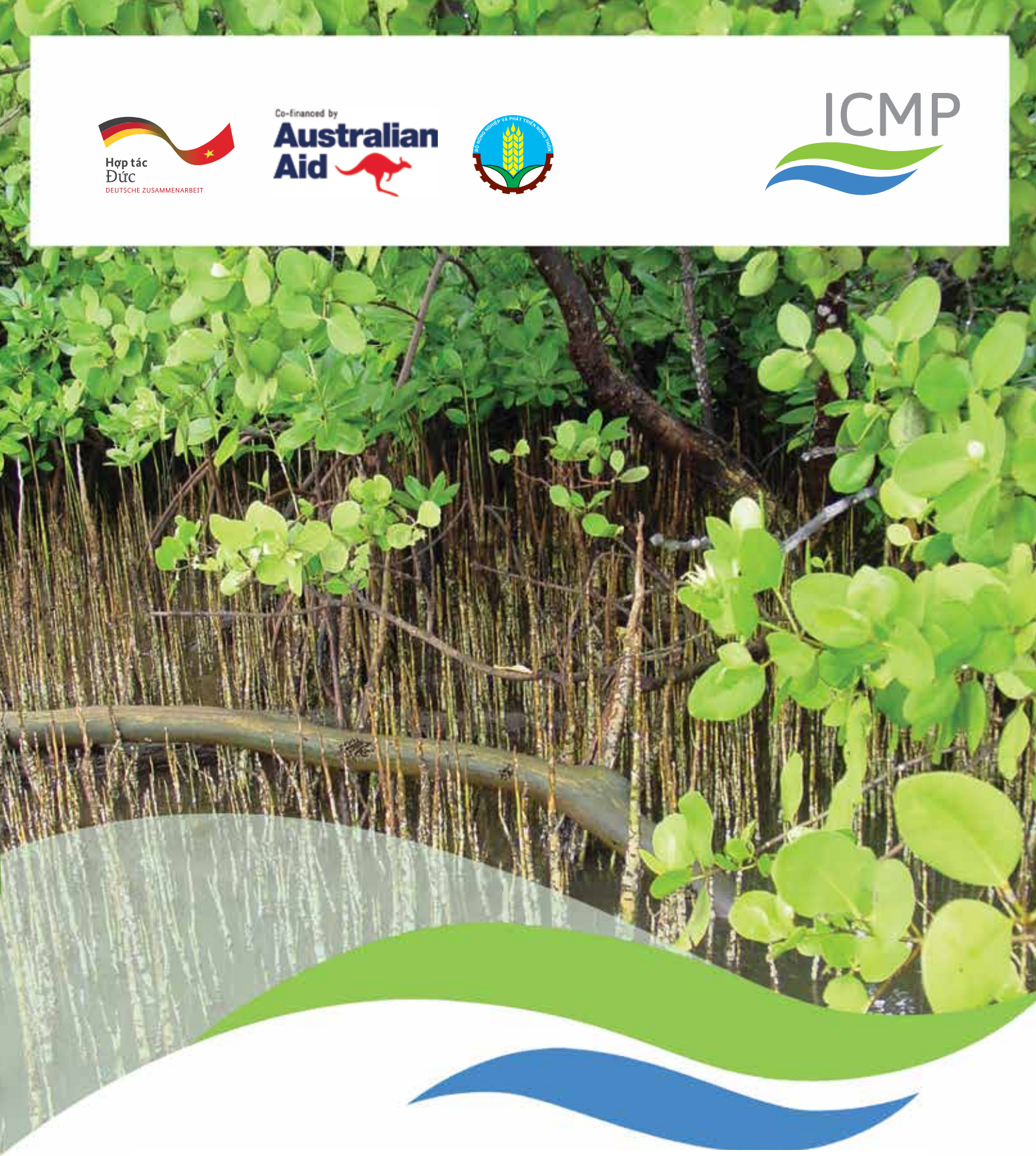

Video Assessment and Shoreline Mapping of the Ca Mau Province, Mekong Delta, Viet Nam

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Video Assessment and Shoreline Mapping of the Ca Mau Province, Mekong Delta, Viet Nam

GIZ in Viet Nam

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has been working in Viet Nam for more than 20 years. We currently have around 250 specialised staff deployed across the country, including national and international personnel, Development Advisors and CIM experts.

On behalf of the German Government, GIZ provides advisory services to the Government of Viet Nam and is currently engaged in three priority areas: (i) Vocational training; (ii) Environmental policy and sustainable natural resource use; and (iii) Energy.

GIZ Viet Nam's main commissioning party is the German Federal Ministry for Economic Cooperation and Development (BMZ). Other commissions come from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Ministry of Finance (BMF). GIZ Viet Nam is also engaged in various projects co-funded by the Australian Government (Department of Foreign Affairs and Trade – DFAT) and the European Union and cooperates closely with the German development bank KfW.

The Integrated Coastal Management Programme (ICMP) is being co-financed by the German and Australian Governments. In order to strengthen resilience and to reduce vulnerabilities to climate change impacts, the ICMP Programme supports Viet Nam in sustainably managing coastal ecosystems of the Mekong Delta affected by climate change. The Programme is being implemented by GIZ in close collaboration with the Ministry of Agriculture and Rural Development (MARD), as well as several departments of the five programme provinces An Giang, Bac Lieu, Ca Mau, Kien Giang and Soc Trang of the Mekong Delta.

For further information, please visit www.giz.de/en, www.giz.de/viet-nam, and http://daln.gov.vn/icmp-cccep.html.

Contents

List of Maps

Executive Summary

This report presents a summary of the condition of the mainland coastline of Ca Mau Province as determined from Shoreline Video Assessment (SVAM) carried out in May 2013. The assessment focused on both the extent and severity of erosion and the extent and condition of the mangrove resource. Published reports outlining the spatial extent of the key pressures on the mangrove ecosystem both now and as they are projected to occur in the future as a result of climate change modelling are reviewed.

There are 64 km of coastline where the erosion is classed as severe or extreme with much of it on the east coast of the province particularly on the eastern side of Ngoc Hien where there is 26.3 kilometres. There is also severe or extreme erosion on the coast of Tran Van Thoi with some also in U Minh and on the south-western coastline of Ca Mau Cape. There are 24 kilometres of depositional shore much of it is concentrated in the more protected shallow estuaries to the north of Ca Mau Cape. There is a small section in the north coast of the province and small areas along the west coast of Phu Tan and near the southern tip of the province.

Almost all of the coastline of Ca Mau can be considered to be a mangrove coast and mangroves were found along 96% of the shoreline of Ca Mau province although only 72% of the coast was considered to be mostly mangrove. Some areas have experienced considerable erosion or removal of the mangroves for development and over 4 kilometres of the coast is now effectively terrestrial coastline. Much of the coastline that is now exposed to erosion is made up of plantations or abandoned aquaculture.

Very high biomass forests make up 88 kilometres of the coastline and are concentrated in the more protected estuarine conditions north of Ca Mau Cape. The presence of plantations along the east coast also results in high biomass forest along that shoreline. All of the districts have some coastline classed as very low biomass up to a maximum of 3 kilometres in Tran Van Thoi. Low biomass forests make up 51 kilometres of coast and are also present in all districts but are concentrated in Tran Van Thoi and the east coast of Ngoc Hien. A long section of low biomass coastline in the centre of U Minh district is associated

with severe erosion and is currently being protected by double concrete pole wave break fences filled with rocks.

Climate change and sea level rise are expected to have significant and widespread impacts on Ca Mau affecting natural systems both directly and through increased pressure due to changed human systems. Climate change may lead to decreased sediment supply from the Mekong River, altering the erosion and depositional conditions. An increased incident of extreme storm events is likely and in addition typhoons, while relatively rare in the province pose a significant threat to mangrove ecosystems.

There are also a number of indirect pressures as a result of human activities. The most extensive human related pressure is clearing for aquaculture, but cutting wood, clearing for development and the collection of aquatic resource also impact resource condition.

Stress on the coastal mangroves due to human Influence occurs along 119 kilometres of coastline of the province. Almost the entire eastern coastline of Ngoc Hien shows some stress and this section of coast has half of the total 12.5 kilometres of high and very high stress coastline. Much of the coastline of the two other east coast districts show some stress and have more than a kilometre of coastline with high or very high stress. Significant amounts of the coastline in the two northern districts show some stress from human impact but the estuarine coastline has lower levels of human impact.

The extreme values of each of the three condition classifications; erosion, biomass and human influence can be used to identify hot spots of each condition. The Distribution of the hot spots is shown in Figure 1. The development and coordination of protection, restoration or prevention measures can then be focused on these areas.

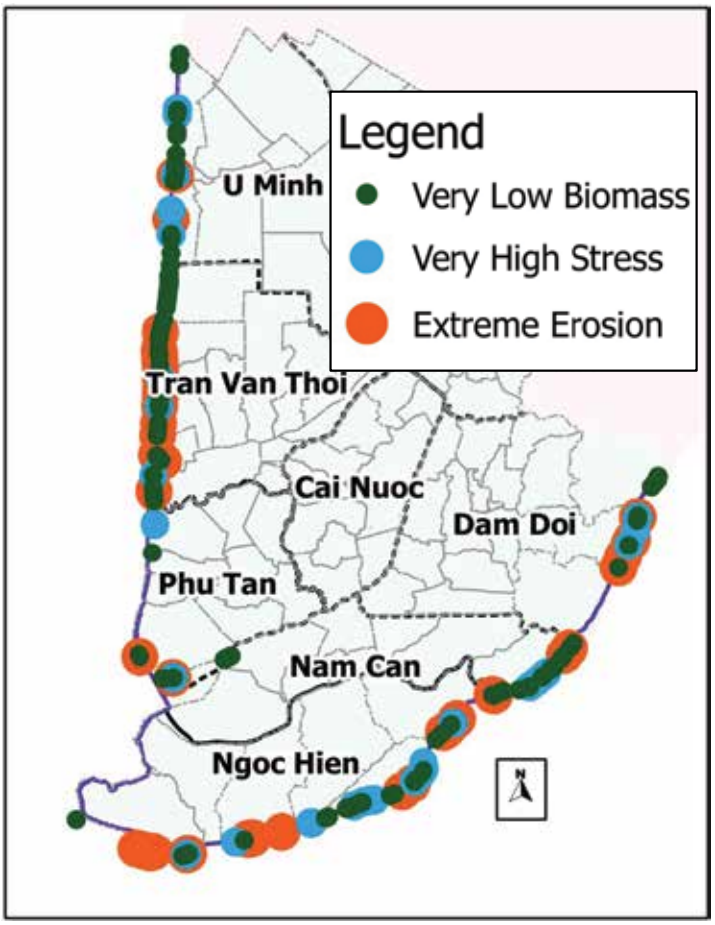

Figure 1. Location of hot spots of erosion, low mangrove biomass and stress from human activities

001 Methods

Background Documents

There are four important documents that helped to form the background to this report: The manual accompanying this report and three documents that have come out of a study that was funded by Australian Aid and managed by the Asian Development Bank (ADB); *Climate Change Impact and Adaptation Study in The Mekong Delta – Part A; Climate Change Vulnerability and Risk Assessment Study for Ca Mau and Kien Giang Provinces, Vietnam.*

The technical report Shoreline Video Assessment Method (SVAM) Manual is published by the GIZ Project: "Integrating Climate Change Adaptation into Planning for Coastal Area Management" in Ca Mau as part of this project.

The documents from the ADB study are:

1. A report to (ADB) published by the Institute of Meteorology, Hydrology and Environment (IMHEN).

Climate Change Impact and Adaptation Study in The Mekong Delta – Part A Final Report: Climate Change Vulnerability and Risk Assessment Study for Ca Mau and Kien Giang Provinces, Vietnam. (2011). **By IMHEN, Ca Mau Peoples Committee, and Kien Giang Peoples Committee.**

2. A knowledge product published by ADB.

Climate Change Risks in The Mekong Delta –Ca Mau and Kien Giang Provinces, Vietnam. (2013). By **ADB (Asian Development Bank).**

3. A 2012 report to the GIZ Conservation and Development of the Biosphere Reserve of Kien Giang Province Project.

Coastal Dynamics of Kien Giang and Ca Mau, Vietnam; 2009 – 2050. By **Dr Michael Russell and Dr Nguyen Huu Nhan.**

These products present an assessment of the present vulnerability of the districts of Ca Mau and Kien Giang and of potential changes in vulnerability due to climate change. The report and atlas presents the results of the latest (as of 2010) climate change modelling study. The IMHEN, Ca Mau Peoples Committee, and Kien Giang Peoples Committee report also presents modelling of wind and wave dynamics and the subsequent erosional pattern for three time periods, 2009, 2030, and 2050, including the potential effects of Typhoons. Further analyses of the coastal modelling are presented in the third report.

SVAM Method

Video data were collected and analysed using the Shoreline Video Assessment Method (SVAM). This section briefly describes the methods used to collect the video and to analyse the data to produce classes of erosion, biomass and human influence. The collection of video and the methodology of attaching geographic location data to the video are described in detail in the Shoreline Video Assessment Method (SVAM) Manual.

Video Collection

Video was collected from a boat that followed the coastline. While the ideal track of the boat is 50 meters from the coastline, due to the presence of fishing nets and fishing traps close to the shore, and due to extensive sedimentary shoals the distance varied from 50 m to a number of kilometres. The zoom on the video was utilised to ensure that the video could still be assessed despite distance.

Video Interpretation

The interpretation the video is based on scoring a series of indicators of: shoreline physical condition; mangrove forest type, extent and condition and mangrove resource use. The indicators shown in Table 1 are described in detail in the Shoreline Video Assessment Method (SVAM) Manual. The video is scored at 30 second intervals.

Table 1. Indicators Used to Score the Video

Shoreline Physical Condition	Mangrove condition	Resource Use
What is there?	Mangrove position	Cutting
Shore Type	Seedlings	Plantation
Behind the Shore	Dominant Species 1	Development
Bank Slope	Dominant Species 2	Recently Cleared Mangroves
Bank Substrate	Height	Wave Break Fence
Tidal Flat Substrate	Mangrove Density	
Erosion condition	Canopy Condition	
Small Inlet / canal	Dead Trees	
Active Erosion		

Further Analysis

The data from the video interpretation are also used to classify the erosion condition (an extra class of extreme is derived from the Erosion Condition indicator), biomass class (from Height, Mangrove Density and Canopy condition) and the extent of human influence (from Development, Cleared Mangroves and Cutting indicators).

Attaching geographic location data

A GPS was used to collect geographical location of the boat, and the time on the GPS and the video camera were synchronised. This means that the GPS locations could be attached to the spread sheet that was used to record the video interpretation and distance from the preceding point could be calculated. As a result the distance and geographical information presented in this report represent the data for the location of the boat rather than the precise location of the coast.

Where the track of the boat was a long distance off the coast the GPS locations were moved closer to the coast that corresponded to the information recorded on the video. Reference points that could be seen in the video were used to ensure that the correct interpretation was moved to the correct location based on the existing GIS layers. In the case of the large shallow complex of estuaries to the north of Ca Mau Cape, the track of the boat did not fit the shape of the estuaries. In this case the GIS layers were

used to create a new track with points spaced 30 meters apart. Again using visual reference points the information from the video was transferred to the new geographical location.

The result is a GIS layer of data points spaced approximately 30 m apart that is located just off the actual coastline of the province.

Description of Terms

District

The results of the video assessment are presented for each district. As the district of Nam Can has two distinct coastlines with one open to the West Sea and one open to the East Sea the results are presented as Nam Can W and Nam Can E. The island district of Ngoc Hien also has two distinct coastal types, therefore the results for this district are similarly presented as Ngoc Hien W and Ngoc Hien E, with the two sections divided at the southern tip of the mainland. For ease of description the term district will be used to refer to the district and coast combination.

Plantations

Plantations are almost exclusively Rhizophora apiculata. In some cases scattered individual Avicennia alba that may have grown within or between blocks of plantation may also be present. Plantations can be recognised by continuous stands of even aged, even height monocultures planted in straight rows. However variable growth rates, infilling by natural means, disease or human activities can all result in age or height variability. Natural regrowth after abandonment or natural disaster can also mimic the appearance of a plantation. The presence of plantations was only identified as plantation if it was obvious due to straight lines of even aged trees.

As a result the documented extent of plantation at the shoreline in likely to be an under-estimate.

Presentation of Results

Tables displaying SVAM results are presented by district/coast starting from the north-west coast district of U Minh and continuing anticlockwise around Ca Mau Cape and eastwards to the easternmost district of Dam Doi.

Maps displaying SVAM results are presented in three sections of the province:

1. The northern portion of the west coast made up of U Minh and Tran Van Thoi.
2. The southern portion of the province made up of Phu Tan, the west coast of Nam Can including Ca Mau Cape, the southern coast of Ngoc Hien and a part of the East coast of Ngoc Hien.
3. The east coast of the province made up of part of Ngoc Hien E, the east coast of Nam Can and the coast of Dam Doi.

Description of the Ca Mau mainland coastline

The province of Ca Mau is shown in Figure 2. The geographical extent and population density of the communes that make up each district are also shown.

The coastline of Ca Mau is made up of several different landform types:

- A straight section of coastline in the northwest made up of U Minh and Tran Van Thoi.
- A series of shallow estuaries on the south coast of Phu Tan, Nam Can W and the north west coast of Ngoc Hien that empty into a large embayment formed by the westward progression of Ca Mau Cape.
- Ca Mau Cape which defines the location of the south-western tip of Vietnam and the south coast of Ngoc Hien that is made up of sandy sediments. These areas have extensive offshore sediments that are moving westward under the influence of currents.
- A highly eroded coastline running from southwest to north east that is oriented towards the south east.

Except where slopes are gentle, mangroves are generally located on top of and to landward of steep to shear eroded mud flats. On a large part of the East coast and in small areas on the west coast there are very low sand dunes on top of the underlying mud strata. These may be remnant dunes that have been exposed by erosion or may represent the accumulation of sand and shell sediments that have deposited in high wave conditions.

Almost all of the coastline of Ca Mau can be considered to be a mangrove coast. The exceptions are; the small rocky island of Da Bac close to the coast of Tran Van Thoi, 1.6 kilometres of beach on the southern tip of the mainland, and the unsurveyed Khoai Island group off the south Coast. Some areas have experienced considerable erosion or removal of the mangroves for development and over 4 kilometres of the coast is now effectively terrestrial coastline.

Mangroves were found along 96% of the shoreline of Ca Mau province although only 72% of the coast was considered to be mostly mangrove and only 53% of the coastline was considered to be high or very high biomass forest. Pressure on these forests through clearing for development or cutting was evident along 119 km of coastline, affecting 50% of the mangroves along the shoreline. Almost one third of the mangrove coastline (64km) was experiencing active mangrove loss due to erosion. Overall, two-thirds of the total coastline was found to be eroded or eroding.

In most places along the western coastline of Ca Mau, the mangrove fringe is dominated by Avicennia alba (Vietnamese name: Mắm trắng). The eastern coastline is dominated by actively eroding plantations of Rhizophora apiculata (Vietnamese name Đước) with scattered mixed forest dominated by A. alba and R. apiculata in the gaps between plantation blocks or by low to medium height regrowth forests dominated by A. alba and/or R. apiculata. In the southwest of the province there is a complex of estuaries that are protected by Ca Mau cape and by extensive areas of sediments that have been transport around the cape and out of the Lon River.

The population density of each coastal commune can be used to as a measure of pressure on mangrove resources. High population density of Song Doc Town in Tran Van Thoi district (12 persons/km2) and Cai Doi Vam Town in Phu Tan district (8 persons/km2) indicate that pressure on resources on the coast will be high. Khanh Hoi commune in U Minh also has a relatively high population density of over 3 persons per km2. Phu Tan and Tan Hai communes in Phu Tan district and Khanh Binh Tay in Tran Van Thoi have population densities of over 2 persons per km^2.

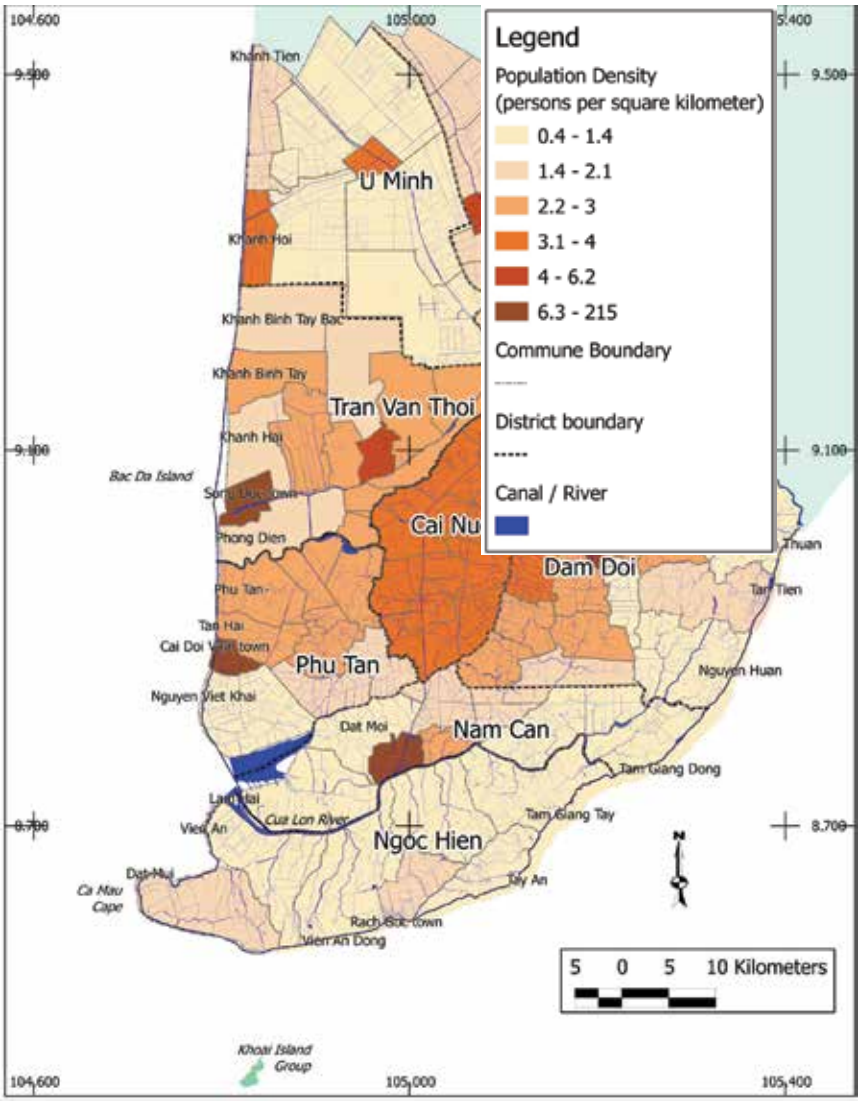

Figure 2. Ca Mau Province, Showing the Population Density of Each Commune (only coastal communes are labelled)

A more detailed description of the coast of each of the six coastal districts is given in Table 2. From the Table it can be seen that the two rice growing districts of U Minh and Tran Van Thoi have extensive areas of natural mangrove forests but in U Minh only two thirds is of high biomass and in Tran Van Thoi only 40% was classed as high biomass. Much of the existing mangroves are regrowth in aquaculture ponds that have been abandoned due to erosion.

The estuarine shore on the western side of Nam Can has most of its shoreline made up of intact natural high biomass forest. The western side of Ngoc Hien is backed by protection forest and also has a large proportion of the coastline with natural high biomass forests. Much of the coastline of Phu Tan has natural high biomass forests, but there is pressure from aquaculture close to the shore on some parts of the District.

The East coast of the province has experienced considerable coastal retreat due to erosion. As a result much of the coastline is made up of mangroves that have been exposed by this erosion. Only two thirds of the coast of eastern Ngoc Hien is of high biomass and at least one third is plantation that is currently

eroding. On the East coast of Nam Can while much of the forest appears to be natural regrowth, almost half is of low biomass. Dam Doi has a high proportion of its coastline that is of high biomass but over half of this is made up of eroding plantation forest.

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Table 2. Description of the Coastline of Each District

District	Coastline (km)	Communes	Land use of Hinterland	Description of Coastal Fringe	Mangroves (km)	% of Coast that is Natural or Regrowth Mangroves	% of Coast with Plantation Exposed by Erosion	% of Coast with High Biomass Forest
U Minh	28,2	Khanh Tien Khanh Hoi	Rice	Abandoned aquaculture	26,8	80	0	68,3
Tran Van Thoi	34,9	Khanh Binh Tay Bac Khanh Binh Tay Khanh Hai Song Doc town Phong Dien	Rice	Thin belt of Eroding Mangroves	31,7	85	4	38,9
Phu Tan	34,9	Phu Tan Tan Hai Cai Doi Vam town Nguyen Viet Khai	Aquaculture	Stable or Prograding and Estuarine	34,1	96	0	88,3
Nam Can W	21,4	Dat Moi Lam Hai	Aquaculture	Estuarine	21,1	99	0	98,7
Ngoc Hien W	43,5	Vien An Dat Mui	Protection Forest	Eroding and Stable Tall Mangroves	40,8	85	0	92,5
Ngoc Hien E	49,1	Vien An Dong Rach Goc town Tay An Tam Giang Tay	Aquaculture	Eroding abandoned aquaculture and plantations	48,6	68	30	66,9
Nam Can E	13,1	Tam Giang Dong	Aquaculture	Eroding abandoned aquaculture	13,0	90	9	52,8
Dam Doi	26,0	Nguyen Huan Tan Tien, Tan Thuan	Aquaculture	Eroding abandoned aquaculture and, Plantations	25,7	43	55	81.5

02 Key pressures

A number of recent reports have examined the vulnerability of Ca Mau and Kien Giang coastlines particularly with regard to climate change. This section reviews the key pressures on the mangrove resources of the mainland coast of Ca Mau found in these reports.

Climate Change

Low lying coastal and deltaic ecosystems are especially vulnerable to the combination of impacts associated with climate change and sea level rise, and climate-induced factors will have a major influence on changes to coastal geomorphology. However it needs to be recognised that coasts are not passive systems. The coastline of Ca Mau has historically changed over time in response to a combination of geomorphological and oceanographic factors. Analysis of satellite imagery shows that the cape of Ca Mau for example has undergone significant geomorphological change over the last 100 years.

Erosion and Sedimentation

The most substantial impacts of changes to the climate on Ca Mau are expected to be increased erosion due to more energetic wave conditions and intense monsoonal conditions and storms. Combined with higher sea level, this will result in the degradation of coastal protection works and progressive loss of coastal land. Coastal erosion is already a problem, with estimated rates of land loss of 5–10 m per year in some locations. Changes in coastal erosion and sedimentation patterns are also projected to occur.

One of the key findings from the coastal modelling is the dramatic reduction in sediment loads in the Mekong mainstream (and the Bassac River in particular), and its effects on sedimentation and deposition on the Ca Mau peninsula and the Ca Mau coastline. It is estimated that there will be a 60% reduction in sediment loads over the next 20 years.

The projected coastal erosion will lead to:

- Loss of mangroves and other erosion buffers leading to damage and loss of agricultural land and infrastructure.
- Changes in livelihood systems due to flooding and salt water intrusion resulting in increased pressure on mangrove resources.

Sea level Rise

Sea level is projected to rise by 30 cm by 2050 (MONRE 2010). The current height of the sea-dyke system is around 1.2 meters, so even at 2050 any change in the area that is simply inundated will be limited to the current low lying coastal wetland areas and river estuaries that are not protected by sluices. More substantial sea level rise at longer time frames will threaten to overtop sea dykes. The major effects of a rise in sea level are that storm surge effects are increased and larger waves are able to penetrate further into the coast. This increases the erosive power of the waves and consequently increases the amount of sediment that is removed.

Waves

The Coastline of Ca Mau is not exposed to oceanic swells and waves are generated by wind action. The wind regime of the region is influenced by airflow driven by a two season monsoon system; the 'Wet Season' from May to October where moisture laden winds blow from the southwest resulting in widespread thunderstorms due to the unstable atmospheric conditions and; the "Dry Season" where dryer and atmospherically more stable winds blow from the NE from December to April. During each monsoon season, wider scale synoptic conditions can combine to reinforce the strength of the winds up to force 8. There is a transitional period of variable winds in between each monsoon.

Typical southwest monsoons bring onshore winds and waves of up to 0.5 m offshore to much of the exposed coast of the Ca Mau peninsular. These waves impact on both the east and west coasts of the peninsular.

Stronger SW monsoons bring stronger waves of 2 - 2.5 m offshore along the entire coast of the study region. Waves of this size can cause destruction of exposed infrastructure along the coast. These waves will undermine mangroves and erode exposed earth banks. During strong NE monsoon conditions, waves of up to 3 m impact the west coast. However, the east coast experiences low wave conditions.

Currents

Currents influence both the direction and distance that eroded sediments are transported. Strong currents will exacerbate wave erosion and the strength and direction of currents determine the direction and distance that sediments that have been eroded are transported.

Strong winds will generate currents that flow in a downwind direction, and these generated currents are particularly strong where waves interact with the shallow depths near the shore. As a result during strong southwest monsoon conditions the current along both coasts is predominantly a northerly flow regardless of tidal conditions. Strong northeast to east monsoons in the dry season induce a north to south current to flow along both coasts regardless of the tide.

In typical monsoon conditions, currents are determined by the tide. However the two different tidal regimes of the West Sea and the East Sea make the tidal currents more complicated. The larger tidal

range in the East Sea means that the East Sea dominates the tidal currents even in the southern part of the West Sea off the west coast of Ca Mau province.

The larger tidal range in the East Sea dominates the tidal currents in the southern part of the West Sea (off the coast of southern Ca Mau and the west coast of Ca Mau province). The combination of high tide in one sea and low in the other can lead to significant current flow which is concentrated off Ca Mau cape.

Storm Surge

During a storm event, the combined effect of low pressure and high winds result in higher than normal water levels. Both wind set-up and wave set-up are affected by the depth of the coastal waters. Where there is a narrow shallow shelf, the wave set-up is predominant, while a broad region of shallow water would cause a dominant wind set-up.

For the coastline of Ca Mau, there is medium potential for wave setup to contribute to storm tide on the ocean facing coastlines that are exposed to waves from the dominant wave direction during the northeast and southwest monsoons. It is clear from both the observed effects on low lying study areas in the past, and the simulations from modelling, that extreme weather events pose a significant threat.

Typhoons

3 shows the tracks of cyclones from 1980 to 2005. In 1997, Typhoon Linda moved across the southern tip of the Ca Mau peninsula and caused widespread damage across the two provinces. It resulted in flooding, damage to mangrove and plantation forests, damage to housing and power infrastructure and inundation and associated damage to agricultural production. As more mangroves are removed the exposure of the occupied hinterland to significant damage is increased.

Figure 3. Regional tropical cyclone tracks from 1980 – 2005, coded by Saffir-Simpson category. The points show the locations of the storms at six-hourly intervals. Source: Wikipedia.

Figure 4 shows the ICOE modelled significant wave heights during Typhoon Linda in 1997. The greatest physical effects of Linda on the mainland would have been felt on the lightly populated East coast of Ca Mau when the typhoon approached and crossed the coast. This occurred at high tide and the associated low atmospheric pressure would have led to severe storm surge conditions and the accompanying wave field had a long fetch with waves of over 3 meters directed onto the shore.

Modelled water surface elevation in Ca Mau is up to 2 m high and combined with 4- 5 m waves will result in severe damage to coastal protection dykes, and fishing villages in estuaries and canal mouths along the entire coast. This would threaten road infrastructure particularly the proposed southern highway, transport and industrial infrastructure such as wharves and ferry terminals, urban areas and rural housing.

Modelled Significant Wave heights during Typhoon Linda

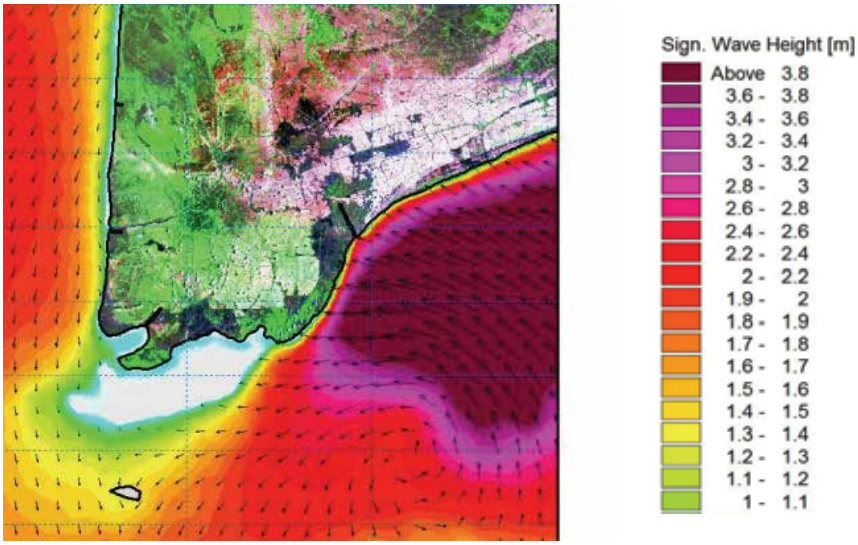

Figure 4. Modelled Significant Wave heights during Typhoon Linda. (From Russell and Nhan 2010)

Summary of Regional scale coastal processes

The predominant regional scale coastal processes operating in the region include:

- Wave refraction and tidal currents drives movement of sediment as suspended plumes and bottom sediment around Ca Mau Cape.
- Transport of material finer materials and colloidal sediments along the west coast of the Cam Mau Peninsular.
- Onshore entrapment of sediments in coastal fringing mangroves, and movement landwards - a result of swell induced transport.

- Erosion and inundation due to heavy swell, rough seas and strong currents generated by typhoons and monsoonal storms that can carry increased quantities of sand and silt alongshore as well as offshore.

Vulnerability of Human Systems to Climate Change

The ADB study (ADB 2013) measured exposure to climate change impacts by using the application of GIS to map the projected size of the area of each district that is impacted by a variety of hazards. This mapping was carried out for each time period and climate scenario. Table 4 shows the calculated overall vulnerability of the Districts in three important areas. With regards to agriculture and livelihoods of all of the districts except Dam Doi are projected to be at least moderately vulnerable by 2050, with Tran Van Thoi becoming moderately vulnerable by 2030 and very highly vulnerable by 2050 and U Minh becoming highly vulnerable by 2050. Dam Doi and Tran Van Thoi are projected to be highly vulnerable due to population pressure by 2050. Dam Doi and Ngoc Hien are projected to be highly vulnerable with regards to poverty by 2050.

Table 3. Vulnerability Ranking of the Coastal Districts in the Dimensions of Population, Poverty and Agriculture and Livelihoods (from ADB 2013).

District	Population			Poverty			Agriculture & Livelihoods			Overall Vulnerability
	2010	2030	2050	2010	2030	2050	2010	2030	2050	2050
Dam Doi	5	9	19	4	14	20	2	9	21	High
Nam Can	2	3	7	2	2	4	2	6	14	Low
Ngoc Hien	4	3	7	6	17	29	4	5	12	High
Phu Tan	4	6	11	3	6	6	3	4	12	Medium
Tran Van Thoi	6	13	28	6	9	12	4	17	36	High
U Minh	3	5	9	5	10	16	2	9	21	Medium

In the ADB study, expert opinion of the level of measures that are in place to protect infrastructure was incorporated into the vulnerability rating for each time slice; baseline, 2030 and 2050. An overview of the exposure to hazards and the status of control measures to protect agricultural infrastructure is shown in Table 4. The table indicates that improvements in the control measures that are in place to protect agricultural infrastructure are required in the medium term (10 – 20 years) for all districts except Ngoc Hien where rehabilitation or upgrading is urgently needed.

Table 4. Expert Assessment of the control measures in place to protect agricultural infrastructure for each district.

District	Expert Assessment of Control Measures in Place to Protect Agricultural Infrastructure.
Dam Doi	Improvements are desirable in the medium term in view of economic development
Nam Can	Improvements are desirable in the medium term in view of economic development
Ngoc Hien	Rehabilitation or upgrading urgently needed
Phu Tan	Improvements are desirable in the medium term in view of economic development
Tran Van Thoi	Improvements are desirable in the medium term in view of economic development
U Minh	Improvements are desirable in the medium term in view of economic development

Impacts of Key Pressures

Many of the coastal areas of the province are potentially threatened by a combination of human pressures, climate change and sea-level rise, with possible future changes in monsoonal conditions and increases in extreme weather events. Future impacts on these low-lying coastal areas will almost certainly include changes in coastal morphology, through accelerated coastal erosion, sedimentation in the coastal embayment's, and overtopping of sea dykes from the sea and storm surge. The effects of storm surge are exacerbated by human pressures on mangrove systems such as fuel-wood and timber cutting that is contributing to the loss of mangroves and resource collecting methods that are interfering with natural regeneration.

The primary pressure on the coastline is loss of mangroves forests through erosion.

The first line of defence from the effects of wave action on the coast is mangroves. In the past the mangrove ecosystem was up to 2 kilometres wide. Behind the mangroves, protection of crops and urban structures was achieved through the construction of earth sea dykes. Larger wave heights will readily penetrate through a thin line of mangroves and erode earth dykes.

In many areas of the northern section of the west coast of the province the band of fringing mangroves is relatively thin (<100 m) and the sea dyke forms the major protection from storm surge. In these areas breaching of a dike has a number of results. The conversion of mangroves into aquaculture ponds has made considerably more infrastructure potentially exposed to storm surge. As mangroves are removed or eroded, aquaculture ponds are exposed and breached. This leads to saline intrusion into ponds, and generally abandonment. As a result the regular line of fringing wave tolerant mangroves (Avicennia spp.) is fragmented, exposing less robust species to wave action resulting in further mangrove loss. The fragmented mangrove system allows waves to penetrate to the back of the abandoned pond advancing erosion in steps of 50 to 100 meters.

Earth dykes that have been exposed by mangrove removal or erosion can be breached within a single wet season. In districts where agriculture occurs behind the sea dyke E.g. U Minh and Tran Van Thoi, significant waves that overtop a dyke, or flow through breached dykes, can destroy houses and farm infrastructure. Salt water that comes through breached dykes will inundate crops and fish ponds. In aquaculture areas, sea water will breach pond walls and wash away stock.

The mangrove fringe is often used by natural resource dependant poor households who construct illegal dwellings behind the mangrove fringe of coastal towns and cities. The direct consequence of storm surge is loss of housing compounded by a loss of resources due to damage to mangroves and associated natural vegetation and fisheries. Poor fisher families are also located on the outer parts of canal and river entrances leaving their houses and boats with little protection from storm surge.

03 Coastline Condition

Erosion and Accretion along the Ca Mau Coast

The extent of erosion and accretion of the coastline of each district/coast is shown in Table 5. There are 64 km of coastline where the erosion is classed as severe or extreme with much of it being on the east coast of the province particularly on the eastern side of Ngoc Hien where there is 26.3 kilometres. There is also severe or extreme erosion on the coast of Tran Van Thoi with some also in U Minh and on the south-western coastline of Ca Mau Cape. There are 24 kilometres of depositional shore concentrated the more protected shallow estuaries to the north of Ca Mau Cape.

The Estuarine coast of western Nam Can shows only 1.7 km of minor erosion and has 7 km of depositional shore and a further 12.6 km classed as being stable. The western side of Ngoc Hien is protected by extensive shoals, of mud in the estuarine north coast and of mega ripples of sand to the west of the southern tip of the mainland. This section of the coast has a 13.7 km of depositional shore and a further 14.2 km classed as being stable. However 15 km of coastline shows erosion with 6.7 km classed as severe or extreme (much of this is concentrated along the south facing shore). While Phu Tan has only 1.7 km of depositional shore 22.6 km is classed as stable. The district has 10.3 km of erosion but most of it is classed as minor.

The two districts on the northern part of the west coast have only small amount of depositional shore. U Minh has only 7.8 km of stable shoreline (including some coastline stabilised by concrete fences) and has 19.4 km of erosion, although apart from 3.6 km of severe erosion, much of this is classed as minor or moderate. The coastline of U Minh that may have been classed as experiencing extreme erosion has been protected by erosion protection infrastructure. Tran Van Thoi has only 6 km of stable coastline and 28.4 km of erosion, over half of which is severe or extreme.

Table 5. Erosion Condition of the Coastline of the Coastal Districts of Ca Mau (In Kilometres)

Huyện	Depositional Shore	Stable	Erosion	1. Minor	2. Moderate	3. Severe	4. Extreme
U Minh	0,8	7,8	19,4	12,5	3,3	3,6	-
Tran Van Thoi	0,2	6,0	28,4	5,8	7,5	14,1	1,0
Phu Tan	1,7	22,6	10,3	6,8	1,2	2,2	0,1
Nam Can W	7,0	12,6	1,7	1,7	-	-	-
Ngoc Hien W	13,7	14,2	15,4	4,8	3,9	5,1	1,6
Ngoc Hien E	-	0,5	48,3	5,0	18,4	23,6	1,3
Nam Can E	-	0,3	12,9	3,4	3,1	6,1	0,3
Dam Doi	0,4	4,7	20,8	0,2	15,5	4,2	0,9
Total	24	69	157,3	40	53	59	5

There is very little depositional or stable coastline on the east coast of the province. The eastern coastline of Ngoc Hien has 48.3 km of eroding coastline, predominately classed as moderate or severe. The eastern coast of Nam Can has almost 13 km of eroding coastline with 6.4 km classed as severe or extreme. Dam Doi has a small amount of depositional coast (see the discussion on the spatial distribution below) and 4.7 km of stable coastline. This district has 20.8 km of eroding coastline, with much of this classed as moderate (15.5 km) and severe (4.2 km).

Location of Coastline at Risk from Erosion

Figures 5 - 7 show the geographical distribution of the erosion classes presented for three different sections of the coast.

Northern West Coast

Much of the northern West coast shown in Figure 5 is classed as eroded. There is a small section of prograded coastline towards the north of the coast. To the north of this section the coast shows minor to moderate erosion up to the border with Kien Giang province. Eroded conditions are also found to the south of the prograding coast and the severity of the erosion remains fairly high until a section of coast that has required protection by concrete pole rock filled wave break fences or rock filled gabions. This section of the coast makes up the southern portion of Khanh Tien commune and a small proportion of the other coastal commune of U Minh Khanh Hoi. The remainder of this commune has a coastline that

is predominantly classed as minor erosion, with some areas of moderate and high erosion and one area identified as extreme.

The coastline of Tran Van Thoi that is north of Da Bac Island in the centre of (Khanh Binh Tay Bac and Khanh Binh Tay communes) is dominated by moderate erosion. The coastline south from Da Bac Island down to Song Doc Town is predominantly severely eroded and there are a number of points where the erosion has been classed as extreme. The southern commune of Tran Van Thoi, Phong Dien is mostly classed as minor erosion with some moderate erosion and one small area classed as extreme.

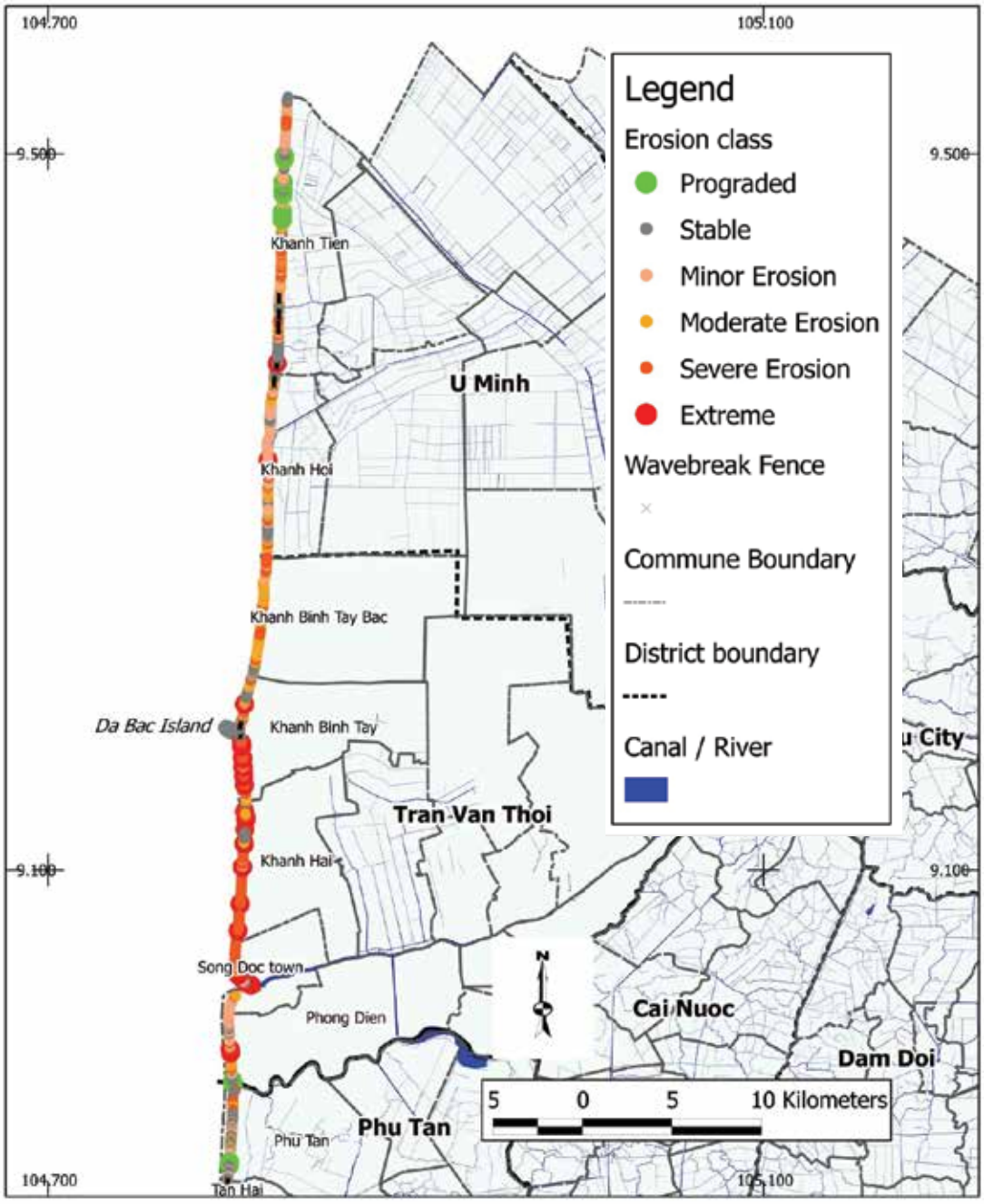

Figure 5. Geographical Distribution of the Erosion Classes on the North Coast of the Province

South Coast

The southern section of the West Coast shown in Figure 6 is dominated by more stable and depositional areas. The northern coast of Phu Tan (Phu Tan and Tan Hai communes) is predominantly stable interspersed with some lengths of minor, moderate and sever erosion. There is an area of coast at the border of the two communes where protection methods have been put in place. There is a small area of deposition to the north of this section and an area in the canal on the border with Tran Van Thoi.

The remainder of Phu Tan province exhibits much less erosion. It is predominantly classed as alternating sections of minor erosion and stable coastline, interrupted by; shorter sections of depositional areas particularly in Cai Doi Vam town, and a few small patches of severe erosion and two points where the erosion is classed as extreme on the more exposed southeast coast of Nguyen Viet Khai commune.

The estuarine coast of Nam Can shows deposition deep inside the estuary of the Bay Hap River and stable conditions in the outer part of the estuary. Strong currents result in stable banks within the Cua Lon estuary which is part of both Lam Hai commune in Nam Can, and Vien An commune in the north-western tip of Ngoc Hien province. The remainder of the coast of Vien An is also depositional or stable. The estuarine conditions on the north coast of Dat Mui commune are also classed as depositional except on the northern section of Ca Mau cape that shows minor erosion. The north western section of Ca Mau Cape is classed as stable or depositional. While the large amounts of sediments of the cape limit the penetration of large waves onto the coast, the western section of the cape that is more exposed to SW winds shows some minor and medium erosion. Much of the south-western coast of Ca Mau Cape is experiencing moderate to severe erosion and a section of concrete pole – rock fill wave break fences are being constructed. There is a long section of coastline classed as having extreme erosion. There is also a section of coastline where there is active deposition at the end of a long sand spit formed from sediments moving around the cape.

The section of the east coast of Ngoc Hien that is described in the tables above as Ngoc Hien E is split across Figures 6 and 7. The western section made up of the communes of Vien An, Vien An Dong and Rach Goc Town is predominantly classed as moderate or severe erosion. There are a few small sections of the coast of Vien An Dong that are classed as being extreme.

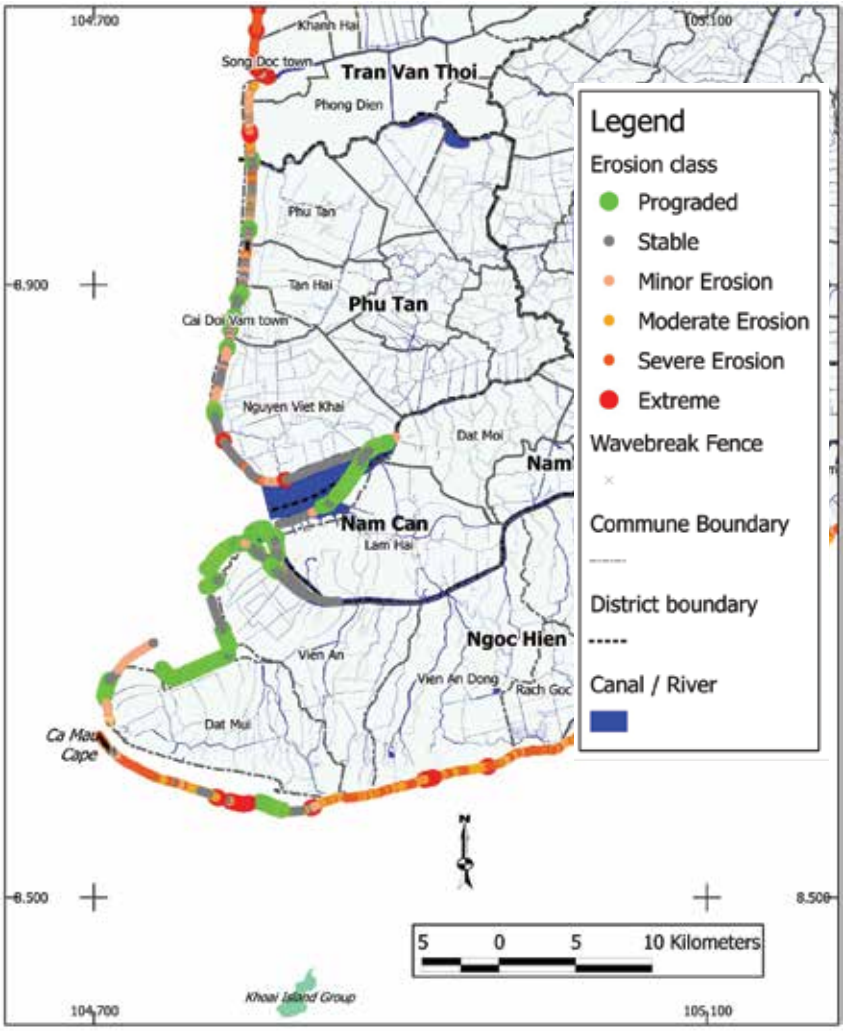

Figure 6. Geographical Distribution of the Erosion Classes on the South Coast of the Province.

East Coast

The erosion condition of the eastern section of the province is shown in Figure 7. The eastern part of Ngoc Hien E is a mix of moderate and severe erosion with small sections classed as being extreme on in both Tay Am and Tam Giang Tay communes and some areas of minor erosion on the coast of Tam Giang Tay commune.

Nam Can west is also dominated by moderate and severe erosion with short sections of minor erosion and two short sections classed as being extreme.

In Dam Doi province, the coastline of the commune of Nguyen Huan is predominantly classed as minor erosion with some extreme erosion at the border with Tan Tien commune. The coastline of Tan Hien commune is made up of four main sections; a section of alternating minor and severe erosion with a small amount of extreme erosion; a long section of minor erosion; a long section of extreme erosion; and a section of relatively stable coast in the north. There is some extreme erosion at the border with Tan Thuan commune.

The north of the coast of Dam Doi (Tan Thuan commune) is predominantly classed as having minor erosion interspersed with small sections of stable coast. In the south of commune there is some severe erosion and in the north there is some deposition behind the wave break fence in the Gang Hao estuary.

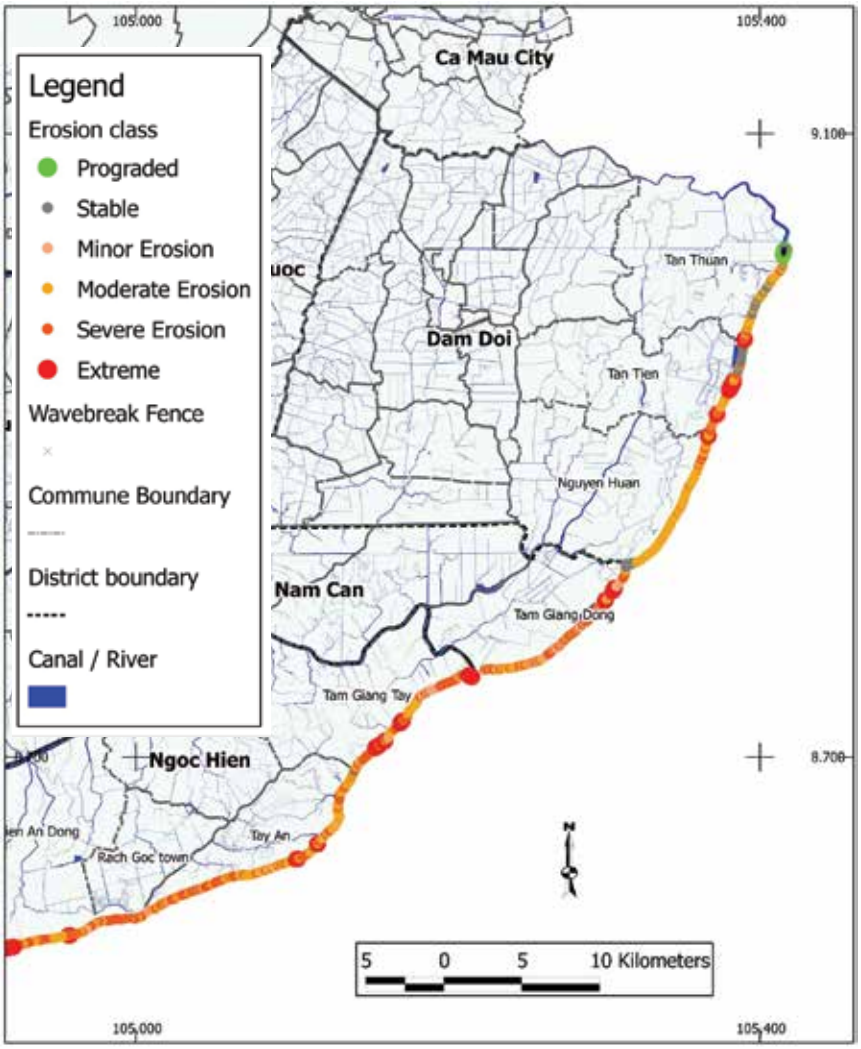

Figure 7. Geographical Distribution of the Erosion Classes on the East Coast of the Province

Vegetation

The condition of the vegetation along the coastline of each district/coast is shown in Table 6. Very high biomass forests make up 88 kilometres of the coastline and are concentrated in the more protected estuarine conditions north of Ca Mau Cape, although the presence of plantations along the east coast also results in high biomass forest along the shoreline. Low biomass forests make up 51 kilometres of coast and are also present in all districts but are concentrated in Tran Van Thoi and the east coast of Ngoc Hien. All of the districts have some coastline classed as very low biomass up to a maximum of 3 kilometres in Tran Van Thoi.

Table 6. The Condition of the Mangroves Along the Coastline of each District/Coast

	Mangroves (km)	Biomass					Actively Prograding (km)	Recovery Replanted with No or Little Erosion (km)
		Very low (km)	Low (km)	Medium (km)	High (km)	Very high (km)		
U Minh	26,8	1,8	6,7	14,5	2,2	1,6	0,6	15,1
Tran Van Thoi	31,7	3,0	16,4	7,0	4,6	0,7		7
Phu Tan	34,1	1,0	3,0	5,3	6,4	18,4		14,1
Nam Can W	21,1		0,3	0,8	3,3	16,7	4,9	4,9
Ngoc Hien W	40,8	0,2	2,8	2,9	8,1	26,7	10,2	5,9
Ngoc Hien E	48,6	2,0	14,1	9,9	12,6	10,0		5
Nam Can E	13,0	2,2	4,0	3,1	2,3	1,5		3,4
Dam Doi	25,7	0,8	3,9	2,9	5,2	12,9		0,2
Total	242	11	51	47	45	88	16	55,7

Although U Minh has a small section of actively prograding coast, much of the coastline is dominated by mangroves of medium biomass and almost 2 km of coastline has very low biomass. There are a few km of high or very high biomass forests. Despite the lack of prograding or high biomass forests there are long lengths of coast where the mangroves have recovered and show limited or no erosion.

The mangrove coastline of Tran Van Thoi is dominated by low and medium biomass forests. There are 3 km of very low biomass forests and 700 m of very high biomass forests. There are no actively prograding forests and 7 km of coast where the mangroves have recovered and show limited or no erosion.

While Phu Tan has no actively prograding coast, over half of the coast has very high biomass forest and there are 14.1 km of replanted or recovered areas showing little or no erosion. The district has only 1 km of coastline with very low biomass and 3km with low biomass.

Along the entire coast of the province, only the outer parts of the estuarine systems of Ngoc Hien W and Nam Can W where sediments are being deposited are actively prograding at present. These prograding forests are dominated by A. alba. Along the shore of the channels of the estuaries, currents prevent the build-up of sediments and the shoreline is classed as stable. The protection from ocean waves means that these areas are dominated by stable mixed species high biomass forests. Nam Can W has almost 5 km of actively prograding coastline and the same amount of coast where the mangroves have recovered and show limited or no erosion. Only 1.1 km of coastline is classed as having low or medium biomass.

Ngoc Hien W has over 10 km of prograding coastline with a further 6km where the mangroves have recovered and show limited or no erosion. The coastline is dominated by high biomass forests with only 200m of very low biomass, less than 3 km of low biomass and a further 3 km of medium biomass forest.

The eastern coast of the province is dominated by erosion conditions and there are no areas of prograding forest and only small areas of recovering shoreline that do not show significant erosion. The east of Ngoc Hien has 5 km classed as recovering shoreline that does not show significant erosion and the district has 2 kilometres of very low biomass forest. Ngoc Hien E also has over 14 km of low biomass forest with the remainder of the coastline spread across the higher biomass classes. The short mangrove coast of Nam Can E is made up almost entirely of plantation forest that is actively eroding and the biomass ranges from very low to very high. The district has 3.4 km of coastline where the mangroves have recovered and show limited or no erosion.

More than half of the coast of Dam Doi is made up of plantation forest that is actively eroding .Only 200m of the coastline of Dam Doi is classed as recovering shoreline that does not show significant erosion. Dam Doi has 800 m of coastline with very low biomass forest and almost 4 km of low biomass forest. The high percentage of the coast that consists of eroding plantation means that half of the coastline has high biomass mangroves.

Distribution of Vegetation Condition

Figures 8 - 10 show the geographical distribution of the biomass class presented for three different sections of the coast.

Northern West Coast

Much of the northern West coast Figure 8 is classed as low or medium Biomass. In U Minh district, the northern coastline of Khanh Tien commune to the Kien Giang border the mangroves generally have a medium biomass interspersed with small sections with low and high biomass respectively. In the centre of the commune there is a section with very low biomass while the south is dominated by low biomass. In the south of the commune there is a section where the mangroves have been completely removed. The coastline of Khanh Hoi commune is predominantly medium biomass with small sections of low and small sections of high biomass.

The district of Tran Van Thoi has a lot of coastline with low biomass. In the northern commune of Khanh Binh Tay Bac the low biomass forest is interspersed with small patches of medium and very low biomass in the north and small patches of high and very high biomass in the south. The coastline of Khanh Binh Tay commune is also dominated by low biomass mangroves forests with small areas of very low biomass forest and some more extensive lengths of medium and high biomass. The section of coastline to the north of Da Bac Island is predominantly medium to high biomass with small patches of low and very low biomass. There are two lengths of coast that have very low biomass, one in the north of the commune near the border with Khanh Binh Tay Bac commune and one in the south near the border with Khanh Hai commune. There is some high and very high biomass forest in the north of Khanh Hai commune with the remainder dominated by low biomass forest with small lengths of very low biomass mangroves. The exposed coastline north of Son Doc Town has low biomass. Within the slightly more protected estuary there are more medium and high biomass mangroves but there are also areas of low biomass due to pressures from the high population of Son Doc Town. The southern coastline of Tran Van Thoi (Phong Dien commune) has medium biomass forest extending southwards from Son Doc Town into an area of alternating small sections of coastline with biomass classes ranging from very low to high.

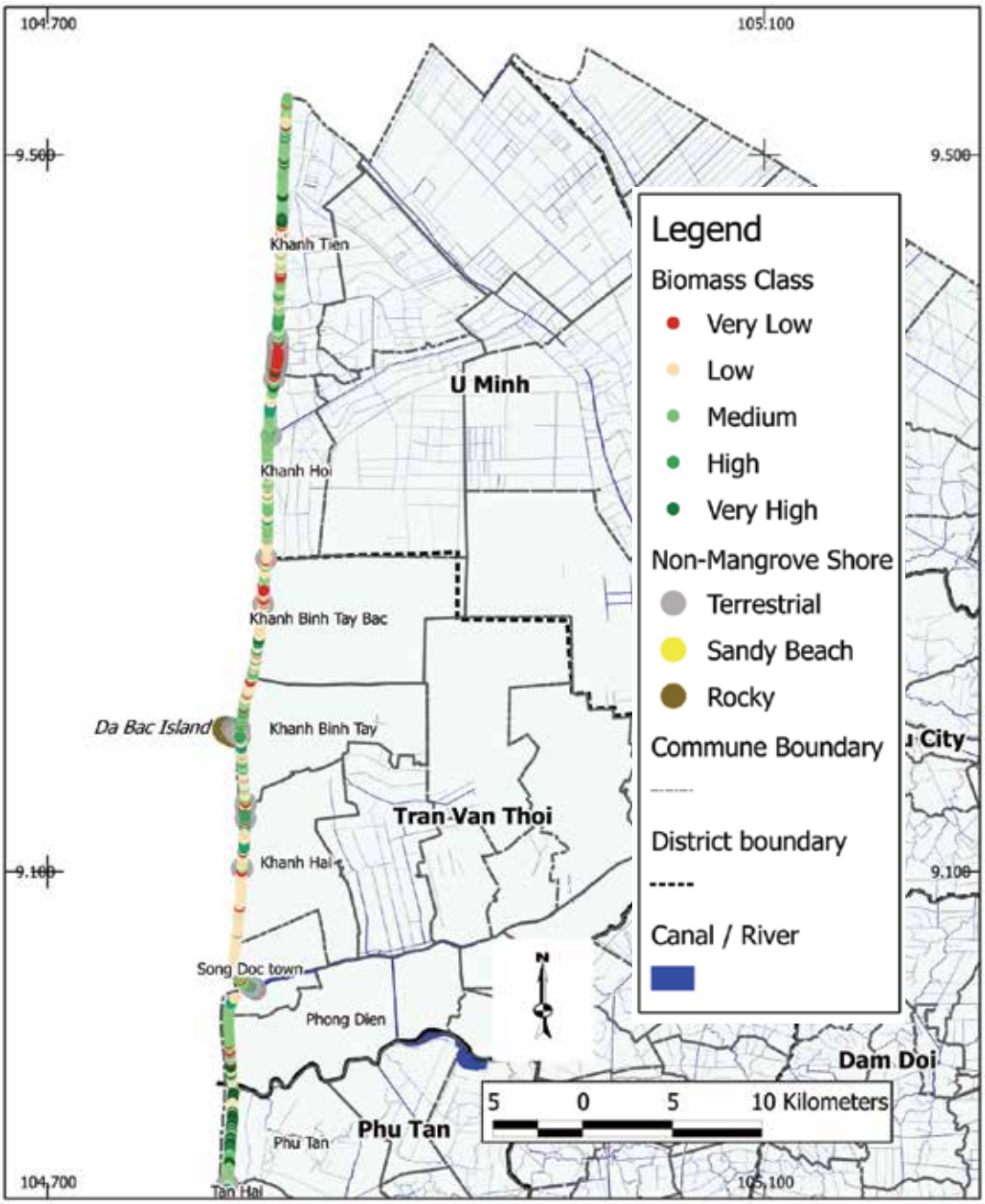

Figure 8. Geographical Distribution of the Biomass Classes on the North Coast of the Province.

South Coast

The southern section of the West Coast of Ca Mau province shown in Figure 9 is dominated by forests with medium to high biomass. On the coast of Phu Tan district, as well as the predominantly medium to high biomass there is a length of coast with low biomass in the north and a length of coast with medium biomass in the south. The southern part of Phu Tan district is predominantly very high biomass forest interspersed with some high biomass forest and short lengths of medium and low biomass. There are also a few small areas of very low biomass scattered along this section of coastline. Tan Hai commune is

predominantly medium biomass with a length of high biomass forest in the north and a length of very high biomass forest in the south.

The estuarine coastline of Nam Can W is predominantly high biomass mangrove forests with some lengths of high biomass forests. The north coast of Ngoc Hien is dominated by high biomass forests except for a stretch of coast on the south west coast of the commune of Vien An that is exposed to SW winds and has medium biomass. The western side of Ca Mau cape has a mix of high and medium density biomass with a small section of low biomass. On the south of Ca Mau Cape, the south coast of Dat Mui commune has a long section of coastline with high biomass in the west, a long section of very high biomass forest interspersed with high biomass, and in the east a section of low biomass that merges into very high biomass and finally a sandy beach in the east.

The section of Ngoc Hien E that is shown in Figure 9 is the south coast of Vien An and Vien An Dong communes. This coastline shows the variable nature of the entire east coast of the province. Small sections of each biomass class alternate along the coast.

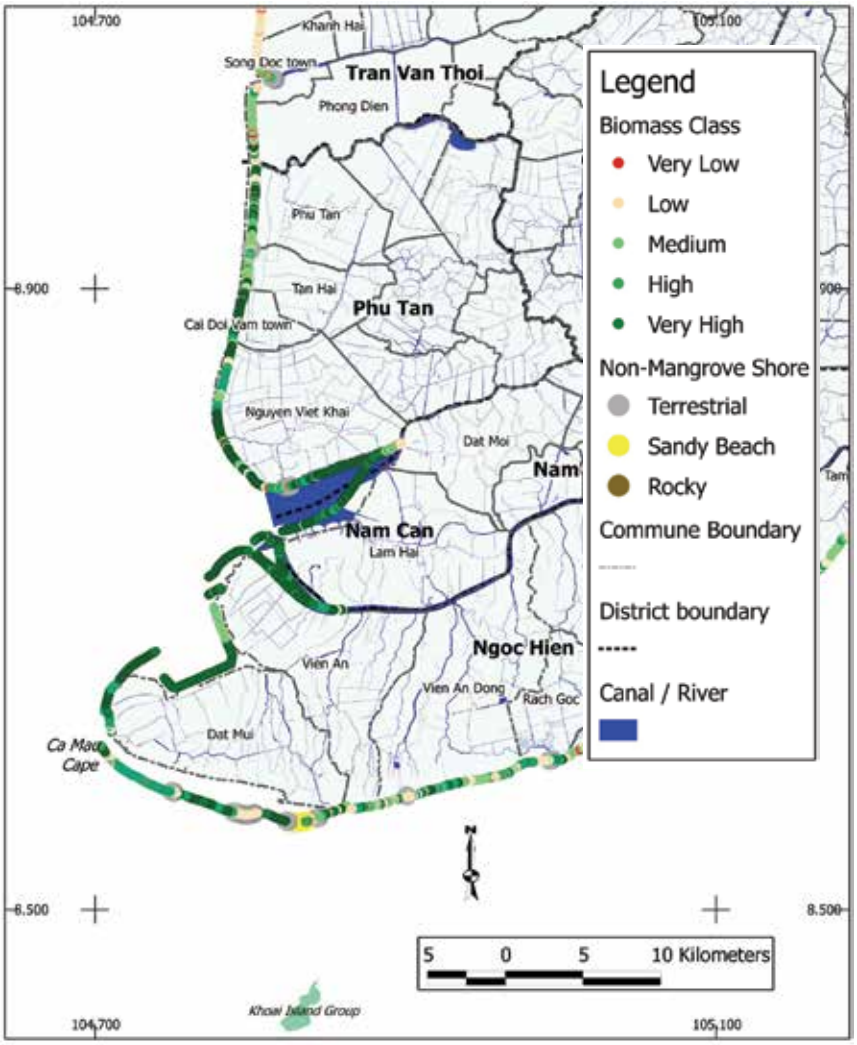

Figure 9. Geographical Distribution of the Biomass Classes on the South Coast of the Province.

East Coast

The biomass found along the remainder of the east coast of Ca Mau province is shown in Figure 10. There are small sections very low biomass along the coast of both of the communes of Tay An and Tam Giang Tay. The northern section of Tay An commune shows a slight increase in the dominance of very high biomass forest. Tam Giang Tay commune has very little of its coastline classed as very high and in the east is dominated by low and medium biomass. There is a section of very low biomass near the border with Nam Can district.

Nam Can E also shows the alternating biomass classes, however this district has many small sections of coast with very low biomass and few sections of very high biomass.

In the district of Dam Doi the coastline of the commune of Nguyen Huan is dominated by very high biomass mangrove plantation. This merges into the typical alternating biomass found along much of the east coast of the province. Neither Nguyen Huan nor Tan Tien communes have any very low biomass forests. The alternating biomass on the coast of Tan Tien commune is made up of more high and very high biomass than medium or low biomass. This pattern continues into the south of Tan Thuan commune. However the northern coastline of Tan Thuan commune is predominantly low biomass mangroves and there are a number of areas of very low biomass including some near the border with Tan Tien commune.

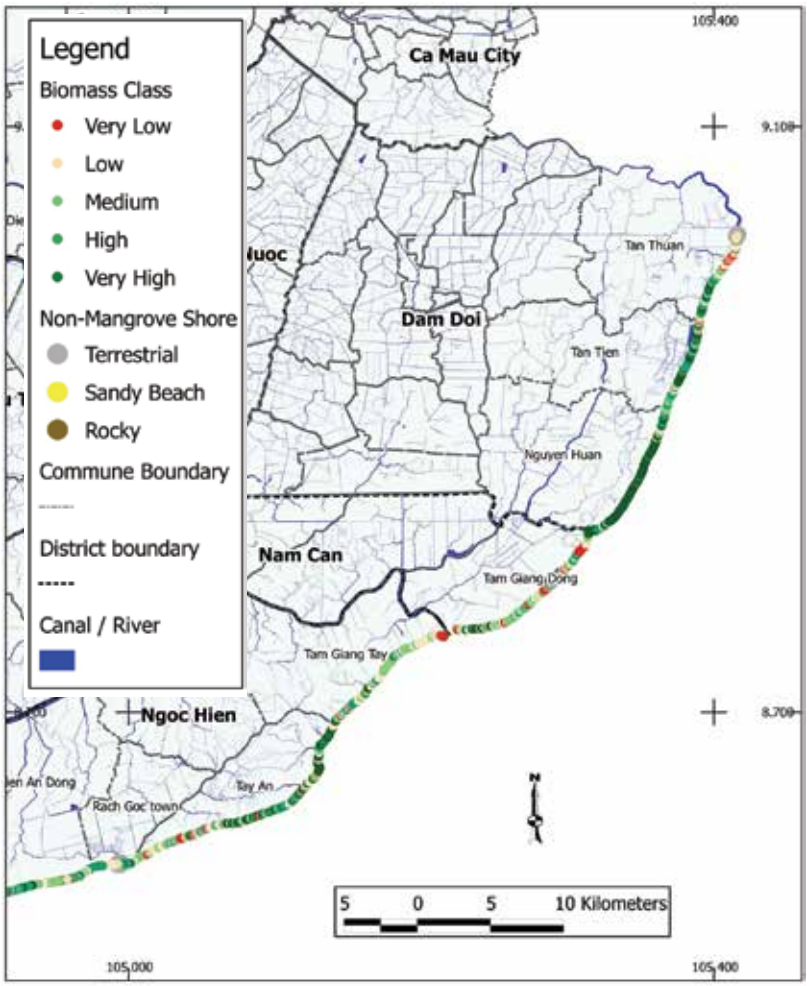

Figure 10. Geographical Distribution of the Biomass Classes on the East Coast of the Province.

Human Influence

The extent of human influence along the coast is displayed as coastline length in Table 7. Stress on the coastal mangroves due to human Influence occurs along 119 kilometres of coastline of the province. Almost the entire eastern coastline of the province shows some stress from human impact with around 9 km of high and very high stress. The estuarine coastline has lower levels of human impact.

Almost half of the coastline of U Minh showed visible infrastructure and over one third of the coast is under stress from human activities. Mangroves have been completely removed from over one km of coastline and a further one km is under high or very high stress from human activities. Most of the construction of rock filled concrete post wave break fences and shore protection in the form of gabions has been carried out in U Minh.

Tran Van Thoi has also started using wave break fences and gabions to protect the shore and also has small sections of concrete wall. Infrastructure is visible behind 11.9 km of the coastline and almost half is under stress from human activities. About 700 m of shoreline is under high or very high stress from human activities and mangroves have been completely removed from 1.6 km.

The shorelines of Phu Tan and Nam Can W show much less human impact that the rest of the province. Only 1.2 km of the Phu Tan coast shows significant cutting or urban infrastructure and of that only 200m is classed as high or very high stress. Mangroves have been completely removed from 500 m of coastline and 500m is protected by concrete or rock walls. Only a small section of the Nam Can W coast shows impact from human activities.

Much of the west coast of Ngoc Hien also shows little impact from human activities. Infrastructure is visible behind 2.2 km of coastline and mangroves have been completely removed from 2 km of coastline. A further 5 km of coast shows stress from human activities with 1.8 km of that being classed as high or very high. Over 400 m of shore has been protected by concrete or rock wall and the district is actively constructing at least 1.5 km rock filled concrete post wave break fences of which 400m has been completed.

While infrastructure is only visible behind a small part of the coastline on the east of Ngoc Hien almost the entire eastern coastline (49 km) shows some human impact and this section of coast has more than half of the total 12.5 kilometres of high and very high stress.

Along the coastline of Nam Can E, mangroves have been completely removed from a short section and a concrete wall is used to protect the shore. The rest of the coastline of the district shows some human impact with 1.4 km being classed as high or very high.

Half a km of the coast of Dam Doi has been protected by rock filled concrete post wave break fences and mangroves have been completely removed from part of that section of coastline. The remainder of the coast shows some human impact with 1.3 km classed as high or very high.

Table 7. The Extent of Human Influence on Each District.

	Coastline Length (km)	Mangroves Removed (km)	Concrete or rock wall (km)	Protected by Gabions (km)	Protected by Concrete Wave Break Fence (km)	Coast with Anthropogenic stress (km)	High- very high Anthropogenic Impact (km)	Infrastructure behind Shore (km)
U Minh	28	1,2	-	1,8	2,9	10,7	0,9	13,9
Tran Van Thoi	35	1,6	0,1	0,4	0,6	16,6	0,7	11,9
Phu Tan	35	0,5	-	-	0,5	1,2	0,2	-
Nam Can W	21	-	-	-	-	0,1	-	-
Ngoc Hien W	44	2	0,4	-	0,4	5,1	1,8	2,2
Ngoc Hien E	49	-	-	-	-	47	6,3	0,1
Nam Can E	13	0,1	0,1	-	-	12,9	1,4	-
Dam Doi	26	0,1	-	-	0,5	25,4	1,3	-
Total	251	5,5	0,5	2,2	4,8	119	12,5	28

Distribution of human impact from development and mangrove cutting

Figures 11 - 13 show the geographical distribution of the impact of human influence presented for three different sections of the coast.

Northern West Coast

Much of the northern West coast Figure 11 is classed as having little direct impact from development or mangrove cutting. The central coast of Khanh Tien commune in U Minh district shows two areas of very high stress and much of the southern coastline of the commune has had significant impact with mangroves completely removed in some areas and a large amount of coastline has required artificial protection measures. The coastline of Khanh Hoi commune has two areas of very high stress due to human influence.

In Tran Van Thoi district almost the entire coastline of the commune of Khanh Binh Tay Bac shows some human impact with some small areas of moderate and high stress. The central coast of Khanh Binh Tay commune shows significant changes with mangrove removal and artificial protection of the shoreline on

the coastline behind Da Bac Island. South of Da Bac Island the coastline shows generally moderate stress until the border with Khanh Hai commune. The far north of Khanh Hai commune shows considerable pressure due to human influence. Mangroves have been completely removed along a small section and the coastline is classed as being under moderate to very high stress from development and mangrove cutting. The central coast of the commune also shows small areas of high and very high stress. The coastline of Song Doc Town shows only a low impact except for a few small areas of artificial protection and complete removal of mangroves at the mouth of the harbour. Similarly, Phong Dien commune shows mostly little or no stress except for a small area of very high stress near the border with Song Doc Town and some small areas of high stress along the coast.

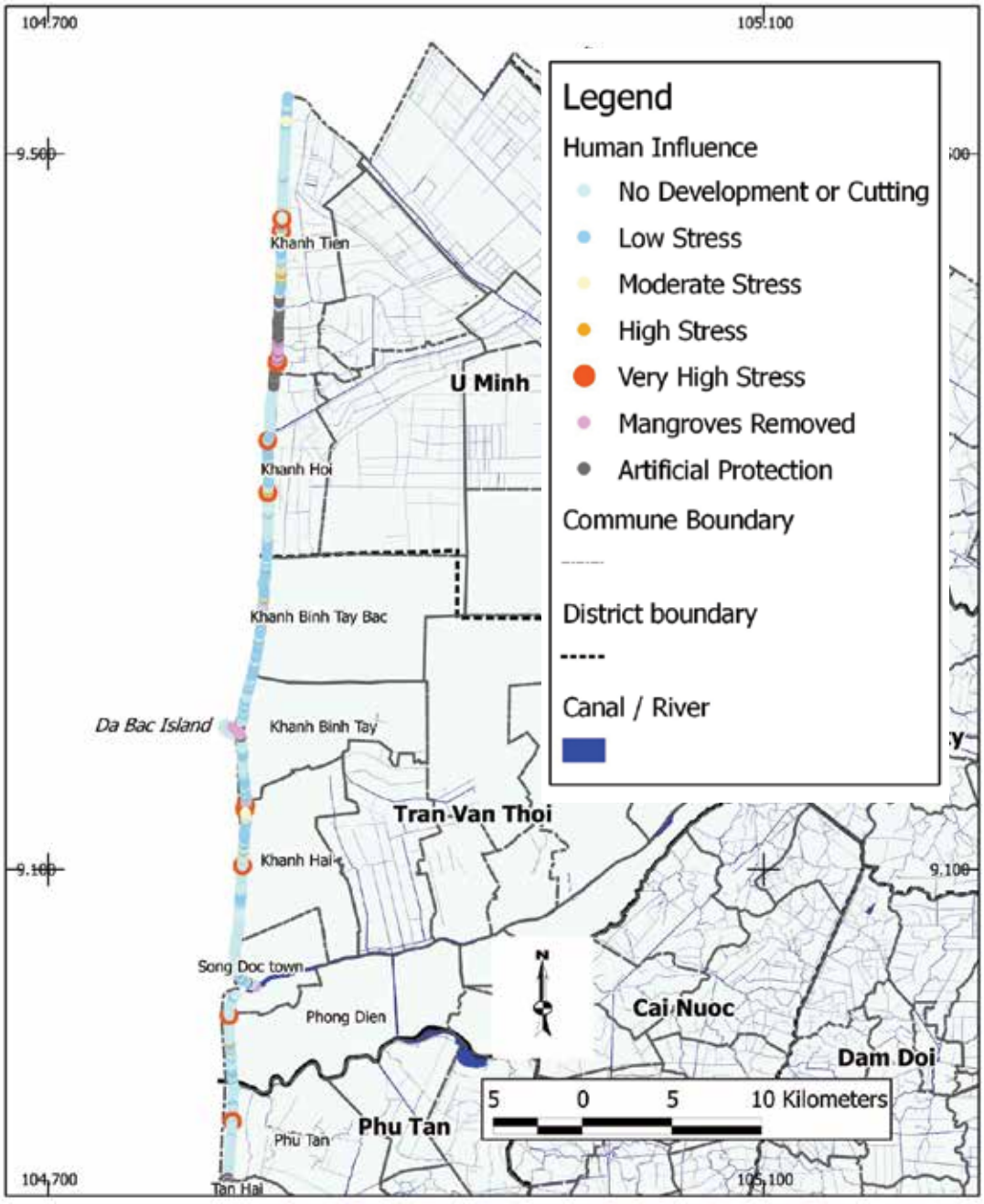

Figure 11. Geographical Distribution of Impact of Human Influence on the North Coast of the Province.

South Coast

The southern section of the West Coast of Ca Mau province shown in Figure 12 shows little impact from human influence due to development and mangrove cutting. On the coast of Phu Tan district there is a small area of very high stress on the central coast of the commune of Phu Tan. At the mouth of the canal that forms the border of the communes of Phu Tan and Tan Hai there has been complete removal of mangroves and the construction of a wave break fence. There are 2 small sections of the central coast of Cai Doi Vam town with high stress. There is a small section of high stress on the exposed southwest coast of Nguyen Viet Khai commune and further into the estuary on the south coast of the district there is a length of coast under very high stress next to a section where the mangroves have been completely removed.

The entire coastline of Nam Can W shows very little human impact due to development or mangrove cutting. The north coast of Ngoc Hien W and the west coast of Ca Mau Cape also show little or no stress due to human influence. On the extreme southwest of the cape there is a long section of coast that has been protected by a concrete pole rock filled wave break fence. Along this section there are areas where the mangroves have been completely removed. While the south coast of Ngoc Hien W is dominated by coastline classes as having no stress due to human impact, there are long sections of coastline showing moderate stress, high stress and where the mangroves have been completely removed. There are also short lengths of coastline of low, moderate and high stress and mangrove removal scattered along this section of coast. An area of very high stress is also evident at the eastern end of Ngoc Hien W.

The section of Ngoc Hien E that is shown in Figure 12 (the south coast of Vien An and Vien An Dong communes) is dominated by low and moderately stressed coastline. There are numerous small sections of high stress along the coast and one section of very high stress in the west of Vien An Dong commune.

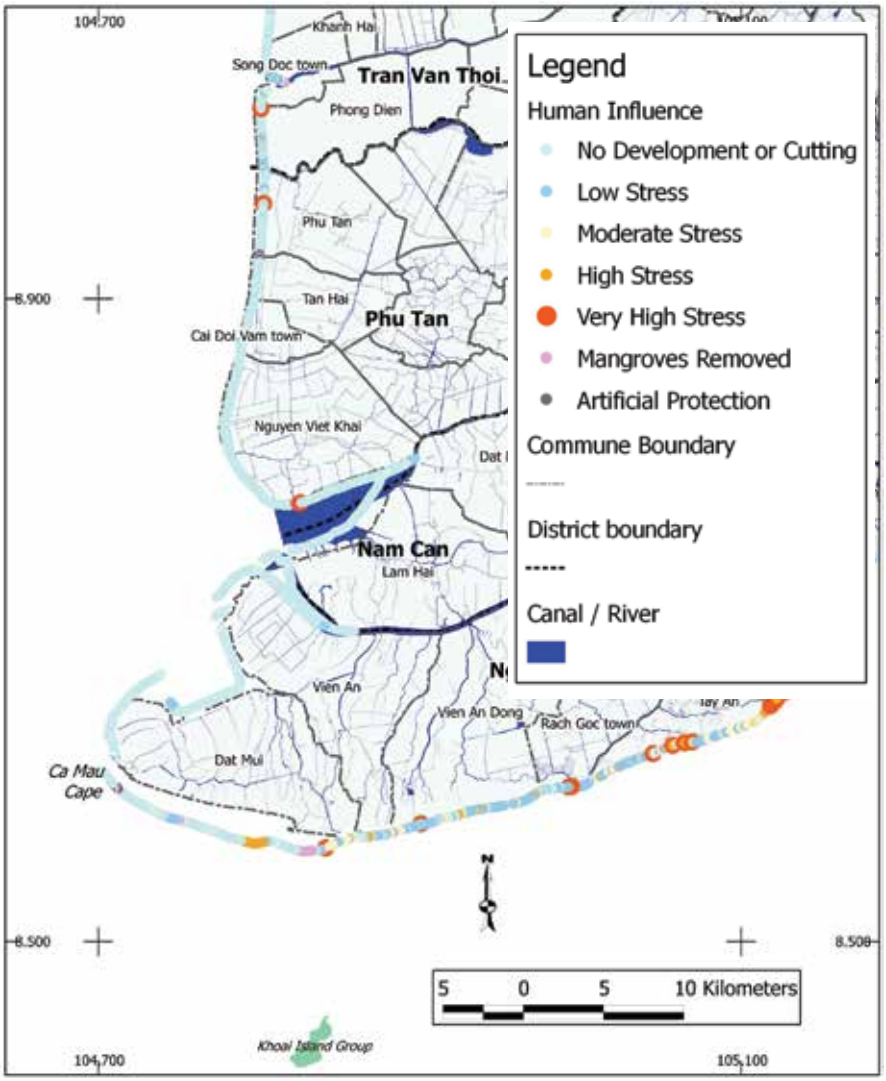

Figure 12. Geographical Distribution of Impact of Human Influence on the South Coast of the Province.

East Coast

The extent of human influence due to development and mangrove cutting found along the remainder of the east coast of Ca Mau province is shown in Figure 13. Ngoc Hien E shows predominantly low to moderate stress. The short coastline of Rach Goc Town mainly shows low stress but does have a short section of very high stress. The western coastline of Tay An commune is dominated by low stress but has short lengths of high and very high stress. There is a long section of coastline that shows high and very high stress due to human impact and the northern coastline of Tay An is dominated by moderate stress with small areas of high stress. The coastline of Tam Giang Tay commune has short lengths of high stress scattered along the coast and a small area of very high stress in the centre of the coastline. The remained of the coastline is dominated by moderate stress with an increase in the proportion of low stress in the eastern coast.

The coastline of Nam Can E is also predominantly under low or minor stress due to development or mangrove cutting. There are a number of small sections of high and very high stress scattered along the coast and one long section of high stress in the centre of the coast.

In the district of Dam Doi, the southern coast of Nguyen Huan is almost entirely under low stress. The remainder of the coastline of the province is predominantly under moderate stress except for some sections of low stress and small lengths of high stress scattered along the coast and three small areas of very high stress on the northern coast of Tan Tien commune. There is a short length of wave break fences and a small area where the mangroves have been removed in the mouth of the Ganh Hao estuary in the far east of the province.

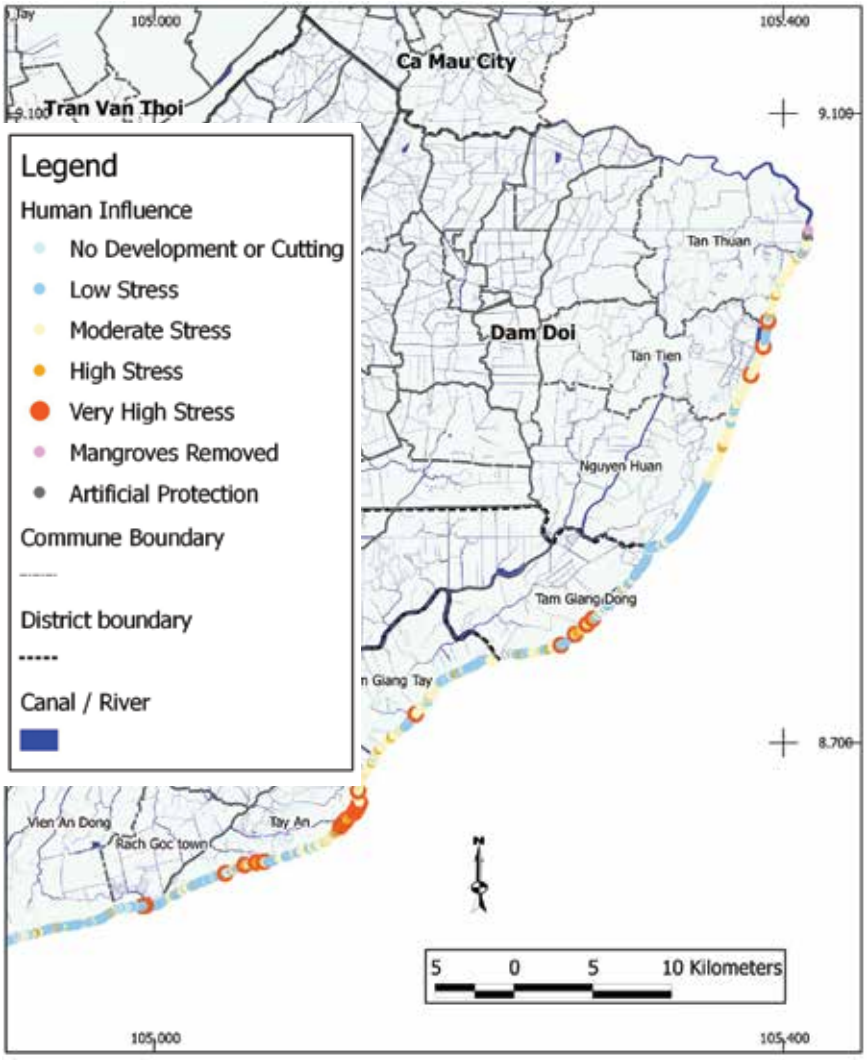

Figure 13. Geographical Distribution of Impact of Human Influence on the North Coast of the Province.

Summary of Coastal Condition

The coastline of Ca Mau is made up of several distinct sections with each section having different erosion and mangrove biomass conditions and human impact:

- A straight section of coastline in the northwest in the districts of U Minh and Tran Van Thoi that is generally eroding. These two rice growing districts of U Minh and Tran Van Thoi have extensive areas of natural mangrove forests but in U Minh only two thirds is of high biomass and in Tran Van Thoi only 40% was classed as high biomass. Much of the existing mangroves are regrowth in aquaculture ponds that have been abandoned due to erosion.
- In the southwest of the province there is a complex of shallow estuaries that empty into a large embayment formed by the westward progression of Ca Mau Cape. These estuaries form the south coast of Phu Tan district, the north-west coast of Nam Can and the north-west coast of Ngoc Hien. This area is protected from the action of strong waves by Ca Mau cape and by extensive areas of sediments that have been transport around the cape and out of the Cua Lon River. Much of the coastline of Phu Tan has natural high biomass forests, but there is pressure from aquaculture close to the shore on some parts of the District. The estuarine shore on the western side of Nam Can has most of its shoreline made up of intact natural high biomass forest. The north-western coast of Ngoc Hien is backed by protection forest and a large proportion of the coastline has high biomass natural forests.
- Ca Mau Cape which defines the location of the south-western tip of Vietnam, and the south coast of Ngoc Hien that is made up of sandy sediments. These areas have extensive offshore sediments that are moving westward under the influence of currents. While the large amounts of sediments of the cape limit the penetration of large waves onto the coast, the western section of the cape that is more exposed to SW winds shows some minor and medium erosion. Much of the south-western coast of Ca Mau cape is experiencing moderate to severe erosion and a section of concrete pole – rock fill wave break fences are being constructed.
- A highly eroded coastline of the East Sea runs from south-west to north-east and is oriented towards the south east. The East coast of the province has experienced considerable coastal retreat due to erosion. As a result much of the coastline is made up of mangroves that have been exposed by this erosion. Only two thirds of the coast of eastern Ngoc Hien is of high biomass and at least one third is plantation that is currently eroding. On the East coast of Nam Can while much of the forest appears to be natural regrowth, almost half is of low biomass. Dam Doi has a high proportion of its coastline that is of high biomass but over half of this is made up of eroding plantation forest.

04 Identification of Hot Spots

The extreme values of each of the three condition classifications; erosion, biomass and human influence are used to identify hot spots of each condition. Table 8 summarises the distribution of highly eroded areas, low mangrove biomass and high human impact across the coastal districts of Ca Mau province.

Table 8. Distribution of Highly Eroded Areas, Low Mangrove Biomass and High Human Impact across the Coastal Districts of Ca Mau Province.

District	Coastline (km)	Mangroves (km)	% of coast that is Natural mangroves	% of Mangrove Coast with Low or Very Low Biomass	Coast with Anthropogenic stress (km)	Coast with Moderate - Severe Erosion (km)
U Minh	28,2	26,8	80	32	1,2	10
Tran Van Thoi	34,9	31,7	85	61	52,1	64
Phu Tan	34,9	34,1	96	12	12,8	13
Nam Can W	21,4	21,1	99	2	16,6	28
Ngoc Hien W	43,5	40,8	85	8	10,7	19
Ngoc Hien E	49,1	48,6	68	33	118,9	157
Nam Can E	13,1	13,0	90	48	0,1	2
Dam Doi	26,0	25,7	43	19	25,4	21

Figure 14 shows the geographical distribution of hot spots of erosion, human influence and reduction of mangrove biomass on the coastline of Ca Mau province. The map indicates that loss of mangroves is a common problem in all districts but is particularly important on the northern part of the west coast in the districts of U Minh and Tran Van Thoi. Mangrove loss is also important along the east coast of the province. Areas of high stress due to development and cutting of mangroves are also common along the entire coastline of the province but is concentrated on the north-western and eastern coasts. Erosion hot spots are prevalent along the coastline of Tran Van Thoi and are also found along the entire east coast of Ca Mau province.

Two of the hotspots identified are impacted by all three issues and a large number are impacted by two issues.

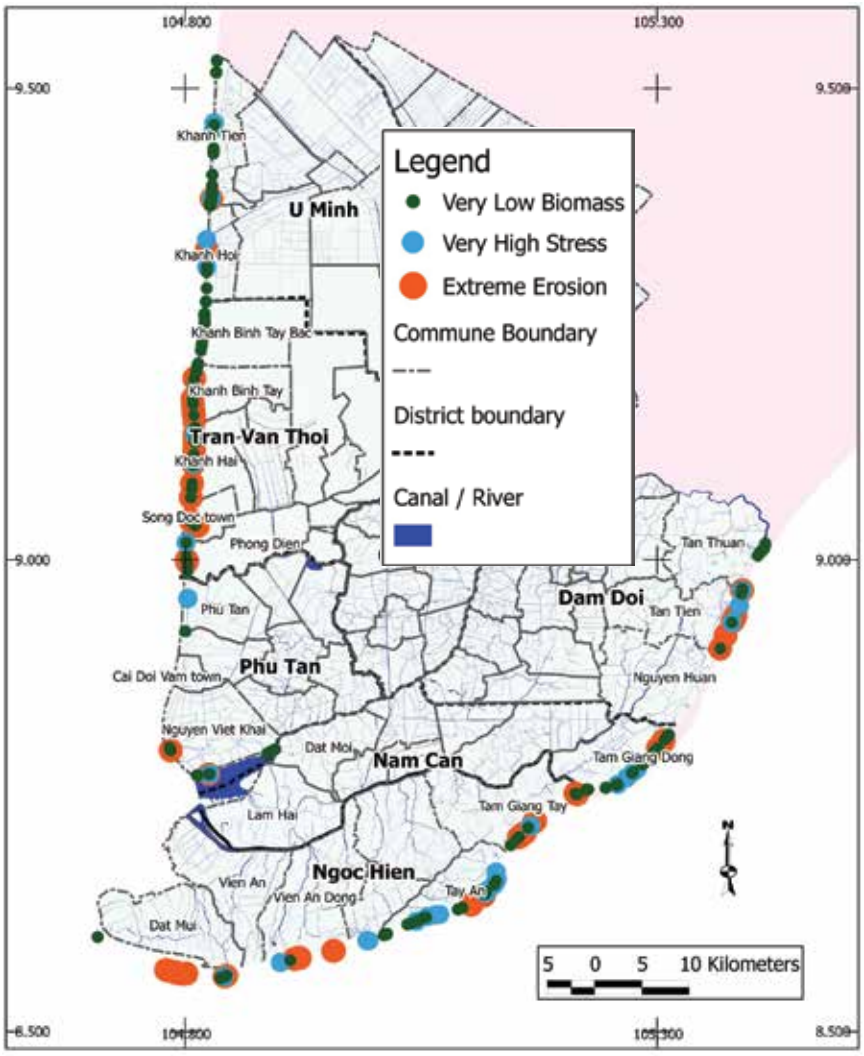

Figure 14. Geographical Distribution of Hot Spots of Erosion, Low Biomass and high Stress from Human Influence on the Coast of Ca Mau Province.

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