province and is the head of the committee and all its departments. This means that he has a lot of overlapping values with the MAE/DAE, namely feasibility, compliance, and effective governance. The chairman signs off for the continuation of all investment projects in the conceptual phase, which gives him the final say in these investment projects. Because of this, the chairman is held personally accountable for the consequences of implemented interventions [A.1]. This results in the addition of a personal value for the chairman, accountability. This could make him more likely to agree on solutions that are perceived as safe and non-controversial.

The chairman also has a lot of overlapping information needs with the MAE/DAE, as he bases his decision on the same information. He needs technical, legal, financial and environmental information, as well as risk assessments. Usually this information is provided in the form of expert advice and (pre-)feasibility reports and EIA's. However, because the chairman is personally accountable, this information needs to come from a trustworthy and familiar source. In Vietnam, people want to see something work before they believe it [A.1]. This results in decision-makers often looking at other successful projects when deciding which intervention to implement [A.1]. For this they need monitoring data as well.

Governmental experts

Governmental experts are well informed about coastal challenges, and understand the technical processes and implementational limits. They advise the government and can write (pre-)feasibility

reports or EIA's. Because they are one of the two breakaways of the expert stakeholder described in Section 2.2.4, they have a lot of overlapping values, namely technical quality, applicability and efficiency. But because the experts described in this paragraph are specifically working for governmental institutions, they have an additional value: compliance. This means that they work following established procedures. In practice, this mean that they prefer standardized technical solutions over innovative solutions [34].

Experts base their advice on a range of information needs, including broad, cross-sector, and up-to-date data; stakeholder knowledge; and reliable benchmarks, as well as legal and financial parameters. But because they strongly value compliance, they need clear procedural guidelines that they can work with.

External experts

External experts also share a lot of values with the experts described in Section 2.2.4. They distinguish themselves by being a private entity. They look at the problem with an outsider view, which can give refreshing insights. Their existence depends on project-based income and client contracts. This is why one of their core values is maintaining strong and trustworthy relationships with their clients [35]. To maintain this relationship, they need to know what the clients expectations are, and why their priorities lie.

Table 2.4: Values and information needs for the relevant stakeholders for the Digital Living Lab in practice

Stakeholder	Values	Information needs
Chairman of committee	Feasibility, compliance, Effective governance, **Accountability**	Technical data, Legal Frameworks, Financial parameters, Environmental and land-use data, Expert advice, Risk assessments, Concise (pre-)feasibility reports, **Monitoring results**
Governmental experts	Technical quality, Applicability, Efficiency, **Compliance**	Broad and up-to-date data, Cross-sector input, Benchmarks, Legal frameworks, Financial parameters, Broad stakeholder view, **Clear procedural guidelines**
External experts	Technical quality, Applicability, Efficiency, **Client relations**	Broad and up-to-date data, Cross-sector input, Benchmarks, Legal frameworks, Financial parameters, Broad stakeholder view, **Client expectations & priorities**

2.4. **Linking policy research to design**

In the previous sections, information to answer research questions 2a–2c and 3c is provided. They form the knowledge base for answering research question 4a and 4b. This section summarizes the key findings on Vietnam's political structure, decision-making in practice, and stakeholder values, and translates them into general design requirements for the DLL. This will start to answer research question 4b. The concrete translation of insights into design requirements for placing information on the DLL is presented later in Chapter 5, Section 5.4, thereby handling research question 4b.

Key takeaways from understanding the political system

- Formal elections do not determine who governs in practice.
- Vietnam has a strong vertical hierarchy, therefore local plans move upward for approval and national strategies move downward for implementation.
- Because of the 2025 reform, the government system was simplified, the effects are still uncertain but could open opportunities for the DLL.
- Laws promote transparency and participation, yet measured participation and transparency remain low.
- In rare cases, news can reach national attention and allow for quick reaction from high-level politicians.

Key takeaways from understanding the decision-making process

- Influence must be exercised through direct engagement with CPV members or experts in their networks.
- Decision-makers carry personal accountability for their approvals, creating a strong reluctance to sign off on plans or investments. Building trust in both the people and the data behind ideas is therefore essential for decisions to move forward.
- Most choices lock in during the informal conceptual phase, therefore early information sources are important.
- Communication and information sharing happens via workshops, meetings, and private channels (e.g. Zalo & Linkedin)

Key takeaways from understanding relevant stakeholders

- Chairman decides on continuation and plays a large role during conceptualization by deciding appraisal councils and meetings.
- Chairman has personal accountability for signing off documents. Therefore needs information to be reliable and with a strong technical foundation.
- MAE/DAE value feasibility, compliance, and effective governance. They need legally aligned, financially grounded, and technically clear briefs.
- Many ministry/department members are not always specialists in the field they decide on. Information must therefore be understandable without deep technical background.
- External consultants operate across multiple phases in the decision-making process by drafting EIA and feasibility reports and advising on solutions.
- Bottom-up signals often originate from commune and provincial staff through routine field checks. But increasingly arises from local stakeholders.

2.4.1. Integrating takeaways into DLL design

Taken together, these findings imply that the DLL must be technically correct, concise and presentable for use in decisions. Since most policy decisions in Vietnam take place in informal settings, trusted information that can be quickly shared matters more than lengthy reports. These technical reports, however, remain essential foundations because decision-makers must rely on verifiable data. The DLL should therefore translate technical information into accessible formats and combine that with financial implications. By explicitly including economic effects, the DLL connects project information to national plans.

Because much communication, even at higher levels, takes place via Zalo [A.4], the DLL must be fully mobile-friendly. This allows decision-makers and advisors to share data within their existing communication channels. Presenting information in short, visually supported summaries makes it easier for them to access findings directly during discussions or approval moments.

Information on the DLL must follow clear communication principles. Text should be short and use plain language fit for university-level people. Jargon should be limited to background pages. Key numbers and years should be highlighted in **bold**, and staments are backed by data.

If these constraints are built into the DLL, the platform will be convenient for decision-makers. It turns the collected research into a practical tool that fits their way of working. In doing so, it answers research question 4a: making the DLL convenient and usable for decision-makers. Chapter 6, Section 6.2 addresses research question 4b, it discusses how these design constraints are integrated into a framework allowing future researchers to contribute to the DLL.

3

Storyline and Coastal System Understanding for the DLL

This chapter provides the main content for the Digital Living Lab. It starts by introducing what a storyline is and possible storylines for the Mekong Delta. AFter that, the selected storyline is described in more detail, and the important drivers, processes and interventions in the Mekong Delta are covered. These all form the basis of the content for the DLL.

3.1. Storyline

In order to develop a framework that the researchers from the Living Lab can use in the future, a storyline is created for the Digital Living Lab. Our perspective of a storyline for the DLL is that it connects different locations, natural phenomena, human interventions and stakeholders, over a long-term period. Such a storyline is valuable for the DLL, because it helps to build an initial understanding of the causes and consequences of the problems in the Mekong Delta. At the same time, it raises awareness of gaps in existing knowledge and highlights where further information is needed.

Using our definition of a storyline, we identified three possible approaches for the platform:

- **Single location**: The storyline focuses on one specific location, exploring in detail the human interventions, drivers, processes and stakeholders that influence this area.
- **Multiple locations**: This approach connects several locations by emphasizing one human intervention (e.g., a dike). This way the link between multiple locations in the MKD can be obtained.
- **Single stakeholder**: Alternatively, the storyline may center on one stakeholder. This perspective connects human interventions, drivers, processes and multiple locations through the lens of that stakeholder's role and influence.

After evaluating the three approaches, the single-location storyline was selected. This approach enables a detailed examination of relevant drivers, processes, and human interventions over a long-term period. It also provides a solid basis for developing a framework that researchers at Thuyloi University can use and expand by applying the same method to other locations in the MKD.

Nhà Mát was selected as the location for the storyline. The following section provides more detailed information about this area.

3.2. Nhà Mát

3.2.1. Background

Nhà Mát is a coastal ward in Cà Mau province, located in Vietnam's Mekong Delta along the South China Sea. The ward is well known for its aquaculture, salt production and offshore fisheries, while it is also a center for coastal tourism. In recent decades, Nhà Mát has developed into a center of shrimp farming, supported by provincial plans for intensive and semi-intensive shrimp, clam and oyster production [36].

At the same time, the area faces severe coastal challenges, including mangrove degradation, shoreline erosion, and repeated damage to the Nhà Mát sea dike system. In response, numerous coastal protection measures have been implemented, ranging from hard-engineering dikes to nature-based solutions.

What makes Nhà Mát particularly interesting is that despite these interventions, the mangrove forests have almost fully disappeared in recent years. This contrast between extensive protection efforts and continuing mangrove degradation makes Nhà Mát a good fit for the storyline, which aims to explore how natural phenomena, anthropogenic activities, and stakeholders in the area interact to drive mangrove loss.

3.2.2. Mangrove loss & coverage

Figure 3.1 shows the mangrove loss in the Nhà Mát area. Along the shoreline, the mangroves have retreated by 150–200 meters since the year 2000. Further inland the loss extends up to 500 meters, where mangroves have been cut for aquaculture. This decline in mangrove cover reduces natural coastal protection, leaving the land and local communities more vulnerable to flooding.
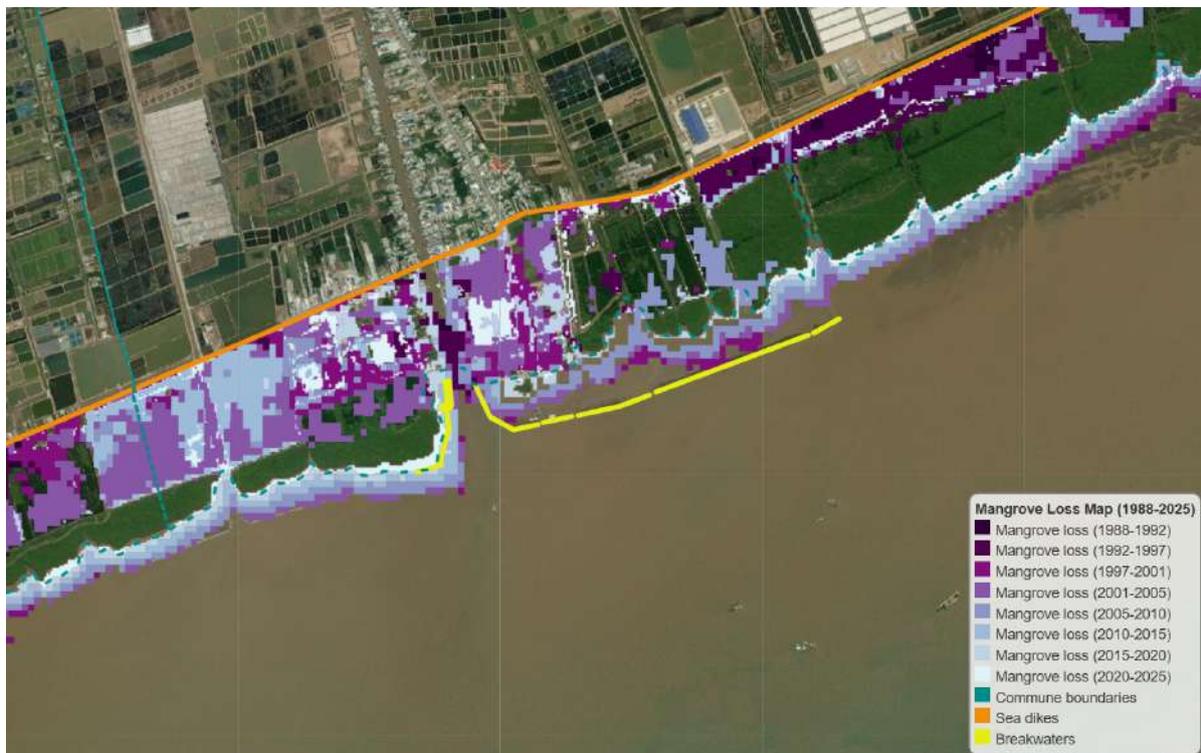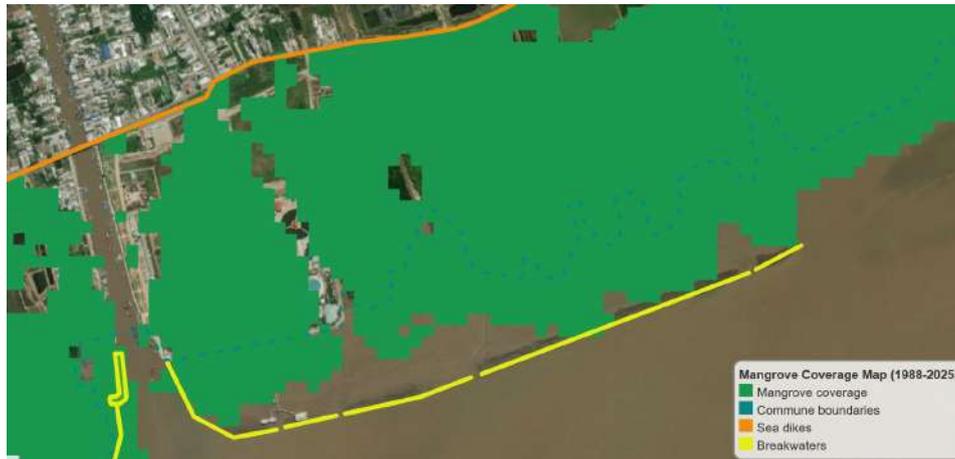

Figure 3.1: Mangrove loss in Nhà Mát from 1988-2025.

Figure 3.2 shows a comparison of the mangrove coverage in Nhà Mát between 1997 and 2025. Just like

the loss map, it shows a significant decline in mangrove forest area along the Nhà Mát coast. Despite multiple reforestation projects (explained in Subsection 3.2.3), there is no sign of mangrove growth along the coast.

(a) Mangrove coverage Nhà Mát 1997

(b) Mangrove coverage Nhà Mát 2025

Figure 3.2: Comparison of mangrove coverage in Nhà Mát between 1997 and 2025

Figure 3.3 shows that there seems to be mangrove coverage where the Nhà Mát resort is located. However, this is not accurate, as the vegetation identified as mangroves actually consists of a few individual trees within the resort. Further details on how the mangrove coverage is calculated are provided in Section 4.3 and recommendations to improve this method can be found in Chapter 8.

Figure 3.3: Mangrove coverage Nhà Mát 2025.

3.2.3. Anthropogenic activities

Urbanization of the Nhà Mát coastline

In 2015 the Nhà Mát resort was constructed. This resort is located along the coastline with an area of more than 15 hectares [37]. Dr. Phan Manh Hung provided us with valuable insights about Nhà Mát [B.1.3]. The local people do not want a mangrove forest in front of the Nhà Mát resort, because the tourists would like to be able to see the ocean, not a mangrove forest. This highlights the clear conflict of interest between the local community and the researchers of the Living Lab.

Figure 3.4: Nhà Mát resort in 2017 [37].

Permeable breakwaters

In 2019 a permeable breakwater was built at the coast of Nhà Mát. This has also been referred to as a 'detached riprap pillar breakwater'. The cost of building this breakwater was 40 billion VND per kilometer [38]. Next to this, a perforated dome breakwater was placed. This type is round and has holes to let water and sediment through. The detached riprap pillar breakwater is highly effective at reducing wave transmission but less effective at facilitating the transport of nutrients from the sea to the coast. The perforated dome breakwater better maintains nutrient exchange and has a lower reflection coefficient than the detached riprap pillar breakwater [39].

Figure 3.5: Detached riprap pillar breakwater (left) and perforated dome breakwater (right) [38].

Nature-based solutions

In 2012, bamboo fences were placed at the Nhà Mát beach, as can be seen in Figure 3.6. These fences cost around 1-2 billion VND per kilometer [38].

Figure 3.6: Satellite image of Nhà Mát with the bamboo fences placed in 2012 [40].

Four years later, the bamboo fences were removed and new bamboo fences were installed (see Figure 3.7). These new fences had a total length of approximately 1.5 kilometers.

Figure 3.7: Satellite image of Nhà Mát with the bamboo fences placed in 2016 [41].

The intention of these bamboo fences is to stabilize the coast and support mangrove recovery. The structures succeeded in retaining fine sediments, yet the accumulated material proved insufficient to foster mangrove regeneration [42]. Despite several rounds of replanting, no new mangroves have become established, underscoring the limits of such interventions when broader ecological conditions remain unfavorable.

Figure 3.8: Bamboo fences constructed along the Nhà Mát coast in 2016 [42].

Mangrove reforestation

Many reforestation projects have been implemented in Nhà Mát. From 2000 to 2010, 150–200 hectares of new mangroves were planted on the beach in Nhà Mát. From 2015 to 2020, an additional 200 hectares of forest were replanted. In 2019, around 2000 mangrove trees were planted. [43, 44]. Despite these mangrove reforestation projects, there is still no sign of mangrove regrowth at Nhà Mát.

Figure 3.9: The Nhà Mát coast in 2024.

3.2.4. Drivers and processes

The drivers that have an influence on processes in Nhà Mát, also occur in other locations in the MKD. For the DLL, it is decided to create different pages for all the drivers that affect the MKD and all the processes that are influenced by these drivers. This is explained in Section 3.3.

3.2.5. Stakeholders and their influence

The following stakeholders have an influence on the activities and developments occurring in Nhà Mát:

- **Department of Agriculture and Environment of Cà Mau**: They are responsible for implementing policies and setting targets for the agriculture, aquaculture and forestry sectors. Bac Liêu, which falls under Cà Mau province, has set a target of 1.2 billion USD in shrimp exports by 2025 [45].
- **Local fishers and shrimp farmers**: For realizing the target of the Department of Agriculture and Environment, the local fishers and shrimp farmers need both predictable water conditions, as well as stable policy frameworks to maintain a steady production.
- **Local households**: The Department of Agriculture and Environment also carries the responsibility to coordinate climate adaptation and disaster risk to protect local households. To do this, the department assigned about 400 of these households to protect and plant an area of 3,100 hectares of mangrove forests themselves [46]. They have been paid by the Government to prevent deforestation of mangrove forests in the premises of their land. Pham et al. [47] have shown that these payments are too low to prevent landowners from turning the mangrove forests into more lucrative shrimp or vegetable farming. Therefore, higher payments, together with other alternative incentives, are needed to increase involvement of local households to prevent land conversion of inland mangrove forests.
- **Researchers and consultants**: The Department of Agriculture and Environment is advised by researchers and consultants. Researchers conduct measurements and experiments to generate new knowledge. Research institutions such as Can Tho University and the Living Lab are both actively involved in the area. Consultants, like ICOE (public) or Haskoning (private), collect and report on information, and bring stakeholders together to realize project implementation.

3.3. Drivers and processes in the MKD

There are many drivers that have an influence on processes in the MKD. Drivers are defined as human or natural factors that influence change in the environment. Examples of human drivers are groundwater extraction and sand mining. Examples of natural drivers are waves and currents. These drivers have an

influence on the processes in the MKD, such as land subsidence, erosion and floods. Figure 3.10 shows the relation between drivers, processes and interventions.

Figure 3.10: The relation between drivers, interventions and processes.

There is a difference between the impact of interventions on natural and human drivers. Natural drivers are beyond human control. Interventions targeting these drivers can only mitigate the effects of the natural drivers. Human drivers can be directly influenced through policy or behavioral change. Interventions at this level can therefore address the root causes of the problem. This difference is visualized in Figure 3.11.
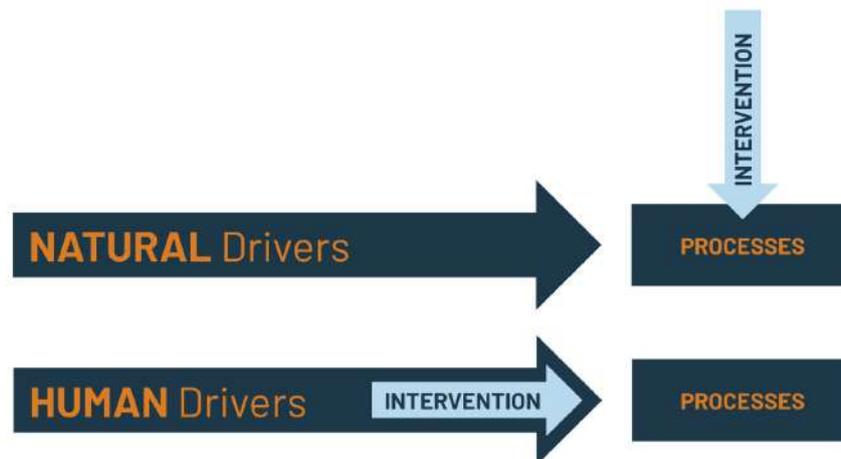

Figure 3.11: The difference between the impact of interventions on natural and human drivers.

3.4. Choice of interventions, drivers and processes for the DLL

On the DLL, different webpages are made for all the human and natural drivers, processes and interventions happening in the MKD. This list can be found in Appendix C. Some web pages are fully developed, the technical information on which the web pages are based can be found in Section 3.5, 3.6 and 3.7.

For developing the framework of the DLL, it was necessary to determine which interventions, processes

and drivers form the best basis for the storyline. Research on the decision-making process showed that interventions are often implemented quickly due to the urgency of erosion and deforestation [A.1]. As a result, decision-makers mostly focus on the short-term impact of interventions. Therefore, the DLL framework should emphasize the long-term impacts of these interventions. The intervention 'Sea Dikes' effectively illustrates both the positive and the negative long-term effects. Additionally, the underlying causes of coastal challenges are not confined to the coasts but originate further upstream in the Mekong River. This is explained with the human driver 'Sand Mining'. Finally, the framework also highlights the importance of mangroves in general.

The webpages were developed following the flowchart described in Section 6.2. This approach resulted in illustrations and texts that are easier to understand for people without a technical background, with particular emphasis on the costs associated with the different interventions. These fully developed webpages serve as an example of how the other webpages can be built as well.

3.5. The importance of mangroves

In this section, the most important functions of mangrove forests are explained.

One of the most critical defenses for the Mekong Delta is its estuarine mangrove forests, which act as natural barriers by dissipating wave energy [1]. This protective function is illustrated in Figure 3.12.
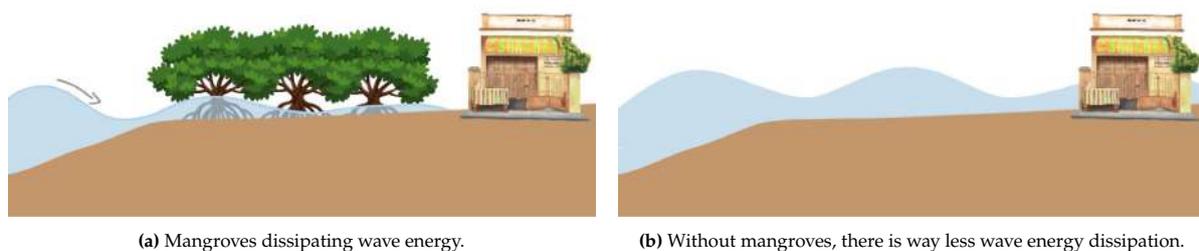

(a) Mangroves dissipating wave energy.   **(b)** Without mangroves, there is way less wave energy dissipation.

Figure 3.12: Protective function of the mangroves.

Beyond dissipating wave energy, mangroves provide three other physical functions. They enhance sediment deposition, reduce erosion by soil reinforcement and are highly effective at storing carbon, contributing to climate change mitigation. Beyond the physical functions, mangroves also deliver significant economic value through timber production, fisheries and tourism. Moreover, mangroves support rich biodiversity [1]. Figure 3.13 shows the four physical functions of mangroves.
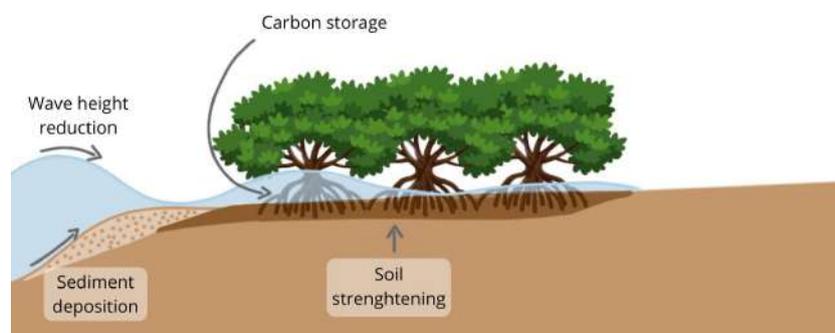

Figure 3.13: The four physical functions of mangroves.

The loss of mangrove forests due to deforestation, combined with processes such as sea level rise and land subsidence, leads to a vicious cycle, which is shown in Figure 3.14. Mangrove degradation leads to less wave damping, which increases erosion, resulting in further mangrove loss. Once the system is out of balance, the increased erosion process is difficult to stop.

Figure 3.14: The vicious cycle of mangrove degradation.

3.6. Sea dikes

This section describes the technical information on which the Sea Dikes webpage of the DLL is based.

Sea dikes are protective embankments built along the coast to keep seawater from flooding inland areas. In the Mekong Delta, where on average the land is around 0.8 m above sea level [7], dikes play an important role in protecting people, farmland, and infrastructure from tides, storms, and saltwater intrusion.

Usually, a sea dike is a sloped structure made from compacted soil often with reinforced slopes of concrete, asphalt or vegetation. The slope helps absorb wave energy, while the protective layer prevents the dike from eroding away.

In the MKD, building very high dikes to withstand absolute sea level rise and land subsidence can be economically challenging [48]. Therefore, sea dikes are often combined with foreshore solutions such as mangroves, breakwaters or other interventions that help reduce the required dike height by dissipating part of the wave energy.
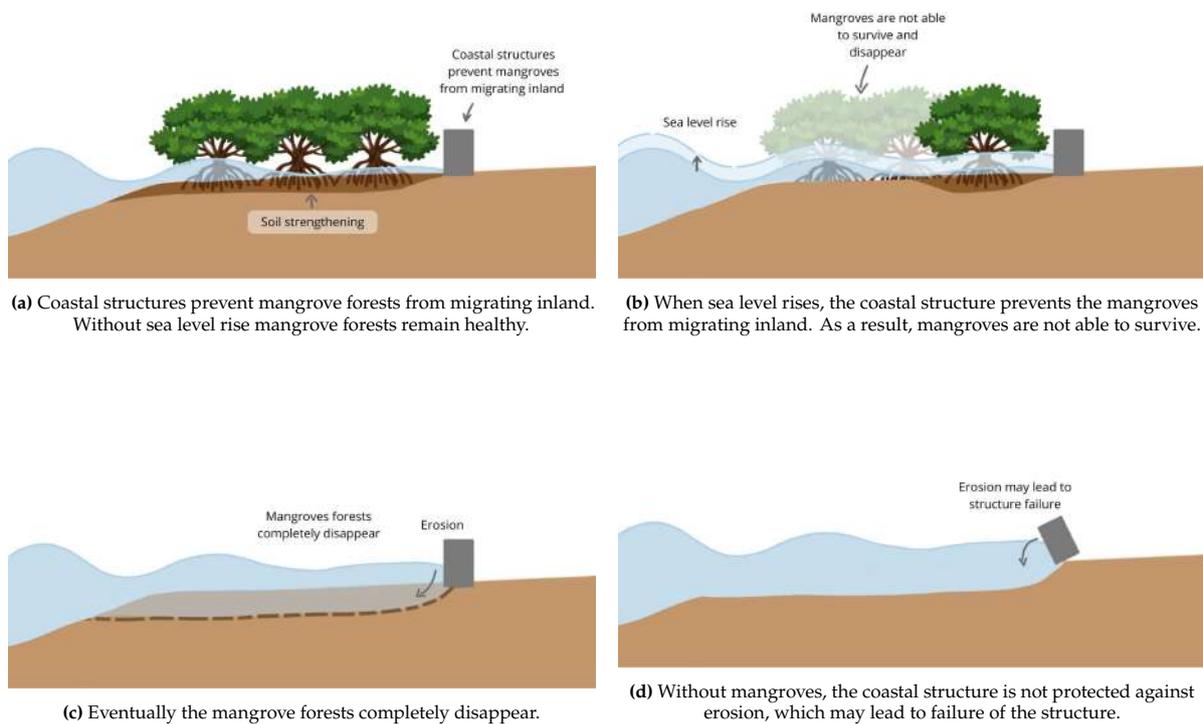
3.6.1. Mangrove squeeze

Sea dikes are widely used and can provide effective short-term protection. However, they also have negative effects. Under natural conditions, mangroves can counteract rising sea levels by enhancing sediment deposition [49], as shown in Figure 3.15a. However, climate change is causing sea levels to rise faster than mangroves can adapt. Combined with the effects of land subsidence, mangrove forests are unable to survive just by vertical accretion of the bed. In such cases, mangroves can survive by migrating inland to higher elevations, as illustrated in Figure 3.15b. This process is prevented when structures such as sea dikes are constructed within mangrove areas.

(a) Mangroves can counteract rising sea levels by enhancing sediment deposition.

(b) Mangroves can survive even higher sea level rise by migrating inland.
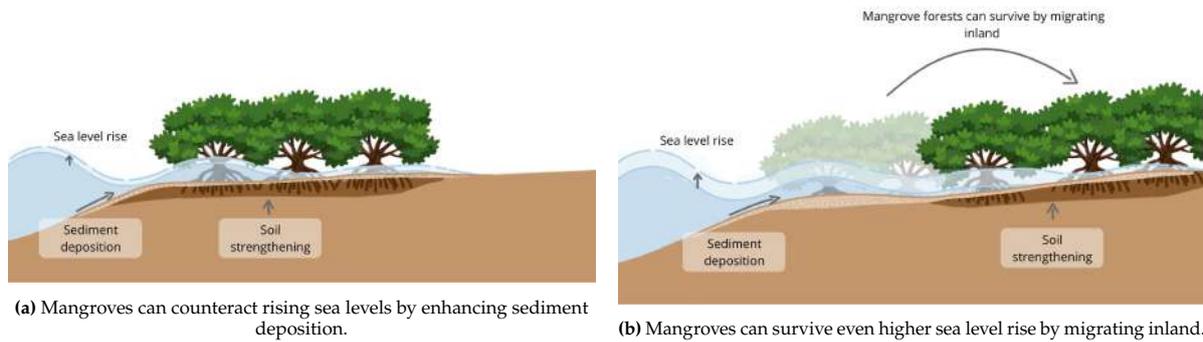
Figure 3.15: Mangrove forests naturally adapting to sea level rise.

A fixed dike line can divide mangrove forests into isolated parts, starting a process called "coastal squeeze" [50]. Behind the dike, mangroves remain in isolated areas or are replaced by aquaculture. In front of the dike, mangrove forests lose the space they need to migrate inland in response to rising sea levels. Over time, this "coastal squeeze," combined with increasing coastal erosion, weakens both the mangrove ecosystem and the long-term effectiveness of the dike itself. When mangrove forests eventually completely disappear, erosion can cause risks for the dikes' stability. In Figure 3.16 this process is illustrated.

(a) Coastal structures prevent mangrove forests from migrating inland. Without sea level rise mangrove forests remain healthy.

(b) When sea level rises, the coastal structure prevents the mangroves from migrating inland. As a result, mangroves are not able to survive.

(c) Eventually the mangrove forests completely disappear.

(d) Without mangroves, the coastal structure is not protected against erosion, which may lead to failure of the structure.

Figure 3.16: The risk of coastal structures for the survival of mangrove forests.

3.6.2. Costs

Due to the processes described above, dikes should be designed with great care. The initial construction costs represent only a fraction of the total life-cycle costs if erosion and structural damage increase

over time. A healthy mangrove forest in front of a dike can mitigate these costs, especially in extreme weather events. The Viet Nam Red Cross studied the difference in repair costs following two similar typhoons, comparing areas with and without mangroves in front of sea dikes in the Red River Delta [51]. After mangroves were successfully restored, dike repair costs decreased from about 400,000 USD to 180,000 USD and shrimp-farm losses dropped from 5.7 million to 0.79 million USD. These findings highlight that designing dikes and mangroves to function as one integrated system can significantly reduce long-term costs.

3.6.3. Long-term vision

Sea dikes are essential, but they function within a complex and changing coast. Poorly designed structures that do not match local waves, sediment supply, subsidence and other conditions can create long-run risks and higher costs. The right path for long-term protection is site specific: in some areas, a higher dike may be needed, in other areas a mangrove forest and often a good combination of both. Short-term interventions are sometimes necessary, but their long-term impacts are hard to predict. Therefore, monitoring of waves, water levels, shoreline position, subsidence and mangrove conditions around sea dikes is essential. These efforts help ensure that coastal protection remains both resilient and economically sustainable.

3.7. Sand mining

This section describes the technical information on which the Sand Mining webpage of the DLL is based.

Sand mining is the extraction of sediments from riverbeds. The extracted sand is primarily used for concrete production and land reclamation, which are essential for infrastructure and industry [48].

The extraction of sand from the riverbeds stops a significant part of the sediment flow, which results in a sediment shortage in the Mekong Delta. In the Lower Mekong River, the sediment extraction amount is approximately seven times the natural sediment supply [48]. This is a huge problem, as the delta needs enough sediment to avoid sinking below sea level.

From 2010 to 2020, Vietnam's cement production has doubled: from approximately 50 Mt to more than 100 Mt, and in the coming years this demand will continue to increase [48]. If this demand is going to keep being met with sand mining from the Mekong River, this will increase the sediment shortage in the Mekong Delta even more.

A major part of the problem is the under-reporting of the amount of sand extracted [52]. Although there are regulations specifying how much sand companies are allowed to extract from the Mekong River, this is difficult to check. In addition, illegal sand mining is occurring.

The negative effects of sand mining, combined with the effects of hydropower dams in the upstream region of the Mekong River, absolute sea level rise and land subsidence, are causing extremely high relative sea level rise in the MKD. This is a very serious threat for the people living in the area. The effects of sand mining are displayed in Figure 3.17
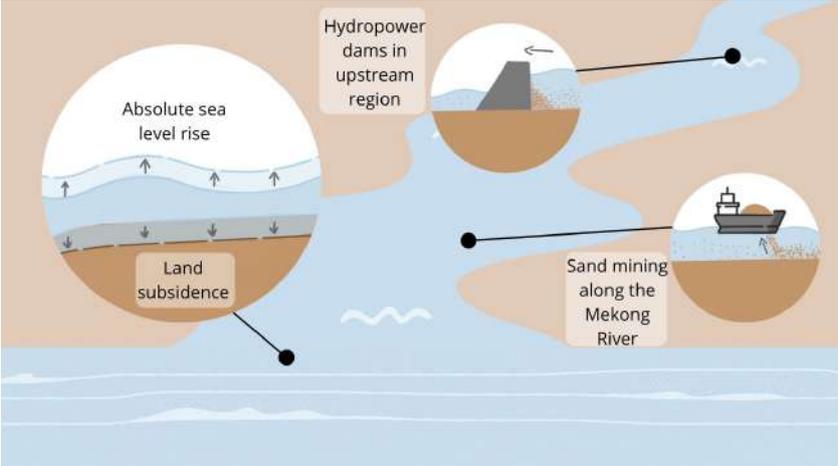
Figure 3.17: The effects of hydropower dams, sand mining, absolute sea level rise and land subsidence lead to extremely high relative sea level rise in the Mekong Delta.

4

Mangrove coverage maps

This chapter presents the mangrove coverage maps that were developed to visualize how mangrove forests have changed over time. It describes the data sources, processing methods, system integration and final outputs, which show the mangrove coverage, loss, and gain from 1988 to 2025.

4.1. Introduction

Coastal areas are constantly changing because of both natural processes and human activities. Understanding how and why these changes happen is important for good coastal management and for protecting communities and ecosystems along the shore. By tracking how the area of mangrove forests changes over time, the locations where erosion and accretion occur can be identified. This information can then be used to support the decision-making process about interventions such as coastal protections, reforestation, and changes in land use. Mangrove forests are valuable coastal ecosystems, having important physical functions such as wave attenuation, carbon storage, soil reinforcement, and sediment deposition [49]. This is why monitoring the mangrove areas over time is important for understanding how mangroves thrive and what kind of interventions affect the mangrove areas.

For the purpose of the initial development of the Digital Living Lab, the main goal of creating the mangrove maps is to make visually clear and informative maps rather than conducting an in-depth scientific analysis. The intention is to provide an accessible tool that supports understanding of mangrove forests.

To create the maps, satellite data from Landsat and Sentinel are processed in Google Earth Engine (GEE) to calculate the Normalized Difference Vegetation Index (NDVI), which highlights areas with vegetation. After post-processing these satellite datasets, interactive maps are created showing mangrove coverage, loss, and gain for each time period.

In addition to tracking mangrove change, the mangrove maps are designed so that other layers can be added with coastal structures and other human interventions. This allows for a better understanding of how these human interventions influence mangrove development in different locations. For example, at location X, mangrove gain can be observed multiple years after the construction of a breakwater, while at location Y, the mangrove coverage is constant. Comparing this information helps to understand how different types of interventions and processes affect mangrove development.

4.2. Data

The mangrove maps are created using a combination of satellite images and spatial data. Together, these datasets make it possible to observe mangrove change over time, and to relate them to location-specific conditions and human interventions.

The area of interest (AOI) covers the coastal zone between the sea dikes and offshore, in this way, all coastal mangroves are included and noise is reduced by excluding vegetation inland of the sea dikes. The southeast coast of the Mekong Delta was selected, as this is the initial focus of the Living Lab project.

The main source of satellite images used comes from the Landsat and Sentinel-2 satellites. Landsat data (from Landsat 5, 7, and 8) were used to analyze the mangrove forests from 1988 to 2015 with a spatial resolution of 30 meters [53]. Sentinel-2 images were used for the most recent years because of their higher resolution (10 meters) and better spectral quality [54]. which allows for more detailed mapping. The different satellite images are shown in Table 4.1. How these datasets are processed is treated in Section 4.3.

Table 4.1: Satellite imagery sources used for mangrove analysis.

Type	Dataset (GEE ID)	Years Used	Resolution (m)
Landsat 5	LANDSAT/LT05/C02/T1_L2	1988, 1992, 1997	30
Landsat 7	LANDSAT/LE07/C02/T1_L2	2001, 2005, 2010	30
Landsat 8	LANDSAT/LC08/C02/T1_L2	2015	30
Sentinel-2	COPERNICUS/S2_SR_HARMONIZED	2020, 2025	10

In addition to the satellite images, spatial data in the form of shapefiles were used to add information to the maps to better understand the coastal system. These consist of the following types:

- Polygons: used to define larger areas or boundaries, such as the AOI or commune boundaries.
- Lines: represent linear shapes like breakwaters or sea dikes.
- Point markers: indicate specific locations of interest, such as human interventions,urban areas, or reforestation projects.

4.3. Methods

All datasets mentioned in Table 4.1 are available for free through the Google Earth Engine platform, after which Python is used for image processing and analysis. For each year, several cloud-free images within the AOI are selected which creates one composite images with minimal cloud coverage.

To analyze relative change between time periods, the goal was to use time intervals of 5 years. However, as can be seen in Table 4.1, the number of suitable satellite images is limited to the listed years, which are as close as possible to this five-year interval. This approach allows a consistent comparison between the rate of change between different periods.

From the selected satellite images, spectral bands in the red and near-infrared (NIR) range were used to compute the Normalized Difference Vegetation Index (NDVI):

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{4.1}$$

NDVI values range from -1 to 1, where higher values indicate denser or healthier vegetation. This index is commonly used to isolate areas with vegetation from areas without vegetation such as water, soil, and infrastructure. According to [55], NDVI has been commonly applied for mangrove mapping, where a threshold of NDVI > 0.3 is used to identify dense mangrove.

For this project, a lower threshold of NDVI > 0.1 was used. During visual validation on satellite images at several locations, it was found that the higher threshold of 0.3 excluded areas with a less dense mangrove forest. After testing different threshold values, NDVI > 0.1 gave the best balance between capturing all mangrove areas, and still minimize the inclusion of areas without vegetation.

By applying this threshold, areas with vegetation are identified with the intention of isolating mangrove forests from other vegetation types within the AOI. This method gives all vegetation within the AOI but does not distinguish between types of vegetation. Therefore, it is assumed that most of the vegetation that is found corresponds to mangrove trees.

In Figure 4.1, an example of comparison of NDVI can be seen. After doing this analysis for multiple locations, it can be concluded that for the goal of this map, the NDVI > 0.1 works best: it covers most mangrove trees, but leaves spots open where the mangrove forest has a low density. Of course there are also spots that the threshold now takes into account (e.g. canalized areas), but this is likely balanced by areas that should have been classified as mangrove but were not.

(a) NDVI threshold > 0.1

(b) NDVI threshold > 0.2

(c) NDVI threshold > 0.3

(d) Reference satellite image
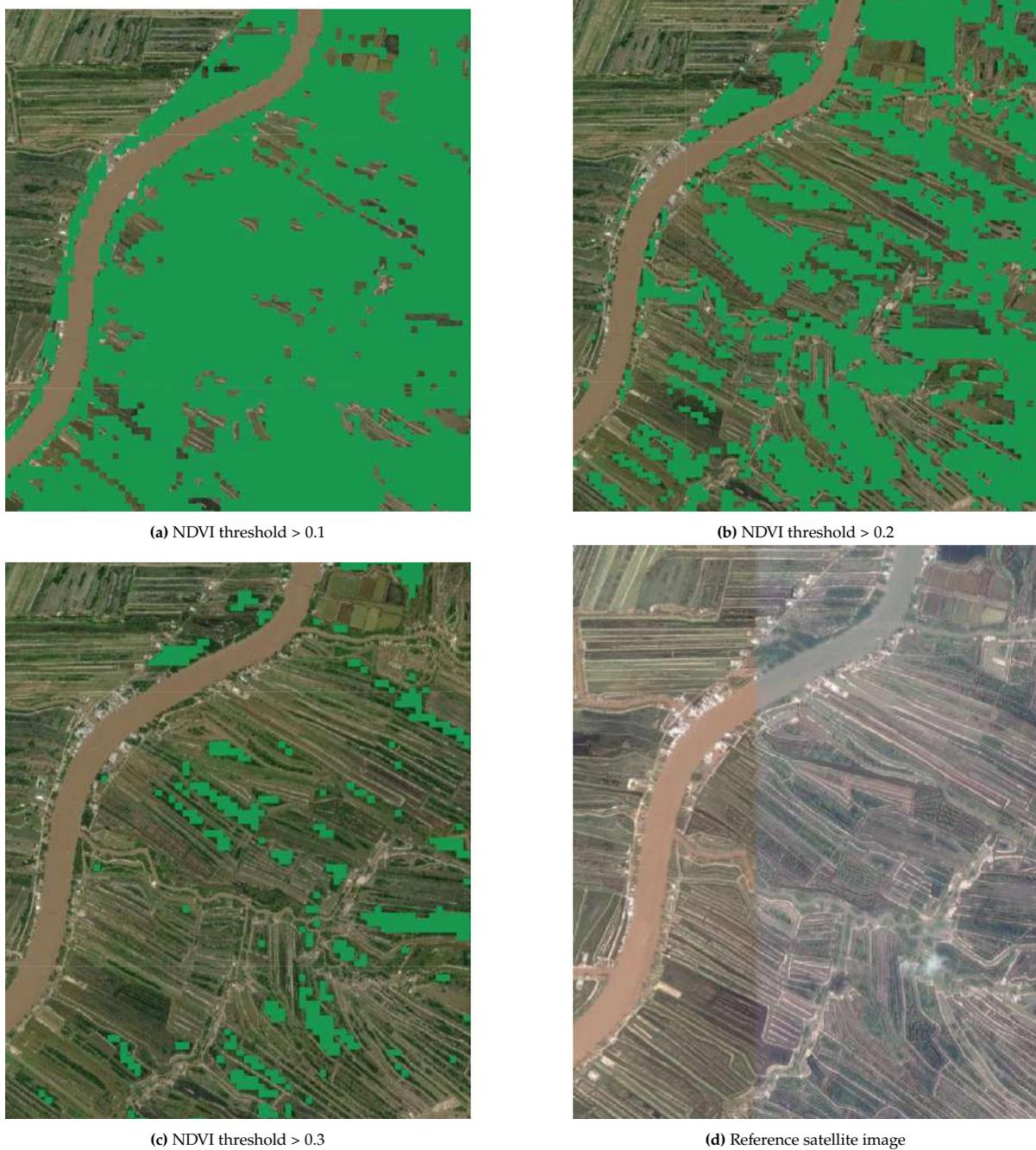
Figure 4.1: Comparison of NDVI threshold values used for mangrove detection in the area of Tan Tien. A lower threshold (NDVI > 0.1) captures more vegetation, while higher thresholds show only dense mangrove cover.

To visualize the mangrove change over time, the NDVI vegetation layers from different years are compared. By subtracting the images of two years or looking at the coverage of one year, three maps are created to separate different goals and minimize noise:

- Mangrove Coverage: all mangrove area within the specific year and the AOI.
- Mangrove Loss: areas where mangrove areas disappeared between the two time periods within the AOI
- Mangrove Gain: areas where mangrove appeared between the two time periods within the AOI

These maps can show the change in mangrove forestation quantitatively and are checked visually with the satellite images of that specific year on Google Earth Engine, to check if the mangrove areas that are produced by image processing, correspond with the real satellite images.

All types of spatial data mentioned in Section 4.2 are projected on the processed satellite images. Together with this, information about the type of spatial data is added as a pop-up on the map. This can be in the form of, for example, text, but also photos or hyperlinks. This allows a better understanding of human interventions, and their affect on the mangrove areas, and gives the user the ability to recognize specific locations or areas along the coast.

4.4. System integration

The mangrove maps are part of a system that combines satellite images, spatial data, and automated updating processes. This setup ensures that the maps are refreshed every four days with the most recent satellite data, which provides the latest information on mangrove coverage, loss, and gain.

4.5. Output and visualization

The main output of the system are interactive maps that visualize the mangrove coverage, loss and gain from 1988 to 2025 within the defined AOI. All interactive maps have an HTML layout in which users can zoom, pan, and switch between time periods.

The maps are automatically updated and published through GitHub and embedded in the Digital Living Lab. This allows easy access for decision-makers, or researchers.

4.5.1. Mangrove coverage map

The mangrove coverage map shows the mangrove forest area each year in a green color. Layers can be toggled on and off, this way the mangrove area between two years can be seen. As an example, the area of Tam Giang Đông is shown in 1988 and 2025 in Figure 4.2

(a) Mangrove coverage near Tam Giang Đông in 1988   (b) Mangrove coverage near Tam Giang Đông in 2025
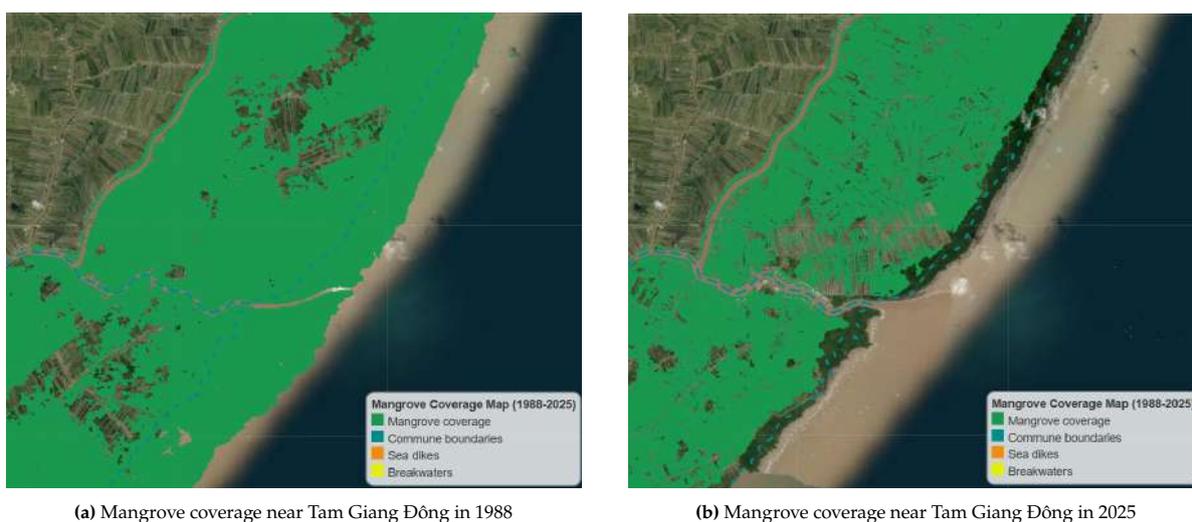
Figure 4.2: Mangrove coverage maps showing the total mangrove forest area near Tam Giang Đông in 1988 (a) and 2025 (b).

4.5.2. Mangrove loss map

The mangrove loss map has a color coding from dark purple to white, which shows the loss in a specific time interval mentioned in the legend on the map. A snapshot of the mangrove loss map is given in Figure 4.3. The map is zoomed into the Tam Giang Đong area, where approximately two kilometers of mangrove have disappeared over the last decades.

Figure 4.3: Mangrove loss map showing the loss in mangrove forest in the Tam Giang Đông area from 1988 to 2025

4.5.3. Mangrove gain map

The mangrove gain map has a color grading from dark green to white, as shown on the legend in the map. A snapshot of the gain map is given in Figure 4.4. The Vinh Chau commune is shown in which the mangrove forest area has been growing the past couple of decades. It can be observed that the rate of change differs along the coast in different time intervals.
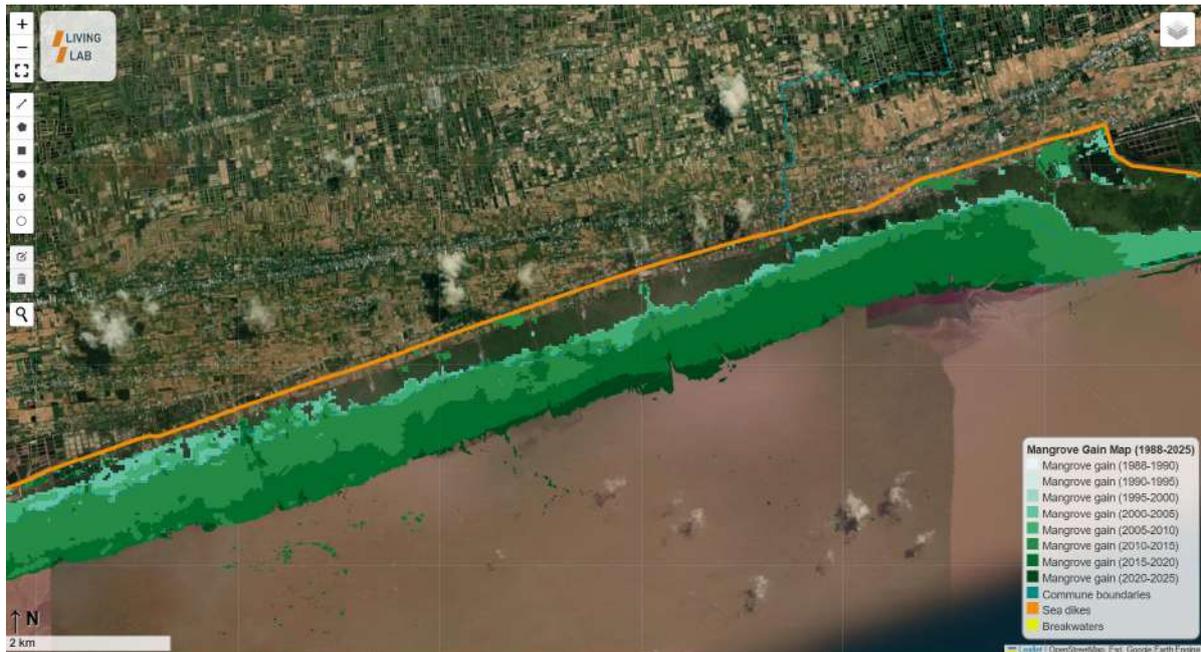
Figure 4.4: Mangrove gain map showing mangrove forest growth in the Vinh Chau area from 1988 to 2025

4.5.4. Spatial data

Next to information about the mangrove coverage, other spatial data in the form of shapefiles are added to the map as mentioned in Section 4.3. These layers consist of commune boundaries, sea dikes, breakwaters and other human activities in the area, and can be toggled on and off, helping to connect mangrove coverage changes to specific coastal interventions. As mentioned in Section 3.1, the focus of the story line is on Nha Mat. This is the location where, for now, the spatial data is applied, as seen in Figure 4.5.
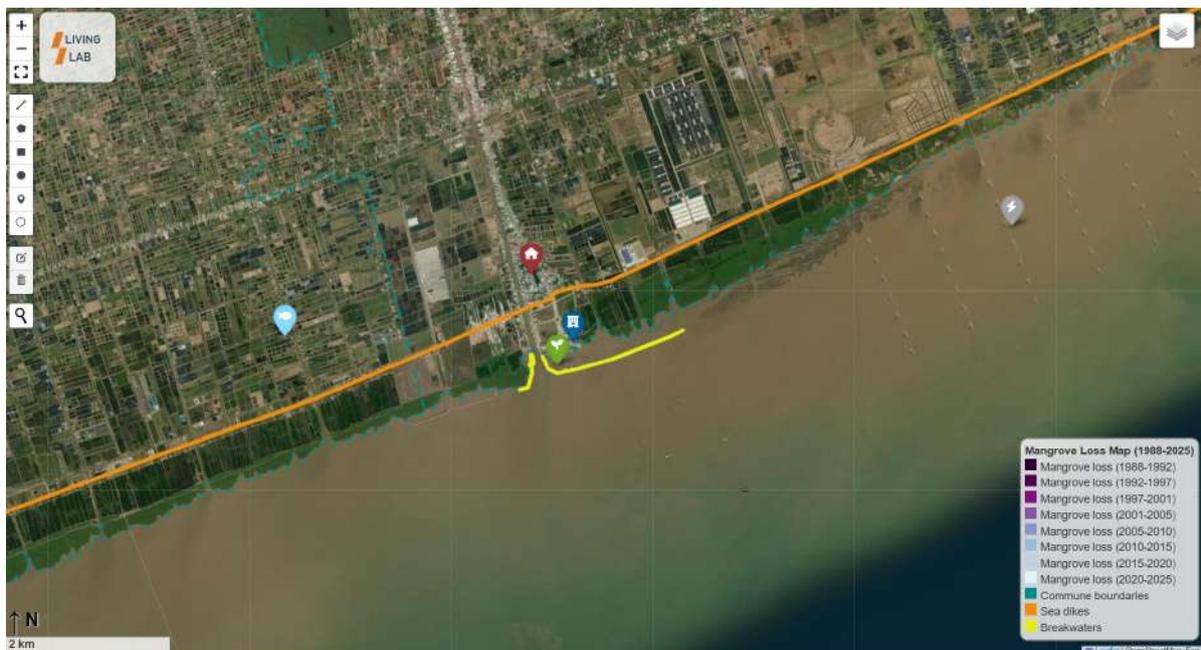
Figure 4.5: Use of shapefiles to create geometries in the mangrove coverage maps. Pop-ups give more (historical) context, illustrative photo, and link to DLL webpages.

Clicking on specific elements gives a pop-up with information about the location or structure, giving more context. An example of a pop-up of a breakwater can be seen in Figure 4.5.
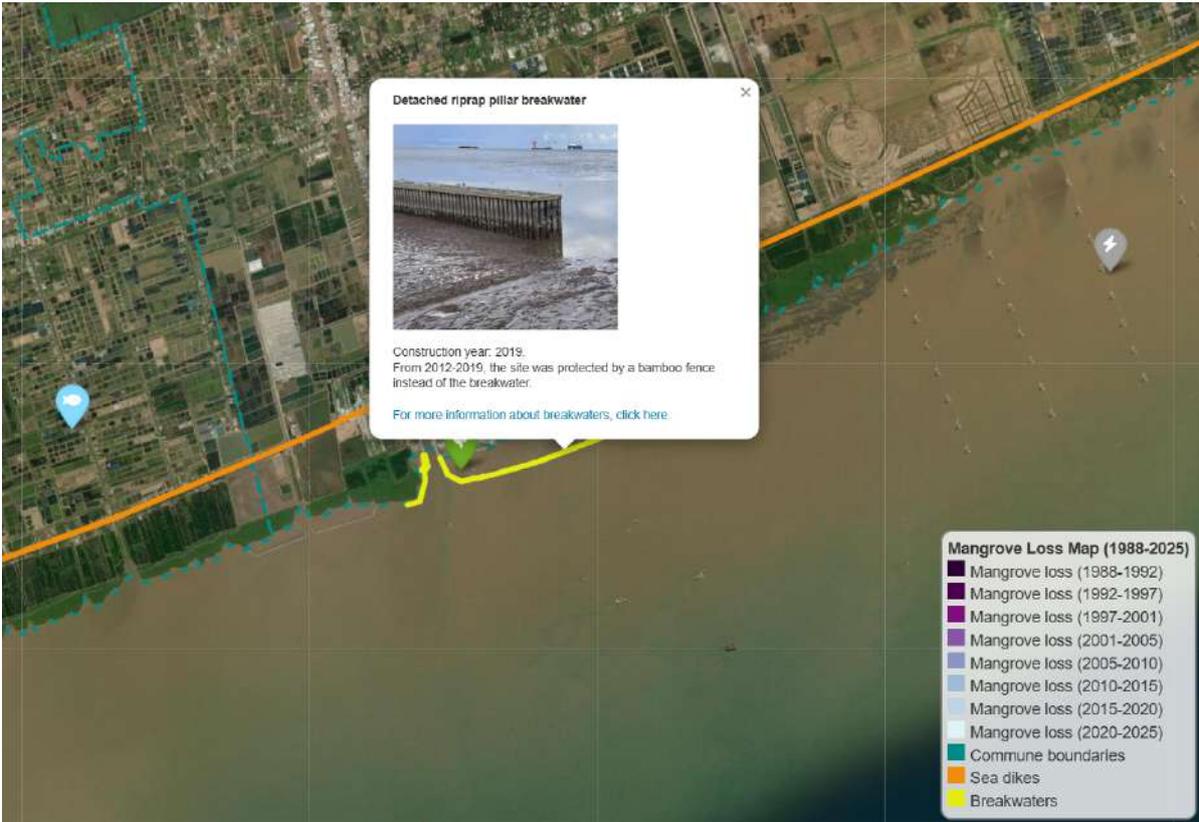
Figure 4.6: Example of a pop-up when clicking on a breakwater

4.5.5. Map use

Now that these maps are introduced, it should be noted that the use of these maps can seem clear, but need to be used differently for specific purposes. For example, the area of Tam Giang Đông shown in Figure 4.3 can also be shown in the mangrove gain map.

Figure 4.7: Shows mangrove gain at a location with a lot of mangrove degradation (Tam Giang Đông).

In this area with a lot of mangrove degradation, there is also quite some growth. This is the reason that loss and gain cannot be shown in the same map, as this can easily confuse users and not achieve the intended goal. If one wants to show the effect of a specific reforestation project, the gain map can be very powerful, whereas the loss map can be effective to make the user realize that there is a large amount of mangrove degradation at one location. Of course both can be shown to give the complete view of the area, but placing these images out of context next to each other can create confusion.

The total coverage map, can be used to showcase the difference between a time period (for example, 20 years). Next to this, the coverage map can be a source for animating the coverage over time.

4.6. Summary and recommendations

In this chapter, a set of mangrove coverage maps was developed to show how mangrove forests have changed from 1988 to 2025. The final interactive maps can be accessed through:

- https://dllmekongdelta.github.io/gee-mekong-map-dll/Mangrove_LOSS_map.html
- https://dllmekongdelta.github.io/gee-mekong-map-dll/Mangrove_GAIN_map.html
- https://dllmekongdelta.github.io/gee-mekong-map-dll/Mangrove_COVERAGE_map.html

Recommendations on future work and research on the map are covered in Chapter 8

5

Website design

The Digital Living Lab aims to make complex research on coastal protection in the Mekong Delta accessible and understandable for decision-makers. This medium, therefore, needs to connect data, research, and stakeholder perspectives in one coherent story.

To achieve this, the design journey focused on three main goals for the Digital Living Lab (related to the research questions; see Subsection 1.3.1):

1. It communicates the main message, avoiding unnecessary and highly complex information (guided by research questions 3b and 3c)
2. The design and storyline are convenient for the Vietnamese target group (guided by research questions 3a and 4a)
3. The underlying framework enables Living Lab researchers to easily maintain and develop the website over time (guided by research question 4b).

This chapter brings together the stakeholder insights from Chapter 2 and the technical storyline developed in Chapter 3. It contains two parallel design journeys: one focused on the structural storyline and the other one focused on the visual layout design. The chapter concludes with a framework for future website development to make the Digital Living Lab an ongoing project; see Figure 5.1.

Figure 5.1: Design process structure of Digital Living Lab

5.1. Research website development for Vietnamese culture

It is highly important to make sure that the design of the Digital Living Lab closely fits the wants and needs of the Vietnamese target audience. It must be taken into account that the designers have

a Dutch background rather than a Vietnamese one, and therefore might have Dutch biases. A Dutch designer might unconsciously design for the Dutch market if Vietnamese consumers are not deliberately researched. It is crucial to determine the best way of conveying a message specifically to your target audience and to understand what aesthetic values they hold.

5.1.1. Method

The research that was conducted consisted of two parts: desk research and field research. The field research consisted of both qualitative and quantitative research. Although the report refers to quantitative research, the number of respondents was insufficient to formally qualify it as such. Due to time constraints, further data collection was not possible. However, for clarity and consistency, the term "quantitative" is retained throughout the report.

5.1.2. Desk research

The project started off with desk research. The goals of this research were to learn more about the fundamentals of building a website and to write guidelines for the field research. Research showed that there are three criteria for a website that are highly important in determining whether it will be a success or not [56]:

- **Navigation:** Make sure it is easy to navigate through the website.
- **Graphical representation:** The website should utilize icons, contrasting colors, and multimedia content.
- **Organization:** Make sure the website is logically organized.

These three criteria will be taken into account when conducting further research and when building the website. This research explores what it means for Vietnamese people to easily navigate through a website and how a website can be logically organized for them.

The visual aesthetics of a website are important for capturing interest and attracting the attention of the visitor. This research was conducted among people with different cultural backgrounds, and for all of them these two factors were of high importance [57].

As aesthetics and comprehensibility have both been proven to be of high importance, two design journeys will be undertaken. To make sure both factors are equally taken into account, one will focus on conveying the structural storyline and the other on the visual layout.

5.1.3. Field research

Qualitative research
The field research started with unstructured interviews. The Vietnamese interviewees were asked to show websites they often use. They explained why they use them and what their favorite and least favorite features are. This provided a first impression of important aspects of Vietnamese websites that should be paid attention to in further research.

It became clear that these often-used Vietnamese websites have a few general things in common (see Appendix D.1.1). All websites:

- Use a lot of pictures and little text to explain.
- Use visuals with rounded edges.
- Use clearly explained buttons that navigate you through the website.

Quantitative research

Based on the results of the qualitative research, quantitative research was conducted to validate the insights and gain new ones.

A Google form was used for the quantitative research (see Appendix D.1.2). The first form was tested in English, but no useful answers were obtained from this research, as it turned out that the language barrier was too great for the Vietnamese students. So it was decided to have this form translated into Vietnamese by a Vietnamese student from Thuyloi University. The questions were tested with this same student in order to confirm their clarity. When the form was finished, it was sent out to Vietnamese students from the same university.

During this quantitative research, students were asked to rate four Dutch websites on their visual appeal and their level of understandability without being able to read the text on the website. The websites shown in this research were chosen based on the answers obtained from the qualitative research D.1.1. These websites had very different visual layouts and were selected to validate whether rounded shapes and minimal text supported by images are indeed important for visual appeal and understandability in Vietnamese websites (see Appendix D.1.2). Based on the preferences that resulted from this questionnaire, conclusions were drawn about which aspects are most important for the understandability and recognition of the website (See Appendix D.1.2).

The respondents were also asked to share a link to their most frequently used website and explain why they like to use it. These websites were analyzed.

5.1.4. Results

Important insights

The field research confirmed what was learned during the desk research and provided more insight into how to achieve these goals (see Subsection 5.1.2). First of all, the desk research proved that it is highly important that the website will be easy to navigate. Second, it is important that the interface will be intuitive. People should instantly understand how to use the website without the need for any explanation. It is important for the target audience that the most important information is highlighted, so it is easy for them to make decisions. They should also intuitively know which buttons to press. Third, recognition is very important. The target audience wants to see elements in a website that they recognize from other websites they use, not only visually, but also in terms of navigation. This helps them intuitively understand how to use the website.

Analysis of the submitted Vietnamese websites

In order to find out how to design a website based on the recognition of consumers, the submitted Vietnamese websites were analyzed (see Appendix D.1.3). A list was compiled of items that appeared repeatedly:

- All websites have pictures, visuals, and icons with rounded edges. There are few to no sharp edges on the websites.
- All websites have a very consistent use of color: a lot of white for the background and a maximum of two different complementary colors, which often vary in shade.
- Many images are used to explain what is going on; all text is supported by images.
- Each button has a short title or description, making it clear which page it will navigate to.

5.1.5. List of requirements for the Digital Living Lab

Based on all insights gained in this research, the following list or requirements was formed:

- The DLL should consist of text supported by photos.

- The DLL should be available in Vietnamese.
- The buttons and visuals on the website are round-shaped, as this is easily recognized by Vietnamese people.
- Buttons should include keywords that clearly show their meaning and purpose.
- The storyline should be easy to follow on the DLL website.
- The website should only contain information that contributes to the storyline.
- The website should serve as a starting point for adding additional information and storylines.
- The website must be easy to update and understandable for Dr. Son Truong Hong.

Based on this list, the website will be designed and tested.

5.2. The design journey of the structural storyline

As mentioned above, a clear website structure and storyline are essential to communicate the message of the website effectively. It helps filter information and ensures that the content is relevant for the target audience.

This section describes how the structure of the website was designed and how the chosen Nhà Mát storyline mentioned in Chapter 3, was integrated into this structure. It was an iterative process, taking into account background knowledge of the decision-makers (see Chapter 2) and ensuring alignment with their priorities.

5.2.1. Method

The design process of the storyline involved repeated cycles of ideation, iteration, and evaluation; see Figure 5.2. Iterations were tested, leading to feedback that was again analyzed and integrated to improve clarity and relevance of the website storyline and structure continuously.
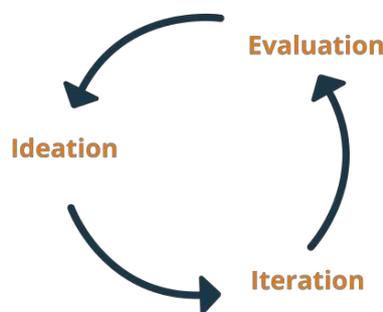
Figure 5.2: Design cycle of ideation, iteration, and evaluation

5.2.2. Storyline research

To create an effective storyline and website structure, the relevance of topics and information needs was researched. The insights were gathered from different interviews and form the basis for the storyline and structure requirements. The input came from:

Researchers: For the context and goal of the DLL

- Dr. Son Truong Hong (see Appendix D.2.1)

- Dr. Phan Khanh Linh
- Prof.dr. Thom Bogaard

Actors that work together closely with decision-makers: For the information needs and communication methods with decision-makers

- ICOE: Dr. Phan Manh Hung (see Appendix A.1)
- Dutch Embassy (see Appendix A.2)
- Haskoning (see Appendix A.4)

Locals: For communication methods

- (Former) shrimp farmer (see Appendix B.4)
- Fisherman (see Appendix B.5)

Based on the input from the different interviews mentioned above, a list of storyline and website structure requirements was created:

Researchers
- The Digital Living Lab needs to demonstrate that the Mekong Delta is facing major challenges and that its mangrove forests are under pressure.
- The Digital Living Lab should illustrate the complexity of coastal challenges and mangrove restoration, emphasizing that each location requires site-specific solutions.
- The Digital Living Lab needs to support decision-making by providing a comprehensive understanding of the bigger picture.
- Researchers of the Living Lab need to be able to store complex data and research materials through the back end of the website.
- The Digital Living Lab should be suitable for both formal and informal settings.
- The information on the website should be supported by visuals.
- The Digital Living Lab should finally be available in the Vietnamese language.

Actors decision-makers - Chapter 2
- The Digital Living Lab should include financial information and arguments, as economic viability is the most important consideration for decision-makers.
- The DLL should show costs and benefits of interventions on longer time scales.
- Decision-makers generally have university-level knowledge, but not necessarily in the specific field and therefore need to rely on work of researchers for details. It is therefore very important that technical information is correct. However, technical terminology should be minimized in non-technical topics on the website.
- The link between interventions and their coastal effects in the long term should be clear.

Civil Engineering Input for the Storyline - Section 3.1
- The content of the website should be structured around the three Living Lab research locations in the Mekong Delta.
- The information for each location should be linked to the many different natural and human drivers in the Mekong Delta.
- The storyline visualizes long-term and large-scale impacts of interventions through a map showing coastal development and interventions placed.

5.2.3. Ideation of the storyline

With the above list of website requirements and the storyline developed in Chapter 3, the first rough prototype of the website structure was created (see Appendix D.2.2). Grey blocks on slides represented the content on each website page, a slideshow navigated the participants through the pages. To evaluate whether this structure aligned both the technical context and the interests of policymakers, the prototype was tested with team members of the TPM and Civil Engineering disciplines.

5.2.4. Concept creation of the storyline

This test mainly validated that the insights from all disciplines were correctly incorporated into the website storyline and structure. Based on this validation, this was integrated into the chosen website design (see Appendix D.3.1). This leads to the following key aspects:

- The front page presents the large-scale problem through an interactive map.
- The navigation bar leads to all pages that are not directly shown on the front page.
- At the footer of the website there is a link to datasets and a link to the research papers.
- Multiple navigation paths lead to the same page.
- The detailed technical information is organized around the three Living Lab locations, in line with the storyline described in Chapter 3.
- Human actions and natural processes are both on the front page to show their combined impact on the Mekong Delta.

5.2.5. First iteration of the storyline

The prototype shown in Appendix D.3.2 was tested within this MDP project group. This led to the following insights with corresponding adjustments in Table 5.1.

Table 5.1: Design insights and their translation into website changes

Insights	Translation
The landing screen on the frontpage did not immediately grab attention	The sentence 'The Mekong Delta for 90% underwater by 2050?' was added
The navigation bar was recognized as the main tool to navigate through the website	The navigation bar now gives access to all main pages
Human actions and natural processes: The website did not make a clear distinction between actions that damage the environment and those intended to restore it	Pages are now organized in drivers, processes and interventions. On the specific page, a distinction is made between, for example, human and natural factors.
The connection to mangroves is missing on the website	A page 'The importance of Mangroves' is added
Lack of problem explanation	The problem was added to the front-page and later relocated to the Living Lab page

After implementing the adjustments, the updated website prototype in Figma was translated into the website-building software Wix Studio, here the pages were linked. The decision was made to work in Wix Studio as Dr. Son Truong Hong is already familiar with this software and Wix Studio makes it possible to easily translate the English website into a Vietnamese website as well.

5.2.6. Second iteration after test in the Mekong Delta

This new concept of the website was tested during the trip to the Mekong Delta. At Can Tho University, an interview was conducted with Vo Quoc Thanh (see Appendix A.3) from the Department of Water Resources. The main insight from this interview was the lack of contextual and structural clarity on the website. For new visitors, it was not immediately clear that the website was part of the Digital Living Lab or what the goal of this organization is. Also, the link between processes, drivers, and interventions is not immediately clear. To improve this, a short introductory explanation about the Living Lab was added to the front page, including shortcuts to the pages of processes, drivers, and interventions (Figure 5.3).

Figure 5.3: Frontpage shortcut/explantion Drivers/Processes/Interventions

Also, a visual that explains the link between processes, drivers, and interventions was added to the explanation page of the Living Lab, see Figure 5.4.

Figure 5.4: Connection between Drivers, Processes and Interventions

To further explain this structure, another image has been added to the website. This image illustrates the difference between natural and human drivers and shows how interventions can influence each type of driver in different ways; See Figure 5.5
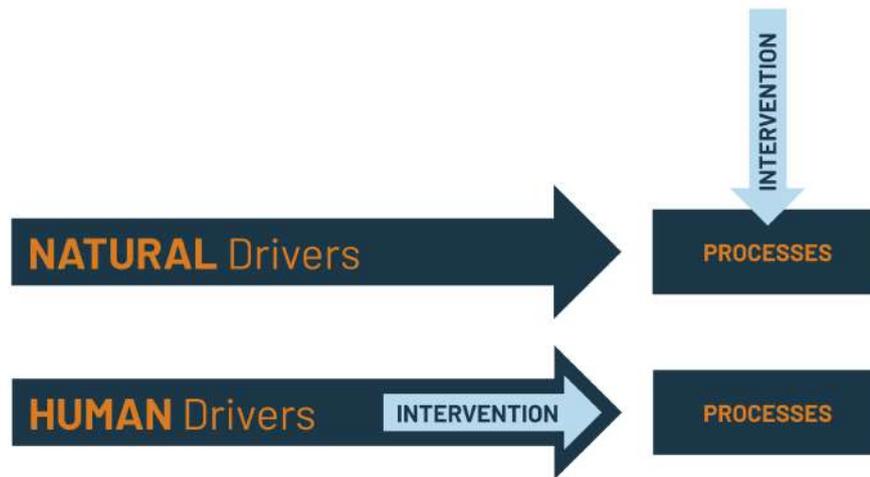
Figure 5.5: Difference between Humand and Natural drivers

5.2.7. Third iteration after test with ICOE employees

Before finalizing the website, the structure and storyline were tested one more time. Three employees of the ICOE (Dr. Phan Manh Hung, Pham Vu Phuong Trang and Nguyen Thanh Tung, see Appendix D.2.3) individually navigated through the Living Lab website. They were asked to think out loud while exploring the website and give feedback on things being clear or unclear. This led to the following insights with corresponding adjustments in Table 5.2.

Table 5.2: Additional insights and their translation into website changes

Insights	Translation
For navigation the navigation bar was mainly used, confirming the earlier insight	Keep using the navigation bar to all the important pages
The drivers, interventions and processes visual was not clear (Figure $)	A new version of the visual is created and integrated on the website
At the three locations page the sentence 'Want to visit?' was confusing	The text is changed to 'Want to learn more?'
Feedback on technical content	Comments were discussed with the Civil Engineers of our group and integrated in the website
All images should be from landscape in the Mekong Delta	Used mainly self-made images or stock images where possible from the Mekong Delta
Participants mentioned that there are more possible governmental interventions while only five are mentioned	Added a note stating: 'Examples of rules, plans and incentives made by governments or communities'
The overall website navigation was perceived clear and convenient; they easily navigate through the website.	–

5.3. Design journey of visual layout design

This section shows the iterative process of developing the visual design of the website, from the first conceptual drafts to the finalized version. The design stages, important insights, and requirements are explained.

5.3.1. Method

Based on criteria and the feedback obtained from interviews and user tests, the webpage was continuously refined according to the Double Diamond process (see Figure 5.6) and the iterative design cycle (see Figure 5.7).
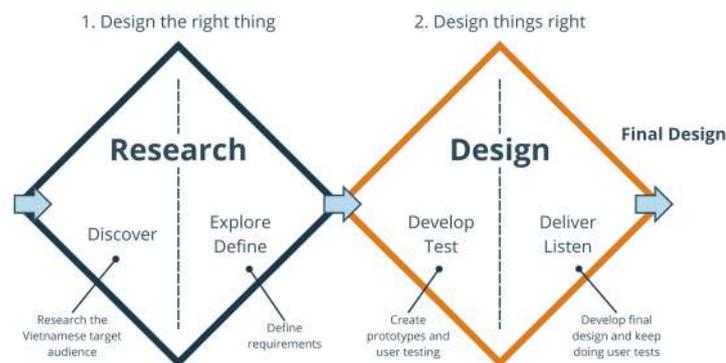
Figure 5.6: Double Diamond Method
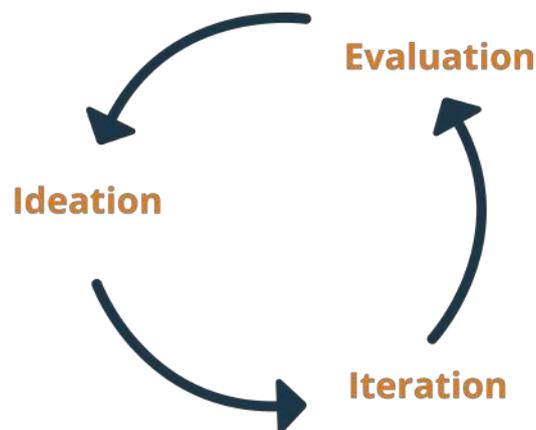
Figure 5.7: Design cycle of ideation, iteration and evaluation

5.3.2. First design

Based on the research that was conducted in Section 5.1, four distinctly different website homepage designs were created (see Appendix D.3.1). All these designs met the requirements described in Subsection 5.1.5. These designs were developed in order to test which type of design best matched the Vietnamese style and appealed most to the target audience. The supervisors provided feedback (Appendix D.2.4) on these designs. Based on this, a final design was selected. Furthermore, the feedback given on the designs that were not selected provided valuable insights into how the chosen design could be improved.

5.3.3. Iteration design criteria

The most important insights gained from the given feedback were:

- The visitor to the website should not be overwhelmed by an overload of information: The homepage should introduce the main subject, while the other pages provide a more detailed explanation.
- Keeping the right balance between images and text is very important.
- Make sure to immediately grab the visitor's attention with their first view of the website.
- Vibrant colors positively influence visitor engagement.
- The use of concrete numbers is intriguing and engages the visitor.

5.3.4. Insights of graphic designer

A graphic designer analyzed the chosen design (see Appendix D.3.2). The main takeaways from these analysis were:

- Use a different font for the title and the text.
- Make sure the fonts are consistent on all web pages.
- Increase the size of the titles.
- Make use of softer shapes without sharp edges.

5.3.5. User tests and evaluation

In order to validate the development of the website, several user tests were conducted. These user tests focused on both the structural storyline of the website and its layout design. In this chapter, the focus is on the insights gained regarding layout design. The prototype was user-tested with four people: three from ICEO (see Appendix D.2.3) and one from Can Tho University (see Appendix A.3).

The most important insights from these user tests were:

- Not all clickable buttons are clear.
- It needs to be clearer how to navigate back to the first page.
- The main menu at the top of the website should move down when scrolling.
- Share the email addresses of the team members.
- Increase the size of the text in the "Living Lab" image.

5.3.6. Design of informative images

In order to ensure that all processes described on the website are clear to the target audience, explanatory images were developed. These images should aesthetically fit with the rest of the website to ensure that they blend in well and attract attention. They should also contribute to the storyline and be informative.

Thirty-five images were analyzed to ensure that the most effective form of communication was used in the visuals. The images were analyzed by a person with no expertise in the field, which helped determine whether they were clear enough for the target audience, who also does not necessarily have expertise in the field. Imaging styles that were not intuitively understandable were not used in the visuals on the website. Based on this analysis, a list of requirements was created (see Appendix D.2.5).

5.3.7. Living Lab logo design

For the Living Lab, a new logo was developed. The main requirement was that the logo should align with the visual style of the website. Therefore, the first version was inspired by the existing logo of the Living Lab but redesigned using the website colors. The two orange stripes are based on the double 'L', as both Living and Lab start with this letter Figure 5.8. Eventually, the decision was made to remove the shape and keep the logo simple; see Figure 5.8. This is more professional and fits better within the navigator bar on the website.

Figure 5.8: Logo draft (left) Final logo (right)

5.4. Digital Living Lab framework

The development of the Digital Living Lab will be a continuous process. As this project only lasted ten weeks, the handover was just as important as the actual development of the website. Therefore, from the start of the project, the future development of the platform was taken into account.

The main person responsible for this development will be Dr. Son Truong Hong. The design journey started with a meeting with him to ensure his preferences and knowledge about website development were taken into account. To support the continuation of the website development, a manual (see Chapter 6) was created, and a handover meeting with Dr. Son Truong Hong was planned to discuss the basics of the development process.

6

DLL framework

To ensure a smooth handover, a framework for future development on the DLL was developed. This framework takes the form of a manual. The manual can be found at the end of this PDF. It explains extensively how to build further on the progress made. In addition, several meetings with Dr. Son Truong Hong were organized to explain all relevant aspects of the project and its continuation. The manual has three main components: First, a technical manual explaining how to use and further develop the mangrove coverage maps (Section 6.1). Second, instructions explaining how to develop and design the website itself in the future (Section 6.3). And third, a content manual, explaining how to create content for on the website (Section 6.2).

6.1. Mangrove maps manual

The mangrove maps manual provides an explanation on how the mangrove forest area maps were built and how they can be maintained and updated in the future. It explains how to update data, edit code, and implement this on the website. The goal is to make sure that everything can be understood and reproduced, also by someone that was not involved in the initial development. The complete manual can be found in Appendix G.

6.1.1. Goal of the mangrove maps

The main goals of creating the mangrove maps is:

- Identify and monitor changes in mangrove forest area over time, including gain, loss, and total coverage.
- Produce regularly updated maps showing mangrove forest changes using recent satellite imagery.
- Develop a workflow that can be updated with new data.
- Visualize mangrove change information online, making it easier to share with others.
- Ensure the workflow can be maintained and continued by future researchers.

6.1.2. How to use this manual

The manual consists of the following parts:

- **System Setup**: explains the structure and setup of the maps.
- **Environment Set-up**: shows how to set up and use the environments: Google Earth Engine, Python, GitHub, Wix.
- **Data Management**: explains how to add new satellite or spatial data to the maps.
- **Recommendations Tips** Gives suggestions for additional map functions that can be added in the future, and good practices to keep the maps up-to-date and working.

6.2. Content manual

This section explains how the findings from Subsection 2.4.1 are integrated into a manual that helps future researchers determine exactly *what*, *where*, and *how* to include information in the DLL, thereby addressing a part of research question 4b. The content manual can be found in Chapter 2.1 of the manual at the end of this document.

The goal of this manual is to create a simple, repeatable path from "*I have new material*" to "*I know exactly what, where, and how to publish it on the DLL.*" It does so with two elements used together: a flowchart to classify the information type and a table that guides placement, form, audience, and constraints for that type of information. Together they make the translation from raw inputs to website-ready outputs fast and comprehensible.

6.2.1. Design of the flowchart & table

The findings in the previous chapter showed visual representation of information is the preferred form in Vietnam. The manual leverages this through a flowchart that tries to visualize text on how to write other text. The manual consists of:

1. A **flowchart** consisting of two questions that determine the information type. The first question establishes the primary audience. The second question selects the information type based on content characteristics.
2. A **table** with one column per information type, 4 columns in total. The rows define the goal, relevant DLL pages of this information type, content forms, main target audience, and constraints/guidelines to apply when writing information for these pages. An example application is included in the manual.

6.2.2. Contents of the table

Each table row maps directly to a design decision you must take to publish effectively. The information in the table, per row, was based on the following:

- **Goal:** The goals named in the table aligned with the Living Lab's two core goals: generating new knowledge, and showcasing solutions. With a focus on convincing decision-makers to do more research and better understand the complex MKD system.
- **Relevant pages:** These were derived from the research in the previous chapter. Page titles and content types were found to pair consistently for the users' information needs.
- **Content:** The content specifies suitable information forms (e.g., datasets, figures, short texts) that match the information needs and capabilities of the target audience. As followed from the research in Chapter 2 Section 2.4.
- **Main target audience:** This followed from the research performed on the decision-making process, combined with the goal of the DLL.

- **Guidelines/constraints:** This translates the communication lessons from Section 2.4 into concrete rules on tone, level, and other requirements. This ensures outputs remain consistent and useful.

It is important to note that the characteristics that help the researcher answer the questions are guiding, not deterministic. They narrow options and point to the best-fitting place for information.

The table concretizes insights from Section 2.4. Combined with the flowchart, they provide a fixed path from *input → type → page → form → guidelines*. This enables researchers to contribute independently and consistently, thereby addressing research question 4b.

6.2.3. Image manual

The informative images make the technical and complex information on the website clearer and more understandable. To ensure the images are effective, extensive research was conducted on style, consistency, and information transfer.

To maintain consistency, effectiveness, and correctness when new images are created in the future, a step-by-step guideline on how to design these images is included in the manual. In addition, a list of image requirements is provided that explains in detail how the visuals should be designed.

6.3. Website development manual

To ensure the Digital Living Lab website can be further developed after this project, it is essential that Dr. Son Truong Hong understands both the layout design requirements and the software tools needed to expand the website. Therefore, the website development manual consists of two chapters:

- **Webpage development in Figma:** This chapter provides a guideline on how to work in Figma, including the structure of website pages and the key layout design requirements for the Digital Living Lab.
- **Webpage Integration in Wix Studio:** This chapter explains how to export the Figma designs to Wix Studio, integrate the webpages into the existing Digital Living Lab environment, and apply general tools to further improve the website.

6.3.1. Structure of the website development manual

The website development manual is designed as a chronological step-by-step guideline. Each topic is explained in logical order, allowing the user to be navigated step-by-step throughout the website development. The explanations are supported by images to help visualize the instructions and make the manual more convenient to use.

In addition to the written guideline, relevant YouTube hyperlinks are added to several sections. These videos support the manual and were also used during the development of the website to gain a clear understanding of the software tools.

Finally, the manual includes the 'lessons learned' during the past ten weeks of development. These are highlighted as **TIP** throughout the document.

7
Conclusion

To conclude this technical report, the following research question is answered:

How can we develop a storyline-based framework for the Digital Living Lab that communicates the long-term impacts of drivers, processes, and interventions in the Mekong Delta in a way that is understandable and actionable for decision-makers in Vietnam?

In order to make sure the answer to this research question is clear, complete, and well-structured, it is answered by means of four main themes: 1. The Storyline, 2. Target group, 3. Information & Communication, and 4. The DLL Framework

The storyline
To develop a framework that researchers from the Living Lab can use in the future, a single-location storyline is created for the DLL. This storyline provides a clear structure and overview for the website, ensuring that the information is logically organized and easy to navigate. Finally, it emphasizes that addressing challenges in the Mekong Delta requires location-specific solutions. To support this, a mangrove loss, gain, and coverage map was developed, enabling visualization of changes in mangrove forests over time.

The storyline is focused on Nhà Mát, located in Cà Mau Province in the Mekong Delta. Nhà Mát experiences severe coastal challenges, including mangrove degradation, shoreline erosion, and repeated damage to the Nhà Mát sea dike system. Numerous coastal interventions have been implemented, without significant positive results: mangrove forests have nearly disappeared in recent years. This contrast between extensive protection efforts and continuing mangrove degradation makes Nhà Mát a good fit to the storyline.

In 2012 and 2016, bamboo fences were placed at Nhà Mát beach to stabilize the coast and support mangrove recovery. In 2015, the construction of the Nhà Mát resort introduced a conflict of interest between the local community and Living Lab researchers: while researchers aim to restore mangroves, local residents, and tourists prefer unobstructed ocean views, discouraging mangrove growth in front of the resort. In 2019, two types of breakwaters were constructed along the Nhà Mát coast: a detached riprap pillar breakwater and a perforated dome breakwater. From 2000 to 2019, multiple mangrove reforestation projects were implemented in Nhà Mát. Neither the bamboo fences nor the breakwaters succeeded in supporting mangrove growth at this location.

There are many drivers that have an influence on processes in Nhà Mát. Drivers are defined as human or natural factors that influence change in the environment. Examples of human drivers are groundwater extraction and sand mining. Examples of natural drivers are waves and currents. These

drivers have an influence on the processes in the MKD, such as land subsidence, erosion, and floods. A complete list can be found in Appendix C. For the framework of the DLL, three webpages have been fully developed: The importance of mangroves (Section 3.5), Sea Dikes (Section 3.6) and Sand Mining (Section 3.7). Together, these pages form a coherent foundation for the storyline, as they illustrate the long-term impacts of interventions, explain the underlying causes of coastal erosion problems and emphasize the crucial role of mangroves in protecting the coastline.

Target group
The decision-making process in Vietnam follows both informal and formal steps. Most choices are shaped during the informal conceptual phase, when the chairman identifies a problem and decides whether to continue and which experts or consultants to involve. In the formal phase, these consultants prepare reports that are reviewed by various authorities before implementation. The chairman therefore holds the strongest influence, followed by consultants who shape the content of these reports. Locals and researchers have limited formal influence, although there is gradual movement toward more bottom-up participation. Decision-makers are personally accountable for outcomes, which makes them favor options that align with national strategies and proven methods. They highly value economic and visible benefits from trusted sources with a strong technical foundation.

Information & communication
There are several factors of importance in making sure the way of communication is effective in Vietnamese culture. The way of communication needs to be in a form that the target audience recognizes. There should be a right balance between images and explanatory text. The platform on which the DLL is created should provide the opportunity to switch from English to Vietnamese, as the target audience doesn't always master the English language. Using vibrant colors and concrete numbers in the DLL positively influences visitor engagement, which facilitates the way of communication.

In order to build and support the chosen storyline, the DLL needs to demonstrate that the Mekong Delta is facing major challenges and that its mangrove forests are under pressure. The complexity of coastal challenges and mangrove restoration should also be illustrated in the DLL with a focus on site-specific solutions. Decision-making needs to be supported by providing a comprehensive understanding of the bigger picture.

Technical information and data can be made understandable for the chairman, MAE/DAE members, and consultants by limiting technical jargon to background sections and presenting results through clear visuals and short summaries. It can be made actionable by linking findings to economic consequences and showing how certain choices would affect budgets and investments. Referring to national plans helps frame these effects within existing policy goals, making decision-makers see the need for more research and data before deciding.

The DLL framework
To make sure the DLL is convenient for decision-makers, they should not be overwhelmed by an overload of information. The homepage should introduce the main subject, while the other pages provide a more detailed explanation. Keeping the right balance between images and text is very important. The buttons should also include keywords that clearly show their meaning and purpose to help guide the visitor through the website. The DLL should also be suitable for both formal and informal settings.

For researchers, a framework was developed that supports every step of the DLL's continuation. This framework has taken the form of a manual and covers three main parts: the technical part, the design part, and the content part. The technical part explains how to further develop the mangrove maps; the design part guides how to structure and update the website in Figma and Wix, and the content part provides a framework to help decide what, where, and how to publish new material.

8

Discussion and recommendations

8.1. Discussion

Despite the target group of the website being decision-makers, there has not been an opportunity to interview them directly. This brings uncertainty to the platform, as the findings are largely based on the perceptions of other actors who work closely with decision-makers. These actors provided valuable insights into what they believe decision-makers need and value in terms of information, but their views are based mainly on experiences prior to the 2025 government reforms, of which the practical effects are still unknown. In addition, the preferences regarding the layout design of the website are informed mostly by interviews with Vietnamese stakeholders outside the decision-making group. As a result, these design choices are currently based on general Vietnamese preferences rather than specifically on those of decision-makers. The research from Chapters 2 and 5 do provide a good basis to continue future research on the political system of Vietnam and the preferred layout design of information presentation among the decision-makers.

In addition to validation, this study leaves several knowledge gaps regarding the decision-making process. While Chapter 2 clarifies what types of information decision-makers value and in what form, it remains unclear how it is actually used and how informal and formal channels interact after the 2025 reforms. Moreover, the suitability of a digital platform as the medium was not evaluated. In this project the idea of a digital platform was suggested, and therefore work focused on optimizing and designing its content. Apart from understanding decision-makers better, it is equally important to understand how researchers perceive the decision-making context and adapt their communication to it. Addressing these gaps will help align future Living Lab work with real policy dynamics and sharpen the DLL's role as a two-way interface between science and governance.

Apart from the absence of direct input from decision-makers, the number of interviews conducted to represent their perspective was limited. Cultural and language barriers also influenced the process. Feedback in Vietnam is expressed more indirectly than in the Netherlands, meaning that user testing and interviews for the website layout design required careful interpretation. Interpreting feedback and interviews required collaboration between design and policy. By translating insights from policy research into design constraints, a better understanding of how communication affects the credibility of technical information was achieved.

An important conclusion that should still be validated is that decision-makers require a strong technical foundation to trust the information they receive. Another important result that requires validation is the set of mangrove maps developed in Chapter 4. These maps were constructed solely using satellite imagery, without checking them with on-the-ground measurements. Consequently, it remains uncertain

whether these maps accurately represent the real situation. When combining these two findings, their interrelation becomes clear: if the maps contain inaccuracies and if decision-makers indeed attach high value to technical accuracy, then the perceived credibility of the DLL may be affected.

To improve a strong technical foundation, it is important to see that the use of NDVI in the mangrove coverage maps also has limitations. Although it is commonly used in research on mangrove forests, it does not distinguish between different vegetation types. The computed mangrove coverage can include other vegetation. The effect of the NDVI threshold in this study has only been tested qualitatively, as mentioned in 4.3. If the maps were based on a better resolution and distinction between vegetation types, the maps would have been more clear to decision-makers who will use these maps to understand the long-term effects of mangrove change. Setting the threshold of NDVI > 0.1 also has constraints. It includes most mangrove areas, but sometimes also includes areas without vegetation, such as small canals or shrimp farms. This is partly caused by the resolution of Landsat and Sentinel images (30 meters and 10 meters respectively), which can blur the lines between vegetation and water.

Apart from the limitation that the maps are not quantitatively validated, they also cannot fully capture short-term dynamics of the processes and interventions, and the conclusions that could be drawn from them. For instance, in the Nhà Mát area, the maps indicate that despite the construction of breakwaters, the reforestation projects had little or no visible effect. This may be influenced by the five-year time intervals used in the dataset, during which both mangrove growth and loss can occur. The absence of these short-term dynamics currently limits the conclusions that can be drawn from the maps.

The use of a five-year interval in the maps is effective for comparing rates of change in mangrove forest area. However, maintaining this fixed interval is difficult, especially for older years where less cloud-free satellite images are available within the AOI. In some cases, the time difference is four years, which can distort the rate of change that can be seen, and thus confuse users. This means that the difference between periods should be interpreted carefully, as they might not give a consistent overview. Despite the limitations, the connection between GEE, GitHub and Wix is effective to ensure the maps are openly accessible and updated regularly.

The selection of a single location storyline for the DLL provided an understanding of the local situation and all interventions and processes present near Nhà Mát, but it was not fully effective in showing the broader context of the Mekong Delta. While this approach allowed for a detailed look at drivers and interventions, it limited the ability to link findings between locations and how these interventions influence processes differently at other locations. Once the other locations are elaborated, a more complete view of the system will emerge, making the storyline more relevant for decision-makers who need to compare areas or identify larger-scale problems.

In this project, the foundation of how the Living Lab should express itself to the world has been laid. The research in Chapter 2 successfully established a clear distinction between formal and informal aspects of Vietnamese decision-making and identified the key actors involved in both. It also illustrated how power and information flow through the system. However, it must be noted that these findings are primarily based on sources and interviews related to coastal projects. While national laws determine the general structure of investment decision-making, informal practices may differ across other governmental sectors. This could lead to different preferred methods of information transfer. The inclusion of policy, technology, and design expertise is essential to achieve such results.

8.2. Recommendations

In this section, recommendations on how to further develop the Digital Living Lab can be found. Subsection 8.2.1 Good Practices, describes how to maintain the website while effectively communicating its core message. Subsection 8.2.2 Future Work, delves deeper into operational next steps for the project. And Subsection 8.2.3 Future Research, suggests research directions for strengthening the theoretical background.

8.2.1. Good practices

To update the DLL while maintaining its core message, a manual was created. This manual can be found in Appendix G. One crucial thing to keep in mind is that the website is made to communicate information to decision-makers who are not necessarily experts on the specific topics. It is therefore important to be concise and comprehensive. Too much technical information on main pages could lead to noise in the storyline. Therefore a rule of thumb would be: "Only add information that is essential to conveying the storyline.".

8.2.2. Future work

The main output of this project is the development of two tangible deliverables. The first deliverable is the Digital Living Lab itself, and the second is the interactive map that shows mangrove coverage over time. This subsection provides suggestions for operational next steps, divided into two parts: one focusing on further development of the Digital Living Lab, and the other on improvements to the interactive map.

The Digital Living Lab

- **Fill in empty pages and create new pages on the website:**
  Due to the duration of the project, not all pages of the DLL are completed. One of the most important next steps is to complete the website by filling in the empty pages and creating new pages. This includes adding the other locations, as well as completing the pages on drivers, processes, and interventions. While completing the DLL, researchers can refer to the manual and the texts already written. The manual can be found in Appendix G.
- **Make a mobile-friendly DLL:**
  Vietnamese people use their phone for almost everything, including reading reports [A.4]. A mobile-friendly DLL would therefore lower the barrier for people to use the website, and therefore lead to more people using it.
- **Translate the website to Vietnamese:**
  A lot of decision-makers do not have a good knowledge of the English language, which is why a Vietnamese website would be very helpful for the researchers explaining the problems to the decision-makers.
- **Create a live data station:**
  It could be an interesting addition to create a page in which live data can be shown, coming from measurement equipment active in the field.
- **Check the website using Wix wizard:**
  Wix Wizard is a tool within the Wix software that checks the positioning and accessibility of the website layout. It can be used to verify whether every page is structured correctly and accessible to users. However, this tool only became available after the upgrade of the Wix account, meaning there was not enough time to perform this check during the final project week.

The interactive maps

- **Add more spatial data:**
  The current mangrove maps only display human interventions in the Nhà Mát area. When the other locations are developed on the DLL, human interventions should also be added for those Living Lab sites.
- **Create animations:**
  It would be a very interesting visualization to make an animation of mangrove coverage, loss or gain over time. There is one manually made animation, but it could be a good idea to write a script, linked to the map, that continually updates automatically.

- **Add measurement locations:**
  An addition to the map could be the exact location of measurement stations. It would be even better with the implementation of a link to the data station. This way, it becomes visible where the live data comes from.
- **Add more information for each commune:**
  The current mangrove maps only display commune boundaries, but it could be useful to view the commune name and related data (e.g., mangrove coverage) when you hover over the commune.
- **Fix the layout of the legend:**
  For some desktops, the toggle tool partly hides behind the legend. When switching to full screen, the legend and logo disappear. To have a professional and polished website, this defect still needs to be fixed.
- **Better visualize layers in the coverage map:**
  Currently, the total mangrove coverage map uses the same color for each time period. It would be interesting to see some difference between layers of mangroves from different periods.

8.2.3. Future research

This subsection provides guidelines for future research about the mangrove map, the decision-making process and the use of the website by decision-makers.

- **Conduct research on the consequences of the governmental reforms :**
  This report emphasizes the importance of the conceptual phase in the decision-making process. The recent governmental reforms aim to increase public participation, which could influence the decision-making dynamics. However, the consequences of these reforms are not yet clear. It is therefore interesting to research the developments in the investment decision-making processes due to the reforms.
- **Validate the effectiveness of the website with decision-makers:**
  To validate the effectiveness of the DLL's ability to influence the decision-making process, it is interesting to conduct some qualitative research on the use of the DLL by policy-makers.
- **Validate the information needs and values of decision-makers:**
  Only other stakeholders were consulted to understand decision-makers' values and information needs. It would be valuable to directly assess what decision-makers themselves would want to see, in which way on the DLL.
- **Conduct more research on the best way of spectral mapping:** In the current mangrove maps, Landsat and Sentinel-2 satellite images are used. However, other satellite images or sensors might result in higher resolution. Moreover, developing methods to quantify the quality of satellite imagery could further improve the reliability of the mapping results.
- **Conduct more research on the best way of identifying mangrove trees:** Mangrove areas are identified using a threshold of NDVI > 0.1. Alternative thresholds should be tested for a more accurate NDVI. Since NDVI does not differentiate between vegetation types, this limitation could also be investigated. Moreover, exploring alternative vegetation indices may result in a better solution for isolating mangrove forests from satellite images.
- **Derive quantitative data from a certain area (such as communes):** Decision-makers might be interested in a specific area, in which case a corresponding dataset could be useful. This dataset could include graphs about:

  - Land area change per year.
  - Amount of mangrove loss per year.
  - Amount of mangrove gain per year.
  - Total mangrove coverage per year.
  - A comparison of the mangrove loss/gain for the different communes.

- **Validate the mangrove maps for specific sites:** A validation could be done with field visits or drone footage.

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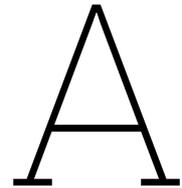
Appendix interviews

As part of this research, a series of interviews were conducted. Since the goal of this research is to communicate information to decision-makers, it is essential to understand how their knowledge base is formed. Decision-makers generally rely on two main sources of knowledge when making decisions: their own experience and information provided by others. In this appendix, interviews and/or meetings with the four most important categories of people who provide such information are presented. These interviews are referenced throughout this report. They include questions about the roles of different actors in the decision-making processes in Vietnam and the methods and ways in which information is shared between them. All interviews were conducted with full consent of the participants and in accordance with TU Delft's ethical research guidelines. By understanding the information flows decision-makers already rely on, the DLL can be designed in a way that aligns with these practices.

A.1. Interview with Dr. Phan Manh Hung

Name: Dr. Phan Manh Hung **Position:** Director, Center for Marine and Coastal Resources Research – Institute of Coastal and Offshore Engineering (ICOE), Vietnam Academy for Water Resources, Ministry of Agriculture and Environment of Vietnam
Expertise: Coastal Dynamics, Hydroinformatics, Remote Sensing, GIS

Purpose of the interview: The interview took place on September 10'th, 2025, with the goal of gaining insights into decision-making processes regarding coastal management in the Mekong Delta and the role of research institutes and the DLL in this context.

Key Findings:

- **Causes of mangrove loss and ineffective interventions:**

  - Interventions were often implemented quickly due to the urgency of erosion and deforestation, leaving no time for thorough research.
  - Decision-makers and researchers still do not fully understand the mechanisms behind erosion; knowledge remains largely qualitative.
  - Limited budgets make it impossible to establish permanent monitoring stations, leading to a lack of reliable data.

- **Role and potential of the DLL:**

  - The DLL can make the situation and developments in the Mekong Delta more visible to decision-makers.
  - According to Dr. Phan Manh Hung, the DLL can provide investment committees with the bigger picture and with data to support better decision-making.

- **Decision-making process for interventions:**

  - Local farmers and staff members identify problems and report them to the Department of Agriculture and Environment.
  - The department creates a *project investment committee*, which includes:

    - 2–3 representatives of cooperatives (farmers/mangrove users)
    - 3–4 experts from the department itself
    - 2 researchers (universities/ICOE)
    - 3 staff members from the local government

  - The committee assesses the situation, prepares a pre-feasibility study, and decides whether to proceed with the project.
  - The province makes the final decision, after advice from the Department of Finance regarding the costs feasibility and accuracy.
  - For very expensive projects, the provincial or even national government may become involved.

- **Collaboration and communication:**

  - ICOE or Thuyloi university are regularly involved as an advisor in investment.
  - Information from local communities travels through several layers (district → province → ministry), but this process is often slow and bad.
  - The LL can currently influence investment committees (commune level).
  - There is a need to also influence decision-making on a larger scale, to ensure decisions align with holistic understanding of the Mekong Delta.

A.2. Meeting with the Embassy of the Kingdom of the Netherlands in Vietnam

Name: Embassy of the Kingdom of the Netherlands in Vietnam
Position: Ambassador and representatives of the Embassy
Expertise: Governance processes, decision-making in Vietnam, international cooperation

Purpose of the meeting: The meeting took place on September 23'th, 2025, during a lunch at the Embassy of the Kingdom of the Netherlands. The aim was to gain insights into the informal and formal decision-making processes in Vietnam, communication differences between Dutch and Vietnamese people, and the potential role of the DLL in supporting effective policy making. However, this interview cannot be quoted in the report, as the embassy has not signed the consent form.

A.3. Interview with a researcher from Can Tho University

Interviewee Vo Quoc Thanh, Lecturer (PhD) – Department of Water Resources, College of Environment and Natural Resources, Can Tho University
Expertise: Coastal Engineering, Sediment Dynamics

Purpose of the interview: The interview took place on October 9'th, 2025, at Can Tho University. The goal was to understand how university researchers contribute to decision-making in the Mekong Delta, how they interact with decision-makers, and how the DLL could strengthen these interactions.

Key Findings:

- **Influence on decision-making:**
  - University researchers occasionally advise local authorities. Mainly through informal channels such as personal discussions or requests to review official documents.
  - University researchers are mostly consulted in the conceptual phase of decision-making.
  - His influence on decision-making is small but meaningful. It is mostly influential in to cases where advice aligns with national plans or where personal trust is established.
  - Decision-makers consult university researchers because they seek expert validation.

- **Communication with decision-makers:**
  - Decision-makers prefer clear numbers and visible results. They want practical evidence of interventions with a focus on the economic consequences.
  - Decision-makers need to rely on the researchers. This is done through seeing results in practice rather than through academic metrics.
  - Communication occurs through report sharing or requests of specific information to researchers. It also happens through discussions at meetings and conferences.

- **Website feedback**
  - The website should be more organized so users intuitively understand how to navigate.
  - Add keywords on the front page to make topics easy to find:
    - Mangrove restoration
    - Mangrove protection
  - The goal of the website is clear, but it should be tested with users who do not have background knowledge to confirm accessibility.
  - The target audience needs to understand:
    - Why they should choose a specific intervention or action.
    - What criteria decision makers should use when making choices.
  - Decision-makers will likely understand the website because they have enough knowledge.
  - Trust is essential: They have to believe what you show them, so clear visual evidence is important.
  - The website should also be translated into Vietnamese.

- **Informative images feedback**
  - Images must be completely accurate, otherwise people will not believe them.
  - Houses should look simpler, using a real Mekong style.
  - After the mangroves, the wave should continue; this needs to be shown in the image.
  - Images are good but look similar to existing visuals: Vietnamese audiences would prefer something more exciting and unique.

- **Implications for the DLL:**
  - To make the DLL trustworthy it should integrate visuals to make decision-makers understand how things are like.

- Up-to-date information is key: decision-makers are interested in current events such as recent disasters or cases.
- The "How to act" section of the website should clearly explain why certain actions are recommended and on what evidence these choices are based.

A.4. Interview with Haskoning

Interviewee: Expert from Haskoning
Expertise: Coastal engineering, project and policy consultancy in Southeast Asia

Purpose of the interview: The interview took place on October 9, 2025. The goal was to understand how private consultants contribute to decision-making on coastal projects in Vietnam, how they interact with authorities, and what the DLL should provide to be useful in these processes.

Key Findings:

- **Influence on decision-making:**

  - Consultants like Haskoning can contribute everywhere in the decision-making progress of projects. Exact activities are highly project dependent. Activities include writing (parts of) pre-feasibility and feasibility reports, advising before studies are formally commissioned and reviewing the work of other consultants. They have also helped shape several project organization regulations.
  - Projects frequently involve international financiers like the World Bank. This increases documentation requirements. Consultants guide the Vietnamese government through this process.
  - Haskoning guides the Vietnamese government through dozens of projects per year, and roughly one NbS project per year in recent years.
  - In the current process, there is little room for conceptual thinking; pre-feasibility studies are already highly detailed and legal frameworks limit solution possibilities. There is however a big interest in Vietnam to change this.
  - Conceptual thinking and multidisciplinarity are improving due to external pressures from parties like the World Bank.

- **Communication among decision-making:**

  - Information sharing between decision-makers is mostly through workshops and formal meetings with ministers. These happen largely before the formal process.
  - Formal meetings are hierarchal, giving little room for non-established newly found ideas.
  - Workshops usually include more local stakeholders.
  - Readers of (pre) feasibility studies, usually also the decision-makers, are capable and provide practical, critical feedback on (pre) feasibility studies. In reports they look for a solid technical basis. Integration with social context comes after that.
  - Information is also shared through formal reports. On the ground, Zalo and LinkedIn are widely used. Videos and presentations work well; outputs must be mobile-friendly.

- **Implications for the DLL:**

  - Keep the content technical, but clearly show benefits in other areas.
  - Design mobile-first and presentation-ready (short, visual, slide-friendly).
  - To achieve better long-term solutions, there is an increased demand for high quality data and monitoring. This is however in its early stages. The DLL can contribute to this.

A.5. Interview with locals

A.5.1. Local fisherman

Name: Anonymous
Position: Local fisherman from the village of Vinh Chau
Expertise: Daily life at the coast of Vinh Chau

Purpose of the interview: The interview took place on October 7th, 2025, with the goal of gaining insights into what local people from the MKD know and think about coastal interventions and their implementation.

Key Findings:

- **Livelihood:**

  - Works full-time as a fisherman, going out to sea from a small local village.
  - Notes increasing competition from large industrial vessels, making small-scale fishing less profitable.
  - Many fishermen have already left the village in search of alternative livelihoods.
  - Main issues are social conflicts among fishermen, especially regarding the distribution of caught fish.

- **Knowledge of the Coastal Environment:**

  - Finished lower school.
  - Understands that mangroves protect against erosion and considers them valuable.
  - Observes coastal accretion (land expansion due to sediment deposition) rather than erosion in Vinh Chau.
  - Reports no hard coastal structures (e.g., dikes or fences) present in the area.
  - Has no specific opinion on dikes, bamboo fences, or mangrove planting.

- **Information and Communication:**

  - Learned about coastal processes during school education and through news on his phone.
  - Receives most project or environmental information from other local residents.
  - Occasionally, soldiers from the nearby military base visit the area to inspect issues but rarely engage with local people.
  - Military personnel sometimes assist in resolving local social disputes.

- **Interaction with Authorities:**

  - Can contact military representatives in case of village conflicts.
  - Reports infrequent contact with government officials.
  - When communication occurs, it mainly concerns social issues, not environmental management.
  - Communicates problems verbally, not through visual or written means.
  - Feels that authorities generally listen, though engagement is limited.

- **Opinions and Influence:**

  - Has never been consulted before new projects such as dike construction or mangrove planting.
  - Unsure whether local people like him can influence government decision-making.
  - No specific message or advice for government shared during the interview.

- **Information Preferences:**

  - Prefers spoken communication (direct conversation) over visual materials.
  - Would like to stay informed about coastal developments but did not specify preferred frequency.
  - Finds phones and local meetings the easiest way to receive information.

A.5.2. Local shrimp farmer

Name: Anonymous
Position: Former shrimp farmer from the village of Vinh Chau
Expertise: Shrimp farming, local representative

Purpose of the interview: The interview took place on October 7th, 2025 with the with the goal of gaining insights into what local people from the MKD know about coastal interventions and their influence in the decision-making process.

Key Findings:

- **Livelihood and experiences:**

  - Worked as a shrimp farmer for many years but stopped due to repeated losses caused by disease, pollution and storm damage.
  - Transitioned from shrimp farming to taking an active role in community representation.

- **Knowledge of the coastal environment:**

  - Understands the role of mangroves in blocking waves, protecting dikes, and reduce erosion.
  - Observes coastal erosion and the construction of barricades to prevent this.
  - Aware that dikes and bamboo fences are built to block saltwater intrusion and reduce erosion.
  - Believes that these dikes and fences help protect mangroves.
  - People in his area no longer cut mangroves, they only dig small canals to bring water into their ponds.

- **Information and communication:**

  - Information mainly comes through community meetings.
  - He receives updates about new or ongoing projects from local authorities and neighbors.
  - Researchers and organizations regularly visit him and other locals to conduct interviews and collect data about their knowledge of the coast.

- **Interaction with authorities and researchers:**

  - He meets up with local authorities about twice a month to exchange information.
  - Discusses issues such as blocked tidal flow, which increases salinity and causes the mangroves to die.
  - By talking to local authorities and showing them directly on site what is happening, he influences what the authorities do locally.

- **Opinions and influence:**

  - Believes that local people can meaningfully support government decisions because they understand what happens on the ground best.
  - Confirms that officials ask for community opinions before starting coastal projects.
  - His main suggestion to the government would be to dig more canals to reduce salinity and improve water flow.

- **Information preferences:**

  - Prefers information sharing through direct explanations and seeing things in person.
  - Would like to receive more information about ongoing coastal projects.
  - Finds community meetings and direct conversations with authorities or neighbours the most effective communication methods.

B

Appendix field trip

B.1. Field trip to the Mekong Delta

A field trip to the Mekong Delta was conducted on Monday October 6 and Tuesday October 7. The main objectives of this trip were threefold: to install measuring equipment, to conduct interviews with experts and local residents, and to gain a deeper understanding of the issues at Nhà Mát. In addition, the field trip provided valuable insights into the culture and daily life of the people in the Mekong Delta. In this appendix a short overview of our findings is presented.

B.1.1. Installation of measuring equipment

On Tuesday October 7, we traveled to the Dai Ngai hydrological station in Soc Trang to install the Riverkin Suspended Sediment Sensor. At Dai Ngai, the chairman of the measurement station assisted us with the installation. However, this did not go exactly as planned. There was no wave buoy for the sensor, making it impossible to ensure a stable construction for a longer time. We installed the equipment temporarily, and after some time, we were able to retrieve initial data.

The next day, we planned to install the same equipment at Vinh Chau, but this was also not possible for the same reason as at Dai Ngai.

This experience was very valuable for us. Since most of us had little to no prior experience with installing measuring equipment, it was insightful to encounter the practical challenges involved in such fieldwork. We now have a better understanding of why measurement data in the Mekong Delta are often limited.

B.1.2. Interviews

One of the main goals for the field trip was to conduct different types of interviews from local stakeholders. Up until now we had interviewed stakeholders who knew a lot about the coastal and governmental processes in general. Now was our chance to talk to people who look at these processes specifically from a local perspective. We conducted interviews with two types of stakeholders.

Local expert

For the interview with the local expert, we were introduced to **Dr. Võ Quôc Thành** from the

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department of Water resources at Cân Tho University. He did his PhD at Delft University of Technology in Water Science and Engineering. The goal of this interview was to gain more detailed insights in the decision-making process, specifically for MKD.

We arrived at the University of Cân Tho on Monday the 6'th of October. Upon arrival, we were welcomed by Thàn and taken to his office. We gave a short presentation about our project, after which there was room for a public discussion. Here we were able to ask him some questions we had prepared. Details about the contents of this interview can be found in Appendix A.3. After this conversation, we got a tour around campus. Here we were shown the new building in which all the labs of the university were based.

Local people

For the interviews with local people, we went to the coast at Vinh Chau. We arrived the 7th of October in the afternoon, where we split up. We conducted one interview with a local fisherman, and one with a local fish farmer. The goal of these interviews was gain better understanding of the values and motivations of locals in the MKD. Detailed information about the contents of these interviews can be found in A.5.

B.1.3. Visiting Nhà Mát

We traveled to Nhà Mát to visit the location that serves as the main focus of the DLL storyline. It was very valuable to see the area in person, as in the previous weeks we had only observed it through Google Earth images. During our visit, we saw the remnants of the bamboo fence and the two types of breakwaters: the detached riprap pillar breakwater and the perforated dome breakwater. We were also able to take several interesting photos for the DLL. Moreover, dr. Phan Manh Hung provided us with valuable insights about Nhà Mát. He mentioned that the local people do not want a mangrove forest in front of the Nhà Mát resort, because the tourists would like to be able to see the ocean, not a mangrove forest. This was very interesting for us to hear, as it highlights the clear conflict of interest between the local community and the researchers of the Living Lab.

B.1.4. Pictures of the field trip

Figure B.1: Installing measurement equipment in the Mekong river at Dai Ngai hydrological station

Figure B.2: Presentation at Can Tho University

Figure B.3: Group picture at Can Tho University

Figure B.4: Shrimp farm at the coast of Vinh Chau

Figure B.5: Fisherman's village at the coast of Vinh Chau

Figure B.6: Fishermen boats in low tide at the coast of Vinh Chau

Figure B.7: Culvert at the coast of Vinh Chau

Figure B.8: Mangroves at the coast of Vinh Chau

Figure B.9: Low tide at the coast of Nhà Mát

Figure B.10: Detached riprap pillar breakwater (left) and a perforated dome breakwater (right) at the coast of Nhà Mát

Figure B.11: Sea dike at the coast of Nhà Mát

Figure B.12: Eroded bamboo fence at the coast of Nhà Mát

C
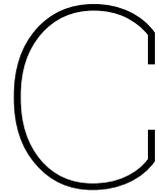
Appendix drivers, processes and interventions

This appendix provides a list of human and natural drivers, processes and possible interventions happening in the MKD. The definitions used for the website are given as well.

C.1. Drivers

C.1.1. Human drivers

- **Groundwater extraction:** Pumping of water from the ground for drinking or farming.
- **Aquaculture:** Farming of fish shrimp, or other marine species.
- **Mangrove deforestation:** Cutting mangrove trees for wood or different land use.
- **Waste pollution:** Pollution of water by chemicals or other waste.
- **Sand mining:** Mining of sediment from river beds.
- **Hydropower dams:** Constructions creating water reservoirs and electricity from water level difference.
- **Agriculture:** Farming of cattle or vegetables.
- **Urbanization:** Increased amount of land used for industry or housing.
- **Infrastructure development:** Building of roads, power lines, wind turbines etc.

C.1.2. Natural drivers

- **Sea level rise:** Increase of average sea level over time.
- **Tides:** Regular rise and fall of sea levels caused by the moon and sun.
- **Waves:** Surface movement of water.
- **Storms:** Extreme weather events such as typhoons.
- **Rainfall:** Water falling from clouds.
- **Droughts:** Long periods of little to no rain.
- **Currents:** Flows of water in rivers or seas.
- **Monsoon wind:** Seasonal wind causing wet and dry seasons.

C.2. Processes

- **Land subsidence:** Gradual sinking or settling of the ground.
- **River sediment supply:** Movement of soil particles by rivers.
- **Erosion:** Wearing of soil particles by wind or water.
- **Coastal sediment transport:** Movement of soil particles along the shoreline.
- **Flooding:** Overflow of water on land.
- **Water quality degradation:** Decline in water quality from pollution.
- **Change in biodiversity:** Increase or decrease in the variety of plants and animals.
- **Salt intrusion:** Entry of salt water into fresh water areas.

C.3. Possible interventions

C.3.1. Hard infrastructure

- **Sea dikes:** Structures built along coasts to block water.
- **Breakwaters:** Offshore barriers that reduce wave height.
- **Sluice gates:** Mechanical gates that control water flow.
- **Canalization:** Artificial channels that deliver water to crops.

C.3.2. Nature-based Solutions

- **Wooden fence:** Barriers made of materials like bamboo to capture sediment.
- **Mangrove reforestation:** Replanting mangrove trees in coastal areas.
- **Sediment nourishment:** Adding sediment to rebuild eroding coasts.

C.3.3. Policy agreements

- **Groundwater regulation:** Rules for using water in the ground.
- **Land-use planning:** Organizing land for farming, housing, nature.
- **Sediment management policies:** Rules for mining and protecting river beds.
- **Payment for keeping mangrove forests:** Incentives for communities to preserve mangroves.
- **Climate adaptation strategies:** Plans to adjust to climate change impacts.

D
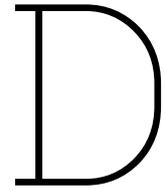
Appendix website development

As part of the iterative process of developing the website, both in terms of design and the storyline, several interviews were conducted to create a well designed and substantiated website. Input from the Living Lab, Vietnamese cultural perspectives, disciplinary insights and the stakeholders feedback were essential for the process.

In this appendix, interviews, meetings and analyses are presented, which are referenced throughout this report. All interviews were conducted with full consent of the participants and in accordance with TU Delft's ethical research guidelines.

D.1. Research website development for Vietnamese culture

D.1.1. Field research qualitative

VNexpress.net
Characteristics:

- Clean
- Consistent
- Simple
- Navigation tool
- Little amount of text

a80.hanoi.gov.vn
Characteristics:

- Consistent
- Clear buttons
- Images that support text
- Head banner
- Color in line with theme
- Consistent color theme
- Color fade

Figure D.1: Website VNexpress
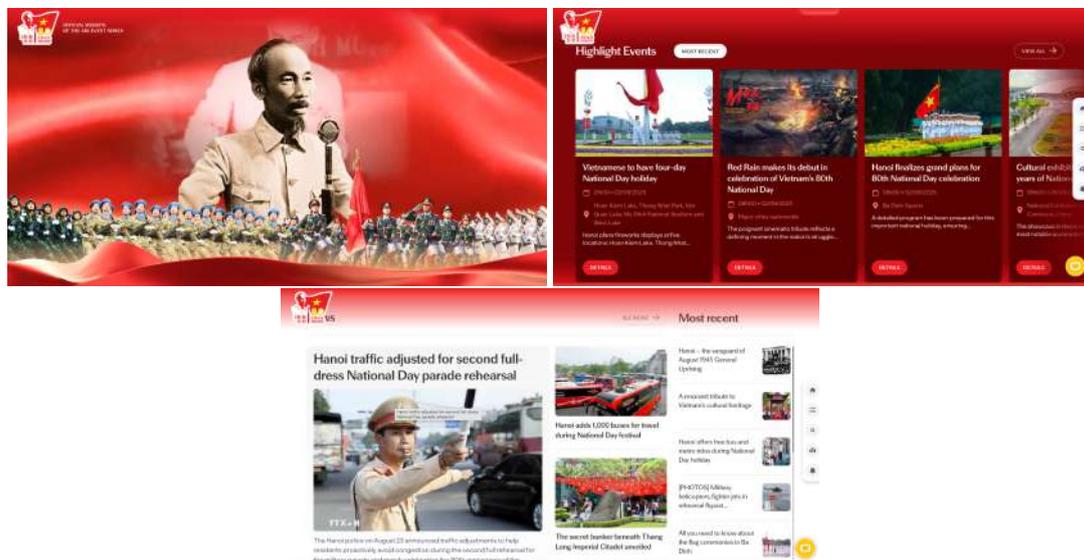
Figure D.2: a80 website

vpbank.com.vn/en/ca-nhan
Characteristics:

- Clear titles

- Images support buttons
- Fantasy pictures
- Short text
- Clear color theme
- Fade in colors
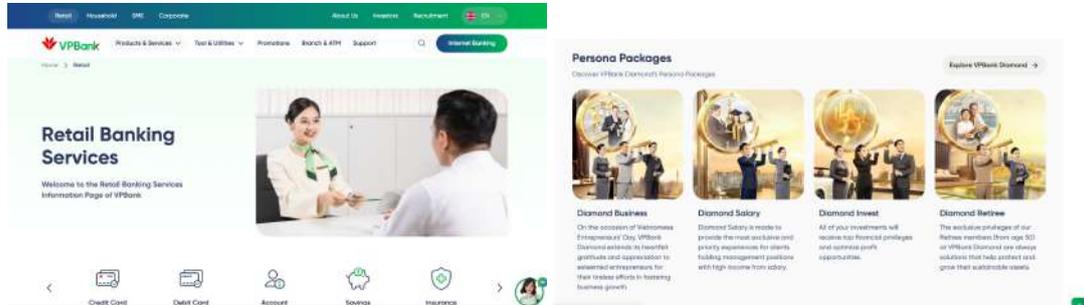
Figure D.3: VP bank website

topcv.vn
Characteristics:

- Fade in colors
- Buttons with titles
- Short text

Figure D.4: Top CV website

Characteristics of all websites:

- Every website places images in rectangles with rounded corners.
- Each website uses a maximum of four colours.
- All websites use photos.
- Every button is described with a word or sentence.
- Two websites use gold in areas where they highlight something as "very good" or premium.
- Overall, the colour palettes are clearly chosen and consistently used across the website, with only variations in colour tones.

D.1.2. Field research quantitative

Google forms questions

English Google Forms link

Vietnamese Google Forms link

4 different Dutch Website Designs mentioned in the questionnaire:
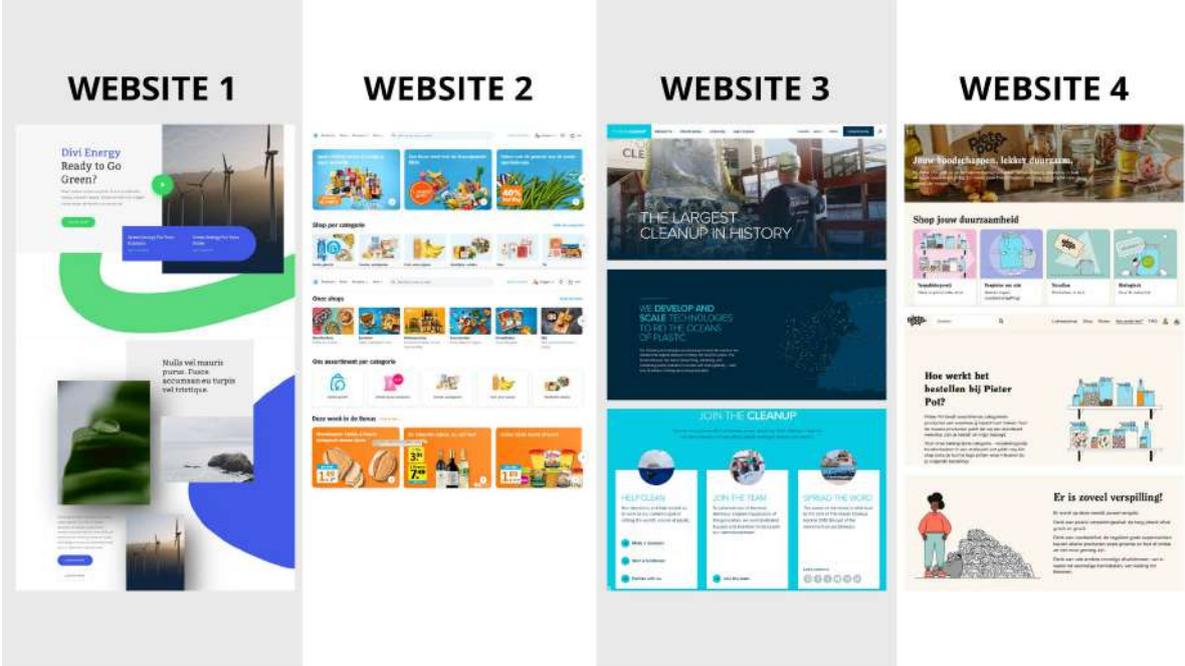
Figure D.5: 4 different styles of Dutch websites

Answers on the questionnaire in Vietnamese:

Xin hãy xếp hạng các website ở đây: Diagram kopiëren
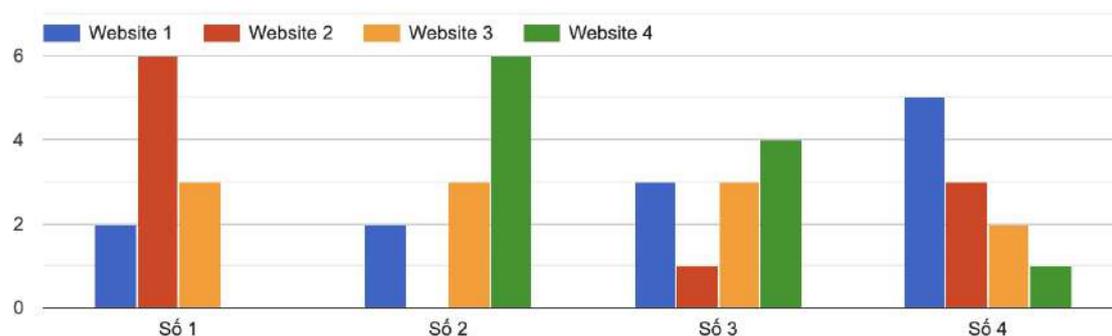
Tijdstempel	Số 1	Số 2	Số 3	Số 4	Xin hãy cho biết lý do tại sao bạn chọn như trên?
15-9-2025 10:31:50	Website 3	Website 1	Website 4	Website 2	Website số 3 có giao diện trực quan và dễ nhìn nhất
15-9-2025 11:11:21	Website 2	Website 4	Website 3	Website 1	Tôi thấy các web đều đơn giản và dễ nhìn nhưng tôi đánh giá web số 2 tốt bởi vì nó phân bố các mục khá rõ ràng và nó cũng trông khá giống những web đặt taxi,đặt xe tôi thường dùng nên tôi thấy rất quen thuộc và có lẽ là nó khá dễ tiếp cận tới người mới khi vào web lần đầu.
15-9-2025 12:02:52	Website 1	Website 3	Website 4	Website 1	W1 is eye catching, W3 looks professional, W3 also looks nice. I don't really like W2
15-9-2025 12:54:08	Website 3	Website 1	Website 4	Website 2	Nổi bật nội dung thu hút người dùng và thuận tiện trong việc lựa chọn
15-9-2025 14:59:07	Website 3	Website 4	Website 1	Website 2	khá dễ nhìn
15-9-2025 16:48:24	Website 1	Website 4	Website 2	Website 3	Theo cảm nhận
15-9-2025 16:48:33	Website 2	Website 3	Website 1	Website 4	Tôi thấy nó đẹp theo rank của tui
15-9-2025 16:53:11	Website 2	Website 4	Website 1	Website 3	tôi thấy nó đẹp mắt
15-9-2025 16:56:10	Website 2	Website 4	Website 3	Website 1	Tại vì tôi thấy màu sắc nó cuốn hút
15-9-2025 16:59:50	Website 2	Website 4	Website 3	Website 1	colorful. It impressed to me
15-9-2025 18:34:55	Website 2	Website 3	Website 4	Website 1	Web 2 có nhiều thông tin hơn phù hợp với giới trẻ nhiều hơn

Answers on the questionnaire translated to English:

Please rate the websites here:
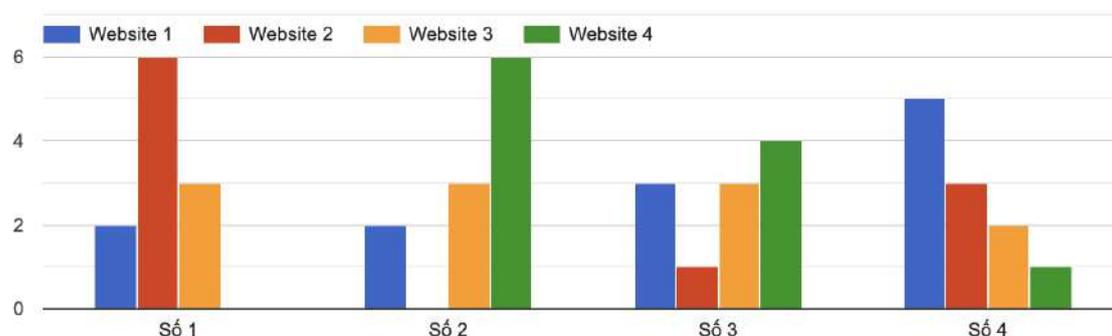
	Number 1	Number 2	Number 3	Number 4	Please tell me why you chose the above?
15-9-2025 10:31:50	Website 3	Website 1	Website 4	Website 2	Website number 3 has the most intuitive and easy-to-see interface
15-9-2025 11:11:21	Website 2	Website 4	Website 3	Website 1	I find the websites simple and easy to see, but I rate website number 2 as good because it allocates the sections quite clearly and it also looks quite similar to the taxi and car booking websites I often use, so I find it very familiar and perhaps it is quite accessible to newcomers when accessing the website for the first time.
15-9-2025 12:02:52	Website 1	Website 3	Website 4	Website 1	W1 is eye catching, W3 looks professional, W3 also looks nice. I don't really like W2
15-9-2025 12:54:08	Website 3	Website 1	Website 4	Website 2	Highlight content that attracts users and makes it convenient to choose
15-9-2025 14:59:07	Website 3	Website 4	Website 1	Website 2	quite easy to see
15-9-2025 16:48:24	Website 1	Website 4	Website 2	Website 3	According to feeling
15-9-2025 16:48:33	Website 2	Website 3	Website 1	Website 4	I think it's beautiful according to my rank
15-9-2025 16:53:11	Website 2	Website 4	Website 1	Website 3	I find it beautiful
15-9-2025 16:56:10	Website 2	Website 4	Website 3	Website 1	Because I find the color attractive.
15-9-2025 16:59:50	Website 2	Website 4	Website 3	Website 1	colorful. It impressed to me
15-9-2025 18:34:55	Website 2	Website 3	Website 4	Website 1	Web 2 has more information and is more suitable for young people.

D.1.3. Field research quantitative answers favorite Vietnamese websites

This is a list of the answer on the question 'Could you please share a link of a website you like to use below?' With these answers we validated the analyse of the Qualitative Research D.1.1.

- thanhnien.vn
- Daominhha.com
- mcrp.mard.gov.vn
- ielts.idp.com
- tlu.edu.vn
- youtube.com
- tlu.edu.vn (HTTP)
- grab.com
- spotify.com
- Motchill.com
- linkedin.com
- topcv.vn
- Samsung Galaxy Z Fold 7

D.2. Design journey of the storyline and website design

D.2.1. Interview with Dr. Son Truong Hong

Name: Dr. Son Truong Hong
Position: Researcher at Thuyloi University **Expertise:** Hydrodynamics, coastal dynamics, mangroves
Purpose of the interview: The interview took place on September 16, 2025, at Thuyloi University. The goal was to gain insights into the vision for the Digital Living Lab and to collect feedback on the first draft of the website requirements.

Key findings

Main goal of the Digital Living Lab: The Digital Living Lab should become a platform where people can learn about the Mekong Delta and mangroves. Website visitors should be able to see what happened in this area and how problems can be solved in different ways. He described an information flow:

1. Search for a location
2. See the problem at that location
3. See the interventions at that location

Key message of the Digital Living Lab: Many people believe they understand the problems in the Mekong Delta. The DLL needs to show that the problem is more complex and highly location-specific. For decision-makers, trust is essential: they require a centralized, reliable platform with all information in one place. According to him, people in Vietnam do not easily trust each other so a credible platform is crucial.

Settings in which the Digital Living Lab will be used: It should work in different contexts: casually on the street, but also during official meetings. It must work well on both iPad and desktop.

Purpose of use: The DLL should present the most important data, but not only data. Storing data on the website is useful, but it risks creating information overload.

Storytelling: A strong storyline should start with something dramatic or emotional (e.g., loss of land) to draw people into the problem. There is a big educational gap in Vietnam between farmers, students, and researchers.

Design preferences

- He showed many websites without rounded corners, but later added that slightly rounded corners may feel more intuitive, though not essential.
- He prefers a simple design: show the content, nothing extra.
- The website should be easy to use in the background.
- Example from Winmart: he liked the pop-up with a larger image.

Images and communication

- Decision-makers prefer real photos first: Real images show the disaster clearly and grab attention.
- Drawings can be added afterwards to visually explain the process.
- Vietnamese audiences do not want to read too much text: keep communication short, visual, and direct.
- He used Obsidian because it is easy to use, not for design reasons.

Digital Living Lab platform

- He will update the DLL every two weeks with new activities.
- He wants to update general knowledge about mangroves and link information from different locations.
- The website needs a large number of images and videos.

Technical considerations

- He is familiar with Wix and is concerned whether it will remain easy to add more and more content.
- It would be useful to connect Figma with Obsidian, if possible.
- Obscape measurements might be too technical for the DLL.

D.2.2. Rough prototype storyline website
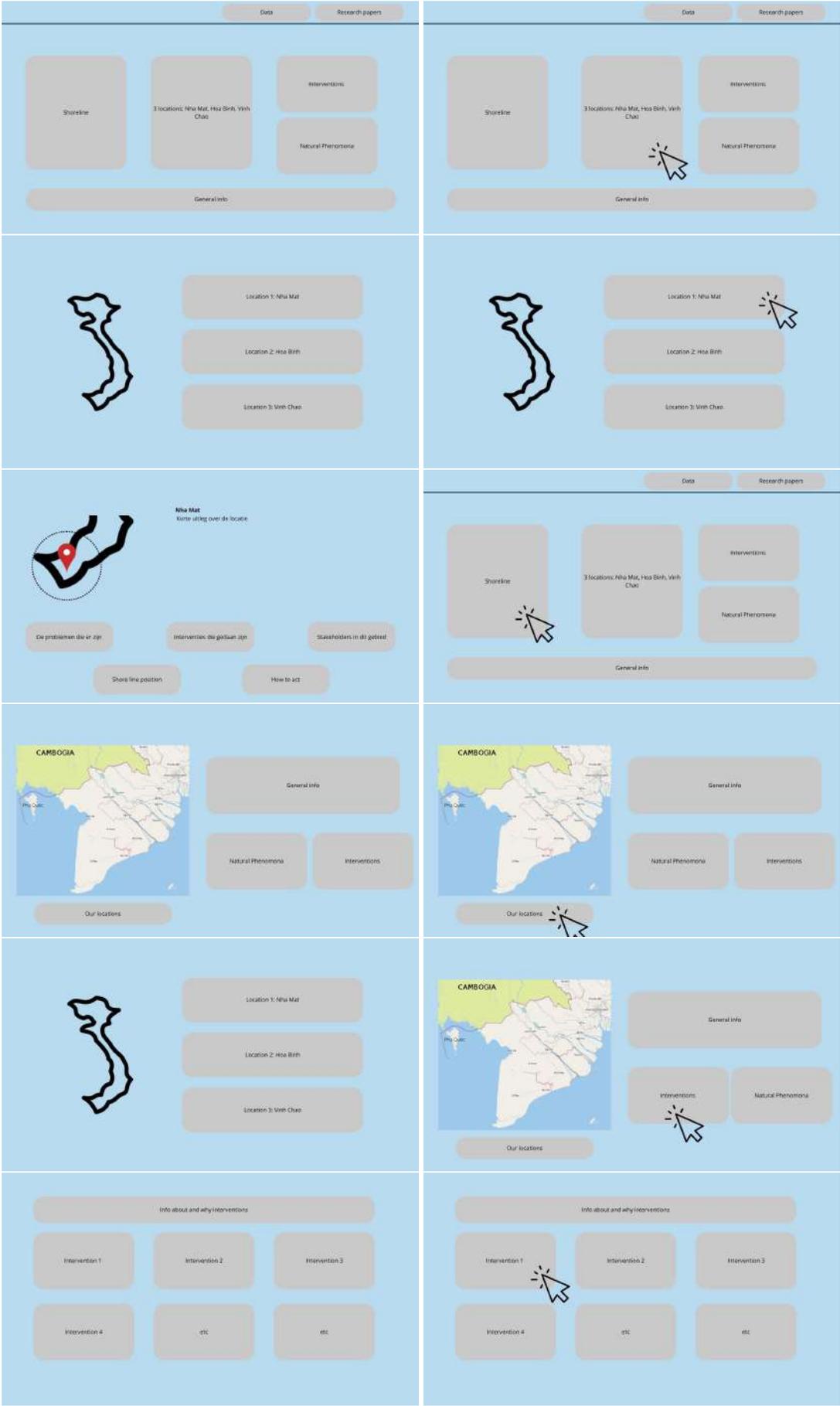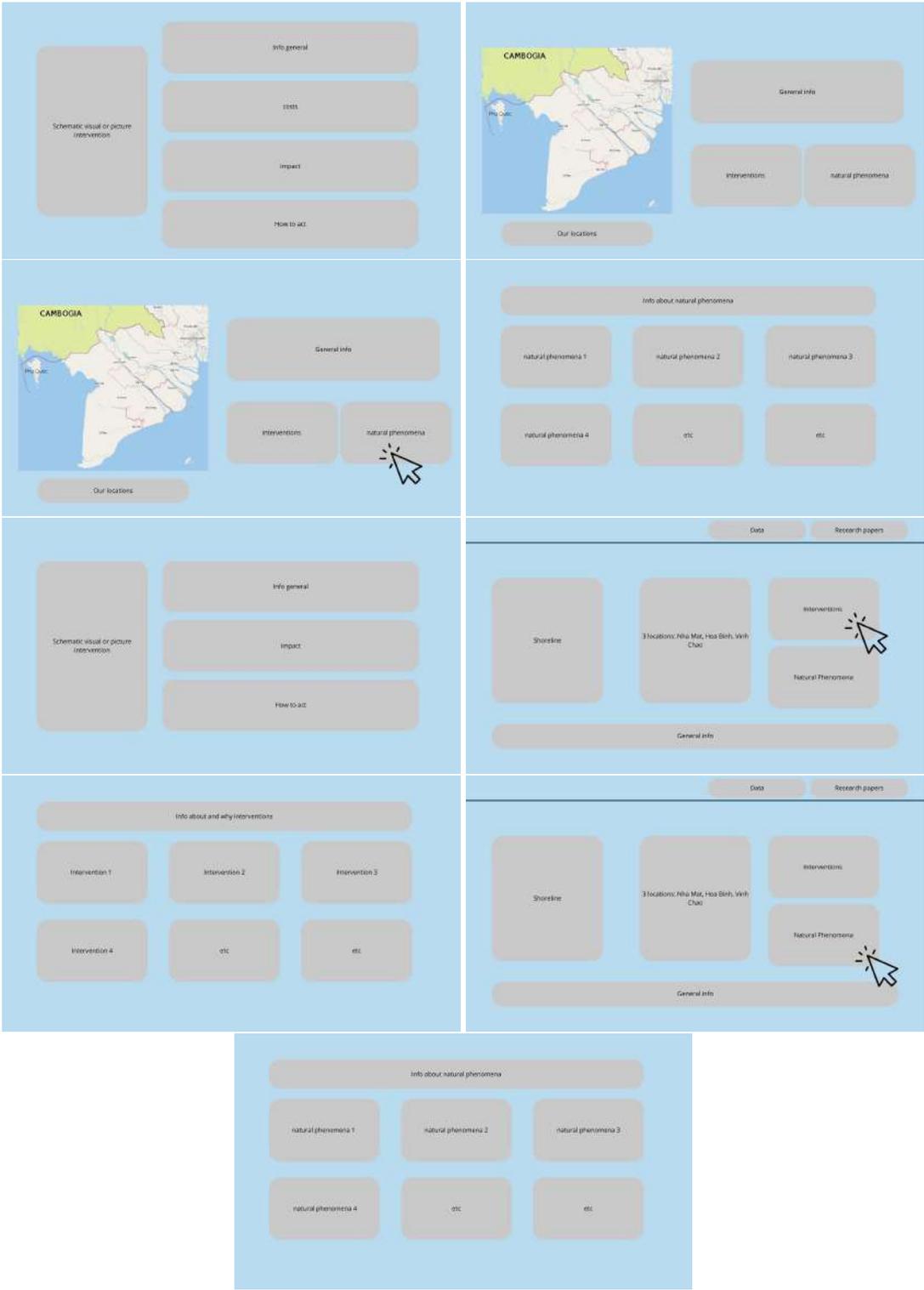
D.2.3. Usertest with Dr. Phan Manh Hung, Pham Vu Phuong Trang and Nguyen Thanh Tung

Name: Dr. Phan Manh Hung, Pham Vu Phuong Trang and Nguyen Thanh Tung
Position: ICOE employees
Purpose of the usertest: The interview took place on October 13, 2025, at the ICOE office. The goal was to gain insights into user experience and clarity of the website.

Usertest with Dr. Phan Manh Hung

- Consider adding a scrollbar on the side to make navigation clearer.
- Clicking on the Nha Mat page is difficult: make the arrow/button wider and easier to click.
- The navigation bar should scroll along with the page, so users always see it.
- The test user immediately started searching on the top navigation bar.
- Dr. Hung understands the terms *drivers, processes* and *interventions* already, but check with other colleagues whether this representation is intuitive.
- Dr. Hung provided a list of team members to display. **Tip:** show the email address of each team member.

Usertest with Pham Vu Phuong Trang and Nguyen Thanh Tung

- Users start by scrolling down on the homepage and they pause longer at the locations section.
- The text on the Living Lab image should be larger to be understandable.
- Most of the buttons and clickable elements are clear.
- The *Drivers–Interventions–Processes* diagram needs better explanation with text.
- On the Locations page, the meaning of "Want to visit" is not clear.
- A short animation or videos grab attention, maybe add this.
- "Sediment dredging" is incorrect, this must be **sand mining**.
- All images should truly be from Vietnam/Mekong Delta; incorrect pictures distract viewers.
- For hydropower dams, use examples from Laos, China, or Thailand, since Mekong Delta does not have them.
- Under "Storms", users expected a weather forecast or prediction tool.
- Monsoon winds should be listed separately; they are not the same as storms.
- There are many more government policies than the five listed; consider expanding or explain why these.
- It's very easy for users to quickly navigate to what they need.

D.2.4. E-mail with feedback on the four website options from Dr. Son Truong Hong and Dr. Phan Khanh Linh

Many thanks to both of you for working so hard on this, all four layouts are very eye-catching and engaging!

From my personal impression, I would prefer Option 1 the most.

- Firstly, the colors are vibrant and immediately make me want to explore further.
- Secondly, the balance between images and content feels just right — not too sparse (as I feel with Option 2, where there is more empty space between sections) and not too crowded (as with Option 4). While Option 4 does not necessarily contain more information than Option 1, the way the three info blocks with images are placed at the top makes me feel like I have to process a lot right at the start.
- I think with Option 1, starting the story with a simpler layout (like your current shoreline change section) is a great way to engage readers first. Then, once they are interested, you can lead them further down into more complex layouts.
- The way you present numbers for events is also intriguing and makes me curious. Placing the "About us" section at the bottom also feels very appropriate.
- Option 3 also feels quite balanced in terms of information and illustration, but it does not make as strong a visual impression on me as Option 1.

I hope my feedback is helpful, and once again, thank you very much for your hard work on our project!

D.2.5. List of requirements of informative images

1. **Color:**

   - HEX Color codes:
     - Sediment → #C3966B (100% opacity)
     - Sediment holding by the trees → #693708 (60% opacity)
     - Sediment movement → #E1CBB6 (100% opacity)
     - Water → #B0D0E6 (70% opacity)
     - Water outline → #B0D0E6 (100% opacity)
     - Water that is moving → #DFEEF8 (70% opacity)
     - Structures created by humans → #7A7A7A (100% opacity)
     - Arrows → #666769 (100% opacity)
   - When using extra colors:
     - For parts representing nature, choose soft warm natural colors.
     - For parts representing things built by people, use gray tones.

2. **The use of arrows:**

   - Use arrows to show processes and to link text to specific parts of the image.
   - Make sure arrows do not have sharp edges or corners.
   - Arrows should have a natural flow, with rounded lines.

3. **The use of text:**

   - Use a limited amount of text (only strictly necessary).
   - Place text on white (HEX #FFFFFF) rectangles with an opacity of 50%.
   - The edges of the rectangles should have a radius of 20px.
   - The text should use the font *Open Sans*, size 22pt, color black (HEX #000000).

4. **The use of dotted lines:**

   - Use a dotted line when something is changing.

5. **The use of shapes:**

   - Use rounded shapes for natural things (sea, sediment, trees, etc.).
   - Use angular shapes with sharper edges for things built by people.
   - When drawing lines the size should be 2.0.

6. **Sizes:**

   - The size of a desktop: 1440 × 1024 px.
   - The width of the area where the image can be in the desktop is 1065 px.
   - Keep in mind when creating a picture that the maximum width can be 1065 px.

7. **Circles:**

   - Use a picture with circles if you want to show different processes that are affecting each other in different areas.

D.3. Website prototypes in Figma

D.3.1. Four options for website designs

Option 1 - Final design

Option 2

Option 3

Option 4

D.3.2. First version of multiple page website

E

Appendix decision-making process

In Figure E.1 an overview is created which shows the detailed steps of the decision-making process. Phase 1 is already elaborately explained in Section 2.3.2, but in this section, the other phases will be explained shortly.

In phase 2, the pre-feasibility report is drafted by governmental or external experts. Beforehand, in step 1a, an appraisal council is selected consisting of both public and private actors. Subsection 2.2.3 delves deeper into the responsible entity that oversees appraisal. If the appraisal council deems the report sufficient, the chairman can decide to continue the process and start drafting the feasibility report.

Phase 3, is very similar to phase 2. In this phase, the feasibility gets drafted and appraised. The appraisal council differs from the council in phase 2, which again is described in Subsection 2.2.3. It is important to note that during this phase, the law explicitly states that the appraisal council needs to be a different entity than the one drafting the report. Parallel to the feasibility report, an Environmental Impact Report gets drafted. The procedure for this report is very similar to the feasibility report, but the experts writing the report, and appraisal commission differ. If both reports are sufficiently appraised, the chairman can approve the project.

In the final phase, the Ministry of Finance and the Ministry of Planning & Investment check on the financial aspects of the investment project. The project then gets incorporated in the Medium Term Investment Plan. After that, the project will receive funding, and the tender process can start.
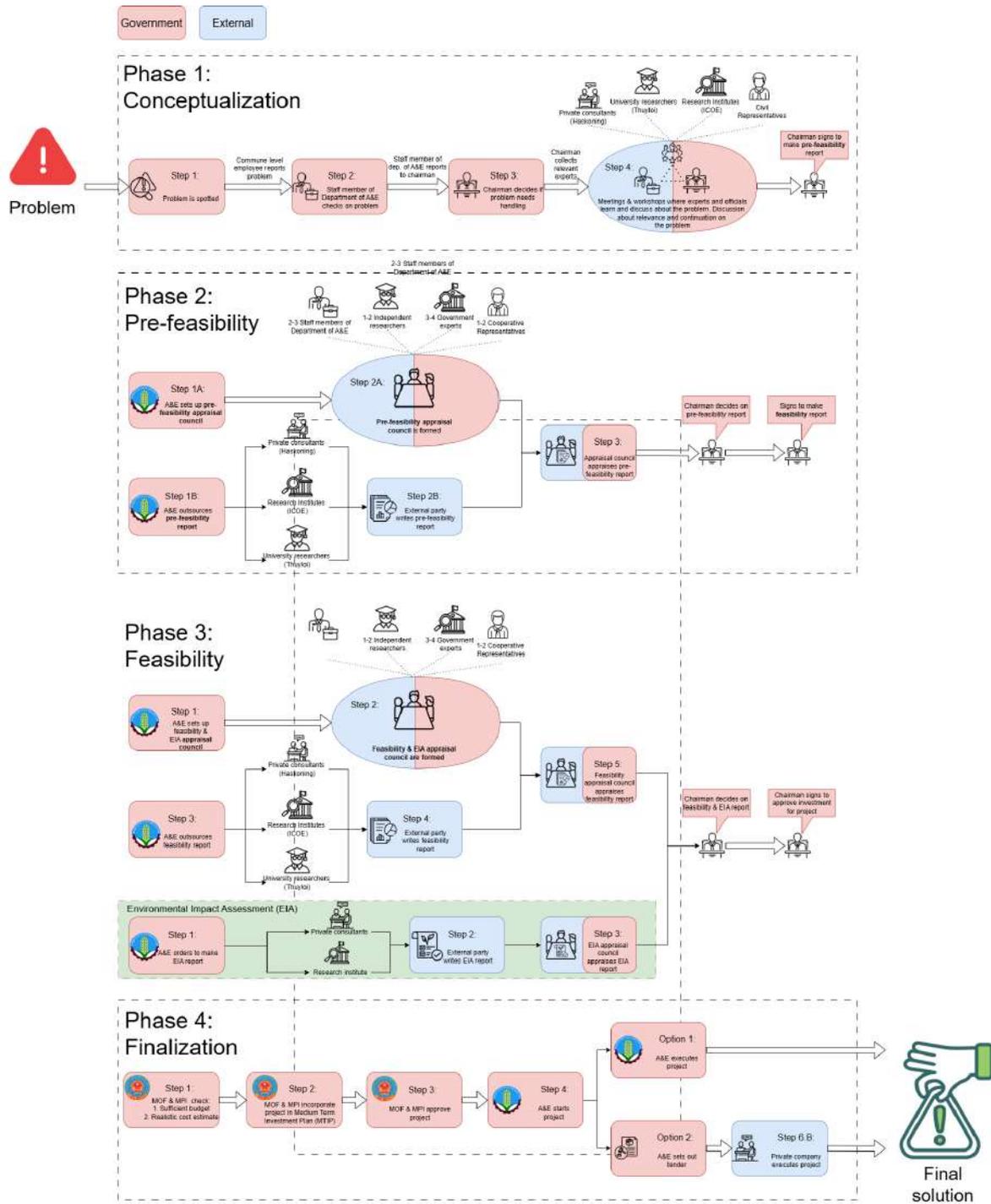
Figure E.1: A detailed overview of the four phases of the decision-making process

Appendix Vietwater conference & fieldtrip

On October 23rd, we were invited to join the Vietwater conference in Ho Chi Minh City. This conference focuses on water related industries. On the conference there was a Dutch pavilion, in which multiple panel discussions and presentations were organized. The Dutch embassy and the RVO were both present at the conference. The Living Lab was also invited to tell about conducted research, and even our group had the opportunity to give a presentation about our work.

The next day, we went on a fieldtrip to the Mekong Delta. This time, we were not there to actually conduct measurements, but to showcase physical locations of the LL to the embassy and the RVO. We visited two locations: one in Hoà Bình at the wind farm, and one in Vĩnh Châu.

Pictures

Figure F.1: Group picture with the embassy at the Vietwater conference

Figure F.2: Mark, giving a presentation about the DLL at the Vietwater conference

Figure F.3: Group picture with the embassy and RVO at the LL location in Hoà Bình

Figure F.4: Dr. Dao Hoang Tung presenting the location in Hoà Bình

Figure F.5: Dr. Phan Manh Hung presenting the location in Vĩnh Châu

G

Appendix manual

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Digital Living Lab Manual

A framework for future development of the Digital Living Lab

Created as part of the MDP project at the Mekong Delta Living Lab

Delft University of Technology
Thuy Loi University
Institute of Coastal and Offshore Engineering
November 2025

Contents

1

Mangrove maps manual

1.1. Introduction

This chapter provides an explanation on how the mangrove forest area maps were built and how they can be maintained and updated in the future. It is meant to guide anyone who will work on the project (updating data, editing code, maintaining the website). The goal is to make sure that everything can be understood and reproduced, also by someone who was not involved in the initial development.

1.1.1. Project overview & goals

The main goals of creating the mangrove maps are:

- Identify and monitor changes in mangrove forest area over time, including gain, loss and total coverage.
- Produce regularly updated maps showing mangrove forest changes using recent satellite imagery.
- Develop a workflow that can be updated with new data.
- Visualize mangrove change information online, making it easier to share to others..
- Ensure the workflow can be maintained and continued by future researchers.

1.1.2. Main tools used

The maps rely on multiple platforms and programs that work together:

1. Google Earth Engine (GEE): Used for analyzing and visualizing satellite data. GEE uses image processing and produces the layers for the maps.
2. Python: Used for additional data processing, creating the map and exporting results.
3. GitHub: Used to publicly store and organize the project files and scripts.
4. Wix: Website platform where the interactive map is displayed.

1.1.3. How to use this manual

The manual consists of different parts:

- Section 1.2 explains the structure and set-up of the maps.
- Section 1.3 shows how to set up and use the environments: Google Earth Engine, Python, GitHub, Wix.
- Section 1.4 explains how to add new satellite or spatial data to the maps.
- Section 1.5 fives suggestions for additional map functions that can be added in the future, and good practices to keep the maps up-to-date and working.

1.2. System set-up

This section shows how the different parts of the mangrove mapping work together. The project combines data collection, processing and visualization using several tools as explained before. In general the workflow is as follows:

Satellite data → GEE processing → Python post-processing → GitHub storage → display on Wix.

1.2.1. Data collection & processing (GEE)

To create the maps, satellite images (Landsat and Sentinel) are retrieved from GEE. Using the Normalized Difference Vegetation Index, the mangrove forests coverage is obtained.

1.2.2. Data post-processing (Python)

With the Python scripts, the mangrove forest coverage in one year is obtained. The coverage in year X can be subtracted by the coverage in year Y. This is how the gain and loss can be obtained in the time interval X-Y (e.g. 2010 - 2015).
Python packages like Geemap or Folium are used to generate interactive maps, HTML code is also implemented for adding functions as a legend, scalebar, and a project logo. After post-processing, Python is also used to generate an HTML file that displays the complete interactive map.

1.2.3. File management (GitHub)

All files (images, shapefiles, scripts, notebooks, documentations) are saved in a GitHub repository. This helps organize files, track changes in files and collaborate with others. This repository is also an openly accessible place for the interactive map to be linked to. The GitHub repository also contains three .yml files (one for each map) which contains an automatic refresh script that runs every 4 days around midnight. There are 30 minutes between the runs, to keep them separated and avoid errors. The .yml files run the Python scripts and create the updated HTML files. This has two functions:

1. Maintain GEE authorization: The workflow uses a service account key stored securely in the Github Secrets section.
2. Update the map with the latest satellite images: Each run retrieves and processes the newest available data, ensuring the interactive maps to calculate and include the most recent coverage, loss, and gain.

1.2.4. Website display (Wix)

The final maps are shared on the Wix website, as described in Chapter 3. Each map is embedded using a Wix iFrame, which directly links to the files that are located in the GitHub repository with a URL. The

HTML code option in Wix is not used, since it would prevent the maps from updating automatically when new maps are generated.

1.3. Environment set-up

This section explains how to set up all the tools needed to run, update and maintain the mangrove forest maps. Now that the different platforms have been introduced in Section 1.2, their environments can be created. This ensures the smooth operation of all components and enables the map to be updated automatically.

1.3.1. GEE project set-up

Account access
Go to https://earthengine.google.com/ and sign in with the DLL Google account. If you do not already have access, you should request permission to use Earth Engine. The Google Cloud project in GEE is called *gee-mekong-map*. This project is currently registered for non-commercial use within an academic institute. This project uses a service account instead of manual login. This service account allows automated scripts or applications (like GitHub) to access and do actions on Google Earth Engine. The service account key, a .json file, which is like a project password in the form of a file, is uploaded in GitHub Secrets. More information about this is given in Subsection 1.3.3.

The username for this service account is: gee-map-bot@gee-mekong-map.iam.gserviceaccount.com. *Keep the .json file safe, as it functions as a password for the GEE project*. If the key is accidentally lost or shared with unauthorized users, generate a new key and add it to the project. In the Google Cloud Console, go to IAM & Admin → Service Accounts, open your existing service account, navigate to the Keys tab, click Add key → Create new key → JSON → Create, and the JSON key file will download to your computer. The procedure for adding this key to GitHub Secrets is described in Subsection 1.3.3.

Shapefiles
The GEE Code Editor is used to create vectorized lines or boundaries which have several functions in the maps:

1. Define the area of interest (AOI) for mangrove forest area.
2. Draw shapes for interventions like breakwaters, sea dikes etc.
3. Add a point marker to the map to show windmill farms, urban areas, aquaculture, or other interesting points in the area.

In the GEE Code Editor, create an asset using the drawing tools. When ready, export to the feature collection. In the Code Editor, use Export.table.toDrive() or the UI export, export as a Shapefile (.zip). The Shapefiles can now be downloaded from Google Drive (same credentials as Google account). Download the files related to that shapefile to your local computer. In the Code Editor, a file named shapefiles_example is available, which contains example code for creating a new shapefile. With this example code, a name like Shapefile7 is created. A number at the end is needed to be able to loop through the files to import them into the map. A spreadsheet in the GitHub repository (Shapefiles_information.xlsx) contains the names and contents of the shapefiles. Make sure to add the new shapefile to this spreadsheet to keep track of the shapefiles.

1.3.2. Python environment set-up

In this project, Miniconda is used together with Visual Studio Code (VS Code) to manage the Python environment. There are other options for this, but Miniconda is used as it is lightweight and easy to

install, and VS Code works well together with Python and GitHub.

Install Visual Studio Code (VS Code)
Download it from https://code.visualstudio.com/. After completing the installation, open VS Code and install the following extensions in the Extensions tab:

- Jupyter: Optional, for notebooks.
- GitHub Pull Requests and Issues: For version control of the GitHub repository
- Python: For running and editing the scrips and notebooks.

Install Miniconda
Download Miniconda from https://www.anaconda.com/download. Choose the correct version for your operating system (Windows, macOS, Linux), allow it to add Miniconda to PATH. In this way, it can be used from the terminal from Visual Studio Code.

Create and activate the conda environment
Open the terminal in VS Code and create a new environment: conda create -n *YOUR ENVIRONMENT NAME* python 3.10. This creates an environment in which Python can be used and its packages can be installed. Now activate it: conda activate *YOUR ENVIRONMENT NAME*.

You should now see *YOUR ENVIRONMENT NAME* at the beginning of your terminal prompt. This means that the environment is active.

Install required packages
Once the environment is activated, install the needed Python libraries. This can be done as follows: conda install earthengine-api geemap folium ipyleaflet ipywidgets branca geopandas matplotlib glob2.

- earth engine api: Connects Python to Google Earth Engine, allowing access to satellite data and cloud processing.
- geemap: Makes it easy to visualize and analyze Earth Engine data in Python notebooks and maps.
- folium: Creates interactive Leaflet maps that use HTML, which is useful for showing the created maps online.
- ipyleaflet: Also a library for interactive maps in Jupyter, useful for widgets on the map.
- ipywidgets: Similar functions as ipyleaflet.
- branca: Used inside the folium map to create a scalebar.
- geopandas: Library for working with shapefiles (points, lines, polygons) as described in Subsection 1.3.1.
- matplotlib: Standard Python plotting package for basic computations.
- glob2: Used to find list files or folders, used for the shapefiles.

With these packages, the Python notebooks and scripts can be executed. The notebooks and scripts are linked to each other and eventually create an HTML file that contains the generated map. How to test or add code will be covered in Subsection 1.3.3 and 1.3.4. First the GitHub repository is covered.

1.3.3. GitHub repository

All files (scripts, notebooks, HTML files and documentations) are stored in a GitHub repository. This makes the project:

- well-organized and easy to track changes;

- easy to maintain and update;
- linked to GEE by the Key secret;
- linked to VS Code to change the Python files;
- able to run all Python files with an automated .yml script;
- linked to the Wix website for map updates.

The GitHub repository can be accessed by logging in with the DLL Google account. The username of the GitHub account is *dllmekongdelta* and the repository is called *gee-mekong-map-dll*.

Repository structure
The repository is organized to keep code, data and outputs clearly separated.

- **.github/workflows/**: Contains the **update .yml** files that automate map updates through GitHub Actions.
- **images/**: Folder that has images used in the output HTML file.
- **shapefile_* folders**: Contains the exported shapefiles from Google Earth Engine (e.g., breakwaters, communes, sea dikes, point markers). Each folder stores a different kind of shapefile.
- **Python scripts (GEN01–GEN06)**: Contains the general coding process, which is used in every notebook to create the maps:
  - **GEN01_GEE_Authenticate.py**: Initializes GEE authentication.
  - **GEN02_AOI.py**: Defines the area of interest.
  - **GEN03_helper_functions.py**: Consists of reusable helper functions.
  - **GEN04_mangrove_layers.py**: Processes satellite images such that they are prepared for computing mangrove coverage, gain and loss.
  - **GEN05_HTML_layout.py**: Consists of HTML code that adds properties like a scalebar, north arrow, logo.
  - **GEN06_shapefiles.py**: Imports the shapefiles and creates a pop-up when you click on the shape in the interactive map.
- **MAP0X_Mangrove_*.ipynb**: Jupyter notebooks for individual map products (Loss, Gain, and Coverage). These have an HTML file as output that is connected to the Wix website.
- **Mangrove_*_map.html**: HTML output file generated by the automated script that runs the MAP0X notebooks.
- **.gitignore**: GitHub folder that knows which files (like temporary files) should not be uploaded to the repository (currently empty).

Uploading and version control
To clone the repository from GitHub to your local computer, the following link can be pasted in the source control tab of VS Code: https://github.com/dllmekongdelta/gee-mekong-map-dll.git. This link can also be retrieved from GitHub within the repository → Code → https → copy URL.

After editing any of the files or code, the changes can be pushed again to GitHub using the Source Control tab. It is also possible to test the changes on your local computer in VS Code. This is why two different ways of GEE Authentication are given in the MAP0X notebooks.

Connect GitHub to VS Code with SSH key
To connect Visual Studio Code with the GitHub account without entering login credentials every time, an SSH key can be used.

1. In VS Code, open the terminal and generate a new SSH key:

       ssh-keygen -t ed25519 -C "dll.mekongdelta@gmail.com"

2. Press enter through the prompts to save it in the location of the folder you use.
3. Copy the key using:

```
cat ~/.ssh/id_ed25519.pub
```

4. Go to GitHub → Settings → SSH and GPG keys → New SSH key, and paste the copied key.
5. Test if it works in VS Code:

```
ssh -T git@github.com
```

6. If it is confirmed, the function is enabled to clone the repository with using SSH instead of HTTPS, this way pushing and pulling can be done without entering a username and password each time.

1.3.4. GEE authentication

There are two ways of doing the GEE Authentication.

1. **On GitHub** (automatic authorization): When the script runs in GitHub actions, it can not open a login window, instead, it uses the service account key that is stored hidden in GitHub Secrets. For this the following part of code needs be active:

   SERVICE_ACCOUNT = os.environ.get("GEE_SERVICE_ACCOUNT")
   KEY_FILE = "key.json"
   credentials = ee.ServiceAccountCredentials(SERVICE_ACCOUNT, KEY_FILE)
   ee.Initialize(credentials)

   This uses the created key from the service account. These are already added in the tab: Settings → Secrets and Variables → Actions.

2. **VS code** (on local computer): For this, the following code needs to be active in the MAP0X notebook:

   ee.Authenticate()
   ee.Initialize(project="gee-mekong-map")

   This opens a window for log-in and creates a code that needs to be pasted in VS Code. After this, the GEE project can be accessed from VS Code.

1.3.5. Automatic map updates

As mentioned before, automatic map updates are required to keep the GEE project authenticated and to ensure that the most recent satellite images are used. This process is handled by three .yml workflow files, which run every 4 days, separated by 30 minutes, to prevent errors. The workflow can also be executed manually on GitHub if new changes have been pushed and need testing. To do this, go to Actions → Update Loss Map (or one of the other maps) → Run workflow. Once the workflow has finished running, the updated HTML file will be automatically pushed to the repository. If an error occurs, the workflow will indicate where and why this happened. The new HTML file containing the updated map will automatically be shown on the Wix website. It can take several minutes for this to be shown. By clearing your browser cache, the updated HTML file, should automatically be shown on Wix.

1.3.6. Linking GitHub to Wix

The final maps are stored as HTML files in the GitHub repository. At the tab; Setting → Pages, the published link of the GitHub repository can be seen:

https://dllmekongdelta.github.io/gee-mekong-map-dll/

Behind this link, the HTML file name is added which completes the full name link to the map, for example:

https://dllmekongdelta.github.io/gee-mekong-map-dll/Mangrove_LOSS_map.html

This works the same for the other maps by changing LOSS into GAIN, or COVERAGE. This link is implemented in Wix using the iFrame function in Wix. Remember that the HTML code should not be copied in the HTML code editor in Wix, as this prevents the map from being updated. The map has to be linked through the GitHub URL.

1.4. Data management

This section explains how to manage, add and update data used for the mangrove maps. It covers the data sources, the steps for updating satellite images and shapefiles, and how to maintain consistent naming and storage.

1.4.1. Data sources

The maps use three types of data:

- **Satellite imagery:** Landsat (5, 7, 8) and Sentinel-2 collections from Google Earth Engine.
- **Shapefiles:** Polygons, lines and point markers: boundaries, infrastructures and human activities (commune boundaries, sea dikes, breakwaters, windmill parks, etc.).
- **Images:** Displayed in pop-ups or logos (stored in the `images/` folder on GitHub).

1.4.2. Adding new satellite data

New satellite images can be included when a year starts:

1. Open `GEN04_mangrove_layers.py`.
2. Duplicate one of the existing Sentinel code blocks and update:
   - The data set name (e.g. `COPERNICUS/S2_SR_HARMONIZED/`
   - `The year (e.g. 2025)`.
3. Add a new variable to the NDVI and threshold sections.
4. Update the color palette if needed.
5. Check first in your Python environment, then push to GitHub to see if your updates are visible on the Wix website.

The goal is to use time intervals of approximately five years. When the gap between the most recent and previous datasets is around eight years, the period can be divided into two intervals of four years each. This provides a more consistent and accurate representation of the rate of change than using one single eight-year interval.

1.4.3. Adding new shapefiles

1. First execute the steps covered in the shapefiles part in Subsection 1.3.1.
2. Place the downloaded files into the right folder (or create a new one):

   - `shapefile_commune/`: Commune boundaries
   - `shapefile_seadike/`: Sea dikes
   - `shapefile_breakwaters/`: Breakwaters
   - `shapefile_other/`: Points (e.g. aquaculture, wind parks)

3. Update `GEN06_shapefiles.py`:

   - Add an entry to the list of shapefiles in the section of the Python script corresponding with your shapefile.
   - Create a pop-up text with link to website or image (optional).

4. Check first in your Python environment, then push to GitHub to see if your updates are visible on the Wix website.

1.5. Recommendations & tips

Things to think of when maintaining or updating the maps:

- Do routine checks to see if the maps are still working as they should. But, if there is an error because of the workflow and there is no time to fix it, it just keeps using the old HTML file from a couple of days ago.
- After adding satellite images from a new year into the code, verify it by looking at the satellite images that are used. Cloud coverage or the lack of images for the AOI can cause the code to compute incorrect mangrove areas.
- Keep the GitHub repository, including all files, clean and organized.
- Ensure that the toggle list (which allows layers to be turned on and off) and the legend are not too long. On smaller monitors, these elements may overlap. To prevent this, similar shapefiles can be combined into a single group.
- Avoid using sensitive information (like coordinates of measurement devices) on the map.

2

Content manual

This chapter discusses and recommends what type of content to include on the website, where to include it, and how to do so.

2.1. Information sharing manual

2.1.1. Purpose and structure

This framework helps future researchers decide how to organize and publish new information on the DLL. It combines two tools:

1. The flowchart in Figure 2.1: To identify what type of information you have.
2. The table in Figure 2.2: To show where and how that information should appear on the DLL.

Together, they form a pathway that guides future researchers from *"I maybe have some new information to put on the DLL"* to *"I know exactly how and where to include this information on the DLL."*

2.1.2. Step 1 - Using the flowchart

The flowchart helps you determine the **information type.** Start with the data, report, or message you want to add to the DLL and answer the flowchart's two main questions:

1. Who is this information relevant for?
   Answer this question based on the information characteristics you can find in the flowchart.

   - If this information is relevant for **researchers** only: your information is **Academic information**.
   - If this information is relevant for **other stakeholders** (policymakers, consultants, public, etc.): go to the next question.

2. What type of information is it?
   Answer this question based on the information characteristics you can find in the flowchart.

   - **Technical & practical information**: Supports decision-making or shows how to act.
   - **News**: Announces new or socially relevant developments.

- **Information about the Living Lab**: Explains what the Living Lab is and describes its main activities.

Each information type in the flowchart includes characteristics that describe common traits of that type. These characteristics are meant as indicators, not strict requirements. A piece of information may not contain all of them; use them as guidance to find the best fit rather than a perfect match.

2.1.3. Step 2 - Using the table

Once you know the information type, switch to Figure 2.2. Each column corresponds to one of the four information types. The rows describe how to handle that content:

Table 2.1: Explanation of the rows in Figure 2.2.

Row	What it defines
Goal	The purpose of this type of content
Relevant page	Where it belongs on the website
Content	The format in which the information can be presented (e.g., dataset, infographic, video)
Main target audience	Who will read or use it
Constraints	What rules, tone, and limits apply

Example: If your information fits under "*Technical & practical information*", the table tells you that it should go to pages such as "*Locations*" or "*How to act*". It should include visual data (such as maps and infographics) and follow the corresponding constraints as much as possible. This should be done while keeping in mind the the goal of this information: to inform decision-makers about the system's complexity and to highlight the need for further research.

Note: The "*How to act*" page is now located under "*Technical & practical information*", although its purpose differs slightly from the other pages in this section. Unlike the others, "*How to act*" does not provide extensive technical background information. However, it is not separated in the flowchart because its function is closely related: both aim to demonstrate to decision-makers that further research is needed in the Mekong Delta to fully understand the system.
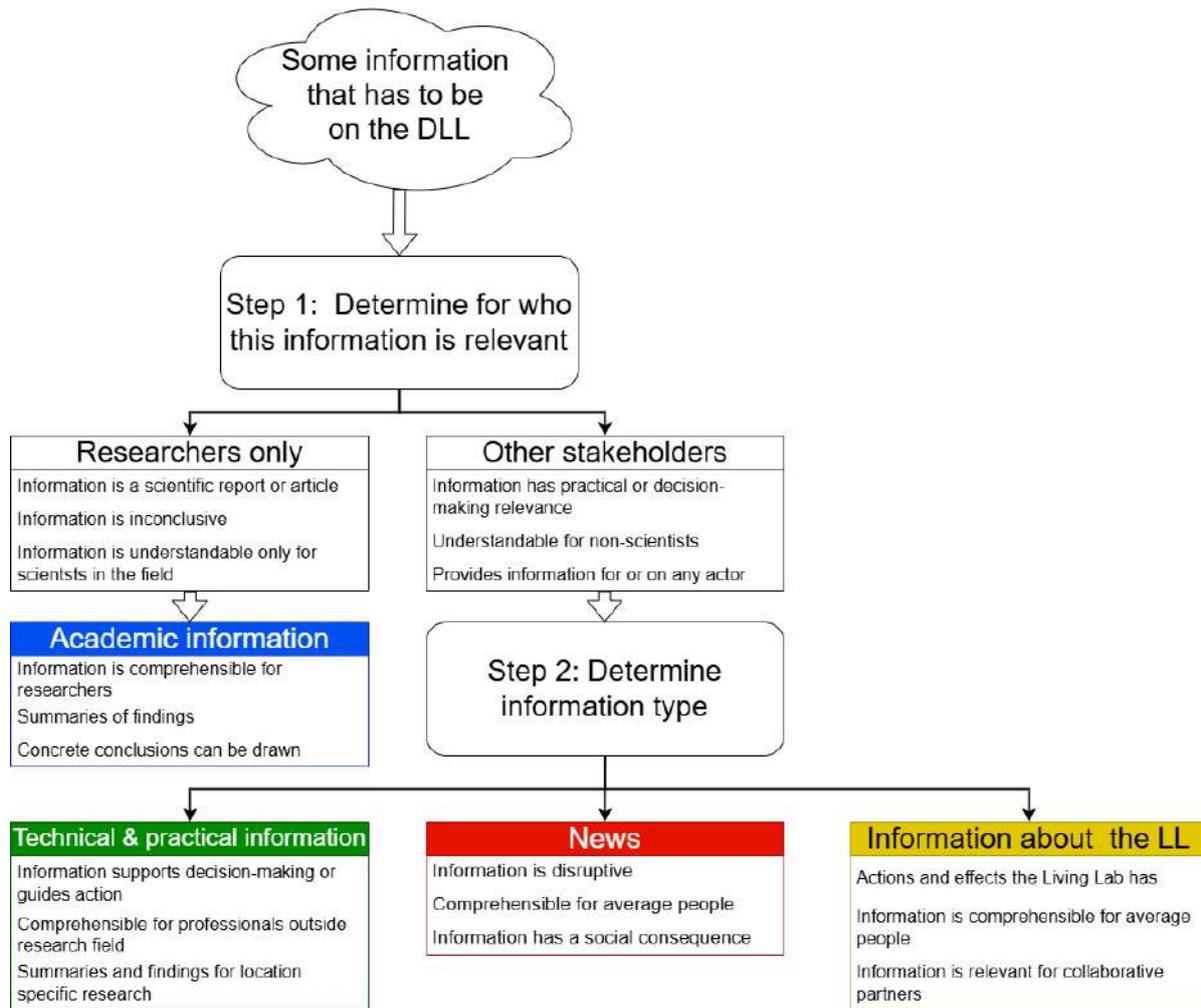
Figure 2.1: Flowchart to determine information type.

	Academic information	**Technical & practical information**	**News**	**Information about the Living Lab**
Goal	- Deepen & connect knowledge from different researchers - Long-term storage for datasets	- Make decision-makers understand implementation challenges for coastal interventions - Show that more research is needed to fully understand coastal dynamics in Vietnam	- Attract attention to new developments affecting policy or projects - Highlight social or environmental consequences	- Explain what the LL and DLL are and why they are needed - Demonstrate why they are relevant partners for collaboration and policy support
Relevant page	- Research papers	- Importance of mangroves - Locations, Drivers, Processes - Possible interventions - How to act	- Latest news	- What we do - About the Living Lab
Content	- Academic reports - Papers - Raw or large datasets	- Summarized datasets - Pictures, infographics, videos, interactive maps - Short texts and references to papers	- Pictures, infographics, videos, interactive maps - Short texts	- Pictures, infographics, videos - Short texts
Main target audience	- Researchers & technical specialists in the relevant field of studies	- Policymakers - Consultants - Engineers - Other interested parties	- Policymakers - Journalists - General public	- Policymakers - Funders - Non-technical stakeholders
Guidelines	- Strong technical foundation - Full accuracy required - All sources cited	- Highlight system complexity - Don't name a need for urgent solutions - Avoid policy statements not backed by data - Some jargon allowed - Show site-specific differences - Use financial reasoning and arguments - Demonstrate that long-term solutions are financially attractive	- Understandable for wide audience - Short and disruptive - Preferably mobile-friendly	- Understandable for wide audience - Highlight system complexity - Build credibility - Avoid naming urgent problems in "how to act" - Show that more research is needed - Indicate rising demand for high-quality data

Figure 2.2: Table to determine how and where to present information types.

2.2. Image manual

This section explains how to include and design images.

2.2.1. Steps to take

1. Decide if the written text needs an image to give extra explanation.
2. Decide what the main goal of your image will be.
3. Make decisions on what you really want to show in the picture and what might be less relevant for your target audience.
4. An image should be clear and simple and should only explain one process. If you would like to explain several processes, create separate images.
5. Decide which online program you want to use for creating the images. So far, the app: **Sketchbook** has been used.

6. Ensure the drawing corresponds precisely to the real process so that the target audience trusts the images.
7. Leave out information that is not relevant to your target audience.
8. Create the image based on the list of requirements below. Make sure to check whether your image meets all these requirements.
9. For the trees and the houses, cutouts from existing images are used; these can be found along with other pictures in the following link: https://drive.google.com/images.
10. When the image is finished, move it to Canva to add text: Canva Design Link.
11. The font of the text should be **Open Sans**, and the size should be **30 pt**.
12. Place the text on a white rectangle with an opacity of 45% and rounded edges of 20px.
13. Take care with the language used; don't use specialized language that only experts can understand.
14. Test the image with a non-expert to make sure it is understandable to people who have no background in the matter.
15. Put the image on the website and add a catchy title.
    https://www.canva.com/design/

2.2.2. List of requirements

1. **Color:**
   HEX Color codes:

   - Sediment → #C3966B (100% opacity)
   - Sediment holding by the trees → #693708 (60% opacity)
   - Sediment movement → #E1CBB6 (100% opacity)
   - Water → #B0D0E6 (70% opacity)
   - Water outline → #B0D0E6 (100% opacity)
   - Water that is moving → #DFEEF8 (70% opacity)
   - Structures created by humans → #7A7A7A (100% opacity)
   - Arrows → #666769 (100% opacity)

   When using extra colors:

- For parts representing nature, choose soft warm natural colors.
- For parts representing things built by people, use gray tones.

2. **The use of arrows:**

    - Use arrows to show processes and to link text to specific parts of the image.
    - Make sure arrows don't have sharp edges or corners.
    - Make sure arrows have a natural flow, with rounded lines.

3. **The use of text:**

    - Use a limited amount of text (only strictly necessary).
    - Place text on white (HEX #FFFFFF) rectangles with an opacity of 50%.
    - The edges of the rectangles should have a radius of 20px.
    - The text should have the font: **Open Sans**, and a size of **22pt** in the color black (HEX #000000).

4. **The use of dotted lines:**

    - Use a dotted line when something is changing.

5. **The use of shapes:**

    - Use rounded shapes for natural things (sea, sediment, trees, etc.).
    - Use angular shapes with sharper edges for things built by people.
    - When drawing lines, the size should be 2.0.

6. **Sizes:**

    - The size of a desktop is: 1440 × 1024 px.
    - The width of the area where the image can be in the desktop is 1065 px.
    - Keep in mind when creating a picture that the maximum width can be 1065 px.

7. **Circles:**

    - Use a picture with circles if you want to show different processes that are affecting each other in different areas.

The link to all the images (the text can also be adjusted): click here for the Canva Link.

3

Website development

This chapter of the manual explains the guidelines for further developing the website. The chapter is divided into two parts: webpage development in Figma and webpage integration in Wix Studio.

3.1. Webpage development in Figma

Figma is the design tool used to create and structure the webpages of the Digital Living Lab. It allows collaborative editing and provides an intuitive interface for designing clear and consistent layouts. This section explains the key steps for working efficiently in Figma.

3.1.1. Steps to take

1. Go to Figma:
   https://www.figma.com/design/mYkTWbHDcWeoCCMl56L2Ze/Figma-naar-Wix-DLL
2. Sign in with:
   Username:
   Password:
3. Decide what information needs to be added to the page. Use the content manual in Chapter 2.
4. For extra explanation about the basics of Figma watch:
   https://www.youtube.com/watch?v=HZuk6Wkx_Eg
5. Make a copy of the first page called: *"Copy this page if you want to add a new page"*. Place this copy at the very end of the line of pages.
6. Don't change the sizes and fonts of the letters to maintain consistency.
7. The Navigator will be added automatically to Wix, so it doesn't have to be added to the top of the page. The same goes for the backend of the website at the bottom of the page.
8. Go to the layout guide and set the settings as shown below.
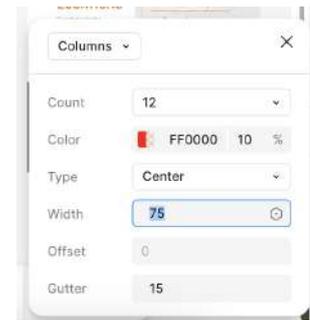
This layout is your guideline. Don't put text, pictures, or graphics outside of these lines.

9. Now that your setup is finished, you can start working from the top to the bottom of the page.

10. Whenever you start a new part of your page with a new subheading, create a separate frame. When you do this consistently, you can update each part separately in Wix.
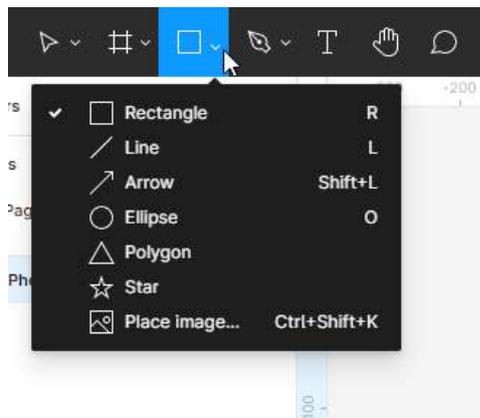
11. Make sure you name each frame and item clearly. This will save you a lot of time and work when converting to Wix.
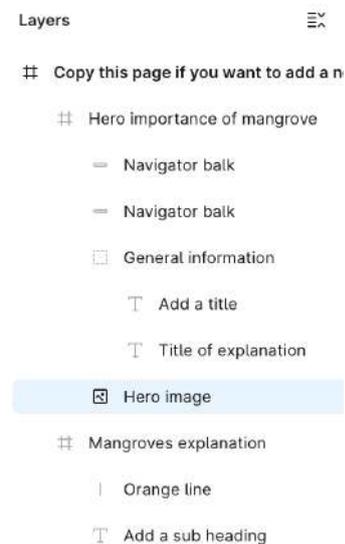
12. Choose a (self-made) picture with a high resolution as a background for the "Hero". The "Hero" is the top part of the page that the visitor sees first when entering the page.

13. Cut the picture to the same size as the Hero frame and paste the white fade on top of the picture. Select both the picture and the layer outside the frame and click **Object → Rasterize Selection** (this ensures it converts into one image so it is accepted by Wix Studio). After it is one image, place it in the right frame and rename the image.
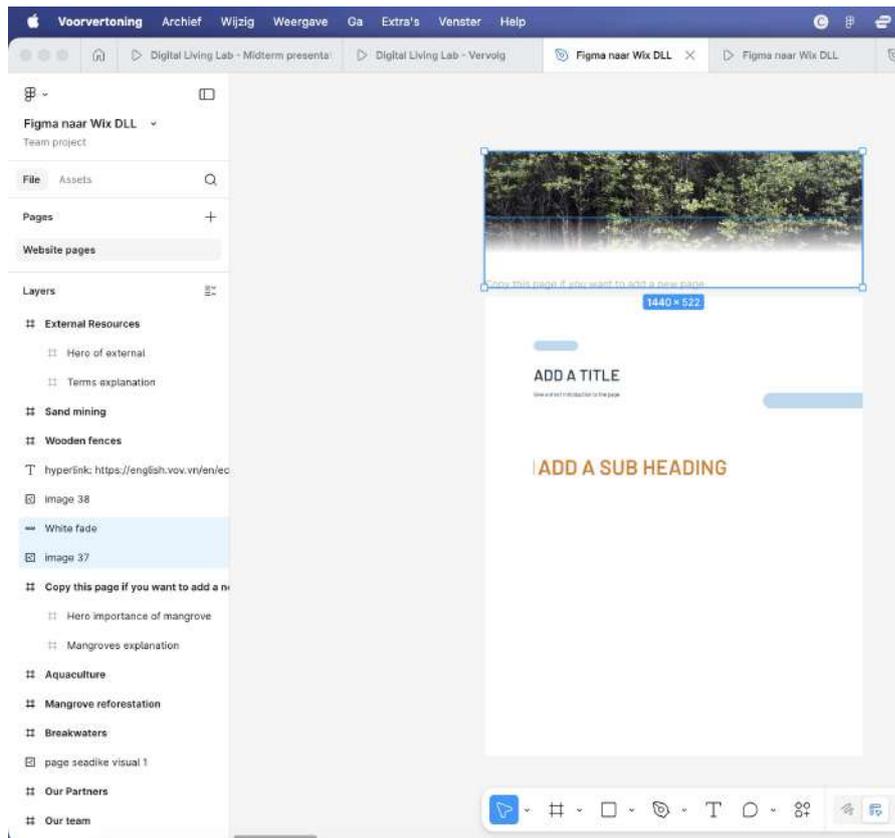
14. Make sure the hero image with the fade effect is placed under the correct layer, otherwise it won't be visible in Wix.

15. Always keep the light blue bars (shown in the orange circles below) in their current position to maintain consistency.

16. When adding new shapes:
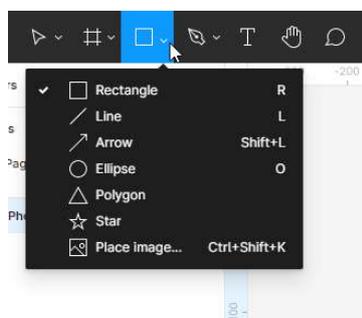
make sure to create shapes with rounded edges (radius: 20px).

17. Add the titles and text you created beforehand to the page.

18. When adding a title or text, please copy an existing text box and replace the text in order to maintain fonts, sizes, and colors.

19. When you want to highlight a word or sentence because it is important or has a link added to it, do it as follows:

20. Animations and moving items can be added in Wix.

21. When the page is final and ready to be added to the website, move on to Wix.

3.1.2. List of requirements for DLL design

1. **Color:**
   HEX color codes of the three main colors:

   - Orange: #DC7C22
   - Dark blue: #1C3848
   - Light blue: #B7DAEF

2. **The use of text:**

   - **Page Titles:**
     All caps
     Font: Barlow
     Size: 60pt
     Color: Dark blue (#1C3848)
     Font weight: Medium
   - **Other Titles:**
     All caps
     Font: Barlow
     Size: 80pt
     Color: Varying
     Font weight: Semibold
   - **Other Text:**
     Font: Overpass
     Size: 20pt
     Colors: Varying
     Font weight: Mostly regular, with exceptions written below

   Show special parts of the text like this:

   - **Highlights in a text** → have the orange color and font weight *semibold*.
   - **Navigate to a different page** → have the font weight *semibold* and are underlined.
   - **Navigate to an external link** ↗ → are underlined and have an arrow added.

3. **General Requirements:**

   - The DLL should consist of text supported by photos.
   - The DLL should be available in Vietnamese.
   - The buttons and visuals on the website are round-shaped, as this is easily recognized by Vietnamese people.
   - Buttons should include keywords that clearly show their meaning and purpose.
   - The storyline should be easy to follow on the DLL website.

3.2. Webpage integration in Wix Studio

Wix Studio is the software in which the Digital Living Lab is developed. It is a convenient environment with many online tutorials available. In this section, the most important elements for working with Wix Studio are explained.

Wix tutorial general: https://youtu.be/NbNPP8jpGVE?si=Fxo9ZgxM6NhthPRS

3.2.1. Log in to Wix Studio

1. Go to **Wix** (https://www.wix.com/).
2. Log in to Wix Studio:
   Username:
   Password:
3. Click on **Edit** for the *Digital Living Lab* website.
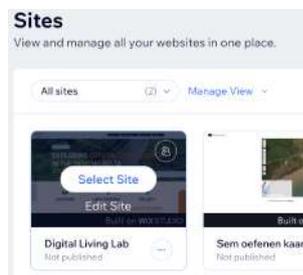
3.2.2. Want to make a new webpage?

In Figma you can create and export pages and parts of pages. A page is a frame that consists of several subframes. Wix automatically recognizes the differences and distinguishes between a page (main frame) and a section (sub frame).
a. To export the whole page, select the main frame of the page.
b. If you want to export a part of the page, select the subframe inside the mainframe.

1. Create the page in Figma, as explained in Section 3.1.
2. In Figma: select the page you want to export by clicking on the title of the page (*Main Page* in this image).
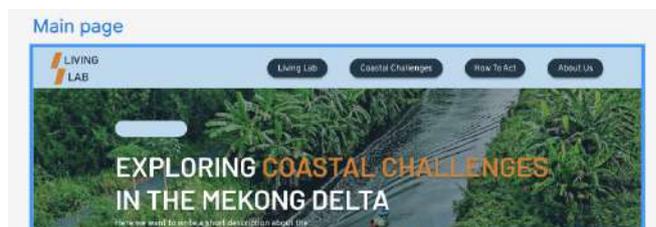
3. In Figma: click on the Figma logo in the upper right corner → click on **Plugins** → click **Figma to Wix Studio**.
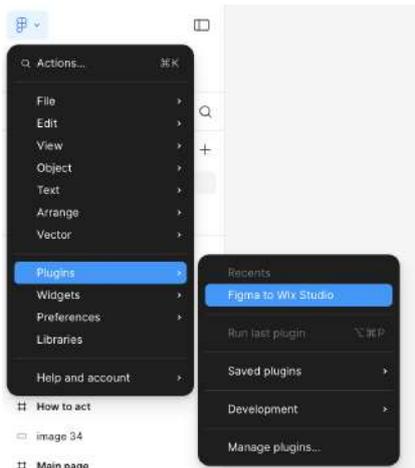
4. In Figma: the following pop-up will appear on your screen:

5. In Figma: for the first time you have to connect your Figma file to Wix Studio → Click **Set Up Export** and follow the steps / Afterwards you can always click **Skip Export**.

6. In Figma: click **Export Frame**.
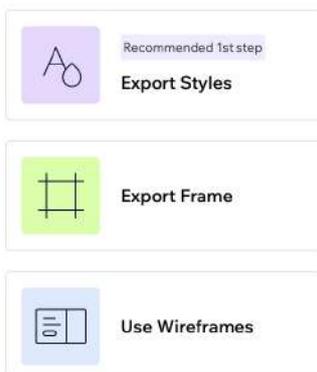
7. In Figma: the page you are exporting appears on the screen. Click the black button → **Export Frame**.

8. In Wix Studio: go to Wix Studio and click the **Figma** logo on the left side of the page

9. In Wix Studio: click on **Refresh Import**, you can see Wix Studio automatically recognizes the frame as a page. Then click on **Add to Site**.
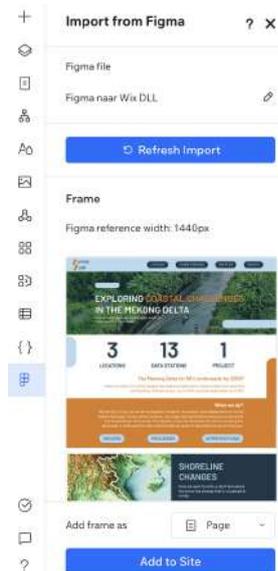
10. In Wix Studio: now you can find your page in Wix Studio and start to edit and connect the page to other pages. For the visitor to find the page, you need to connect it to the menu (see Subsection 3.2.7) or another link (see Subsection 3.2.6). Also give the page the right name (see Subsection

3.2.5).
YouTube tutorial: https://youtu.be/Afpd8iJjyuY?si=Ra7TKDJboZmnfDNn

3.2.3. Want to edit existing webpages?

TIP: If you want to use elements like Titles, Buttons, Text, Blocks, or IFrames from the current pages, copy the element/page and paste it in the correct place. In this way you can easily use things already made and keep the website consistent.

Some basic functions you need to know:

- Different important functions are on the **left side**.
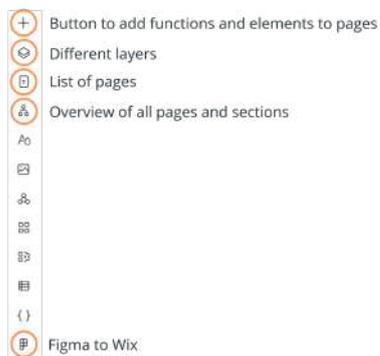
- Functions to edit color, size, position, etc. are on the **right side**.

- Click **+** to add different elements like figures, text, buttons, videos, and *IFrames*.
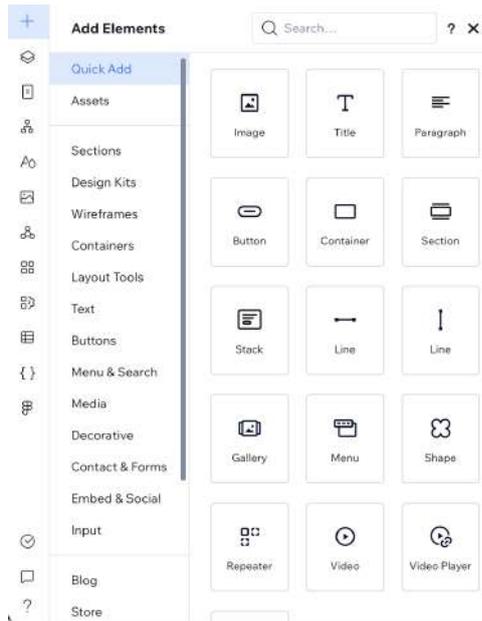
- You can make sections larger by dragging the section below the border of the section.
- You can add a section by clicking on **Add Section**.
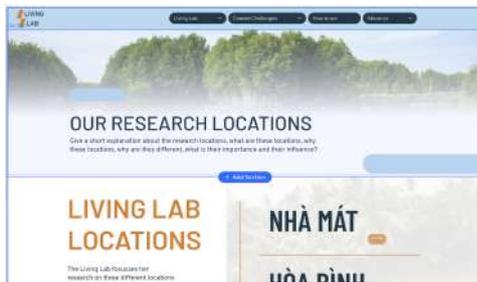
- At the right upper corner you can:
    - remove changes by clicking the **arrow**;
    - preview the website by clicking on the **eye icon**;
    - publish your changes by clicking on **Publish**.
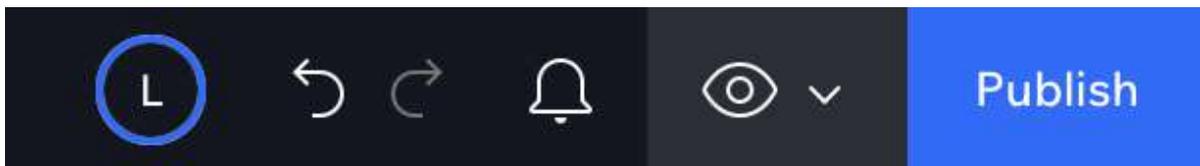
3.2.4. Change text (and images)

By clicking on the arrow (below publish) on the right side you can change the size, position, color and all other settings of texts and images.

1. Click the **Arrow**.
2. Change the size and the position using the dragging option or the X/Y (position) or W/H (size).
3. Drag the pages to order and organize the pages.

4. If the text springs when it needs to be on the same line, click **Responsive Behavior** and set the text on **Fixed**.

5. Click **Design** to change the font and the fontsize.
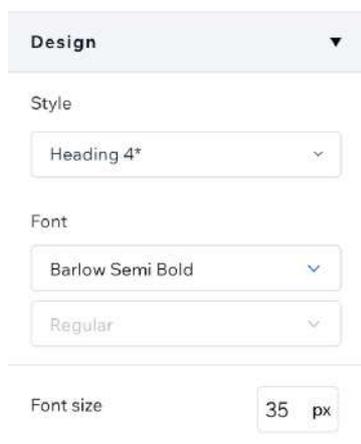
6. By scrolling down further, you can change the colors, styles, and formatting.

3.2.5. Name and order pages

1. Click on the page item on the left side of the screen. Now all the your pages are showed.
2. Double-click on the name of the page to change the it (note: this name is also shown in the navigator tool).
3. Drag the pages to order and organize the pages.
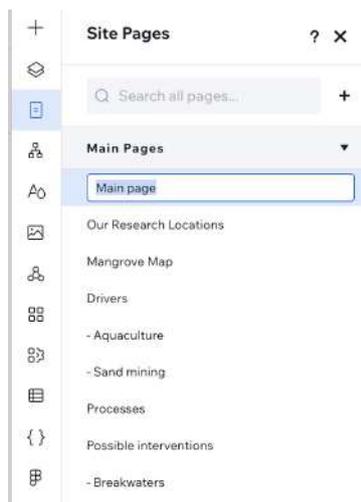
3.2.6. Link pages and create hyperlinks

Link pages:

1. Double-click the **Drivers** button.
2. Click the hyperlink icon.

3. Select **Page** and then select the page you want to link it to.
4. Select **Current Window** for internal website pages.
5. Select **Done**.
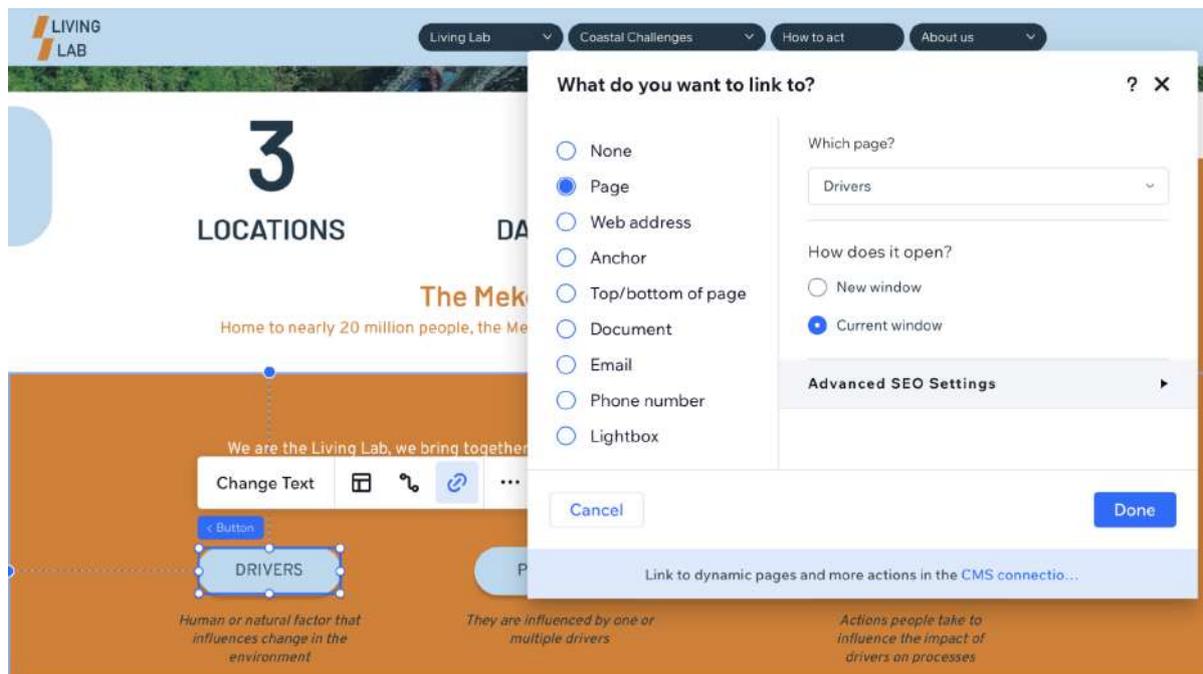
Create a hyperlink:

1. Select the text you want to create a hyperlink of.
2. Click the hyperlink icon.

3. Select **Web address** and paste the URL of the website. **IMPORTANT:** make sure all the URL-links linked to the website start with "https" and NOT "http", this makes sure the site is secured and allowed on most computers.
4. Select **New Window** for external website pages.
5. Select **Done**.
6. Underline the text at the right editing panel of Wix Studio.
7. Add the ↗ symbol.
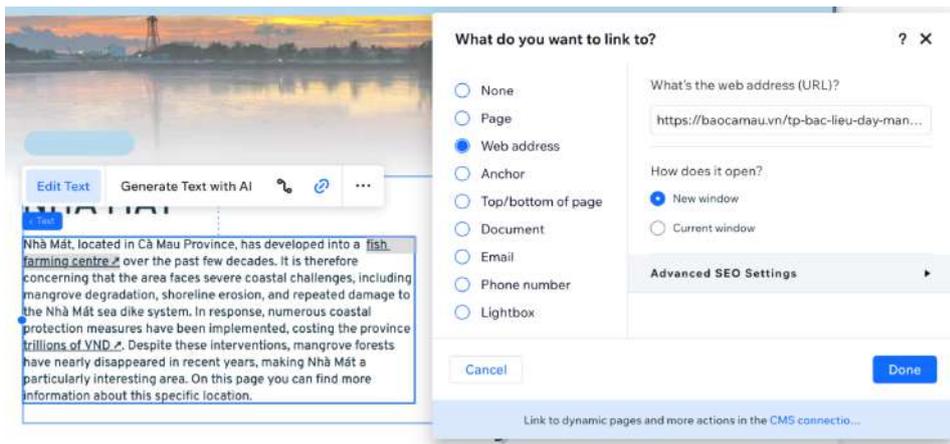
3.2.7. How to edit the menu

1. **Double-click** on the menu.
2. Click on **Manage Menu**.
3. Here you can drag pages under the main titles and add new pages to the menu by clicking on **Add Item**.
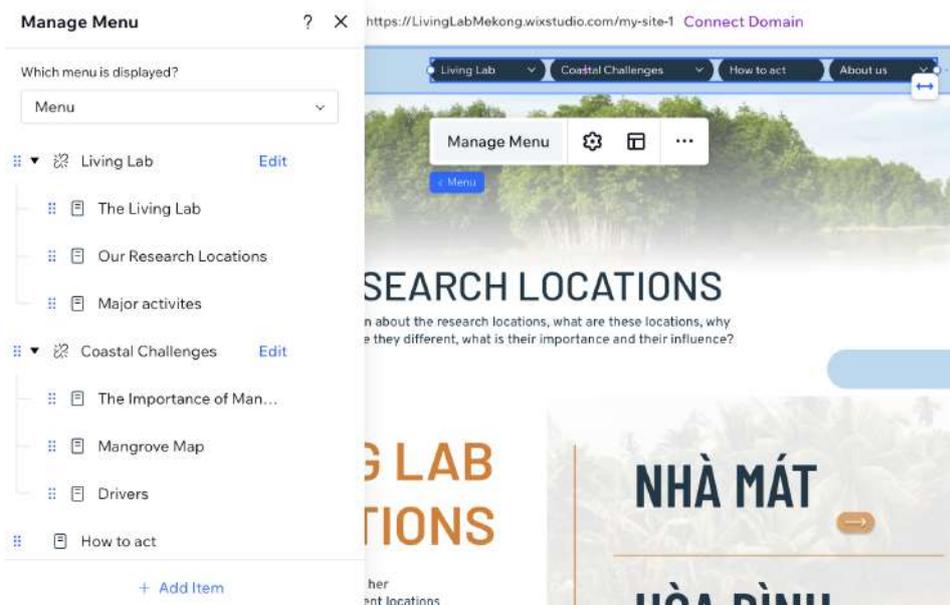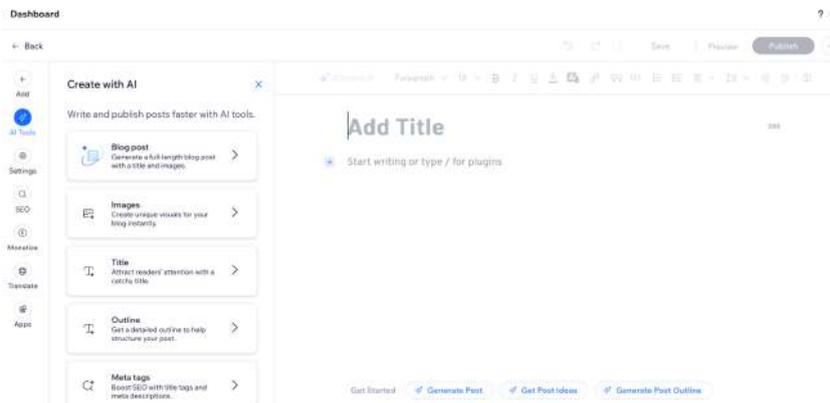
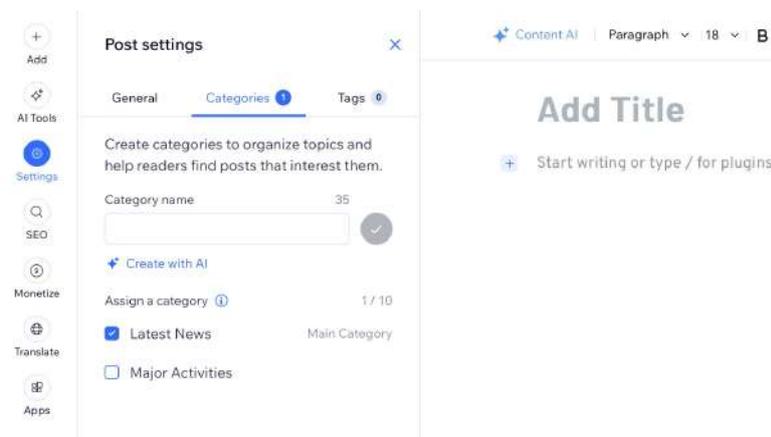### 3.2.8. Manage posts on Latest News and Major Activities

1. Double-click on a post.
2. Click on **Manage Posts**.
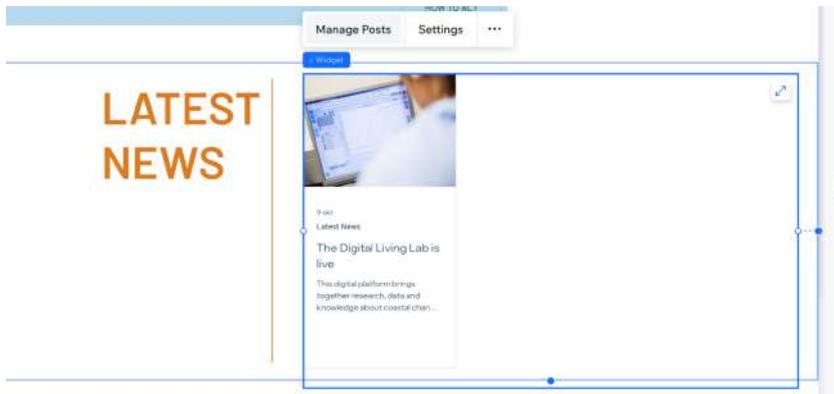
3. Click **Create New Post** in the right upper corner.
4. Write the post, add an image, and click on **Publish**.

Note 1: make sure you connect the blog to the right category: latest news or major activities. Click **Settings** , **Categories** and select the right category.


Note 2: Update the latest news and major activity blog every one or two months. Otherwise it looks like the website is not in use.

3.2.9. Add Drivers, Processes or Possible Interventions

1. Decide if it is a Driver, Process, or Intervention.
2. Decide what kind of Driver (Natural/Human) or Intervention (Hard Infrastructure, NbS, or Policy Agreement) it is.
3. Select a section with 3 blocks.

4. Copy and paste the section below the white section.
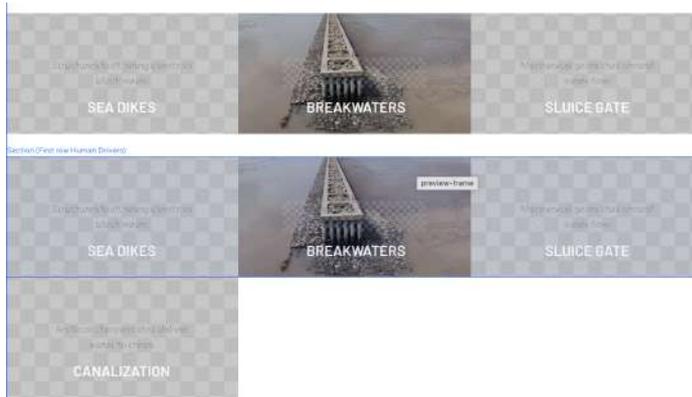
5. Copy and paste the text from (in this example) *Canalization* to the new section and change the image. Also add the text of the new intervention into the new section. If you only want to add one intervention, delete the last block (here *Sluice Gate*) by clicking on it and pressing delete. Also delete the old section with only *Canalization*.
6. Connect the image and both text boxes to the right subpage with the connection tool.

3.2.10. Add a map or other data on the Data Page using IFrame

1. Add your map to GitHub (see the Mangrove map manual in Chapter 1).
2. Click the **+** button on the upper left corner and click on **IFrame**.
3. The **IFrame** appears. Now put it in the right place and make it the right size.
4. Select the IFrame and click **Enter Website Address / Enter Code**.
5. Click on **Website Address**.
6. Add the URL of the website address. **IMPORTANT:** make sure all the URL-links linked to the website start with "https" and NOT "http", this makes sure the site is secured and allowed on most computers.
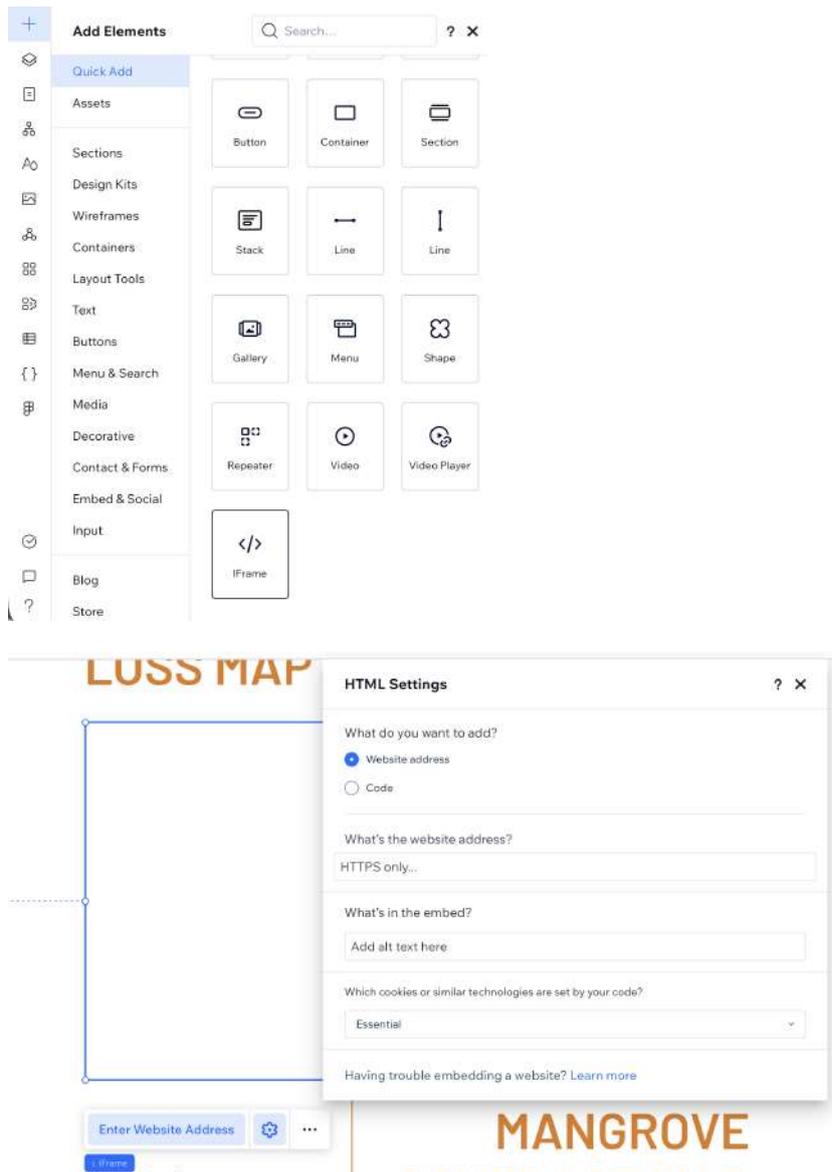
3.2.11. Add or change the OUR TEAM page

1. Copy the photo, name and email of another team member.
2. Change the image, name and email address.
3. Also change the hyperlink to the email address, otherwise the old email address is linked.
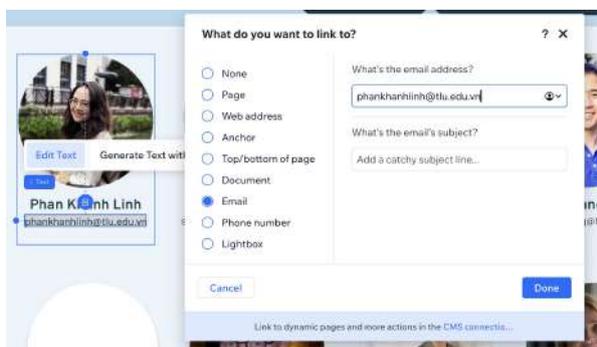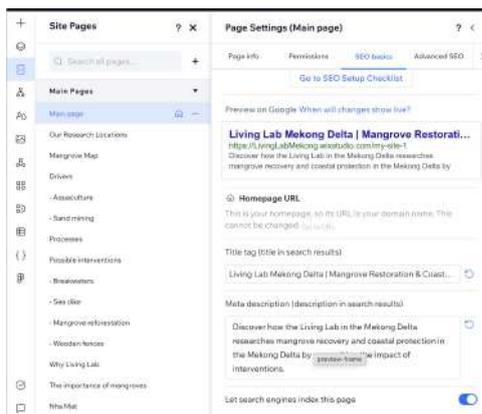
3.2.12. Search Engine Optimization (SEO)

To make sure the website can easily be found on Google, add SEO after uploading a new page.

1. Click the 3 dots on the page name.
2. Click **SEO Basics**.
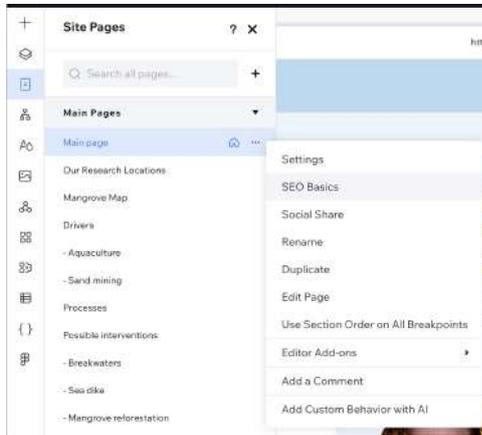
3. Change the Title Tag, URL, and the Meta Description. Think of the words you use to easily find the page on Google.

3.2.13. Images

To avoid copyright issues during website development, many of the pictures were taken by us during trips to the Mekong Delta. Also some stock images were selected. With this link you have access to the images: https://drive.google.com/images.

TIP: If you make changes to the website and click the Publish button, please first check that the changes do not affect how the website appears on other types of devices.