Shoreline and Mangrove Resource Condition of the Mainland Coastline of Kien Giang Province, Vietnam: Key Pressures and Restoration Requirements

Michael J Russell

June 2012

Conservation and Development of the Kien Giang Biosphere Reserve Project

Executive Summary

This report presents a summary of the mangrove resource condition of the mainland coastline of Kien Giang Province, both the condition of the mangrove coastline as seen from Shoreline Video Assessment SVAM and the condition of the gazetted reserved protection forest as measured from satellite images. 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 and the requirements for restoration are also presented.

Rather than using district boundaries the report uses smaller lengths of coastline that share geomorphological and erosion exposure characteristics, crating 19 sectors. Sectors are divided at District boundaries and where a sector boundary is near a commune boundary, thesectors are divided at commune boundaries.

The key pressures on the coastal mangroves of Kien Giang are presented geographically and the exposure to erosion both now and in the future is ranked. The current condition of the mangrove forests, particularly the gazetted protection forests is also ranked. Both the exposure and the measures of condition are used to display the geographical extent of the required restoration measures. Further steps required to produce an integrated adaptation plan and the role of this document are then outlined.

Key Pressures

A spatial view of the key pressures on the mangrove resources for the entire mainland coastline of the Province shows that exposure to erosion by waves and currents is related to the geomorphology of the coastline which has a large influence on exposure to due to strong wind events generated by the predominant SW and NE monsoon winds.

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 and Southern shore of Rach Gia Bay;
- Onshore entrapment of sediments in coastal fringing mangroves, and movement landwards - a result of swell induced transport.
- Erosion and inundation due to heavy swell and rough seas generated bymonsoonal storms and typhoons that can carry increased quantities of sand and silt alongshore as well as offshore.

Sea Level Rise and Climate Change

The National Meteorology and Hydrology Centre (IMHEN) projects a sea level rise for Vietnam of 15 cm by 2030, 30 cm by 2050, 50 cm by 2070, and 100 cm by 2100 under high emissions climate change model scenarios (MONRE 2009). A study by IMHEN,CMPPC and KGPPC (2011) showed that the most important effects of sea level rise in Kien Giang relate to; the corresponding changes in flooding and drainage; its relative effect on salinity in the canal and river system, increased coastal erosion, proneness to inundation and storm surge vulnerability. 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. The most substantial impacts of changes to the climate on Kien Giang are also expected to be increased erosion due to more energetic wave conditions and intense monsoonal conditions and storms. This increases the erosive power of the waves and consequently increases the amount of sediment that is removed.Changes in coastal sedimentation and erosion patterns are also projected to occur.

An analysis of Typhoon trends showed that while the frequency in the East Sea increased slightly, the frequency of typhoon landings in Vietnam has no clear trend. However, Typhoon landings have moved toward the South and the frequency of very strong storms (> level 12) has increased, (IMHEN 2010). The analysis also showed that the typhoon season ends later.

Typhoons

The Institute of Coastal and Offshore Engineering (ICOE) modelling showed that during a Typhoon, water surface in Kien Giang could be elevated by 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.

Changes in regional scale sediment loads

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 Kien Giang coastline. However, some preliminary conclusions can be drawn:

- A net decline in sedimentation of this magnitude will most likely lead to a destabilisation of the coastal erosion and sedimentation patterns on both the East and West coasts;
- A 60% reduction in sediment loads over the next 20 years will most likely lead to a shift in the rates of sediment deposition and replenishment in coastal seagrass and mangrove systems;
- There could be localised loss of nutrients and sediment to support agriculture, aquaculture and marine capture fisheries in coastal areas.

Human System Vulnerability

The interaction of humans has also caused a number of pressures on the mangrove system and the influence of projected climate change impacts on the extent and potential increase in human pressure is also examined. The effects of storm surge are enhanced by the 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 mangrove fringe is often used by natural resource dependant poor households who construct illegal dwellings behind the mangrove fringe of coastal towns and cities and along low lying coastal areas of islands. 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.

The population density of each coastal commune can be used to as a measure of pressure on mangrove resources. High population density of Duong Hoa commune in sector 15 and Soc Son Town and My Lam in sector 10 indicate that pressure on resources may be high.

Vulnerability mapping by IMHEN, CMPC, and KGPC (2011) projected that Agriculture and Livelihood systems of all of the districts except Ha Tien will be highly vulnerable to climate change by 2050, with Hon Dat reaching this value by 2030 and to be very highly vulnerable by 2050. Chau Thanis projected to be very highly vulnerable due to population pressure and highly vulnerable with regards to poverty. This vulnerability is likely to put significant pressure on the remaining few kilometres of mangroves and this pressure will also be transferred to the mangroves of nearby An Bien.

An analysis of the condition of control measures in place to protect agricultural infrastructureshowed that improvements in the control measures that are in place to protect agricultural infrastructure will be required in the medium term (10 – 20 years) for Ha Tien, An Bien, An Minh and Kiel Luong, and in the long term (20+ years) for Hon Dat and Chau Thanh. Management plans for all districts will require the incorporation of improvements to rates of poverty and income streams, agricultural infrastructure and erosion protection.

Consequences of Climate Change

The projected coastal erosion will lead to:

- Loss of mangroves and other erosion buffers leading to exposure of large areas in An Minh, Hon Dat and Kien Luong resulting in damage and loss of agricultural land and urban settlements and infrastructure.
- Increased overtopping of existing sea dyke systems wall along settlements, decrease in buffer zone between wave action and infrastructure. Potential surface overflow over land with subsequent ponding, particular in basin profile locations.
- Changes in livelihood systems due to flooding and salt water intrusion resulting in increased pressure on mangrove resources.

Ranked Exposure to erosion

The sectors were given a ranking based on exposure to waves, currentsand storm surge and condition. The ranking was used to create an erosion index of 1 (low exposure) to 3 high exposure. Five sectors currently have a low exposure to erosion, seven have a moderate exposure and seven sectors have a high exposure to erosion. The most exposed sectors are; the coast of An Minh, the granite headland of Hon Dat, and the limestone headland of northern Kien Luong. The mangrove sector in the north of Rach Gia district, and the three sectors of Ha Tien have a low exposure as they are protected from waves to some extent by Phu Quoc. Modelled projected change in erosion by 2050 were used to develop a change index from -1 (increase in deposition) to 0 no change to 2 (Moderate increase in erosion.Eight sectors, five of which are already highly exposed to erosion, are projected to experience a moderate increase in erosion. The erosion is projected to decrease in three sectors and to remain the same in five.

Mangrove condition

All sectors except sector 4 in An Minh and sector 5 in An Bien do not have the proclaimed 500 m wide Belt of mangroves. Two other sectors in AN Minh do have a moderate width of mangroves along much of the coast.

The sectors that have a low erosionexposure are dominated by low to moderate condition forests with around half or less of the mangrove coast classed as dense. Sector 9 is dominated by

mangroves with a tall mostly continuous canopy but shows no recovery with the entire sector classed as steep or shear.

The sectors with a moderate exposure to erosion have a mangrove canopy condition index of moderate to good. These sectors have over half of the mangrove coast classed as dense generally with half classed as continuous. These sectors have a mix of tall and short canopies and seedling are present along some of the coast, some of which is classed as depositional.

The sectors with a high erosion exposure have the full range of condition index. Sectors 16 and 13 have very low coverage of dense or continuous forest and no depositional environments and consequently very little evidence of seedlings and a large amount of canopy that is in poor condition. The remaining sectorswith a high erosion exposure have increasing amounts of depositional or gentle coastlines dominated by medium or tall dense continuous canopy with seedlings.

Required restoration

The required restoration is divided into four classes:

1. Depositional areas require monitoring and in-filling and natural regeneration of the existing mangroves to improve forest width and quality. Sectors 2 and 5 of An Bien and An Minh and a small sector in Kien Luong are actively accreting and require restoration to improve the ratio of mangrove to clearing and to establish an appropriate width of the forest along the entire coast. These areas equate to the alluvial areas of the KGPC and DARD (2010) report.

2. A second class of sector is one that requires erosion protection along some parts of the coastline as well as therestoration and widening of the existing forest. Depending on local conditions at the small scale, this type of sector would require single melaleuca fencing to promote natural regeneration and double melaleuca fencing to reduce exposure to erosion and to protect plantings.

The four northern sectors (Ha Tien and northern Kien Luong) have the same requirements for restoration. Within these sectors management of erosion isrequired in all susceptible embayments and the mangrove areasrequire restoration to improve the width, condition and continuity of the mangrove canopy.

3. The second most intensive amount of restoration effort is required formoderate erosion sectors requiring some protection from erosion and restoration. This class equates to the slight erosion of the KGPC and DARD (2010) report and requires erosion protection using double or single melaleuca fences and substantial mangrove replantingto increase the width and condition of the mangrove forest.

Three Hon Dat sectors on the north of Rach Gia Bay require some erosion protection and widening of the width of the protection forest with two sectors also requiring restoration to improve the condition of the canopy. The inner sector on the southern side of Rach Gia bay on the An Bien coast (sector 6) requires erosion protection in some locations.

Sector 14 covering the limestone cape of Kien Luong which is in this class requires a separate detailed spatial management plan.

4. The greatest amount of effort is required for high erosion sectorsthat need significant measures to protect much of the coastline and to restore and expand the existing mangroves. This class of sector equates to the strong Erosion areas of the KGPC and DARD (2010) report and may require the

construction of substantial fencing or either concrete of double melaleuca fences. Sectors of this class also require significant replanting to increase the width and condition of the mangrove forest.

Substantial erosion protection and improvements in the width of gazetted mangrove forests is required for five sectors; sector 9 north of Rach Gia City and sector 13 on the south eastern side of the limestone cape of Kien Luong. Sector 13 also requires improvements in the retention and condition of mangroves. In An Minh, Sectors 1, 3 and 4 require substantial protection from erosion with sector 1 requiring substantial restoration to improve retention rates, canopy condition and forest width and sectors 3 and 4 requiring restoration to improve retention and forest width.

Development of a Coastal Adaptation strategy

This reportoutlines nine steps to the formulation of a coastal adaptation plan. Under the steps the reportcovers the first two steps in the process by dividing the coast into sectors that share the same pressures on the mangrove forests. The report by Kien Giang People's Committee, Department Of Agriculture And Rural Development (2010) discusses the adaptation options (step 3) and begins the process of a cost-benefit analysis of adaptation options (step 5).

Steps that are required to complete the process are the development of a formal strategy to incorporate community consultation (steps 4 and 8), selection of the preferred adaptation options (step 6), and the development of a process for reviewing and updating the adaptation strategy (step 9).

Key Documents used in the Report

There are five important documents that helped to form the background to this report.

1. A report by The Southern Sub-Institute Of Forest Inventory And Planning

Project of restoration and development of coastal protection forests in KienGiang province, period of 2011 – 2020

Authors;**Kien Giang people's committee, department of agriculture and rural development**

The report is an important companion to the current document that describes and provides costing of the restoration options that are available to the Province. The coastal area of each coastal district of the province is described in great detail as is the status of the gazetted protection forests and the management program and issues.

The report focuses on the 4 key mangrove districts, An Minh, An Bien, Hon Dat and Kien Luong, and has 4 objectives.

- Forest protection
- Forest development
- Sustainable resource use, and
- Support for forest protection and development and infrastructure construction

In terms of forest development, the report divides each district in into three erosion types; alluvial areas, slight erosion areas, and strong erosion areas. However while areal proportions of each type are presented there is no geographical depiction.

For each type of erosion area the project spells out the area of replanting required, replanting practices and techniques, a discussion of options for erosion protectionfence design and costings. Included are a detailed examination of the erosion protection options of; geotextile bags, melaleuca fencing and concrete fencing.

In terms of sustainable resource use the report focuses on forestry – aquaculture production, detailing the appropriate forest management techniques.

2. A technical report published by The Deutsche GesellschaftfürTechnischeZusammenarbeit (GTZ) GmbH Conservation and Development of the Kien Giang Biosphere Reserve Project

Assessment of Mangrove Forests, Shoreline Condition and Feasibility for REDD in Kien Giang Province, Vietnam.2010.

Authors;**Dr Norm Duke, Dr Nick Wilson, Mr Jock Mackenzie, Mr Hai Hoa Nguyen, Dr David Puller.**

The report presents the methodology and results of an assessment of the mangroves of the Kien Giang province in 2009. The methodology of the SVAM described in the report was reproduced for the current study.

3. A report to the Asian Development Bank (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).

Authors;**IMHEN, Ca Mau Peoples Committee, and Kien Giang Peoples Committee.**

The report presents an assessment of the present vulnerability of the districts of Kien Giang and Ca Mau and of potential changes in vulnerability due to climate change. The report presents the results of the latest (as of 2010) climate change modelling study. The 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. This current report presents some of the vulnerability assessment and draws heavily on the modelling outputs of the report.

4. A 2012 report to the GIZ Conservation and Development of the Biosphere Reserve of Kien Giang Province Project provides more detailed analysis of the coastal modelling outputs.

Coastal Dynamics of Kien Giang, Vietnam; 2009 – 2050.

Authors; **Dr Michael Russell and Dr Nguyen Huu Nhan.**

The report presents an analysis of coastal modelling carried out by the Institute of Coastal and Offshore Engineering (ICOE). The report presents present and future exposure to erosion due to waves and currents and displays the resultant erosional conditions now and as projected for 2050. The report also examines potential effects of storm surge due to strong monsoon conditions and as a result of typhoons.

5. A further 2012 report to the GIZ Conservation and Development of the Biosphere Reserve of Kien Giang Province Project provides an analysis of the effectiveness of fences in mangrove rehabilitation.

Effectiveness of melaleuca fences for mangrove restoration rehabilitation efforts.

Authors;**Dr Michael J Russell and Dr Karyl Michaels 2012.**

Kien Giang mainland coastline

Almost 74% of the shoreline of Kien Giang provincecan be considered to be mangrove coastline, although only 65% of the coast can be considered to be mostly mangrove. Pressure on these forests through cutting was evident along 77km of coastline, affecting 58% of the mangrove area along the shoreline. Nearly a quarter of the mangrove coastline (30km) is experiencing active mangrove loss due to erosion. Overall, one half of the total coastline was found to be eroded or eroding.

In most places along the coastline of Kien Giang, the mangrove fringe is dominated by *Avicennia alba* (Vietnamese name: Mắm trắng). In the central area from Rach Gia north to around Vam Rang, a mix of *Sonneratiacaseolaris* (Bần chua) and *A. alba* dominate the mangrove sea fringe. In places, blocks of both *A. alba* and *S. caseolaris* have been planted at the front of the mangrove, extending it seaward. It is possible that nearly all of the valuable *S. caseolaris* stands were planted.

A more detailed description of the condition of the coast of each of the seven mainland coastal districts is given in Table 1.

From the Table it can be seen that An Minh had the largest area of Mangroves gazetted into Protection Forests in 2009. Hon Dat,An Bien and Kien Luong have less than 1,000 ha andChau Thanh, Rach Gia and Ha Tien have only small areas of Mangrove Protection Forest Designation.

An Minh also had the highest percentage of the mangrove coast with a canopy that was classed as non-continuous (either scattered or fragmented). Hon Dat also had a high percentage in this class. The other Districts monitored had low amounts of their mangrove coast with a canopy that was classed as non-continuous. Most Districts had a moderate amount (~60%- An Minh and Kien Luong) or a high amount of the mangrove coast classed as High biomass.

The Ratio of the amount of mangrovethat is retained to the amount that is cleared(the retention ratio)is lowest for An Minh with more mangroves clearedthan preserved. An Bien and Ha Tien are close to the decreed 60:40 ratio, while Rach Gia and Hon Dat are close to 70:30. Most of Kien Luong was not covered by the 2009 SPOT images, the small area that was covered was only 20% cleared.

Over half of the coast of An Minh classified as mangrove was actively eroding in 2009, while only 22% of Hon Dat's mangroves were actively eroding. All the other Districts had smaller amounts of active erosion.

Table 1.Description of the condition of the mangrove coast of each of the seven mainland coastal districts.

District	Sectors	Main Coast type	Area of protected mangrove forest	Ratio of MangrovesRetained : Cleared In Protection Forest	% of Mangrove Coast Actively eroding #	% of Mangrove Coast With Non Continuous Canopy #	% of Mangrove Coast With High Biomass #
An Minh	1 - 4	Mangrove	2,289	44:56	51	39	63
An Bien	5 - 6	Mangrove	900	59:41	3	12	92
Chau Thanh	7	Estuarine mangroves	-				
Rach Gia	8 - 9	Rock Wall / Remnant mangroves	24	72:28	0	9	99
Hon Dat	10 - 12	Mangrove bays / Bights	806	69:31	22	27	89
Kien Luong	13 - 16	Mangrove bays / Bights	678	79:21*	8	6	66
Ha Tien	17 - 19	Mangrove bays	133	59:41	ND	ND	ND

* - Limited coverage by images in 2009 so data is from a small area of the district.
# - Due to border issues both the Duke *et al.* 2010and this study did not cover northern Ha Tien.

Coastal Sectors as Management Units.

The coastline of Kien Giang is made up of several different landform types: a straight section of coastline in the south, a large embayment leading into a large estuary in the centre, and limestone or granite headlands interspersed by small embayments in the north, Figure 1.

While much of the coast is lined with mangroves, the mangrove forests are of varying condition. In addition the complex coastline combined with the SW/NE monsoon climate means that exposure to waves and currents also varies. Phu Quoc provides some protectionfrom SW winds to the northern part of the coast.

In order to facilitate management each district has been divided into a number of sections that are similar in; land form type, mangrove resource condition orerosion risk. The sectors are shown geographically in Figure 1, and each sector is described in Table 2 and 3.

While sectors can span a number of communes, where appropriate the sectors are divided at a commune boundary in order to increase the management continuity.

The map (Figure 1) shows the 19 sectors covering the mainland coast. The map also shows the extent of gazetted forest resources along the Kien Giang coast. These forests are mainly mangrove forests except on headlands in sectors 11, 14, 16, and 19.

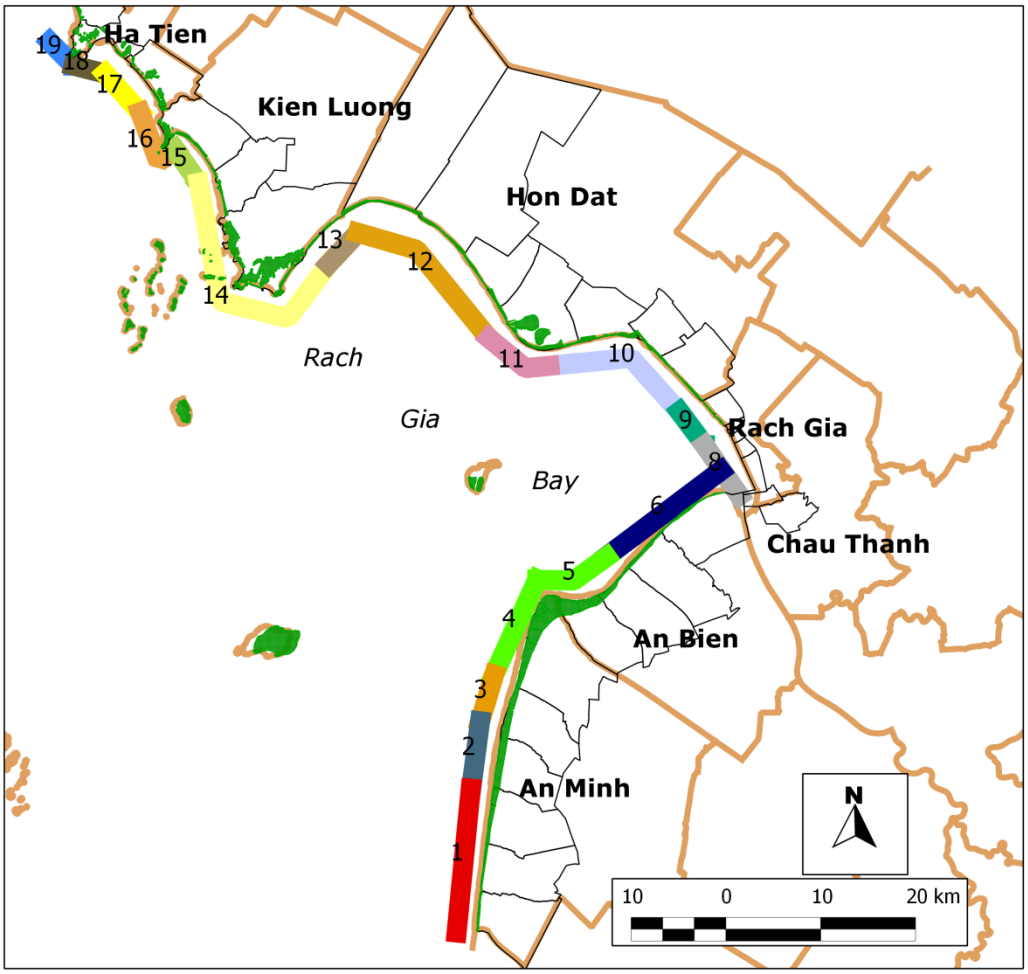

Figure 1. Geographical representation of the 19 management sectors and the gazetted protection forests of the Kien Giang Coastline shown in green. Management sectors are areas with similar land form type, mangrove resource condition orerosion risk.

Table 2.Description of each of the coastal sectors, outlining coastline type, the associated communes and the length and width of the mangrove belt.

No	District	Coast Type	Mangrove Belt	Mangrove (km)	% of Coastline with mangroves	Communes
1	An Minh	Straight Eroding Mangrove	Thin or non existent <250 m	14	90	Van Khanh Tay Van Khanh Dong Van Khanh
2	An Minh	Straight Prograding Mangrove	Moderate Belt of Mangroves >250 m	7	99	Dong Hung A
3	An Minh	Straight Stable Mangrove	Moderate Belt of Mangroves >250 m	2	50	Tan Thanh
4	An Minh	Prograding Mangrove Cape	Thick >500	11	97	ThuanHoa
5	An Bien	Prograding Mangrove Cape	Thick >500	8	99	Nam Thai A Nam Thai
6	An Bien	North Facing Straight Stable Mangrove	Thin <300 m	13	88	Nam Yen Tay Yen
7	Chau Thanh	Estuarine mangroves	Thin <100 m	1	40	Kin HoaHiep
8	Rach Gia	Rock or Concrete Sea Wall		0	0	An Hoa Rach Soi Vinh Lac VinhBao Vinh Thanh Van
9	Rach Gia	Straight Remnant Mangrove	Remnant <100 m	4	93	VinhQuang
10	Hon Dat	Remnant Mangrove Bight	Remnant <200 m	17	98	Soc Son Son Binh My Lam
11	Hon Dat	Granite outcrops. Development. Mangrove	Thin	7	94	Tho Son

No	District	Coast Type	Mangrove Belt	Mangrove (km)	% of Coastline with mangroves	Communes
12	Hon Dat	Remnant Mangrove	Remnant <200 m	22	92	Linh Huynh Binh Giang Binh Son
13	Kien Luong	South Facing Remnant Mangrove	Remnant <100 m	4	74	Binh An
14	Kien Luong	Limestone outcrops Development Mangrove Bays	Scattered	10	33	Binh An Kien Luong
15	Kien Luong	Eroding Mangroves	Thin <200 m	7	99	Duong Hoa
16	Kien Luong	Remnant Mangrove /Limestone Headlands	Thin <100 m	1	19	Duong Hoa
17	Ha Tien	Offshore sand bank with Beach Mangroves	Thin <100m	3	42	Thuan Yen
18	Ha Tien	Rock or Concrete Sea Wall		1	54	To Chau Phao Dai
19	Ha Tien	Limestone Headlands	Remnant <100 m	1	15	My duc

Table 3.Detailed description of the coast and landuse of the backshore zone of each Sector.

No	District	Description of Coast	Landuse of Hinterland
1	An Minh	Actively eroding with erosion scarp, broached aquaculture ponds, Rhyzophera plantations, dykes protecting ponds	Rice
2	An Minh	Stable/active prograding, successful seedlings	Aquaculture
3	An Minh	Eroded with low erosion scarp	Aquaculture
4	An Minh	Prograding Cape successful seedlings	Aquaculture
5	An Bien	Prograding Cape successful seedlings	Aquaculture
6	An Bien	Stable/eroded Poor seedling success	Rice
7	Chau Thanh	Estuarine mangroves	Perennial Fruit Trees
8	Rach Gia		Urban
9	Rach Gia	Remnant mangroves actively eroding	Rice
10	Hon Dat	Remnant actively eroding	Rice
11	Hon Dat	Mangrove bays Interspersed with Granite Outcrops and development	Aquaculture
12	Hon Dat	Remnant actively eroding	Aquaculture
13	Kien Luong	Remnant actively eroding	Aquaculture
14	Kien Luong	Mangrove bays Interspersed with Limestone Outcrops and Large scale development	Aquaculture / Forested Hills Harbour
15	Kien Luong	Remnant actively eroding Mangrove Bight	Aquaculture
16	Kien Luong	Remnant Mangroves Bays between Limestone Headlands	Forested Hills
17	Ha Tien	Sandy coast in North with development in central section and Thin band of mangroves in southern section	Perennial Fruit Trees
18	Ha Tien		Urban
19	Ha Tien	Thin Band of mangroves in northern section	Fruit Trees / Headlands / Tourism

Key pressures

This section outlines the key pressures on the mangrove resources of the mainland coast of Kien Giang.

The primary pressure is loss of mangroves forests through erosion.

Climate change and sea level rise are also expected to have significant and widespread impacts on Kien Giang affecting naturalsystems both directly and through increased pressure due to changed human systems. It is also possible that 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. Any increase in Typhoon frequency will increase the threat of erosion of mangrove forests.

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.

Erosion and Sedimentation

The geomorphology of a coastline has a large influence on exposure to erosion due to its influence on exposure to waves and currents. Projected changes in monsoonal conditions (in terms of wind and waves), increases in sea level, and a probable increase in the frequency of extreme cyclone events will have a marked effect on coastal geomorphological process (especially longshore currents) and likely exacerbate observed trends in areas currently susceptible to erosion and sedimentation.

The Institute of Coastal and Offshore Engineering (ICOE) utilized the MIKE 21/3 Coupled Model Flow Model to simulate the combined processes of hydrodynamics, wind induced waves, mud transport, sand transport, erosion/deposition, storm surge, and typhoons in the near shoreline coastal zone of Kien Giang and western Ca Mau provinces under current and projected future conditions. The results of this modelling work are included in the discussion below.

A baseline scenario (2000-2009) was modelled as was a future scenario for 2050 (i.e. 2050-2059) for the B2 SRES scenario. The modelling also used hydrological modelling outputs from IMHEN. See IMHEN, Ca Mau Peoples Committee, and Kien Giang Peoples Committee (2011) for details.

Wind Action

The Coastline of Kien Giang is not exposed to oceanic swells and waves are generated by wind action. The wind regime of the West Sea 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 force 8.There is a transitional period of variable winds in between each monsoon.

Typical Monsoon Conditions

Typical southwest monsoons bring onshore winds and waves of up to 0.4 m off the coast of Kien Giang and 0.5 m offshore to much of the west coast of the Ca Mau peninsular, as shown in Figure 2.

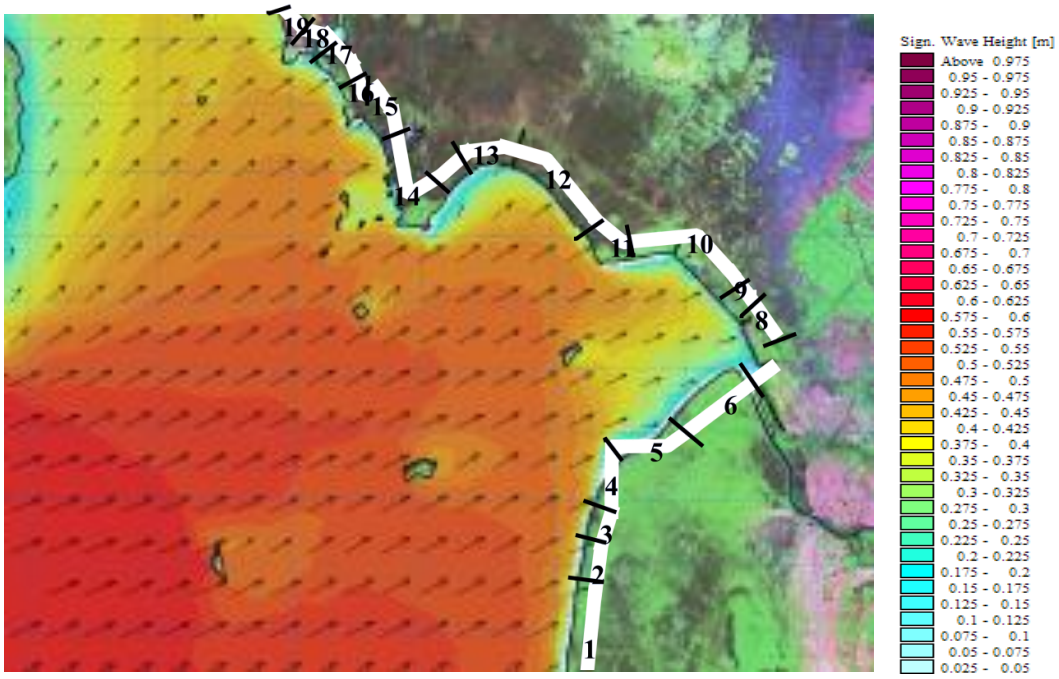

Figure 2.Wave height and direction in typical SW monsoon conditions.

Strong (Force 8) Monsoon conditions

Stronger SW monsoons bring stronger waves of 2 - 2.5 m offshorealong the entire west coast of the study region, Figure 3. Waves of this size can cause destruction of exposed infrastructure along the coast. These waves will undermine mangroves and erode exposed earth banks. Phu Quoc appears to offer some protection with smaller waves evident along the northern coast.

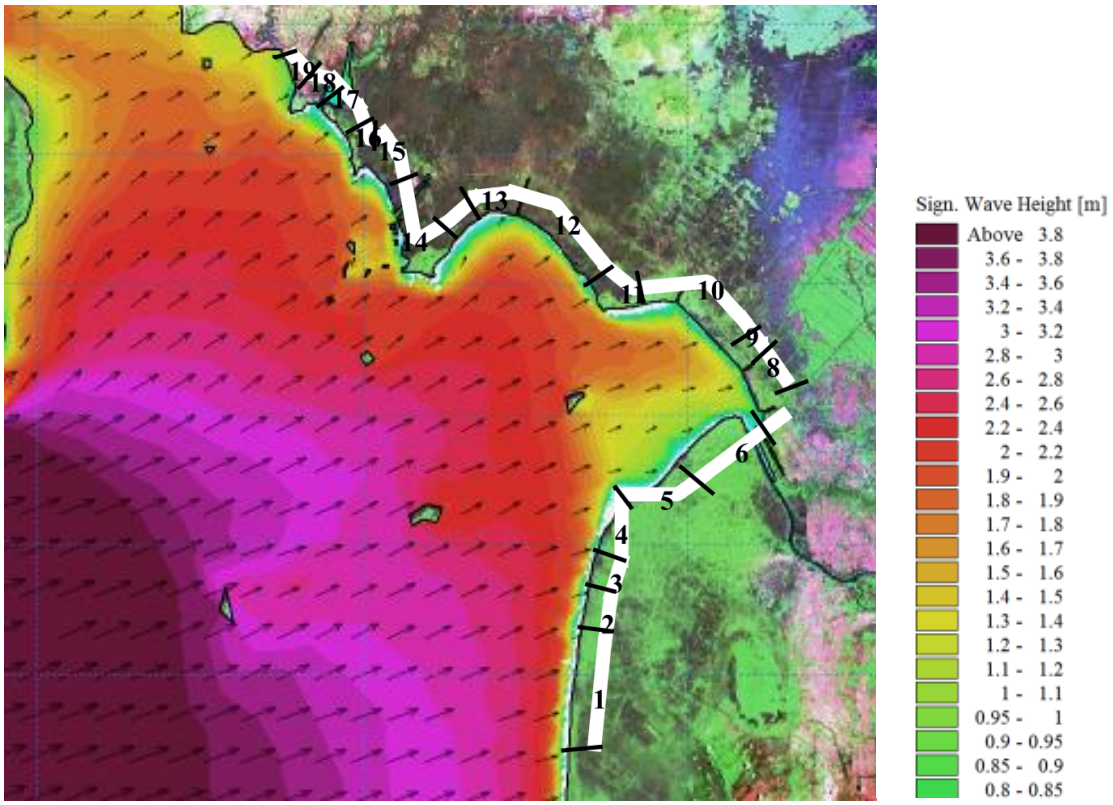

Figure 3.Wave height and direction in Strong SW monsoon conditions.

During strong NE monsoon conditions, waves of up to 2 m are evident on the eastern side of the two headlands of Rach Gia Bay (sectors 5 and 14). The remaining coastline experiences low wave conditions.

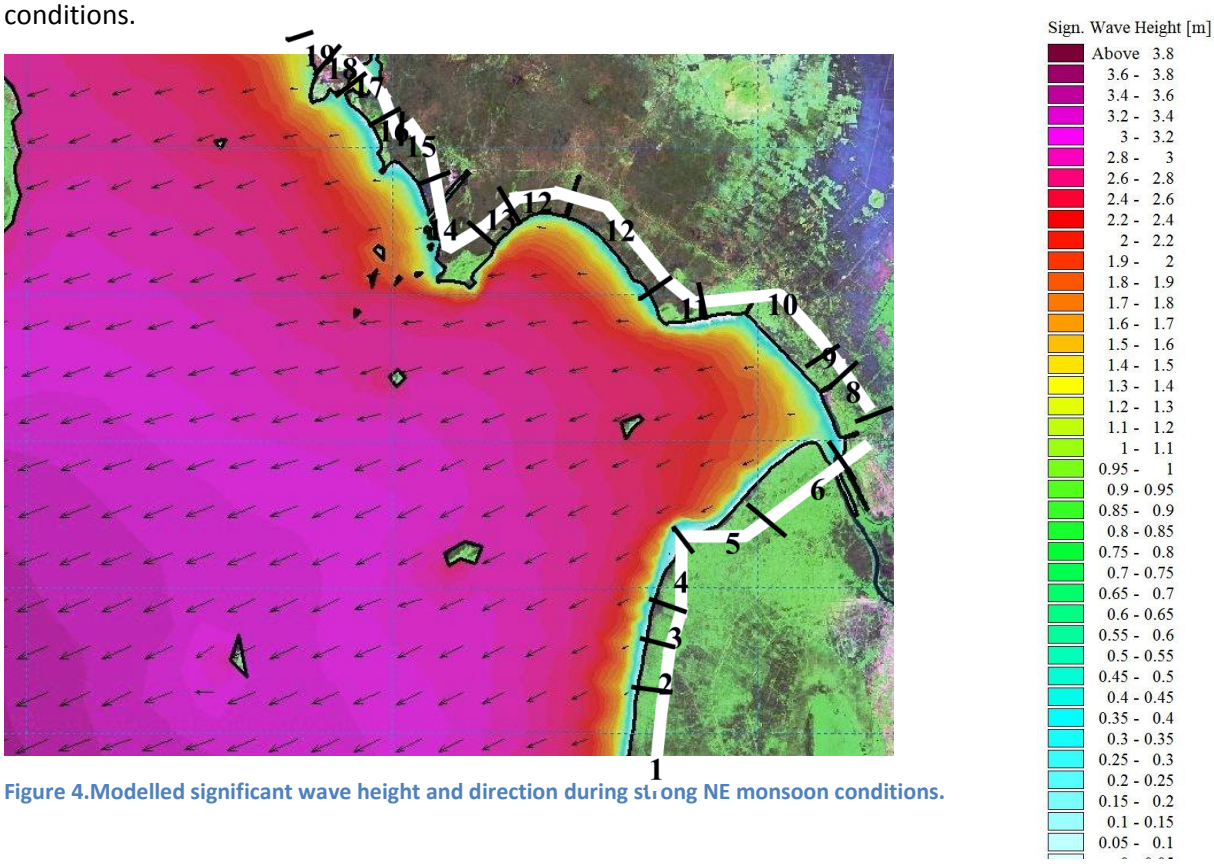

Figure 4.Modelled significant wave height and direction during strong NE monsoon conditions.

Tidal 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.

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 dominates the tidal currents in the southern part of the West Sea off the coast of southern Kien Giang and the west coast of Ca Mau province. In the north of the province the interaction of the West Sea tide and Rach Gia Bay dominates current flow.

Currents, Ca Mau Peninsular

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 Kien Giang and the west coast of Ca Mau province.

Figure 5 shows a schematic representation of the tidal flows around the peninsular. An incoming tide in the West Sea leads to current down the west coast of Ca Mau and around Ngoc Hien towards the East Sea. If this coincides with an outgoing tide in the East Sea the current along the southern shore of Rach Gia Bay and coast of southern Kien Giang and Ca Mau and is reinforced. If it coincides to an incoming tide in the West Sea then the current from the East Sea is muted and speeds are low along the Ca Mau East coast.

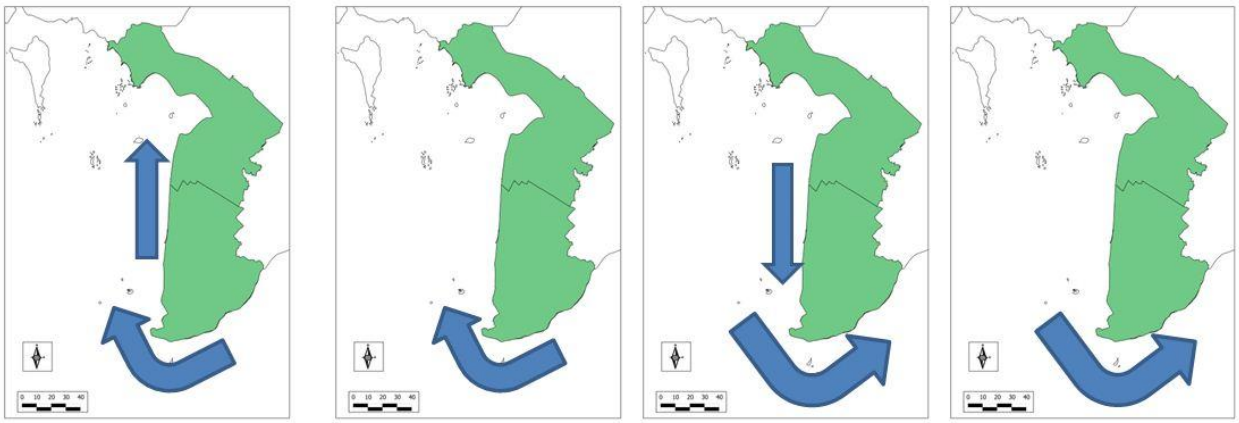

Figure 5.Schematic representation of the current flow due to interaction of tides in the West and East Sea. (a) High tide in East Sea and low tide in West Sea, (b) High tide in West Sea and high in the East Sea, (c) Low tide in East Sea and High tide in East Sea, (b) Low tide in West Sea and low tide in the East Sea.

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. Currents are also increased along the south coast (sectors 1-4).

Currents, Northern Kien Giang

The tidal currents off the northern coast of Kien Giang are primarily influenced by the tidal conditions of the West Sea. The direction and strength of tidal flows are shown in Figure 6. During the outgoing tide the currents flow from the north along the coast and into Rach Gia Bay (with the flow in the southern part of the Bay influenced by the East Sea tidal conditions). The northerly flow caused increased current speeds off Kien Luong Cape (sector 14).

During the incoming tide the current generally flows from south to north and into Rach Gia Bay. Currents are concentrated around the southern cape of Rach Gia Bay (sectors 5 and 6) and on the western coast of Kien Luong (sector 14). Currents are also increased along the south facing shore of the Granite headland of Hon Dat (sector 11).

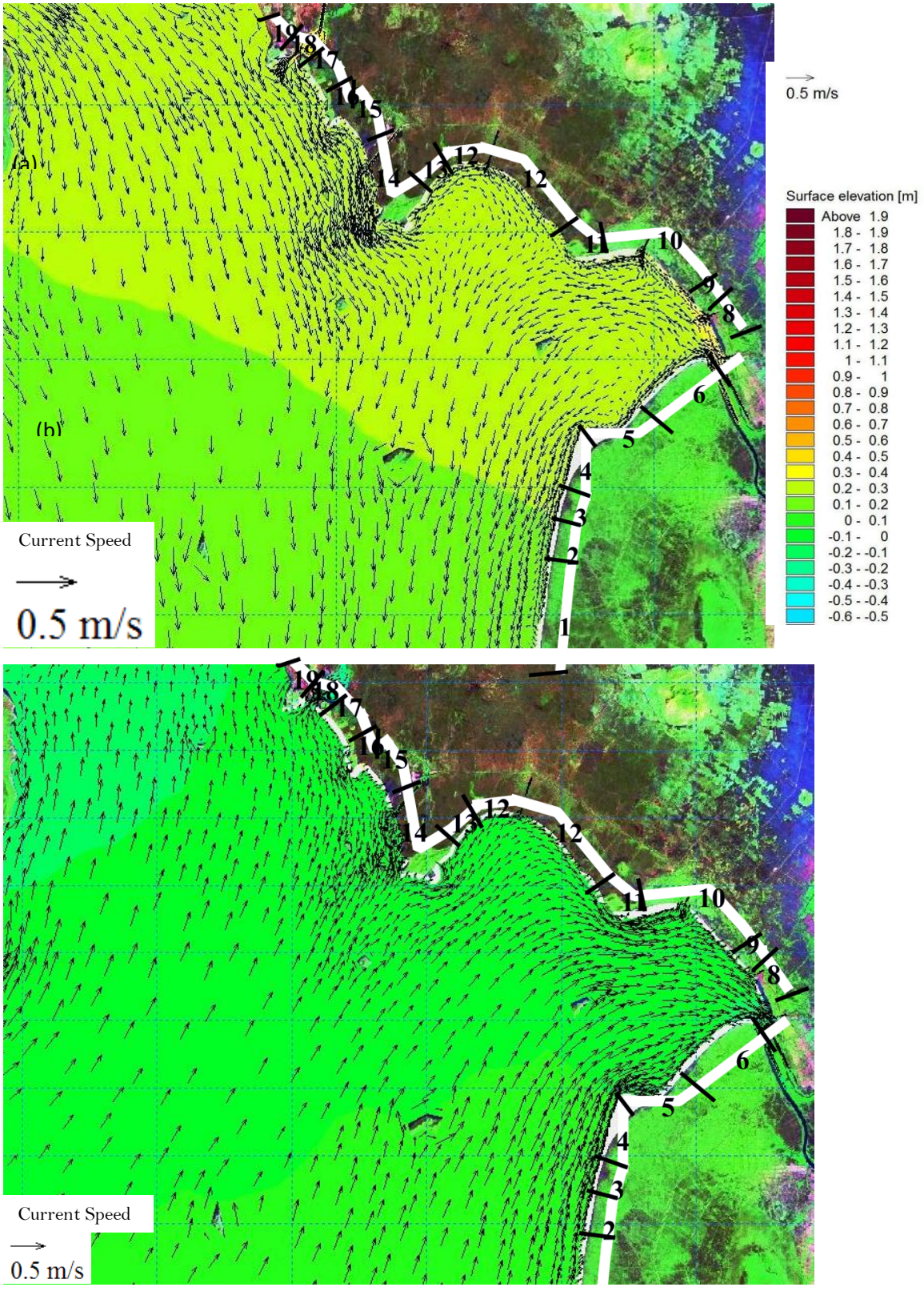

Figure 6.Tidal currents and surface elevation off the coast of Kien Giang during (a) outgoing and (b) incoming tide.

Currents along the northern coastline of Rach Gia bay have a counter current that flows from south towards the north during an outgoing tide and towards the south during an incoming tide.

During the SW monsoon season, due to the interaction of tidal flows around Kien Luong Cape, the tidal flow in Hon Dat Bay flows from north to south regardless of the state of the tide.

Currents Induced by Strong Wind Conditions.

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 resultduring strong southwest monsoon conditions the current along the west coast of the Ca Mau peninsular is predominantly a northerly flow regardless of tidal conditions. Current strength is increased when tidal conditions induce a northerly flow Figure 7 (a). There is still a significant inshore northerly flow when there is no or north to south tidal induced flow Figure 7 (b).

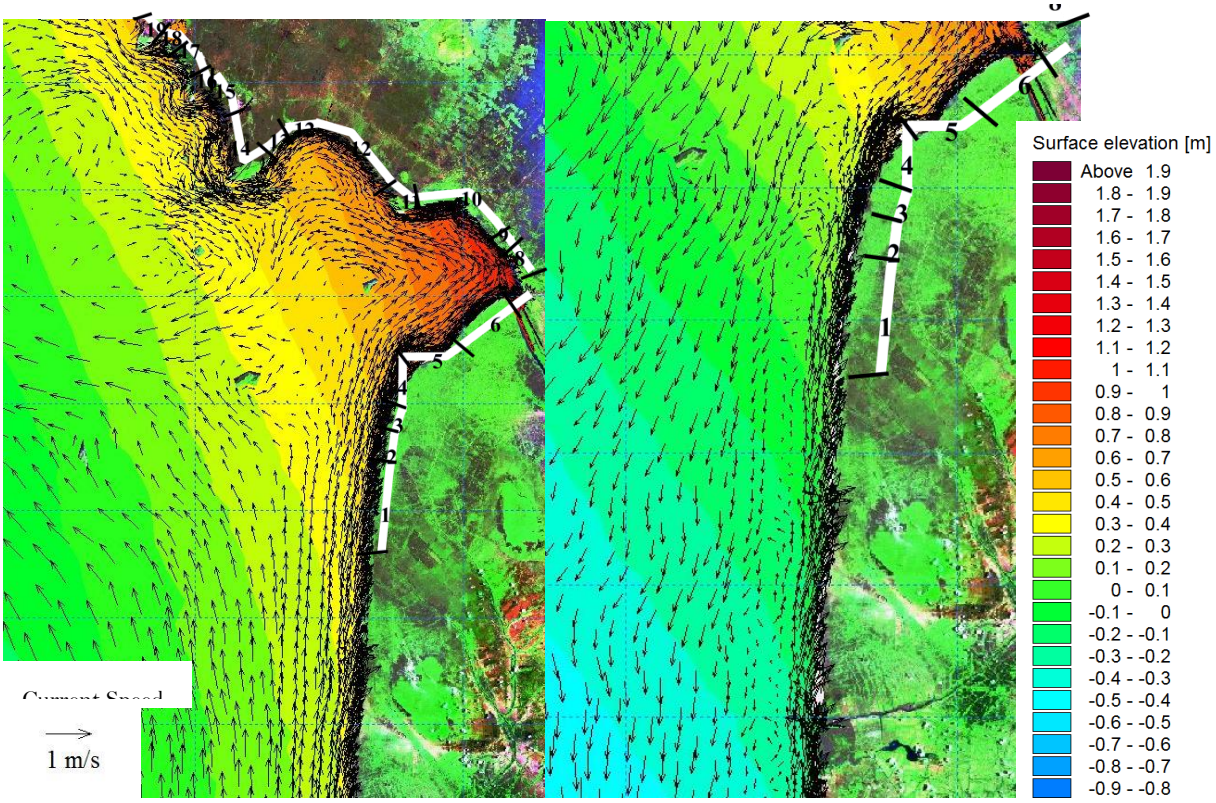

Figure 7.Interaction of tidal and strong SW monsoon induced currents off (a) the coast of Kien Giang during outgoing tide in the West Sea and (b) off the western coast of the Ca Mau Peninsular during an incoming tide in the East Sea.

Strong northeast to east monsoons in the dry season induce a north to south current to flow along the west coast of Ca Mau regardless of the tide. The current is stronger during an outgoing tide.

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 Rach Gia, 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 the modelling, that extreme weather events pose a significant threat.

Erosion Exposure

Typical Monsoon conditions

Figure 8shows the ICOE modelled erosion of fine sediments along the coastline of Kien Giang in typical SW monsoon conditions. As the waves are relatively small the ICOE model shows that conditions are generally depositional with small areas of erosion where currents are concentrated around headlands.

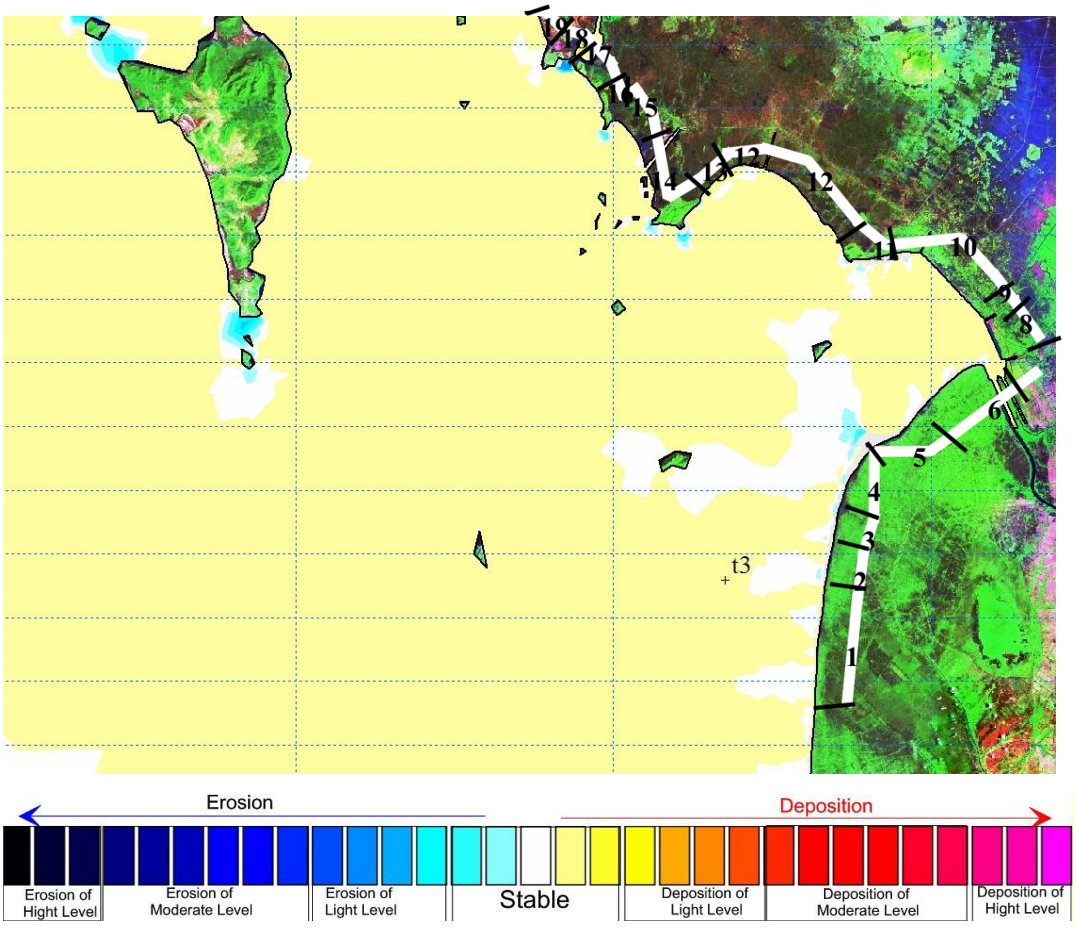

Figure 8.Modelled erosion of fine sediments along the coastline of Kien Giang in a SW monsoon under present conditions.

Monitoring of deposition on the coast of Vam Ray Commune in Hon Dat District reported deposition of around 30cm over a 2 month period of typical wet season monsoon winds (Chu and Brown 2011).

Waves of this size tend to transport sediments onto the shore, increasing deposition. Unfortunately, along with the sediment, inshore waves also bring debris suchas eroded mangrove trees, fishing gear, rubbish and water hyacinth.

Strong (Force 8) Monsoon conditions

Figure 9shows the ICOE modelled erosion along the coastlines of; Kien Giang in a strong SW monsoon.The model indicates extensive areas of erosion along the coasts and deposition of sediments in concentrated areas away from the coast where current speeds are low.

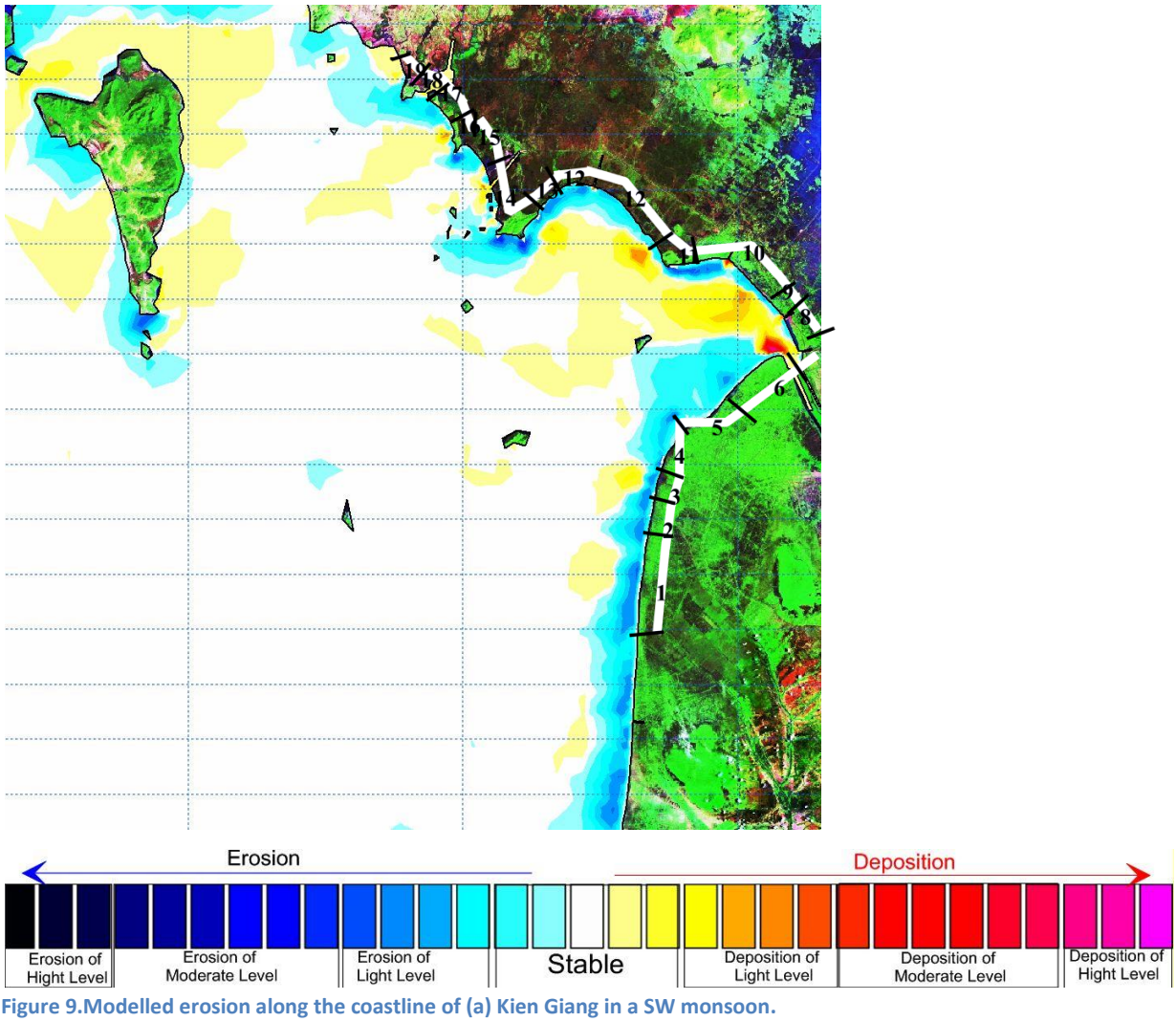

Figure 9.Modelled erosion along the coastline of (a) Kien Giang in a SW monsoon.

Conclusion

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 Kien Giang 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.

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

- Wave refraction and tidal currents drives movement of sediment as suspended plumes and bottomsediment around Ca Mau Cape.
- Transport of material finer materials and colloidal sediments along the west coast of the Cam Mau Peninsular and Southern shore of Rach Gia Bay;
- Onshore entrapment of sediments in coastal fringing mangroves, and movement landwards - a result of swell induced transport.
- Erosion and inundation due to heavy swell and rough seas generated by typhoons and monsoonal storms that can carry increased quantities of sand and silt alongshore as well as offshore.

Projected changes from Climate Change

Climate change and sea level rise are expected to have significant and widespread impacts on Kien Giang Province, affecting naturalsystems both directly and indirectly through increased pressure due to changed human systems.

The National Meteorology and Hydrology Centre (IMHEN) projects a sea level rise for Vietnam of 15 cm by 2030, 30 cm by 2050, 50 cm by 2070, and 100 cm by 2100 under high emissions scenarios. The low-end scenarios project a rise of 28 cm by 2050 and 65 cm by 2100 (MONRE 2009), although the high-end estimate of 100 cm or more cannot be ruled out.

The IMHEN,CMPPC and KGPPC (2011) study showed that the most important effects of sea level rise relate to; the corresponding changes in flooding and drainage; its relative effect on salinity in the canal and river system and increased coastal erosion, proneness to inundation and storm surge vulnerability.

Impacts of Climate Change on Wind and Wave Dynamics

Monsoon Winds

Climate model projections of changes in wind fields are accompanied by large uncertainties and it is difficult to predict the effects a small 0.6m/s wet season increase or a 0.2m/s dry season decrease in mean wind speed will have on the coast. It is likely that strong monsoon conditions will continue to occur every year and combined with higher sea levels storm surge effects will have a greater impact on the coast of both provinces.

Strong Monsoons

Strong monsoon winds from both southwest and northeast directions lead to higher water elevations downwind. With the added higher sea surface levels predicted for the future, storm surge will lead to water levels that are elevated up to 1mduring strong SW monsoons. Water levels of this height combined with waves of 1 – 2 m will lead to overtopping of dykes that are built to the current recommended dyke standards. Waves will also be able to penetrate further into mangrove forests due to a lower surface friction and a thin band of mangroves of 20-30 m will not offer sufficient protection for dykes or pond bunds.

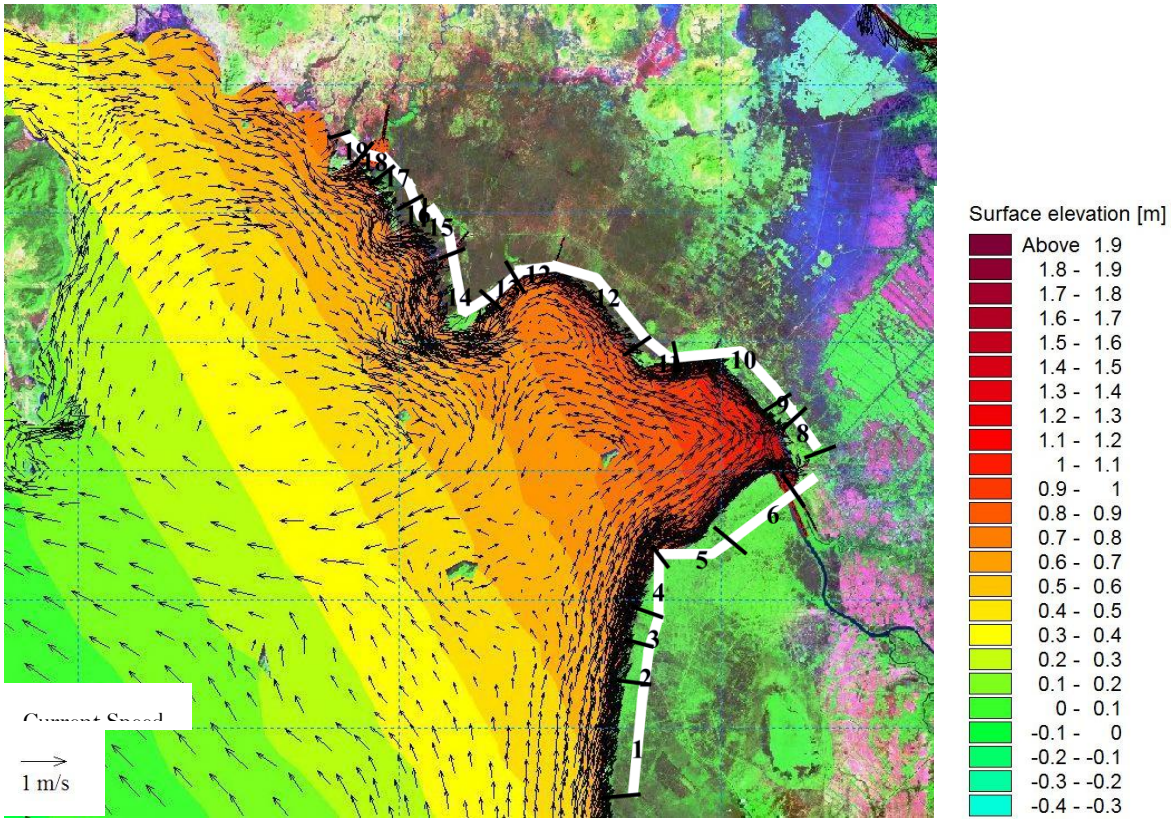

Figure 10.Modelled Water Surface Elevation in Rach Gia Bay in strong SW Monsoon Conditions in 2050.

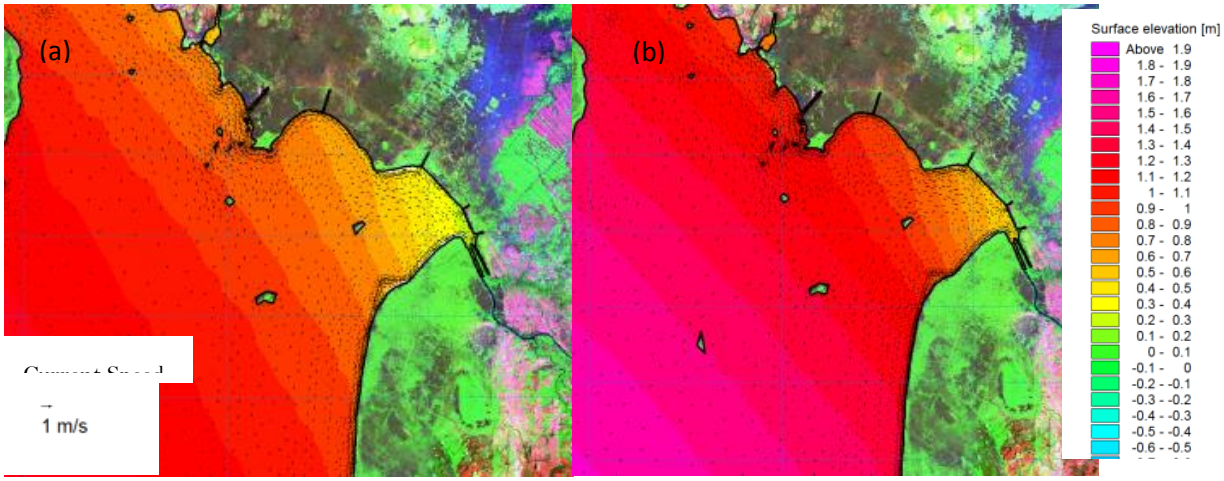

Figure 11.Modelled Water Surface Elevation in strong NE Monsoon Conditions in (a) 2009 and (b) 2050.

During NE conditions, the sectors covering the headlands of Rach Gia Bay are projected to be exposed to higher storm surge water levels in 2050.

Influence of Climate Change on Erosion

The difference in the modelled erosion pattern during a strong SW Monsoon for Kien Giang now and that projected for 2050 is shown in Figure 12. Increased erosion is evident along much of the coastline. The effect is particularly strong on the south facing embaymentsof the northern coast of Rach Gia bay (sectors 13 and 11).

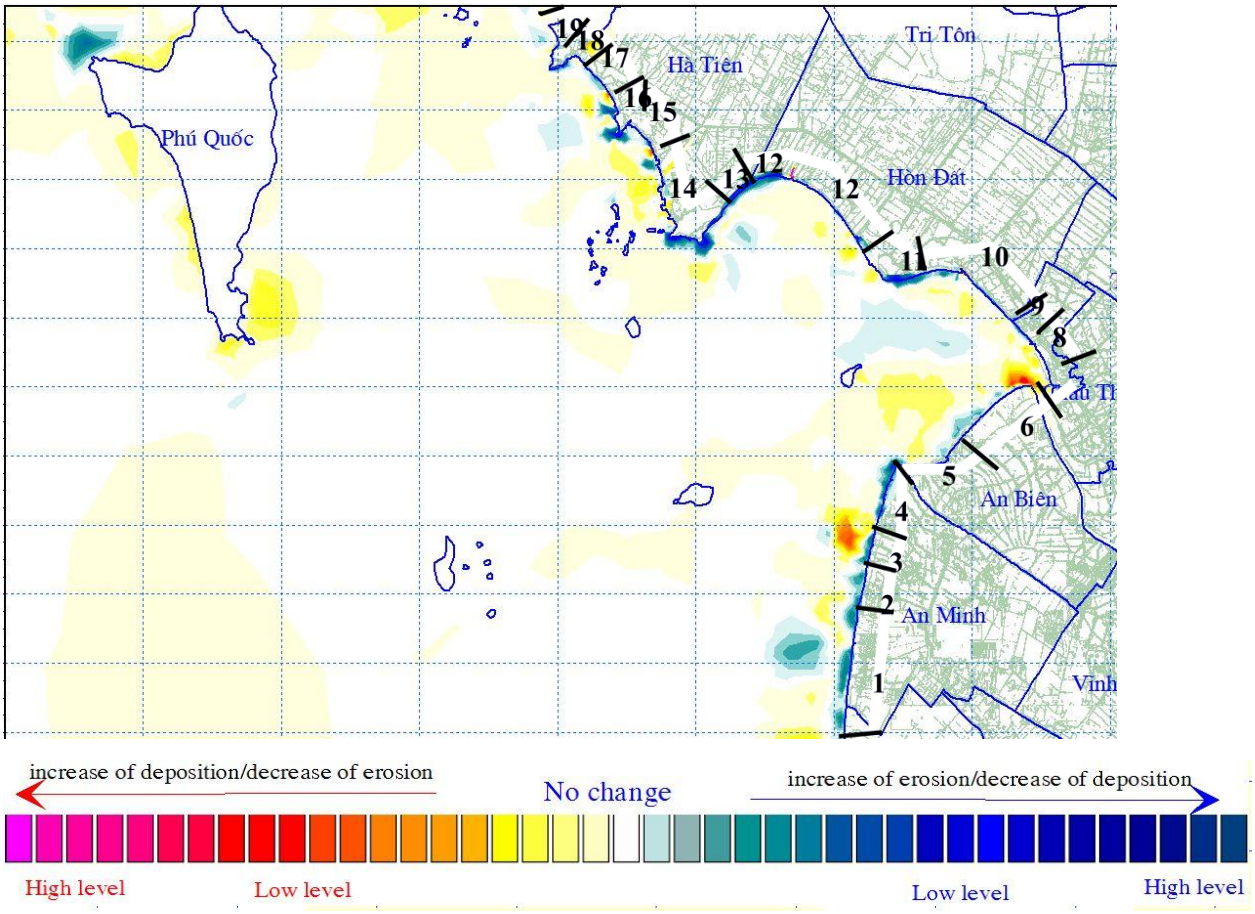

Figure 12.Difference in erosion during strong SW monsoon modelled for 2009 and 2050.

Summary of the Impacts of Climate Change

The current height of the sea-dyke system is around 1.2 meters, and so even at 2050 where projections are for a sea level rise of 30 cm, marked 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.Changes in coastal sedimentation and erosion patterns are also projected to occur.

The most substantial impacts of changes to the climate on Kien Giang are also 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, and in some areas as much as 0.5 km (Duke et al. 2010).

The projected coastal erosion will lead to:

- Loss of mangroves and other erosion buffers leading to exposure of large areas in An Minh, Hon Dat and Kien Luong resulting in damage and loss of agricultural land and urban settlements and infrastructure.
- Increased overtopping of existing sea dyke systems wall along settlements, decrease in buffer zone between wave action and infrastructure. Potential surface overflow over land with subsequent ponding, particular in basin profile locations.
- Changes in livelihood systems due to flooding and salt water intrusion resulting in increased pressure on mangrove resources.

Regional Scale Changes in Sediment Supply

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 Kien Giang coastline. It is estimated that there will be a 60% reduction in sediment loads over the next 20 years. The impacts on of this sedimentation deficit are not well understood, and should be the focus of future research.

However, some preliminary conclusions can be drawn:

- A net decline in sedimentation of this magnitude will most likely lead to a destabilisation of the coastal erosion and sedimentation patterns on both the East and West coasts;
- A60% reduction in sediment loads over the next 20 years will most likely lead to a shift in the rates of sediment deposition and replenishment in coastal seagrass and mangrove systems;
- There could be localised loss of nutrients and sediment to support agriculture, aquaculture and marine capture fisheries in coastal areas.

Typhoons

A Typhoon (or tropical cyclone) is defined as a tropical depression of sufficient intensity to produce gale force winds, i.e. at least 63 km/h. This kind of event is not only dangerous because it produces destructive winds but also because it is associated with torrential rains (often leading to floods), storm surge and wild sea conditions.Figure 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 infrastructureand inundation and associated

damage to agricultural production. As more mangroves are removed the exposure of the occupied hinterland to significant damage is increased.

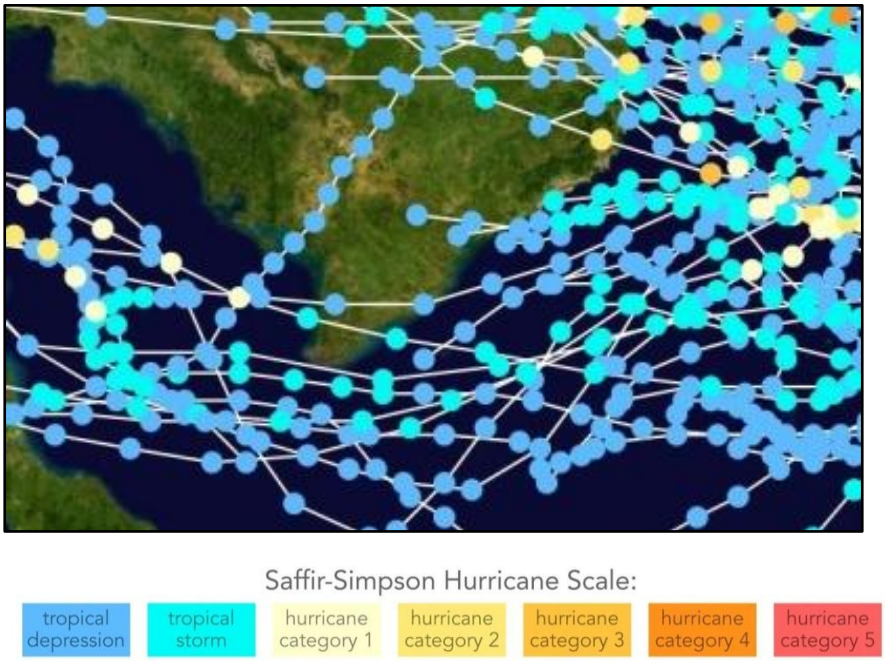

Figure 3. Regional tropical cyclone tracks from 1980 – 2005, coded by Saffir-Simpson category. The points show the locations of the storms at six-hourly intervals. Source: Wikipedia.

Kien Giang and Ca Mau are at the southerly limit for typhoons and many of the storms are at the lower end of the intensity scale. Typhoon Linda was considered to be the worst storm to hit Vietnam this century, and was compounded by the storm landing at high tide in a place where there was little experience with typhoons and few means to communicate to fishermen at sea. Total damages were estimated to be $600 million (UNDHA 1997).

Three factors reduced the extent of the destruction of property and infrastructure and financial loss. Firstly, it was low tide when the typhoon had the maximum effect on the more populated coastal regions of western Ca Mau and Kien Giang, which reduced the effect of storm surge. Secondly, after crossing into the west sea, the typhoon tracked north along the coast. This meant that strong typhoon winds blew from the south and did not strike the coast as direct onshore winds which reduced the fetch and hence the destructive potential of the associated waves. Lastly and most importantly, in 1997 there was a much lower population and associated infrastructure to be affected.

Figure 13 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. The island districts of Kien Hai and Phu Quoc were both exposed to strong wind and large waves of 2-4 m, again a relatively low tide reduced the potential storm surge.

Modelled water surface elevation in Kien Giang 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.

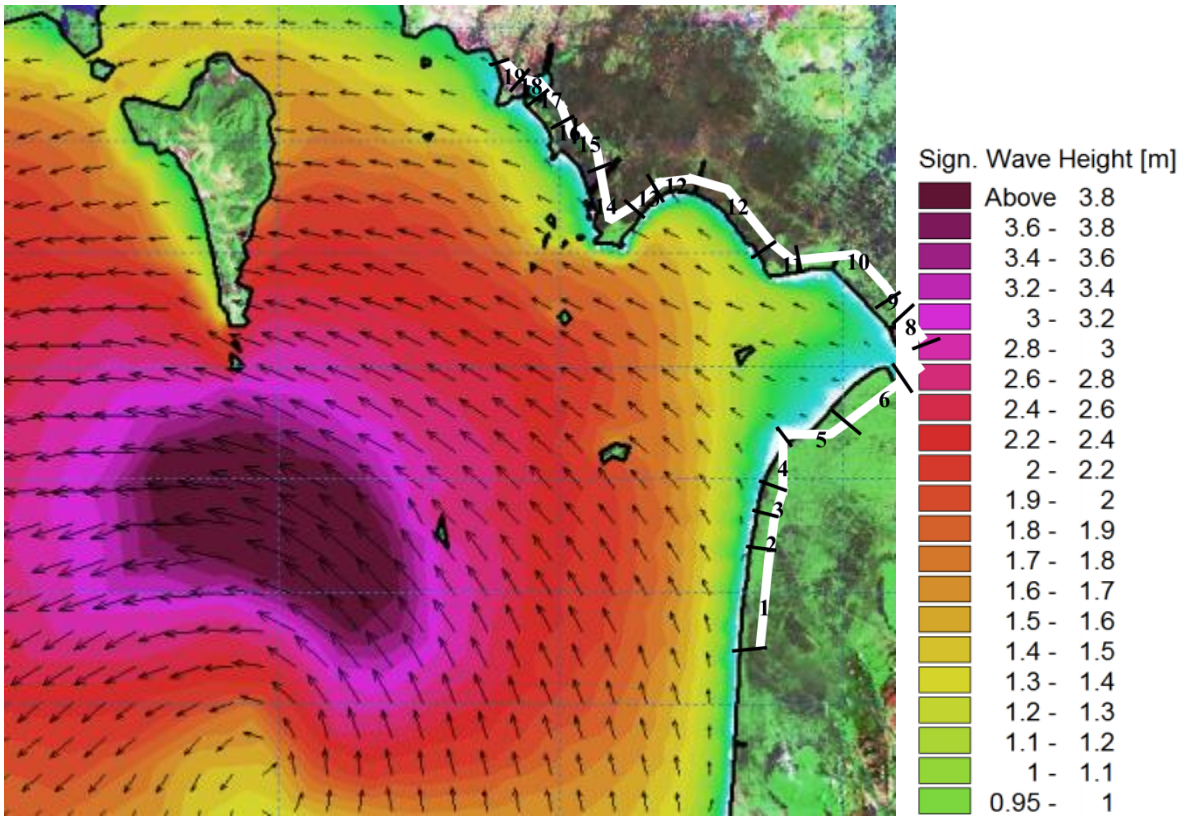

Figure 13.Modelled significant wave height and direction in the West Sea during Typhoon Linda 1997.

Effects of exposure to typhoon storm surge.

The lack of population and poor media coverage, mean that there is a paucity of information about the effects of Typhoon Linda on either coastal morphology or mangrove vegetation. It has been reported that large areas of mangroves were destroyed and have been replanted. There is little in the way of reports of the effect of the typhoon on infrastructure. It was reported that Typhoon Linda, had a purely financial cost of some US$593 million, mostly from destroyed/damaged housing (Le Truong Giang, 2005).There has been considerable investment in building protective harbor break walls on many of the small islands of Kien Hai. It is likely that fishing villages along the coast on the mainland and particularly on the islands would have experienced widespread destruction with loss of housing and boats. This destruction would also have been accompanied by widespread coastal erosion and damage due to strong winds and inland flooding.

Accompanying the large waves and increased water level due to storm surge that occur during a typhoon is the formation of strong currents that transport eroded sediments. This has potential

consequences for the location and severity of subsequent erosion from strong monsoon winds. The coastal modelling suggests that during a typhoon, sediments will be eroded from the nearshore areas along much of the coast. This will steepen the offshore profile leading to greater penetration of wave energy onshore in subsequent strong monsoon episodes.

When future typhoon strike the coast, the actual spatial distribution of erosion and deposition will depend on the direction from which a typhoon approaches and the tidal conditions that occur at the time. Wide scale erosion along the coast is likely to occur and any increase in typhoon frequency will multiply the effect of these changes in sediment patterns.

Effect of climate change on Typhoon frequency

An analysis of Typhoon trends showed that while the frequency in the East Sea increased slightly, the frequency of typhoon landings in Vietnam has no clear trend. However, Typhoon landings have moved toward the South and the frequency of very strong storms (> level 12) has increased, (IMHEN 2010). The analysis also showed that the typhoon season ends later.

This indicates that areas that have not typically suffered from storms (such as the south eastern portion of the country and HCMC) may increasingly be vulnerable. However, cyclones are a complex phenomenon and their formation is very difficult to predict. A number of simulations for typhoons were undertaken to shed light on the potential effects of storm surge and inundation going forward to 2030 and 2050 on the understanding that these projections may never eventuate.

The observations from Typhoon Linda in 1997 were used to simulate the potential effects of typhoons and storm surge on the coastlines of Ca Mau and Kien Giang under different sea level rise scenarios. As illustrated in Figure 11, the simulations show that the water surface elevation for a large scale typhoon event could be as high as 2 m in elevation, and in combined with 4-5 m waves could result in severe damage to coastal protection dykes, and fishing villages in estuaries and canal mouths along the entire coast.

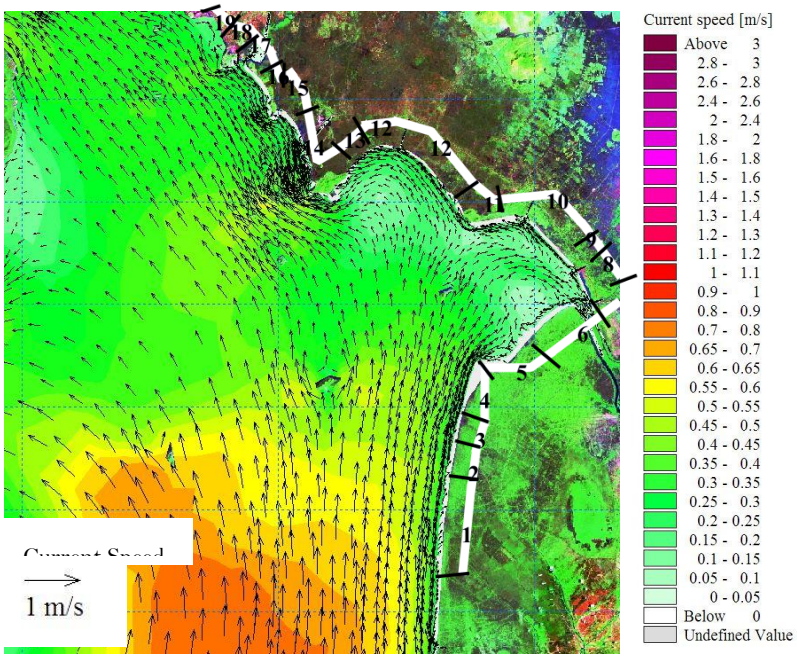

Figure 14.Projected water surface elevation and currents if a typhoon with the same characteristics of Linda were to cross the Ca Mau peninsular at high tide in the 2050 B2 climate scenario.

Human Pressures

Poor countries and people tend to be particularly vulnerable to deviations from average climatic conditions and climatic extremes (ADB 2009).

Poverty diminishes the resilience and adaptive capacity of people and households, especially where people lack savings and capital for investment to adopt better production technology and also lack awareness and knowledge of adaption options available. Like population, poverty encompasses dimensions relevant to climate change vulnerability, such as the vulnerability to impacts and future shocks – and the ability to build resilience and adapt to climate change.

The poor tend to have less diversity of income sources, and less access to credit to fill in income gaps, and less adaptive capacity in terms of diversification of occupations. Hence they are extremely vulnerable when one or more of their income sources are strongly affected by climate.

Agriculture and Livelihoods Vulnerability

FAO (2007) points out that agriculture, aquaculture and fisheries are all highly sensitive to climate change and climate change will have a serious impact on their production functions. When a households' livelihoods depend on a small number of sources of income without much diversification, and when those income sources are in fields that are highly climate dependent, like agriculture and fishing, households can be said to have climate-sensitive resource dependence (Adger 1999).

Table 4.District vulnerability in three important areas; Population, Poverty and Agriculture and Livelihoods to 2050.(From IMHEN, Ca Mau Peoples Committee, and Kien Giang Peoples Committee 2011).

District	Population			Poverty			Agriculture & Livelihoods			Overall Vulnerability
	2010	2030	2050	2010	2030	2050	2010	2030	2050	2050
Rach Gia	8	16	29	2	10	10	5	10	25	High
Ha Tien	3	7	12	2	2	2	4	5	7	Medium
An Bien	5	9	11	5	13	14	6	10	24	Medium
An Minh	4	6	12	4	12	14	5	11	24	Medium
Chau Thanh	8	14	30	5	14	18	4	11	20	High
Hon Dat	7	7	12	3	12	14	2	13	36	High
Kien Luong	2	3	8	1	1	2	2	7	21	Medium

Table 4 shows the calculated overall vulnerability of the Districtsand the vulnerability in three important areas. Agriculture and Livelihoods of all of the districts except Ha Tien are projected to be highly vulnerable by 2050, with Hon Dat reaching this value by 2030 and to be very highly vulnerable

by 2050, Chau Than is projected to be very highly vulnerable due to population pressure and highly vulnerable with regards to poverty. This vulnerability is likely to put significant pressure on the remaining few kilometres of mangroves and this pressure will also be transferred to the mangroves of nearby An Bien.

Measures of exposure to climate change impacts can be estimated using the application of GIS to map the projected size of the area of each district that is impacted by each hazard. This mapping can be carried out for each time period and climate scenario. However, estimates of the level of measures that are in place to protect infrastructure are also required. Accordingly expert opinion was incorporated into the vulnerability rating as a weighting factor 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 5. 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 Ha Tien, An Bien, An Minh and Kiel Luong, and in the long term (20+ years) for Hon Dat and Chau Thanh.

Table 5. 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.
Rach Gia	Adequate, now and in the near future (around 10 years)
Chau Thanh	Adequate, but adaptation needed in the long term in view of climate change
Hon Dat	Adequate, but adaptation needed in the long term in view of climate change
Ha Tien	Improvements are desirable in the medium term in view of economic development
An Bien	Improvements are desirable in the medium term in view of economic development
An Minh	Improvements are desirable in the medium term in view of economic development
Kien Luong	Improvements are desirable in the medium term in view of economic development

Summary of Key Pressures

Many of the coastal areas on the West Coast 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 enhanced by the 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 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 penetrate through a thin line of mangroves and erode earth dykes.

In many areas of the Kien Giang coast 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 will be breached within a single wet season. In districts where agriculture occurs behind the sea dyke E.g. Hon Dat, 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 and along low lying coastal areas of islands. 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.

Extent of coastline at risk from changes to erosion and sea-level

The modelling of coastal processes allows the quantification of the exposure of different areas of the coastline to erosion and the resultant transport of sediments. By using future projections we can identify areas where this exposure is likely to change and the subsequent changes in the depositional environment. Table 6shows the exposure of each sector to waves, currentsand storm surge; the modelled erosion condition; and the projected change in erosion pattern. The sectors were given a ranking based on exposure and condition. The ranking was used to create an erosion index of 1 (low exposure) to 3 high exposure. The index is used to rank the following tables into the three values that are presented as colour gradation. The Table also shows the projected change in erosion by 2050 which can be used to develop a change index from -1 (increase in deposition) to 0 no change to 2 (Moderate increase in erosion.

Table 6. Modelled exposure of each sector to erosion factors (waves, storm surge and currents) and erosion condition now and as projected for 2050. The table also shows the erosion ranking and an erosion index as shading (yellow – low exposure, orange – moderate exposure, red – high exposure).

No	Max Wave Height (m)	Storm Surge Strong SW (m)	Max Current (m/s)	Erosion Condition Strong SW	Change in Amount of Erosion Strong SW 2009 - 2050	Erosion Ranking	Change Index
1	2	0.5	0.4	Moderate Erosion	Moderate Increase	14	2
2	2	0.5	0.4	Moderate Erosion	Moderate Increase	13	2
3	2	0.6	0.4	Moderate Erosion	Moderate Increase	15	2
4	1.3	0.7	0.4	Light Erosion	Moderate Increase	8	2
5	2	0.8	0.4	Light Erosion	None	19	0
6	1.5	0.9	0.4	Light Erosion	Increase	11	1
7	0.75	1.4	0.2	Moderate Deposition	Moderate Deposition	1	-1
8	1	1.5	0.3	Light Erosion	Moderate Deposition	6	-1
9	1	1.5	0.3	Light Erosion	None	5	0
10	1.3	1.4	0.4	Light Erosion	None	12	0
11	2	0.8	0.4	Moderate Erosion	Moderate Increase	18	2
12	1.5	0.8	0.3	Light Erosion	None	10	0
13	1.2	0.7	0.4	Moderate Erosion	Moderate Increase	7	2
14	2	0.6	0.5	Moderate Erosion	Moderate Increase	16	2
15	1.5	0.8	0.3	Light Erosion	None	9	0
16	2	0.7	0.4	Moderate Erosion	Moderate Increase	17	2
17	1	0.8	0.3	Light Erosion	Increase	4	1
18	1	0.8	0.3	Light Deposition	Increase	3	1
19	1	0.6	0.4	Light Deposition	None	2	-1

Five sectors currently have a low exposure to erosion, seven have a moderate exposure and seven sectors have a high exposure to erosion. The erosion is projected to decrease in three sectors and to

remain the same in five. Eight sectors, five of which are already highly exposed to erosion, are projected to experience a moderate increase in erosion.

Location of coastline at risk from erosion

Figure 15 shows the geographical distribution of the erosion index of the sectors. The most exposed sectors are; the coast of An Minh, the granite headland of Hon Dat, and the limestone headland of northern Kien Luong. The mangrove sector in the north of Rach Gia district, and the three sectors of Ha Tien have a low exposure as they are protected from waves to some extent by Phu Quoc

The population density of each coastal commune is also shown. This can be used to as a measure of pressure on mangrove resources. High population density of Duong Hoa commune in sector 15 and Soc Son Town and My Lam in sector 10 indicate that pressure on resources may be high.

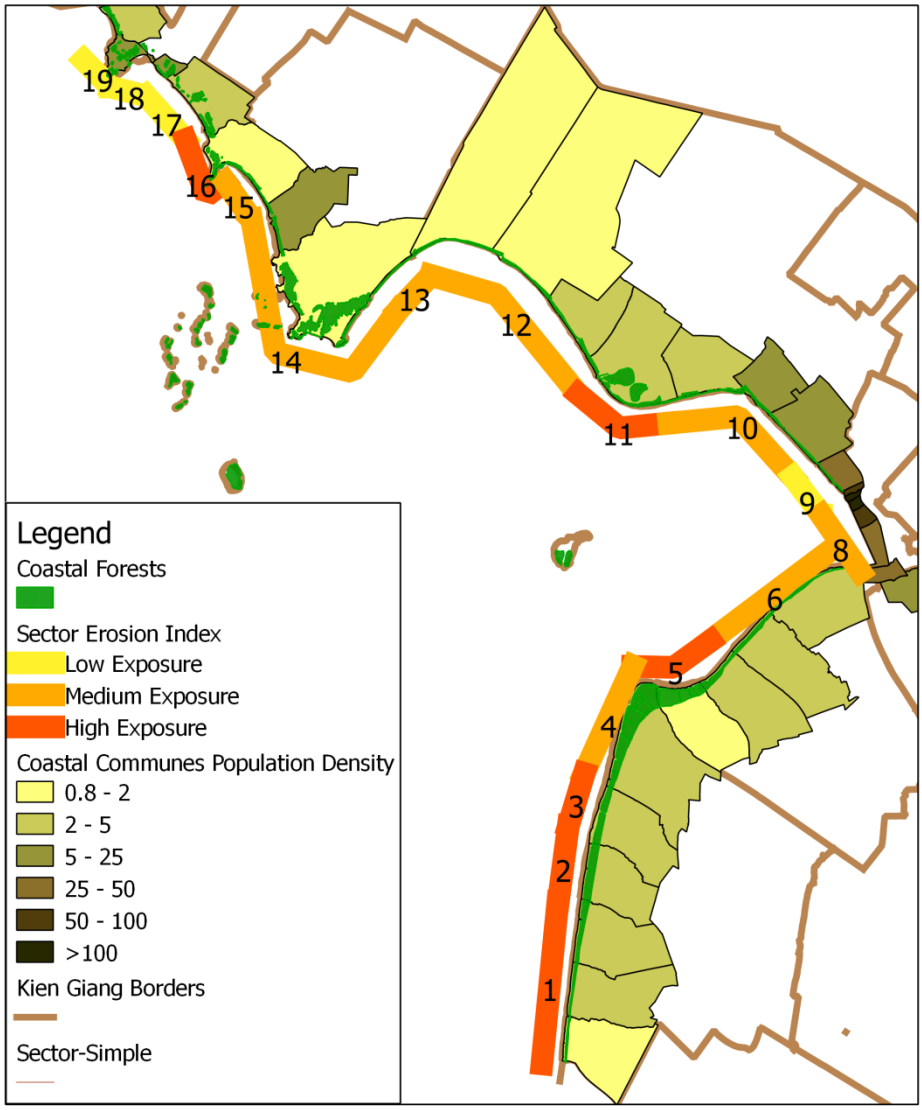

Figure 15.Location of coastline at risk from erosion and commune population density.

Current Erosional Condition of the Coastline

The SVAM carried out as part of the projects identified the current erosional state of the coastline. The length of coastline that is made up of each erosional state is outlined in Table 7. The average erosional state was used to derive an index of current erosion that is displayed as colour coding in the table. Two sectors have rock walls and only two sectors (2 and 5) are largely made up of depositional or stable coastline. The remaining sectors have substantial amounts of their length that are eroded. In seven sectors there is no or very little depositional coastline and the majority of the erosion is major (current erosion index of 3).

Table 7. The length of coastline classified as depositional or eroded and the length that is experiencing major erosion. Also showing the current erosion index (white – Rock Wall, green – Depositional, orange – stable or minor erosion and red – major erosion) and the length of coastline that experienced change between 2009 and 2012.

Sector	Depositional Coast (km)	Eroded Coast (km)	Major Erosion (km)	From Deposition to Erosion (km)	Increased Erosion (km)	Change to Deposition (km)	Current Erosion Index
1	1.7	12.9	7.0	2.0		2.1	3
2	2.7	2.2	1.9	0.9			1
3	0.0	4.2	4.2				3
4	2.7	7.8	5.4			1.8	2
5	6.1	0.1	0.0				1
6	4.5	3.6	1.6		1.5	2.4	2
7	0.0	0.0	0.0				2
8	0.0	0.4	0.0				0
9	0.0	3.2	2.4		2.1		3
10	0.0	11.4	9.2	3.4	2.9		3
11	0.8	6.8	4.3		2.1		2
12	10.3	7.8	4.6		2.5	1.6	2
13	0.0	2.4	1.5				2
14	0.1	12.7	1.2		0.2		2
15	0.4	4.4	1.8		5.7		3
16	0.0	5.7	2.9				3
17	0.0	4.5	0.5				3
18	0.2	0.6	0.0				0
19	0.0	2.4	1.3				2

The erosion index for each sector is displayed geographically in Figure 16.

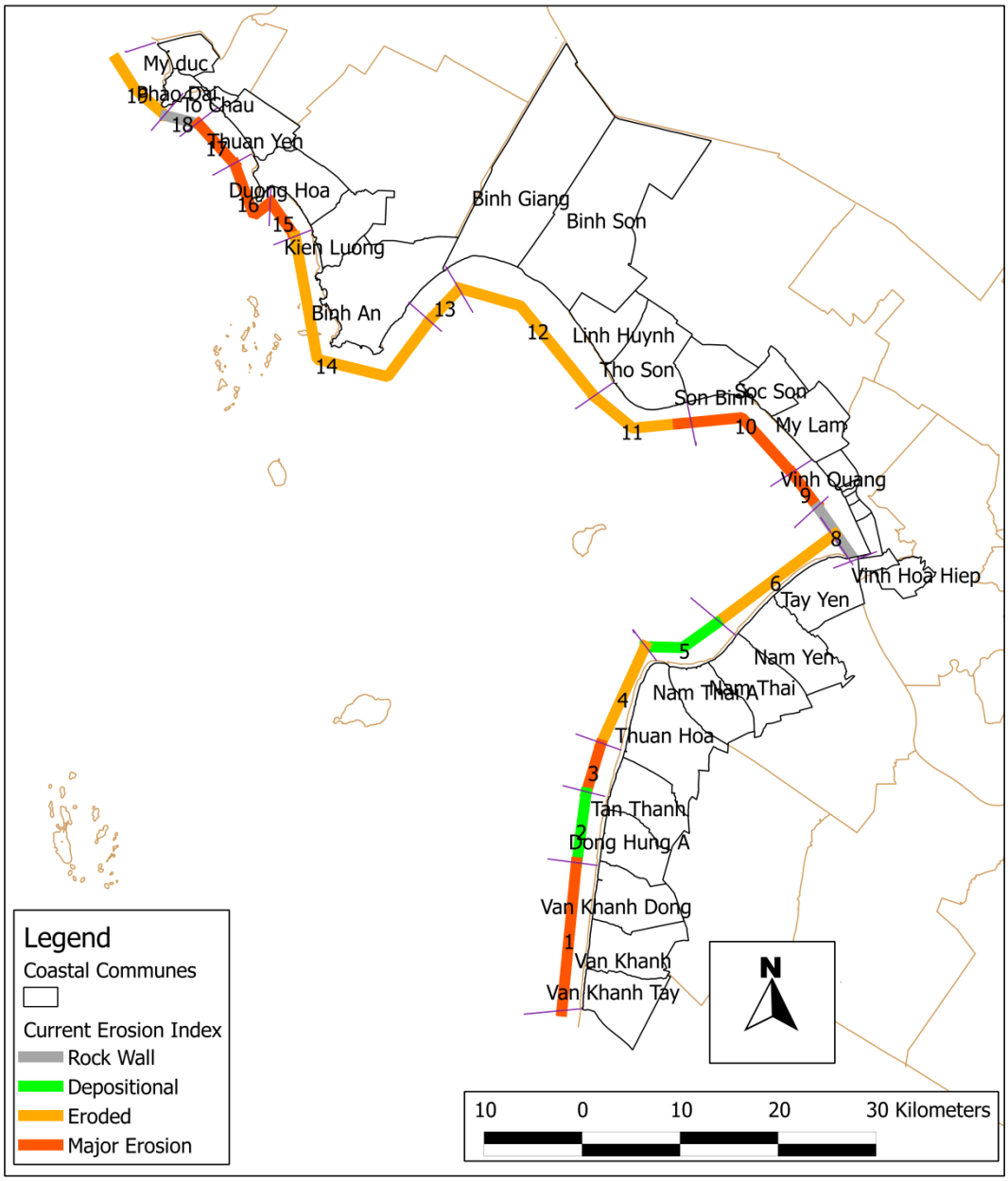

Figure 16.The current state of erosion along the mainland coast of Kien Giang province as measured by the erosion index.

Changes in Coastline Condition 2009 to 2012

The results of the SVAM carried out as part of the present study can be compared to the results that were generated by the Duke *et al.* 2009 study. Figure 17shows the change in the erosion state between 2009 and 2012. In Sector 1 small depositional sites have started to erode. The deposition area that makes up sector 2 has moved southwards changing the erosional coast in the north of sector 1 into a depositional site. There is a short length of the depositional coast of sector 2 that is now experiencing major erosion. Sector 3 shows little change and sector 4 shows a change from erosion to deposition near the tip of the cape. Sector 5 shows little change and sector 6 shows a change from erosion to deposition in a small area and an increase in the rate of erosion near the mouth of the Cai Lon estuary (Tay Yen commune).

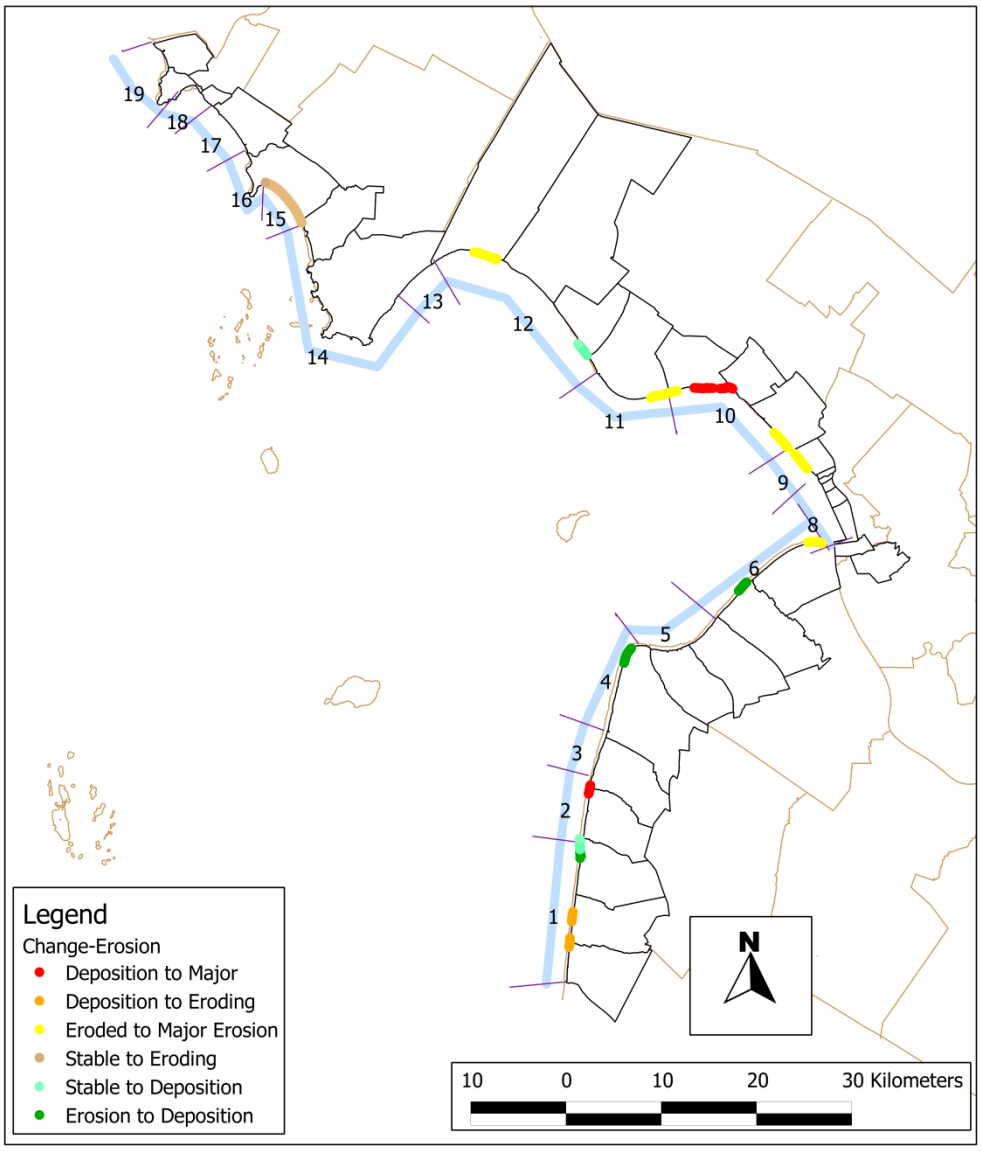

Figure 17.Changes in the erosional condition of the mainland Coast of Kien Giang between 2009 and 2012.

There has been an increase in the amount of erosion along the length of sector 9 and along half of the coastline of My Lam Commune in sector 10. Much of the coastline of Son Binh commune in sector 10 has changed from depositional to major erosion. A section of the south facing coast of Tho Son commune in sector 11 has changed from depositional to eroding.

Sector 12 shows a small area of change from stable to deposition and a small area and an area the has experienced an increase in erosion. The entire length of sector 13 has changed from stable to eroding. The remaining sectors have not shown any significant change in the state of erosion.

Description of Mangrove Condition by Sector

All sectors except sector 8, the southern part of Rach Gia city, contain mangroves, although sectors 7 and 16 do not have any mangroves in gazetted Forests. The extent and the condition of Mangrove resources in each sector are described below.

Mangrove Condition

The condition of mangrove forests and the erosion condition of the sections of the coast of each sector with mangroves is shown in Table 8.

Table 8.Description of the condition of the mangrove coastline showing the length of coast that is allocated to measures of condition and the derived condition index (green - mangroves in very good condition with a dense and continuous canopy,orange - mangroves of moderate density with a non continuous canopy, red - mangroves fragmented by erosion or cutting and canopy sparse or scattered).

Sector	Dense Canopy (km)	Prograding Canopy (km)	Eroded Mangroves (km)	Mangroves with Major Erosion (km)	Poor Canopy (km)	Coast with Seedlings (km)	Mangrove Coast with NO seedlings (km)	Condition Index
1	2.6	0.6	12.8	7.0	3.1	2.9	12.2	1
2	1.8	1.0	2.2	1.9	0.1	3.3	3.2	3
3	0.0	0.0	4.2	4.2	0.0	0.0	4.2	1
4	7.2	0.0	7.8	5.4	0.6	2.2	8.2	3
5	3.5	4.0	0.1	0.0	0.6	1.5	6.5	3
6	12.7	1.0	3.3	1.3	2.5	2.7	11.2	3
7	1.7	0.0	0.0	0.0	0.1	0.0	0.0	1
8	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0
9	1.1	0.0	2.9	2.1	0.0	0.0	3.2	2
10	6.6	0.0	11.3	9.1	4.5	0.0	15.5	3
11	3.4	0.5	6.8	4.3	1.6	0.2	8.5	3
12	15.5	5.4	7.6	4.5	2.9	6.1	16.6	3
13	2.0	0.7	2.4	1.4	0.2	0.9	4.0	1
14	2.0	0.8	7.2	1.1	1.8	1.0	9.2	2
15	2.8	0.5	4.3	1.8	0.5	0.3	5.3	2
16	0.4	0.0	0.5	0.0	1.0	0.0	1.0	1
17	5.3	0.0	1.6	0.0	0.2	0.0	2.8	1
18	1.1	0.0	0.0	0.0	0.5	0.0	0.6	0
19	0.6	0.0	0.4	0.4	0.5	0.0	3.9	2

The two sectors classed as depositional have a large amount of coastline with dense canopy that is in good condition, as do 5 other sectors. However the low amount of coastline in these sectors with seedlings or active mangrove expansion indicates that the canopy is remnant forest that has been eroded. Four sectors have a condition index of 2. These sectors have low amounts of coastline with mangrove canopy that is classed as neither dense nor poor but are also often actively eroding with

little depositional coastline. Six sectors have an index of 1. These sectors have a large amount of coast that has a fragmented or scattered canopy that is in poor condition.

Condition of Gazetted Protection Forests

A more detailed outline of the belt of mangroves that occur in each sector is given in Table 9. The table also outlines the ratio of the area of the mangroves retained to the area that has been converted to other land uses within these Protection Forests. The four northern sectors of An Minh (2-4) and the Western Section of An Bien (5) have a wide band of mangroves designated as protection forest. However, a large amount of the gazetted forests have been cleared for aquaculture.

Table 9. Description of the condition of gazetted protection forests of each sector, and the protection index (green - good protection, orange - moderate protection and red – poor protection).

Sector	District	Min (m)	Max (m)	Mangrove Belt Width	Retention Ratio	Mangrove (km)	Protection Index
1	An Mihn	0	250	Thin or non existant	81:19	14	3
2	An Mihn	100	750	Moderate	32:68	7	1
3	An Mihn	100	600	Moderate	35:65	2	1
4	An Mihn	100	500	Thick	33:67	11	1
5	An Bien	250	500	Thick	52:48	8	1
6	An Bien	0	300	Thin	76:24	13	2
7	Chau Thanh	0	100	Thin	NA	1	3
8	Rach Gia					0	3
9	Rach Gia	50	100	Remnant	72:28	4	2
10	Hon Dat	0	200	Remnant	78:22	17	2
11	Hon Dat	0	200	Thin	49:51	7	3
12	Hon Dat	0	200	Remnant	71:29	22	2
13	Kien Luong	50	100	Remnant	ND	4	2
14	Kien Luong	0	100	Thin	ND	10	3
15	Kien Luong	50	200	Thin	79:21	7	2
16	Kien Luong	0	100	Thin	NA	1	3
17	Ha Tien	0	100	Thin	70:30	3	2
18	Ha Tien	0	100	Thin	73:27	1	2
19	Ha Tien	0	100	Remnant	53:47	1	3

Eight of the sectors have a thin but well retained band of protected forests that are in moderate condition. Two sectors (7 in Chau Thanh and 16 in Kien Luong) have a thin belt of mangroves that are

not in protection forests. The remaining three sectors have a thin or intermittent belt of protection forestthat is often a remnant of an eroding or eroded forest

Changes in Mangrove Condition 2009 to 2012.

Figure 19shows the changes in mangrove canopy condition and in the distribution of seedlings. Sectors 5, 8, 9 and 10 show no change, (Sectors 7 and 19 were not sampled in 2009).Sector 1 in AN

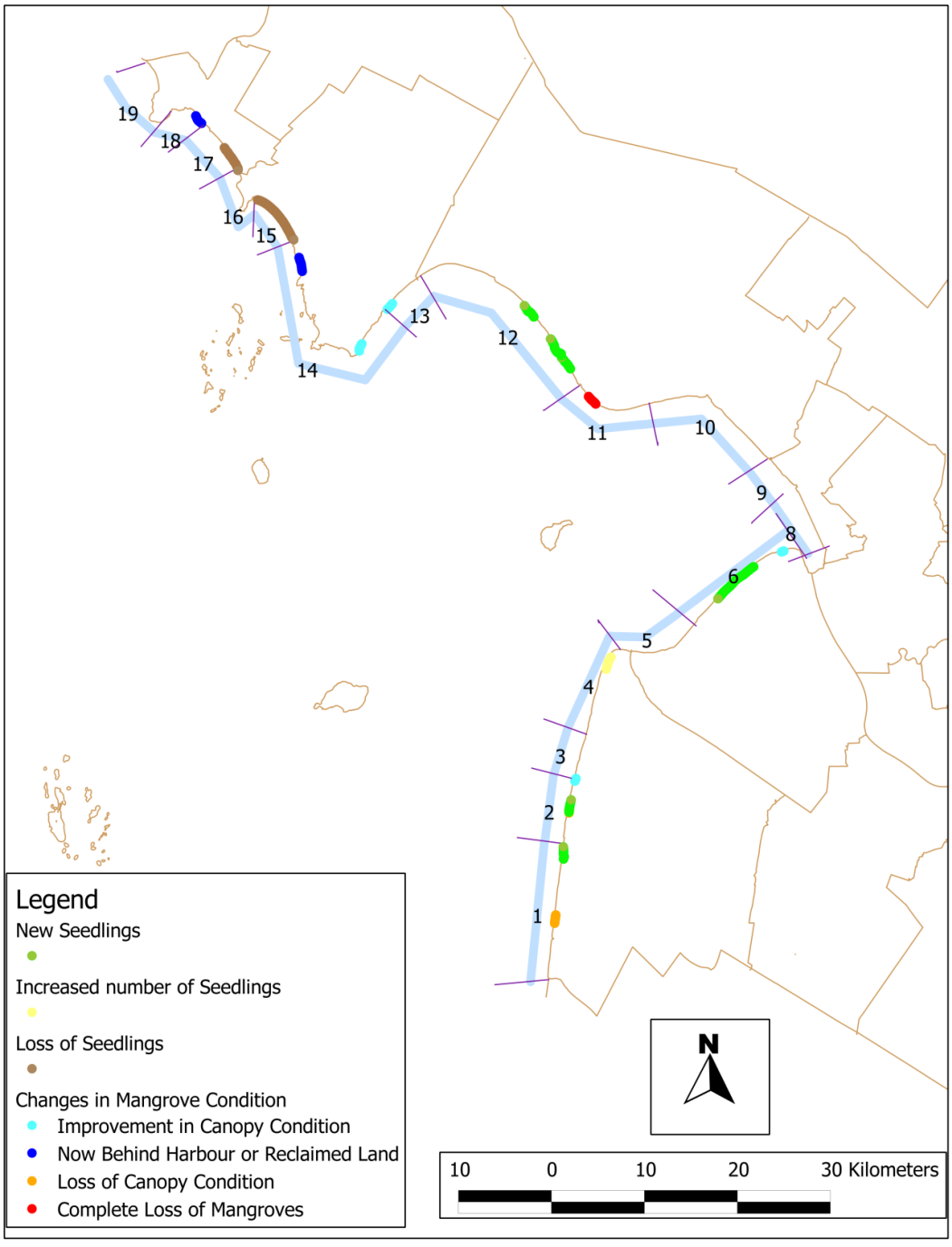

Figure 18. Changes in mangrove canopy condition and in the distribution of seedlings along the Kien Giang mainland coast between 2009 and 2012.

Minh which is heavily eroded along most of the coastline shows a loss of canopy condition in Van Khanh Commune. This loss is associated with a change from depositional to major erosion. The

northern portion of the sector shows increased successful seedling establishment as a result of a southward increase in the depositional area that makes up sector 2. Sector 2 which generally has well established seedlings along the entire length, shows an increase in seedling density over a small area that corresponds to the small path of increased erosion described above, indicating that the erosion may have been an extreme event that is being in filled. At the border of sectors 2 and 3 there is an increase in canopy condition as a result of successful maturing of planted seedlings. Sector 4 shows an increase in the density of seedlings associated with the change to depositional conditions. Sector 6 in An Bien has a large area of newly established seedlings as a result of an increase in deposition and generally stable erosion conditions. Sector 6 has a small area of improved mangrove canopy next to the newly eroded coastline near the Cai Lon estuary. This indicates the dynamic nature of the outer banks of estuaries.

Sector 11 in Hon Dat has an area where mangroves have been completely lost due to severe erosion removing the thin band of mangroves that were in the front of the aquaculture. In sector 12 seedlings have been established along a large amount of the coastline in Lynh Huynh and Binh Son communes. Sector 13 shows a small area where the condition of the canopy has improved, as does the southern shore of BinhAn commune in sector 14. Mangrove seedlings have been lost from the entire length of sector 13 and from the half of sector 17 that has mangroves.

Much of the mangrove coast of Kien Luong Town in sector 14 is now enclosed in a deep water port and all of the mangroves in the Ha Tien Town Sector (sector 18) are now behind a large area of reclaimed land. The reclaimed land and the outer wall of the port will now protect the mangroves from erosion and will favour seedling recruitment. However these two areas will be under pressure from development of the shoreline.

Identification of areas in need of restoration

Kien Giang People's Committee, Department Of Agriculture And Rural Development (KGPC and DARD) in 2010releasedthe 2011 – 2020'Plan for the Restoration and Development of Coastal Protection Forests In Kien Giang Province'(KGPC and DARD 2010) uses three erosion classes to provide totals for the coastal areas of each commune that are made up of each erosion condition. For each of the three erosion conditions, the report makes recommendations on forest protection and replanting techniques. Although the report only covered four Districts, the techniques recommended for each erosion condition would be applicable to sectors in other districts with the same erosion condition which were not covered in the report.

The most common type of each erosion condition for each commune was used to derive the value shown in Table 10. Where there was more than one dominant type the average erosion class is used. Where there was no data available the erosion characteristics from the 2009 SVAM study was used to produce a condition value.All sectors except sectors 4 in An Minh and sector 5 in An Bien do not have the proclaimed 500 m wide Belt of mangroves. Two other sectors in AN Minh do have a moderate width of mangroves along much of the coast.

It must be made clear that this report uses sectors of similar geomorphological and erosional condition that include District and Commune boundaries where possible whereasKGPC and DARD (2010) provide information on a commune or District basis, in addition the assessment in KGPC and DARD (2010) is carried out on an area basis rather than the length based assessment as used in this

report. As a result commune or District totals presented in the two reports are not directly comparable.

Table 10. Erosion condition from KGPC and DARD (2010) and required restoration activities for the coastline of each Commune.

Sector	District	Commune	Erosion Condition from KGPC and DARD (2010)	Erosion Protection	Improved Retention	Improved Condition
1	An Mihn	Van Khanh Tay	3	✓✓		✓
		Van Khanh Dong	3	✓✓		✓
		Van Khanh	3	✓✓		✓
2		Dong Hung A	1		✓	
3		Tan Thanh	3	✓✓	✓	✓
4		Thuan Hoa	2.5	✓✓	✓	
5	An Bien	Nam Thai A	1		✓	
6		Nam Thai	1		✓	
		Nam Yen	2	✓		
		Tay Yen	2	✓		
7	Chau Thanh	Kin Hoa Hiep	2	•		✓
8	Rach Gia	An Hoa Rach Soi Vinh Lac Vinh Bao Vinh Thanh Van			No Mangroves	
9		Vinh Quang	3	✓✓		
10	Hon Dat	My Lam	1.5	✓		
		Soc Son	1	•		
		Son Binh	2			
11		Tho Son	2	✓	✓	✓
12		Binh Giang	1	✓		✓
		Binh Son	2	✓		✓
		Linh Huynh	1			
13	Kien Luong	Binh An	3	✓✓	✓	✓
14		Binh An	1.5	✓		✓
		Kien Luong	2	•		✓
15		Duong Hoa	1			
16		Duong Hoa	2	•		✓
17	Ha Tien	Thuan Yen	2	•		
18		To Chau	2	•		✓
18		Phao Dai			No mangroves	
19		My duc	2	•	✓	

✓✓ - Substantial erosion protection is required, • - management of erosion in localised areas, ✓ - required.

The two large sectors of Hon Dat (sectors 10 and 12) are made up of two large mangrove bights on the north of Rach Gia Bay. The coastline of some of the communes in these sectors is classed as having different requirements for erosion protection and restoration than others. However, any active erosion prevention strategies that are carried out in either of these two sectors must be

considered as part of the management of the sector as a whole as changes in the sediment regime within a bay will be reflected in the rest of the landform unit, so the sector requires management as a single unit. The largest sector of Kien Luong that covers the Limestone Headlands (sector 14) also requires different levels of active protection in some communes. This sector cover a range of morphologies of rocky headlands with little or no mangrove coverage interspersed with mangrove bays and small sandy bays. There is also tourism development and considerable development of port facilities with the recent commencement of construction of a large deep port which has enclosed over 1 km of mangrove coastline. The overall management strategy of the sector requires a more detailed assessment of individual sections of the coastline and should include the management of mangroves, development and tourism.

The information in Table 10shows that sectors can generally be ranked by the required restoration measures. Where sectors have communes ranked in different positions on the Table the highest erosion condition is chosen. The sectors can be ranked as;

0. No Mangroves, requiring only erosion monitoring.

1. Requiring improvement in retention,

2. Requiring management of erosion in localised parts,

3. Requiring some erosion protection and often canopy improvements,

4. Requiring substantial erosion protection and generally some improvements in retention and or canopy condition.

Recommended restoration actions.

The geographical distribution of the requirements for restoration for each sector is outlined in the following maps, Figures 16 to 18. The appropriate restoration activities are guided by theKGPC and DARD (2010) report.

The required restoration actions are divided into four classes. The greatest amount of effort is required for high erosion sectorsthat need significant measures to protect much of the coastline and to restore and expand the existingmangroves. This class of sector equates to the strong Erosion areas of the KGPC and DARD (2010) report and may require the construction of substantial fencing of either concrete or double melaleuca fences. Sectors of this class also require significant replanting to increase the width and condition of the mangrove forest. See KGPC and DARD (2010) for a discussion of management procedures, fence effectiveness and costings, and Michaels and Russell (2012) for a discussion of the effectiveness of Melaleuca Fences.

The second most intensive amount of restoration effort is required formoderate erosion sectors requiring some protection from erosion and restoration. This class equates to the slight erosion of the KGPC and DARD (2010) report and requires erosion protection using double or single melaleuca fences and substantial mangrove replantingto increase the width and condition of the mangrove forest.

Depositional areas require monitoring and in-filling and natural regeneration of the existing mangroves to improve forest width and quality. These areas equate to the alluvial areas of the KGPC and DARD (2010) report.

A further type of sector is defined by Table 8 and Figures 16 – 18 as one that requires erosion protection along some parts of the coastline as well as therestoration and widening of the existing forest. Depending on local conditions at the small scale, this type of sector would require single melaleuca fencing to promote natural regeneration and double melaleuca fencing to reduce exposure to erosion and to protect plantings.

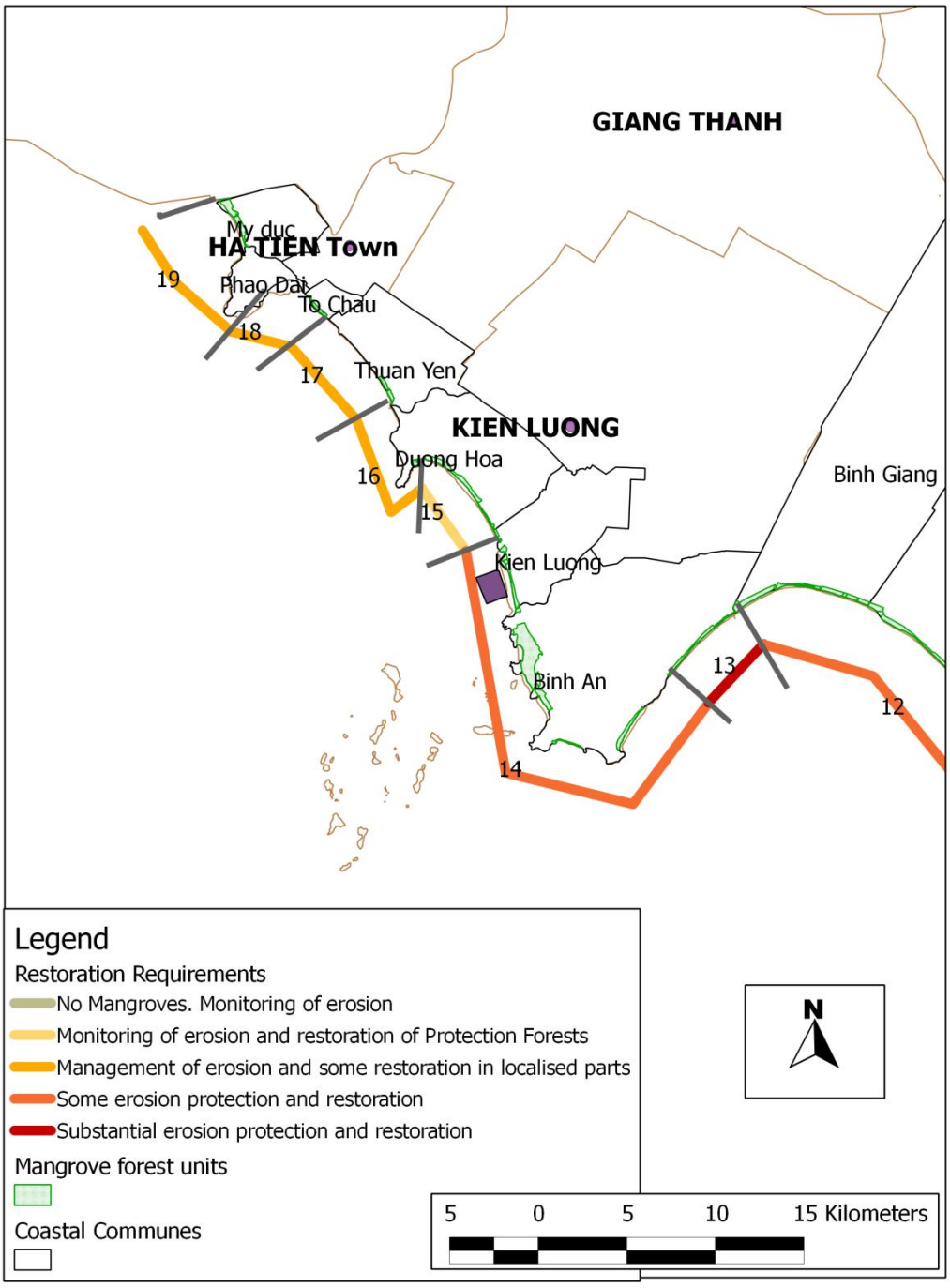

Figure 19. Location of areas requiring restoration in the north of the Province.

Figure 19shows the geographic distribution of restoration requirements in the north of the Province covering the Districts of Ha Tien and Kien Luong. The four northern sectors have the same requirements for restoration. Within these sectors management of erosion isrequired in all susceptible embayments and the mangrove areasrequire restoration to improve the width, condition and continuity of the mangrove canopy. Sector 14 covering the limestone cape of Kien Luong requires a separate detailed spatial management plan. The extent of the mangroves now protected by the port development can be seen near Kien Luong Town.

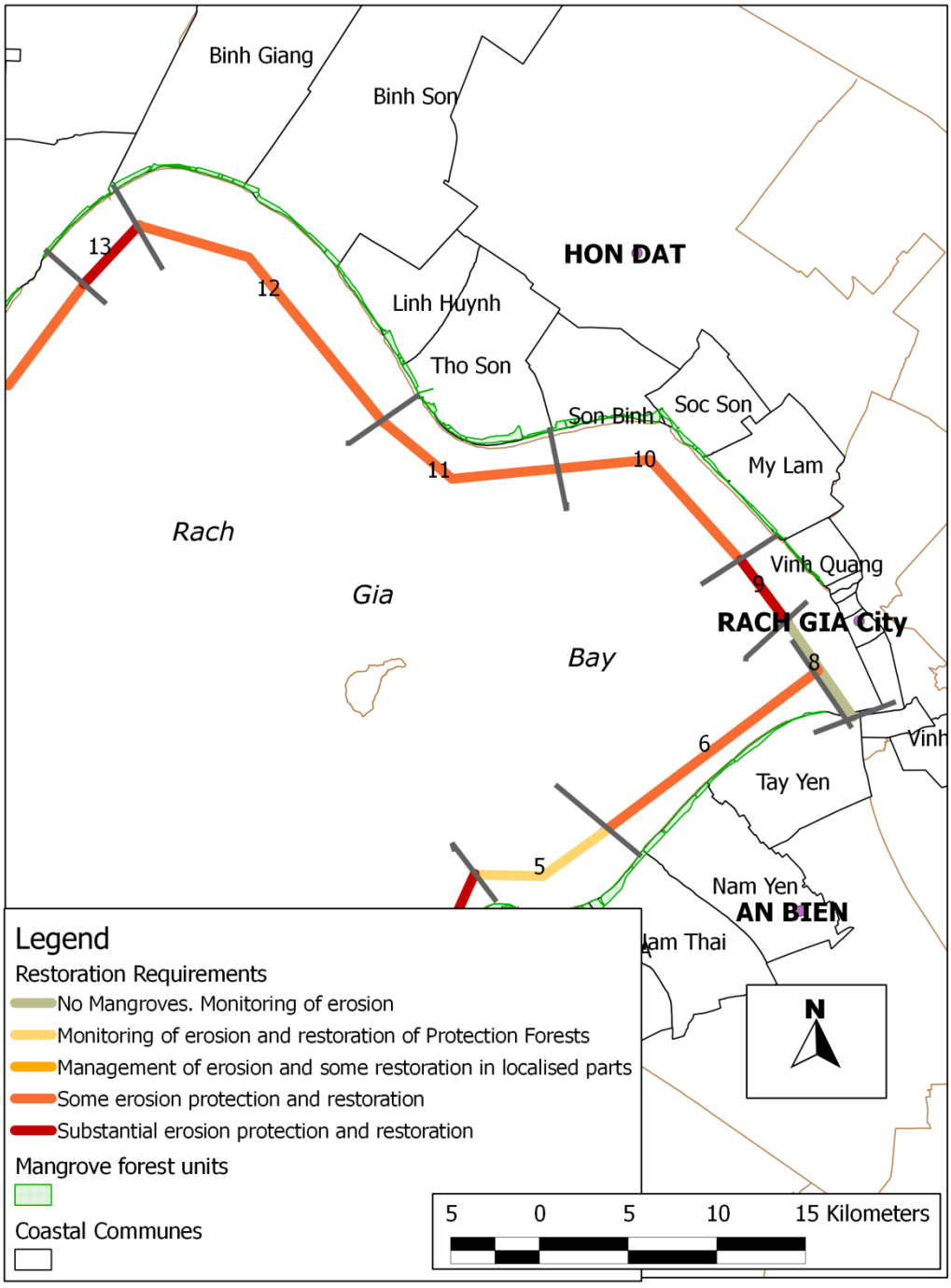

Figure 20. Location of areas requiring restoration in the centre of the Province.

Figure 20shows the geographic distribution of restoration requirements in the centre of the Province covering the Districts of Hon Dat, Rach Gia City, Chau Thanh and An Bien. Substantial erosion protection and improvements in the width of gazetted mangrove forests is required for three sectors; sector 9 north of Rach Gia City and sector 13 on the south eastern side of the limestone cape of Kien Luong. Sector 13 also requires improvements in the retention and condition of mangroves. The three other sectors on the north of Rach Gia Bay require some erosion protection and widening of the width of the protection forest and sectors 11 and 12 also requiring restoration to improve the condition of the canopy. The inner sector on the southern side of the bay on the An Bien coast (sector 6) requires erosion protection in some locations.

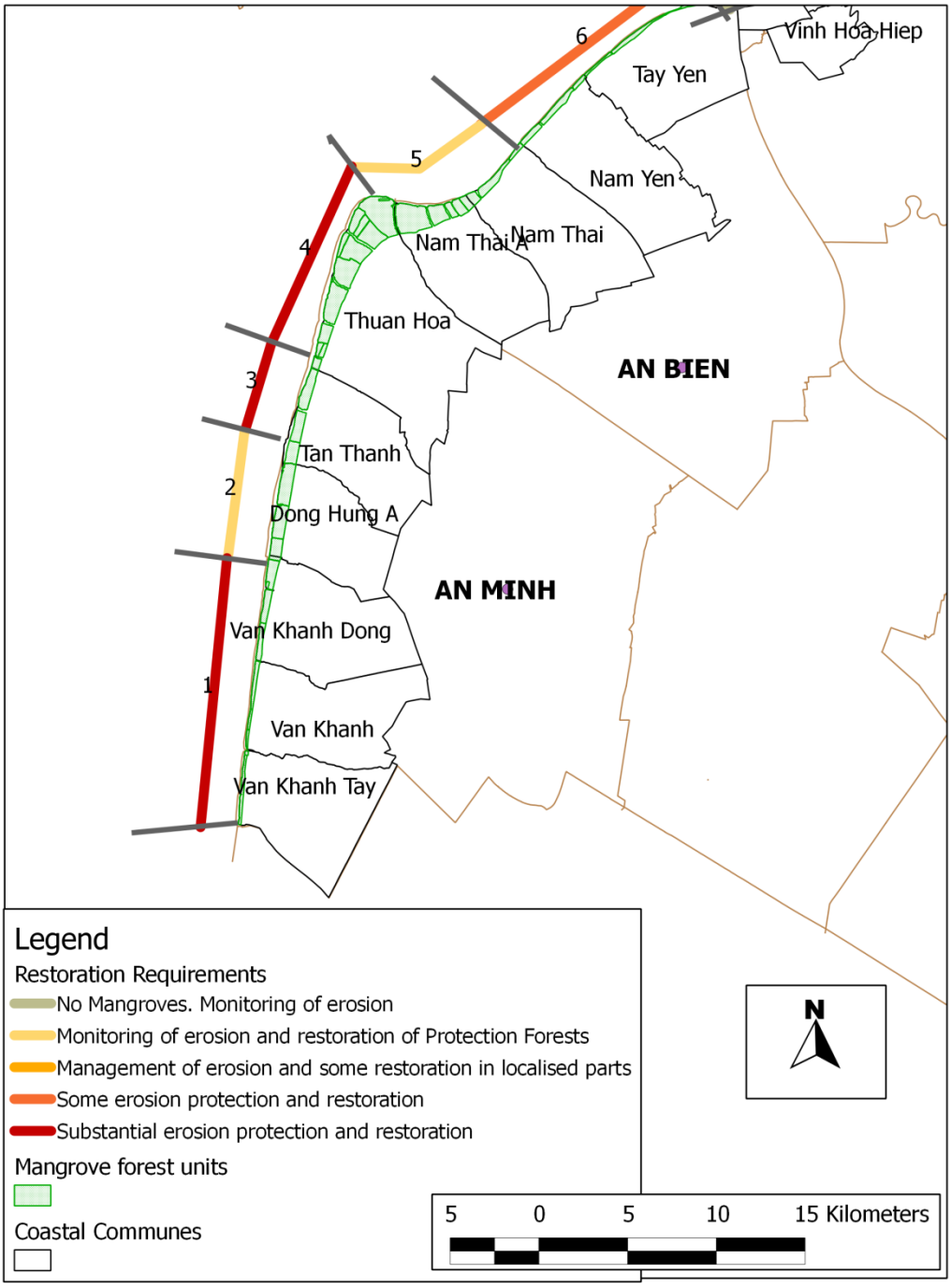

Figure 21. Location of areas requiring restoration in the south of the Province.

Figure 21 shows the geographic distribution of restoration requirements in the south of the Province covering the Districts of An Bien and An Minh. These sectors have a range of restoration requirements. Sectors 1, 3 and 4 in An Minh require substantial protection from erosion with sector 1 requiring substantial restoration to improve retention rates, canopy condition and forest width and sectors 3 and 4 requiring restoration to improve retention and forest width. Sectors 2 and 5 are actively accreting and require restoration to improve the ratio of mangrove to clearing and to establish an appropriate width of the forest along the entire coast.

How This Report can be usedas a Basis for Spatial Strategic Planning for Coastal Rehabilitation

Good planning policy requiresthat adaptation strategies are incorporated into local planning instruments for the relevant high coastal hazard area. The State Government of Queensland, Australia (DERM 2012) proposed that Adaptation strategies should follow the following guiding principles:

•reflect locally-specific objectives,

•incorporate flexibility recognising that climate change benchmarks may change over time. In this regard, adaptation strategies should be considered a 'living' document to deal with changing risks, uncertainties and innovation,

• integrate the range of coastal hazard risks across the inshore, foreshore and hindshore areas rather than treating coastal erosion, storm-tide inundation and sea-level rise independently,

•note that risks from coastal hazards are not uniform and will vary along the coastline affected by topography, sediment type and coastal processes, as well as local adaptive capacity. This makes adapting to coastal hazards a clear case for thinking regionally, but analysing and acting locally,

•be based on the best available science and information,and

•be based on the precautionary principle to mitigate coastal hazards to the year 2100, taking into account the long-term environmental, social and economic factors.

Using these principles, this report has outlined the geographical extent of hazards, the condition of the existing forest and the current erosional state. In order to incorporate locally-specific objectives and to account for the non-uniformity of risks this report divides the coast into sectors that share the same pressures on the mangrove forests. This will facilitate the integration of inshore, foreshore and hindshore areas. The report contributes to flexibility by providing detailed up to date quantitative information.

How to Use this information to formulatean Adaptation Plan

Bestpractice approach requires the establishment of a stepped and consistent approach to mitigating high coastal hazard impacts. The Australian and New Zealand Risk Management Standards (AS/NZS ISO 31000:2009) recommend that coastal hazard adaptation strategies should be developed using the following stages.

1. Spatially identify areas at risk, preferably through local-scale hazard mapping.

2. Identify current and known future 'assets' at risk (residential, commercial, community) and assess their vulnerability to coastal hazards to the year 2100.

3. Identify potential adaptation options.

4. Consult the community about the potential adaptation options.

5. Undertake a cost-benefit analysis of adaptation options.

6. Select preferred adaptation option(s).

7. Develop an implementation program and financial plan.

8. Engage in community consultation on the draft adaptation strategy.

9. Develop a process for reviewing and updating the adaptation strategy.

This document covers the first two steps in the process by dividing the coast into sectors that share the same pressures on the mangrove forests. The report by Kien Giang People's Committee, Department Of Agriculture And Rural Development (2010)discusses the adaptation options(step 3)and begins the process of a cost-benefit analysis of adaptation options (step 5).

The formulation of an adaptation strategy requires; the development of a formal strategy to incorporate community consultation (steps 4 and 8), selection of the preferred adaptation options (step 6), and the development of a process for reviewing and updating the adaptation strategy(step 9).

Towards the development of an implementation program (part of Step 7), Figure 22shows an index of the immediacy of required rehabilitation. The most immediate attention is required for sectors 1 and 3 from the An Minh Coast, and three other sectors that are large mangrove embayments that are exposed to erosion and/or storm surge. The next most immediate attention is required for sectors with a thin or highly cleared band of protection forest. The depositional areas of An Minh (sectors 2 and 4) and An Bien (sector 5) and the mangroves in small embayments around the Granit headlands of Kien Luong (sectors 14 and 16) do not require immediate interference.

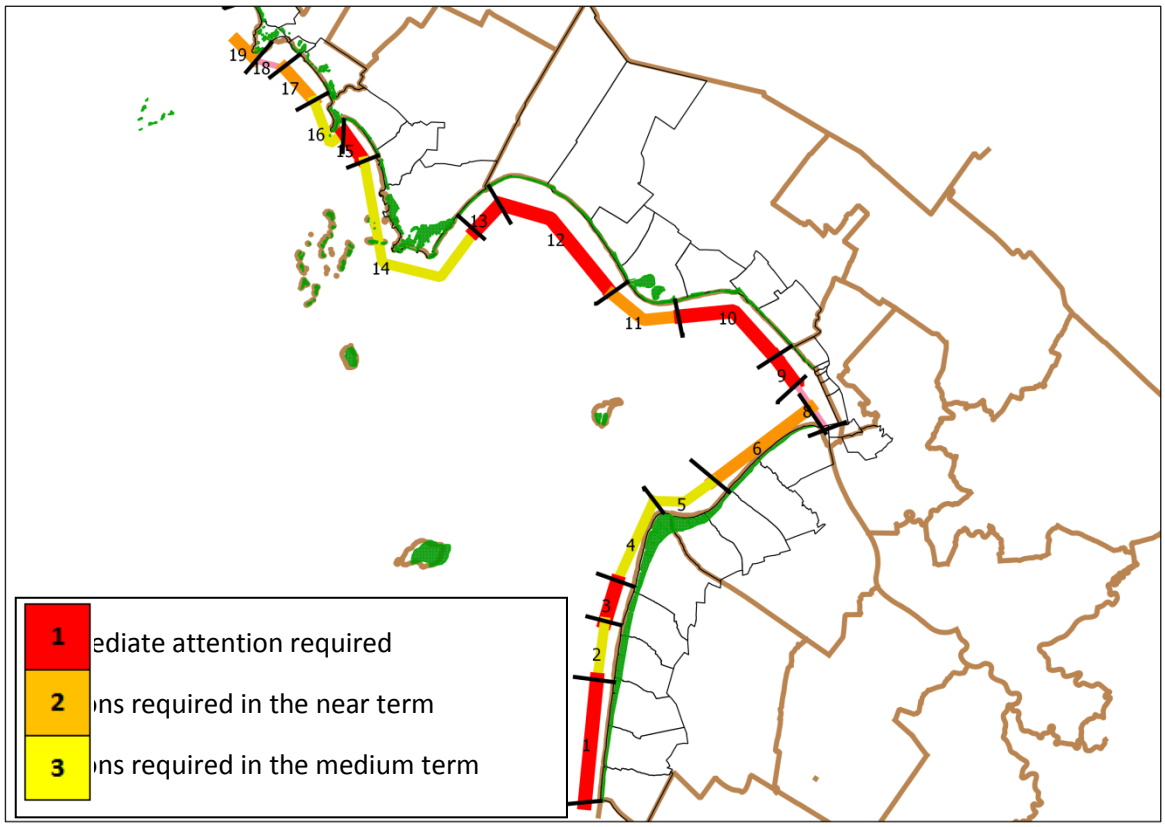

Figure 22.Index of the immediacy of the implementation of management strategies.

References

Adger, W. N. (1999). Social Vulnerability to Climate Change and Extremes in Coastal Vietnam. World Development Vol. 27, No. 2, 1999

Asian Development Bank ADB, 2009. The Economics of Climate Change in Southeast Asia: A Regional Review. Asian Development Bank, Manila.

Chu, C.V. and Brown, S. Eds. (2011). Coastal Rehabilitation and Mangrove Restoration using Melaleuca Fences; Practical Experience from Kien Giang Province.Deutsche GesellschaftfürTechnischeZusammenarbeit (GTZ) GmbH Conservation and Development of the Kien Giang Biosphere Reserve Project. Rach Gia, Vietnam.

Department of Environment and Resource Management (DERN), (2012). Queensland Coastal Plan Guideline for Preparing Coastal Hazard Adaptation Strategies, The State of Queensland (Department of Environment and Resource Management).

Duke, N., Wilson, N., Mackenzie, J., Nguyen, H.H., and Puller, D. (2010). Assessment of Mangrove Forests, Shoreline Condition and Feasibility for REDD in Kien Giang Province, Vietnam.2010. Deutsche GesellschaftfürTechnischeZusammenarbeit (GTZ) GmbH Conservation and Development of the Kien Giang Biosphere Reserve Project. Rach Gia, Vietnam.

Food and Agriculture Organization FAO (2007).The State of World Fisheries and Aquaculture, (2006).Food and Agriculture Organization, Rome.

IMHEN (2010): Sea level rise - scenarios and possible risk reduction in Vietnam. Vietnam Institute of Meteorology, Hydrology and Environment (IMHEN) and Danish International Development Agency (DANIDA), IMHEM, Ha Noi.

IMHEN, Ca Mau Peoples Committee, and Kien Giang Peoples Committee (2011). 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. Institute of Meteorology, Hydrology and Environment (IMHEN), Ha Noi, Vietnam.

Kien Giang People's Committee, Department Of Agriculture And Rural Development (2010).Project of restoration and development of coastal protection forests in Kien Giang province, period of 2011 – 2020.Kien Giang People's Committee, Department Of Agriculture And Rural Development, Rach Gia, Vietnam.

Le Truong Giang (2005).Damage Cause By Strong Wind & Wind Loads Standard For Building In Vietnam. Le Truong Giang.WERC-APEC Wind Hazard Mitigation Centre Graduate School of Engineering, Tokyo Polytechnic University. 18 June 2005

MONRE (2009).Climate change, sea level rise scenarios for Vietnam.Vietnam Ministry of Natural Resources and Environment (MONRE).

Russell, M. and Nhan, N.H. (2010). Coastal Dynamics of Kien Giang, Vietnam; 2009 – 2050.

Russell, K. and Michaels, K. (2012).Effectiveness of melaleuca fences for mangrove restoration rehabilitation efforts. The Deutsche Gesellschaftfür Internationale Zusammenarbeit (GIZ) GmbH Conservation and Development of the Biosphere Reserve of Kien Giang Province Project.Rach Gia, Vietnam.

Standards Australia/Standards New Zealand, (2009).Australian/New Zealand Standard Risk management—Principles and Guidelines.Standards Australia, and Standards New Zealand, Sydney and Wellington.

United Nations Department of Humanitarian Affairs (UNDHA) (1997). "Vietnam Typhoon Linda Situation Report No. 4". ReliefWeb.Retrieved 2010-03-22.