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Coastal land use planning in Ben Tre, Vietnam: constraints and recommendations

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Abstract

There have been few reviews of the effectiveness of the management of coastal mangrove protected areas and coastal land use planning at all levels in the Mekong Delta, Vietnam. Ben Tre province provides a good case study to enable the assessment of typical management practices in the provinces of the Delta. The study aims to critically review the current strategies for managing the Ben Tre coast and to consider what changes are required to ensure effective coastal management. The current coastal management strategies only dealt with symptoms and worked temporarily. There has been insufficient coordination in land use planning and coastal management among the Ben Tre government agencies, substantially contributing to mangrove loss and degradation. Natural regeneration of local mangrove species and secondary succession, although having been practically effective for protecting from coastal erosion, have not been used as coastal management measures. Three strategies, *hold the existing defence line*, *managed realignment*, and *no active intervention*, are recommended to assist in managing the Ben Tre coast for adaptation to climate change and sea level rise, and livelihood improvement.

Keyword: Environmental science

1. Introduction

The extensive use of muddy coastal areas for social economic development (Ramesh et al., 2011) has, in many locations, caused pollution of estuarine and coastal waters, over-exploitation of coastal and marine resources, and contributed to coastal hazards and risks (Tolvanen and Kalliola, 2008; Hinrichsen, 2011; Thampanya et al., 2006; Ko and Chang, 2012), and increased the vulnerability to climate change, particularly the effects of sea level rise.

Common techniques to sustainably manage coasts include combinations of administrative coastal management and planning, technical approaches, integrated coastal zone management (Kay and Alder, 2005), and the application of shoreline management plans (Department for Environment, Food and Rural Affairs (DEFRA) 2006). Administrative coastal management and planning is normally provided and implemented through policy and legislation, guidelines, zoning, regulation and enforcement. Technical approaches, that involve environmental impact assessment, risk and hazard assessment and management, landscape and visual resource analysis and economic analysis, aim to identify the locations of problems or areas of concerns and propose steps for remediating and/or mitigating adverse impacts on the environment in development projects or program proposals. Integrated coastal zone management integrates environmental, social, economic and cultural considerations into a single holistic system, which helps ensure sustainable coastal development, the perpetuation of biodiversity and security from natural hazards (World Bank, 1996; O'Hagan and Ballinger, 2010; Wu et al., 2012). Shoreline management plans utilise strategic coastal defence measures that address coastal risks to people. A shoreline management plan, discussed in this paper, is reflected in the following strategic policies: 1) *hold the existing defence line* (to improve or maintain the standard of protection provided by the existing defence line) 2) *managed realignment* (to move the shorelines backwards or forwards, with management to control or limit movement) or 3) *no active intervention* (no investment in coastal defence or operation needed).

Forests in Vietnam are classified into three categories: special use forests, protection forests and production forests (Vietnamese National Assembly, 2004). Special use forests are national parks, nature reserves, and landscape reserves. Protection forests include watershed protection forests, wind or sand protection forests, mangrove forests and environmental protection forests. Production forests can be natural forests or plantation forests. Special use forests are legally required to be ecologically zoned primarily for nature conservation, gene pool protection, landscape protection, scientific research, and tourism. Protection forests use administrative coastal management planning to protect water resources and environment, conserve soils, minimize negative effects caused by disasters, control erosion, regulate climates, and adapt to climate change. Production forests provide for legal logging and production in

combination with environmental protection and forest protection. Human activities are not permitted within special use forests and protection forests without the permission of competent government agencies. A policy approved by the [Vietnamese Prime Minister in 2001](#) provides opportunities for protected forests to be allocated under contracts to local communities for protecting forest resources while using allocated forest resources for livelihood improvement ([Vietnamese Prime Minister, 2001](#)).

The mangroves in the Mekong Delta of Vietnam are either protection or special use forest areas, or in mangrove national parks ([Vietnamese National Assembly, 2004](#)). [Nguyen et al. \(2016\)](#) and [Nguyen et al. \(2017a; b\)](#) discussed the management and use of coastal mangroves in the Mekong Delta, identifying gaps in management, monitoring and mangrove rehabilitation and providing recommendations for better management of mangrove protected areas. [Bentham et al. \(1999\)](#), [Thornton and Johnstone \(2015\)](#), and [Schmitt and Duke \(2016\)](#) studied mangrove rehabilitation, and [Binh \(1997\)](#), [Ha et al. \(2012\)](#), and [Nguyen et al. \(2016\)](#) undertook research on the use of mangrove resources for livelihood improvement. However, there has been little consideration of management interventions such as zoning, administrative management and planning on mangrove resources. This knowledge is needed, especially because effective management of mangrove resources is problematic, with the challenge likely to become more pronounced with climate change and sea level rise ([Vietnamese Prime Minister, 2009](#); [Vietnam Administration of Forestry, 2012](#)).

Ben Tre province provides an excellent case study outlining the challenges of mangrove management as it is one of two provinces in the Mekong Delta of Vietnam that has special use forests and protection forests in one entity, the Ben Tre Coastal Mangrove Protection Area and Special Use Forest (the Ben Tre CMPSUF), and private land ownership and use. We aim to critically review the current strategies for managing the Ben Tre CMPSUF and to consider the changes required to ensure effective coastal management in Ben Tre province. The review is undertaken to include the points of view of local communities, government agencies and the Management Board, all of whom have been involved in the protection and use of coastal mangroves.

2. Material and methods

2.1. Site description

The Ben Tre CMPSUF has a total mangrove area of 4,147 ha that extends along 65 km of shoreline in Binh Dai, Ba Tri and Thanh Phu districts ([Ben Tre Provincial People's Committee \(Ben Tre PPC\) 2011](#); [Vietnamese Prime Minister 2013](#)). The Ben Tre CMPSUF includes coastal mangrove protection forests (1,962 ha) and the Thanh Phu Mangrove Wetland Nature Reserve (2,185 ha). The Ben Tre

SMPSUF is currently managed by a Management Board established in 1999 (Department of Agriculture & Rural Development of Ben Tre Province (DARD) 2011) (Fig. 1).

The entire Ben Tre coast was extensively used for aquaculture and agriculture in the 1970s. In the 1980s, the coast was severely eroded (Ben Tre PPC, 2011). Since the 1980s, Ben Tre province has taken concrete measures to reverse coastal erosion and

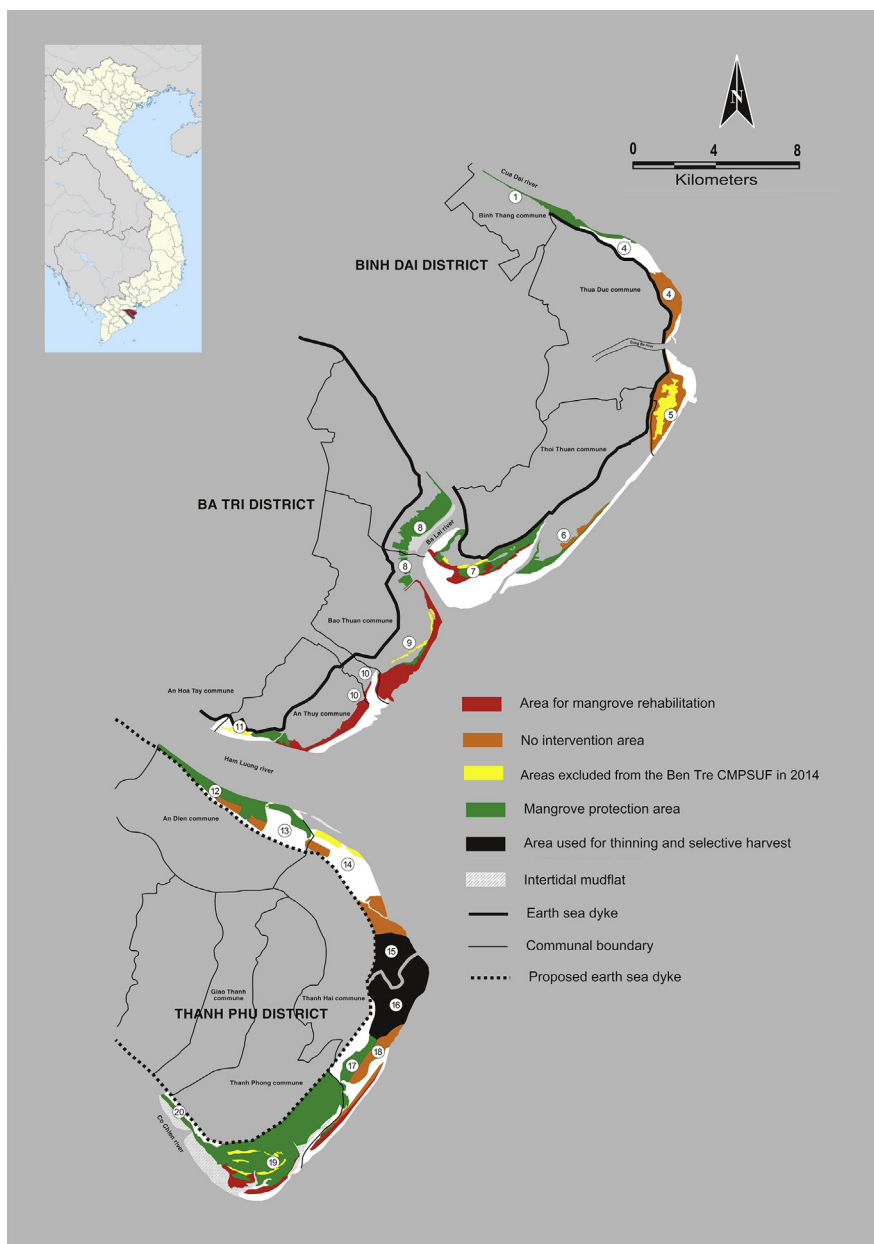


Fig. 1. The location of Ben Tre in Vietnam and the current zones of the Ben Tre CMPSUF (adapted from IUCN 2015).

mangrove loss and degradation (DARD, 2011; Ben Tre People's Council, 2013). In 1999, the Ben Tre CMPSUF was established to maintain, protect, and develop coastal mangroves, and promote integrated mangrove aquaculture management (Ben Tre PPC, 2011). The Ben Tre CMPSUF was divided into twenty ecologically based zones for management purposes (Ben Tre PPC, 2012; Ben Tre People's Council, 2013). Zones 2 and 3, although being surveyed, were not included in this analysis because they are located further landwards and contain only Casuarina species, aquaculture ponds and fragmented mangrove patches.

The Ben Tre CMPSUF comprises areas for strict protection, mangrove rehabilitation, and mangrove allocation. Strict protection involves enforcement of government policies at the national and provincial levels in mangrove protection. Mangrove rehabilitation is undertaken using mangrove transplantation supported by engineered solutions such as sea dykes or revetments. In mangrove allocation areas, protected mangroves are legally allocated to local communities under contract to both protect and use allocated mangroves for livelihood improvement.

Coastal areas adjacent to the Ben Tre CMPSUF were legally designated by the districts as private coastal lands, which are used for aquaculture (*Caridina cantonensis*, *Litopenaeus vannamei*, and *Pangasius hypophthalmus*) and agriculture (water melon and winter melon). The total aquaculture area was 39,000 ha in 2015 and will be increased to approximately 40,000 ha in 2020 (DARD, 2011). Coastal land located outside the ecologically based zones are private lands which have been used for agriculture and aquaculture since the early 1980s.

Coastal erosion became serious between 2012 and 2013, resulting in the majority of the Ben Tre coast being significantly eroded by 2013, with agricultural land and allocated aquaculture ponds being exposed to the sea (IUCN, 2013). Managing coastal erosion has been a major challenge (Ben Tre PPC, 2011; Ben Tre PPC, 2012; Ben Tre People's Council, 2013).

2.2. Methods

The study was undertaken applying mixed methods (Morse, 2003) (Fig. 2). The mixed methods used included secondary data analysis (a desk-top review) (Schutt, 2009), the use of a geographical information system (GIS), and MapInfo software for land use mapping, semi-structured interviews (Ayres, 2008), focus group interviews (Thomas et al., 1995), and field visits, participatory community meetings, and participatory diagramming (Kinson et al., 2008).

Technical reports and maps related to coastal mangrove protection and management were reviewed. Satellite images from 2009 and 2015 were retrieved and transferred to MapInfo Software Ver. 12.0, and digitized for further analysis. The digitized shorelines were overlaid to identify the shoreline changes. Semi-structured

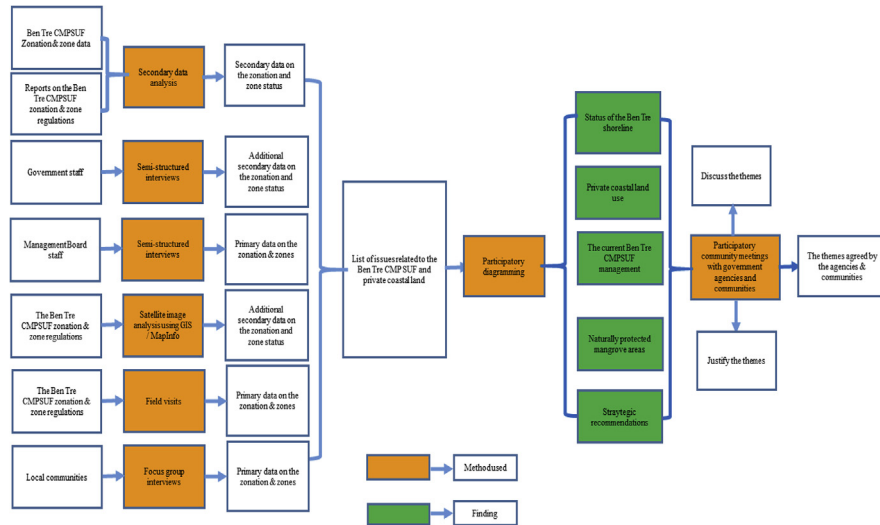


Fig. 2. Summary of the method used in this study.

interviews were conducted with 21 staff members working for the Ben Tre government agencies including DARD (5 staff), Department of Natural Resources & Environment of Ben Tre Province (3), Department of Planning and Investment of Ben Tre Province (1), District People's Committees of Binh Dai (2), Ba Tri (2) and Thanh Phu (3) and the management board of the Ben Tre CMPSUF (5). The semi-structured interviews included two open questions in relation to the current management interventions and management evaluation reports. Each semi-structured interview lasted approximately 30 minutes.

Three field visits were undertaken, with assistance provided by IUCN Vietnam, DARD and District People's Committees of Binh Dai, Ba Tri and Ben Tre. The Ben Tre CMPSUF zonation map was cross-checked against the shoreline changes established from the analysis of the satellite images, and the data obtained from field visits, and semi-structured interviews.

Three focus group interviews were undertaken with five communities (55 local farmers in total) in three districts, with administrative assistance provided by the District's People Committees, IUCN, DARD, and the Ben Tre CMPSUF Management Board. The five communities were Thua Duc (10 farmers) and Thoi Thuan (10) (Binh Dai district), Bao Thanh (5) and Bao Thuan (10) (Ba Tri district), Thanh Hai (20) (Thanh Phu district). Each focus group interview was approximately 2 hours in duration, with questions regarding the current coastal mangrove management and the community perspective on the current land use plan.

The data from all sources were systematically combined using participatory diagramming into themes which were then used to promote local involvement and discussion in subsequent community meetings. The themes were: the status of the

Ben Tre shoreline, the current management of the Ben Tre CMPSUF, private coastal land use, natural protected mangrove areas, and strategic recommendations for sustainable management of the Ben Tre CMPSUF. Three community meetings (55 local farmers) and one provincial workshop (35 representatives) were organized to discuss the themes between January and March 2015. The issues were discussed and agreed in community meetings and debriefings with representatives of the government agencies and the communities.

3. Results

3.1. Status of the Ben Tre shoreline

The image analysis and field visit showed that the 18 coastal zones and surrounding private coastal lands have been impacted to varying degrees by coastal development, national defence, aquaculture, agriculture, erosion, secondary succession and natural regeneration of local mangrove species (Table 1 and Fig. 3).

Table 1. Status of the zones of the Ben Tre CMPSUF (refer to Fig. 1 for zone location).

Zone	Function	Status						
		CD	ND	Aq	Ag	E	SS	NR
1	Mangrove protection	○	○	○	○	○	○	○
4	No intervention	○	●	●	●	●	●	○
5	No intervention	●	○	○	●	●	●	○
6	Mangrove protection, no intervention	○	○	●	●	●	○	○
7	Mangrove protection, mangrove rehabilitation	●	○	●	●	○	○	●
8	Mangrove protection	●	○	○	○	○	○	●
9	Mangrove protection and rehabilitation	●	●	●	●	●	●	●
10	Mangrove rehabilitation	○	○	○	○	●	●	●
11	Mangrove protection	●	○	○	○	○	○	●
12	Mangrove protection, no intervention	○	○	○	○	○	○	●
13	Mangrove protection	○	○	○	○	○	○	●
14	No intervention	●	○	○	○	○	○	○
15	Permitted thinning and harvest	○	○	●	○	○	○	○
16	Permitted thinning and harvest	○	○	●	○	○	○	●
17	Mangrove protection	○	○	○	○	○	○	●
18	Mangrove protection	●	○	●	●	○	○	●
19	Mangrove protection, mangrove rehabilitation	●	○	●	○	●	○	●
20	Mangrove protection	○	○	○	○	○	○	●

CD = Coastal Development; ND = National Defence; Aq = Aquaculture; Ag = Agriculture; E = Erosion; SS = Secondary Succession; NR = Natural Regeneration; ● = Yes; ○ = No

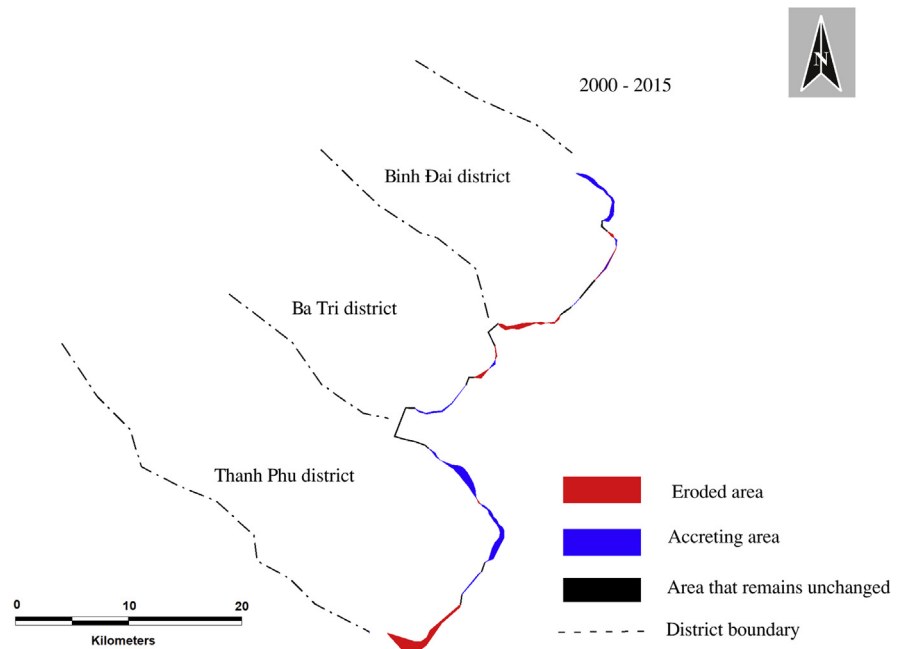


Fig. 3. Changes to the shoreline of the Ben Tre CMPSUF between 2000 and 2015.

3.2. The current Ben Tre CMPSUF management

GIS analysis showed that zones of 4, 5, 6, 9, 10, 14, 15, 16 and 19 were severely eroded at 9 sites with a total loss of approximately 645 ha (approximately 15% of total mangrove areas in Ben Tre). Mature trees of *Sonneratia alba* and *Avicennia marina* and *Avicennia alba* were found dead in zones 4, 5, 6, 9, 10 and 14 because their extensive root systems were buried by sand (Fig. 4). Two soil profiles were observed by digging two holes (1 m × 1 m × 1 m) in Zones 6 and 9. The results showed that surface sand layers were approximately 70 cm deep overlying fine grained mud.

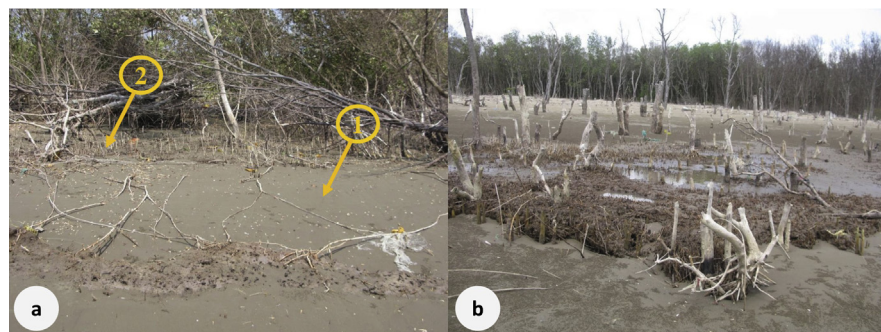


Fig. 4. (a) *Avicennia* trees were killed on Thanh Hai coast, Thanh Phu district. In (a), (1) sand was transported and re-deposited onshore by strong waves on high tides as a consequence of vegetation loss; (2) roots of *Avicennia* trees were buried by sand; (b) dead *Avicennia* trees were illegally cut for firewood.

Mature trees of *Rhizophora apiculata* along a 2 km length of the Cay Dua coastline of Thanh Hai commune, Thanh Phu district (zones 14, 15, 16 and 19) were uprooted. Dead trees of *Rhizophora apiculata* were illegally cleared for firewood. The Management Board of the Ben Tre CMPSUF and DARD were permitted to clear dead trees of *Rhizophora apiculata* to prevent forest fire in 2012. Many coastal margins in Cong Be area (Thua Duc commune, Ba Tri district), and in the Cay Dua area (Thanh Hai commune, Thanh Phu district) where *Rhizophora apiculata* were degraded or cut, had collapsed (Fig. 5).

Mangrove rehabilitation involved transplantation using seedlings of *Rhizophora apiculata*, *Avicennia alba* *Avicennia marina* mainly on intertidal mudflats. In some areas, 6 month old seedlings of Casuarina species were transplanted in areas that had been covered with sand. The field visits showed that mature trees of Casuarina had been uprooted in many coastal areas. Seedlings had not been transplanted in eroded areas. The interviews with staff working for The Ben Tre CMPSUF indicated that there had been failures in transplanting mangroves in eroded areas. Some of the problems resulted from the transplantation on mudflats occurring in inappropriate places only because it secured jobs; and the results were required for annual reporting. Seedlings of *Rhizophora apiculata* did not survive strong waves over periods of high tides.

Sea dykes had been expected to protect agriculture coastal lands and mangrove areas. Sea dykes were constructed in Ba Tri and Binh Dai districts, using sediment

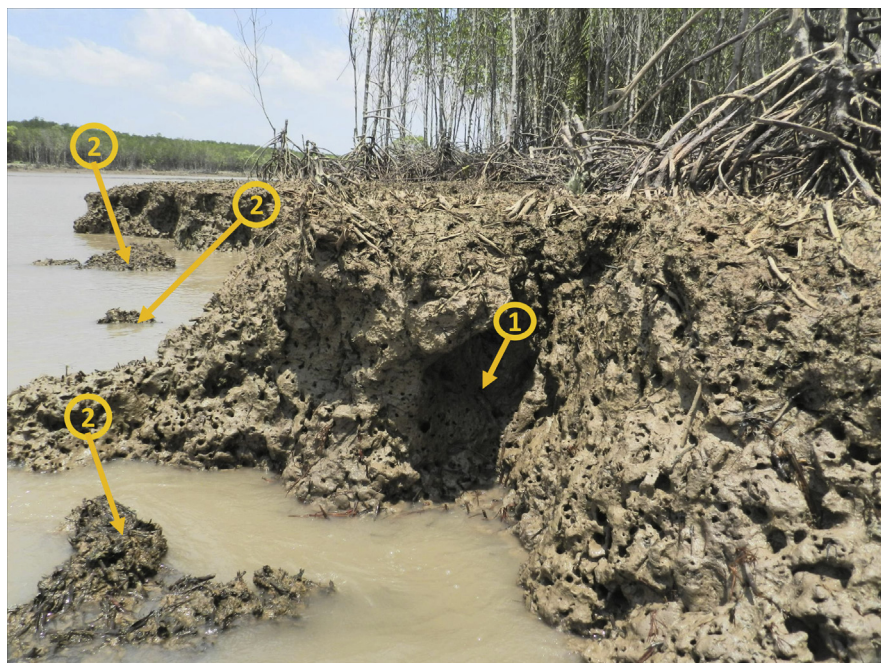


Fig. 5. The status of the Thanh Phu coast. (1) Dense burrows of fiddler crabs were enlarged by strong waves on high tides; and (2) Many sections of the Thanh Hai coast collapsed caused by strong waves propagating into burrows with force.

excavated on site. The sea dyke construction in Thanh Phu district was planned for 2019. However, the inundation and sea level rise map for the Mekong Delta, prepared by the Ministry of Natural Resources & Environment of Vietnam showed that even if Ba Tri and Binh Dai districts were flooded under the influence of the projected sea level rise in Ben Tre, Thanh Phu district would still remain above water level.

A mangrove allocation programme commenced in the mid-2000s, with contracts being valid for 5 years. In many cases, households were contractually paid to transplant additional *Rhizophora apiculata* on allocated areas covered with less than the required mangrove areas. A household was additionally paid an amount of 100,000 VND (equivalent to 5 USD) per month for protecting each ha of allocated mangroves. However, the payment for mangrove protection was terminated in 2013 and no reasons were given for termination. The payment termination caused increased tension between households and the Management Board, meaning that local communities did not continue much of the mangrove protection.

As a contractual benefit, household used allocated mangrove areas for aquaculture. Contracts did not provide clear rules and regulations on using allocated mangroves for aquaculture, with households determining how they implemented mangrove based aquaculture. Ponds were constructed within stands of mature trees of *Rhizophora apiculata*. During the field visits, a number of ponds were found to be protected by a thin line of mature trees of *Rhizophora apiculata*. A substantial number of ponds located in zones 4, 5, 6, 9 and 14 were abandoned.

Thinning and selective harvests are contractually permitted under mangrove allocation contracts. Zones 15 and 16 were designated for thinning and selective harvests. Although contractually permitted, contract holders needed permission and supervision from the Management Board when thinning or harvesting mature trees of *Rhizophora apiculata* in allocated mangrove areas. The field visits revealed that there were many gaps in cover as a consequence of selective harvests in stands of mature trees of *Rhizophora apiculata* in many areas.

Semi-structured interviews with staff working for district people's committees and the Ben Tre CMPSUF indicated that a total area of 371 ha (8 sites) in zones 5, 7 (Binh Dai district), 8, 9, 11 (Ba Tri district), 14, 18 and 19 (Thanh Phu district) were approved to be excluded from the Ben Tre CMPSUF for coastal development and national defence purposes. Field visits revealed that coastal development included construction of restaurants and coffee shops and tourism facilities. In national defence zones, mangroves were cleared and local crops were removed (with farmers compensated). Further areas were proposed by district people's committees to be excluded from the Ben Tre CMPSUF in 2014.

Intertidal mudflats, despite being located within the Ben Tre CMPSUF, were leased to 10 Cooperatives in Ben Tre by three district people's committees under contracts for aquaculture for the purpose of farming Lyrate Asian hard clam (*Meretrix lyrata*) on the intertidal mudflats. Field visits showed that coastal mangroves around clam farming areas were heavily deforested and degraded. The semi-structured interviews with staff working for the Management Board and local government agencies revealed that areas between the boundaries of the Ben Tre CMPSUF and Cooperatives' farming areas were poorly demarcated. There was a lack of coordination between the Management Board and the Cooperatives in enforcing laws in the poorly demarcated areas.

3.3. Private coastal land use

A small number of people who settled in the area in the 1970s were issued formal land use right certificates (locally called 'red books'), effectively becoming private land. Private land included coastal mangrove areas and coastal sand ridges. Land owners legally cleared coastal mangrove areas for the construction of aquaculture ponds. The cleared coastal mangrove areas were as close to open sea water areas as possible to allow for saline water to enter the ponds. Many of private aquaculture ponds were breached in the 1980s, causing a substantial loss of private lands in many areas. Abandoned ponds are still obvious in areas near zones 4, 5, 6, 9 and 14.

While only a minority of the migrants were issued formal land use right certificates, the remaining population, especially those who migrated to the areas after 1995 have not been issued with red books. The 2013 land law stipulates that a red book will not be issued until an area is clearly demarcated on the ground. The boundaries of the Ben Tre CMPSUF had not been demarcated on the ground by July 2014. Local communities are anxious to know when red books will be issued as they would assist people in making decisions on housing issues, incomes and their children's futures.

3.4. Naturally protected mangrove areas

The field visits showed that many coastal areas were naturally protected against coastal erosion with the spread of beach morning glory (*Ipomoea pes-caprae*) or weeds growing on sand accumulation areas and underdeveloped lands, and nearby natural regeneration of local mangrove species in zones 4, 5, 6, 9, 10, 14 and 20. Empty shells, dumped in a large area in front of mangrove stands in zone 9, were observed to have assisted in protecting mangrove areas and the coast of Bao Thuan commune, Ba Tri district. These forms of protection were observed to have significantly assisted in dissipating the energy of strong waves and trapping sand and fine mud, minimizing negative impacts of coastal erosion and storm surge.

4. Discussion

4.1. Land use planning and the management of the Ben Tre CMPSUF

The zones of the Ben Tre CMPSUF are protected to assist in balancing coastal protection and management with demands for socio-economic development. However, the districts, who administratively manage the zones, in most cases, prioritized economic development over environmental issues. As a consequence, land use conflicts occurred, leading to weak coordination in coastal protection among the relevant government agencies, and over-exploitation of coastal resources, with the coastline dissected by agriculture areas and aquaculture ponds of all sizes. Private agriculture and aquaculture areas along the Ben Tre coastline were legitimately designated by the districts. Agriculture and aquaculture operation and practice involved mangrove clearance, presumably causing mangrove loss. The presence of cash crops and aquaculture ponds along the coastline caused disconnection or gaps in mangrove areas, which reduce the capacity and resilience of mangroves to assist during periods of storm surges, and for sea level rise adaptation.

National defence is prioritized not only in Ben Tre but throughout Vietnam. However, the location of the military training ground is controversial. This area is predicted to be inundated by 2020 under the sea level rise scenarios put forward by the Ministry of Natural Resources & Environment of Vietnam in 2011 ([Ministry of Natural Resources and Environment of Vietnam, 2011](#)). The presence of agriculture, aquaculture and the military training ground have resulted in a discontinuous mangrove belt in many coastal sections.

4.2. Mangrove allocation and coastal mangrove protection

Local communities were involved through contracts, in coastal mangrove protection since the mid-2000s. However, contracts were for a short period of time (5 years) and did not secure sufficient income and livelihood futures. According to the 2013 Vietnam Law on Land, the ownership of lands and forest lands, which are allocated or leased for agriculture, aquaculture, and salt production, is granted for a maximum period of 50 years ([Vietnamese National Assembly, 2013](#)). Kien Giang has applied the 50 year contracts for the mangrove allocation programme since 2011 ([Nguyen et al., 2017b](#)). For them to be effective, allocation contracts in Ben Tre should be extended, ideally up to 50 years, which is a sufficiently long period of time to allow for appropriate investment for sustainable outcomes.

This study showed that contracts did not provide sufficient technical guidelines on using allocated mangroves. Insufficient technical guidelines forced contractees to use different and sometimes poor management practices in the allocated areas, resulting in the Ben Tre coast being fragmented or dissected with aquaculture ponds of all sizes.

Although providing an alternative income, thinning and selective harvests of mature trees of *Rhizophora apiculata* in allocated mangroves dominated by *Rhizophora apiculata*, even when controlled properly, reduce the capacity of coastal mangroves to fulfill the primary purpose of protection from erosion by creating gaps and disconnections in an otherwise mainly continuous mangrove belt. The findings of this study are closely in accordance with those of [Nguyen et al. \(2017 a; b; and c\)](#).

4.3. Coastal mangrove protection

Many sea dyke sections in Binh Dai district and some in the northern part of Thanh Phu district have been exposed to the sea after construction ([Nguyen, 2015](#)). Under the most extreme sea level rise scenario made for the Ben Tre area in 2011 (1 meter by 2020) ([Ben Tre PPC, 2011](#)) where Ba Tri and Binh Dai districts would be completely inundated, the coastal areas of Thanh Phu district remained above the sea level. This means that the sea dyke construction planning had not properly taken into consideration morphological aspects and future sea level rise in Thanh Phu. Even if constructed, the sea dyke would not be cost-effective in term of coastal protection and mangrove protection. Therefore, sea dyke construction in Thanh Phu should not proceed.

Despite being a common management practice, transplantation of seedlings of *Rhizophora apiculata* on mudflats is generally ineffective. The study showed that stands of *Rhizophora apiculata*, in Thanh Phu were uprooted, resulting in failure to control coastal erosion. [Lewis \(2005\)](#), [Kamali and Hashim \(2011\)](#), and [Nguyen et al. \(2016\)](#) showed that a much more effective approach to mangrove area regeneration is to remove stressors rather than implement transplantation. Trees of *Rhizophora apiculata* were not effective in protecting mangrove dominated muddy coasts from erosion, supporting the findings of [Nguyen et al. \(2017b; c\)](#).

Casuarina tree is an exotic species that was not effective in preventing and controlling coastal erosion. The introduction of Casuarina trees could not only result in the Ben Tre shoreline being dominated by these trees, but also poses an ecological threat to local floral assemblages. Transplantation accompanied by the removal of other mangrove species in the past may have caused a significant change in coastal mangrove ecosystems and increased the potential effects of sea level rise and storm surge. Transplantation with Casuarina trees have not assisted in establishing the mangrove belt.

4.4. Coastal areas well protected by thick layers of weeds and secondary succession

The study showed that many coastal areas have been well protected by thick layers of weeds and secondary succession of *Ipomoea pes-caprae* that assisted in

stabilizing the coasts. Natural regeneration of local mangrove species occurred through piles of dead branches of *Nypa fruticans*, coconuts, tree trunks, and agricultural wastes, called entrapping microsites by Farrell et al. (2012). This is supportive to the findings of Nguyen (2015). However, despite being clearly beneficial, encouragement of secondary succession of *Ipomoea pes-caprae*, weeds, and entrapping microsites has not been used as a management measure in Ben Tre or elsewhere in the Mekong Delta region.

Table 2. Summary of the integrated strategic measures for sustainable managing the Ben Tre CMPSUF.

Strategic measures	Objective (s)	Zone (refer to Fig. 6 for zone location).	Main activities
Managed realignment	<ul style="list-style-type: none"> Mitigating adverse impacts of coastal erosion on aquaculture and agriculture areas. Establishing a continuous mangrove belt. Protecting private aquaculture and agriculture areas 	4, 5, 10, 14	<ul style="list-style-type: none"> Participatory land use zoning (livelihoods and co-management areas) to demarcate or adjust the Ben Tre CMPSUF boundaries and to agree future coastal development scenarios with the relevant stakeholders, including the military forces. Flood and shoreline protection guidelines developed (i.e. sea dykes and sluice gates). Private aquaculture pond and agriculture areas voluntarily configured at a proper ratio to establish a mangrove belt and protect ponds and production areas from erosion Education, awareness and improved enforcement programmes Issuing 'red books' to local households after the boundaries are demarcated
Hold the existing defence line	<ul style="list-style-type: none"> Strengthening protection of coastal mangroves in designated mangrove rehabilitation areas. Establishing a continuous mangrove belt that can accommodate local livelihood improvement 	1, 6, 7, 8, 9, 11, 12, 13, 15, 16, 17, 18	<ul style="list-style-type: none"> Understand past shoreline changes, erosion mechanisms and future shoreline development. Incorporate lessons learned into flood and shoreline protection measures. Flood and shoreline protection measures developed. Mangrove protection and restoration promoted using natural regeneration. Technical guidelines on mangrove allocation developed with extended contract time. Promote possible future coastal development scenarios to be agreed by the relevant stakeholders.
No active intervention	<ul style="list-style-type: none"> Promoting natural regeneration of local mangrove species, education and awareness. Protecting and managing mangroves as a mangrove green belt. 	19, 20	<ul style="list-style-type: none"> Stabilization of eroded coasts promoting natural regeneration. Education, awareness and improved enforcement programmes.

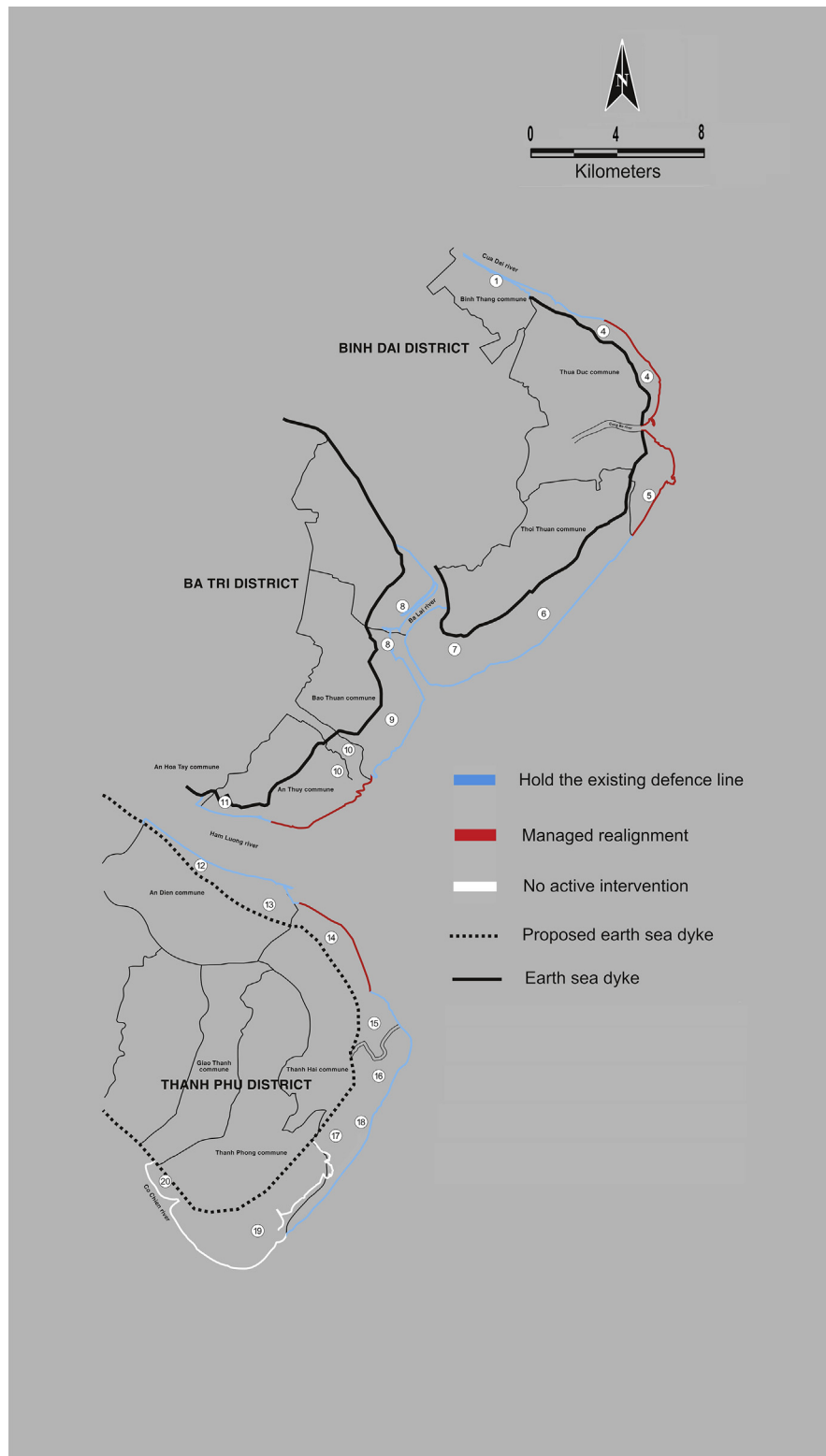


Fig. 6. Recommended future coastal land-use planning for the Ben Tre CMPSUF (adapted from IUCN 2015).

4.5. Sharing the results in the region

Protected mangroves in the Mekong Delta region have been made vulnerable to coastal erosion (Ministry of Natural Resources and Environment of Vietnam, 2011; Vietnam Administration of Forestry, 2012). In 2009, sustainable management of protected mangroves in the Mekong Delta for adaptation to climate change and sea level rise was required by the Vietnamese Prime Minister (2009). Together with the findings of Thu and Populus (2007), Cuc and de Ruyter van Steveninck (2015) and Nguyen et al. (2017a), with respect to causes of mangrove loss and degradation in other provinces in the Mekong Delta, the findings reported in this study can assist in understanding why protected mangroves are lost or degraded in the region.

4.6. Recommendations

The development of a shoreline management plan is recommended to address short and long term coastal management issues in Ben Tre. This study supports three approaches to shoreline management: *Hold the existing defence line, managed realignment, and no active intervention*. *Hold the existing defence line* aims to strengthen the protection of coastal mangroves in the mangrove rehabilitation zones. *Managed realignment* involves adjustment of, or rezoning of, the Ben Tre shoreline in response to the current and future coastal development scenarios and sea level rise. The adjustment and rezoning aim to mitigate adverse impacts of coastal erosion on the ‘no intervention’ and ‘mangrove rehabilitation’ zones, and assist in establishing a continuous mangrove belt. *No active intervention* fully supports mangrove protection and natural mangrove regeneration in strictly protected zones, and promotes education and awareness of mangrove resources (Table 2 and Fig. 6).

Clearance of dead Rhizophora and Casuarina trees created gaps among the current mangrove stands. As recommended by Nguyen (2015) and Nguyen (2018), dead Rhizophora and Casuarina trees should be left in places and could function as entrapping microsites that assist in breaking the energy of the incoming waves and protecting mangroves located landward.

5. Conclusions

The current management of the Ben Tre CMPSUF has been critically reviewed. Approximately 15% of the coastal areas in Ben Tre have been severely eroded, mainly due to the inadequate coordination in land use planning and ineffective management strategies. Strategic measures that include managed realignment, hold the existing defence line and no active intervention are recommended for effectively managing the Ben Tre coast in adaptation to climate change and sea level rise, and livelihood improvement.

Declarations

Author contribution statement

T.P. Nguyen: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

K.E. Parnell: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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