OCCASIONAL PAPER

Opportunities and challenges for mangrove restoration in the Mekong Delta

Status, policies and stakeholder outlook

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Photo by Tran Ngoc My Hoa/CIFOR
Shrimp production in mangrove area in Mekong Delta, Vietnam

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Abbreviations

COP 26	26th UN Climate Change Conference
GCF	Green Climate Fund
GEE	Google Earth Engine
ICRSL	Integrated Climate Resilience and Sustainable Livelihoods project
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MARD	Ministry of Agriculture and Rural Development
MONRE	Ministry of Natural Resources and Environment
NDC	Nationally Determined Contribution
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared band
OBIA	Object-Based Image Analysis
ODA	Official development assistance
PFES	Payment for Forest Environmental Services
REDD+	Reducing Emissions from Deforestation and Forest Degradation

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Executive summary

The Mekong Delta is home to the largest mangrove area in Vietnam and is also highly exposed to climate change and coastal squeeze. Vietnam's Nationally Determined Contribution (2022), as well as forestry and sectoral policies, positions mangrove restoration as a national priority for mitigating climate change and achieving sustainable coastal development. While policymakers have established national and provincial targets for mangrove restoration, and a significant number of foreign and national projects are already underway, questions remain over where restoration should take place. Mangrove restoration is a complex undertaking that requires political, social, economic and biophysical enabling conditions. It should also be conducted on the basis of local knowledge and expertise, and involve participatory decision-making processes. Based on a literature and policy review, spatial analysis, participatory mapping and stakeholder consultations, this paper identifies potential sites for mangrove restoration; looks at policy planning, possibilities for natural regeneration, and stakeholder perceptions; and discusses opportunities and challenges for mangrove restoration in the Mekong Delta.

Our findings show most provinces have low or medium restoration potential due to unfavourable conditions for mangrove restoration, such as serious coastal erosion or coastal squeeze. According to 80% of stakeholders participating in our survey, areas with the highest potential for mangrove restoration are those with mudflats because of their high capacity for natural regeneration. Meanwhile, 50% of surveyed stakeholders felt areas with mudflats or permanent embankments (dikes) had the highest potential for mangrove restoration. Despite current policies and land-use planning indicating production forests as potential areas for restoration, surveyed stakeholders felt the presence of aquaculture ponds meant such areas have little or no restoration potential as there are no strong financial incentives or sustainable livelihood models for encouraging local people to increase the area of mangrove in and around their shrimp ponds.

Our findings show a slight increase in total mangrove area in the Mekong Delta from 2016–2020. This increase was due mostly to international and national projects relating to mangrove plantation and restoration, and sectoral policies on improving water discharges and combatting environmental and water pollution to improve human health. However, any increases in mangrove forest cover were not significant, and results varied widely between study provinces and districts. Only four of the nine study provinces had experienced increases in mangrove forest cover, while the majority of districts across all nine provinces had experienced losses in total mangrove area. The regions where mangrove area had increased were those with a strong presence of international and national programmes and projects on mangrove restoration. This indicates the importance of finance and stable support programmes for mangrove restoration, as well as a vulnerability in regions where support programmes are absent.

Our paper shows that despite large numbers of policies and projects being aimed at mangrove restoration, they have been impeded by weak political will to preserve and protect mangroves due to: other land uses having higher opportunity costs; increasing pressure from industrial infrastructure development; and urbanization and aquaculture expansion leading to mangrove

loss. Our analysis also shows large areas of land allocated for forestry purposes that could be potential sites for mangrove restoration. However, these areas will require careful assessment to ensure their biophysical conditions are appropriate for mangrove restoration to avoid ineffective and inefficient investment.

While this study focuses mainly on policies, planning and stakeholder perceptions of potential sites for mangrove restoration, validating these perceptions will require rigorous impact assessments and further studies to offer reliable scientific evidence on what works best, where and when.

1 Introduction

The Mekong River Delta in Vietnam is highly exposed to climate change impacts (Government of Vietnam 2020). Vietnam's Nationally Determined Contribution (NDC) 2020 says the Mekong Delta has a high inundation risk from sea level rise. If the sea level were to rise by 100 cm, nearly 38.9% of the Mekong River Delta would be inundated, with around 10% of its population affected by land loss, saline intrusion, droughts, a significant fall in rice cultivation area, reduced coastal biodiversity and forest area with changes to low-lying ecosystems in and along rivers, and reduced supply of fresh water and water quality (Government of Vietnam 2020). Projections from the Ministry of Natural Resources and Environment (MONRE) show that even if all countries do meet their 2016 Paris Agreement targets, 40% of the delta region will still be underwater by the end of the century, causing an associated reduction in GDP of 10% (MONRE 2016).

Previous research has shown that mangroves not only play an important role in climate change adaptation and mitigation, but also provide natural, social, human, financial and physical capital for local livelihoods across the world, including Vietnam (Dahdouh-Guebas et al. 2005; Kuenzer and Vo 2013; Vo et al. 2013; Rogers et al. 2015; Jennerjahn et al. 2017; Veettil et al. 2019; Cinco-Castro and Herrera-Silveira 2020; Pham 2021; Wang and Gu 2021; IPCC 2022). However, these resources are facing significant pressures from coastal development, altered hydrology due to mangrove clearance for aquaculture expansion, urbanization and coastal erosion (Brander et al. 2012; Chen et al. 2017; Veetil et al. 2019; Pham et al. 2021a) largely for mangroves in Southeast Asia. Values are standardised to USD per hectare per year in 2007 prices. The mean and median values are found to be USD 4185 and 239 per hectare per year, respectively. The values of mangrove ecosystem services are highly variable across study sites due to, among other factors, the bio physical characteristics of the site and the socio economic characteristics of the beneficiaries of ecosystem services. We include explanatory variables in the meta-analysis to account for these influences on estimated mangrove values. The total mangrove area in the Mekong Delta region fell from 185,800 hectares (ha) in 1973 to 102,160 ha in 2020 at rates of approximately 2,150 ha annually due to aquaculture expansion, and 430 ha annually due to coastal erosion (Phan and Stive 2022). Consequently, a significant number of policies and projects on mangrove restoration, rehabilitation and plantation have been implemented in the Mekong Delta region. These include Decision No. 120/QD-TTg approving a project on protection and development of coastal forests during 2015-2020, to respond to climate change; a World Bank project on coastal wetlands protection and development; and a project from Oxfam (World Bank 1999; Salim 2008; Government of Vietnam 2015). However, evidence to date shows mangroves being degraded and shrinking in area, and mangrove conservation being impeded by poorly designed policies; weak coordination between sectors; inconsistent land-use planning; a lack of local community involvement in decision-making processes; challenges reconciling national economic development priorities with environmental protection; insufficient funds and limited financial incentives for conserving and protecting mangroves; and a narrow focus on planting new mangroves while overlooking the need to protect existing mangrove ecosystems (Pham et al. 2019a, 2019b; Veettil et al. 2019; Nguyen et al. 2020; Pham et al. 2022). Rapid climate change and failures in protecting mangroves necessitate a new adaptative pathway to help Vietnam mitigate climate change impacts and improve its governance of mangrove ecosystems.

At COP 26, Vietnam's Prime Minister, Pham Minh Chinh, joined global leaders in signing the Glasgow Leaders' Declaration on Forests and Land Use, and committed to reducing emissions from forestry and land-use sectors, and preventing and reversing deforestation in Vietnam. To translate this commitment, government agencies are gearing up their political and financial resources to implement Vietnam's NDC, which includes mangrove restoration as a key mitigation measure (Government of Vietnam 2020). During the 2015–2020 period, 140 projects under different programmes and capital sources were implemented to protect and restore mangroves in 27 of Vietnam's 28 coastal provinces, and many more projects are now underway (MARD 2021). However, many scientists have warned that mangrove restoration in the Mekong Delta is challenging due to coastal squeeze, failing sediment supply and prevailing erosion, and a poor understanding of site and species selection (Phan et al. 2015; Besset et al. 2019; Pham et al. 2019b, 2022). A successful mangrove restoration project may not necessarily include a planting phase, as when the stressors are removed and suitable environmental conditions such as correct hydrology and a calm area, particularly on exposed coasts, are provided, natural regeneration processes could enable degraded mangroves to recover (Kamali and Hashim 2011). Where, when and how mangrove restoration should take place in the Mekong Delta remain contentious issues that require more rigorous assessment and participatory decision making to ensure Vietnam can achieve its national targets.

Based on a policy review, spatial analysis and key informant interviews with government agencies, donors and international organizations engaged in mangrove restoration policies and projects, this paper identifies potential sites for mangrove restoration, discusses political, social and technical opportunities and challenges for mangrove restoration in the Mekong Delta, and looks at pathways for addressing those challenges.

2 Methods

The authors adopted mixed research methods.

2.1 Study area

Mangrove forests are distributed across four zones in Vietnam (Figure 1). As Zone 4 - which comprises nine coastal provinces/cities, including seven in the Mekong Delta: Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau, Kien Giang, Vung Tau and Ho Chi Minh City - accounts for more than 70% of total mangrove area in Viet Nam,, it was selected as our study area. Compared to the other three zones, natural conditions in Zone 4 are more favourable for establishing mangroves. The zone already has the largest and richest mangrove ecosystems in Vietnam, with its low-lying topography and abundant nutrient-rich alluvial deposits from the Mekong and Dong Nai rivers (Veettil et al. 2019), providing food, medicine, building materials/fuel for local communities, as well as carbon storage

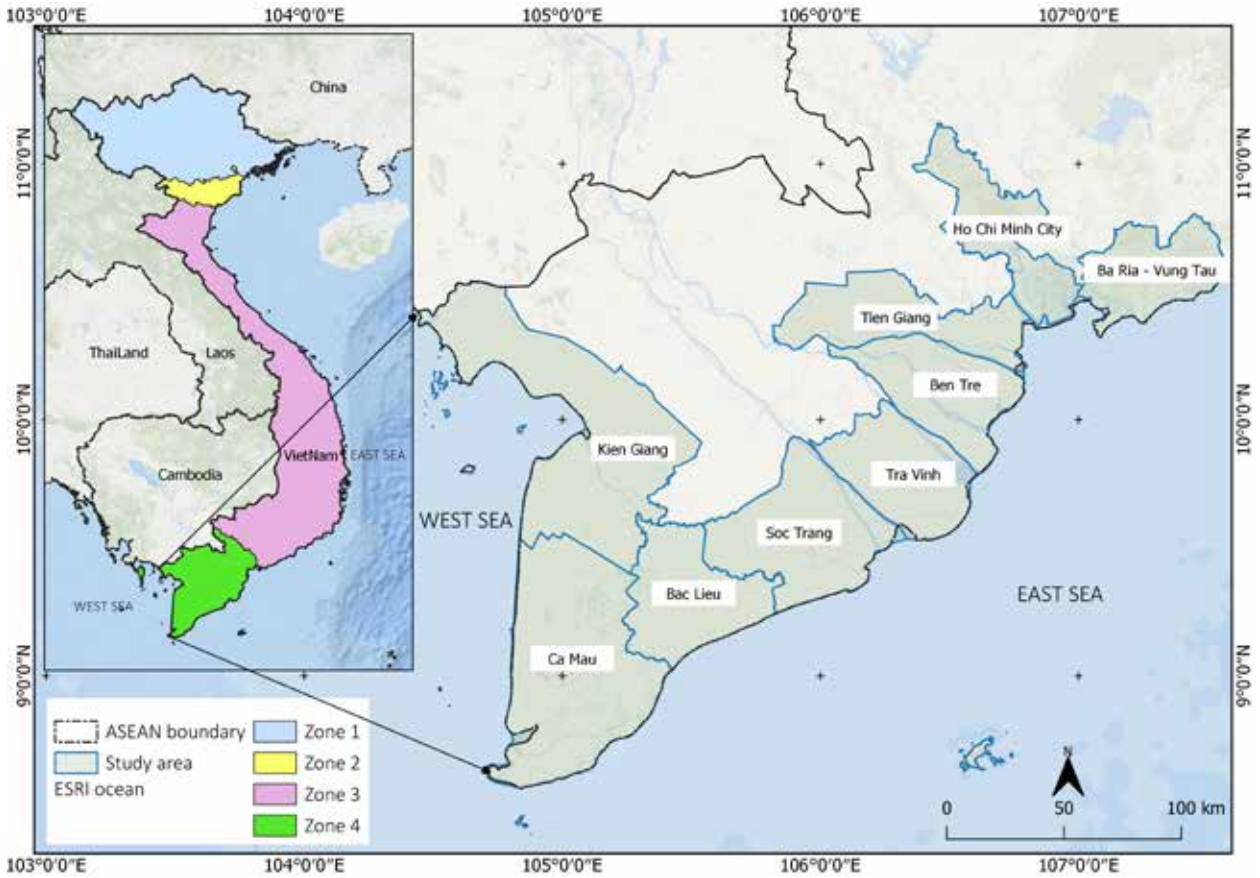

Figure 1. Map of the study area in southern Vietnam showing the nine coastal provinces/cities in Zone 4

Source: Authors' compilation

(blue carbon). The long and wide Sai Gon-Dong Nai river system, and branches of the Mekong River that flow through the massive plain area, enrich the zone's alluvia.

2.2 Approaches and methods to identify potential areas for mangrove restoration

Different approaches and indicators can be used to identify potential areas for mangrove restoration. These can include determining sites with coastal hydrological suitability for mangrove species; choosing topographies with appropriate soil conditions for mangroves and lower levels of human disturbance and stress; matching species and climate conditions; using appropriate planting techniques (van Loon et al. 2016; Kodikara et al. 2017; Thivakaran, 2017; Lewis et al. 2019; Pham et al. 2021a); and addressing causes of site degradation while ensuring monitoring and maintenance (Field 1999; Lewis et al. 2019). Several authors have applied these approaches and criteria to map potential areas for mangrove restoration. These include hydrology classification in Can Gio (van Loon et al. 2007).

While authors have tended to adopt a biophysical condition lens in assessing areas' suitability for mangrove restoration, few studies have used a political economy lens in determining potential sites for such efforts despite political economy playing a crucial role in ensuring the viability of future mangrove restoration schemes. Lewis (2000) and Pham et al. (2022) point out that political will and appropriate policies are prerequisites for ensuring successful mangrove restoration. While government agencies, donors and investors are now advocating for more mangrove restoration projects in Vietnam, little effort has been put into analysing areas current Vietnamese policies are prioritizing for mangrove restoration; ensuring efforts are well implemented; or looking at areas that have suffered serious deforestation. Despite advice suggesting mangrove restoration efforts should be based on stakeholders' preferences and knowledge, few studies to date have either explored this knowledge in regard to potential sites for mangrove restoration, or what criteria stakeholders may use to assess such potential. While acknowledging that potential sites for mangrove restoration should be determined with sufficient knowledge and understanding of biophysical conditions, this paper focuses on identifying areas for mangrove restoration based on government policy objectives and stakeholder knowledge. Our key assumptions for mangrove restoration sites are that:

- Designated areas for mangrove restoration, as stipulated by Viet Nam's 2017 Forestry Law, as well as the country's NDC and provincial land-use plans, need to be protected and afforested. If deforestation occurs in these areas, mangroves need to be reforested and restored as a priority;
- Restoration efforts should be avoided in areas that national and provincial policies have planned for future conversion for other land uses;
- Mangrove restoration must be based on stakeholders' knowledge and preferences to ensure its success and viability.

Accordingly, we adopted a mixture of research methods and participatory research approaches, as outlined below.

Step 1. Policy review

We first reviewed forestry and land-use policies to identify: current and future plans for mangrove protection and restoration; potential threats from land-use change that could lead to mangrove deforestation; and prioritized areas for mangrove restoration as stipulated in central and provincial government policies and planning.

Step 2. Assessing changes in mangrove area during 2016–2020 using spatial analyses of Sentinel-2 and Google Earth imagery for further rapid ground truthing exercises

Previous studies, including research from IUCN (2016), have already assessed mangrove forest area and cover up until 2016. Our research built on these studies while focusing on the 2016–2020 period. Changes in mangrove area during 2016–2020 were analysed through spatial analyses of Sentinel-2 and Google Earth imagery for further rapid ground truthing exercises. A temporal series of Sentinel-2 images from 2016 to 2020 was acquired for district-level mapping of southern Viet Nam's mangrove forests. We minimized the possibility of missing data due to cloud cover by selecting images for each year

Table 1. Spectral region and spatial resolution of bands from Sentinel-2 imagery

Band	Spectral region	Resolution (m)
Band 1	Coastal Aerosol	60
Band 2	Blue	10
Band 3	Green	10
Band 4	Red	10
Band 5	Vegetation red edge1	20
Band 6	Vegetation red edge2	20
Band 7	Vegetation red edge3	20
Band 8	Near Infrared (NIR)	10
Band 8A	Narrow Near Infrared	20
Band 9	Water vapour	60
Band 10	Cirrus	60
Band 11	Short-wave Infrared (SWIR1) (SWIR1 – This band is very sensitive to moisture and is therefore used to indicate and monitor soil moisture and vegetation in the image)	20
Band 12	SWIR1	20

captured during the dry season. Pre-processing steps were carried out using the Google Earth Engine (GEE) platform to allow rapid analysis of a large collection of satellite images. The advantage of this cloud computing platform is its availability of imagery and ability to process temporal series data rapidly. We then used a temporal series of high-resolution Sentinel-2 imagery with data consisting of 13 spectral bands (Table 1). A spectral band is a matrix of points defined by three dimensions, its coordinates and the intensity relating to the radiance. For this study we used bands 2 (Blue), 3 (Green), 4 (Red), and 8 (Narrow Near Infrared).

The Object-Based Image Analysis (OBIA) approach was used to classify the satellite images due to its high performance in image classification. This approach is widely used for land use and cover change (LUCC) classification, and has many advantages over pixel-based classification approaches. In general, OBIA comprises two main steps: segmentation and classification (Vo et al. 2013).

Segmentation: This process breaks the image up into meaningful objects representing land-based features based on spectral and spatial properties (Heumann 2011). This allowed us to examine habitat for terrestrial and marine fauna, and coastal hazard mitigation. The use of satellite remote sensing to map mangroves has become widespread as it can provide accurate, efficient and repeatable assessments. Traditional remote sensing approaches have failed to accurately map fringe mangroves and true mangrove species due to relatively coarse spatial resolution and/or spectral confusion with landward vegetation. This study demonstrates the use of the new Worldview-2 sensor, Object-Based Image Analysis (OBIA). Based on our prior knowledge of patch sizes of mangrove forests in the region, segmentation parameters chosen were: scale = 40, shape = 0.01 and compactness = 0.5; while weights for layers were: NIR = 5 and other bands = 1. We deemed these sufficient for collectively delineating mangrove patches in the region, so they were applied for the segmentation process used in this analysis.

Classification: The mangrove forests were classified using a Normalized Difference Vegetation Index (NDVI) threshold of greater than 0.2. This threshold was adjusted accordingly to expert knowledge using trial and error at different mangrove locations. This is one of the most successful and widely used image processing indices for areas of vegetation, and enhances images by detecting higher spectral responses on living green plant canopies from multispectral remote sensing data (Vo et al. 2013). The NDVI is the ratio of the subtraction of the near infrared and red bands divided by their sum, and its values range from -1 to 1.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

where NIR is Near Infrared band and Red is Red band

Here, the NDVI was used as the main threshold to differentiate vegetation, including mangrove areas from other surface types. The NDVI is ideal for mapping mangroves, because they are the dominant vegetation in coastal areas in southern Vietnam. The multi-resolution algorithm (Baatz and Schäpe 2000) embedded in eCognition 8.9 was used to perform image segmentation and classification. The research team then used Google Earth, which provides multiple layers of imagery with different acquisition

dates to display the historical data. This allowed us to assess changes in mangrove cover and provide accurate assessments for each year from 2016 to 2020.

Step 3. Identifying potential areas for mangrove restoration based on projected future land-use planning

As government policies on land-use planning have significant impacts on mangrove areas, we overlaid land-use maps with existing mangrove areas to identify practical and realistic areas for mangrove restoration based on the latest government policies and planning.

Step 4. Participatory mapping and Participatory Rapid Appraisals

To ensure mangrove restoration areas reflected stakeholder perceptions, knowledge and understanding, we carried out participatory mapping and consultation workshops with local stakeholders. In total, 61 people took part in this study between February and May 2022 (Table 2). During these participatory mapping and Participatory Rapid Appraisal processes, stakeholders were asked to identify potential sites for mangrove restoration; explain their rationale for their chosen criteria for mangrove restoration; discuss opportunities and challenges for mangrove restoration in their regions; and provide recommendations for future mangrove restoration areas.

Table 2. Numbers of stakeholders consulted

		Stakeholder group					
	Total number	Academics	Government agencies	National park/ protected area staff	International organizations	Private companies	Forest owners
Ca Mau	30		9	12	0	4	5
Soc Trang	6		5	0	0	0	1
Kien Giang	2		2	0	0	0	0
Ho Chi Minh City	7	2	3	1	1	0	0
Hanoi	16	2	8		5	1	
Total	**61**	**4**	**27**	**13**	**6**	**5**	**6**

3 Legal framework on mangrove management and restoration in Vietnam

Vietnam has a strong legal framework for mangrove restoration (Box 1).

These policies all emphasize the need to enhance mangrove restoration in Vietnam and reflect government commitments to provide financial support towards this vision. In addition to national policies, each province in the region has also issued policies on mangrove management and restoration (Box 2).

Box 1. Key policies on mangrove management and restoration in Vietnam

- The national programme on coastal forest protection and development to mitigate climate change during the 2015–2020 period (Decision No. 120/QD-TTg, 2015) had specific targets to:
  - Protect 310,695 ha of forest
  - Rehabilitate 9,602 ha of poor quality forest; an average of 1,600 ha annually
  - Plant 46,058 ha of new forests; an average of 7,676 ha annually, by:
    - Planting 37,008 ha of protective and special use forests along coastlines, including 29,500 ha of mangroves, and planting 7,508 ha of windbreaks and coastal sand protection forests
    - Planting 9,050 ha of production forests along coastlines combined with protection
    - Planting 23.5 million trees scattered along the coast.
- Decision No. 770/QD-TTg dated 23 June 2019 adjusting the objectives and tasks of coastal forest protection and development for the 2015–2020 period under Project 120 to suit the practical conditions of localities. According to the medium-term plan and approved projects, specific tasks for the 2015–2020 period, after adjustment were:
  - Protect the existing coastal forest area of 310,695 ha
  - Plant 14,930 ha of new forest
  - Additional planting and rehabilitation of 6,670 ha of poor quality forests
    Therefore, the total target area for coastal afforestation during the 2015–2020 period was 21,600 ha, a decrease of 34,000 ha compared to the original task according to Decision 120/QD-TTg.
- National programme on the sustainable management, protection and development of coastal forests to mitigate climate change (Decree No. 119/2016/ND-CP)
- National target programme for sustainable forestry development during the 2016–2020 period (Decision No. 886/QD-TTg, 2017)
- National programme on reducing greenhouse gas emissions from deforestation and forest degradation, conservation and enhancement of forest carbon stocks and sustainable management of forest resources through 2030 (Decision No. 419/QD-TTg, 2017)
- The 2017 Forestry Law (Law No. 16/2017/QH14)

continued on next page

Box 1. Continued

- The Vietnam forestry development strategy for 2021–2030, and vision to 2050 (Decision No. 523/QD-TTg, 2021)
- Project on protecting and developing coastal forests to respond to climate change and promote green growth in the 2021–2030 period (Decision No. 1662/QD-TTg, 2021)
- Vietnam's Nationally Determined Contribution (NDC)
- Prime Ministerial Decision No. 18/2009/QD-TTg dated 3 February 2009 approving the master plan on socioeconomic development of Vietnam's sea and coastal areas in the Gulf of Thailand up to 2020
- Prime Ministerial Decision No. 886/QD-TTg dated 16 June 2017 approving the target programme for sustainable forestry development during the 2016–2020 period
- Prime Ministerial Decision No. 667/QD-TTg dated 27 May 2009 approving a programme to strengthen and upgrade the sea dike system from Quang Ngai to Kien Giang combined with a 500-metre mangrove strip
- MARD (2021): Through the State's investment programmes, medium-term public investment plans are allocated by the central budget in stages, mobilized from local budgets . These plans called for investment from other lawful capital sources, and organized for the construction and implementation of projects on:
  - Establishing seedling forests and nurseries to produce seedlings for local coastal afforestation
  - Protecting and developing mangrove forests to protect against coastal erosion, giving priority to the Mekong Delta
  - Planting protective forests to block wind and storms, prevent sand from flying, and protect the environment in coastal areas, especially in the central provinces
  - Zoning and promoting forest regeneration and enrichment, biodiversity conservation, and rare and endangered forest fauna and flora in national parks and coastal nature reserves
  - Providing forestry extension, seed transfer and production afforestation techniques, building agroforestry models, improving livelihoods, and linking people and businesses along product value chains
  - Public-private partnerships on afforestation, protection and development of forests in coastal areas associated with livelihood development, combining ecotourism and community forest management
  - Organizing, monitoring and updating the database of coastal forest resources
  - Reviewing land, organizing land allocation and forest allocation, planting boundary markers to delineate forest boundaries, and making forest management documents according to the provisions of law.

Box 2. Policies on Mekong Delta regional development

- **Prime Ministerial Decision No. 245/QD-TTg dated 12 February 2014** approving the master plan on socioeconomic development of the Mekong Delta key economic region until 2020, with a vision until 2030
- **Prime Ministerial Decision No. 939/QD-TTg dated 19 July 2012** approving the overall plan on socioeconomic development of the Mekong Delta until 2020
- **Prime Ministerial Decision No. 1581/QD-TTg dated 9 October 2009** approving the Mekong Delta regional development plan until 2020 with a vision until 2050.

During the 2015–2020 period, 140 projects from various programmes and capital sources were implemented to protect and develop coastal forests in 27 of Vietnam's 28 coastal provinces (MARD 2021).

Table 3 provides an overview of mangrove restoration status during 2015–2020 in the Mekong Delta region.

Large-scale mangrove restoration projects in the Mekong Delta include: restoration of mangroves through sustainable shrimp farming and emission reductions in Ca Mau Province in the 2013–2016 period; a GIZ funded project in Kien Giang and Bac Lieu provinces for the restoration and development of coastal protection mangrove forests during 2006–2010; and a World Bank funded project on the protection and development of coastal wetland areas in southern Vietnam during 2002–2007.

MARD (2021) claimed that implementation of these policies has led to the total area of mangroves in Vietnam reaching 256,310 ha in 2020, most of which were in protection forest areas (Table 4).

However, MARD (2021) also pointed out several challenges hindering effective mangrove reforestation and afforestation projects (Table 5).

Table 3. Numbers and status of mangrove restoration projects in the Mekong Delta during 2015–2020

	Total number of projects	Newly planted mangrove (ha)	Mangrove restoration (ha)	Mangrove protection contract area (ha)
Ba Ria Vung Tau	5	265	-	
Ho Chi Minh City	2	156	6	32,446
Tien Giang	4	150	-	-
Ben Tre	4	221	-	4,236
Tra Vinh	11	695	-	10,185
Soc Trang	6	1,864	850	23,426
Bac Lieu	3	208	44	-
Ca Mau	7	1,330	1,162	49,000
Kien Giang	4	832		1,331
Total	**50**			

Source: MARD 2021

Table 4. Mangrove use by area in 2020

Mangrove area	Mangrove forest area (ha)	Categories of mangrove forest by use		
		Special use forest	Protection forest	Production forest
Total	256,310	20,440	164,656	71,214
Forest covered area	150,107	13,291	107,052	29,764
Natural forest	54,751	9,615	40,151	4,984
Plantation	95,356	3,676	66,901	24,779
Forest land/area	106,203	7,149	57,604	41,450
Afforestation (young forest) area	10,802	267	6,862	3,674
Restoration area	1,170	185	826	160
Others	94,230	6,698	49,916	37,616

Source: VNFOREST/MARD 2021

Table 5. Challenges for effective mangrove restoration projects

Challenges	Details
Institutional	• Many projects have been implemented much slower than planned due to poor and untimely guidance from policymakers. • Weak law enforcement has been a problem with poor implementation of afforestation and construction of dikes and embankments as required by laws. • Weak monitoring of newly planted mangroves and mangrove quality. • Statistics and reports on the current status of forest areas, changes and implementation results of coastal afforestation projects are still inadequate, inaccurate and inconsistent, leading to decisions that are not evidence based. • 2015 was the first year of implementing the new Law on Public Investment and Law on Bidding, so many localities are still confused in the appraisal and approval of silvicultural investment projects, bidding organization, and contractor selection, leading to many projects falling behind the required schedules. • Afforestation investment projects are mostly Group C projects, according to the provisions of Government Decree No. 77/2015/ND-CP dated 10 September 2015 on medium-term and annual public investment plans. According to provisions, Group C projects have no more than three years to allocate capital and reach completion; while according to technical guidelines, effective coastal afforestation involves maintenance for four years after planting to ensure forest can become established. In addition, annual investment capital allocation plans for projects are often late, which affects the preparation of seedlings, planting seasons and progress. Consequently, some provinces (Soc Trang, Kien Giang) failed to comply with the public investment plan on time, and had their capital recovered and not re-granted after three years of project implementation, or had to request an extension or transfer investment capital to the next year. • Decree No. 120/2018/ND-CP amended and supplemented a number of articles in Decree No. 77/2015/ND-CP, thereby allowing "For projects under the Targeted Program for Sustainable Forestry Development: time to allocate capital to complete the project according to the silvicultural cycle". However, after three years of implementation (2015–2017), many projects that had not completed the forest care period had their capital recovered and not re-granted, affecting the quality of planted forests. • Investment projects in silviculture works with specific characteristics are often implemented in remote, isolated, disadvantaged areas, and forest land for the implementation of projects is mainly assigned or contracted to households for management and protection, and is combined with production in small, scattered areas. Therefore, only local people can implement afforestation and forest care effectively and save costs (because it is associated with the interests of households). However, according to current regulations, silvicultural investment projects must be tendered, which takes a long time and involves additional costs. This makes it difficult for contractors to implement projects on allocated or contracted land because they must have the consent of the people involved. Consequently, the implementation of silvicultural investment projects in some places has encountered many difficulties and has had to be reviewed and adjusted many times. • Local governments have failed to handle illegal land encroachment in a timely manner to recover land for reforestation in accordance with plans.
Conversion to other land uses	• Issues of changing land uses to other purposes in areas planned for coastal afforestation and encroachment on forest land for farming, fishing and other illegal activities remain complicated, and in some places are becoming increasingly difficult. • Planning for coastal areas often fluctuates due to land-use needs for socioeconomic development, infrastructure construction projects, industrial development, seaports, electricity, tourism and resorts, aquaculture, being allocated on forestry land. • The conversion of forest land for resorts, energy generation and other activities in coastal areas remains complicated.

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Table 5. Continued

Challenges	Details
Technical	• Incorrect site selection is a problem, with areas having inappropriate biophysical conditions being earmarked for afforestation. • The technical capacity of contractors implementing the national programme on afforestation is weak, and surveys, designs, site preparation and seedling production are not closely adhered to. • Scientific research and silvicultural technical guidelines have established initial planting requirements for restoring and protecting coastal forests. However, solutions to support wave breaks and prevent coastal erosion remain limited. Effective silvicultural models for responding to climate change have yet to be established for sites with difficult conditions, such as eroded coastlines, and arid, sandy and rocky areas. There are no guidelines for building organic product chain- or community forest management-based livelihood models to increase community earnings from forest protection and development, or effective solutions to prevent pests, diseases and damage to forests, especially mangroves.
Climate change and biophysical	• Each year, coastal provinces are affected by frequent storms and tropical depressions, high tides, strong winds and sea-level rise, which cause erosion of estuarine shores. • Ba Ria Vung Tau and Binh Thuan provinces lost over 1,700 ha of mangroves due to heat and prolonged drought in 2020. • Some provinces have carried out land reclamation for many years, but have not been able to plant forests (Tien Giang); have had to change project location and design (Phu Yen, Quang Ninh); or even had to halt mangrove afforestation due to poor conditions and erosion (Bac Lieu, Thai Binh). • The afforestation situation is becoming increasingly difficult with alluvial ground being flooded with deep water; land becoming fallow from aquaculture or agricultural cultivation; land being used for salt production; and areas of nutrient-poor sandy soil becoming hot and dry with flying sand and exposed rock.
Pests	• Pests such as barnacles and crustaceans (Isopoda) are causing mangroves to die in Quang Ninh, Thai Binh, Ha Tinh and Binh Dinh provinces, while casuarina leafworms are doing the same in Quang Ninh, Thai Binh, Ha Tinh, Binh Dinh and Tra Vinh.
Pollution	• Environmental pollution from industrial parks or aquaculture areas, along with oil spills and widespread plastic waste hinder the growth and development of forest trees.
Financial	• Investment capital for coastal forest protection and development is still limited. For example, total investments mobilized for Project 120 and National Program 886 for 2016–2020 only met 65.6% of the plan and 32.4% of total approved capital, respectively. • Unit costs for mangrove reforestation and afforestation have increased significantly over time, while budget allocations from central to local governments are limited and not distributed in a timely manner. As the result, most provinces prioritize protecting existing mangrove areas rather than planting new ones. • Although there is significant foreign financial support for mangrove restoration, disbursement is slow and rates are low, with an ODA disbursement rate of only 18.7%. • The mobilization of capital from local budgets and from organizations, enterprises, individuals, etc. remains very low (5.1%) due to the difficult socioeconomic conditions of coastal communities. Meanwhile, forest protection and development projects have not been able to integrate capital for hunger eradication and poverty reduction to combine protection and development goals. • Due to economic pressures, people in coastal areas are encroaching illegally on sites planned for afforestation for aquaculture and fishing.

Source: MARD 2021

4 Changes in mangrove area in the Mekong Delta (2016–2020)

The research team analysed changes in mangrove area at both provincial and district levels.

4.1 Provincial level

The total area of mangroves in the nine provinces (Zone 4) in 2016 was approximately 110,000 ha. This increased slightly to approximately 115,000 ha in 2020. Interviews with both central and provincial stakeholders suggested this slight increase was due to natural regeneration and various mangrove forest plantation efforts. Increases in mangrove cover in Ca Mau and Bac Lieu can be traced back to restoration programmes implemented in the Mekong Delta. The national forest establishment plan from 1998 under Decision 661 also provided the motivation for coastal provinces in the Mekong Delta to maintain and establish mangrove cover in order to play their part in the national plan. In addition, several foreign funded projects to rehabilitate mangrove areas were established in Ca Mau during the 1990s under the Mekong Delta Master Plan (Son et al. 2014). The World Bank Coastal Wetlands Protection and Development Project, for example, planted 25,262 ha of mangroves in Ca Mau Province (IUCN 2012).

In interviews, provincial stakeholders also highlighted other sectoral policies having specific impacts on increasing mangrove forest cover. Examples cited included policies strengthening wastewater management and installing wastewater treatment plants in industrial zones, urban areas and rural areas helping reduce water pollution threats to mangroves. Such policies include Prime Ministerial Decision No. 2066/QD-TTg dated 12 November 2010 approving the master plan on water drainage in the Mekong Delta key economic region until 2020; Prime Ministerial Decision No. 1873/QD-TTg dated 11 October 2010 approving the plan on building solid waste treatment facilities in the Mekong Delta key economic region until 2020; and Prime Ministerial Decision No. 1581/QD-TTg dated 9 October 2009 approving the Mekong Delta region development plan to 2020 and vision to 2050.

Provincial stakeholders also perceived Prime Ministerial Decision No. 18/2009/QD-TTg dated 3 February 2009 approving the master plan on socioeconomic development of Vietnam's sea and coastal areas in the Gulf of Thailand until 2020 to be an important driving force in increasing mangrove area as it prompted the establishment of an emergency response task force for handling oil spill incidents, and controlling discharges from ships in coastal regions, thereby resulting in a less polluted and healthier environment for newly planted mangroves to grow in. This policy also shifted the traditional approach to mangrove management, which relied heavily on state funding, to a more market-based approach and advocated for beneficiary-pays and polluter-pays principles to tackle pollution caused by local enterprises.

Figures 2, 3 and 4 show Ho Chi Minh City and Ca Mau having the highest percentages of mangroves in the Mekong Delta, and four of the region's nine provinces experiencing slight declines in mangrove forest area during 2016–2020.

Figure 4 also shows mangrove forest area in the nine provinces remaining relatively stable during 2016–2020.

According to central and provincial stakeholders, falls in mangrove area in Ba Ria Vung Tau, Tra Vinh, Kien Giang and Ho Chi Minh City were due to riverbank erosion, tide fluctuation, conversion to aquaculture and infrastructure development pressures. Studies show mangrove loss

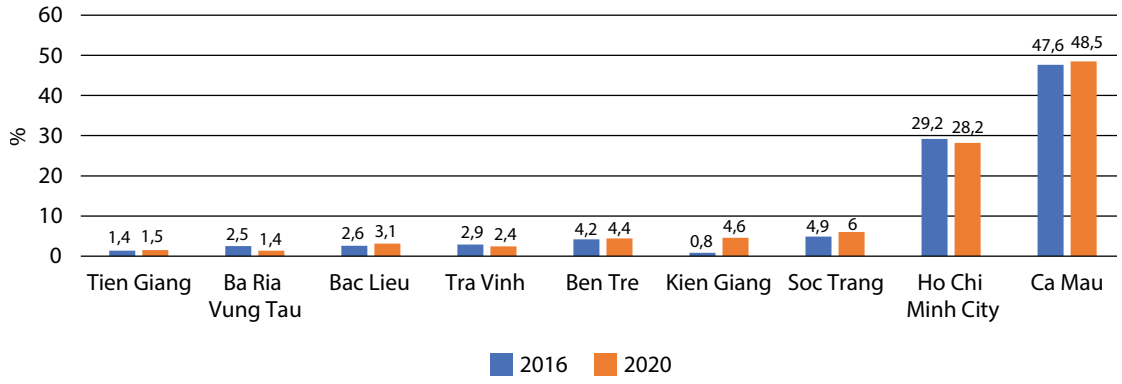

Figure 2. Changes in mangrove forest cover percentages during 2016–2020

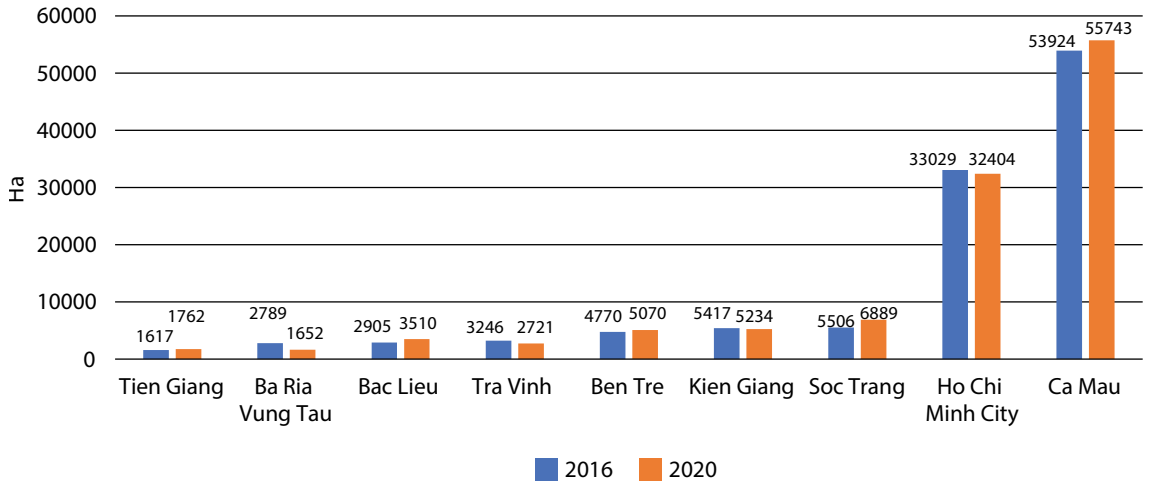

Figure 3. Changes in mangrove forest area during 2016–2020

in recent years being mainly from coastal erosion on the eastern coast of the Mekong Delta and from land conversion (Pham and Populus 2007; Son et al. 2014; Thi et al. 2014). The latter analysed changes in the mangrove shoreline over time along the East Sea and found annual erosion rates varying from 10.28 m to 38.31 m. As in other countries, Vietnam is also experiencing tension between mangrove conservation and aquaculture development (Son et al. 2014). The Government of Vietnam has been encouraging shrimp exports since the early 1990s, and shrimp farming has become widespread in most of the Mekong Delta's coastal provinces. The expansion of aquaculture in the 1990s resulted in the loss of around two-thirds of Vietnam's remaining mangroves by 2000 (Van et al. 2014). Mangrove areas are now small and fragmented, and not uniform in terms of spatial location (Figures 5, 6, 7, 8, 9 and 10).

Figure 11 to 15 maps of the points where the team carried out ground truthing.

MARD (2021) also said coastal erosion is becoming increasingly serious, directly threatening people's lives and properties in riverside and coastal areas, especially in the Mekong Delta, and some other coastal areas. On average, erosion causes the loss of around 370 ha of land and coastal mangrove forests annually. This coastal erosion combined with intensive shrimp farming behind sea dikes contributes to severe land subsidence which is increasing disaster risk for people and communities along the coast.

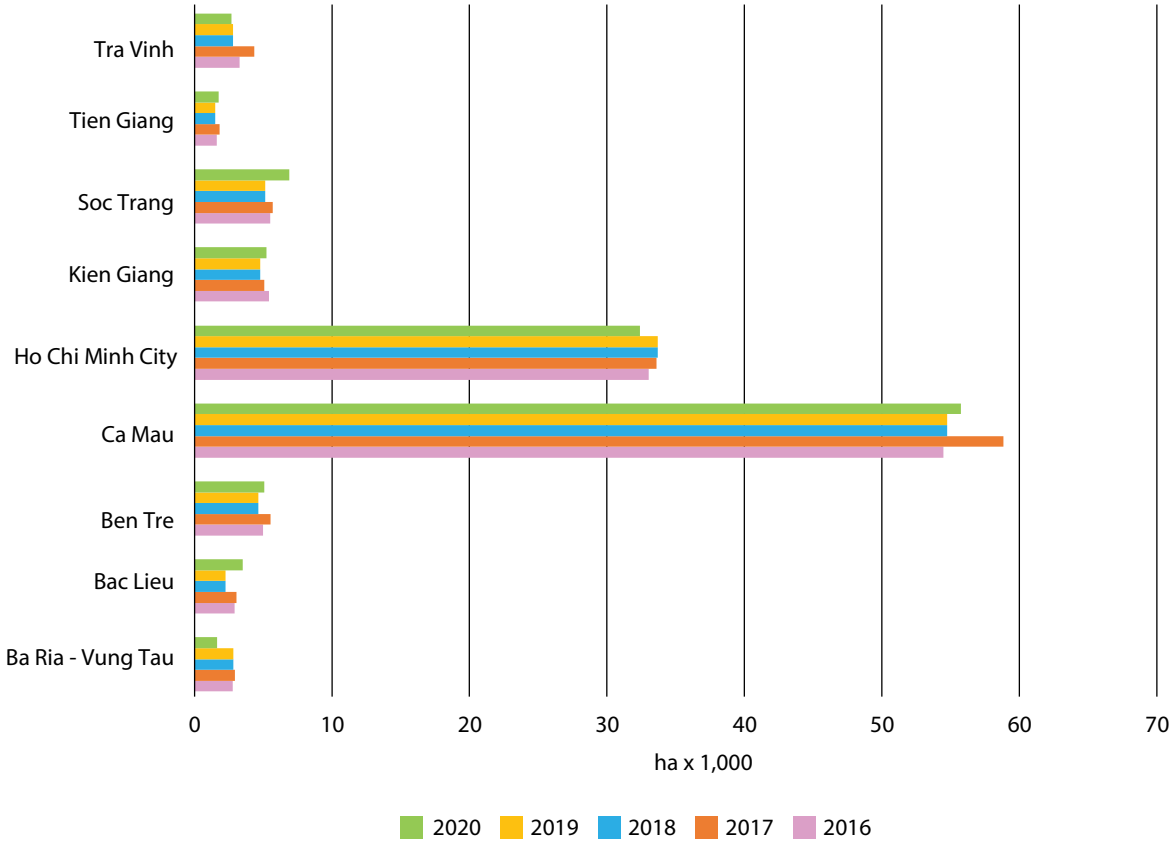

Figure 4. Mangrove forest area from 2016 to 2020 by province

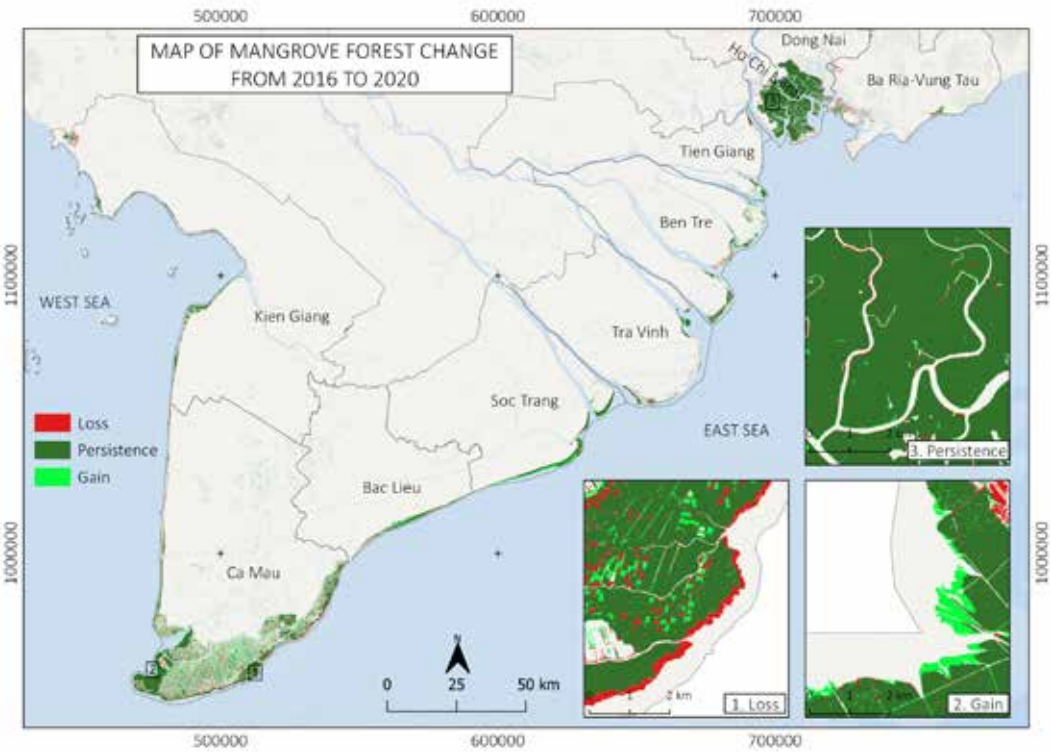

Figure 5. Mangrove forest change from 2016 to 2020

Source: Authors' own analysis (2022)

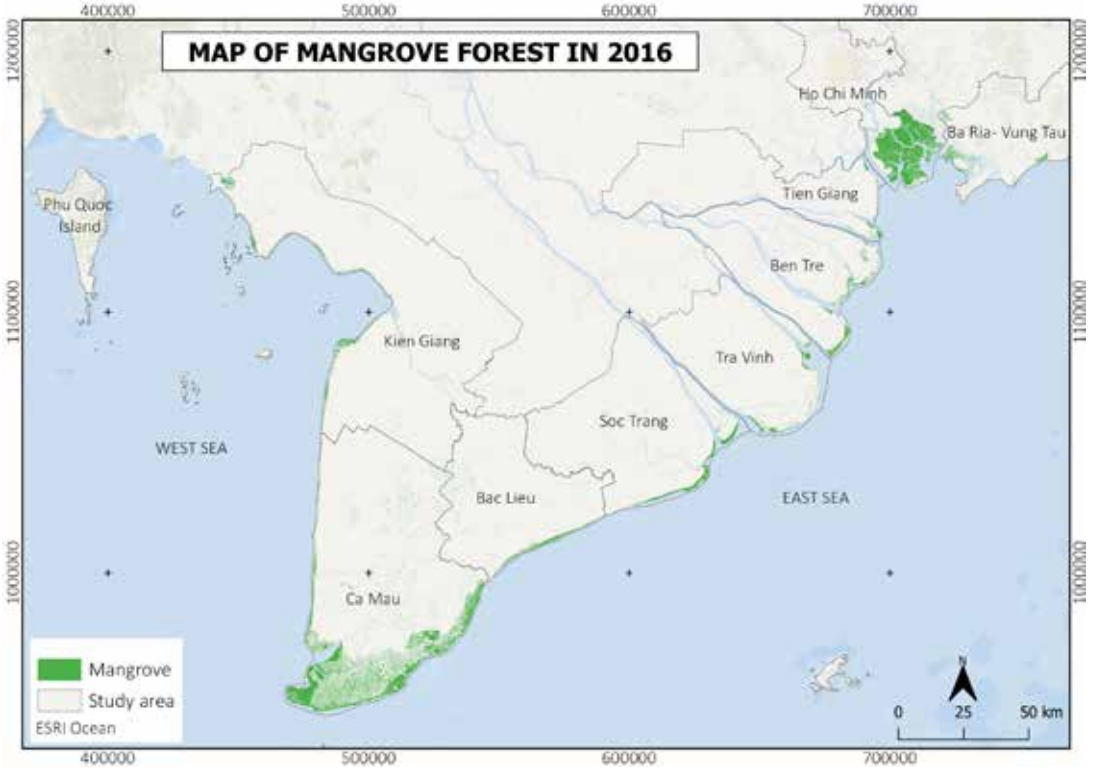

Figure 6. Mangrove forest area in Mekong Delta in 2016

Source: Authors' own analysis (2022)

Figure 7. Mangrove forest area in Mekong Delta in 2017

Source: Authors' own analysis (2022)

Figure 8. Mangrove forest area in Mekong Delta in 2018

Source: Authors' own analysis (2022)

Figure 9. Mangrove forest area in Mekong Delta in 2019

Source: Authors' own analysis (2022)

Figure 10. Mangrove forest area in Mekong Delta in 2020

Source: Authors' own analysis (2022)

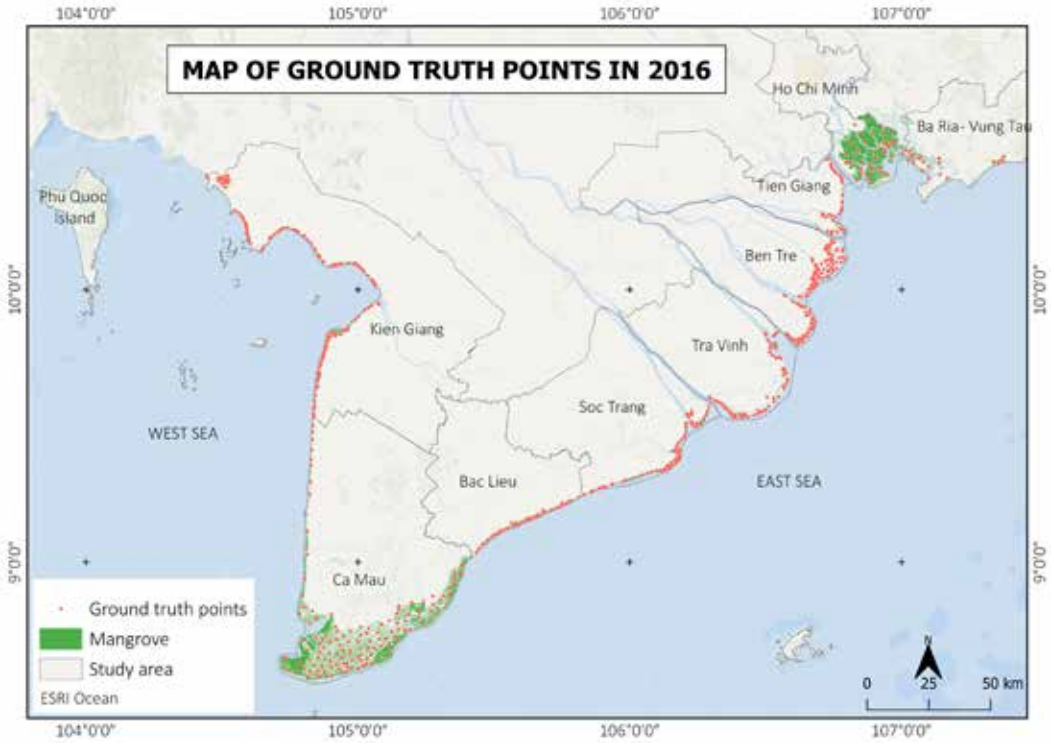

Figure 11. Ground truthing points used in 2016

Source: Authors' own analysis (2022)

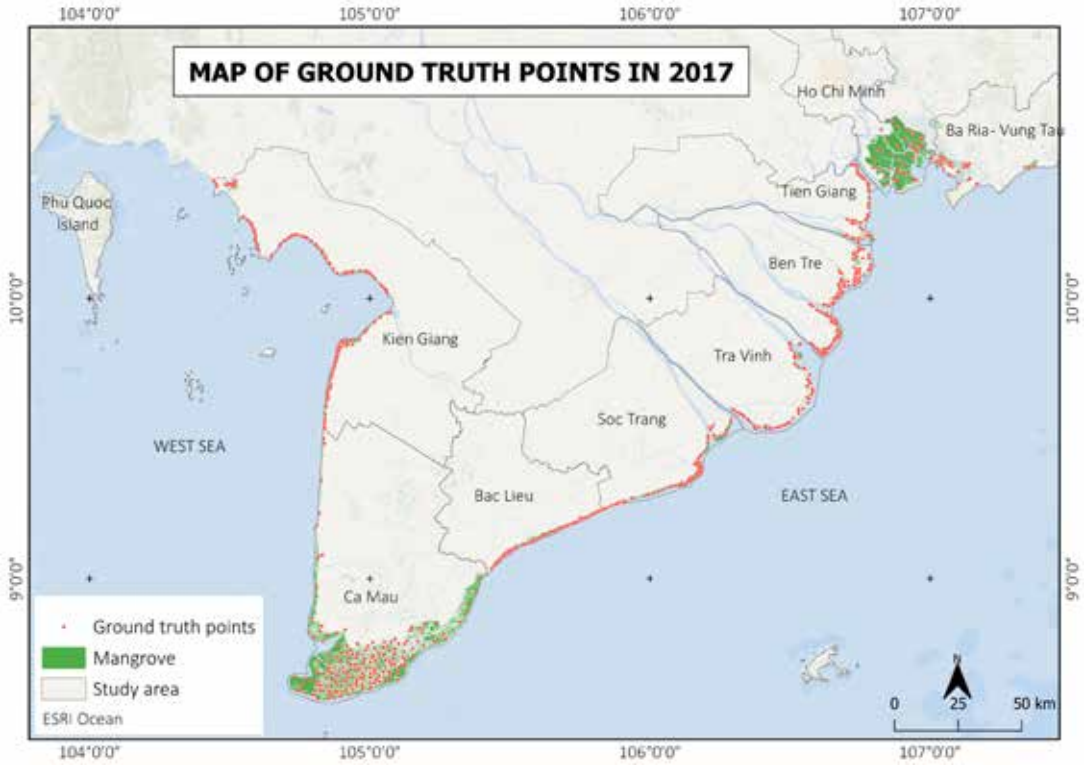

Figure 12. Ground truthing points used in 2017

Source: Authors' own analysis (2022)

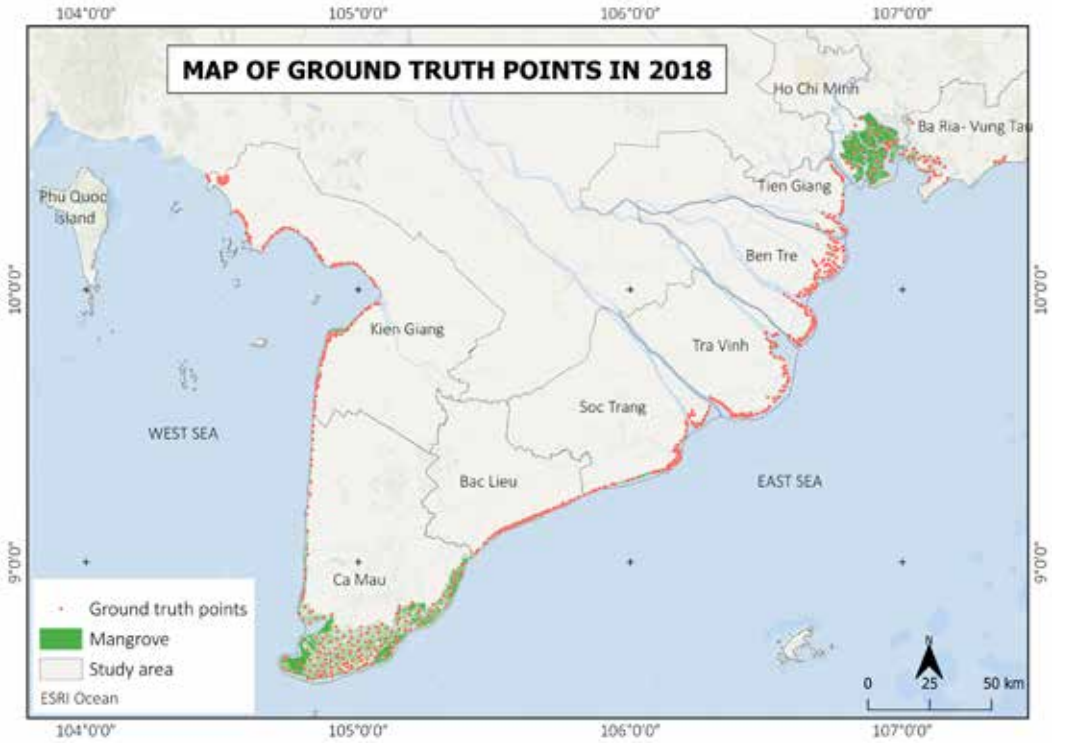

Figure 13. Ground truthing points used in 2018

Source: Authors' own analysis (2022)

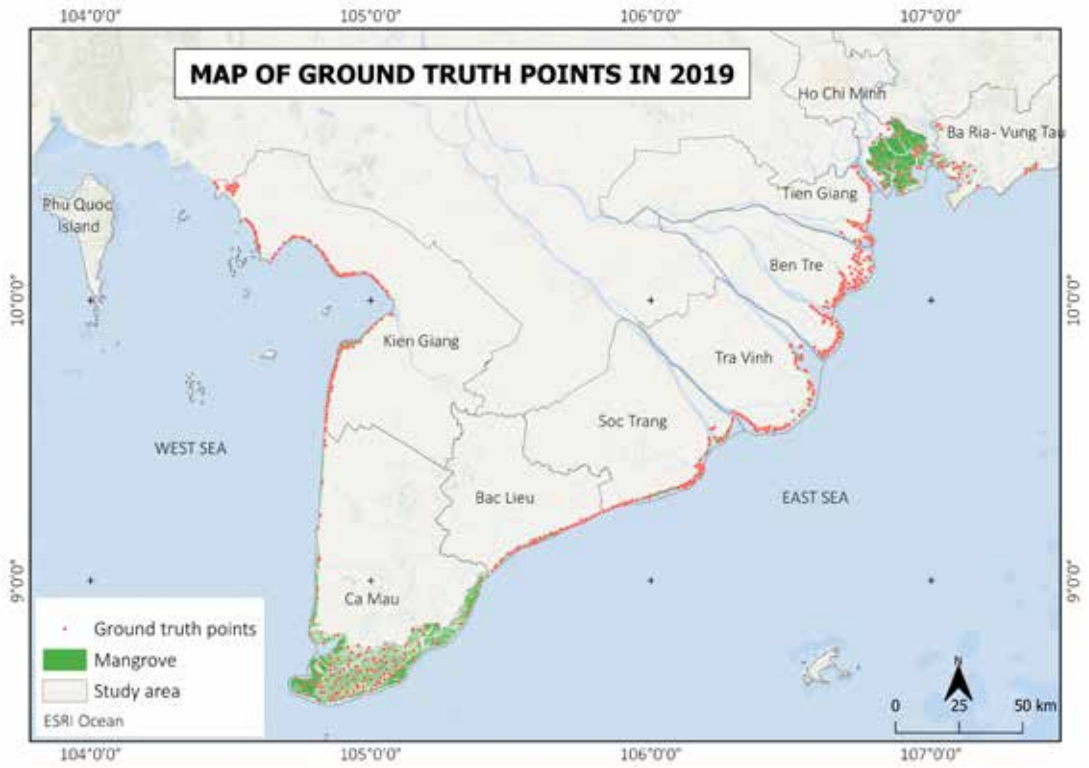

Figure 14. Ground truthing points used in 2019

Source: Authors' own analysis (2022)

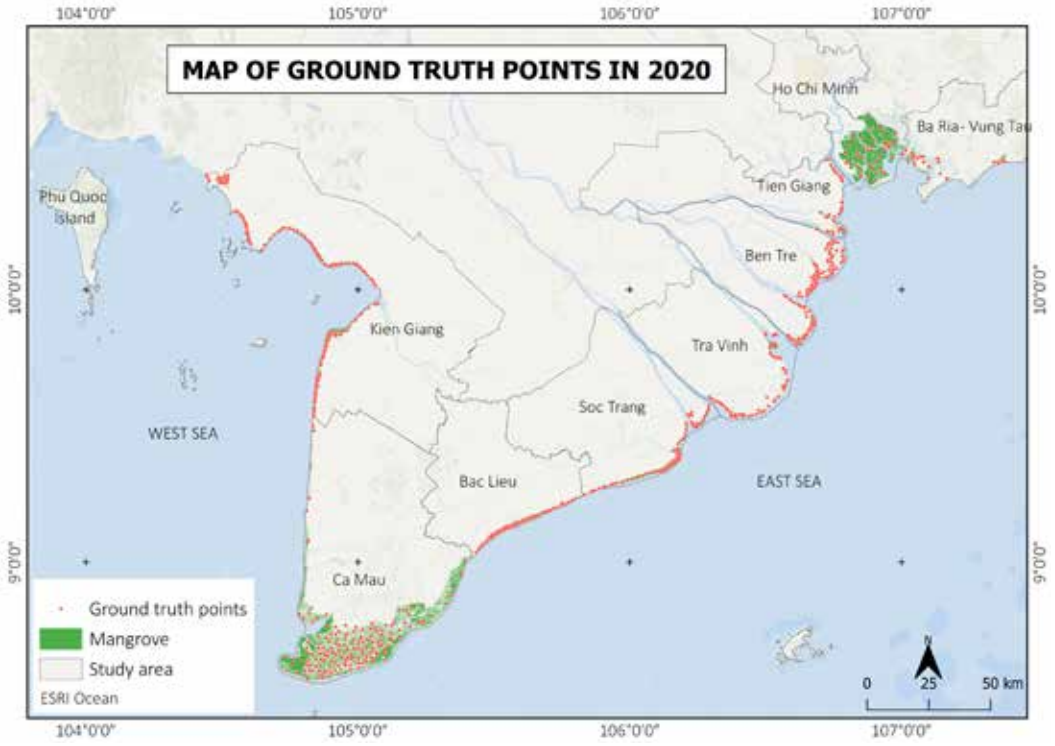

Figure 15. Ground truthing points used in 2020

Source: Authors' own analysis (2022)

Table 6. Changes in mangrove area from 2016 to 2020 by district

Province/District	Mangrove area in 2016 (ha)	% of land area in 2016	Mangrove area in 2020 (ha)	% of land area in 2020	Change in area (ha) from 2016 to 2020	% change in mangrove area from 2016 to 2020
Ba Ria Vung Tau						
Ba Ria City	140.1	1.5	57.5	0.6	-82.6	-59.0%
Xuyen Moc	213.5	0.3	214.8	0.3	1.3	0.6%
Dat Do	325.0	1.7	260.0	1.4	-65.0	-20.0%
Vung Tau	523.0	3.7	250.7	1.8	-272.3	-52.1%
Tan Thanh	1,587.9	4.6	869.3	2.5	-718.6	-45.3%
Subtotal	**2,789.5**	**2.0**	**1,652.3**	**1.2**		
Ho Chi Minh City						
Can Gio	33,028.6	48.2	32,403.6	47.3	-625.02	-2.0%
Subtotal	**33,028.6**	**48.2**	**32,403.6**	**47.3**		
Tien Giang						
Tan Phu Dong	975.7	6.0	1,148.9	7.0	173.2	17.8%
Go Cong Dong	641.3	2.7	613.6	2.5	-27.7	-4.3%
Subtotal	**1,617.0**	**4.0**	**1,762.5**	**4.4**		
Ben Tre						
Binh Dai	1,456.5	3.6	1,847.3	4.6	390.8	26.8%
Ba Tri	1,027.6	2.9	918.5	2.6	-109.1	-10.6%
Thanh Phu	2,286.1	5.5	2,303.5	5.5	17.4	0.8%
Subtotal	**4,770.1**	**4.1**	**5,069.2**	**4.3**		
Tra Vinh						
Chau Thanh	224.1	0.6	197.9	0.5	-26.3	-11.7%
Duyen Hai District	1,619.9	6.0	1,195.4	4.4	-424.5	-26.2%
Duyen Hai Town	411.3	2.0	261.4	1.3	-149.9	-36.4%
Cau Ngang	991.2	3.0	1,066.1	3.3	74.9	7.6%
Subtotal	**3,246.5**	**2.7**	**2,720.8**	**2.3**		
Soc Trang						
Cu Lao Dung	1,472.0	5.8	1,515.3	6.0	43.3	2.9%
Tran De	736.0	1.9	696.3	1.8	-39.7	-5.4%
Vinh Chau	3,298.2	6.8	4,677.5	9.6	1,379.3	41.8%
Subtotal	**5,506.2**	**4.9**	**6,889.1**	**6.1**		
Bac Lieu						
Bac Lieu City	338.2	2.3	389.9	2.6	51.7	15.3%
Hoa Binh	1,408.2	4.1	1,953.8	5.7	545.7	38.8%
Dong Hai	1,158.9	2.2	1,166.6	2.2	7.8	0.7%
Subtotal	**2,905.3**	**2.8**	**3,510.4**	**3.4**		

continued on next page

Table 6. Continued

Province/District	Mangrove area in 2016 (ha)	% of land area in 2016	Mangrove area in 2020 (ha)	% of land area in 2020	Change in area (ha) from 2016 to 2020	% change in mangrove area from 2016 to 2020
Ca Mau						
Dam Doi	5,505.5	6.7	5,115.3	6.3	-390.2	-7.1%
Nam Can	11,844.8	24.9	12,215.9	25.7	371.1	3.1%
Ngoc Hien	32,039.2	45.9	34,092.9	48.8	2,053.7	6.4%
Phu Tan	2,930.4	6.7	3,058.9	7.0	128.6	4.4%
Tran Van Thoi	1,136.1	1.6	881.8	1.3	-254.3	-22.4%
U Minh District	467.9	0.6	378.3	0.5	-89.7	-19.2%
Subtotal	**53,923.8**	**13.8**	**55,743.1**	**14.3**		
Kien Giang						
An Bien	1,083.0	2.7	1,185.7	3.0	102.7	9.5%
An Minh	1,698.0	2.9	1,710.5	2.9	12.5	0.7%
Hon Dat	1,039.1	1.0	1,098.1	1.1	59.0	5.7%
Kien Luong	662.6	1.4	648.2	1.4	-14.5	-2.2%
Ha Tien	934.1	8.8	575.6	5.4	-358.4	-38.4%
Rach Gia City	0	0.0	16.3	0.2	16.3	100.0%
Subtotal	**5,416.7**	**2.0**	**5,234.4**	**1.9**		
Total	**113,203.7**	**8.3**	**114,985.1**	**8.5**	**1,781.5**	**1.6%**

4.2 District level

Mangrove area and percentages of mangrove cover by district are presented in Table 6.

Gains and losses in mangrove forest area were found in all provinces, but the most significant losses were in districts in Ba Ria Vung Tau, Tra Vinh and Ca Mau. Consultations with provincial stakeholders revealed the main reasons for mangrove forest cover gain in Ngoc Hien and Nam Can being the presence of international and national mangrove restoration projects and payments for mangrove environmental services in these areas. In interviews, stakeholders put losses of mangroves in Vung Tau and Kien Giang districts down to coastal erosion and conversion for other land uses. Examples cited were the industrial zone in Duyen Hai District, Tra Vinh Province; housing development in Ha Tien City, Kien Giang Province; and construction and operation of a coal-fired power plant in Duyen Hai District, Tra Vinh Province. National and provincial stakeholders also pointed out numerous sectoral policies with major impacts on mangroves, saying inconsistencies had led to mangrove loss (Table 7).

A large part of the decrease in mangrove cover is due to fast and persistent erosion on the eastern coast of the Mekong Delta. Natural colonization and progression of mangroves on accreted sediments on the western side as well as restoration efforts have compensated in part for the mangrove loss on the eastern side. Recently, a provincial regulation in Ca Mau Province changed the minimum area of tree cover in mangrove-shrimp farming systems to 70% for pond areas greater than five hectares, 60% for pond areas of three to five hectares, and 50% for pond areas smaller than three hectares. This has contributed to increases in mangrove area in the province.

Table 7. Stakeholder perceptions on sectoral policies impacting mangroves in the Mekong Delta

Sector	Specific policies	Impact on mangroves
Water	**Prime Ministerial Decision No. 2065/QD-TTg dated 12 November 2010** approving the master plan on water supply in the Mekong Delta key economic region until 2020	The reorganization of the flows of important waterways, which may cause erosion and lead to forest loss
	Prime Ministerial Decision No. 1581/QD-TTg dated 9 October 2009 approving the Mekong Delta regional development plan until 2020 with a vision until 2050	
Infrastructure development	**Prime Ministerial Decision No. 1581/QD-TTg dated 9 October 2009** approving the Mekong Delta regional development plan until 2020 with a vision until 2050	The building of coal-fired/diesel-fired power plants totalling 20,800 MW has led to mangrove loss
	Prime Ministerial Decision No. 11/2012/QD-TTg dated 10 February 2012 approving the master plan on development of transport in the Mekong Delta key economic region until 2020, with a vision until 2030	The establishment of new seaports, development of shipbuilding industries, and expansion of road transport systems in coastal regions have led to significant loss of mangroves
	Prime Ministerial Decision No. 939/QD-TTg dated 19 July 2012 approving the master plan on socioeconomic development of the Mekong Delta until 2020	
	Prime Ministerial Decision No. 548/QD-TTg dated 4 April 2013 on adjusting direction, tasks and plans on transport infrastructure development in the Mekong Delta until 2015, with a vision until 2020	
	Prime Ministerial Decision No. 245/QD-TTg dated 12 February 2014 approving the master plan on socioeconomic development of the Mekong Delta key economic region until 2020, with a vision until 2030	
Economic development	**Prime Ministerial Decision No. 2270/QD-TTg dated 21 November 2013** issuing the plan implementing the conclusion number 281KL/TW dated 14 August 2012 of the Politburo of the Vietnamese Communist Party on the directions, tasks and solutions for the socioeconomic development and ensuring security and national defence of the Mekong Delta until 2020	
Agriculture development	**Prime Ministerial Decision No. 939/QD-TTg dated 19 July 2012** approving the master plan on socioeconomic development of the Mekong Delta until 2020	The policy's approval and encouragement of aquaculture expansion in brackish water areas and intensive agriculture development has led to mangrove loss

5 Mapping potential areas for mangrove restoration

5.1 Potential areas for mangrove restoration according to government planning

According to MARD (2021), the nine Mekong Delta study provinces have large areas designated for mangrove restoration and afforestation, particularly in areas that are allocated for forestry purposes but either currently without forest cover or having newly planted forests with low survival rates that could be enriched with additional planting (Table 8). Of these provinces, Ca Mau and Tra Vinh have the largest potential areas for mangrove restoration. Table 8 also shows the largest area designated through government planning for mangrove restoration in the Mekong Delta region being inside production forest.

Provincial authorities in the nine study provinces have also set their own mangrove reforestation and restoration targets for 2021–2025. It is clear that their targets focus mainly on protecting existing mangroves through mangrove protection contracts, while their mangrove restoration planting targets are quite modest (Table 9).

Table 8. Land in coastal areas in the Mekong Delta allocated for forestry purposes, but currently without forest or having newly planted forest

		Total		Special use forest		Protection forest		Production forest	
	Total (ha)	Newly planted forest	Land without forest	Newly planted forest	Land without forest	Newly planted forest	Land without forest	Newly planted forest	Land without forest
Ba Ria Vung Tau	5,433.36	893.50	4,539.86	576.11	1,410.32	189.85	3,118.15	127.54	11.39
Ho Chi Minh City	1,972.29	17.60	1,954.69			17.60	1,954.69	0.00	
Tien Giang	5,746.33	158.83	5,587.50			158.83	2,723.02	0.00	2,864.48
Ben Tre	3,955.46	204.53	3,750.93	7.45	677.16	35.37	1,983.11	161.71	1,090.66
Tra Vinh	12,575.25	545.02	12,030.23			545.02	12,030.23	0.00	
Kien Giang	7,368.13	533.06	6,835.07		551.90	453.04	5,712.73	80.02	570.44
Soc Trang	5,502.58	1,333.28	4,169.30			1,333.28	4,169.30	0.00	
Bac Lieu	1,100.84	85.45	1,015.39		31.33	79.21	984.06	6.24	
Ca Mau	54,670.34	7,451.69	47,218.65	110.54	5,831.79	2,873.86	13,100.64	4,467.29	28,286.22

Source: MARD 2021

Table 9. Planned coastal forest protection and development for 2021–2025 by province

Province/City	Newly planted mangrove area in protection forest and special use forest (ha)	Mangrove forest enrichment and restoration in protection and special use forests (ha)	Mangrove protection contract area in protected and special use forest (ha)
Ba Ria Vung Tau	25	0	17,696
Ho Chi Minh City	200	0	19,396
Tien Giang	80	0	1,027
Ben Tre	200	n/a	4,000
Tra Vinh	379	200	5,398
Soc Trang	400	150	49,901
Bac Lieu	400	0	5,654
Ca Mau	814	800	3,168
Kien Giang	564	400	31,346

Source: MARD 2021

Box 3. Key ODA projects for mangrove restoration during 2021–2025 (MARD 2021)

The ICRSL project Integrated Climate Resilience and Sustainable Livelihoods in the Mekong Delta (WB9) has components on adaptation to changes in salinity and coastal area protection in the Mekong Delta peninsula. The project is being implemented in coastal provinces such as Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau and Kien Giang. Components 3 and 4 of the project include afforestation activities, supporting forest-shrimp farming towards sustainability, and adaptation to climate change combined with coastal protection works. The total cost of components 3 and 4 is around USD 209.814 million.

Component 2 of the GCF project Building Resilience to the Impacts of Climate Change for Vulnerable Coastal Communities in Vietnam has an afforestation component, which is being implemented in Nam Dinh, Thanh Hoa, Quang Nam and Quang Ngai provinces. The GCF project was originally implemented in the 2018 to 2021 period, but will continue to undertake 77.06 ha of new planting (9.00 ha in Nam Dinh and 68.06 ha in Ca Mau); and 590.54 ha of additional planting (172.31 ha in Nam Dinh, 418.23 ha in Ca Mau) and 1,389 ha of forest protection in Ca Mau. Project costs for 2021 were around VND 100 billion.

The Combining Coastal Protection and Mangrove Belt Restoration in Kien Giang and Ca Mau Provinces project uses ODA loans from the Government of the Federal Republic of Germany. The 2018 approved project is an umbrella project, where Kien Giang and Ca Mau provinces are allocated around EUR 7.5 million each without having to borrow again. Activities include contracting for forest protection (1,000 ha in Kien Giang); planting and rehabilitating forests on 1,800 ha (1,500 ha in Kien Giang and 300 ha in Ca Mau); planting 5 million scattered trees in Kien Giang; and building two afforestation models on eroded soil (one in each province).

According to the KfW office, **another project is being proposed for implementation in four provinces: Kien Giang, Ca Mau, Bac Lieu and Soc Trang;** with a proposed loan amount of EUR 30 million, EUR 9.5 million of which is non-refundable. Specific areas and activities in each province have yet to be determined.

The project **Improving Resilience, Developing Sustainable and Cohesive Human Settlements and Ecology through Small-scale Infrastructure Interventions in the Coastal Areas of the Mekong Delta** applied for funding from the Adaptation Fund, which was approved in July 2020 and is being implemented in Bac Lieu and Tra Vinh provinces with investment capital of USD 6.3 million.

To meet these targets, five large-scale ODA projects with international financial support are underway during 2021–2025 (Box 3).

5.2 Potential for mangrove restoration based on spatial analysis and stakeholder knowledge

According to most provincial stakeholders, natural regeneration of mangroves is likely to occur in areas that have experienced deforestation. Figure 16, which shows a map of areas with mangrove restoration potential through natural regeneration post-deforestion, also reflects where mangroves were not present in 2016, but were present in 2020, due to the expansion of mudflats and natural regeneration. The total area with potential for restoration is approximately 4,000 ha distributed across several districts, as shown in Figure 17.

Interviews with key informants, and remote sensing analysis results indicated production forests where mangrove-shrimp integrated farming systems are taking place being other potential areas for mangrove restoration. Recent provincial regulation in Ca Mau Province has changed the minimum area of tree cover in mangrove-shrimp farming systems to 70% for pond areas greater than five hectares, 60% for pond areas of three to five hectares, and 50% for pond areas smaller than three hectares. However, as most mangrove-shrimp farms have yet to achieve the compulsory tree cover percentages required by the regulation, and a payment for mangrove environmental services programme is in place which pays VND 500,000 per hectare of mangroves, there is an opportunity for mangrove restoration by pond owners to meet their obligations as well as financial motivation for them to do so. Figure 18 shows mangrove-shrimp pond areas that might be a potential sites for mangrove reforestation and enrichment, while Figure 19 shows by district the area of mangrove-shrimp ponds by district that could be potential sites for future mangrove restoration.

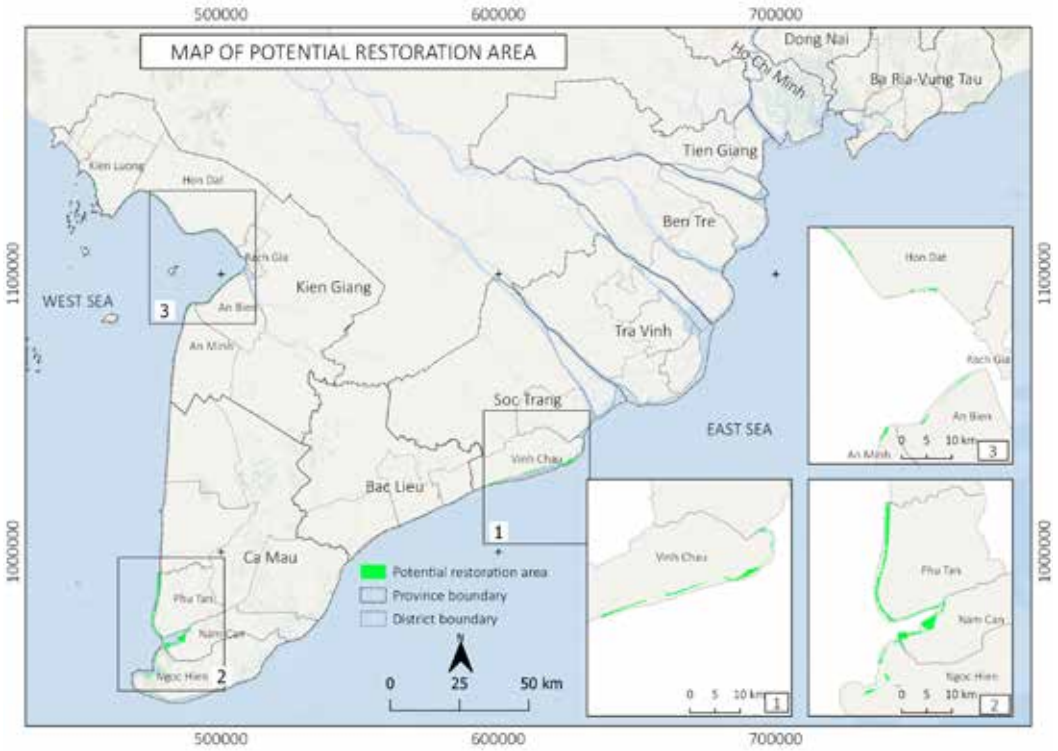

Figure 16. Map of areas with mangrove restoration potential through post-deforestation natural regeneration

Source: Authors own analysis 2022

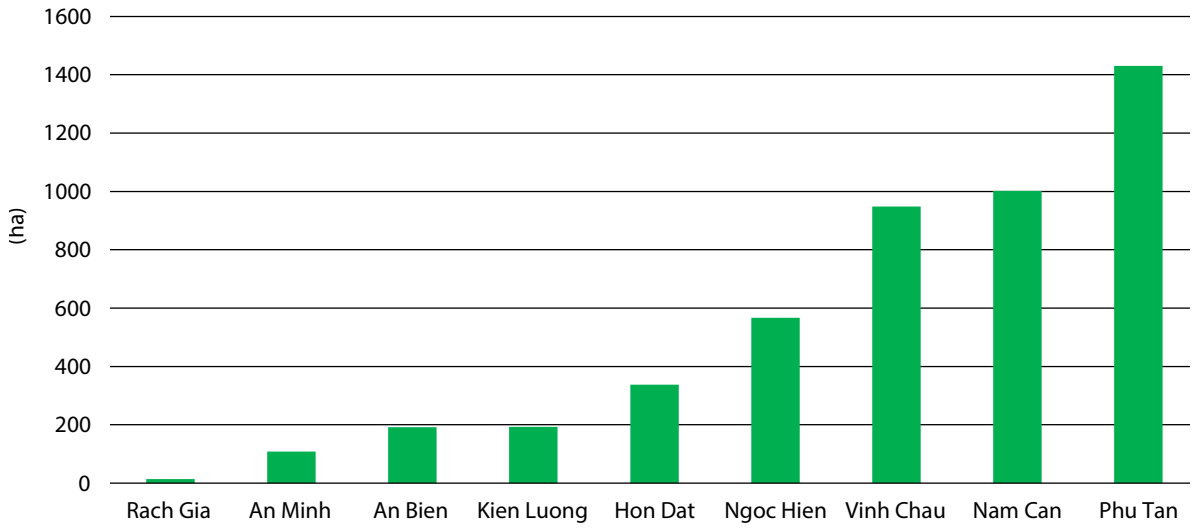

Figure 17. Distribution of areas with mangrove restoration potential through post-deforestation natural regeneration

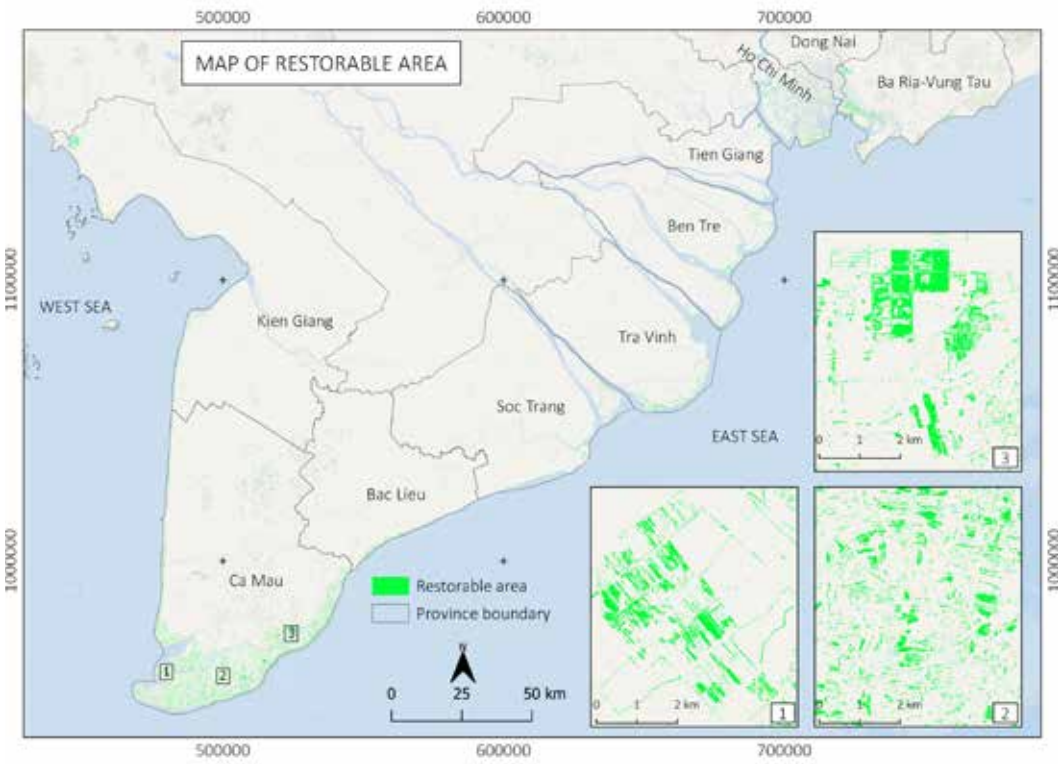

Figure 18. Map of potential mangrove restoration areas in mangrove-shrimp pond systems

Source: Authors' own analysis 2022

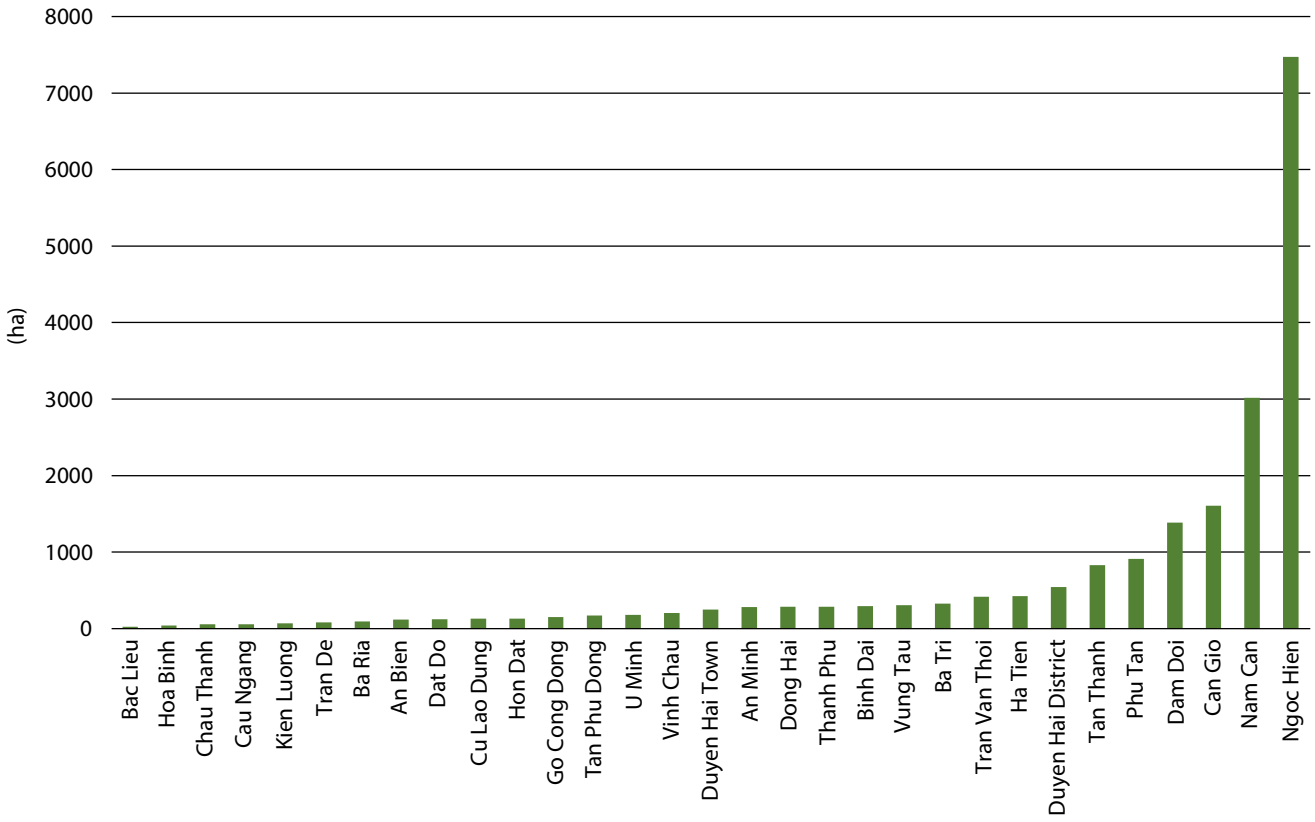

Figure 19. Potential area for mangrove restoration in mangrove-shrimp farms by district

5.3 Stakeholder assessments of potential mangrove restoration sites

After producing maps of potential mangrove restoration sites based on government policies and land-use planning, potential sites for natural regeneration where mangrove deforestation has occurred, and potential sites in mangrove-shrimp pond aquaculture areas, participatory mapping exercises were carried out with local stakeholders to validate these maps with local knowledge. Due to COVID-19 restrictions, we were only able to carry out participatory mapping in four of the nine study provinces: Ca Mau, Kien Giang, Soc Trang, and Can Gio/Ho Chi Minh City. However, as discussed in the previous section, because Ca Mau and Ho Chi Minh have the largest areas of mangrove forest, our research findings are still highly relevant to the Mekong Delta context. Our consultations with provincial stakeholders revealed that despite study areas having potential for mangrove restoration, levels of potential vary between them. Local stakeholders differentiated potential mangrove restoration areas into five categories; those with high potential, medium potential, low potential, no potential and uncertain potential.

As local stakeholders explained, their assessments of mangrove restoration potential were based on a set of criteria:

- **Environmental and ecological condition**: 100% of stakeholders consulted used this criteria to assess the mangrove restoration potential of different sites. All stakeholders pointed out that mangrove restoration is a challenging task and requires careful consideration of hydrological, coastal squeeze, tidal and soil conditions. In the absence of suitable enabling conditions, mangrove restoration is unlikely to be successful.
- **Land-use and socioeconomic planning**: Approximately 70% of stakeholders used this criteria to assess the mangrove restoration potential of different sites. These stakeholders highlighted that despite large areas with potential for mangrove restoration, many of these areas are at risk of being converted to other land uses to serve national and provincial development priorities. Consequently, in determining potential and realistic sites for

mangrove restoration, these factors need to be taken into account. While we were able to identify past and ongoing policies that might influence the area of mangrove forests in the Mekong Delta, participatory mapping with local stakeholders also integrated upcoming and planned future polices to provide higher accuracy in terms of projections for the future.

- **Political commitment**: During interviews, most provincial authorities said short-term economic gains are often prioritized as the total economic value of mangroves is not fully recognized, and mangroves are often the easiest places to convert to other land uses. Whether potential sites for mangrove restoration can actually become successful mangrove restoration sites is dependent on strong political commitment from provincial leaders.
- **Financial resources and capacity**: Mangrove restoration is not cheap, and requires sufficient funding for planting trees, selecting appropriate species, planting in the right places, and monitoring and protecting newly planted trees. Local stakeholders analysed potential mangrove protection sites based on their existing funding and potential to secure the financial resources necessary to carry out works effectively.
- **Experts' own experiences**: Most of the experts we consulted had been working in the forestry sector and been involved in mangrove restoration over the last two decades. These experts used their personal experience to judge which places have potential for mangrove restoration.

Participatory mapping results are presented in Figure 20, while more detailed analyses carried out by stakeholders to categorize mangrove restoration potential in different study sites are presented in the subsequent figures.

Mui Ca Mau National Park is a special use forest and it is located in four communes: Dat Mui, Vien An, Lam Hai and Dat Moi. This is an area with great potential for forest restoration, especially in the mudflats that have formed on the western side, which facilitate natural regeneration. In addition, the area has concrete dikes, which also allow natural regeneration. However, the eastern part of the park has experienced severe erosion, meaning it is unlikely to be suitable for mangrove forest restoration in the future.

The above figures and results from consultations with stakeholders show several key patterns:

- Most provinces having low or medium restoration potential.
- Areas with the highest potential being those with mudflats because of their high natural regeneration capacity. This was the opinion of 80% of surveyed stakeholders.
- Despite current policies and land-use planning indicating production forests having potential for mangrove restoration, stakeholders felt such areas have low or no restoration potential where aquaculture is taking place, as there are no strong financial incentives or sustainable livelihood models that encourage farmers to increase the area of forest in and around their shrimp ponds.
- Fifty percent of surveyed stakeholders also ranked areas with mudflats or permanent embankments as having the highest potential for mangrove restoration.
- Seventy percent of surveyed stakeholders cited erosion as the main reason for many areas having either low or no potential for mangrove restoration.

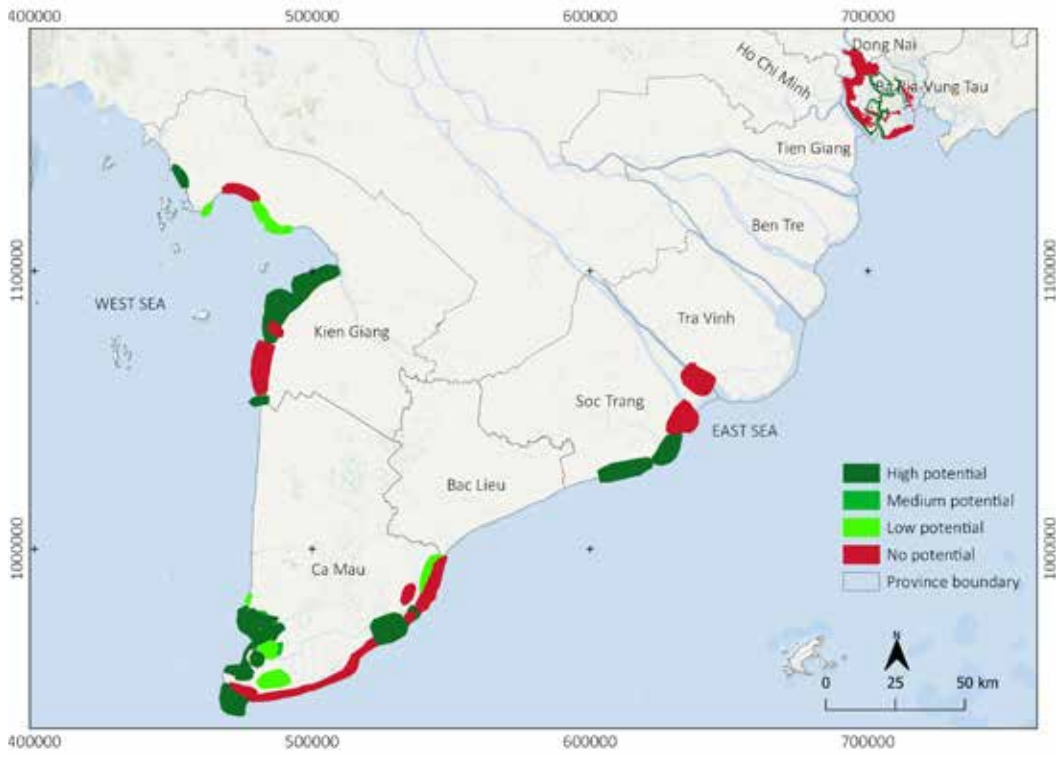

Figure 20. Participatory mapping results of mangrove restoration potential in the study provinces

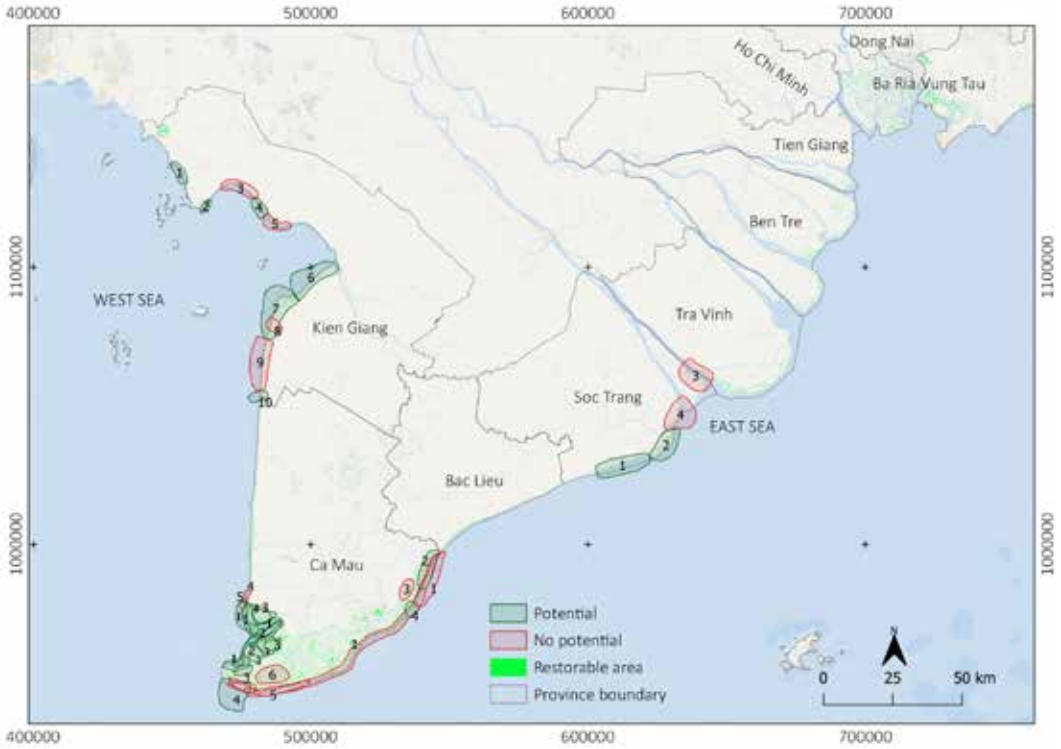

Figure 21. Reasons for different levels of mangrove restoration in the study areas

Legend: 1: Natural regeneration (accretion/mudflats); 2: Existing dike; 3: Poor performance of new mangrove plantation; 4: Fulfils the ratio of 60:40 for mangroves and shrimp ponds as required by national regulations; 5: Failure from previous projects on mangrove restoration; 6: Based on experience; 7: Erosion; 8: Farmers do not want to plant more mangroves; 9: Seaport planning; 10: Could not find bare land to plant.

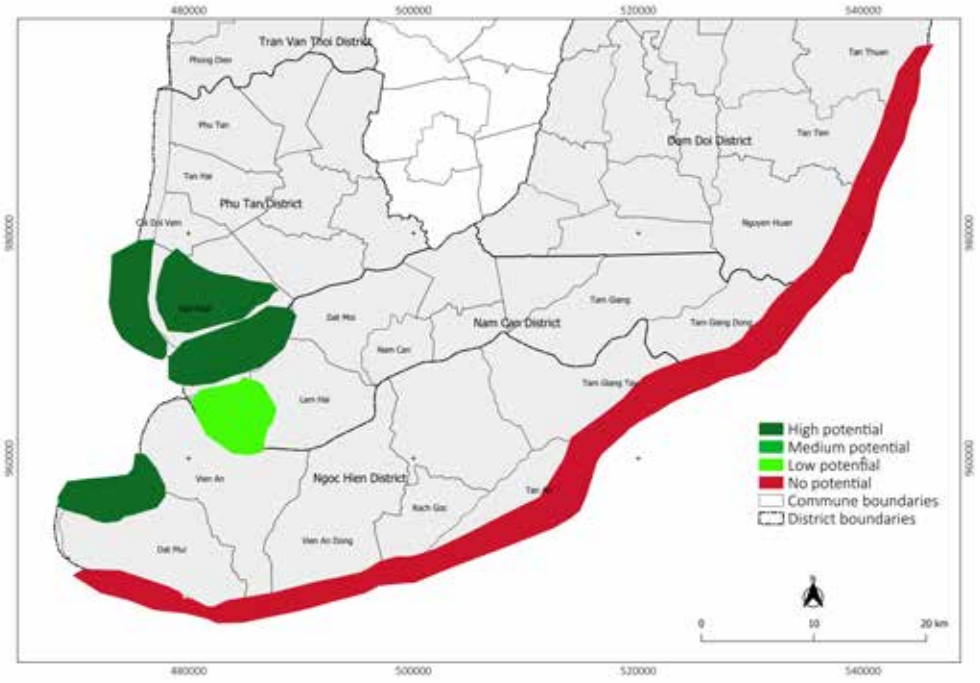

Figure 22. Participatory mapping results of mangrove restoration potential in Ca Mau Province

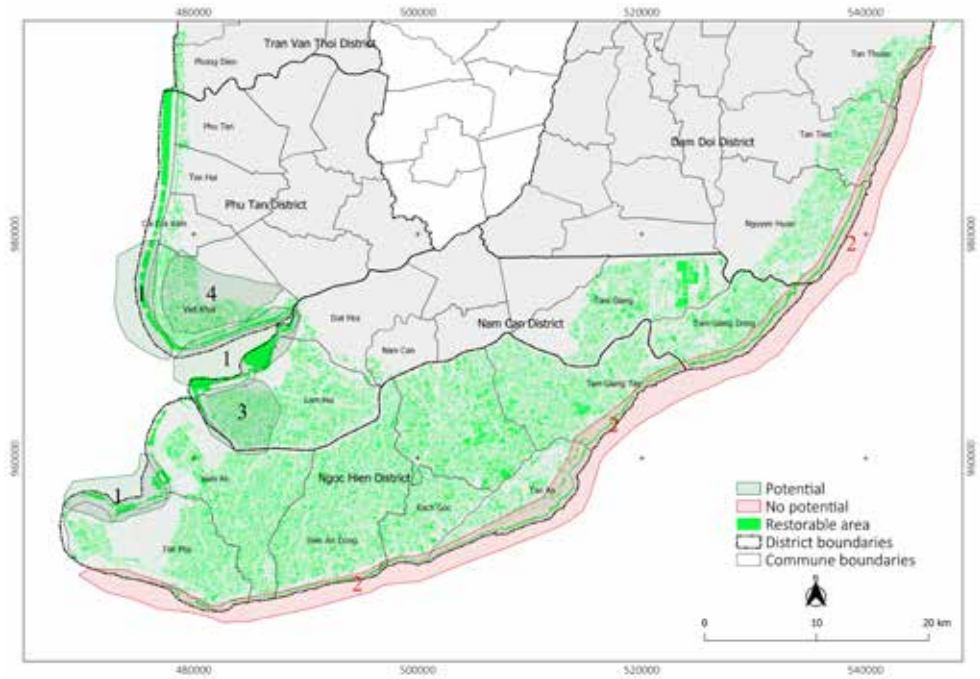

Figure 23. Reasons for differences in mangrove restoration potential in areas in Ca Mau Province

Legend: 1: Natural regeneration (accretion/mudflats); 2: Existing dike; 3: New mangrove plantation; 4: Fulfils the ratio of 60:40 for mangroves and shrimp ponds as required by national regulations.

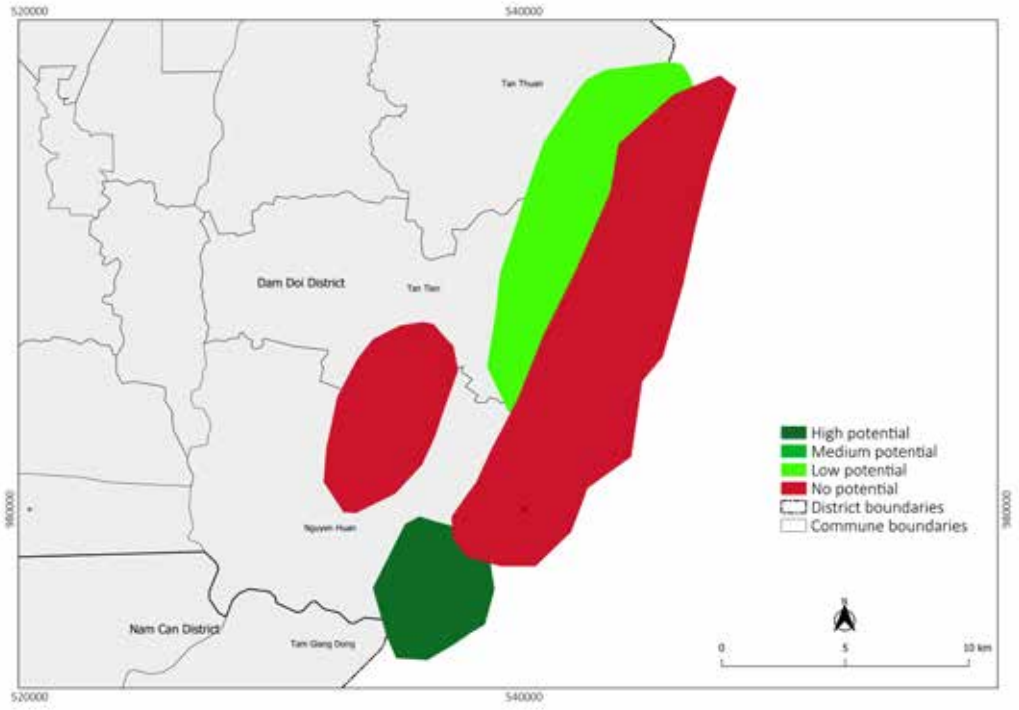

Figure 24. Restoration potential in Dam Doi District, Ca Mau Province

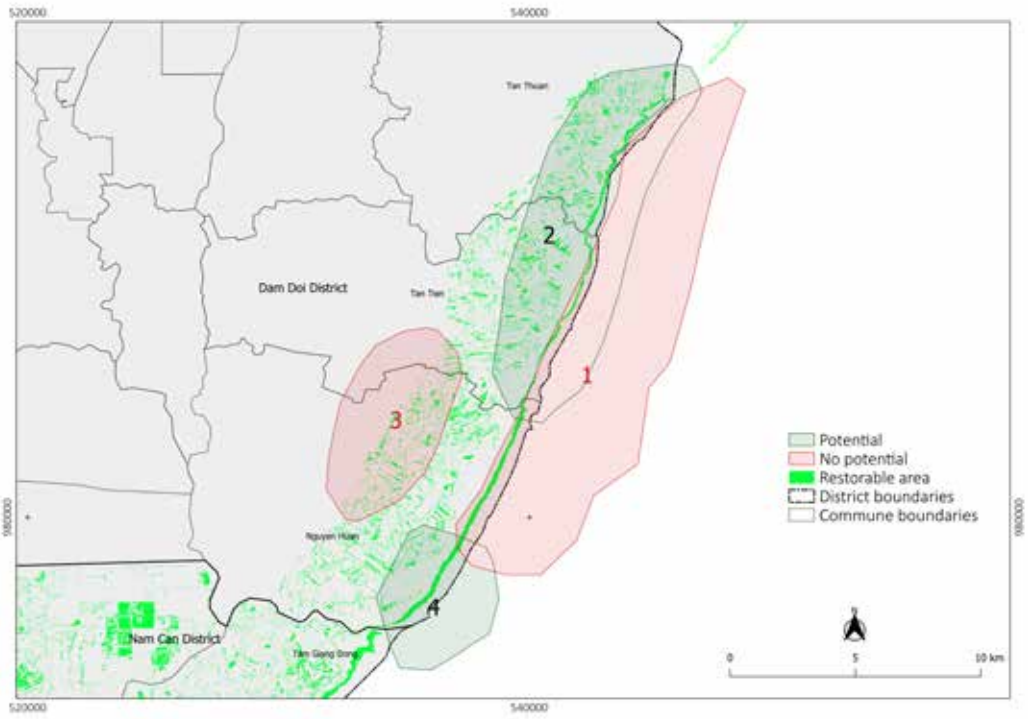

Figure 25. Reasons for differences in mangrove restoration potential in areas in Dam Doi District, Ca Mau Province

Legend: 1: Low potential for natural regeneration; 2: Existing dike; 3: Poor performance of new mangrove plantation; 4: Fulfils the ratio of 60:40 for mangroves and shrimp ponds as required by national regulations.

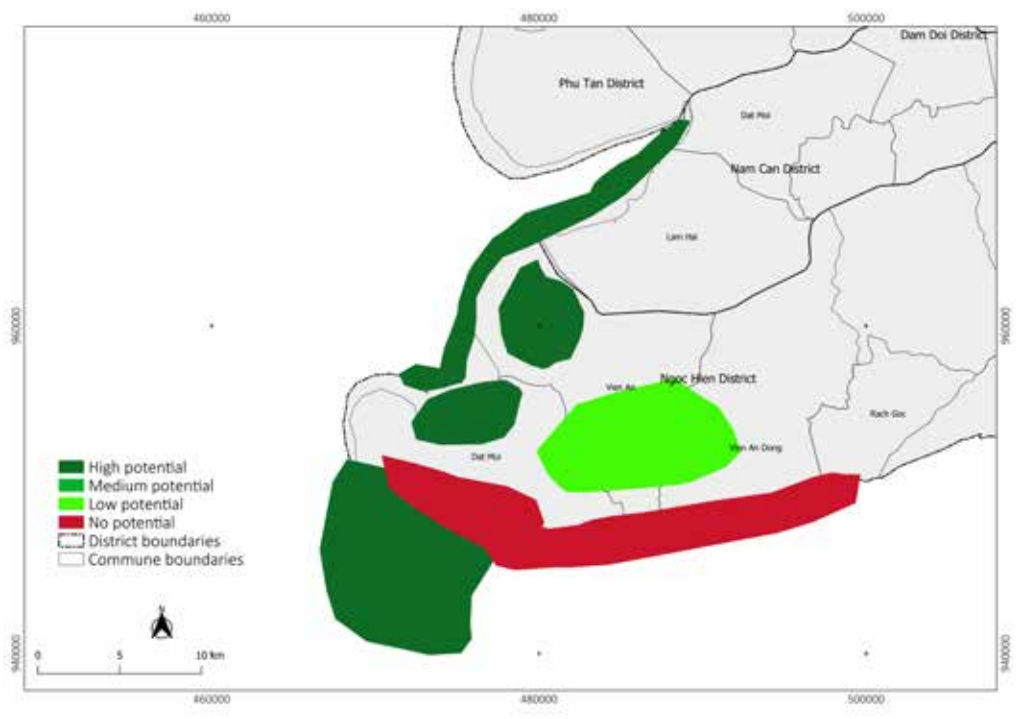

Figure 26. Mangrove restoration potential in Dat Mui Commune

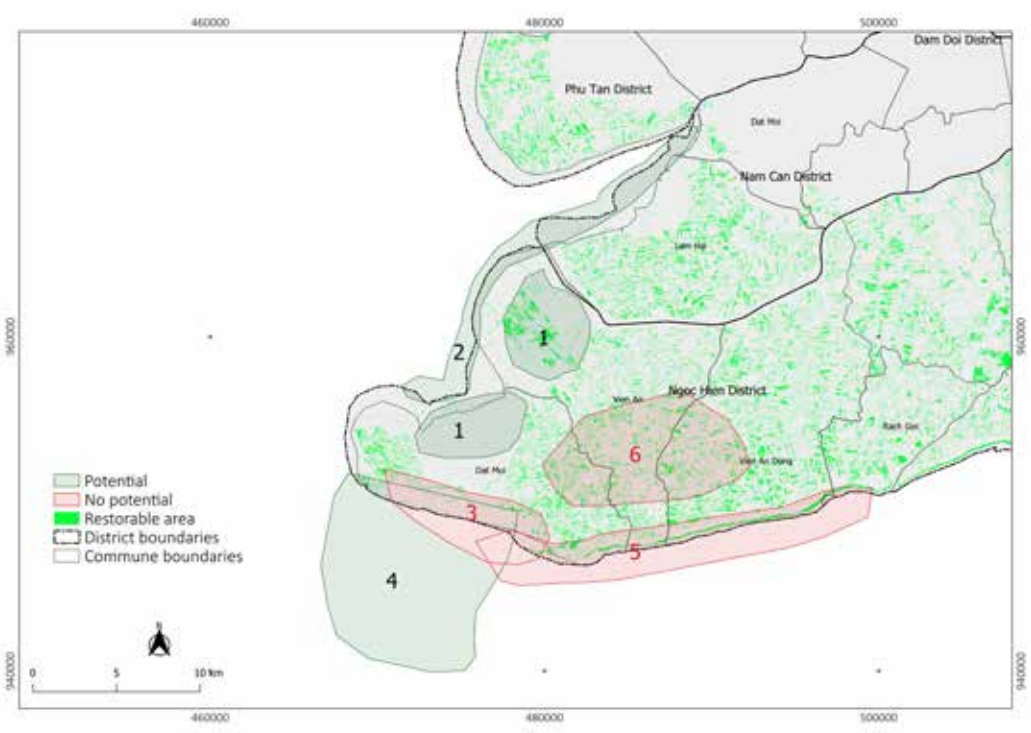

Figure 27. Reasons for different sites in Dat Mui having potential for mangrove restoration

Legend: 1: Natural regeneration (accretion/mudflats); 2: Existing dike; 3: Poor performance of new mangrove plantation; 4: Fulfils the ratio of 60:40 for mangroves and shrimp ponds as required by national regulations; 5: Failure from previous projects on mangrove restoration; 6: Based on experience

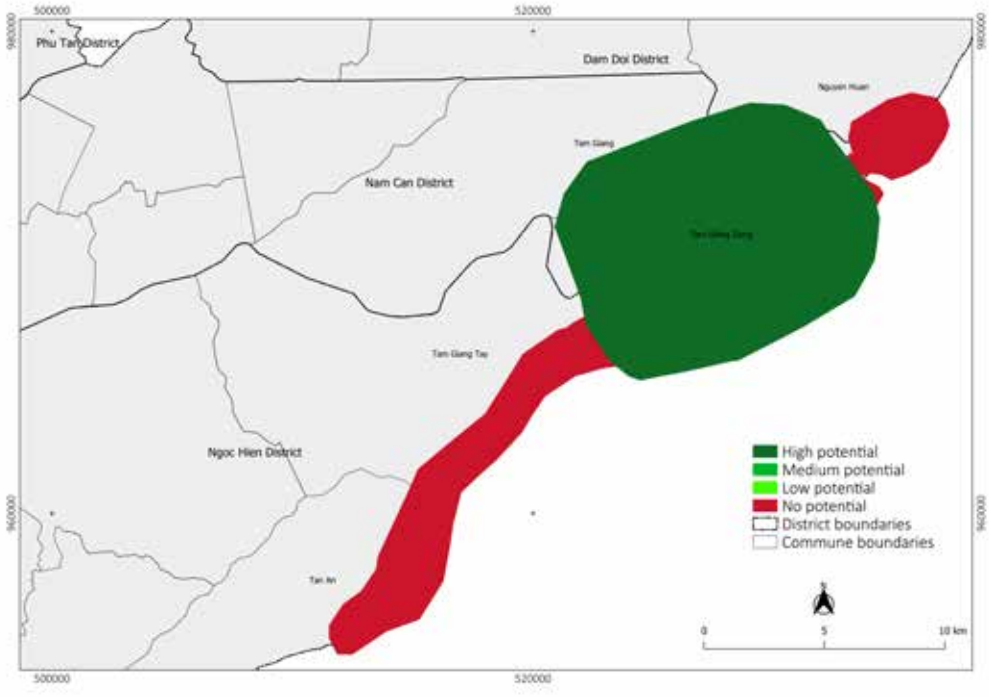

Figure 28. Potential sites for mangrove protection in Tam Giang Commune, Ca Mau Province

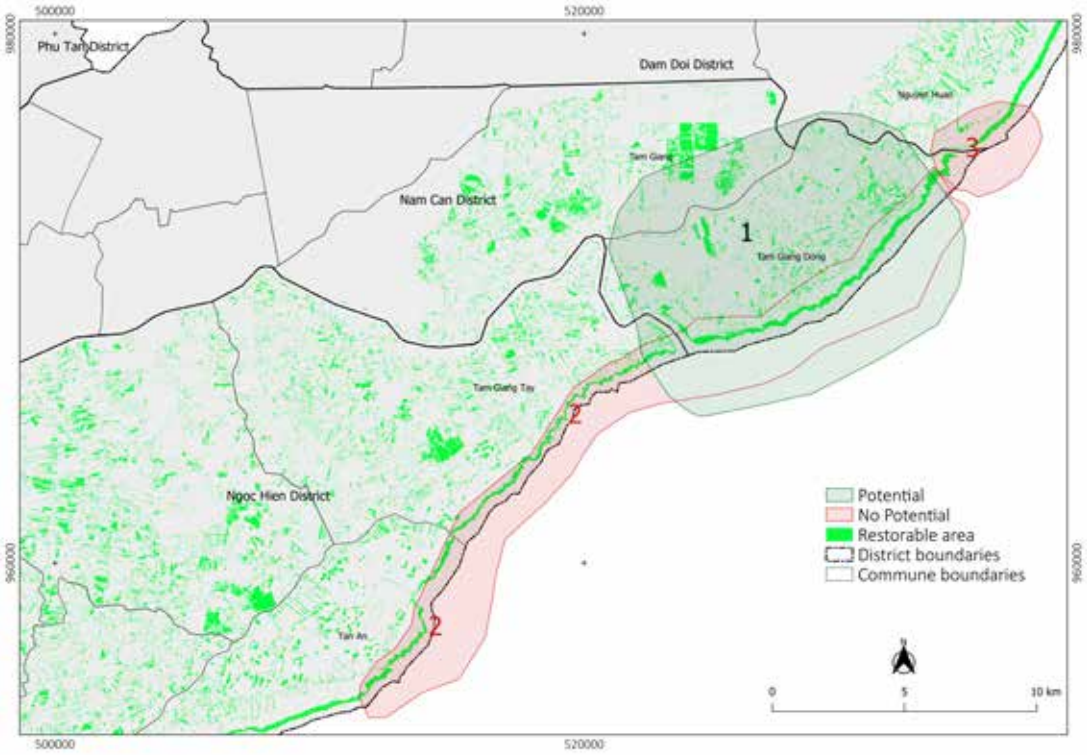

Figure 29. Reasons for different sites in Tam Giang Commune, Ca Mau Province having potential for mangrove protection

Legend: 1: Natural regeneration (accretion/mudflats); 2: Existing dike; 3: Poor performance of new mangrove plantation

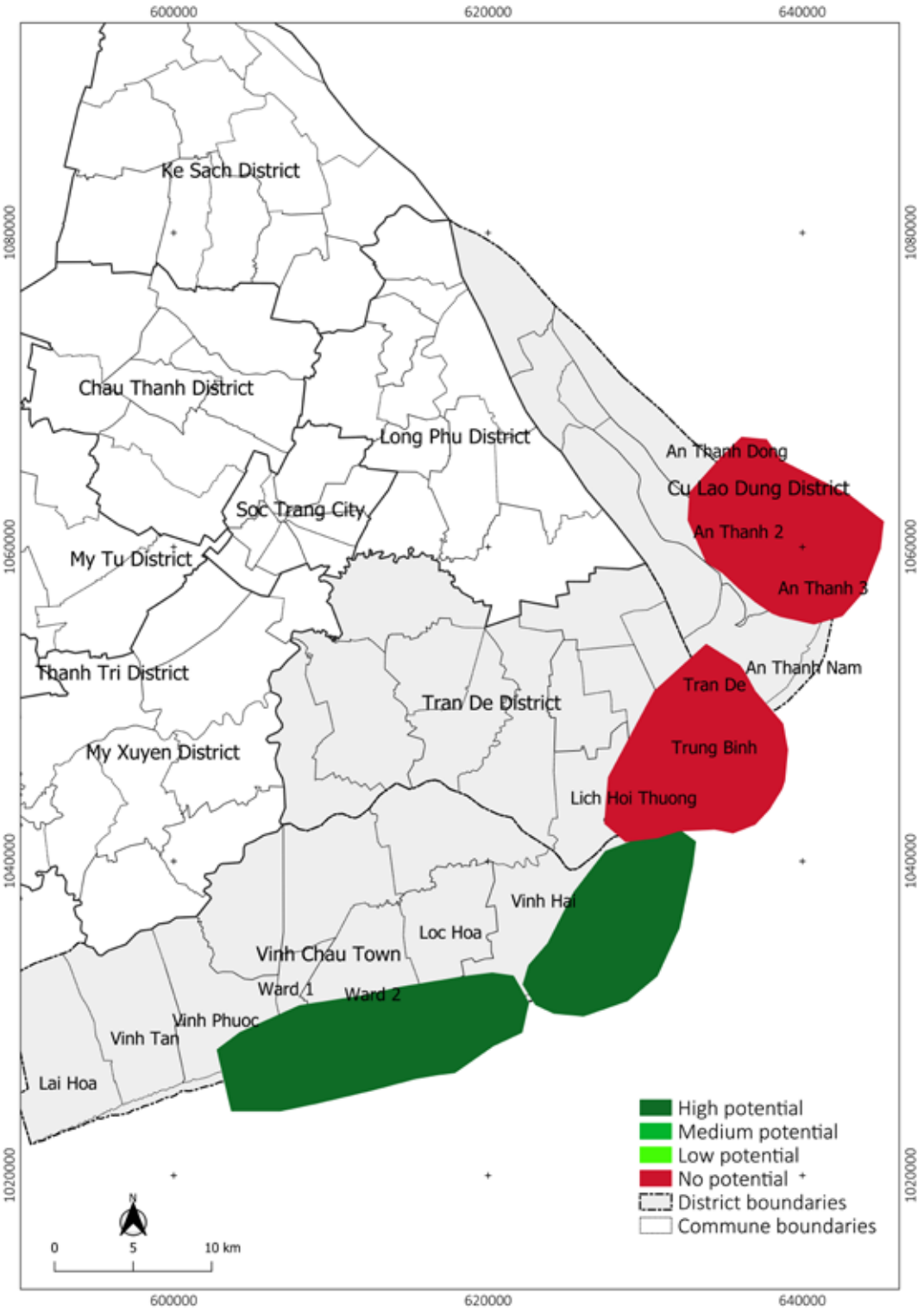

Figure 30. Potential sites for mangrove restoration in Soc Trang Province

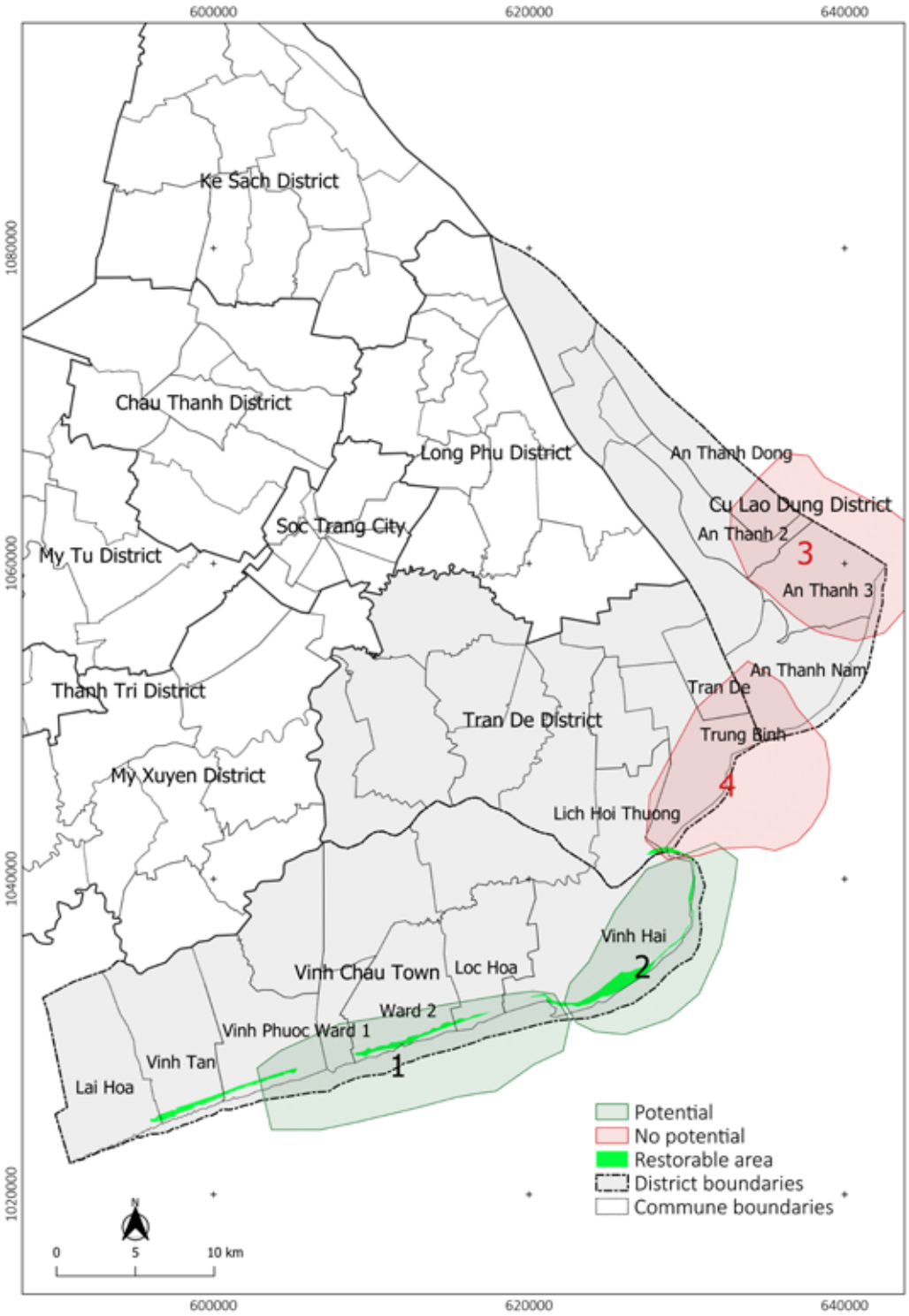

Figure 31. Reasons for different sites in Soc Trang Province having potential for mangrove restoration

Legend: 1: Natural regeneration (accretion/mudflats); 2: Existing dike; 3: Poor performance of new mangrove plantation; 4: Low willingness of local people to plant and restore mangrove.

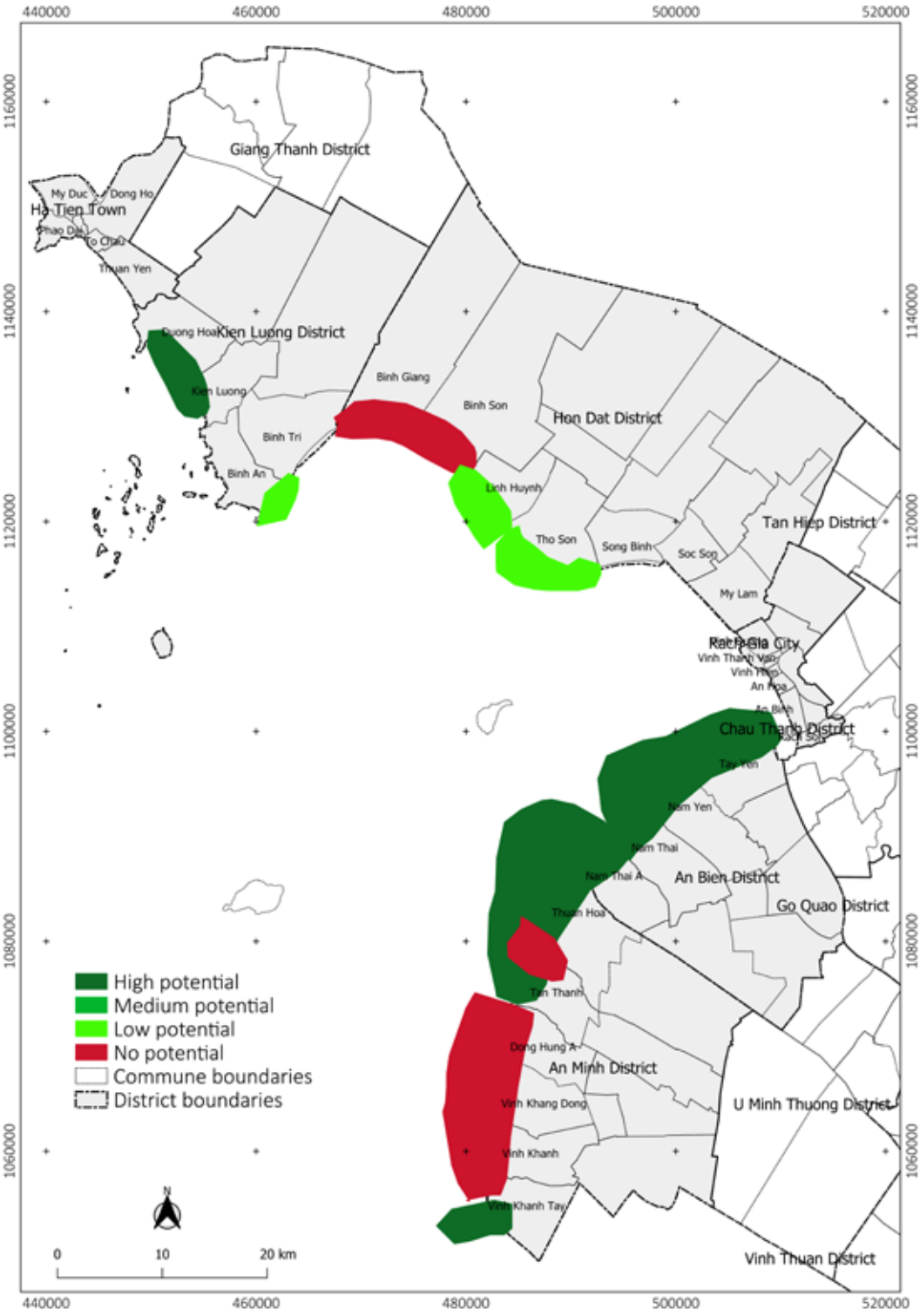

Figure 32. Mangrove restoration potential in Kien Giang Province

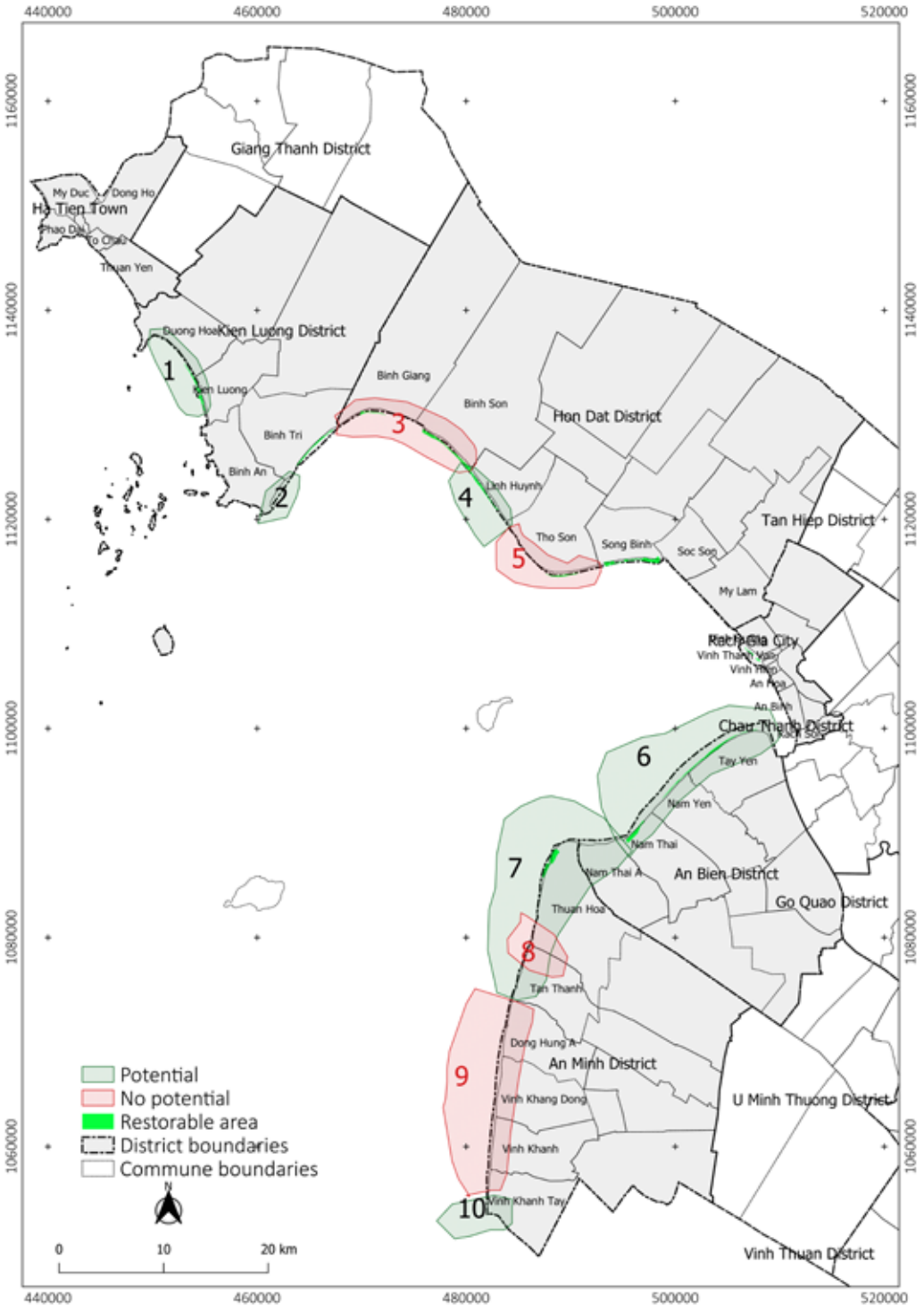

Figure 33. Reasons for different sites in Kien Giang Province having or lacking potential for mangrove restoration

Legend: 1: Natural regeneration (accretion/mudflats); 2: Existing dike; 3: Poor performance of new mangrove plantation; 4: Fulfils the ratio of 60:40 for mangroves and shrimp ponds as required by national regulations; 5: Failure from previous projects on mangrove restoration; 6: Based on experience; 7: Erosion; 8: Farmers do not want to plant more mangroves; 9: Seaport planning; 10: Strong political will from provincial government.

6 Discussion

Uneven distribution of mangrove loss

Our findings show that while mangrove area has increased in some places, most study districts and provinces have experienced mangrove loss. Increases in mangrove forest area are concentrated in only a few districts. This means mangroves remain at high risk of deforestation. It also shows that despite central and provincial governments developing large numbers of policies aimed at conserving mangrove forests, there has been a mismatch between policies and practice, and challenges to protect and expand mangrove areas still remain. This also suggests a need to assess the efficiency of existing financial investments in order to understand what works best, where and how, and to prioritize channelling limited financial resources to the right places and models.

Soft and hard engineering solutions?

Our study reflects stakeholder concerns about erosion, which they feel is the main determining factor for the success or failure of mangrove restoration. This is confirmed in a previous study which found the Mekong Delta experiencing increasingly frequent storms, floods and erosion (Albers and Schmitt 2015). Phan and Stive (2022) found the main threats to the survival of mangroves in the Mekong Delta being pollution, land-use conversion, insufficient nutrient-enriched sediment and coastal erosion, while Truong et al. (2017) cited coastal mangrove squeeze and inappropriate mangrove restoration techniques in local regions.

While donors, organizations and several studies have advocated for the use and effectiveness of Melaleuca fences as soft coastal engineering solutions in the Mekong Delta to improve the resilience of planted mangrove seedlings in erosion areas and trap unstable mud for mangroves to grow in (Chu et al. 2015), stakeholders consulted during our study expressed a preference for sites with solid embankments as potential restoration sites. This demonstrates a mismatch between policy and practice, and suggests the need to adopt both hard and soft approaches where they best fit. Albers and Schmitt (2015) argued that the most effective coastal protection systems should consist of natural floodplains vegetated with mangroves and a sound dike line. In sites where severe erosion has destroyed the mangrove belt, restoration of floodplains and mangrove rehabilitation is only possible after wave energy has been reduced by physical barriers. This can be achieved with soft fences, which reduce erosion and stimulate sedimentation. Restoration of eroded floodplains creates the pre-conditions for rehabilitation of destroyed mangrove forest.

One previous study also highlighted that sea mud accumulation and mangrove regeneration greatly contribute to controlling erosion and establishing muddy coasts, but little is known about whether sea mud accumulation and mangrove regeneration have been integrated or considered in the design and construction of offshore structures (Nguyen 2022). Cross-sectoral solutions and multidisciplinary approaches are required.

Economic drivers of mangrove loss, and constraints to and new financial incentives for mangrove restoration

Economic pressures such as aquaculture expansion, as this paper has highlighted, continue to be the main threat to mangroves in the Mekong Delta. Huynh et al. (2019) found that the area of dense

and sparse mangrove forests in Soc Trang and Bac Lieu had decreased by 90% from 5,495 ha to 515 ha and by 55% from 14,105 ha to 6,289 ha, respectively from 1988 to 2018. Meanwhile, aquaculture farms had increased at an average rate of 5,024 ha annually over the same 30-year period.

Our paper shows that places where mangrove restoration has been supported by stable and sufficient financial resources have experienced slight increases in mangrove cover. In the context of limited state funding and uncertain financial resources for mangrove restoration, most provinces have prioritized protecting existing mangroves rather than replanting and restoration. Our findings also reveal a view among stakeholders that mangrove-shrimp pond system areas have low potential for mangrove restoration due to a lack of financial incentives for aquaculture farm owners to plant mangroves. Stakeholders considered a sustainable financing mechanism for ensuring local people's livelihoods to be an essential precondition for successful mangrove restoration in such areas.

To address this challenge, Vietnam has already been active in searching for and developing policy options and market-based instruments to fund mangrove protection and restoration. These include Payment for Forest Environmental Services (PFES) and Reducing Emissions from Deforestation and Forest Degradation (REDD+). However, these mechanisms have yet to be implemented effectively on the ground (Pham et al. 2013, 2019b, 2022) due either to an inability to mobilize payments for mangrove environmental services in the aquaculture sector, or to low levels of payment being incomparable to high opportunity costs. While central and provincial governments are placing an emphasis on further application of payments schemes for aquaculture, several studies have drawn attention to other mangrove services, like carbon sequestration and water filtering services, that could also become potential sources of funding (Pham et al. 2021a, 2021b). Warner et al. (2016) estimated that mangrove biomass was 70–150 t ha–1, but considerably larger storage of carbon occurs in sediments beneath mangroves in the Mekong Delta. Vien et al. (2016) found the mean of total ecosystem carbon (C) stocks in planted mangroves in the Can Gio Mangrove Biosphere Reserve (889 ± 111 Mg C ha–1) to be not significantly different to naturally regenerated mangroves in the Mekong Delta (844 ± 58 Mg C ha–1). As Vietnam is now developing its domestic carbon market and actively engaging in an international carbon financing scheme, supporting and implementing payment for mangrove carbon services might generate additional payments for local people. However, spatial payment strategies might need to be examined as it is unlikely that payment for environmental services schemes can be implemented in areas with high opportunity costs. Consequently, such schemes might only be feasible in areas where opportunity costs are low (Guo et al. 2020).

Integrating science and local perceptions on mangrove restoration initiative design and implementation

In Vietnam, mangroves have been and still are being planted in various places specifically to protect shorelines and sea dikes from wave impacts and sea level rise. The success of such projects depends on using ecological knowledge describing the physical conditions under which mangroves thrive. Recent papers on mangrove restoration in several countries show survival rates of young mangrove stands in restoration projects varying substantially, and in several instances, being extremely low (Pham et al. 2018; Ranjan, 2019; Jakovac et al. 2020; Sharma et al. 2020; Rodríguez-Rodríguez et al. 2021). One major cause of mangrove planting failures is unsuitable site selection (Vien et al. 2016). Examples include planting on lower intertidal mudflats or subtidal zones, which are unsuitable for all mangrove species, or on sandy substrates of exposed coastlines where most mangrove species cannot succeed. Effective restoration requires a basic understanding of a site's mangrove history and hydrology, local knowledge of hydraulic and sediment conditions, and some effort to restore or improve coastal conditions to encourage mangrove growth. Therefore, the success of planting projects depends on a combination of proper site selection and choosing the right mangrove species. Successful restoration results are usually achieved in places where mangroves previously existed, but were converted for other land uses such as aquaculture.

MARD has suggested the following for future mangrove restoration:

- During the formulation of an investment project, it is necessary to survey and evaluate the site and conditions for afforestation carefully, and have specific investment capital sources to ensure the implementation of a feasible forest protection and development plan.
- Coordination between ministries and sectors in directing the implementation of plans and allocating capital for projects under target programmes should be timely and consistent. Provincial and city people's committees should provide supervision and direction, conduct regular checks and monitoring, and promptly resolve any difficulties or obstacles to implementation processes. There should be close coordination between MARD – as the central authority for unified management of coastal forest protection and development projects – and relevant departments, agencies, functional agencies and local authorities in the construction, appraisal, approval and organization of project implementation.
- The selection of consulting contractors for site surveys, plans, project design and construction must ensure quality, experience and sufficient capacity. This is essential to produce seedlings of sufficient quantity and quality; formulate annual coastal afforestation plans for localities that reflect actual conditions; balance resources for project investment; ensure feasibility and efficiency; and plant mangroves in a timely manner.
- It is important to promulgate comprehensive policies in a timely and step-by-step manner on land-use planning, investment support, land allocation, forest allocation, contracts for forest management and protection, documents on economic and technical norms, other relevant regulations, and technical guidelines on planting and reforestation. At the same time, to ensure successful projects, it is also important to review, supplement and adjust investment project formulation processes in a clear, concise and effective way, and ensure the disbursal of funds for afforestation projects is timed to appropriate seasons.
- Close coordination between sectors and provinces is vital in the process of formulating and implementing laws, and applying policies on forest protection and development, climate change response, integrated coastal management, and land use for economic and social development goals. In particular, the planning and management of land for coastal afforestation must promptly resolve any instances of illegal land encroachment, to ensure a strong basis for the protection and growth of coastal forests.
- It is essential to evaluate, summarize and disseminate livelihood models in combination with forest protection and development. The ecological shrimp farming model implemented in Ca Mau has created linkages between commercial product processing enterprises and shrimp farmers in combination with forest protection and development. Promoting production linkages, benefit sharing and payment for forest environmental services improves stakeholder awareness, and increases the earnings of poor communities involved in forest protection and development. Attracting investment capital is necessary for awareness raising, and public-private cooperation in performing forest protection and planting tasks.
- It is necessary to integrate national target programmes, improve livelihoods, raise community incomes and integrate gender issues with forest protection and development activities in order to take advantage of the current attention and support from international organizations, and attract more investment capital for the management, protection and development of coastal forests.
- It is also important to disseminate experiences in implementing coastal protection techniques; especially combining forest protection and development with a system of dikes and breakwaters to protect sea dikes in coastal provinces. Creative application of mangrove planting experiences in combination with works will save money and improve the efficiency of coastal protection projects.

It is common for restoration projects to be reviewed by government organizations, but is much less common for them to be reviewed by the local communities that are directly impacted (Nguyen et al. 2016). While this study aimed to capture local voices by consulting select groups of on-ground government officers and forest owners, more research will be necessary to incorporate local and traditional knowledge in mangrove restoration design.

By reviewing existing policies and land-use planning, and through key informant interviews, we have determined that the total mangrove restoration area across the study region is approximately 24,000 ha. It is practical to direct restoration efforts towards places where mangroves have recently been lost, as long as the drivers of loss can be prevented from recurring and the local conditions remain suitable. Such sites are most likely to have soil conditions, tides and elevations appropriate for restoration, while their proximity to remaining mangroves can greatly facilitate natural regeneration processes. Where mangroves are degraded rather than lost, they present an opportunity for rapid and effective intervention. Restoration of such areas may require little more than a reduction in, or cessation of damaging actions. Some ecosystem services are still maintained by degraded mangroves, albeit at lower levels. Allowing mangrove forests to recover to full diversity and stature will safeguard and enhance these services and prevent the consequences of full loss, such as subsidence and erosion, which can make recovery a challenging and highly costly task. In other cases, the feasibility of restoration may depend on the proposed methods, scale and level of investment. Eroding coastlines are not always ideal for restoration; however, some highly successful methods are being developed in Southeast Asia that may enable such restoration, with sufficient investment. It remains critically important that decisions of where and how to restore are also locally informed. This will of course include local ecological and physical conditions, but equally local social, legal and economic influences. Mangrove restoration can be greatly facilitated if local land tenure is understood and respected. Community engagement and support can ensure long-term security for restoration projects, and equitable benefit sharing can prevent further degradation and provide an example which, in turn, leverages further restoration efforts.

Mangrove restoration or natural regeneration

While many policies and international projects are devoted to mangrove restoration, coastal squeeze and rapid climate change have given rise to debate over whether Vietnam and the Mekong Delta should prioritize mangrove restoration or support natural regeneration and prioritize the maintenance and protection of existing mangrove forests, which often have high ecological and biodiversity values. Determining which direction the government and projects should take is not straightforward, and requires careful analysis of political, social and economic contexts, and biophysical conditions in the context of climate change. So far, as most research has looked at past trends, while few studies have explored future scenarios, climate change projections, or how future mangrove restoration (if that option is indeed chosen) should be prioritized, further research is required to address these knowledge gaps.

Conclusion

This paper shows most provinces in the Mekong Delta having low and medium restoration potential due to their unfavourable conditions for mangrove restoration, such as serious coastal erosion and coastal squeeze. Areas with the highest potential are those with mudflats because of their high capacity for natural regeneration. Despite current policies and land-use planning indicating production forests as areas with potential for mangrove restoration, stakeholders felt such areas have low or no potential for restoration where aquaculture is taking place, as there are neither strong financial incentives nor sustainable livelihood models encouraging farmers to increase the area of forest in and around their shrimp ponds.

Our findings show a slight increase in total mangrove area in the Mekong Delta between 2016 and 2020. This increase was due mostly to international and national projects on mangrove plantation and restoration, and sectoral policies on improving water discharges and combatting environmental and water pollution to improve human health. However, any increases in mangrove forest cover were not significant, and results varied widely between study provinces and districts. Only four of the nine study provinces had experienced increases in mangrove forest cover, while the majority of districts across all nine provinces had experienced losses in total mangrove area. The regions where mangrove area had increased were those with a strong presence of international and national programmes and projects on mangrove restoration. This indicates the importance of finance and stable support programmes for mangrove restoration, as well as a vulnerability in regions where support programmes are absent.

Our paper shows that despite large numbers of policies and projects aimed at mangrove restoration, they have been impeded by weak political will to preserve and protect mangroves due to other land uses having higher opportunity costs; increasing pressure from industrial infrastructure development; and urbanization and aquaculture expansion leading to mangrove loss. Our analysis also shows large areas of land allocated for forestry purposes that could be potential sites for mangrove restoration. However, these areas will require careful assessment to ensure their biophysical conditions are appropriate for mangrove restoration to avoid ineffective and inefficient investment. While this study focuses mainly on policies, planning and stakeholder perceptions of potential sites for mangrove restoration, validating these perceptions will require rigorous impact assessments and further studies to offer reliable scientific evidence on what works best, where and when.

References

Albers T and Schmitt K. 2015. Dike design, floodplain restoration and mangrove co-management as parts of an area coastal protection strategy for the mud coasts of the Mekong Delta, Vietnam. *Wetlands Ecol. Manage.* 23: 991–1004. https://doi.org/10.1007/s11273-015-9441-3

Baatz M and Schäpe A. 2000. Multiresolution segmentation: An optimization approach for high quality multi-scale image segmentation. *In* Strobl J, Blaschke T, Griesbner G. eds. *Angewandte Geographische Informations-Verarbeitung, XII*. Heidelberg, Germany: Wichmann. pp. 12–23.

Besset M, Gratiot N, Anthony EJ, Bouchette F, Goichot M and Marchesiello P. 2019. Mangroves and shoreline erosion in the Mekong River Delta, Viet Nam, *Estuarine, Coastal and Shelf Science* 226: 106263. https://doi.org/10.1016/j.ecss.2019.106263

Brander L, Wagtendonk AJ, Hussain SS, McVittie A, Verburg PH, de Groot RS and van der Ploeg S. 2012. Ecosystem service values for mangroves in Southeast Asia: A meta-analysis and value transfer application. *Ecosyst. Serv.* 1: 62–69. https://doi.org/10.1016/j.ecoser.2012.06.003

Chen B, Xiao X, Li X, Pan L, Doughty R, Ma J, Dong J, Qin Y, Zhao B, Wu Z, Sun R, Lan G, Xie G, Clinton N and Giri C. 2017. A mangrove forest map of China in 2015: Analysis of time series Landsat 7/8 and Sentinel-1A imagery in Google Earth Engine cloud computing platform. *ISPRS Open Journal of Photogrammetry and Remote Sensing* 131: 104–120. https://doi.org/10.1016/j.isprsjprs.2017.07.011

Chu VC, Brown S, Huynh HT and Hockings M. 2015. Using Melaleuca fences as soft coastal engineering for mangrove restoration in Kien Giang, Vietnam. *Ecological Engineering* 81: 256–265. https://doi.org/10.1016/j.ecoleng.2015.04.031

Cinco-Castro S and Herrera-Silveira J. 2020. Vulnerability of mangrove ecosystems to climate change effects: The case of the Yucatan Peninsula. *Ocean & Coastal Management* 192: 105196. https://doi.org/10.1016/j.ocecoaman.2020.105196

Dahdouh-Guebas F, Jayatissa LP, Di Nitto D, Bosire JO, Lo Seen D and Koedam N. 2005. How effective were mangroves as a defence against the recent tsunami? *Curr. Biol.* 15: R443-7. https://doi.org/10.1016/j.cub.2005.06.008

Field CD. 1999. Mangrove rehabilitation: Choice and necessity. *In* Dodd RS. ed. *Diversity and Function in Mangrove Ecosystems*. Dordrecht, Netherlands: Springer. https://doi.org/10.1007/978-94-011-4078-25

Government of Vietnam. 2015. *Decision No. 120/QĐ-TTg 2015 development of coastal forests to cope with climate change 2015–2020.* Accessed 5 June 2022. https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Decision-No-120-QD-TTg-2015-development-of-coastal-forests-to-cope-with-climate-change-2015-2020-287295.aspx

Government of Vietnam. 2020. *Updated nationally determined contribution (NDC). Government of Vietnam*. Accessed 5 June 2022. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Viet%20Nam%20First/Viet%20Nam_NDC_2020_Eng.pdf

Guo Y, Zheng H, Wu T, Wu J and Robinson BE. 2020. A review of spatial targeting methods of payment for ecosystem services. *Geography and Sustainability* 1(2): 132–140. https://doi.org/10.1016/j.geosus.2020.04.001

Heumann BW. 2011. An object-based classification of mangroves using a Hybrid Decision Tree—Support Vector Machine

Approach. *Remote Sens.* 3: 2440–2460. https://doi.org/10.3390/rs3112440

Huynh TCH, Avtar R and Fujii M. 2019. Monitoring changes in land use and distribution of mangroves in the south-eastern part of the Mekong River Delta, Vietnam. *Trop. Ecol.* 60: 552–565. https://doi.org/10.1007/s42965-020-00053-1

[IPCC] Intergovernmental Panel on Climate Change. 2022. *Climate Change 2022: Impacts, Adaptation and Vulnerability*. Accessed 5 June 2022. https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/

[IUCN] International Union for Conservation of Nature. 2012. *Vietnam National Strategy and Action Plan (2011–2013)*. Mangrove for the future. Gland, Switzerland.

[IUCN] International Union for Conservation of Nature. 2016. *Mangrove restoration potential: Mapping tool*. Accessed 5 June 2022. https://www.iucn.org/theme/forests/our-work/forest-landscape-restoration/mangrove-restoration/mangrove-restoration-potential-mapping-tool

Jakovac CC, Latawiec AE, Lacerda E, Leite LI, Korys KA, Iribarrem A, Malaguti GA, Turner RK, Luisetti T and Baeta Neves Strassburg B. 2020. Costs and carbon benefits of mangrove conservation and restoration: A global analysis. *Ecol. Econ.* 176: https://doi.org/10.1016/j.ecolecon.2020.106758

Jennerjahn TC, Gilman E, Krauss KW, Lacerda LD, Nordhaus I and Wolanski E. 2017. Mangrove ecosystems under climate change. *Mangrove Ecosystems: A Global Biogeographic Perspective*: 211–244. https://doi.org/10.1007/978-3-319-62206-47

Kamali B and Hashim R. 2011. Mangrove restoration without planting. *Ecological Engineering* 27(2): 387–391. https://doi.org/10.1016/j.ecoleng.2010.11.025

Kodikara, K., Mukherjee, N., Jayatissa, L., Dahdouh-Guebas, F. and Koedam, N. 2017. Have mangrove restoration projects worked? An in-depth study in Sri Lanka. *Restoration Ecology* 25(5): 705–716. https://doi.org/10.1111/rec.12492

Kuenzer C and Vo QT. 2013. Assessing the ecosystem services value of Can Gio Mangrove Biosphere Reserve: Combining earth-observation- and household-survey-based analyses. *Appl. Geogr.* 45: 167–184. https://doi.org/10.1016/j.apgeog.2013.08.012

Lewis RR. 2000. Ecologically based goal setting in mangrove forest and tidal marsh restoration. *Ecological Engineering* 15 (3-4): 191-198. https://doi.org/10.1016/S0925-8574(00)00070-7

Lewis RR, Brown BM and Flynn LL. 2019. Chapter 24 - Methods and Criteria for Successful Mangrove Forest Rehabilitation. *In* Gerardo, MEP, Eric W, Donald RC, Charles SH. eds. *Coastal Wetlands (Second Edition).* Amsterdam: Elsevier. pp. 863–887. https://doi.org/10.1016/B978-0-444-63893-9.00024-1

[MARD] Ministry of Agriculture and Rural Development. 2021. *National program on protection and development of forests in coastal target to climate change and promote green growth for 2021–2030*. Hanoi, Vietnam.

[MONRE] Ministry of Natural Resources and Environment. 2016. *Climate Change and Sea Level Rise Scenarios for Vietnam (In Vietnamese).* Ministry of Natural Resources and Environment. Hanoi, Vietnam.

Nguyen QH, Tran DD, Dang KK, Korbee D, Pham LDMH, Vu LT, Luu TT, Ho LH, Nguyen PT, Ngo TTT, Nguyen TKD, Wyatt A, van Aalst M, Tran AT and Sea WB. 2020. Land-use dynamics in the Mekong Delta: From national policy to livelihood sustainability. *Sustainable Development* 28(3). https://doi.org/10.1002/sd.2036

Nguyen TP, Nguyen VT, Le PQ and Parnell KE. 2016. Community perspectives on an internationally funded mangrove restoration project: Kien Giang Province, Vietnam. *Ocean & Coastal Management* 119: 146–154. https://doi.org/10.1016/j.ocecoaman.2015.10.008

Nguyen TP. 2022. Offshore structures, sea mud accumulation and mangrove regeneration: Insights from the Vietnamese Mekong Delta, Vietnam. *Ocean & Coastal Management* 22: 106243. https://doi.org/10.1016/j.ocecoaman.2022.106243

Pham MT and Populus J. 2007. Status and changes of mangrove forest in Mekong Delta: Case study in Tra Vinh, Vietnam. *Estuarine, Coastal and Shelf Science* 71(1-2): 98–109.

Pham TD, Kaida N, Yoshino K, Nguyen XH, Nguyen HT and Bui DT. 2018. Willingness to pay for mangrove restoration in the context of climate change in the Cat Ba Biosphere Reserve, Vietnam. *Ocean Coast. Manag.* 163: 269–277. https://doi.org/10.1016/j.ocecoaman.2018.07.005

Pham TT, Bennet K, Vu TP, Brunner J, Le ND and Nguyen DT. 2013. *Payments for forest environmental services in Vietnam: From policy to practice*. Occasional Paper No. 93. Bogor, Indonesia: Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/004247

Pham TT, Hoang TL, Nguyen DT, Le HN and Atmadja S. 2019a. *Funding the protection and development of mangrove forests at sub-national level: Lessons from Ben Tre, Tra Vinh and Ca Mau provinces, Vietnam*. Infobrief No. 250. Vietnam: Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/007234

Pham TT, Vu TP, Pham DC, Dao LHT, Nguyen VT, Hoang NVH, Hoang TL, Dao TLC and Nguyen DT. 2019b. *Opportunities and challenges for mangrove management in Vietnam: Lessons learned from Thai Binh, Quang Ninh and Thanh Hoa provinces*. Occasional Paper No. 197. Bogor, Indonesia: Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/007404

Pham TT. 2021. *Mangrove environmental services and local livelihoods in Vietnam*. Infobrief No. 339. Vietnam: Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/008148

Pham TT, Nguyen TVA, Nguyen TTA, Tang KH, Dang HP, Nguyen TKN, Dang LH, Pham TT and Hoang TL. 2021a. *The role of mangroves in supporting shipping industry commitments to environmental protection and sustainable development*. Occasional Paper No. 224. Bogor, Indonesia: Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/008143

Pham TT, Dang LH, Tang TKH, Dang HP, Hoang TL, Pham TT, Nguyen TKN, Nguyen TVA, Nguyen TTA and Pham TT. 2021b. *Willingness to participate in Payment for Mangrove Environmental Services: Maritime sector and shipping industry stakeholder perspectives*. Infobrief No. 334. Vietnam: Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/008084

Pham TT, Vu TP, Hoang TL, Dao TLC, Nguyen DT, Pham DC, Dao LHT, Nguyen VT and Hoang NVH. 2022. The effectiveness of financial incentives for addressing mangrove loss in Northern Vietnam. *Front. For. Glob. Change*. https://doi.org/10.3389/ffgc.2021.709073

Phan LK, van Thiel de Vries JSM and Stive MJF. 2015. Coastal mangrove squeeze in the Mekong Delta. *Journal of Coastal Research* 31(2): 233–243. https://doi.org/10.2112/JCOASTRES-D-14-00049.1

Phan MH and Stive MJF. 2022. Managing mangroves and coastal land cover in the Mekong Delta. *Ocean & Coastal Management* 219: 106013. https://doi.org/10.1016/j.ocecoaman.2021.106013

Ranjan R. 2019. Optimal mangrove restoration through community engagement on coastal lands facing climatic risks: The case of Sundarbans region in India. *Land use policy* 81: 736–749. https://doi.org/10.1016/j.landusepol.2018.11.047

Rodríguez-Rodríguez JA, Mancera-Pineda JE and Tavera H. 2021. Mangrove restoration in Colombia: Trends and lessons learned. *For. Ecol. Manage.* 496: https://doi.org/10.1016/j.foreco.2021.119414

Rogers JN, Parrish CE, Ward LG and Burdick DM. 2015. Evaluation of field-measured vertical obscuration and full waveform lidar to assess salt marsh vegetation biophysical parameters. *Remote Sens. Environ.* 156: 264–275. https://doi.org/10.1016/j.rse.2014.09.035

Salim L. 2008. *Oxfam Mangrove Rehabilitation Helps Vietnam Aquaculture.* Accessed 5 June 2022. https://www.seafoodsource.com/news/supply-trade/oxfam-mangrove-rehabilitation-helps-vietnam-aquaculture

Sharma S, MacKenzie RA, Tieng T, Soben K, Tulyasuwan N, Resanond A, Blate G and Litton CM. 2020. The impacts of degradation, deforestation and restoration on mangrove ecosystem carbon stocks across Cambodia. *Sci. Total Environ.* 706: 135416. https://doi.org/10.1016/j.scitotenv.2019.135416

Son N, Chen Chi-farn, Chang N, Chen Cheng-ru, Chang L and Thanh B. 2014. Mangrove mapping and change detection in Ca Mau Peninsula, Vietnam using Landsat data and object-based image analysis. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.* 8: 1–8. https://doi.org/10.1109/JSTARS.2014.2360691

Thivakaran GA. 2017. Mangrove restoration: An overview of coastal afforestation in India. *In* Prusty B, Chandra R, Azeez P. eds. *Wetland*

Science. New Delhi: Springer. https://doi.org/10.1007/978-81-322-3715-026

Truong SH, Ye Q and Stive MJF. 2017. Estuarine mangrove squeeze in the Mekong Delta, Vietnam. *Journal of Coastal Research* 33(4): 747–763. https://doi.org/10.2112/JCOASTRES-D-16-00087.1

van Loon AF, Dijksma R and van Mensvoort MEF. 2007. Hydrological classification in mangrove areas: A case study in Can Gio, Vietnam. *Aquatic Botany* 87(1): 80–82. https://doi.org/10.1016/j.aquabot.2007.02.001

van Loon AF, Te Brake B, van Huijgevoort MHJ and Dijksma R. 2016. Hydrological classification: A practical tool for mangrove restoration. *PLoS ONE* 11(3). https://doi.org/10.1371/journal.pone.0150302

Van TT, Wilson N, Thanh-tung H, Quisthoudt K and Quang-minh V. 2014. Changes in mangrove vegetation area and character in a war and land use change affected region of Vietnam (Mui Ca Mau) over six decades. *Acta Oecologica*: 1–11. https://doi.org/10.1016/j.actao.2014.11.007

Veettil BK, Ward RD, Ngo XQ, Ngo TTT and Tran HG. 2019. Mangroves of Vietnam: Historical development, current state of research and future threats. *Estuarine, Coastal and Shelf Science* 218: 212–236. https://doi.org/10.1016/j.ecss.2018.12.021

Vien NN, Sasmito SD, Murdiyarso D, Purbopuspito J and MacKenzie RA. 2016. Carbon stocks in artificially and naturally regenerated mangrove ecosystems in the Mekong Delta. *Wetlands Ecol. Manage*. 24: 231–244. https://doi.org/10.1007/s11273-015-9479-2

Vo QT, Oppelt N, Leinenkugel P and Kuenzer C. 2013. Remote sensing in mapping mangrove ecosystems: An object-based approach. *Remote Sens.* 5: 183–201. https://doi.org/10.3390/rs5010183

Wang YS and Gu JD. 2021. Ecological responses, adaptation and mechanisms of mangrove wetland ecosystem to global climate change and anthropogenic activities. *International Biodeterioration and Biodegradation* 162: 105248. https://doi.org/10.1016/j.ibiod.2021.105248

Warner R, Kaidonis M, Dun O, Rogers K, Shi Y, Nguyen TXT and Woodroffe CD. 2016. Opportunities and challenges for mangrove carbon sequestration in the Mekong River Delta in Vietnam. *Sustain Sci.* 11: 661–677. https://doi.org/10.1007/s11625-016-0359-3

World Bank. 1999. *Project Appraisal document on a proposed credit in the amount of SDR 23.1 million (US$31.8 million equivalent) to the Socialist Republic of Vietnam for a coastal wetlands protection and development project*. Accessed 5 June 2022. https://documents1.worldbank.org/curated/en/633501468779402279/pdf/multi-page.pdf

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Based on a literature and policy review, spatial analysis, participatory mapping and stakeholder consultations, this paper identifies potential sites for mangrove restoration; looks at policy planning, possibilities for natural regeneration, and stakeholder perceptions; and discusses opportunities and challenges for mangrove restoration in the Mekong Delta, Vietnam.

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