Mekong Delta Living Lab Project

An Open-Air Laboratory for Coastal Protection and Nature-based Solution

Annual Report

Vietnam, December 2024

CONTENTS

List of Abbreviations

MARD	Ministry of Agriculture and Rural Development	Bộ Nông nghiệp & Phát triển Nông thôn
ADB	Asian Development Bank	Ngân hàng phát triển Châu Á
DARD	Departments of Agriculture and Rural Development	Sở Nông nghiệp & phát triển nông thôn
IUCN	International Union for Conservation of Nature	
MBFP	Management Board of Forestry Project	Ban quản lý dự án lâm nghiệp
MKD	Mekong Delta	Đồng bằng sông Cửu Long
ODA		
PFMB	Protection Forest Management Board	Ban quản lý rừng phòng hộ

CHAPTER 1: INTRODUCTION

1.1. Purpose and Background

The Mekong Delta, located in southwestern Vietnam, is a vast and fertile region formed by the Mekong River. This intricate network of waterways, mangroves, and rice paddies creates a unique and biodiverse ecosystem. It's home to over 20 million people and plays a crucial role in Vietnam's economy, particularly in agriculture and aquaculture. The Delta is often referred to as the "rice bowl" of Vietnam, producing a significant portion of the country's rice, fruits, and seafood. Despite its richness, the Mekong Delta faces a number of serious environmental challenges, many of which are exacerbated by climate change and human activities. Currently, the Mekong Delta is one of the world's most vulnerable regions to climate change, with rising sea levels and land subsidence posing significant threats to its communities and ecosystems.

One of the major environmental concerns in the Mekong Delta is the preservation and restoration of coastal mangrove forests. Mangroves provide a multitude of benefits to the region: Coastal Protection: They act as natural barriers against storms, erosion, and rising sea levels, protecting coastal communities and infrastructure. Biodiversity Hotspots: Mangrove forests support a rich diversity of species, serving as breeding grounds for fish, crustaceans, and birds. Livelihoods: Many communities in the Delta depend on mangroves for fishing, aquaculture, and timber resources. Carbon Sequestration: Mangroves are highly effective at storing carbon, contributing to climate change mitigation.

However, the Mekong Delta's mangrove forests are under threat from various factors: Conversion to Aquaculture: Large areas of mangroves have been cleared for shrimp farming and other aquaculture activities. Coastal Development: Infrastructure development, such as roads and embankments, can encroach on mangrove habitats. Pollution: Agricultural runoff and industrial discharge can degrade water quality and harm mangrove ecosystems. Climate Change: Rising sea levels, increased salinity, and more frequent extreme weather events pose challenges to mangrove survival.

The Mekong Delta Living Lab Project - An Open-Air Laboratory For Coastal Protection And Nature-Based Solutions seeks to address these challenges by developing innovative, nature-based solutions for coastal protection. The Mekong Delta Living Lab Project is an innovative initiative aimed at addressing the pressing environmental challenges facing the Mekong Delta, particularly those related to coastal protection and the loss of vital mangrove ecosystems. It's essentially a large-scale, real-world experiment that combines scientific research, community engagement, and nature-based solutions to find sustainable ways to protect the Delta's coastline and enhance its resilience to climate change.

Workpackage I and II of the project, conducted throughout 2024, focused on the foundational phase: scoping and selecting a suitable location for the Living Lab. The objectives of these phase were to:

- ✓ Conduct comprehensive site investigations across target provinces to assess their suitability for the Living Lab.
- ✓ Engage with local stakeholders, including government officials, community representatives, and researchers, to gather insights and foster collaboration.
- ✓ Select an appropriate location that balances environmental, social, and logistical considerations while aligning with regulatory requirements.

This report outlines the activities undertaken, results achieved, and challenges encountered during the implementation of Workpackage I and II in this year, 2024.

1.2. Activities in 2024

- ✓ Conducting site investigations and analysis in the different provinces and understanding the differences between the provinces, their difficulties and their coastlines.
- ✓ Researching current solutions for coastal protection and developing an extensive database of findings regarding the different solutions that have already been tested.
- ✓ Organising meetings on the idea of a living lab with the responsible local authorities and communities to gather their input.
- ✓ Involving Msc students of TUDelft to visit the living lab in the field work.
- ✓ Based on the scoping of possible living lab locations in the Mekong Delta and the results of the stakeholder workshop, our team discuss to make the selection of a suitable site in one of the provinces in the Mekong Delta.
- ✓ Involving the local communities with the search of a location for the living lab by organizing focus group sessions and creative sessions.

1.3. Deliveries

A written report including photos for activites of the first year of Mekong delta living lab.

CHAPTER 2: RESULTS OF MAIN ACTIVITIES in 2024

2.1. Meetings with local authorities and field work

During April 4th-6th 2024, the ICOE team made several meetings and site visits to exchange ideas and collaborate with local departments in Soc Trang and Bac Lieu provinces for Mangrove Living Lab. The ICOE group asked the current coastal situation of provinces and described the overall project of Mangrove Living Lab. Currently, the two provinces of Bac Lieu and Soc Trang are very enthusiastic in supporting the project implemented to address issues related to erosion and mangrove forest restoration. Then, the group and local authorities went to the field work to see some projects for mangrove restoration.

Figure 1. Survey of mangrove forests in Soc Trang

Figure 2. The ICOE team discussed with local departments in the provinces: Bac Lieu (above) and Soc Trang (below)

2.2. Study Tour of TUDelft's students

In August, student group of TUDelft visited ICOE in the Study Tour. Besides, they were carried to Living Lab in Nha Mat to see some projects of breakwater to create sedimentation to restore mangrove and protect coastal area. More over, they also visited to aquaculture area, sea dyke system and the coastal erosion in the wind power plant area to see the coastal squeeze.

Figure 3. ICOE staff, Prof. Thom and TUDelft's student group in the field trip at Nha Mat, Bac Lieu province

Figure 4. ICOE staff, Prof. Thom and TUDelft's student group in the field trip at Nha Mat, Bac Lieu province

Figure 5. ICOE, Can Tho University staff, Prof. Thom and TUDelft's student group in the field trip at Can Tho University, Can Tho city

Figure 6. ICOE staff, Prof. Thom and TUDelft's student group at ICOE office

2.3. Field measurement in August 2024:

The fieldwork took place from 12 to 22 August 2024. The goals of this field work contain:

+ Evaluating the possibilities for all fieldwork processes, such as logistics, device installation, and more.

+ Capturing measurement data at the shallow zone.

+ Addressing the differences between Hoa Binh I and Nha Mat in other aspects, which become the criteria for living laboratory, for example, logistics (shops, restaurants), livelihood accesses for surveys, craft shop for external items for installing devices, and more.


PA

Figure 7. Vietnamese team in the field work in Bac Lieu province

2.4. Meeting at ICOE and Field trip along coastal Mekong Delta with Prof. Thom và Prof. Bas

Meeting has been taken places at ICOE office to discuss the aims for the first years and in the future of the projects. We discussed many topics including the research questions, what kinds we should have measurements, the locations and times for measurements, the equiments, etc…Besides we had fieldwork along coastal Mekong delta area to see the coastline retreat, breakwaters (Geotube, triangle hollow breakwater), mangroves, suitable permanent living lab…

Figure 8. ICOE staff and Prof. Thom, Prof. Bas and Dr. Son dicussed at ICOE office

2.4.1. Mekong Delta Visited Locations

The Mekong Delta field trip took place on 6-9 September 2024 with the participants of team members including: Le Hai Trung, Truong Hong Son, Phan Manh Hung and Thom Bogaard and Bas van Maren. The investigations and assessments were conducted across several target provinces.

Figure 9. The visited locations during the Mekong Delta Trip on 6-9 September 2024

The list of visited locations are shown in Table 1:

Table 1. The details of visited locations

No.	Locations	Provinces	Date
1.	Hoa Binh 1 Windmill Park	Bac Lieu	06 Sep 2024
2.	Nha Mat beach		
3.	Thap Canh	Soc Trang	07 Sep 2024
4.	Windmill Park No.7		
5.	Mo O beach		
6.	Ba Dong beach	Tra Vinh	07 Sep 2024
7.	Con Lon beach	Ben Tre	07 Sep 2024
8.	Tan Thanh beach	Tien Giang	08 Sep 2024
9.	Tan Dien beach		08 Sep 2024

During the year 2024, the Team had conducted several trips to some possible living lab locations across five target provinces in the Mekong Delta including Tien Giang, Ben Tre, Tra Vinh, Soc Trang, and Bac Lieu. The findings for each province are summarized below:

2.4.2. Tien Giang:

a) Tan Thanh, Tien Giang:

This coastline is located in Go Cong district, Tien Giang province, nearby Cua Tieu river belonging to Mekong River. Due to erosion, series of triangle breakwater was built along this coast. In this area, there are also signs that previous anti-erosion solutions such as cajuput piles and sandbags have failed. In addition, there is also a lot of garbage and pollution appearing here due to human activities and tourism activities.

It seems that deforestation has negative effects such as loss of biodiversity and increased risk of coastal erosion, but the positive seems to be that tourism activities are developing quite vigorously here.

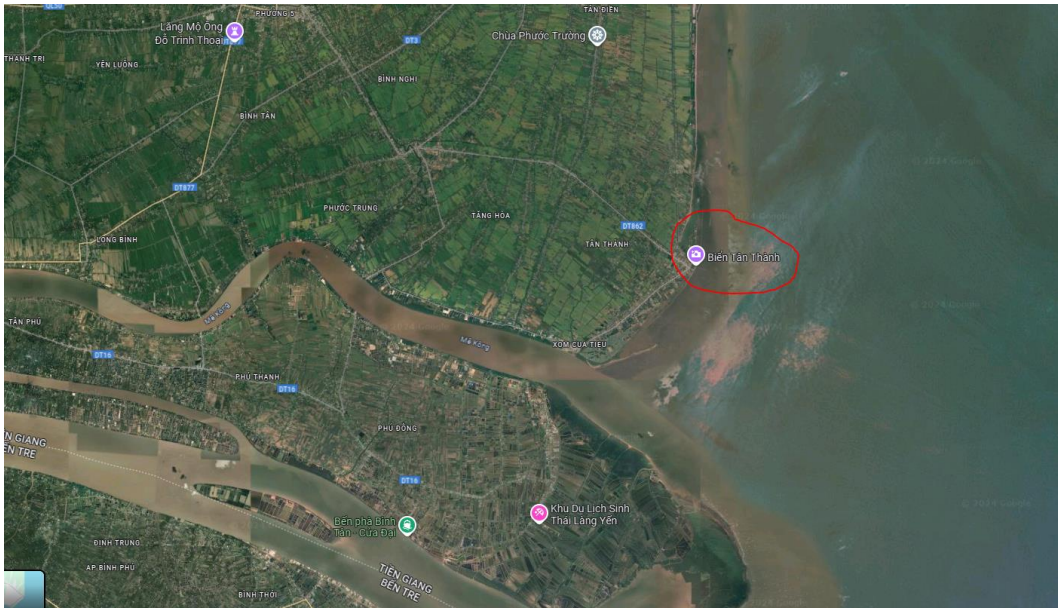


Figure 10. Location at Tan Thanh beach

b) Tan Dien, Tien Giang:

The coastline along this stretch used to be fringed with mangroves. The area is now eroding. A large part of the coastline is now protected with triangular parallel breakwaters not filled with stones (costs: 2 million euro / km). These breakwaters may have resulted in some deposition The underlying mechanism seems to be a reduction in updrift sediment supply from the Saigon River (which may have been connected to the Mekong River in the past) reducing the amount of sand and mud. Possibly the construction of the dike has led to a reduction in mud deposition along the embankments.

Most interesting to these sites seems to be the effect of the breakwaters.

- ✓ The openings between the breakwaters is varying, likely related to availability of material. What is the effect of the width of the opening on wave propagation and sedimentation? This could be investigated with observations and modelling.
- ✓ What is the role of the width between the dike and breakwater? If the width does not influence the bed level, then a wider distance leads to more wave dissipation
- ✓ What is the degree of reflection against the dike and how does this influence the morphodynamic stability?
- ✓ How much energy is propagating through the construction, and how can this best parameterized?

These questions could be addressed using a combination of field observations (field arrayc of 2-3 or more waterlevel sensors), bed level changes and modelling (SWASH for details on waves; Delft3D for bed level changes). Similar experiments could be done for other sites as well to come up with generic insights into the functioning of the breakwaters. This knowledge is needed because these physical constraints are key to understanding the effectiveness nature-based solutions.

Figure 11. Location at Tan Dien beach

2.4.3. Ben Tre:

a) Con Lon, Ben Tre:

- ✓ Sand-dominated site situated close by and downdrift of a river mouth. A sandy barrier providing natural coastal protection is overgrown with salt-tolerant trees (casuarina) while sparse mangrove vegetation occupies the intertidal area seaward of the barrier. The area was prone to erosion resulting leading to installment of geotubes aiming to protect the area. At present, the coastline is accreting, with many geotubes covered in sand. Further downdrift, the coastline seems to erode.
- ✓ The larger-scale morphology of the area shows signs of cyclic behaviour in coastal erosion resulting from a creek interacting with wave-dominant

longshore sediment transport. This cyclic behaviour leads to phases of erosion alternating with phases of deposition. At present the coast is accreting. It may be possible that the presently observed accretion would also have taken place without geotubes. It may also be that the geotubes strengthened downdrift erosion. On top of this cyclic behaviour, the coastline may be experiencing net erosion due to sediment decline from the updrift river. This could then mean that the erosion phase of each cycle becomes progressively worse.

- ✓ This side provides an example of a natural dynamic system subject to phases of erosion and deposition. Knowing these natural dynamics are needed for sustainable coastal management. With better scientific knowledge of the natural dynamics of the area, in combination with stakeholder involvement, would have probably prevented the interventions. A study of the dynamics of this systems requires thorough analysis of satellite images, mapping the bathymetry in combination with sediment sampling, and numerical modelling (delft3D-type morphological models or Shoreline S-type coastline models). Tra Vinh: Wooden fences, mudflat elevation.

2.4.4. Soc Trang:

a) Vinh Chau beach:

Example of a wide mangrove fringe, which was planted in 1989. Plantation was very successful, resulting a wide stretch. Since 2001 erosion has been observed. Erosion still apparently occurs, although at the time of visit the mangrove front appeared to be expanding. The foreshore appears to be muddy rather than sandy (observed from a large distance, may be wrong). Fish nets occupy the mudflat just seaward of the dike.

The area is limitedly accessible. A large watchtower exists providing an aerial view of the system (though in very poor state therefore dangerous to climb).

Although an interesting contrast with the marginal mangrove fringes elsewhere, the site has limited potential as a mobile lab because of limited accessibility, limited room for improvement, limited field options (because of fish nets)

b) Mo O beach:

Boardwalk into a very muddy area near the mouth of one of the Bassac distributaries where mangroves were planted in 2001. Mangrove restoration continued from a pre-existing mangrove forest. The existing forest is composed of multiple mangrove species including juveniles. The restored forest is a single species with very tall, mature and healthy mangroves with wide spacing. Interestingly, no juveniles were observed.

Although the area is very beautiful and reasonably accessible it seemed less suitable as living lab because of the absence of potential for experiments, and no comparison with areas with / without erosion and / or measures.

2.4.5. Bac Lieu:

This area encompasses a part of the Mekong coastline which has stretches of mangrove of which some are eroding while others are expanding, despite various interventions aimed at protecting the mangroves. The main anthropogenic activities along the coastline are:

- Construction of dikes (probably existing for a long time, possibly originally in weaker conditions
- Reduction in sediment supply from the Mekong delta
- Large-scale subsidence due to groundwater extraction
- Various interventions aimed at mitigating coastal erosion

What makes Bac Lieu interesting is that

- it offers two sites, one mainly eroding (Nha Mat) and one approximately stable (Hoa Binh 1 windmill park). Within both sites, mangrove areas that are protected by interventions are in the vicinity of mangrove areas with much less protection. Per site, comparison between locations with & without mangrove allows analysis of why one location erodes and the other does not, while comparisons within the two sites (Hoa Binh 1 and Nha Mat) allow evaluation of the effect of interventions.
- there is a pier in both sites allowing visualization of mangroves; one short (200 m; Nha Mat) while the other extends 6 km into the sea (Hoa Binh 1,which may be helpful for surveys). This also allows easy access for demonstration purposes , allowing access and see a site where mangroves still exist and actively dampen waves while the other site is mainly a mudflat. This is helpful for demonstration purposes showcasing the living labs.
- one site has a thick mangrove area (anthropogenically influenced) with boardwalks, allowing tourists/stakeholders/students/school children to see the mangroves. This is also helpful for showcasing the living labs.
- the area is easily accessible by car.
- the area with mangroves is closed from the landward site for general public, allowing relatively safe deployment of instruments. The other site contains a fishing platform on walkable distance which can be used to deploy instruments.
- the decline of eroding sites can be well visually shown with historic photos of a pier in-between mangrove trees which has now become mudflat.

a) Nha Mat beach:

3.2 Nha Mat

3.2.1 Research questions (suggestions, to be refined)

Main Research question: why have mangroves eroded in the past 20-50 years, and why do protection measures not promote mangrove re-establishment despite substantial sediment deposition?

- What is the historical development of the area (coastline retreat, mangrove change, anthropogenic developments such as dike construction, canalization of nearby river, protective measures, anthropogenic mangrove clearance)

- What is the role of the delta front and more recent mud deposits in dissipating wave energy? Is there a historic lowering of the area as suggested by (1) relatively low bed levels inside protected area despite a recent deposit of ~1 meter of mud and (2) the sandy foreshore? Is such a lower bed level explaining the difference with the Hoa Binh 1 site?

- Why is mangrove replantation unsuccessful?

- What is the role of mangroves (the small remaining stretch) in wave dissipation relative to the mudflat section?

- What is the role of wave reflection against the dike in (1) direct mangrove seedling overtopping and (2) providing unfavorable (low-density) mud by preventing wave consolidation? How do waves transform relative to a section without dike?

- What is the effectiveness of the various protective measures in dissipating waves (either too much or too little), focusing on (1) permeable solid structures, (2) the width and location of the entrances, and (3) the non-permeable geotubes?

3.2.2 Living lab aspects:

- Combination of two types of wave protection (permeable solid structure and non-permeable geotube)

- Relatively small (200 by 200 meter) protected area, close to area without protection

- Mangroves are recurrently replanted, but all unsuccessful.

- Accessible and with good overview of site through pier (showcase of unsuccessful mangrove protection?)

- Comparison with Hoa Binh site with comparable protection, which is unsuccessful (hypothesis – bed level at Bac Lieu is lower than the bed level in Hoa Binh 1).

3.2.3 Measurements

- Array of locations: on fishing platform several 100 meter seaward of the protection works (over sandy area), just seaward of the protection works, and within protected area (over mudflat and close to / within mangroves).

- Water level (from pier at Hoa Binh site?)

- Standard tripod measurements: turbidity (OBS sensor), velocity (preferably ADV near mangroves)

- Bathymetry: offshore cross-section on same location as transect in 2006 and 2007 survey – partly by boat, partly RTK; larger domain (for models)

- Bed level changes: (1) install home-made Sedimentation-Erosion Bar (SEB) or pin (long-term, reusable), and /or (2) place sedimentation mats (one time)

- Measure map with grain size of deposits (preferably in combination with bed level changes to see grain size changes during periods of accretion / erosion)

b) Hoa Binh 1 Windmill Park:

3.3.1 Research questions (suggestions, to be refined)

Main Research question: What is the role of the permeable solid structures in protecting the mangrove area around the pier?

- Are the protected mangroves more stable than the exposed mangroves NE and SW of the site?

- What is the role of the permeable solid structures and the wooden poles in protecting the mangroves?

- What is the effectiveness of the various protective measures in dissipating waves (either too much or too little), focusing on (1) permeable solid structures, (2) the width and location of the entrances, and (3) the wooden poles close to the mangroves?

- What is the historic development & human interventions of the site?

3.3.2 Living lab aspects:

- Combination of two types of wave protection (permeable solid structure and wooden poles) nearby area without protection

- Relatively small (200 by 200 meter) protected area, close to area without protection

- Accessible and with good overview of site through pier (showcase of successful mangrove protection?)

- Comparison with Bac Lieu site with comparable protection, which is unsuccessful (hypothesis – bed level at Bac Lieu is lower than the bed level in Hoa Binh 1).

3.3.3 Measurements

- Array of locations: on / under pier (should be accessible on foot when only several 100 meter, similar to fishing platform at Bac Lieu), just seaward of the protection works, and within protected area (over mudflat and close to / within mangroves).

- Water level (from pier)

- Standard tripod measurements: turbidity (OBS sensor), velocity (preferably ADV near mangroves)

- Bathymetry: offshore cross-section – partly by boat, partly RTK; (possibly data from windmill company? + larger domain (for models)

- Bed level changes: (1) install home-made Sedimentation-Erosion Bar (SEB) or pin (long-term, reusable), and /or (2) place sedimentation mats (one time)

- Measure map with grain size of deposits (preferably in combination with bed level changes to see grain size changes during periods of accretion / erosion)

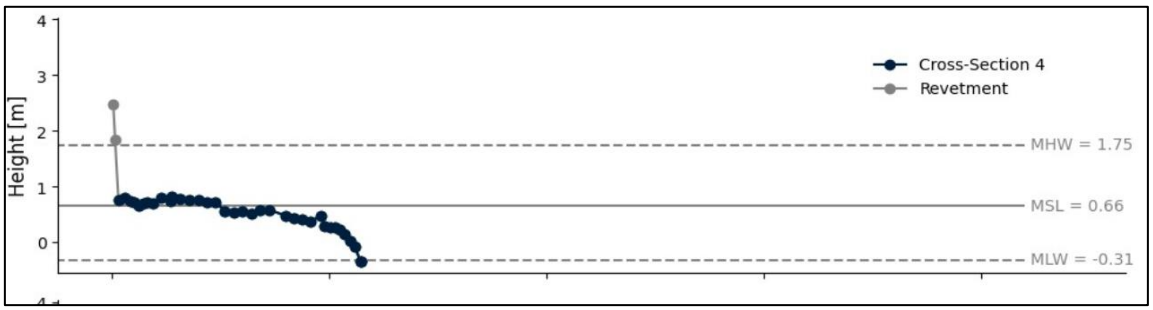
Figure 12. TUDelft and Vietnamese team had field trip along provinces of coastal Mekong delta.

2.5. Working with MDP Group

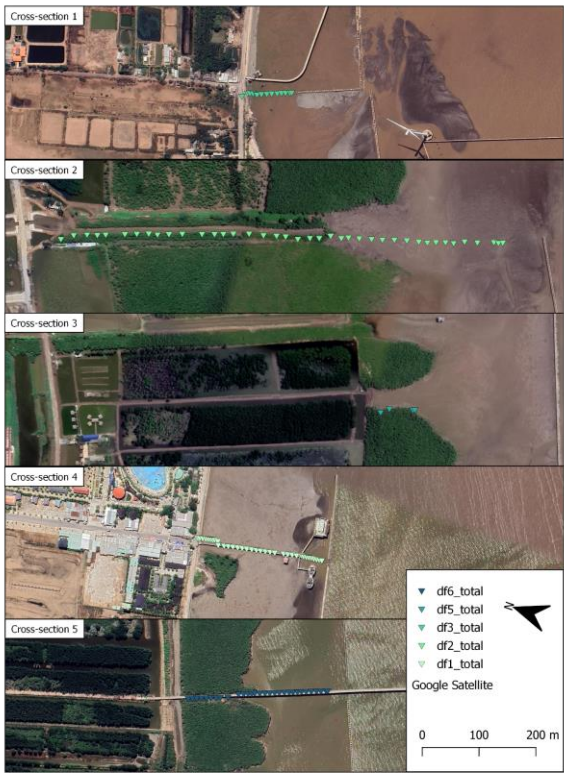
In September and October 2024, a MDP group of students from the two faculties of Civil Engineering and the Faculty of Technology, Policy and Management of Delft University of Technology visited and worked at the Institute of Coastal and Offshore Engineering as well as interviews and field measurements in Bac Lieu province including social and economical issuses with local people and authorities as well as hydraulic issues. The group of students experienced many interesting activities, experiences and useful knowledge during their time studying at the Institute of Coastal and Offshore Engineering.

Figure 13. The meeting between ICOE staff and MDP student group at ICOE office

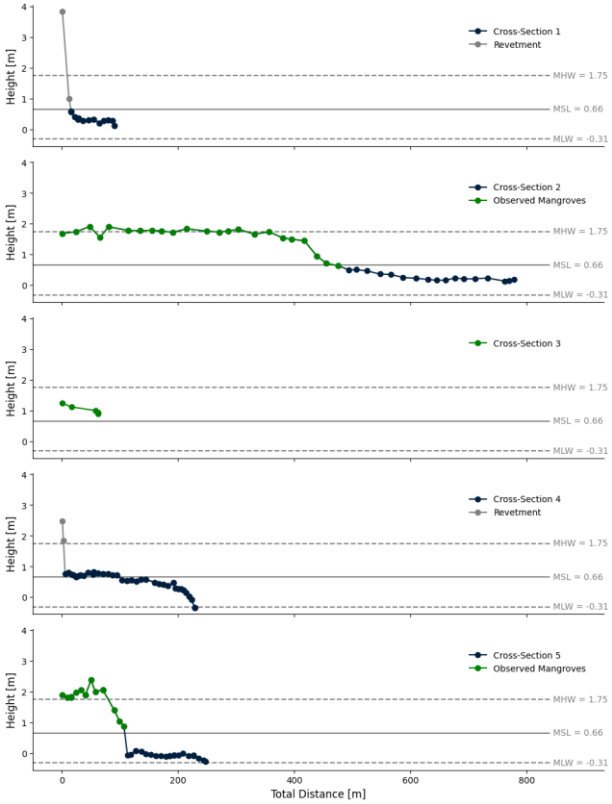
a) Hydraulic measurements



Satellite



Bathymetry

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Thành phố Bạc Liêu
Bạc Liêu


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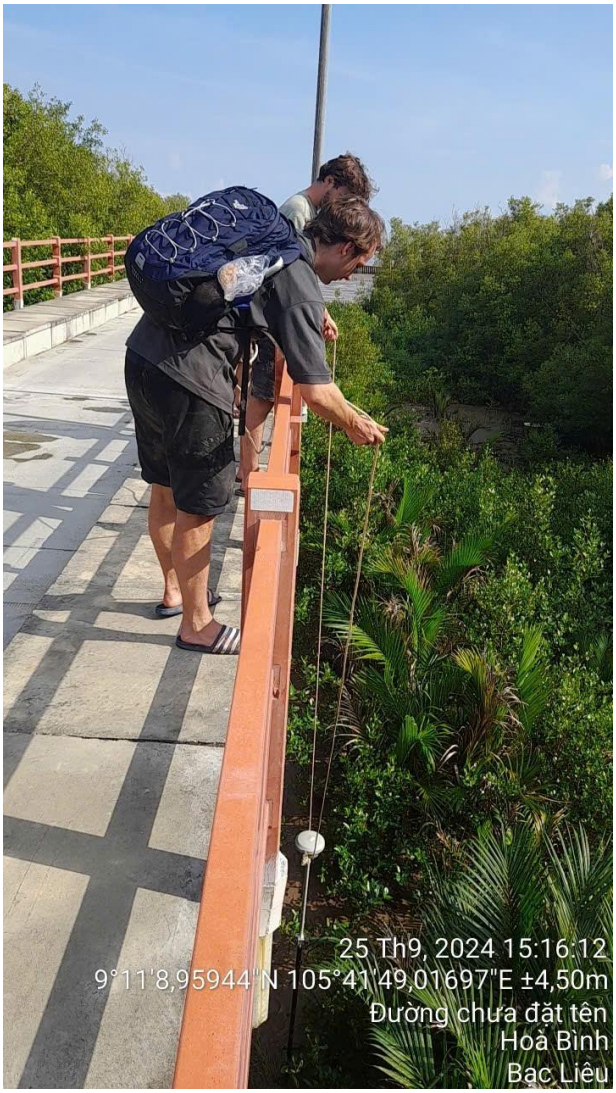
Thành phố Bạc Liêu
Bạc Liêu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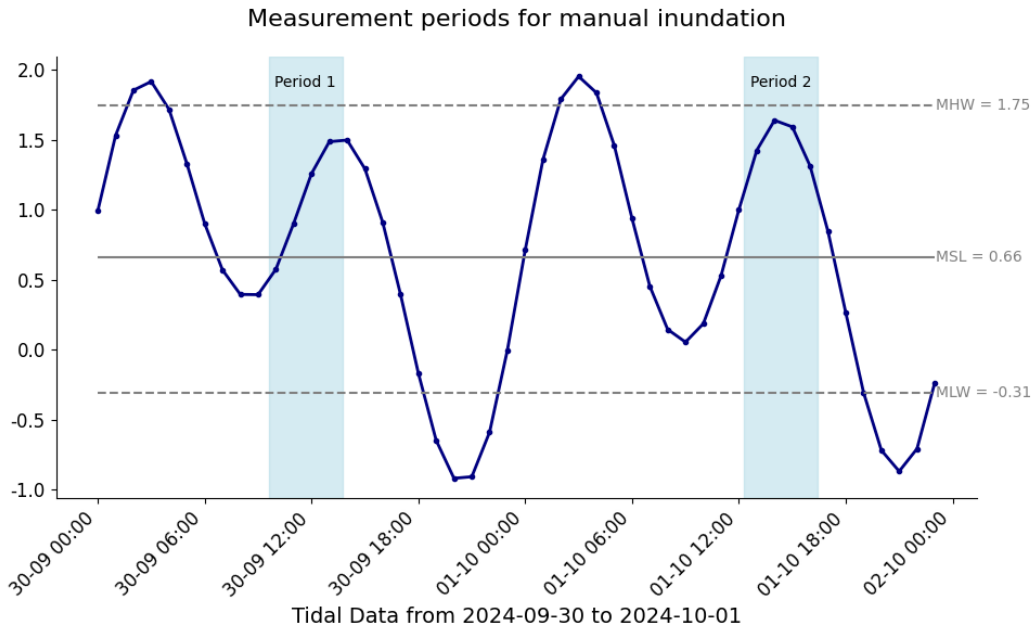
Hoà Bình
Bạc Liêu

Figure 14. MDP students and ICOE staff implemented field work in Bac Lieu province

Soil & Inundation



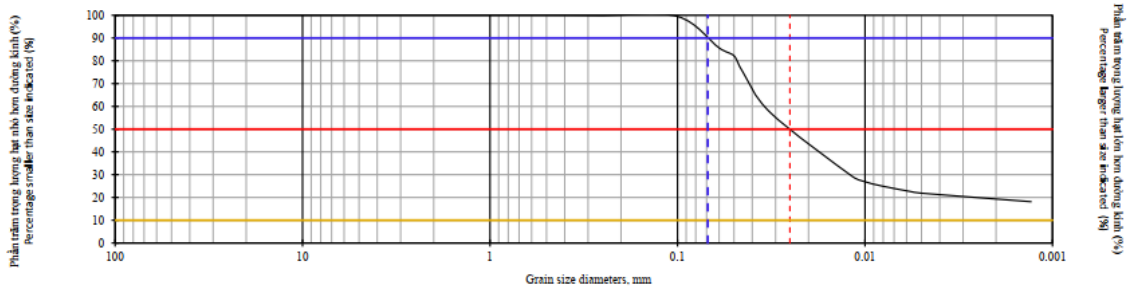
Location	Sample	Sand [%]	Silt [%]	Clay [%]	D_{50} [mm]
Cross-Section 4	NM1	17.8	60.3	21.9	0.0252
Nha Mat	NM2	14.3	62.2	23.5	0.0232
	NM3	23.8	54.3	22.0	0.0273
Cross-Section 5	M1	3.5	52.6	43.8	0.0070
Hoa Binh	M2	2.0	53.5	44.4	0.0070
	M3	21.9	69.7	8.3	0.0345
	M4	98.1	1.4	0.5	0.1750

KẾT QUẢ PHÂN TÍCH THÀNH PHẦN HẠT

RESULT OF GRAIN SIZE DISTRIBUTION TEST

Gói thầu - Package: Mekong Delta Living Lab Y90385
Địa điểm - Location: Nhà Mát - Tỉnh Bạc Liêu
Phương pháp thí nghiệm-Test method: TCVN 4198:2014

Ký hiệu mẫu-Sample name: NM1
Người thí nghiệm-Tested by: Phương, Thủy, Ngọc
Ngày thí nghiệm-Test date: 26/8/2024 - 30/8/2024



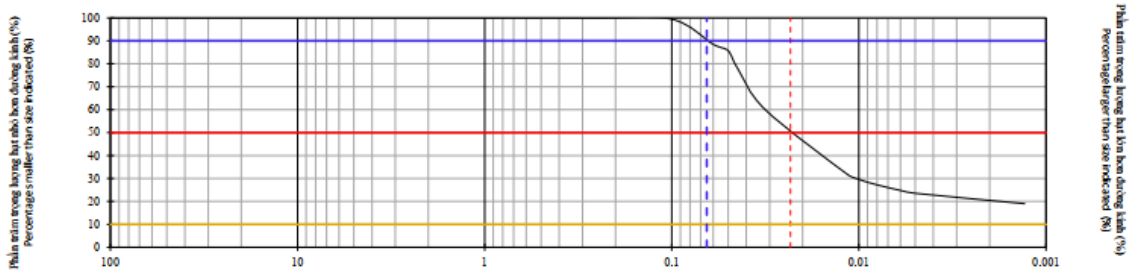
Loại hạt Grain type	Hạt sỏi sạn - Gravel						Hạt cát - Sand					Hạt bụi - Silt		Hạt sét Clay
	To Coarse			Trung Medium		Nhỏ Fine	Thô Coarse		Trung Medium	Nhỏ Small	Mịn Fine	Thô Coarse	Nhỏ Fine	
Đường kính hạt (mm) Diameter (mm)	>50,8	50,8-25,4	25,4-20	20-10	10-5	5-2	2-1	1-0,5	0,5-0,25	0,25-0,10	0,10-0,05	0,05-0,01	0,01-0,005	< 0,005
Thành phần hạt (%) Grain composition (%)									0.1	0.4	17.3	55.3	5.0	21.9

KẾT QUẢ PHÂN TÍCH THÀNH PHẦN HẠT

RESULT OF GRAIN SIZE DISTRIBUTION TEST

Gói thầu - Package: Mekong Delta Living Lab Y90385
Địa điểm - Location: Nhà Mát - Tỉnh Bạc Liêu
Phương pháp thí nghiệm-Test method: TCVN 4198:2014

Ký hiệu mẫu-Sample name: NM2
Người thí nghiệm-Tested by: Phương, Thủy, Ngọc
Ngày thí nghiệm-Test date: 26/8/2024 - 30/8/2024



Loại hạt Grain type	Hạt sỏi sạn - Gravel						Hạt cát - Sand					Hạt bụi - Silt		Hạt sét Clay
	To Coarse			Trung Medium		Nhỏ Fine	Thô Coarse		Trung Medium	Nhỏ Small	Mịn Fine	Thô Coarse	Nhỏ Fine	
Đường kính hạt (mm) Diameter (mm)	>50,8	50,8-25,4	25,4-20	20-10	10-5	5-2	2-1	1-0,5	0,5-0,25	0,25-0,10	0,10-0,05	0,05-0,01	0,01-0,005	< 0,005
Thành phần hạt (%) Grain composition (%)									0.1	0.5	13.7	56.1	6.1	23.5

KẾT QUẢ PHÂN TÍCH THÀNH PHẦN HẠT
RESULT OF GRAIN SIZE DISTRIBUTION TEST

Gói thầu - Package: Mekong Delta Living Lab Y90385
Địa điểm - Location: Nhà Mát - Tỉnh Bạc Liêu
Phương pháp thí nghiệm-Test method: TCVN 4198:2014

Ký hiệu mẫu-Sample name: NM3
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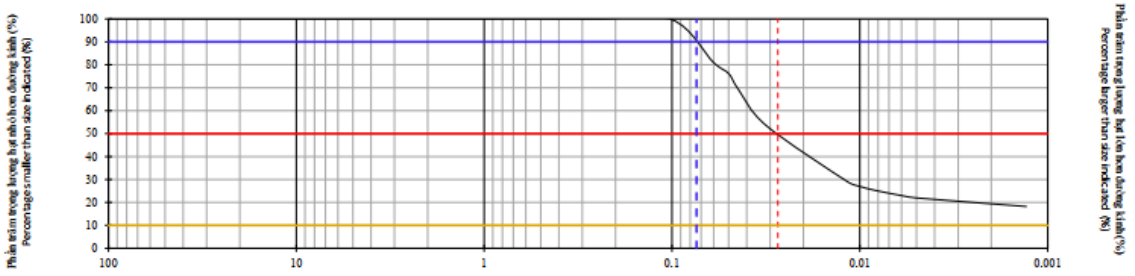
Ngày thí nghiệm-Test date: 26/8/2024 - 30/8/2024

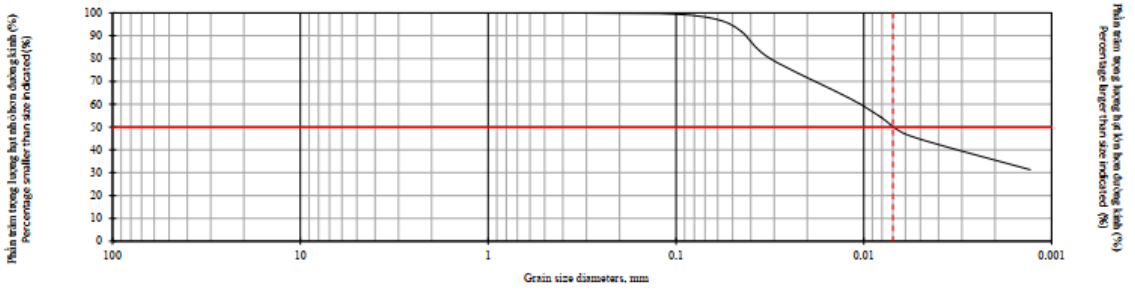


Loại hạt Grain type	Hạt sỏi sạn - Gravel						Hạt cát - Sand					Hạt bụi - Silt		Hạt sét Clay
	To Coarse			Trung Medium		Nhỏ Fine	Thô Coarse		Trung Medium	Nhỏ Small	Mịn Fine	Thô Coarse	Nhỏ Fine	
Đường kính hạt (mm) Diameter (mm)	>50.8	50.8-25.4	25.4-20	20-10	10-5	5-2	2-1	1-0.5	0.5-0.25	0.25-0.10	0.10-0.05	0.05-0.01	0.01-0.005	< 0.005
Thành phần hạt (%) Grain composition (%)									0.1	0.3	23.4	49.3	5.0	22.0

KẾT QUẢ PHÂN TÍCH THÀNH PHẦN HẠT
RESULT OF GRAIN SIZE DISTRIBUTION TEST

Dự án - Project : Living Lab
Đơn vị yêu cầu - Requestment Organization : Viện Kỹ thuật Biển
Phương pháp thí nghiệm-Test method: TCVN 4198:2014
Ký hiệu mẫu-Sample name: M1 - xanh

Người thí nghiệm-Tested by: Phương, Dương, Thủy, Ngọc
Ngày thí nghiệm-Test date: 16/10-21/10/2024



Loại hạt Grain type	Hạt sỏi sạn - Gravel						Hạt cát - Sand					Hạt bụi - Silt		Hạt sét Clay
	To Coarse			Trung Medium		Nhỏ Fine	Thô Coarse		Trung Medium	Nhỏ Small	Mịn Fine	Thô Coarse	Nhỏ Fine	
Đường kính hạt (mm) Diameter (mm)	>50.8	50.8-25.4	25.4-20	20-10	10-5	5-2	2-1	1-0.5	0.5-0.25	0.25-0.10	0.10-0.05	0.05-0.01	0.01-0.005	< 0.005
Thành phần hạt (%) Grain composition (%)									0.1	0.4	3.0	35.7	16.9	43.8

KẾT QUẢ PHÂN TÍCH THÀNH PHẦN HẠT
RESULT OF GRAIN SIZE DISTRIBUTION TEST

Dự án - Project : Living Lab

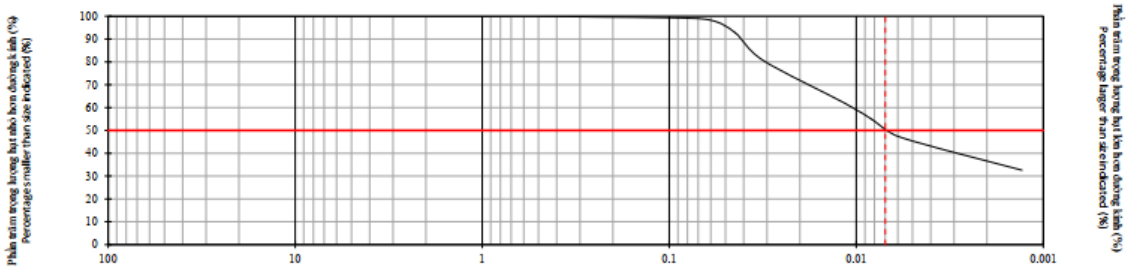
Đơn vị yêu cầu - Requestment Organization : Viện Kỹ thuật Biển

Người thí nghiệm-Tested by: Phương, Dương, Thủy, Ngọc

Phương pháp thí nghiệm-Test method: TCVN 4198:2014

Ngày thí nghiệm-Test date: 16/10-21/10/2024

Ký hiệu mẫu-Sample name: M2 - xanh



Loại hạt Grain type	Hạt sỏi sạn - Gravel						Hạt cát - Sand					Hạt bụi - Silt		Hạt sét
	To Coarse			Trung Medium		Nhỏ Fine	Thô Coarse		Trung Medium	Nhỏ Small	Mịn Fine	Thô Coarse	Nhỏ Fine	Clay
Đường kính hạt (mm) Diameter (mm)	>50.8	50.8-25.4	25.4-20	20-10	10-5	5-2	2-1	1-0.5	0.5-0.25	0.25-0.10	0.10-0.05	0.05-0.01	0.01-0.005	< 0.005
Thành phần hạt (%) Grain composition (%)									0.3	0.4	1.3	37.5	16.0	44.4

KẾT QUẢ PHÂN TÍCH THÀNH PHẦN HẠT
RESULT OF GRAIN SIZE DISTRIBUTION TEST

Dự án - Project : Living Lab

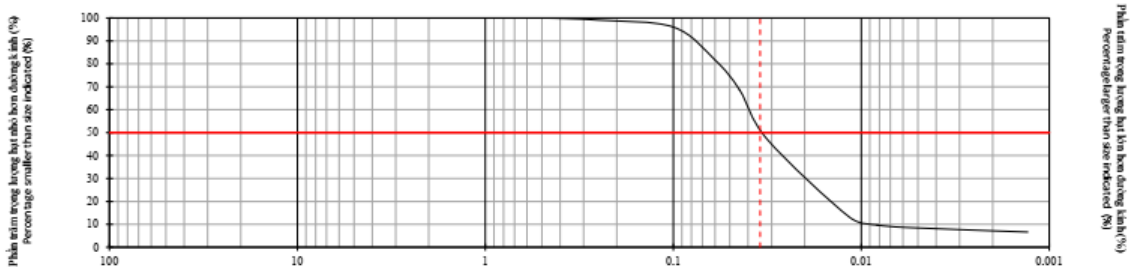
Đơn vị yêu cầu - Requestment Organization : Viện Kỹ thuật Biển

Người thí nghiệm-Tested by: Phương, Dương, Thủy, Ngọc

Phương pháp thí nghiệm-Test method: TCVN 4198:2014

Ngày thí nghiệm-Test date: 16/10-21/10/2024

Ký hiệu mẫu-Sample name: M3 - đỏ



Loại hạt Grain type	Hạt sỏi sạn - Gravel						Hạt cát - Sand					Hạt bụi - Silt		Hạt sét
	To Coarse			Trung Medium		Nhỏ Fine	Thô Coarse		Trung Medium	Nhỏ Small	Mịn Fine	Thô Coarse	Nhỏ Fine	Clay
Đường kính hạt (mm) Diameter (mm)	>50.8	50.8-25.4	25.4-20	20-10	10-5	5-2	2-1	1-0.5	0.5-0.25	0.25-0.10	0.10-0.05	0.05-0.01	0.01-0.005	< 0.005
Thành phần hạt (%) Grain composition (%)									0.9	3.0	18.0	67.5	2.2	8.3

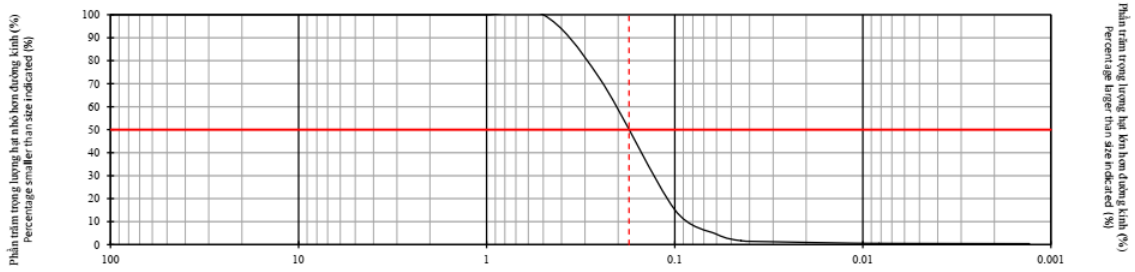
KẾT QUẢ PHÂN TÍCH THÀNH PHẦN HẠT
RESULT OF GRAIN SIZE DISTRIBUTION TEST

Dự án - Project : Living Lab

Đơn vị yêu cầu - Requestment Organization : Viện Kỹ thuật Biển — Người thí nghiệm-Tested by: Phương, Dương, Thủy, Ngọc

Phương pháp thí nghiệm-Test method: TCVN 4198:2014 — Ngày thí nghiệm-Test date: 16/10-21/10/2024

Ký hiệu mẫu-Sample name: M4 - đỏ



Loại hạt Grain type	Hạt sỏi sạn - Gravel						Hạt cát - Sand					Hạt bụi - Silt		Hạt sét
	To Coarse			Trung Medium		Nhỏ Fine	Thô Coarse		Trung Medium	Nhỏ Small	Mịn Fine	Thô Coarse	Nhỏ Fine	Clay
Đường kính hạt (mm) Diameter (mm)	>50.8	50.8-25.4	25.4-20	20-10	10-5	5-2	2-1	1-0.5	0.5-0.25	0.25-0.10	0.10-0.05	0.05-0.01	0.01-0.005	< 0.005
Thành phần hạt (%) Grain composition (%)									27.9	56.9	13.3	1.3	0.1	0.5

Figure 15. Results of soil test in Bac Lieu province

b) Social and Economical Analysis

Conducting research, collecting, and understanding people's perceptions of mangrove protection, as well as the concerns and policies of local authorities, is one of the important bases for selecting the location and planning the construction of the Living Lab. Specifically, the research team conducted surveys, collected, and interviewed communities, people, and local authorities in the coastal provinces of the Mekong Delta. In early 2024, a number of meetings and field visits were held to exchange ideas and cooperate with local departments and agencies in five provinces: Tien Giang, Ben Tre, Tra Vinh, Soc Trang, and Bac Lieu. Through the survey, it was found that Bac Lieu and Soc Trang provinces were very enthusiastic in supporting the project to address issues related to mangrove erosion and restoration. Based on the survey results, by September-October 2024, the ICOE research team continued to conduct more detailed surveys and interviews with local communities, board of mangroves, and local authorities.

Three iterative phases for farmers interviews:

Identifying the problems: 12 Ecological and 5 Intensive

Current state of collaboration: 9 Ecological

Perception of the risks: 3 Ecological

Based on the results of interviews and assessments, according to the farmers, there are many factors affecting the development of mangrove forests as well as combined aquaculture activities. These include: water pollution, dense mangrove forests, erosion, flooding, lack of oxygen, lack of seed stock, etc. Among all the above factors, the issue

of environmental pollution is of concern to many farmers and they want support in handling it. In their opinion, the source of pollution may include wastewater from high-tech aquaculture zones, cultivation activities upstream of river channels, and household waste. In addition, the thickness of canopy, not only limiting the growth of forests by blocking sunlight, but also causing a lack of oxygen. A large quantity of leaves and branches falling into the water have caused eutrophication, which has greatly reduced the amount of oxygen in the water. In addition, the decline in biodiversity in nature is also of concern to many people, especially the amount of natural aquatic products in mangrove forests has gradually decreased in recent years, causing great difficulties for people living and protecting the forest.

Problem	Frequency (out of 19 ecological farmers)
Water pollution	15
Mangrove density (thick canopy)	12
Erosion	10
Flooding	8
Lack of oxygen	9
Lack of seed stock	7
Salinity	5

Problem	Frequency (out of 5 Intensive farmers)
Water pollution	5
Canal blockages	4
Poor quality breeds	3
High mortality rates	3
Flooding	2
Salinity issues	2


Tiger

Figure 16. Meetings, interviews with the local farmer

Figure 17. ICOE staff, Prof. Thom and TUDelft's student group in the field trip at Nha Mat, Bac Lieu province

In addition to interviewing the community, we discussed with local authorities (Department of Agriculture and Rural Development and the Board of Mangrove) in Bac Lieu province about issues affecting forest recovery and development, difficulties in forest recovery and protection activities, and cooperation with households when carrying out these activities. According to the authorities' assessment, many forest areas are currently seriously eroded. In fact, the governments have been building many breakwaters along the coast of Bac Lieu province to protect the coastline and mangrove forests. Moreover, they regularly carry out forest thinning at a rate of 2,000 trees/ha, remove weak and diseased individuals, prioritize growth space for healthy individuals, and limit the risk of spreading diseases on trees on a large scale. At the same time, the authorities also carry out cleaning activities to avoid water pollution, and widely propagate forest protection awareness among the community. According to the discussion, the government has allocated forests to farmers for planting, restoration and protection with 70% of the forest area and 30% of the aquaculture canal area under the forest canopy. In addition to efforts in protecting and restoring mangrove forests, the staffs from the Board of Mangroves still face many difficulties in their work. Despite the problems of lack of machinery and equipment, conflicts with farmers, they also want to have specific studies to fully assess the causes of negative impacts on forest development and restoration, and at the same time be guided to implement effective solutions. In particular, during the discussion, they were very

interested in the Living Lab project and wanted to visit and observe the experiments when the laboratory is built.

Figure 18. Discussion with the Board of Mangroves

2.6. Meeting with TUDelft Staff and working with Msc Students

At the end of November 2024, two master students in Hydraulic Engineering department from Delft University of Technology came to work at the ICOE as well as conduct fieldwork in Nha Mat and Hoa Binh areas of Bac Lieu province.

And in early December 2024, Ms. Marjan, Project Manager of Delft University of Technology, and Ms. Lindsey, Project Manager of Living Lab, visited and worked at the ICOE as well as conduct fieldwork in Bac Lieu province. The Center for Research on Marine and Coastal Resources, on behalf of the Institute, reported on the implementation status of the international project Living Lab in the first year (2024) and the two sides discussed the implementation plan for the second year (2025). The meeting took place in a lively, joyful atmosphere on this Living Lab project.


TUDelft


ẨM THỰC
HOÀNG NGỌC 2
PHỤC VỤ: CÁC MÓN ĂN HẢI SẢN TƯƠI SỐNG CỦA BIỂN NHÀ MÁT BẠC
5555 9099
Địa Chỉ: Khu Du Lịch Nhà Mát - Phường Nhà Mát - TP. Bạc Liêu

Figure 19. TUDelft staff and Msc students, Vietnamese team in the field trip in Bac Lieu province

Figure 20. ICOE staff, Prof. Thom and TUDelft's student group at ICOE office

CHAPTER 3: SELECTION OF LOCATIONS AND MEASUREMENTS FOR LIVING LAB

3.1. Location Selection

Following a comprehensive evaluation using multi-criteria decision analysis, Province was selected as the site for the Living Lab. The selection was based on:

- ✓ Science: Compared to other areas, this place has many factors to fully evaluate the research and science of mangrove survival and mangrove restoration solutions..
- ✓ Community and Institutional Support: Strong engagement from local authorities and residents ensures feasibility and sustainability.
- ✓ Accessibility and Infrastructure: proximity to regional hubs facilitates logistical operations and stakeholder visits.

Mình có thể lập dạng bảng với trục ngang là các khu vực tiềm năng đặt permanent living lab, còn trục ngang các tiêu chí lựa chọn, sau đó sẽ cho điểm có thể 1-5 cho từng tiêu chí cho từng khu vực tiềm năng.

These results provide a robust foundation for the subsequent phases of the Living Lab project, ensuring the selected site is primed for success.

This was followed by a discussion on which field sites were important. We classified the field sites according to Mangrove development (yes or no) and whether protecting measures were implemented (yes or no). This revealed that only Vinh Chau was accreting, but also that Vinh Chau had a much wider range of success rate and measures than visited in the field site, which were also more accessible than the one visited during the field visit. This implies that Vinh Chau is on the top of the list as a potential living lab and an important candidate for the permanent lab. Decision on mobile / permanent labs were not yet made.

The site in the Red River (Phu Long) is difficult to compare with the Mekong according to the classification scheme below. All participants considered Phu Long a very relevant addition to the project. On average the participants would like to spent 20-30% of the field work budget to this Red River Delta site.

Table 2. Classification of sites according to state of the mangroves (accreting or eroding

		Accreting mangrove	
		yes	no
Measures	yes	Soc Trang: Vinh Chau	Bac Lieu: Hoa Binh 1 windpark & Nha Mat Soc Trang: Bac Lieu windfarm Tien Giang: Tan Dien

	no	Soc Trang: Vinh Chau	Soc Trang: Vinh Chau

At all observation points, the mangrove forests are situated in front of a sea dike with an asphalt road that accommodates vehicles with up to 20 seats. The dike itself has a concrete surface. This sea dike was constructed to protect the low-lying areas behind it from flooding. Initially, it was built as an earthen dike and later upgraded to a concrete structure with a revetment (the year of the upgrade is to be determined). Therefore, measures here only refer to the application of engineering structures in front of the mangroves (parallel break water).

However, in reality, these measures were primarily built to protect the sea dike line and promote sedimentation behind the structure, not to restore mangrove forests. The structures that mainly to support mangroves restoration along the Mekong Delta coast including bamboo piles, tree piles, and stone piles, etc... are not observed to exist independently at any visited locations. Remains of these structures from past attempts, where they were used on their own but did not succeed, are still clearly visible at the Nha Mac site. Currently, bamboo pile structures are used as local auxiliary measures to prevent erosion in some mangrove forest areas showing signs of degradation (Hoa Binh wind farm).

Moreover, the impact of constructing series of small-scale aquaculture bunds, intensive and extensive farming, and large projects such as wind farms or ports should not be neglected. These are all direct interventions affecting the status of mangrove areas.

The sequence of impacts and the hierarchy of influence within this system can be outlined as follows:

1- Initially, an intact mangrove forest system, approximately 1 km in width, exhibited healthy development. The construction of a sea dike (originally an earthen dike, with the unknown construction date) marked the first major intervention, during which mild coastal erosion was observed in certain areas.

2- Subsequently, land outside the dike was cleared for intensive aquaculture activities, which resulted in a reduction in the width of the mangrove forest and the loss of its ecological connectivity. The remaining forest was quickly squeeze into a narrow strip between the sea dikes, bunds and the seaward water edge. Continued mangrove degradation was observed, accompanied by significant coastal erosion in several locations.

3- In response to these challenges, intensive aquaculture activities outside the dike were prohibited (date to be determined), while extensive aquaculture was permitted to continue to somewhat extend (200 m of mangrove forest on the outermost side).

4- To mitigate the ongoing erosion, the sea dike was upgraded (unknown date- to be determined) to a more resilient concrete structure. Despite these efforts, the degradation of the mangrove forests remained unchanged, along with continued coastal erosion.

5- To address this issue, soft embankments were installed to act as wave breakers (2014-2016); however, these structures proved unstable, often failing within one to two storm seasons.

6- As a further countermeasure, more durable breakwater systems were constructed parallel to the shoreline at intervals of 150 meters (2017-2024). While these breakwaters facilitated land accretion behind them, in many areas, mangrove regeneration did not occur.

Table 3. Differentiate sites based on the level of intervention, forest status, and shoreline changes.

Location	Interventions						Mangrove status				Coastal Evolution Processes		
	Intensive	**Sea dikes**	**Extensive**	**Soft structures**	**Parallel breakwaters**	**Wind farm**	**No mangroves**	**Unhealthy**	**Healthy**	**Transition**	**Erosion**	**Accretion**	**Stable**
Nha Mat	Yes	Yes			Yes		Yes				Yes		
Hoa Bình	Yes	Yes		Yes	Yes	Yes				Yes	Yes		
Bac Lieu	Yes	Yes	Yes		Yes	Yes		Yes			Yes		
Vinh Chau 1	Yes	Yes	Yes	Yes					Yes			Yes	
Vinh Chau 2**	Yes	Yes							Yes			Yes	
Vinh Chau 3**	Yes	Yes			Yes	Yes		Yes					Yes
Mo o	Yes	Yes								Yes		Yes	
Con Lon	Yes				Yes			Yes				Yes	
Tan Dien	Yes	Yes			Yes		Yes				Yes		

*: Transition: showing signs of degradation, transition from healthy to unhealthy mangrove forest.

**: not visited in the field

The accretion/erosion trend described here reflects only the current situation; however, the historical evolution trends in these regions show notable differences. For instance, in areas like Nha Mac or Hoa Binh, a century ago, the sedimentation process was the dominant trend. Over the past 20-25 years, however, this sedimentation trend has reversed (since about 2000s), leading to increasing shoreline erosion. Conversely, in the Vinh Chau area, the trend is opposite. What appears to be a stable or accreting coastline today was, in fact, experiencing significant erosion until 2000. Since 2000, the sedimentation trend has strengthened, for reasons that remain to be identified.

3.2. Measurements

We first inventoried which measurements were considered relevant, and subsequently grouped them according to priority and price (with low-cost important measurements obviously being on top of the list to execute, and expensive measurements with little importance possibly abandoned at this stage of the project. Bed level changes and SSC (Suspended Sediment Concentration) can be measured in a cheap and more expensive way, so likely we will opt for the cheap version. For SSC observations the added value of the more expensive variant (OBS) the added value of the expensive version is large, so we are still exploring cheaper versions of OBS observations.

Nevertheless, it is important to note that some of our assumptions cannot be verified without simultaneous measurements of these parameters. For example, to isolate the reflected wave in shallow water after the wave has broken, we need to measure both the wave and the current at 2-3 locations simultaneously to filter out this signal.

Table 4. Importance and price of different measurements. Observations in italics will likely not be executed

		Expensive	
		yes	no
Important	yes	• Topography • *Bed level changes with topography* • SSC with OBS • Currents with ADCP & ADV	• Bed level changes with SEB (Sedimentation Erosion Bar) and/or sedimentation tiles • SSC with water samples • Waves with pressure sensors (2 buoys and 2 pressure sensors are already available)Grain size distribution map sediments (samples and lab analyses) • Mangrove characteristics (roots, stem and canopy density, ages) • Water levels with pressure sensor

			• pH • Salinity
	no	• *Cores for characterization of the substrate* • *Biomass*	• BOD / COD of sediments (samples and lab analyses) • Meteorological observations • Water quality • Nutrients

We subsequently briefly discussed how often measurements were to be repeated. The most interesting sites should be visited more than 3 times per year: at least (1) in the transitional season, (2) in the monsoon season, and (3) in the dry season. But preferably also during a storm if possible. It also depends on the type of measurements – the topography has only to be measured once.

Table 5. Deployment frequency of measurements

Measurement type	<= 1 times/year	1-3 times per year	>3 times per year
Waves & currents			
Topography			
Bed level changes			
Waves			
SSC			
Granulometry map			
Mangrove characteristics			
Water levels			
pH			
salinity			
BOD/COD			
Meteo			
Water quality			
nutrients			

Flow velocity			

The next step towards a monitoring plan is a list with, for each site, the relevant parameters, equipment to be including it deployment frequency and duration. This table needs to be completed by adding costs (in order to check the feasibility) and who will do the experiments. This list has not been filled in during the meeting and needs to be completed in the coming months.

Table 6. Parameters, equipment (including deployment frequency and duration), costs and responsible person /institute per site (to be filled in in the coming months) (not complete yet)

Site	***Parameter***	***Equipment***	***Frequency***	***Duration***	***Cost***	***Who***
Nha Mat	Topography Waves and currents Bed level changes SSC Mangrove characteristics pH salinity Water quality		3 times per yeas	15 days		ICE ICOE TUDelft
Hoa Binh 1 windfarm	Topography Waves and currents Bed level changes SSC Mangrove characteristics pH salinity Water quality		3 times per yeas	15 days		ICE ICOE TUDelft
Bac Lieu	Topography			7		ICE

Windfarm	Waves and currents Bed level changes Mangrove characteristics		1 times per yeas	days		ICOE TUDelft
Vinh Chau A	Topography Waves and currents Bed level changes SSC Mangrove characteristics		1 times per yeas	15 days		ICE ICOE TUDelft
Vinh Chau B	Topography Waves and currents Bed level changes SSC Mangrove characteristics		1 times per yeas	7 days		ICE ICOE
Vinh Chau C	Topography Waves and currents Bed level changes SSC Mangrove characteristics		1 times per yeas	7 days		ICE ICOE
Tan Dien	Topography Waves and currents Bed level changes		3 times per yeas	7 days		ICOE

	SSC					
Phu Long	Topography Waves and currents Bed level changes SSC Mangrove characteristics pH salinity Water quality		3 times per yeas	7 days		ICE

Final point of the agenda was the wishlist for instruments. Thom will get a quotation after which the various types of equipment need to be prioritized according to importance and price. The wishlist for purchase of equipment is as follows:

- OBS
- ADV
- 3 additional pressure sensor (for profile)
- WAQ sensor (EC)
- RTK GPS
- Expense for analysis of samples

3.3. Suitable living lab in Bac Lieu province

While numerous hypotheses and research questions have been proposed, answering these questions requires systematic measurements to determine the hydrodynamic processes and morphological changes occurring in the muddy coast-mangrove forest areas at different locations. Consistent measurement of parameters such as waves, currents, sediment, forest characteristics, tidal exposure times, and shoreline changes at various locations along the coast from Soc Trang to Bac Lieu may provide a clearer understanding and address some of the key topics of interest. In this section, we propose a measurement and simulation plan at key sites with distinct characteristics: Nha Mat, Hoa Binh, Vinh Chau, Tan Dien, and Phu Long. Each location represents a unique combination of coastal interventions, mangrove health statuses, and coastal evolution processes.

Hoa Binh and Nha Mat are geographically close, both characterized by intensive shrimp farming, sea dikes, and various structural interventions. However, they face significant erosion challenges in slightly different ways: Nha Mat has almost no remaining mangroves, while Hoa Binh has mangroves in a transitional state. In

contrast, Vinh Chau 1 (near windfarm), which also features similar sea dikes, shrimp farming activities, and infrastructure, maintains much healthier mangroves with accreting coast, offering a unique case to study how these factors coexist positively. Hydrodynamic conditions (waves and currents) and sediment availability may play key roles in understanding the differences between these sites.Tan Dien, with extensive shrimp farming behind the dike, strong sea dikes, and parallel breakwaters, has no remaining mangroves and continues to experience ongoing erosion, presenting similar characteristics to Nha Mac and serving as a potential comparison for validating findings from Nha Mac. Phu Long, located in the Red River, seems to be in a state of equilibrium, with the effects of human intervention still limited and under control. This site could provide insights into the fundamental conditions of a mangrove forest.

Ultimately, our aim is to provide a more comprehensive understanding of how different human activities and interventions impact coastal dynamics, influencing mangrove health and coastal erosion. The diversity of conditions across these five sites allows for a detailed and unique analysis of the effectiveness of various interventions and their roles in either mitigating or exacerbating coastal changes. The findings from this study will help inform better management practices to sustain coastal ecosystems while accommodating human activities.

3.3.1. Measurement philosophy

Basically, at the measurement sites, we need to measure the main parameters including:

- Mangrove characteristics: types, age, natural or planted, density (roots, stems, and canopy), biomass.

- Topography: Ideally measured once during the dry season and once during the monsoon season, to capture the impact of the width of the muddy foreshore on wave attenuation reaching the mangrove forest. It is necessary to extend the topographic measurements to a depth of -10 meters.

- Bed level changes: Continuously measured at least three times a year (once in the dry season, once in the monsoon season, and once during the transitional period).

- Suspended Sediment Concentration (SSC): Measuring SSC along with waves and currents helps us analyze the interactions among these factors, providing a better understanding of how waves and currents affect sediment transport and the maintenance or degradation of mangrove forests. SSC is an important indicator to determine the amount of sediment transported in the water, thereby assessing the processes of accretion or erosion in mangrove areas. SSC data are also important inputs for hydrodynamic and morphological numerical models.

- Water levels, waves, and currents (using pressure sensors and wave buoys):

o Waves: Due to the very gentle coastal topography of the Mekong Delta, a wave buoy is needed at a deep-water location. The buoy can be installed to measure wave conditions over a long period. Currently, there is no deep-water wave measurement station in the study area of the Mekong Delta. At least one wave station (pressure

sensor) is needed in the shallow water area (where waves have broken) and in front of the parallel breakwater. This station is used to calibrate the model. To measure and separate reflected waves in the shallow water area, simultaneous measurements of a wave gauge and a velocity meter (as in Linh's paper) are needed at a location in front of the area where reflected waves are identified. There are three locations where reflected waves can occur: in front of the breakwater, in front of the mangroves, and in front of the sea dike.

o Water level variation: Fluctuations in water levels (along with topography) in the study area inform us about the depth and duration of exposure of mangrove areas, which are important growth conditions and are often described in studies of mangrove ecosystems. Measurements of water levels, inundation depths, and exposure times are inexpensive and can be conducted multiple times throughout the seasons of the year.

o Currents/flow velocity: Flow velocity measurements provide information about the direction and magnitude of cross-shore and longshore currents occurring in the study area. Flow velocity significantly influences sediment transport, beach erosion, and the overall dynamics of the coastal environment. Flow velocities measured at various depths and locations can be used together with advanced computational models to map current patterns and assess their temporal variations in the study area.

- Sediment characteristics
- Water quality

3.3.2. Monitoring Plan

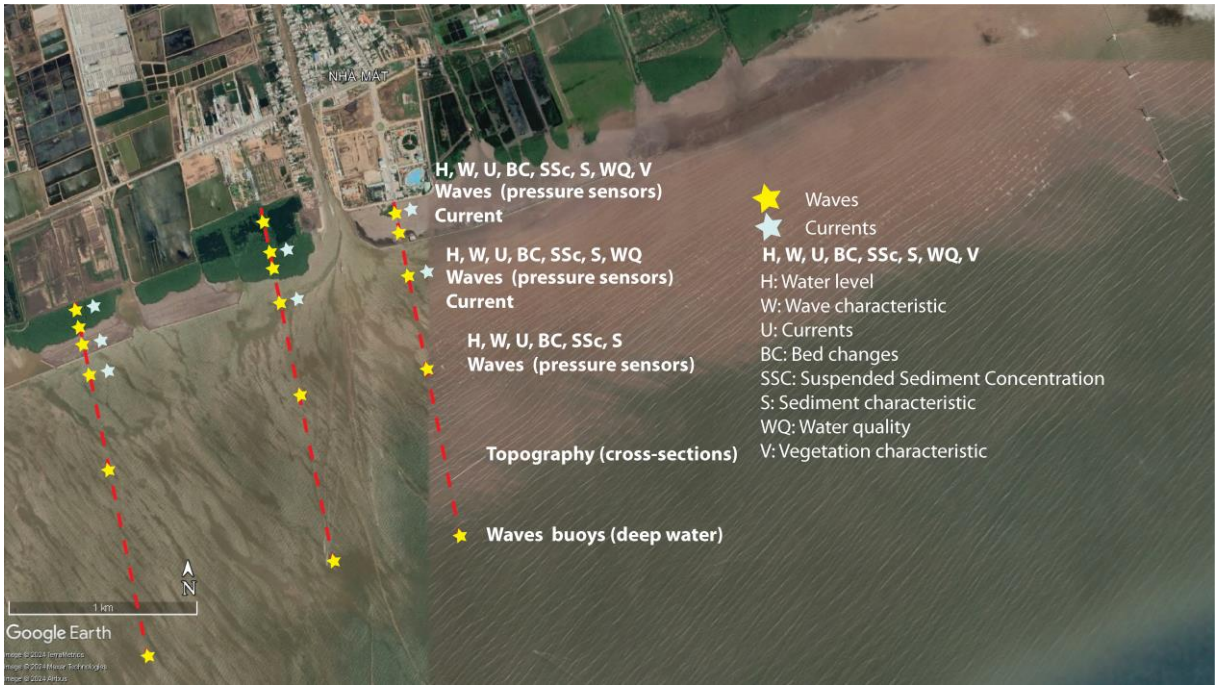
The figure shows a map of a proposed monitoring setup for a representative mangrove living lab location, for example at Nha Mat, Bac Lieu. There are three red-dotted lines extending from the shore into deeper waters, with each line containing several measurement points marked by stars. Each star represents a specific measurement location for different parameters.

Each line represents different intervention conditions, including:

- Sea dike + no mangroves + breakwater
- Sea dike + healthy mangroves + no parallel breakwater
- Sea dike + fish farm (disconnected) + mangroves + parallel breakwater + extra soft protection (for example, moving slightly southward by about 2–3 kilometers is the Hoa Binh wind farm)

Yellow stars indicate locations for measuring waves using buoys (in deep water) and pressure sensors (in shallow water). These measurement points are distributed along the red-dotted lines from the shore to deeper water areas. Light blue stars indicate locations where current measurements need to be taken. The main reason we need current and wave measurements at the same location is to be able to separate the incoming wave and reflected wave in shallow water using the Guza method (as described in Linh's paper). Using two or three wave gauges is suitable for deep water but not for shallow water conditions.

It is noted that if longshore transport varies significantly—due to curved beaches or changes in wave climate—we may have to add one or two more cross-sections to capture the gradient in the longshore current, in order to understand how the longshore current varies along the coastline. At the wave measurement locations, we can simultaneously measure SSC (Suspended Sediment Concentration), grain size, bed level changes, and sediment characteristics. The wave pressure sensors also provide us with water level variations. The characteristics of the mangroves in different areas also need to be measured.



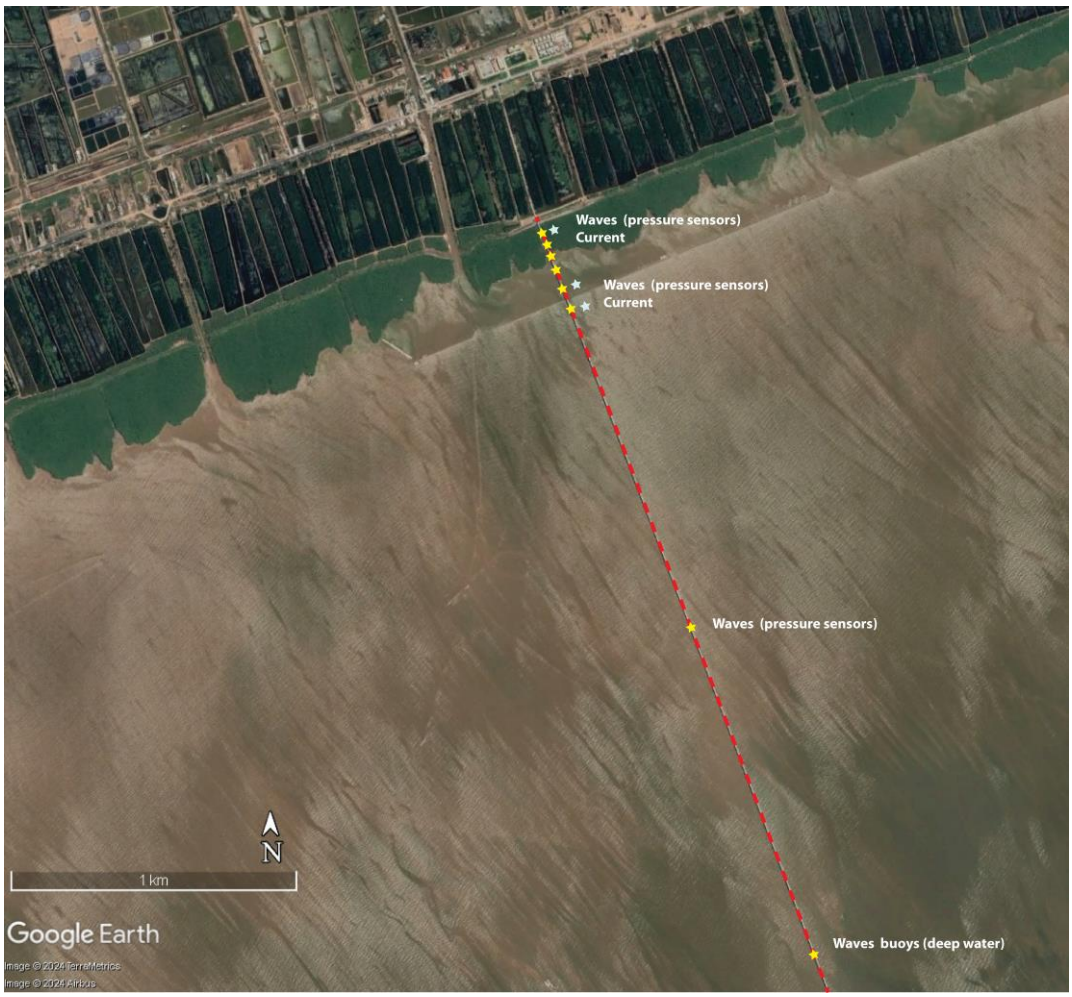
The monitoring stations are strategically placed along the three lines to capture data on how waves and currents interact with the :

1- Changing mud flow conditions

2- Changing mangroves conditions

3- Changing interventions (parallel breakwater, fishfarm bunds and seadikes,…)

This is the example considering for the Nha Mat area in Bac Lieu; similar measurement strategies can be applied to selected areas including Vinh Chau, Tan Dien…



Large-scale monitoring at the Hoa Binh wind farm (For wave transformation from deep water to within the mangrove forest)

CHAPTER 4: RESEARCH QUESTIONS

The most important research questions were discussed and prioritized. The main overall research questions were related to Governance, to the physical aspects, and to impact of measures. The relevant research questions were summarized as follows:

1) What are the current dominant factors for mangrove growth and survival along the Vietnam coast?

a) What are the ecosystem services of mangrove areas in the Mekong delta?

i) What are the differences in CO_2 absorption between natural and planted mangrove ecosystems, and how do variations in biodiversity influence their carbon sequestration capacities?

ii) Is there a difference in biodiversity between planted mangrove forests and successfully planted mangrove forests? How is this difference defined?

iii) Did the transition from a muddy beach to a sandy beach contribute to the decline of mangroves? Given that mangroves do not necessarily require muddy substrates to survive, what factors associated with this transition led to their decline?

b) What is the sediment balance along the Mekong delta coast before and after interventions?

i) What are the sources and amounts of the sediment budget for the Nha Mat area in Bac Lieu?

ii) What are the sources and amounts of the sediment budget for the Vinh Chau area in Soc Trang?

iii) Are there changes and fluctuations in the sediment budget for the Nha Mat area in Bac Lieu, and if so, why?

iv) Are there changes and fluctuations in the sediment budget for the Vinh Chau area in Soc Trang, and if so, why?

c) Is the depth profile (from dike to deeper water) lowering?

i) What is the effect on coastal erosion?

ii) Why is the depth profile lowering?

iii) Does insufficient sediment from the rivers lead to erosion (in the deeper foreshore)?

iv) Does intensive shrimp farming lead to land subsidence (in the upper foreshore)?

d) Does reduction in the mangrove width within mangroves lead to a reduction in tidal prism, therefore less fine sediment transport to the shore?

e) Does a reduction in connectivity within mangroves (bunds) lead to a reduction in tidal prism, therefore less fine sediment transport to the shore?

i) What is the flow path before and after the reduction in connectivity within the mangroves?

f) Is mangrove erosion triggered by a reduction in mangrove width?

i) Is there increased turbulent mixing and momentum exchange at the vegetation edge, resulting in less time and space for sediment to be deposited?

ii) What is the effect of the muddy cliff at the mangrove edge on turbulent mixing?

iii) How the cliff at the mangrove edge triggered?

iv) What is the role of dikes / bunds in reflecting waves?

g) Does water quality reduction (by (1) shrimp farming, (2) human waste) weaken mangrove resilience?

h) Is mangrove degradation related to inundation frequency and period of inundation (=combination of connectivity & bed level)?

2) Why are some mangrove restoration efforts and interventions schemes successful and others not?

a) How does the width of the opening, permeability and cross-shore width of permeable dams influence (1) wave propagation, (2) erosion / sedimentation, and (3) mangrove re-establishment

b) How are soil conditions (grain size, density, bed level, chemical quality of the mud) influencing the success of mangrove replantation?

c) Is mangrove degradation increasing during construction works (of protection schemes but also inlets and/or wind farms and port development)

d) Has a suitable ecological environment been created for forest restoration when there are intervention works?

e) What is the timeline of all interventions and port development (starting centuries ago)?

f) How can we improve design criteria for restoration efforts

3) How are decisions on coastal protection in general and restoration of mangrove in particular been taken in Vietnam?

a) What is the governance structure (large-scale vs small scale interventions)?

b) What are financial motivation for restoration?

c) Is there insufficient knowledge or insufficient transfer of knowledge from scientists to policy makers?