REPORT

Assessing Mangrove Forests, Shoreline Condition and Feasibility of REDD for Kien Giang Province Vietnam

The University of Queensland, Australia

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Assessment of Mangrove Forests, Shoreline Condition and Feasibility for REDD in Kien Giang Province, Vietnam
A Technical Report

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Title page figure: A dense young stand of *Rhizophora apiculata*, typical of areas planted within the last 10 years.

Executive Summary

Mangrove forests in Kien Giang province, southern Vietnam, play a vital role in the mitigation of immerging threats presented by climate change, and in particular sea level rise. Rapidly encroaching saline waters seriously threaten low-lying, coastal floodplain lands along this western margin of the Mekong delta. Local coastal communities have become increasingly aware of the great risks involved, especially where dykes are breached, valuable agricultural lands are flooded by seawater, and human settlements retreat away from the coast. The response and adaptation strategies under urgent development are rapidly becoming a national priority.

A seriously limiting factor in the local response however, has been a general lack of environmental awareness and understanding amongst community members living along the coastal margin. For instance, few people know of the importance of mangrove vegetation as essential coastal stabilizers. Appropriate forest management and aquaculture techniques have never been adequately implemented throughout the province despite good intentions. As a result, mangrove forest quality has declined throughout, in some instances threatening the ability of these tidal wetland ecosystems to provide a range of important, if not essential, benefits and services. The immediacy of shoreline stabilization means that if local mangrove forests are not protected, and/or rehabilitated, the homes and livelihoods of coastal communities of thousands of people will be threatened.

In a local community program for Biodiversity Conservation in the Kien Giang Biosphere Reserve managed by GTZ with AusAID funding, our team with the University of Queensland is working with the Peoples Committee of Kien Giang province under the Vietnamese Government master plan for rehabilitation of mangrove forests 2008-15.

This report presents the current status and findings of our research into the condition and role of mangrove forests of Kien Giang. To advise on the successful management of these valuable tidal wetlands, it has been necessary first to establish the extent and condition of mangrove forests in the region. Here we present results from optical satellite data regarding the area of mangrove forest in ~70% of the province shoreline (limited only by availability of specific satellite imagery at the time of writing). Using plot-based field studies, we further provide data on the biodiversity, biomass and condition of key mangrove forest types across the province. To complete our assessment, we conducted shoreline surveys along the mainland coastline providing: continuous observations of fringing mangroves and coastal landuse; a baseline video record; the physical condition of the coast; the presence of fish traps; and, the extent of rehabilitation works.

In addition, we scaled-up plot based assessments of mangrove forest biomass and carbon storage to provide estimates of current levels of CO_2 storage in mangroves for the province. We expect this information will be useful when considering the implementation of a REDD scheme to encourage greater protection of mangrove forest habitat. However, we emphasize that the value of mangrove areas in Kien Giang far exceed their carbon storage capacity, and their value must always be weighed up also in consideration of the broader range of important benefits provided by these habitats.

Based on such findings, and others related to local community livelihoods, we have assessed the implementation of current shoreline rehabilitation strategies. For these, we offer some recommendations for the improved management of the coastal zone. However, our chief findings concern this first ever review of the current status of mainland coastal areas of Kien Giang province.

Mangrove forests in 2009-2010

- Mangroves occur along the mainland coastline for 133km (74% of the 180 km total coastline).
- Area of mangroves equals around ~3500 ha (based on an extrapolation from current satellite mapping of land use of ~70% of the province).
- Mangrove-fringed shorelines represent the dominant coastal landuse type for the mainland coast – coupled with rice production and aquaculture
- Mangrove biodiversity was high, with 27 mangrove species observed during surveys
- 50% of mangroves along the shoreline were dominated by the genus, *Avicennia*.
- Lesser dominant mangrove species include *Sonneratia* (19%) and *Rhizophora* (9%)
- Herbivory was notable and severe over 13.5 km (10%) of the shoreline
- Mangrove dieback associated with litter accumulation was observed along 800 m of coastline
- Overall condition of mangrove forests was notably poor

Mangrove areas of ~70% of the coastline of Kien Giang province were mapped from 2009 SPOT 5 satellite imagery. Two types of mangrove areas were identified, but these have so far not been fully linked with identifying or distinctive characteristics. The mapping currently shows that there is at least 2,537 ha of mangrove forests present in the province.

The districts of Hon Dat and An Minh exhibit the greatest areas of mangrove forests within the currently mapped ares, with 793 ha and 973 ha respectively. Mangrove species diversity in Kien Giang province is unexpectedly high, with 27 of the 39 species found in Vietnam. Of this, 88% of mangrove forests grow as either medium or dense forests, although the width of these forests may be narrow (may be > 10 m wide), or absent.

The condition of mangrove forests in Kien Giang is generally quite poor. The most notable measure of poor condition was high levels of cutting along most of the shoreine. Observations of cutting were made both during shoreline assessments and in plot based surveys. Cutting is significant in more than 50% of areas. To protect valuable mangrove forests, alternative sources of firewood and building materials must be identified and encouraged.

Coastal erosion in 2009-2010

- Active and severe erosion was observed along 30 km (17%) of the mainland coast
- Damage to vegetation, as evidenced by cutting, was observed in 77% of the often eroded mangrove-lined shoreline
- Coastal retreat of around 25 m per year - for case study site in Hon Dat district.
- 19 villages are directly threatened by erosion
- 5 km of fish ponds currently exposed to the eroding coastline
- 11 km of earthern dykes exposed and beached along the shoreline
- 8 km of earthern dykes partially eroded

There are significant areas of shoreline erosion along the Kien Giang coast. A preliminary assessment of a limited number of historical aerial photographs and recent satellite imagery show that in Hon Dat region, the loss/retreat of some coastal margins is up to 24 m per year.

Shoreline surveys completed along 180 km of coastline show 17% of the Kien Giang coast to be actively eroding, corresponding to 30 km of shoreline. This places 23% current fringing mangroves at high risk of erosion in the near future.

By supporting human communities to protect mangroves, it is hoped this will allow mangroves to better stabilize the coast, and help mitigate further erosion. The implementation of a REDD scheme in Kien Giang may provide further incentives for mangrove restoration and protection.

Rehabilitation and shoreline management in 2009-2010

- Earthern and hardened dykes and sea walls were observed along 38 km (21%) of coastline
- Cutting of trees was observed along much of the shoreline
- Active wood harvesting was noted along 77 km (58% of shoreline mangroves)
- Most wood harvesting was of *Avicennia* sp. (67%) and *Sonneratia* sp. (45%)
- *Nypa* frond harvesting occurs along 6.5 km (3.6%)
- Fish traps were found along 31 km (18%) of coast, mostly (81%) offshore to mangrove-fringed shorelines
- Fenced planted areas were observed along 27 km of mainland coastline
- Shoreline planting was around 50% successful - notably along depositional shorelines
- Fenced protection improved planting establishment with up to 80% survival
- There are many recent human development projects along the coast

Current shoreline management practices are ineffective and inadequate to meet the imminent threat of sea level rise and more severe storms as a result of global climate change.

Our surveys in 2009 and early 2010, found considerable evidence of: broad-scale erosion of shoreline, many instances of coastal retreat measured in terms of 10s of metres per year; erosion and collapse of dykes both earthen and rock-faced; inadequate planting efforts across the province; significant cutting and damage to mangrove forests in 58 % of all coastal stands; notable removal of mangrove forest areas up to the shoreline, replaced with aquaculture and other inappropriate shoreline landuses.

Carbon storage as a complimentary management strategy

- Forest biomass and carbon content was estimated in 41 forest plots
- Mangroves of relatively high biomass occupy 105 km (78%) of the coastline
- Expanding, newly established, mangrove forests occupy 24 km (18%) of the coastline
- Forest biomass as carbon was highly variable along the coast, ranging from 10-424 t/ha
- Carbon stored in mangroves amounted to more than 987550 t CO^2
- With protection, mangrove forest biomass has the potential to increase by as much as 3.5 times current levels. This biomass increase requires only improved mangrove condition, no extension of mangrove area is neccssary.

There is an urgent need to improve management of the coastal environment that includes encouraging local communities to make more effective use of mangrove forest vegetation. There is no reason why the preservation and nurturing of mangrove forests cannot be aided by some form of payment to community members for the carbon they store. Therefore, a REDD carbon scheme using mangrove forests is considered feasible in Kien Giang – especially given the significant potential standing biomass of mangrove forests in the region. By giving a monetary value to healthy mangrove forests, it is hoped that such a scheme might prevent further destruction of mangrove habitat and support much needed improvements to mangrove protection.

Our assessments of forest biomass and carbon storage quantify standing mangrove biomass and carbon storage per hectare in Kien Giang province. These measures are comparable to other tropical forest types, as well as secondary mangrove forests elsewhere. The key factor contributing to high biomass for a given mangrove species was tree size, although spacing of trees (density) was an important additional factor. A further contributor was wood density, with heavier timbered species offering greater carbon storage for similar sized individuals.

Key recommendations

Immediate actions are recommended to enhance protection and longer term sustainability of mangrove-fringed coastlines, and to reduce the impact of sea level rise on coastal communities in Kien Giang province:

- **provide education on coastal protection at all levels** of community, local, provincial, national and international to highlight the scale and severity of the shoreline erosion issue and to highlight the value and role of mangrove forests for coastline protection and other ecosystem services.

- **conduct regular year-to-year monitoring and assessment of shoreline condition and the success of various mitigation strategies**, including construction of dykes and planting, along the entire coastline.

- **facilitate local management and protection of mangrove forests** by improving the direct monetary value of these valuable natural resources through the implementation of a REDD carbon storage scheme in conjunction with targeted livelihood projects.

- **provide alternative sources of firewood and building materials** with the establishment of community plantation forests that can be accessed by the poorest members of the community. This selected harvesting might feasibly be linked with carefully applied shoreline rehabilitation projects.

- **implement and trial well-considered shoreline restoration strategies**, especially like the ‘hedge row’ planting strategy as a method that accommodates the inevitability of sea level rise. This method is notably planned as a strategy to slow down the rate of shoreline erosion, and to specifically ‘buy time’ for coastal communities to adapt and retreat in an orderly way.

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Introduction

Kien Giang is a coastal province (Figure 1) in tropical southern Vietnam where mangrove forests have a pivotal role in climate change mitigation and adaptation in dampening the immediate threats from increased typhoon activity and sea level rise. Mangrove forests also support economic development of tourism, coastal protection and aquaculture throughout the province. It is generally acknowledged that well managed healthy mangrove ecosystems have a greater potential and capacity to: adapt to climate change; resist and recover more easily from extreme weather events; and, provide a wide range benefits on which many people depend. However, local communities living along the shoreline mangrove belt of Kien Giang seem to have limited knowledge and techniques for the sustainable management of these valued forests, and any selected conversion to compatible landuse types, like small-scale aquaculture. As a result, the mangrove belt of Kien Giang is either completely lost, or at best, very narrow and degraded with significantly reduced habitat resilience and little capacity for mitigation of the imminent impacts of climate change. To attend to this issue, specific instances of inappropriate coastal landuse must be addressed, and appropriate mitigation and rehabilitation strategies applied with the necessary urgency to offset immediate threats.

The predominant human impacts on mangrove forests in Kien Giang province include harvesting of wood for firewood and building materials, combined with the conversion of mangrove habitat into aquaculture ponds. In some instances, where mangrove forests have been severely reduced or lost, strong sea currents now erode dykes that were constructed to protect local people and their farmland from inundation during storms. Past attempts to protect the coastline from erosion include mangrove plantings by both Province and District authorities. Because these plantings largely failed, there is a growing need to develop new techniques for the establishment of mangrove forests as coastal stabilisors in Kien Giang. The new techniques build upon a sound knowledge of current coastal stability and lessons from earlier planting efforts. Data gathered from our current shoreline assessment provides further confidence for future planting efforts by applying methods and targeting areas more likely to succeed.

In addition to their role in coastal stabilization, mangroves have other important ecosystem services, including their sequestration of large amounts of atmospheric carbon (Clough 1992, 1998; Saenger & Snedaker 1993; Duke *et al* 2007; Fargione *et al* 2008). Deforestation, however, contributes about 20% of total anthropogenic carbon dioxide emissions into the atmosphere (van der Werf *et al.* 2009), enhancing global warming and environmental changes which potentially will have a devastating effect on Vietnam. To address this threat, and to help change community behaviour, the United Nations Framework Convention on Climate Change has established a program for reducing emissions from deforestation in developing counties (REDD). The REDD program is designed to provide financial incentives to encourage developing countries to voluntarily reduce deforestation and associated carbon emissions (Gibbs *et al.* 2007). Under a REDD program, developed countries would pay countries such as Vietnam for the carbon that is “saved” (as carbon credits) when they show they have reduced local deforestation. Implementation of the REDD carbon scheme is also likely to improve mangrove protection by increasing the monetary value of mangrove forest resources. The feasibility of this program is considered in this assessment as potentially beneficial in Kien Giang Province by preserving mangrove forests to stabilize vulnerable coastal areas.

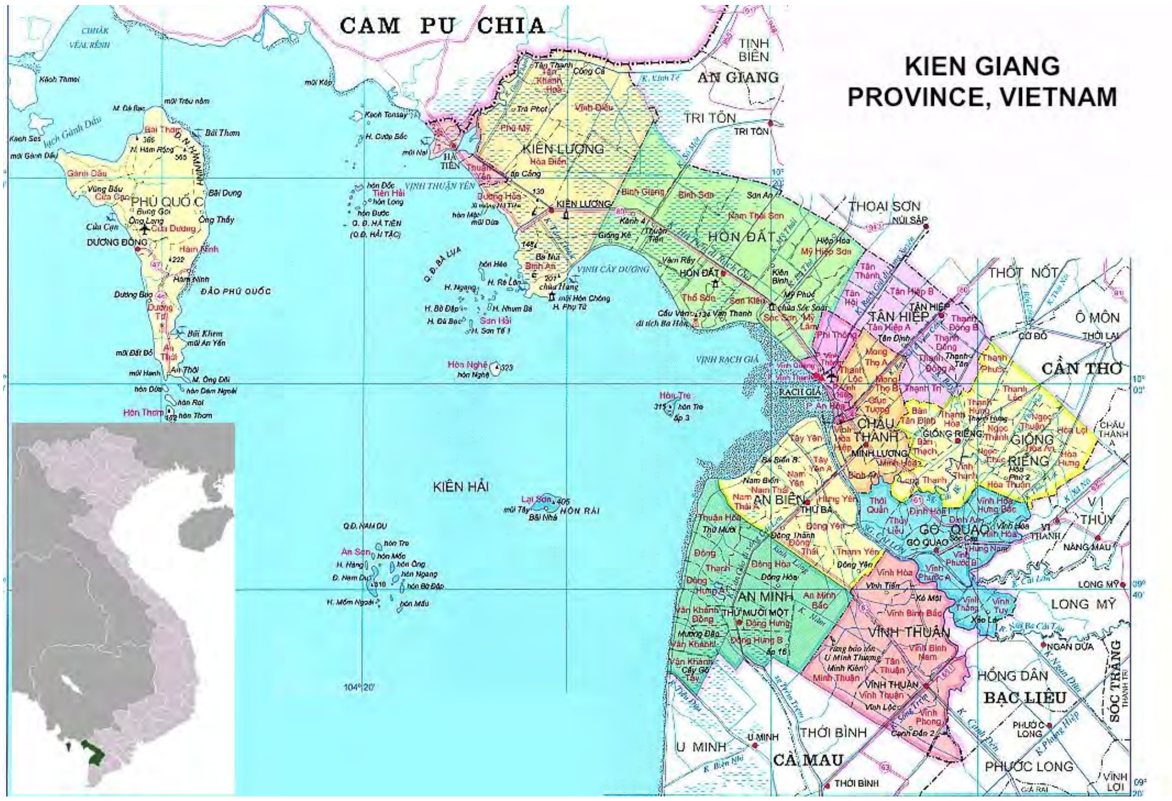

Figure 1: Map of Kien Giang Province showing regional boundaries. Insert shows location of Kien Giang within Vietnam.

A REDD mangrove forest program could provide financial benefits for the land “owners” or leaseholders in Vietnam through a payment for environmental services scheme. Assessment of current carbon storage in existing mangrove forests in Kien Giang Province, and recommendations of methods to enhance carbon storage through increasing forest biomass, as provided in this report, will allow land ownders and leaseholders in Kien Giang to fully exploit the opportunities offered under such a scheme. This will have benefits for coastal protection through improved shoreline management and subsequent increased resilience of mangrove trees to coastal erosion and projected higher sea levels.

Baseline surveys and monitoring (chapters 1-4, this report) have been necessary for the provision of essential preliminary data from which to assess future environmental change. Community education programs that will lead to an improved capacity of local farmers to sustainably manage their tidal wetlands are priorities for the successful conservation of mangroves in Kien Gian province, and elsewhere in Vietnam.

In the absence of similarly encompassing conservation strategy, and unless concerted efforts are made to conserve and rehabilitate mangroves the tidal wetland habitats of Kien Giang will continue to deteriorate and decline. Recent losses to mangrove forests in Vietnam are reportedly extensive (see chapter 2, this report). And, current levels of disturbance and destruction within mangrove forests of Kien Giang province indicate that threats to these important systems continue. In order to work towards more sustainable mangrove management, key gaps in both data and knowledge must be addressed.

The key objectives of this project were to:

1. Prepare a report on shoreline and mangrove resource condition, quantifying: extent and condition of mangrove resources in Kien Giang Province; extent of coastline at risk from erosion and sea-level rise; the carbon storage potential of mangrove forests; identification of areas in need of restoration and key pressures; and recommended restoration actions.
2. Conduct community training, including development of manuals for mapping of mangrove forest resources, shoreline assessment, plus carbon estimation, biomass with condition assessment.

To address assigned tasks, we have conducted this project in the five component sections as follow:

1. Biodiversity surveys;
2. Mapping from remote sensing imagery;
3. Shoreline Assessments;
4. Biomass and Carbon Estimations; and
5. Rehabilitation of eroded shorelines, environmental services and livelihood projects.

1. Biodiversity Surveys

Figure 2: *Lumnitzera littorea* in Phu Quoc Island. A particularly large individual – 16 m tall, and 250 cm girth. All have showy and attractive bright red flowers.

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1.1 Objectives of the Biodiversity Survey

Our goal has been to identify and describe mangrove plant species present in Kien Giang province. This information is needed for coastal management planning and policy development – especially related to shoreline rehabilitation and expansion of appropriate shoreline livelihood projects in the face of sea level rise.

During field investigations for each project component, species of mangrove and associated plants were identified and sampled. Data and specimens have been compiled as a reference collection for the Province.

These investigations have extended upon observations compiled for prior reports and studies, most recently including that conducted in October 2008 (Duke 2008). Current investigations have added significantly to these findings.

1.2 Reference library and Herbarium development

As part of the biodiversity survey a reference Herbarium was initiated. The Herbarium is housed in the GTZ office in Rach Gia, Kien Giang, and includes a number of dry pressed plant collections. Drying cabinets, purpose-built from local items, were used to facilitate preparation of herbarium collections for longer-term preservation and storage of reference material.

A reference library of digital imagery has been gathered showing key diagnostic features for most of the 27 Kien Giang mangrove plants. The standard set of features covered include: growth form, foliage, leaves, flowers, fruits, bark, trunk, stem base and above ground roots. Development of this reference library involved a literature review of relevant scientific articles from prior studies. Where available, sourced publications were added to the library at GTZ office in Rach Gia, Kien Giang.

1.3 Training and communication

As part of the biovidersity survey, training was provided to key team members, including locals and visitors. This experience in identifying mangrove plant speices and associated plant types will be valuable to the team members.

Communication and contact established during the project between GTZ staff and local mangrove experts will prove valuable to the ongoing success of the project. Notably, Dr Vien Ngoc Nam in HCM city and Prof Phan Nguyen Hong in Hanoi have been in communication with project staff regarding mangrove biodiversity in Kien Giang.

1.4 The mangrove vegetation of Kien Giang Province

1.4.1 Mangrove diversity

The mangroves of Kien Giang Province are very diverse in species, with 27 of the 39 reported species found elsewhere in Vietnam. Table 1 lists the observed species in each region of Kien Giang. The resilence of mangroves, and thus the capacity of the mangroves to provide their important ecosystem services is enhanced by the species diversity of the forest itself. High mangrove diveristy in Kien Giang Province will therefore be an assett to natural resource managers in the area.

Table 1. Mangrove plant species in Kien Giang Province, including sites in Phu Quoc, Ha Tien, Kien Luong, Hon Dat, An Bien and An Minh districts, compared with all Vietnam (Hong 2004; Nam 2008; Duke pers. Observations). *Introduced.

Local Name	Latin Name	Phu Quoc	Ha Tien	Kien Luong	Hon Dat	Rach Gia	Chau Thanh	An Bien	An Minh	Kien Giang	Viet nam
Ô rô trắng	Acanthus ebracteatus				1					1	1
Ô rô tím	Acanthus ilicifolius	1	1	1				1	1	1	1
Ráng	Acrostichum aureum	1	1	1	1		1	1	1	1	1
Ráng	Acrostichum speciosum	1	1		1	1	1	1	1	1	1
Sú	Aegiceras corniculatum	1	1	1	1					1	1
Sú đỏ	Aegiceras floridum										1
Mắm trắng	Avicennia alba	1	1	1	1	1	1	1	1	1	1
Mắm biển	Avicennia marina	1	1	1	1	1		1	1	1	1
Mắm lưỡi đòng (Mắm đen)	Avicennia officinalis		1					1	1	1	1
Mắm quăn	Avicennia rumphiana										1
Tim lang	Barringtonia racemosa										1
Vẹt trụ	Bruguiera cylindrica		1		1	1		1	1	1	1
Vẹt dù	Bruguiera gymnorhiza	1		1	1	1				1	1
	Bruguiera hainesii										1
Vẹt tách	Bruguiera parviflora										1
Vẹt khang (Vẹt đen)	Bruguiera sexangula	1	1	1	1		1	1	1	1	1
Dà quánh	Ceriops zippeliana (C.decandra)	1	1	1				1	1	1	1
Dà vôi	Ceriops tagal	1		1				1	1	1	1
Quao nước	Dolichandrone spathacea		1					1	1	1	1
Giá	Excoecaria agallocha	1	1	1	1	1	1	1	1	1	1
Cui biển	Heritiera littoralis	1	1	1	1		1	1		1	1
Trang	Kandelia candel										1
Trang	Kandelia obovata										1
Cóc đỏ	Lumnitzera littorea	1	1		1					1	1
Cóc vàng	Lumnitzera racemosa	1	1	1	1			1	1	1	1
Cóc hồng (cây lai)	Lumnitzera X rosea										1
Dừa nước	Nypa fruticans	1	1	1	1	1	1	1	1	1	1
	Pemphis acidula										1
Đước (Đước đôi)	Rhizophora apiculata	1	1	1	1	1	1	1	1	1	1
	Rhizophora X lamarckii										1
Đưng (Đước bộp)	Rhizophora mucronata	1						1	1	1	1
Đâng (Đước vòi)	Rhizophora stylosa										1
Côi	Scyphiphora hydrophylacea	1	1	1						1	1
Bần trắng	Sonneratia alba	1	1	1	1			1	1	1	1
	Sonneratia apetala										1*
Bần chua	Sonneratia lanceolata (=S. caseolaris)	1	1		1	1	1	1	1	1	1
Bần ổi	Sonneratia ovata	1	1	1	1	1		1	1	1	1
Xu ổi	Xylocarpus granatum	1		1				1	1	1	1
Xu mekong	Xylocarpus moluccensis (ex X. mekongensis)		1						1	1	1
	TOTAL SPECIES	**22**	**22**	**18**	**18**	**10**	**9**	**21**	**21**	**27**	**39**

1.4.2 General mangrove vegetation description

Kien Giang's mangrove vegetation has some interesting features, but is otherwise similar in general pattern to other areas of Vietnam and South East Asia.

Fringe mangroves

- The sea fringe is dominated in most places by *Avicennia alba* (Vietnamese name: Mắm trắng) (Figure 3). This is also typical of much of Ca Mau (Hong & San 1993). Stands of *A. alba* are also typical in the natural re-colonisation of abandoned aquaculture ponds. *Sonneratia alba* (Bần trắng), which is typical of the sea front in other places (Giesen *et al.* 2006) was only seen sporadically with *A. alba* at the front of the mangrove in northern parts of the province (Ha Tien).

- *Sonneratia caseolaris* (Bần chua) with *A. alba* is dominant in the sea fringe that makes up most of the mangrove in the central area from about Rach Gia north to around Vam Rang. In places, blocks of both *A. alba* and *S. caseolaris* have been planted at the front of the mangrove, extending it seaward. These are mostly clear but sometimes difficult to distinguish from natural stands (information on planting has been difficult to procure). It is possible that nearly all of the valuable *S. caseolaris* stands were planted.

Figure 3: Young ocean front forest dominated by small *Avicennia alba*, Vam Ray.

Other mangroves

- With distance from the sea, a more 'mixed' mangrove develops at mid to high tide levels where a number of other species colonise after the first development of mangrove vegetation, joining the initial species (Figure 4). This is the richest type in terms of biodiversity and can develop dense, stable vegetation, with some of the biggest trees. *Avicennia* is still a major component. Hong & San (1993) refer to this vegetation as an *Avicennia alba-Rhizophora apiculata* community, which is appropriate, but other species such as *Bruguiera* spp. (Vet), *Xylocarpus* spp. (Xu) and *Sonneratia alba* (Bần trắng) also appear.

- In the north of the Province, the greater extent of the mangrove allows a drier mixed forest to develop in places, with species such as *Phoenix paludosa* (Chà là), *Heritiera littoralis* (Cui biển) and *Ceriops tagal* (Dà vôi) more prominent.

- Mixed forests with an elevated proportion of *Excoecaria agallocha* (Giá) are present in places subject to past or present cutting of the forest. *E. agallocha* is favoured by heavy cutting, with some stands heavily dominated by *E. agallocha*, but others can still have a reasonable species complement.

Figure 4: 'Mixed' mangrove forest, with *Avicennia alba* in centre larger than that shown in Figure 3.

- In the northern areas of Kien Luong and Ha Tien Districts, stands of an upper intertidal 'scrub' of about 2-3 metres height and good diversity are present (Figure 5). Plants such as *Scyphiphora hydrophylacea* (Côi), *Lumnitzera littorea* (Cóc đỏ) and *L. racemosa* (Cóc vang) that are rare or absent elsewhere in Kien Giang are present, along with commoner species such as *E. agallocha*. South of Kien Luong, the mangrove forests are typically too narrow to support this vegetation.

Figure 5: Scrubby open mangrove vegetation at high intertidal levels in the Giang Thanh River system, Ha Tien. Although always short, the openness and height of this site partially reflects cutting.

- Stands of the palm *Nypa fruticans* (Dừa nước) can be present at the rear of the mangrove on the coast, or at the front along canals or rivers (Figure 6). There are natural occurrences, although many are planted, even on a small scale, due to the utility of their leaves and, to a lesser extent, their fruit. There are some relatively large planted areas along rivers and widespread planting at the rear of the mangrove, seemingly including the replacement of other mangrove trees in at least a few places.

- Fringing strips of mangrove 'associate' species are present at the rear of the tidal influence, with characteristic species such as *Hibiscus tiliaceous* (Tra nhớt) and *Thespesia populnea* (Tra bồ đề) and numerous others. This is a typical situation.

Figure 6: Stand of *Nypa* palms showing cutting of fronds and clumping habit, Vam Ray.

- Significant areas of *Rhizophora apiculata* (Đước) have been planted in blocks. This species is native to this coast, but natural stands like the planted blocks are not found, although there are some fringing stands on small streams on Phu Quoc Island. The older planted stands are about 18 years old and approach 13 metres in height in a good site.

- Low thickets of plants such as the daisy *Pluchea indica* (Lức cây), the shrubs of *Acanthus* spp. (Ô rô), the mangrove ferns *Acrostichum* spp. (Ráng) and the scrambling *Clerodendrum inerme* (Dây chùm gong) grows on degraded former mangrove land (Figure 7). Trees may be absent as tidal exchange is compromised or alternatively because the thicket is suppressing tree regrowth.

Figure 7: *Acrostichum* and *Clerodendrum* thicket and scattered trees, Plot VRy1, Vam Ray. This should all be forest. The very dense thicket can suppress tree regeneration.

Notable vegetation features in Kien Giang province

- The *S. caseolaris* to the north of Rach Gia, particularly in the Vinh Quang area are perhaps the tallest in Vietnam and are very tall for the species generally (Giesen *et al.* 2006). These trees may be planted, but at a maximum of about 21 metres are very notable. This is amongst the highest biomass forest in Kien Giang (see Wilson 2010).

- *Sonneratia caseolaris* prefers brackish conditions, but is well developed on the ocean front in Kien Giang. This is because the tidal water is so low in salinity (effectively fresh water) during the wet season. Other brackish species, including vines, herbs and trees are found within the mangrove although they are not usually considered mangrove plants.

- There are three *Avicennia* species present, with *A. alba* easily the most common. However, the numbers of another species *A. marina* (Mắm biển) are quite high and the species occurs on mud, which is somewhat unusual in Vietnam (V.N. Nam, pers. comm.).

- There is more mangrove diversity in the north of the Province, including species such as *S. hydrophyllacea*, *Lumnitzera littorea*, *Aegiceras corniculatum* (Sú) and the palm *Phoenix paludosa* not seen elsewhere.

- *Lumnitzera littorea* with its red flowers was previously poorly known in Vietnam, but is widely present in the high intertidal scrub mangrove in the north of the Province. Its co-occurrence with the white flowered *L. racemosa* is apparently unusual; Giesen *et al.* (2006) state that the two species have not been collected from the same site previously.

- There are odd mixed stands of mangrove present in places subject to coastal retraction, where upper fringe species, such as *T. populnea* and *H. tiliaceous* currently coexist with low intertidal mangrove species. In essence, the retracting coast has brought greater tidal exchange that in turn has brought regeneration of mangrove species, while the previous fringing species remain healthy. This situation is found particularly in An Minh and An Bien, but also in Kien Luong.

- Natural mangrove regeneration is generally very good within the forest area (e.g. Figure 8) and is not a problem overall in Kien Giang, although some species may be restricted more than others.

Figure 8: *Sonneratia caseolaris* seedlings, Vam Ray. Regeneration is present throughout the mangrove.

- A significant number of species are associated with the mangrove in Kien Giang, but are not generally considered core mangrove species, including many climbers. Most are typical and are detailed in Hung & Tan (1993). A few interesting tree species found within or at the tidal edge of the mangrove, including *Barringtonia acutangula* (Chiếc) and *Cerbera odollam* (local name: Mát sát) in or on the edge of the brackish *S. caseolaris* mangrove fringe and *Phoenix paludosa* and *Instia bijuga* (Gô nủỏc) in the north. Vascular epiphytes are not uncommon on tropical mangrove trees and Hung & Tan (1993) record some from Ca Mau, but none were seen on the trees of Kien Giang.

- Large seeding trees of Xylocarpus granatum identified in Phu Quoc could prove useful 'source trees' for planting trials. An isolated planted area of Rhizophora mucronata located in Kien Luong district may also be a valuable source of seed stock for this uncommon Rhizophora species in Kien Giang province.

1.4.3 Conclusions

Mangrove condition

Mangrove forest areas in northern Phu Quoc have been the rare exception of being in relatively natural conditions. In other areas, while sometimes diversity levels are relatively high, the condition of stands can be seriously depleted. This becomes a serious issue for the capacity of local mangrove forests to fulful their ecosystem service functions. Most degraded are the areas to the south of Rach Gia. There the mangrove fringe has been reduced to a thin narrow strip pressured from landward and seaward sites, as well as from direct cutting (Figure 12). **If these ecosystems are to provide ecosystem services, particularly in shoreline protection – they must be rehabilitated as a matter of urgency.** The resilience of these services is enhanced by the diversity of species known now to exist in the province, albeit at relatively low numbers of trees. For the latter point, this is why it is important to locate particular individuals and stands as seed sources for future rehabilitation works. These stands and trees need the highest level of protection.

2. Remote sensing and mapping of mangroves

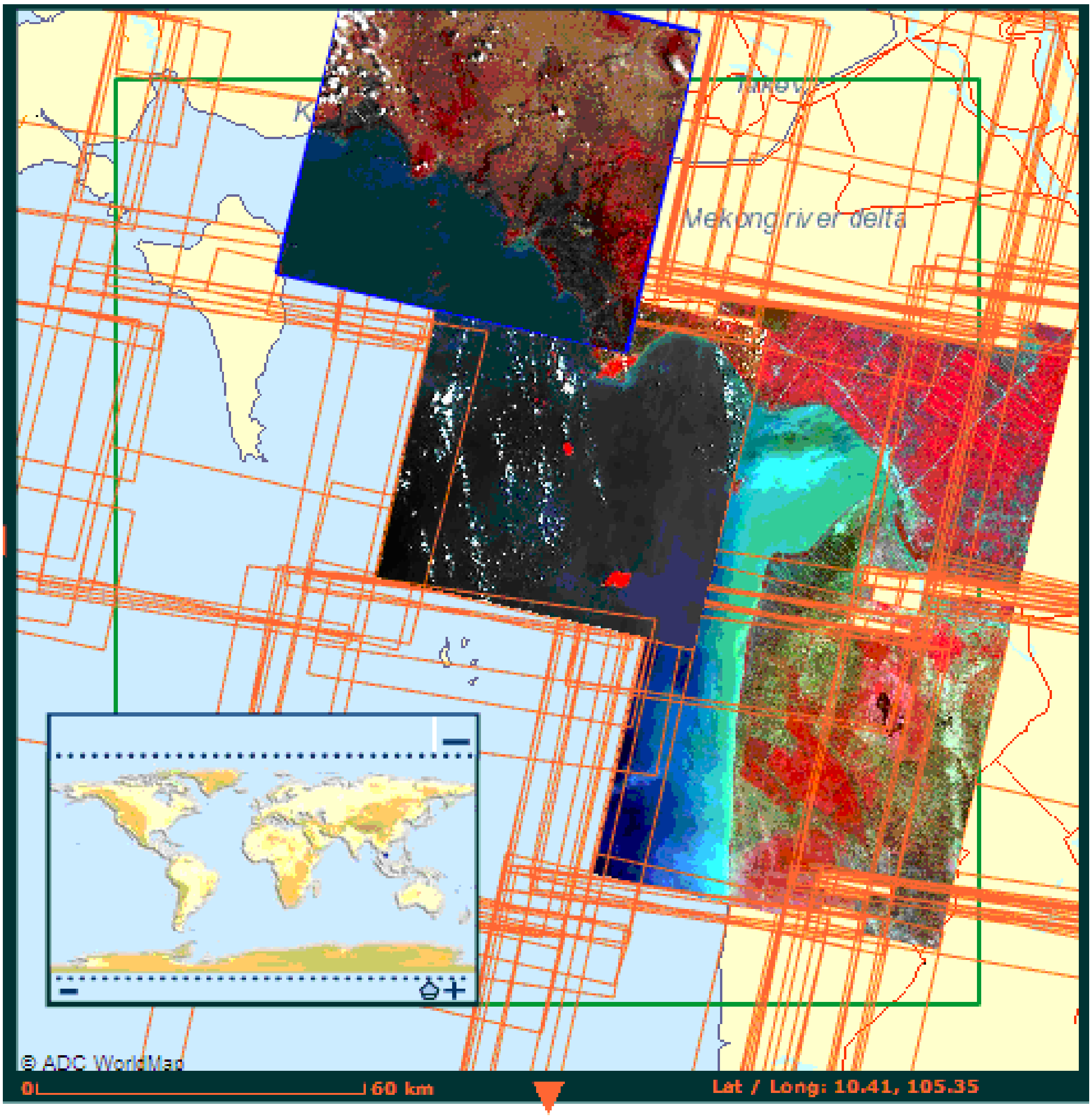

Figure 9: Satellite imagery; an essential part of this project invesitigating mangroves and coastal resource condition of Kien Giang province.

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2.1 Overview

The area of mangrove forest in Vietnam has rapidly declined from 1943 to 2000. In 1943 mangrove area is estimated at 408,500 ha; in 1962, 290,000 ha remained; 252,000 ha in 1982; and 155,290 ha in 2000 (Government of Vietnam 2005; Sam et al. 2005). However, the area of mangroves has recently increased by 51,450 ha (in 2006), due to a National Action Plan for mangrove protection and development (Government of Vietnam 2005; Sam *et al.* 2005; Thu 2007). The overall aim of National Action Plan is to promote the protection, rehabilitation and wise use of mangrove ecosystems towards sustainable development so that their protective functions and biodiversity values can satisfy socioeconomic development and environmental protection objectives in river estuaries and coastal areas (Government of Vietnam 2005; Sam *et al.* 2005). In order to achieve these aims it is necessary to first establish the extent and condition of current tidal wetland habitats in Vietnam, allowing accurate mapping of future changes to these important habitats.

Satellite remote sensing is well suited to provide both landuse area data and estimates of above ground biomass at both local and global scales (Soenen 2010). The combination of satellite remote sensing with plot based biomass studies (Chapter 4, this report), allows estimations of partial levels of carbon storage in Kien Giang mangrove forests. This information will be essential for the successful implementation of a REDD scheme in Kien Giang province.

In Kien Giang, the area of mangroves has been estimated at around 3,936 ha in 1999 and 5,430 ha in 2006 (Cuc et al. 2008) due to the enhancement of mangrove restoration programs. However, the majority of mangroves have been mainly distributed in An Bien and An Minh districts with a strip of mangroves varying in width from 20 m to 500 m (Cuc *et al.* 2008).

Kien Giang is one of the most vulnerable provinces in the Mekong River Delta to a predicted sea-level rise of 100 cm in Vietnam (Carew-Reid 2008). The province is expected to be subject to up to 12.1% of total national inundation, with 1,756 sq km of land being inundated (equivalent to 28.2% of province area) by 2100 (Carew-Reid 2008). To date, no official assessments of historical shoreline dynamics, potential coastal vulnerability and mangrove functions have been conducted in Kien Giang province (Duke 2008; Duke *et al.* 2009). Here we assess temporal and spatial changes in mangrove forests and shoreline erosion over time. This data will aid in the prediction of areas most at risk of extreme erosion events in the near future.

2.2 Methods

2.2.1 Preliminary review of a historical mapping strategy

Historical SPOT (Système pour l'Observation de la Terre) satellite imagery and aerial photographs from 1952 to 2009 were located with two suppliers (Table 2).

Table 2: SPOT imagery and aerial photographs for historical shoreline interpretation**.**

Sources	Year	Resolution/scale	Supplier
Aerial photographs	1952-1954	1/44,000	COSAMD
Aerial photographs	1975-1989	1/40,000	COSAMD
Aerial photographs	1990	1/14,000	COSAMD
SPOT 3	1994-1995	20mx20m	NVRSC
SPOT 5	2003	10mx10m	NVRSC
SPOT 5	2009	10mx10m	NVRSC

Imagery acquired to date includes only the 2009 SPOT5 imagery – as representing our assessment baseline from which future and past change can be measured. Our plan is to use such a range of imagery from various time periods to make a comprehensive assessment of historical change for the entire coastline of Kien Giang province.

The 2009 SPOT 5 imagery was georeferenced to UTM WGS-1984 Zone 48N projection and coordinate system. ER-DAS Image 9.3 will be used to co-register the aerial photographs to the georeferenced SPOT 5. A preliminary assessment has been conducted to review the assessment strategy proposed. The High Water Line (HWL) and Vegetation Line Indicator (VL) were examined to derive historical rates of shoreline change for the coastal study area. The VL was identified from each co-registered image and SPOT 5 as the mangrove-seaward margin. This seaward margin was defined as unbroken canopy edge, thus excluding opportunistic and pioneer mangrove vegetation (Gilman *et al*. 2007). In places where there was no vegetation and artificial structures evident at the seaward edge of a backshore, the seaward limit of artificial structures were taken as VL.

The position of the HWL was selected as shoreline indicator and identified as wet/dry boundary on sub-aerial beach marked by the most recent high tide (Pajak and Leatherman 2002). On the rising tide, the HWL indicates the maximum run up limit while on the falling tide it represents wet/dry boundary (Abuodha 2009). ArcGIS was used to digitise and create a single shoreline position in the specific year and baseline at a scale of 1/10,000.

Measuring historical change in shoreline position was formalised into Digital Shoreline Analysis System Application 4.1 (DSAS). This is an extension to ArcMap, developed by the

United States Geological Survey and used to interpret historical shoreline changes (Thieler *et al.* 2009). Before using the DSAS to compute change statistics, the initial data preparation step is taken to reference all shoreline vectors to the same features (as VL and HWL indicators selected) and each shoreline vector represents in a specific time period and must be assigned to a date in the shoreline feature-class attribute table (Thieler *et al.* 2009). The process of historical shoreline interpretation is demonstrated in Figure 10.

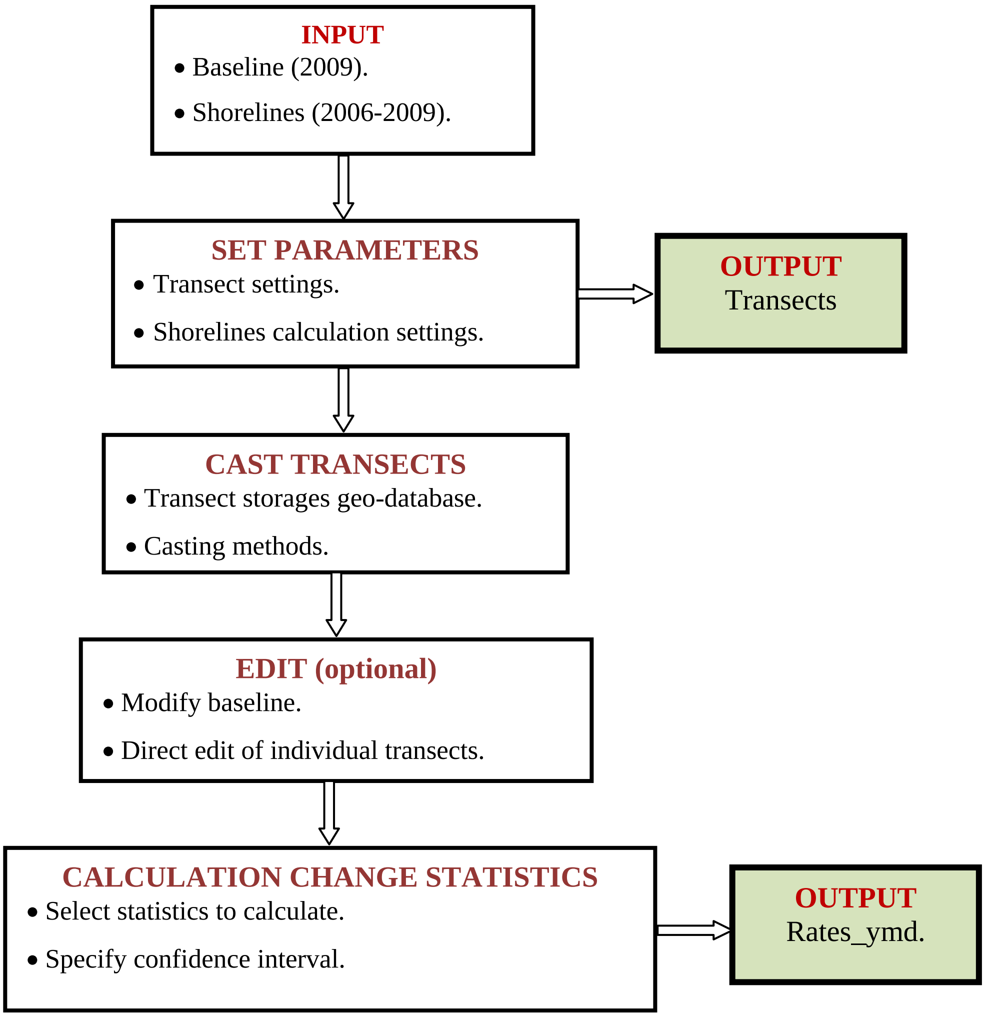


Figure 10: Flow diagram showing the process of historical shoreline interpretation

2.2.2 Mapping of mangrove areas in Kien Giang – central and southern districts

As noted, imagery supplied was 2009 SPOT 5 (10 m x 10 m) satellite imagery covering the districts of Hon Dat, Rach Gia, An Bien, An Minh and Chau Thanh. These were provided by the Remote Sensing Station Tu Liem in Hanoi in late 2009.

The application of Maximum Likelihood Classification in Spatial Analyst Tools of ArcGIS 9.3 was used to classify landuse units from the SPOT 5 imagery. Signatures for land use classes were based upon spectral clusters defined soley on a statistical basis. These spectral clustered were detected using ArcGIS Iso cluster tool from the Multivaiate analysis option of the ArcGIS Spatial Analyst Toolbox. All spectral bands included in classes were normally distributed. A maximum likelihood equation was used to determine into which class spectral clusters belonged. This equation assumes that the probabilities of a cluseter falling into any of the classes is equal. Based on ground truthing (Chapter 4, this report), two of the spectral clusters identified by the maximum likelihood classification tool of ArcGIS were identified as mangrove habitat. These were titled *mangrove type 1* and *mangrove type 2*. The remaining two clusters were identified as *bare wet ground* or *other* based on aerial imagery.

Using the four assigned classes, *mangrove type 1, mangrove type 2, bare wet ground* and *other*, land use was mapped in all areas where satellite imagery was available. This includes the districts of Hon Dat, Rach Gia, An Bien, An Minh and Chau Thanh, encompassing around 70% of the entire Kien Giang Province. The area of the two mangrove classes was calculated for each district using polygons and expressed both as area (ha) and as the percent of the total mangrove area falling into each class.

2.3 Results

2.3.1 Landuse mapping and mangrove areas in 2009

Figures 11 – 15 show mapped land-use units in five districts of Kien Giang province where satellite imagery was available, Hon Dat (Figure 11), Rach Gia (Figure 12), Chau Thanh (Figure 13), An Bien (Figure 14) and An Minh (Figure 15). Coastal districts not assessed at this time include the northern districts of Kien Luong and Ha Tien, as well as the island district of Phu Quoc. Table 3 lists the extent and condition of mangrove forested areas in the five mapped districted of Kien Giang province.

Table 3: Area of mangroves in central and southern coastal districts of Kien Giang for 2009.

Region	Mangrove Type 1		Mangrove Type 2		Total mangrove
	ha	%	ha	%	(ha)
Hon Dat	406	51	387	49	793
Rach Gia	89	46	104	54	194
Chau Thanh	27	48	32	52	60
An Bien	263	51	255	49	518
An Minh	424	44	549	56	973
Totals for mapped districts	**1210**	**48**	**1328**	**52**	**2537**

The coastal mangroves in 2009 exist as a thin narrow strip apparently threatened at the seaward margin by erosion, from the land by expansion and presence of agricultural and aquaculture development, obstruction to landward transgression with dykes, and generally from direct cutting of trees.

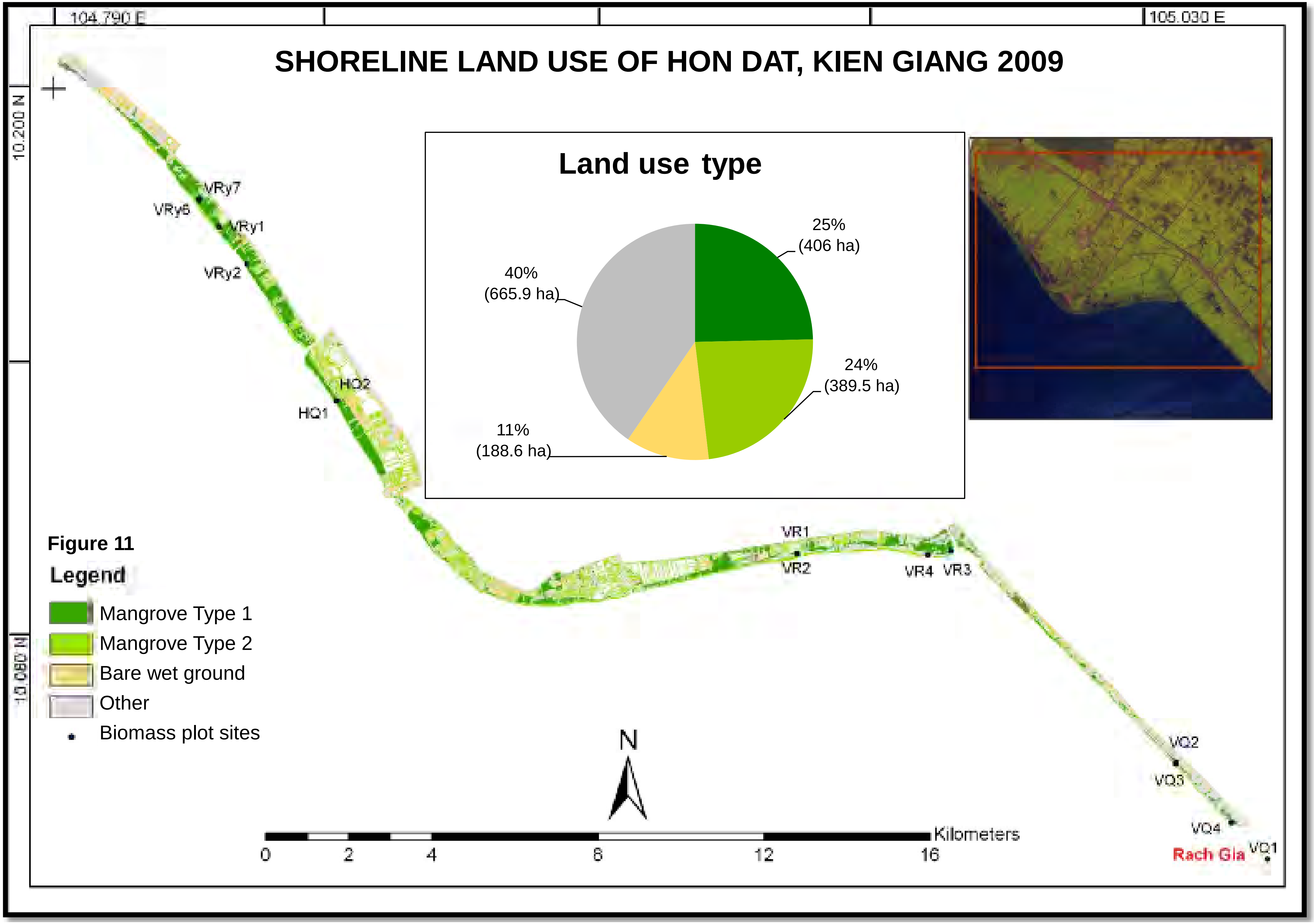

104.790 E
105.030 E
10.200 N
10.080 N
SHORELINE LAND USE OF HON DAT, KIEN GIANG 2009
Land use type
25%
(406 ha)
24%
(389.5 ha)
11%
(188.6 ha)
40%
(665.9 ha)
VRy7
VRy6
VRy1
VRy2
HQ2
HQ1
VR1
VR2
VR4
VR3
VQ2
VQ3
VQ4
VQ1
Rach Gia
Legend
Mangrove Type 1
Mangrove Type 2
Bare wet ground
Other
Biomass plot sites
N
0
2
4
8
12
16
Kilometers

Figure 11

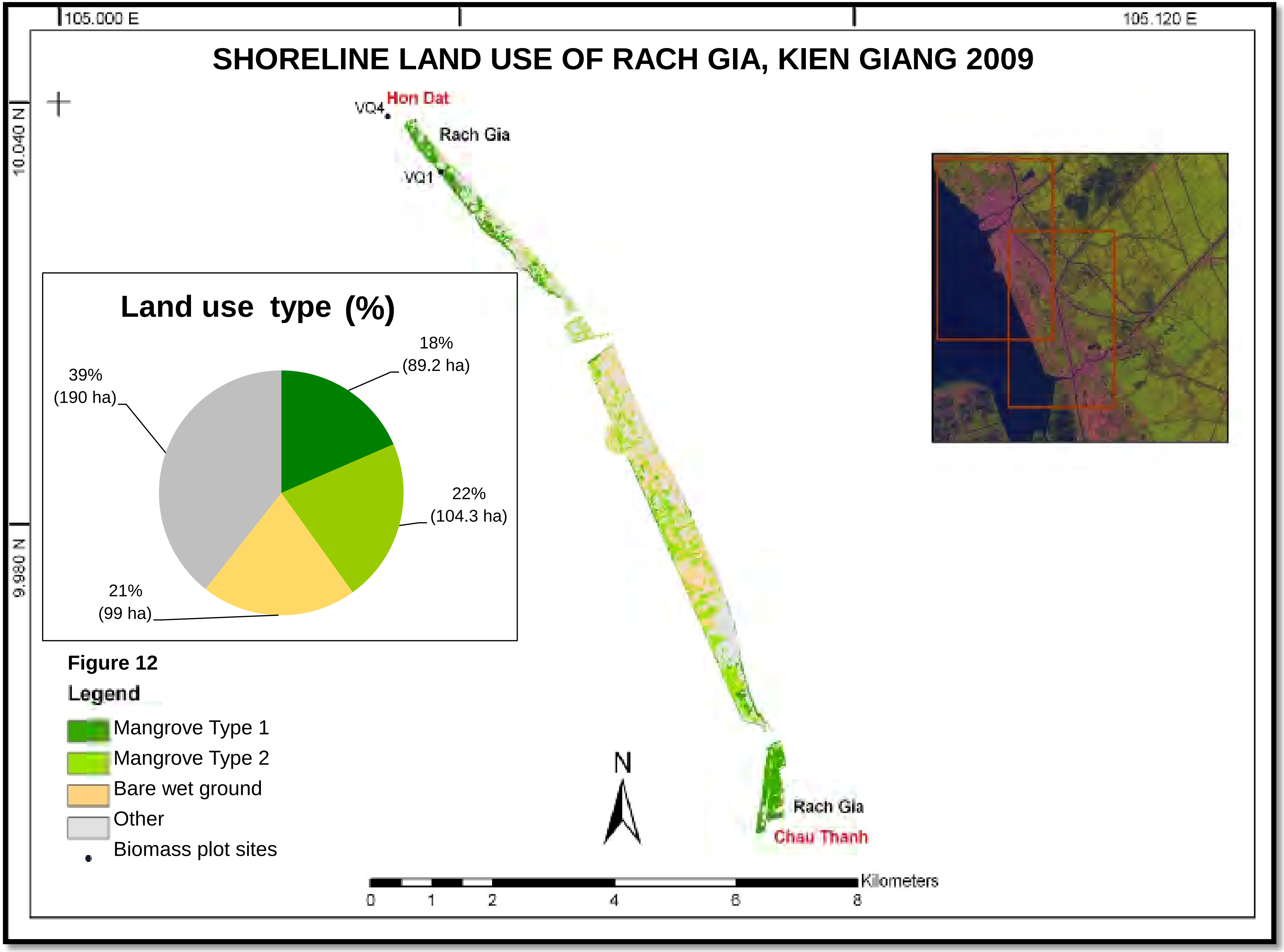
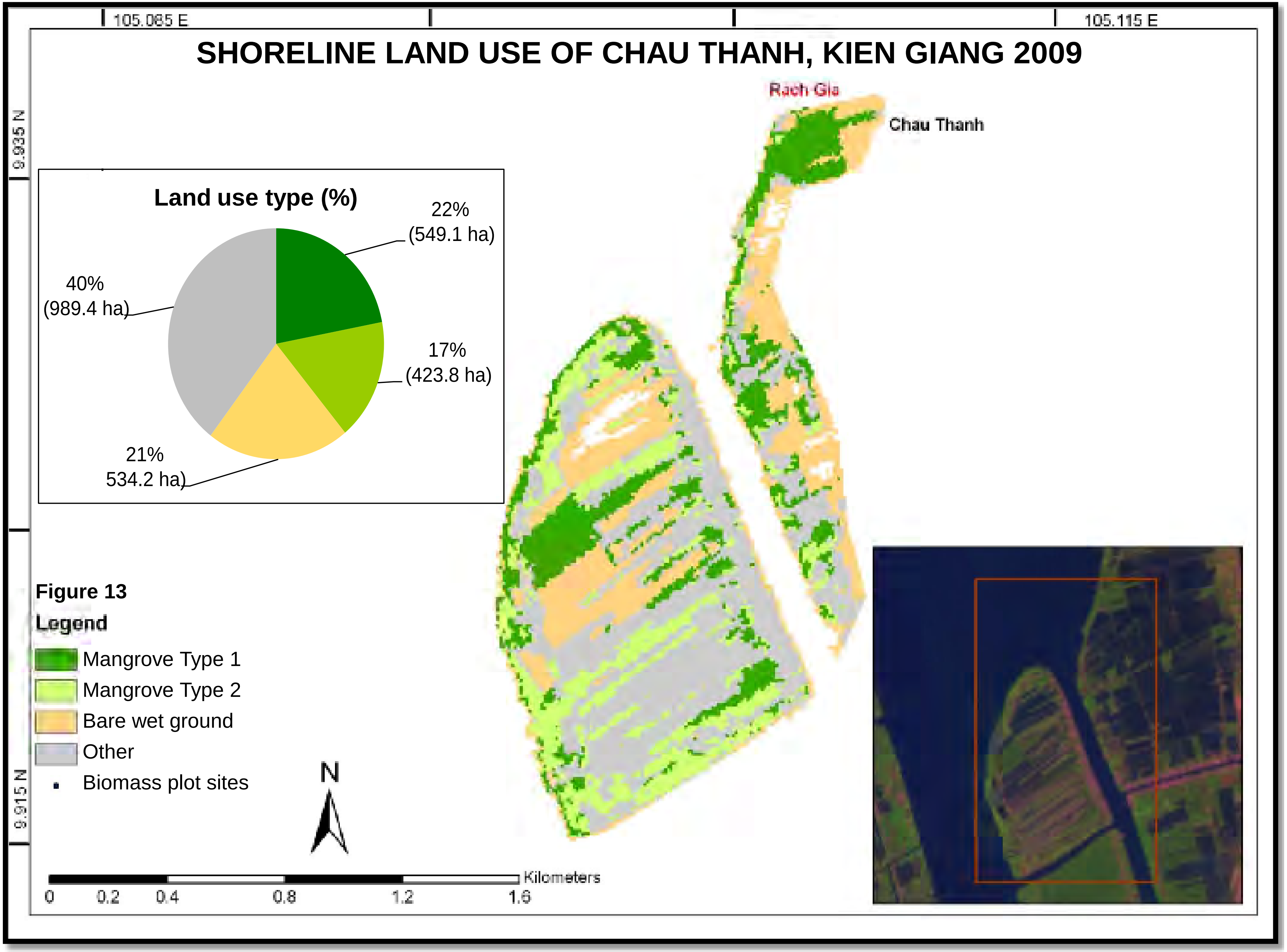
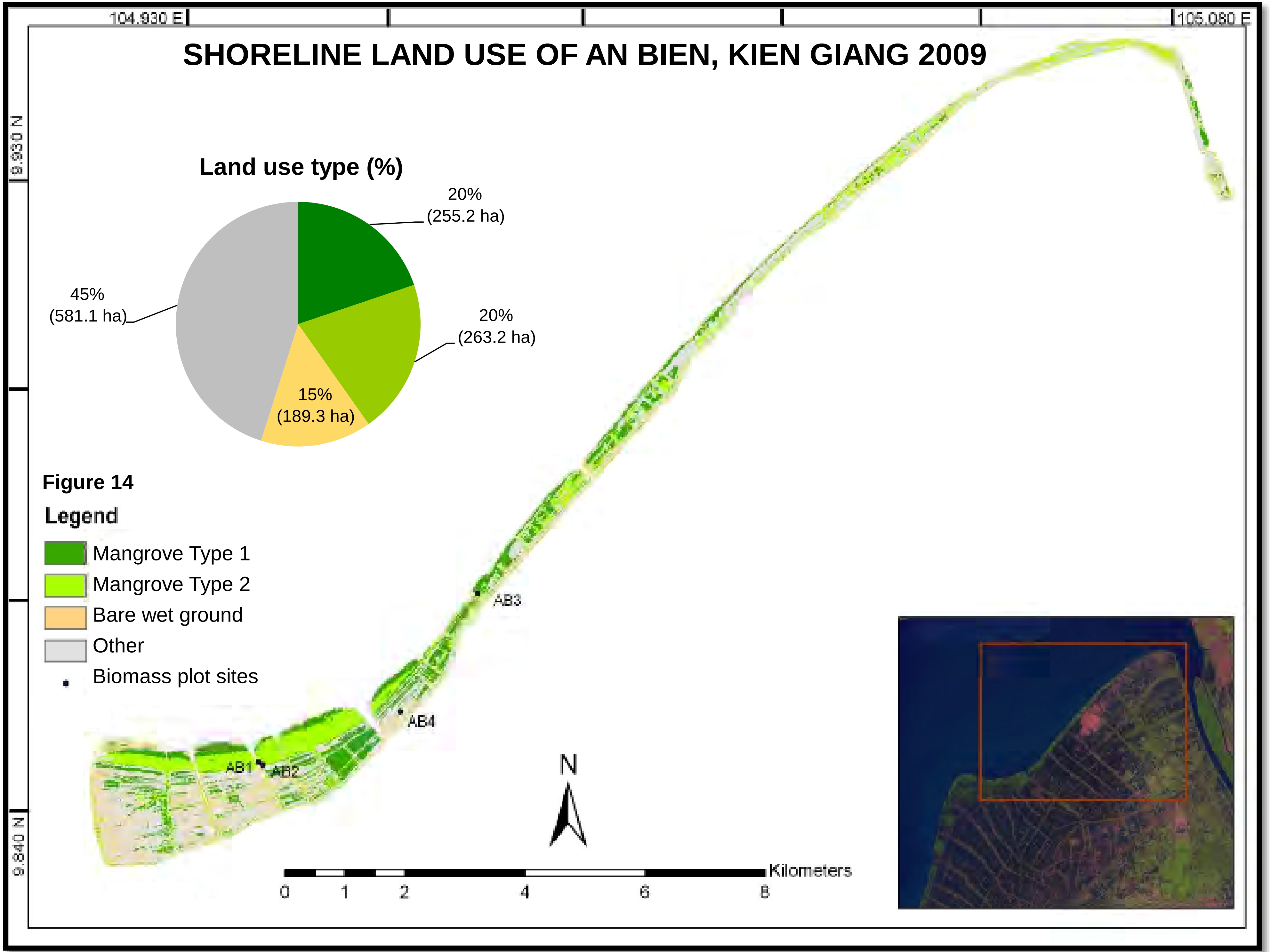
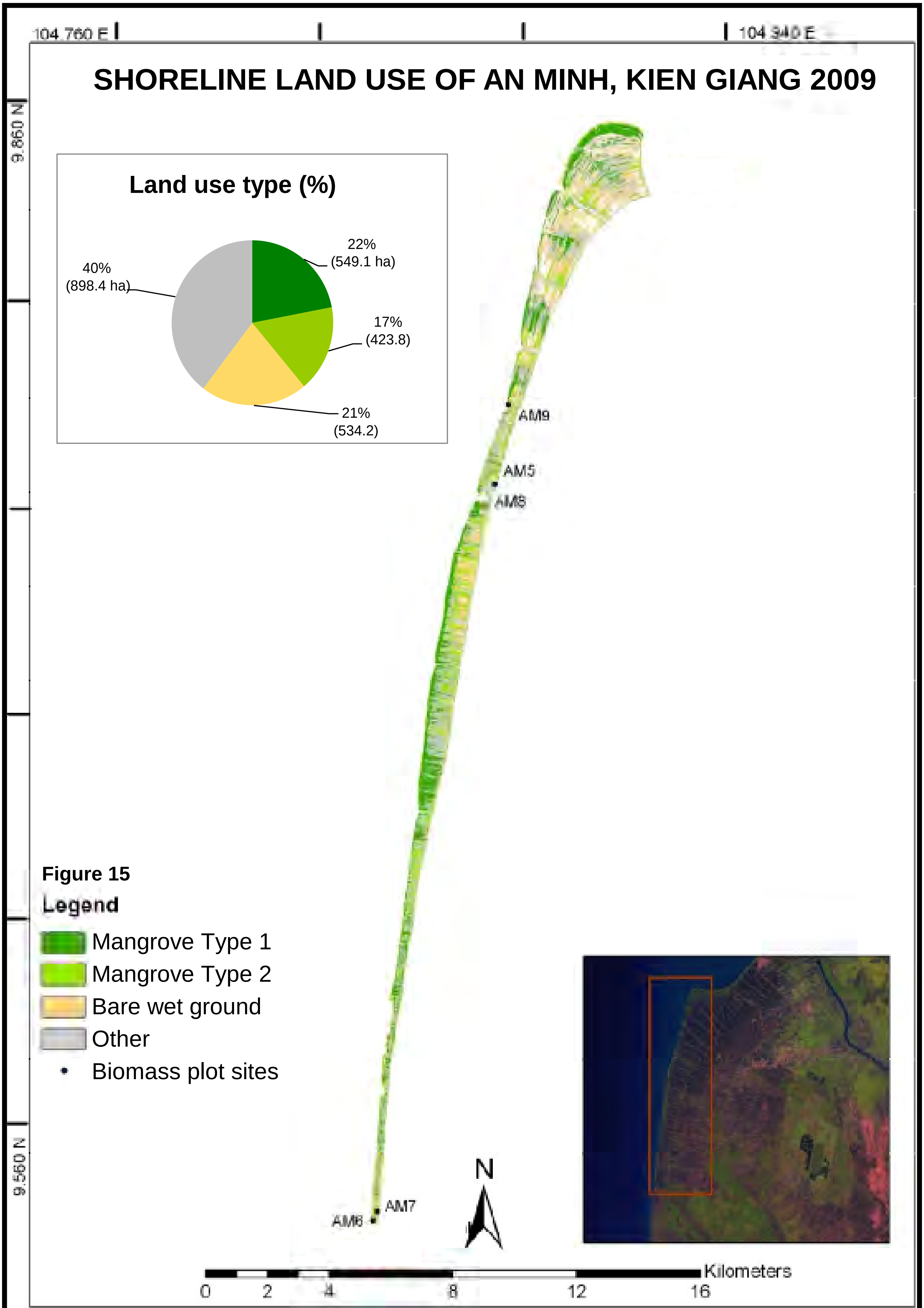

105.000 E
105.120 E
10.040 N
9.980 N
SHORELINE LAND USE OF RACH GIA, KIEN GIANG 2009
VQ4
Hon Dat
Rach Gia
VQ1
Land use type (%)
18%
(89.2 ha)
39%
(190 ha)
22%
(104.3 ha)
21%
(99 ha)
Legend
Mangrove Type 1
Mangrove Type 2
Bare wet ground
Other
Biomass plot sites
N
Rach Gia
Chau Thanh
Kilometers
0
1
2
4
6
8

Figure 12


105.085 E
105.115 E
9.935 N
9.915 N
SHORELINE LAND USE OF CHAU THANH, KIEN GIANG 2009
Rach Gia
Chau Thanh
Land use type (%)
22%
(549.1 ha)
17%
(423.8 ha)
21%
534.2 ha)
40%
(989.4 ha)
Figure 13
Legend
Mangrove Type 1
Mangrove Type 2
Bare wet ground
Other
Biomass plot sites
N
0
0.2
0.4
0.8
1.2
1.6
Kilometers


SHORELINE LAND USE OF AN BIEN, KIEN GIANG 2009
104.930 E
105.080 E
9.930 N
9.840 N
Land use type (%)
20%
(255.2 ha)
20%
(263.2 ha)
15%
(189.3 ha)
45%
(581.1 ha)
Figure 14
Legend
Mangrove Type 1
Mangrove Type 2
Bare wet ground
Other
Biomass plot sites
AB1
AB2
AB3
AB4
N
0
1
2
4
6
8
Kilometers



104 760 E
104 340 E
9 860 N
9 560 N
SHORELINE LAND USE OF AN MINH, KIEN GIANG 2009
Land use type (%)
22%
(549.1 ha)
17%
(423.8)
21%
(534.2)
40%
(898.4 ha)
AM9
AM5
AM8
AM7
AM6
Legend
Mangrove Type 1
Mangrove Type 2
Bare wet ground
Other
Biomass plot sites
N
0
2
4
8
12
16
Kilometers

Figure 15

2.3.2 Indications of significant change in Hon Dat district

We present preliminary evidence of significant coastal erosion in key sections of the coastal margin of Kien Giang province. In this, note the progression of extrapolated coastlines for 1992, 2006, 2007 and 2009 where there is a steady retreat landward in Hon Dat district. The rate of coastline retreat is estimated at up to 24 m per year, as shown in Figure 16.

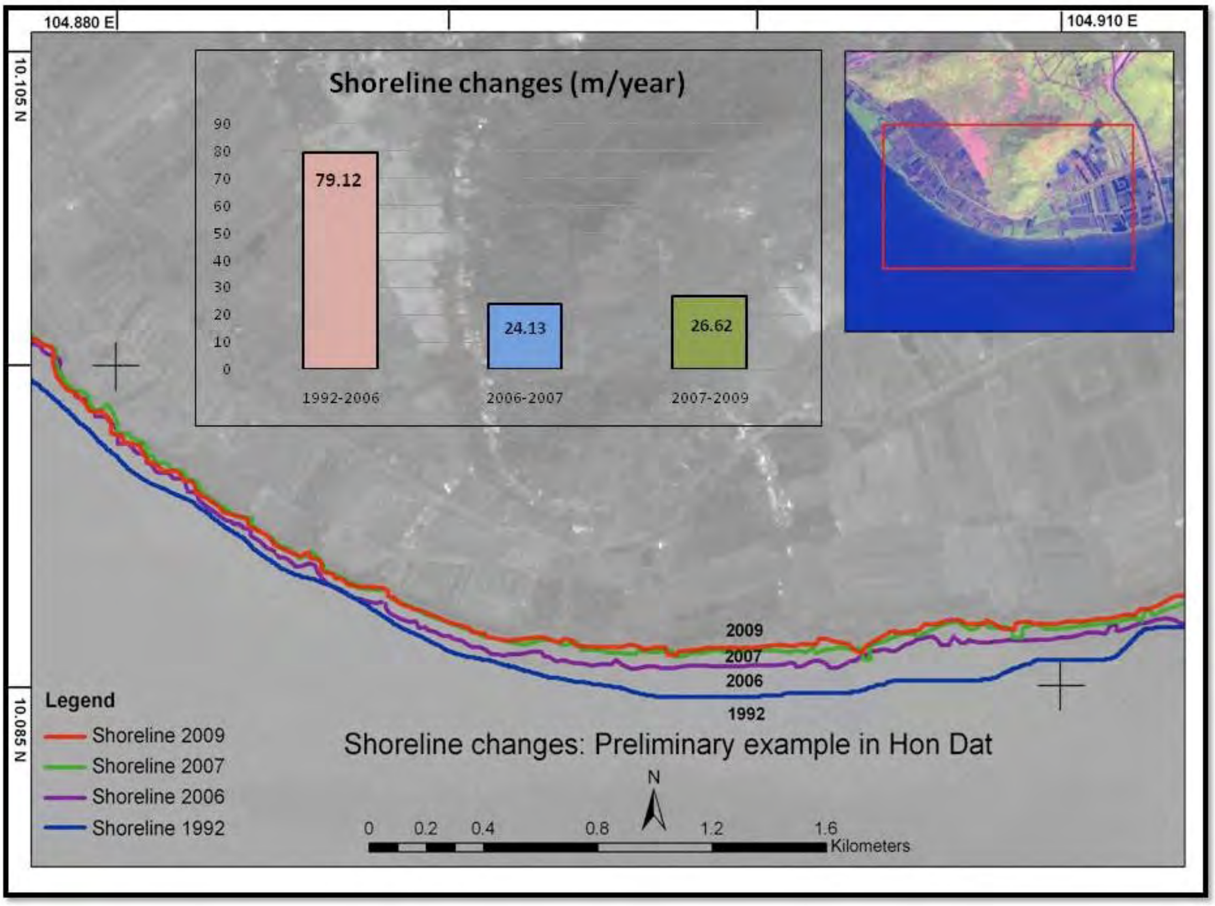


Figure 16: Shoreline changes in Hon Dat region, Kien Giang province

The shoreline vegetative buffer of Hon Dat is severely degrading through erosion of the foreshore in several areas. Dykes in Hon Dat are heavily eroded and will likely be further damaged in coming years unless appropriate mitigation actions are given soon.

2.4 Discussion

2.4.1. Shoreline extent, condition and coastal retreat

Mangrove vegetation was previously more extensive and healthy in Kien Giang province. Complete estimates of change will be presented more thoroughly once we have a full coverage and assessment of recent and past imagery. Based on the data to date giving mangrove area of ~70% of the Kien Giang coastline, we estimate total mangrove area within Kien Giang province to be ~3500 ha. This figure is somewhat lower than the 2006 estimate of Cuc *et al.* (2008), however based on landuse mapping so far we believe it is unlikely that the remaining 30% of unmapped coastline could host another >2500 ha of mangrove area at present. Our area estimate of 3500 ha is therefore used to calculate estimated total mangrove forest biomass and carbon storage in Kien Giang (Chaper 4, this report). The two spectral clusters identified as mangrove classes, *mangrove type 1* and *mangrove type 2,* are yet to be linked to distinctive vegetation characteristics. Future mapping (where satellite and photographic imagery become available), will better allow such links to be made.

In the meantime, we have observed shoreline mangrove vegetation being threatened in two distinct ways: one, by coastal retreat and erosion; and two, by severe pressure from fragmentation, conversion to other landuse types, and high levels of disturbance. The spatial image maps show a very thin line of fringing mangrove vegetation with notable fragmentation (Figures 11-15). The gaps and spaces amongst the coastal mangrove zone are also recognizably geometric – a certain indicator of the disturbances being made by people.

Our observations of retreat, damage and loss correspond with our other observations of on-going conversion of mangrove areas to aquaculture, coupled with wide-scale erosion along the coast edge, and with the pervasive damage of unregulated cutting for timber products.

Further analysis of the historical images will allow the development of models of changes in mangrove areas under different scenarios of predicted sea level rise > 17cm/100 year. The rate of change and the peat accumulation rates will have serious implications for the survival of mangrove forest.

2.4.2. Linking spatial assessments with other study components

The fringing mangrove habitat and habitat resilience

A dramatic feature of the sea-edge mangrove vegetation in Kien Giang is the degree of erosion that is occurring, both in terms of depth of mangrove being lost and the length of coast affected. The rate can be very rapid. Figure 16 shows shoreline changes in the Hon Dat region since 1992, and Figure 17 shows approximate retraction at one site near Hon Queo between 2003 and 2007.

Figure 17: Mangrove retraction between 2003 and 2007 at Hon Queo. Yellow line represents 2003 mangrove front. Note canals cut through forest between dates, plus further loss since 2007 (not shown) (Image: Google Earth).

The worst affected areas in Kien Giang are those of relatively straight open coast, where the mangrove fringe is often thinnest (see Figures 11 - 15). It is well known that open coasts where fringing mangroves have been lost are subject to erosion by sea waves (Mazda *et al.* 2002). Sea-front erosion, including sites with mangroves, is widespread in Vietnam, with very high rates of erosion in places (> 30 m per annum) (Cat *et al*. 2006). Figure 18 shows a localised break-through on to a small dyke enclosing a pond built into the mangrove area in An Bien and wave action in an eroding forest in Vam Ray.

A B

Figure 18: (A) Sea broken through the thin remaining mangrove fringe, threatening the small dyke enclosing aquaculture pond, An Bien; (B) Waves washing into the eroding front of *Avicennia alba* forest, Vam Ray.

Biodiversity and shoreline surveys

Through mapping area of mangrove forest throughout Kien Giang it is possible to identify the regions of the province most vulnerable to erosion and ocean encroachment. This is achieved through quantification of the width of the mangrove forest, as the zone of fringing mangroves at the coastal margin are at greatest risk of erosion. Areas identified as retaining only very narrow fringing mangrove forests will hence be most susceptable to damage from increased storm activity and sea level rise assosciated with climate change.

The vegetation unit mapping from satellite imagery supplements shoreline survey data (Chapter 3, this report) to show the spatial exent of vegetation units observed along the coastal margin. This allows more accurate estimation of the capacity of the mangrove habitats to continue to fulfill their role in coastal stabilisation than is possible if only the shoreline data is considered (see also figures 25 - 74). For example, in many areas where shoreline surveys identify both fringing mangrove and stable coastal condition, from the land use maps it is evident the mangrove forest is restricted only to the extreme edge of the coast (see Figures 14 & 29), and therefore has little resilience to storm events and capacity to adapt to future sea level rise.

Together, shoreline surveys, vegetaion maps and biodiversity assessments provide important information when considering ecosystem reslience. Forests with low biodiversity are less resilient to long term climatic shifts and natural disturbance events. Hon Dat region was found to have the lowerest mangrove biodiversity (16 species present) of the five regions sampled in Kien Giang province. Hon Dat is also subject to high levels of erosion, with 24 m per year of active erosion (Figure 16), and the fringing mangrove forest is clearly very narrow in many area of this region (see Figure 11). Through collation of the spatial assessments (figures 11 – 15 and 25 - 74), and the biodiversity surveys (Chapter 1) it is possible to define the vulnerability of stands, and hence areas requiring hightened conservation management. For rehabilition studies, the maps can be used to define the extent of lands at risk so that restoration works can be prioritized

Biomass and carbon estimations

Spatial mapping of mangrove habitats throughout Kien Giang Province provide fundamental information allowing the scaling up of plot estimates of biomass and carbon. Historical mapping, as demonstrated in the Hon Dat region (Figure 16), will also provide important data which can be used to estimate CO_2 emissions based on degradation and loss of mangrove forest during a set period of time. This infomation will also assist in the prediction of potential increased CO_2 emissions if mangrove forests are continuously degraded and lost throughout Kien Giang Province.

Mature trees survive best and can be left isolated in the sea at the front of the mangrove (Figure 19B). However, mature vegetation is being eroded in many areas (Figure 19A). Sea wave action undercuts the trees particularly during the SW monsoon. This could be related the the possibility that mud supply is inadequate or is not being spread as widely, as continued mud supply must be a factor in mitigating continued sea level rise Other factors, such as the distribution of mud now being channelled by dykes and canals or changes to the sea bed profile through localised dredging might contribute to the deficit of mud in places.

A B

Figure 19: (A) Eroding front of mature mangrove with fallen *Sonneratia caseolaris*, Vinh Quang. (B) Mature *Rhizophora apiculata* surviving longer than *Avicennia alba* in erosion zone, Vam Ray. Picture taken within several metres of Figure 10.

Large scale conversion continues, including the conversion of mangrove habitat for aquaculture ponds, despite the small area of mangrove present. Much clearing and cutting of mangrove is evident, including illegal cutting/clearing.

3. Shoreline Assessment

Kien Giang Mangroves: A disappearing resource on a disappearing coastline.

Results of a rapid video survey of the Kien Ginag Coastline, Vietnam.

Figure 20: The entire coastline of Kien Giang province has been filmed using video imagery. This provides an invaluable assessment tool, and it is a permanent record of the 2009 condition of coastline.

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- Mr. Nguyen Minh Tri (An Minh – An Bien Forest Protection Management Board)
- Mr. Huu To (GTZ Technical Officer)
- Mr. Chu Van Cuong (GTZ Technical Officer)
- Ms. Nguyen Thi Viet Phuong (GTZ Technical Officer)

3.1 Overview

The mangroves of Kien Giang Province in South Vietnam are a highly valuable resource. These unique coastal forests provide multiple ecosystem services including; carbon storage, wood production for building, fish trap construction and firewood, habitat for aquatic food resources and most importantly shoreline stability and erosion reduction. Increased fragmentation of these forests has reduced their capacity to withstand physical processes such as wave action, coastal currents and wind that are related to their location on a semi-exposed coastline. Consequently large areas of coastline are currently eroding or are at risk of erosion in the near future (Figure 21). This coastal erosion problem is not only removing the mangrove resource and associated ecosystem services, but directly threatens the livelihoods of numerous people and greatly increases the vulnerability of Kien Giang Province to the effects of predicted sea-level rise and storm surges associated with large storms and typhoons. The solution to this problem is through an integrated approach to the restoration and re-establishment of mangrove forests at both the landward and coastal margins to restore the natural vegetation buffer that has previously protected the Kien Giang coastline from the forces of the sea. Such efforts will only be successful if effective management solutions are implemented to protect the mangrove resource. Future strategies must include education, improved monetary value of the mangrove resource and the establishment of alternative locally managed wood sources. To achieve effective coastal protection it is necessary to assess and quantify the current condition of the shoreline and the mangrove resource in order to identify, locate and quantify the full extent of the issues that directly threaten mangroves and reduce their resilience to coastal erosion processes.

Figure 21: Actively eroding mangrove, Kien Giang province, Vietnam.

The GTZ Kien Giang Biosphere Reserve project addresses the problem of coastal erosion and is designed to assist with the development and implementation of both management and on-ground solutions in Kien Giang Province. The rapid video survey of the Kien Giang coastline is a sub-component of the GTZ Kien Giang Biosphere Reserve project.

3.2 Objectives of Shoreline Surveys

Here we identify and describe the physical condition of the shoreline margin and quantify the extent, condition, use and threats to the shoreline mangrove resource along the entire coastline of Kien Giang Province.

This information is needed for coastal management planning and policy development – especially related to shoreline rehabilitation and expansion of appropriate shoreline livelihood projects in the face of sea level rise.

The aims of the rapid video assessment were to;

1. Quantify shoreline physical condition – Substrate and erosion
2. Categorize and quantify shoreline mangrove forest type, extent and condition
3. Identify and quantify shoreline mangrove resource use
4. Identify and quantify threats to the shoreline mangrove resource

Achievement of these aims will;

- Improve capacity to raise awareness regarding the scale and severity of the problem of coastal erosion.
- Highlight areas most requiring mangrove restoration and re-establishment.
- Inform the implementation of the most locally appropriate restoration strategies.
- Maximise cost-effective resource allocation to mangrove protection in areas where it is needed most.

3.3 Methods: Shoreline Video Surveys

Coastal erosion directly influences the shoreline margin and the associated shoreline mangrove fringe. To effectively assess and manage coastal erosion it is therefore necessary to focus on changes occurring at this margin. For the purposes of this study it was deemed necessary to include a detailed survey of the entire shoreline of Kien Giang Province to complement remote sensing and plot based assessment. The Shoreline Video Assessment method, developed at the University of Queensland, was used to achieve such a broadscale, detailed assessment of shoreline condition.

The Shoreline Video Assessment Method (SVAM) relies on qualitative assessments of shoreline habitat, physical condition and human influence determined from continuous video recordings of the shoreline and intertidal zone of a coastline. The video is analysed for a number of features that relate to the 'condition' of the coast. Simultaneous GPS data enables shoreline features to be mapped, providing a spatial representation of shoreline habitats and their condition. Qualitative interpretations made during analysis are based on quantitative baseline plot surveys and field observations.

The SVAM enables a rapid, cost-effective assessment of shoreline condition that requires little expertise for data collection, enables detailed assessment of shoreline features and is repeatable for future monitoring purposes. The use of video provides a permanent record of shoreline condition from which to assess future change.

3.3.1 Video Recording

A video of the shoreline was taken using a Sony Handycam from a boat running parallel to the coastline approximately 25m from the shore (Figure 22). A GPS was used to record latitude and longitude every 3 seconds. Both the GPS and Handycam were set to the exact same time.

Figure 22: Recording video imagery of the coastline: ~180 km and many hours.

3.3.2 Video Assessment

The video was assessed as a continuous point intercept transect of the coast.

Video of the coastline was reduced to 1 second frame .jpg files. The time of the video and GPS was used to match each frame to a specific GPS location. Each frame that matched a GPS position was used as a point on the transect. The shoreline features in each frame were then scored. Only the initial 20m intertidal zone visible in the frame and/or the directly adjacent terrestrial habitats (if visible) were used for assessment.

Criteria for Assessment

The SVAM was used to assess the following shoreline features;

Shoreline Habitat Type

Shoreline Physical Characteristics: *Intertidal / Coastal Substrate*, *Coastline Condition* – Erosion Severity, *Erosion Assessment* - Active/ inactive**,** *Bank Slope*

Shoreline Vegetation (mangrove) Characteristics: *Mangrove Forest Structure, Dominant Mangrove Genus****,*** *Mangrove Biomass* – Density and Height

Mangrove Resource Use: Fish Trap/ Aquatic organism harvesting, Wood Collection**,** Planted Nypa

Threats to mangroves: Herbivory, Mangrove removal (Reclamation), Litter accumulation (Root burial).

Mangrove Planting Activity*:* Presence of a mangrove planting fence and seedling density/condition.

Description of Shoreline Features

Shoreline Habitat Type

The dominant shoreline habitat type was defined within each frame. These were classified as;

Mangrove: Shoreline mostly mangrove forest

Terrestrial: Shoreline mostly covered terrestrial vegetation (trees and grass). This category was used where the intertidal zone was absent or extremely limited. Not sandy beach or rocky shore.

Mangrove & Terrestrial: Shoreline a mixture of both mangrove and terrestrial trees. This category was used when the mangrove zone was limited in width (<5m).

Sandy Beach: Presence of a gently sloped shoreline with sandy substrate and intertidal vegetation absent.

Rocky Shore: Substrate dominated by rock with no or sparse vegetation cover. Often steep or sheer.

Urban/Developed: The presence of built structures in the intertidal zone or directly adjacent to the shoreline.

Shoreline Substrate

The shoreline substrate was defined as either; **Mud, Sand, Earthen Wall, Rock, Wall**.

Erosion Severity

The coastline was classified as **severely eroded, moderately eroded, slightly eroded, stable, depositional and armoured sea wall (cement, rock**). Erosion severity was determined using qualitative assessment of exposed sediment layers, slope, exposed roots of mangroves and mangrove condition, fallen trees and exposed/ degraded mud wall/dyke. Depositional shoreline was determined from the presence of mangrove seedlings and/or an obvious shallow mud apron extending seaward from the shoreline. Stable shoreline had no obvious erosion and deposition present. Armoured sea wall was any continuous built hard surface structure present along the shoreline.

Active/Inactive Erosion
Erosion was classified as either **active** (occurring continuously) or **inactive** (present but occurring in the past as a result of infrequent events such as storms and cyclones). The presence of recently fallen trees was used to determine whether erosion was active or inactive.

Shoreline Slope
Bank slope was determined from the steepness of the intertidal zone. The slope was classified as **Gentle, Moderate, Steep landward edge with gently sloping seaward margin, Steep seaward edge with gently sloping landward margin, Steep, Sheer**.

Mangrove Forest Structure
Mangrove forest structure was categorized according the visible growth forms of trees leading to an overall forest appearance that indicates structure. Mangrove forest structure was classified as;

Continuous: Dense continuous shoreline cover of mangrove trees of even height along the shoreline showing a clear height gradient delineation between mangrove and the edge of the intertidal zone.
Fragmented: Dense forest with obvious gaps associated with tree felling/erosion, often showing the presence of fallen and dead trees.
Regrowth/Recovery: Continuous forest along the shoreline, but with mangrove tree height variability suggesting infilling of previous forest gaps.
Prograding: Continuous forest along the shoreline with a gradual decline in tree height towards the seaward mangrove margin suggesting trees of increasing age with distance from the mangrove edge and mangrove expansion to the sea.
Sparse: Non-continuous forest with large gaps between trees, but an overall coverage of the shoreline edge (may be only one tree in width along the shore).
Scattered: Only a few mangrove trees present along the shoreline.

Dominant Mangrove Genus
The dominant mangrove genus was determined for each frame with mangroves present. The dominant species was assessed as the genus which made a clear majority of the mangrove trees along the coastal fringe (not the forest behind). Genus was determined by growth form, leaf colour and root structures present in the frames. Where no dominant genus could be determined, or the forest was an even mix of multiple genus, the forest was classified as mixed.

Mangrove Biomass
The mangrove biomass was determined from qualitative assessments of mangrove forest density and relative heights. The shoreline fringing forest was classified as **dense, medium, sparse** and **scattered** dependent on the spacing between trees, canopy continuousness and forest width. Height was classified as **tall (>10m), medium (3-10m), short (<3m)** based on visual estimates using known forest heights as a reference. The combination of density and height was used to classify fringing forest biomass as high (e.g. tall, dense forest), medium (e.g. short, dense forest) and low (e.g. sparse, medium forest).

Fish Trap/ Aquatic organism harvesting
The presence of permanent fish traps and visible aquatic organism harvesting activities observed in the video frame were recorded.
Wood Collection
Wood collection activity was quantified as cutting severity. The presence and density of cut branches, stumps and felled trees was used to classify cutting severity as either **present** (one or two trees cut), **moderate** (some trees cut, easily noticeable in the frame), **severe** (obvious presence of many cut stumps), **extreme** (majority of shoreline trees cut).

Planted Nypa
The presence of dense Nypa stands with evidence of cut fronds was recorded to indentify Nypa frond harvesting presence.

Threats to Mangroves

Herbivory*:* The occurrence of severe herbivory on trees of the *Avicennia* genus was recorded. Herbivory was visible in the frame as a light brown hue on trees, resulting from the herbivore (an unidentified caterpillar) consuming the leaf blade leaving the leaf skeleton.

Recent Mangrove Removal (Reclamation*):* Areas of shoreline where mangroves had obviously been recently removed for dyke/canal/ industrial construction was recorded.

Litter accumulation*:* Litter accumulation was recorded for shoreline which had obvious litter accumulation along the shoreline.

Mangrove Planting Activity
Mangrove planting activities in Kien Giang generally occur behind a mangrove planting fence, consisting of rows of two stakes crossed to form an X. Areas with dense to moderate seedling/sapling cover present behind the 'planting fence', were recorded as successful planted areas. Areas with few or no seedlings/saplings present behind the fence were considered to be unsuccessful planting areas.

Figure 23: Recently planted mangroves in An Bien region. Note planting fence on the right

3.4 Results

3.4.1 Results Summary

- Mangroves are present on 74% of the shoreline of Kien Giang province. However, nearly a quarter of this area (30km) is experiencing active mangrove loss due to erosion (Figure 24).
- Overall, one-third (58km) of the coastline is eroded or eroding.
- 78% of mangroves along the shoreline have high biomass (although they may be limited in width). Pressure on these forests through cutting is evident along 77km of coastine, affecting 58% of the mangrove area along the shoreline.
- 50% of recent past mangrove plantings have been successfull.
- 80% of fish traps are associated with mangroves present along the shoreline.

Table 4: Summary of key findings from the shoreline surveys

Shoreline Habitat[1]	**km**	**%**
Mangrove	**117**	**65**
Terrestrial Fringe	10	5
Mangrove & Terrestrial	10	6
Sandy Beach	4	2
Rocky Shore	12	7
Human Settlement	21	12
Waterways - Total	6	3
Natural Creek	0.3	<1
Exposed Channel	0.6	<1
Canal	3	2
River	2	1
TOTAL DISTANCE	180	

[1]Figures 25- 30

Shoreline Erosion[2]	**km**	**%**
Severe Erosion	19	11
Eroded	21	12
Minor Erosion	18	11
Stable	74	43
Depositional	29	16
Hardened/ Sea-wall	14	8
Total Eroded	58	33
Total Eroded - Of concern	30	23

[2]Figures 37 - 42

Exposed Mud Wall	**km**	**%**
Stable	**5**	**3**
Eroding	8	4
Degraded/Breached	11	6
Total Exposed Wall	**24**	**13**

Mangrove Forest Structure[3]	**km**	**% mangrove**
Continuous	**53**	**40**
Fragmented	24	18
Regrowth/ Recovery	11	8
Prograding/ Expanding	24	18
Planted	5	4
Sparse	10	7
Scattered	7	5
Total Mangrove Presence	134	74

[3]Figures 49 - 54

Mangrove Biomass[4]	**km**	**%**
High	105	74
Medium	19	14
Low	10	8
Average Biomass Score	**3.4 (High)**	

[4]Figures 61 - 66

Mangrove Loss[5]	**km**	**%**
Active Mangrove Loss	30.8	23
Eroded Mangrove	18.9	14
Stable Mangrove	57.6	43
Prograding Mangrove	28.1	21

[5]Figures 31 - 36

Table 4 continued: Summary of key findings from the shoreline surveys

Mangrove Cutting[6]	km	% mangrove
None	57	42
Present	48	37
Moderate	23	17
Heavy	6	4
Extreme/ All	0.4	0.3
Overall Cutting Pressure	**77**	**58**
Cutting in Eroding Mangrove		

[6]Figure 68

Herbivory – Catepillar[7]	km	% mangrove
Affected Mangroves	13.5	10

[7]Figure 69

Recent Mangrove Removal - Reclamation	km	% Coastline
Removed Mangrove	1.7	1

Dominant Genus[8]	km	% mangrove
Avicennia	**67**	**50**
Sonneratia	25	19
Rhizophora	12	9
Nypa	2	1
Mixed	28	21

[8]Figures 55 - 60

Litter Accumulation	km	% Coastline
Litter	7	4

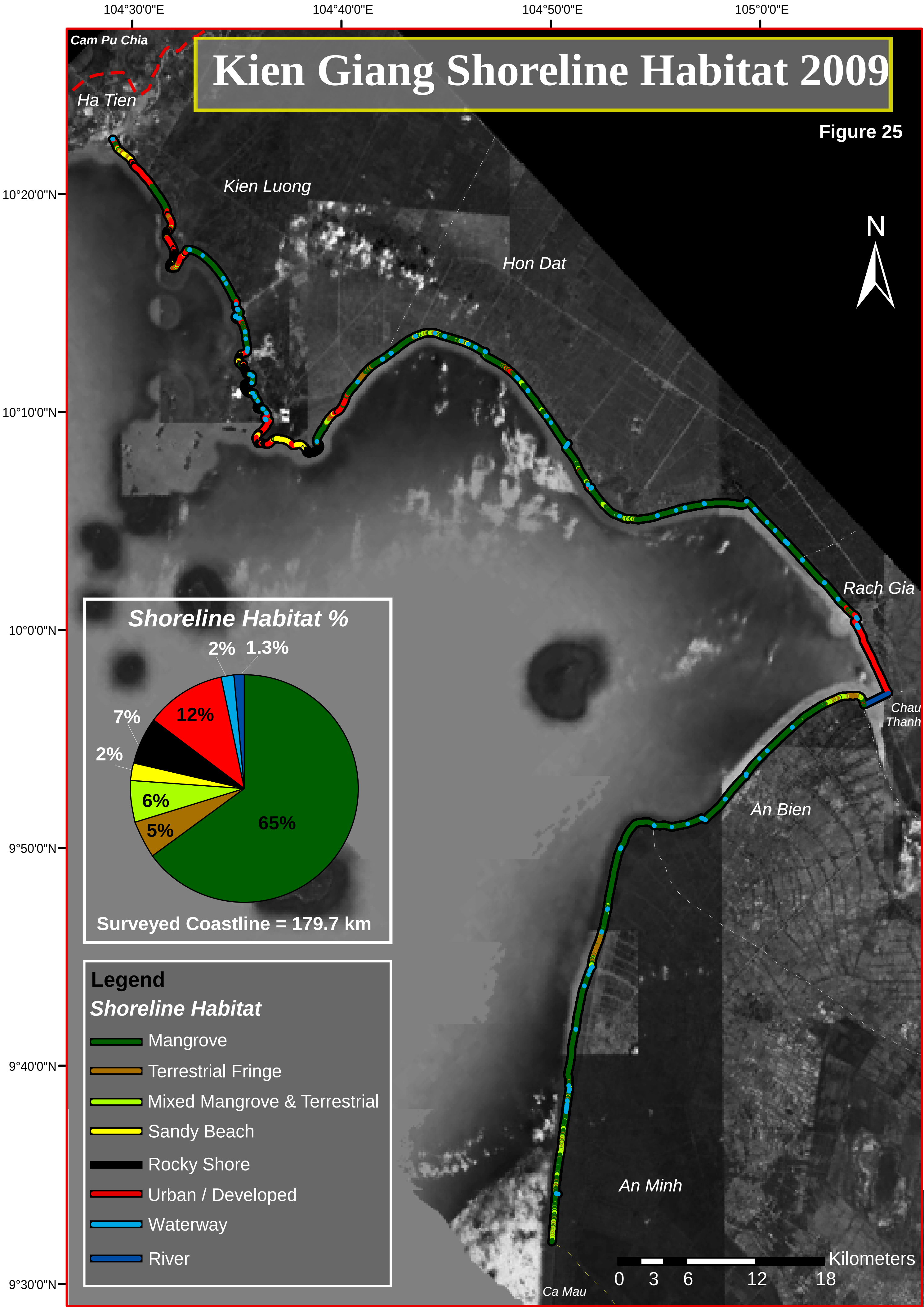
Mangrove Planting[9]	km	%
Fenced	27	15
Success	13	50
Failure	13	50

[9]Figure 70

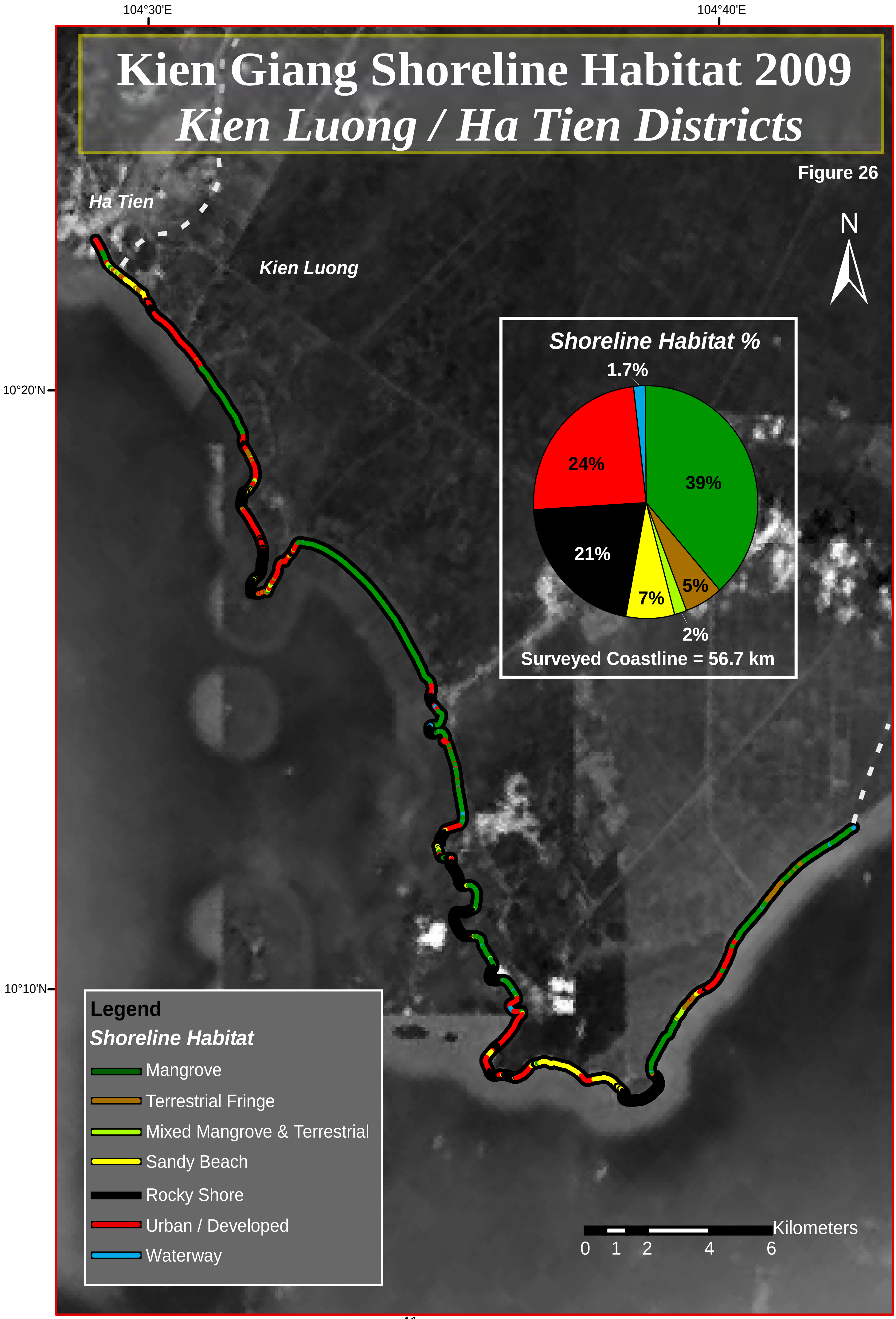
Mangrove Use[10]		
Fish Traps	31	18
Fish Traps associated with mangrove		80
Nypa	6	3
Human Settlement	7	6

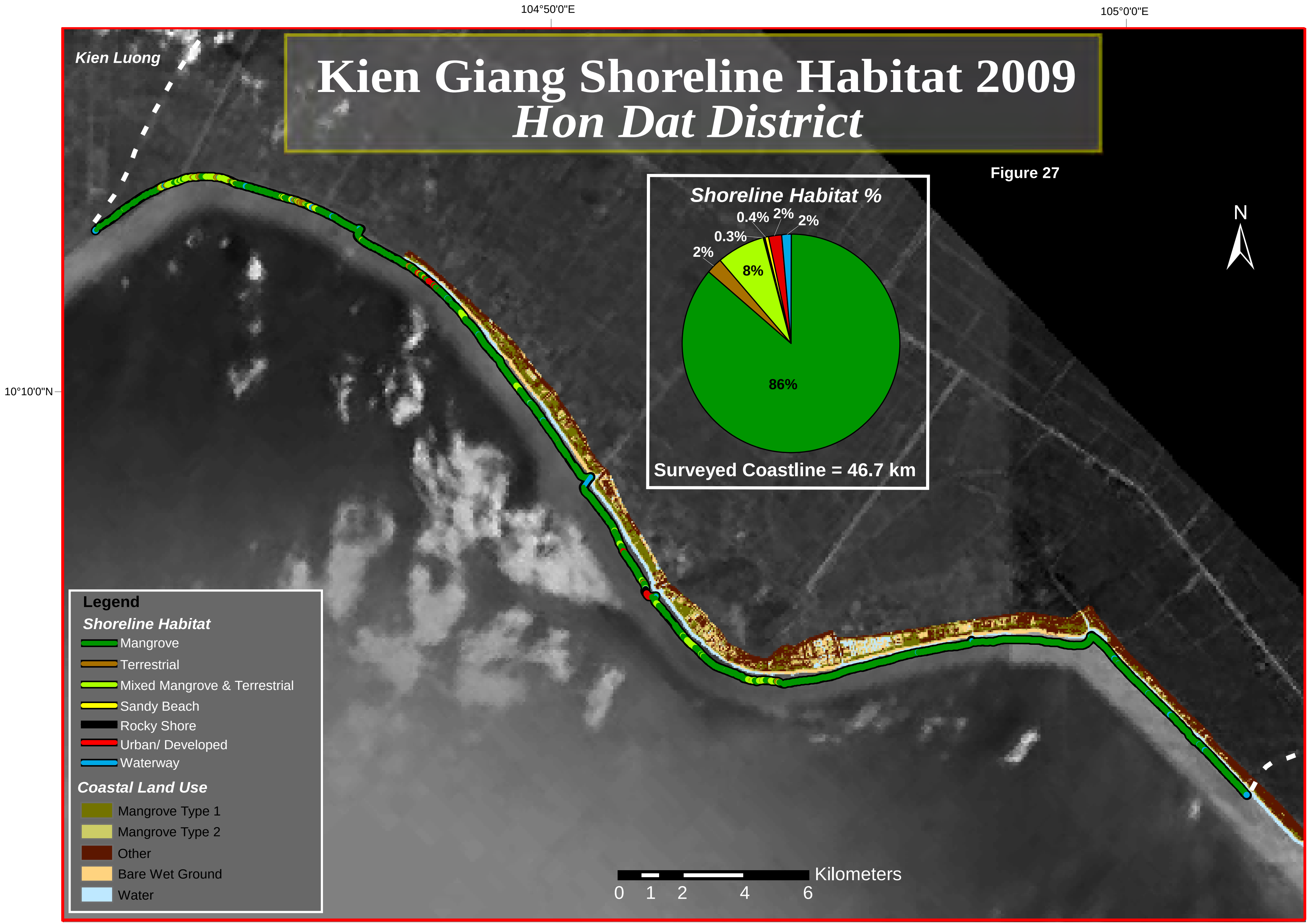
[10]Figure 67

Figure 24: Much of the mainland coast of Kien Giang province is eroding, observed by falling trees, exposed roots, undercut banks, and abandoned houses.

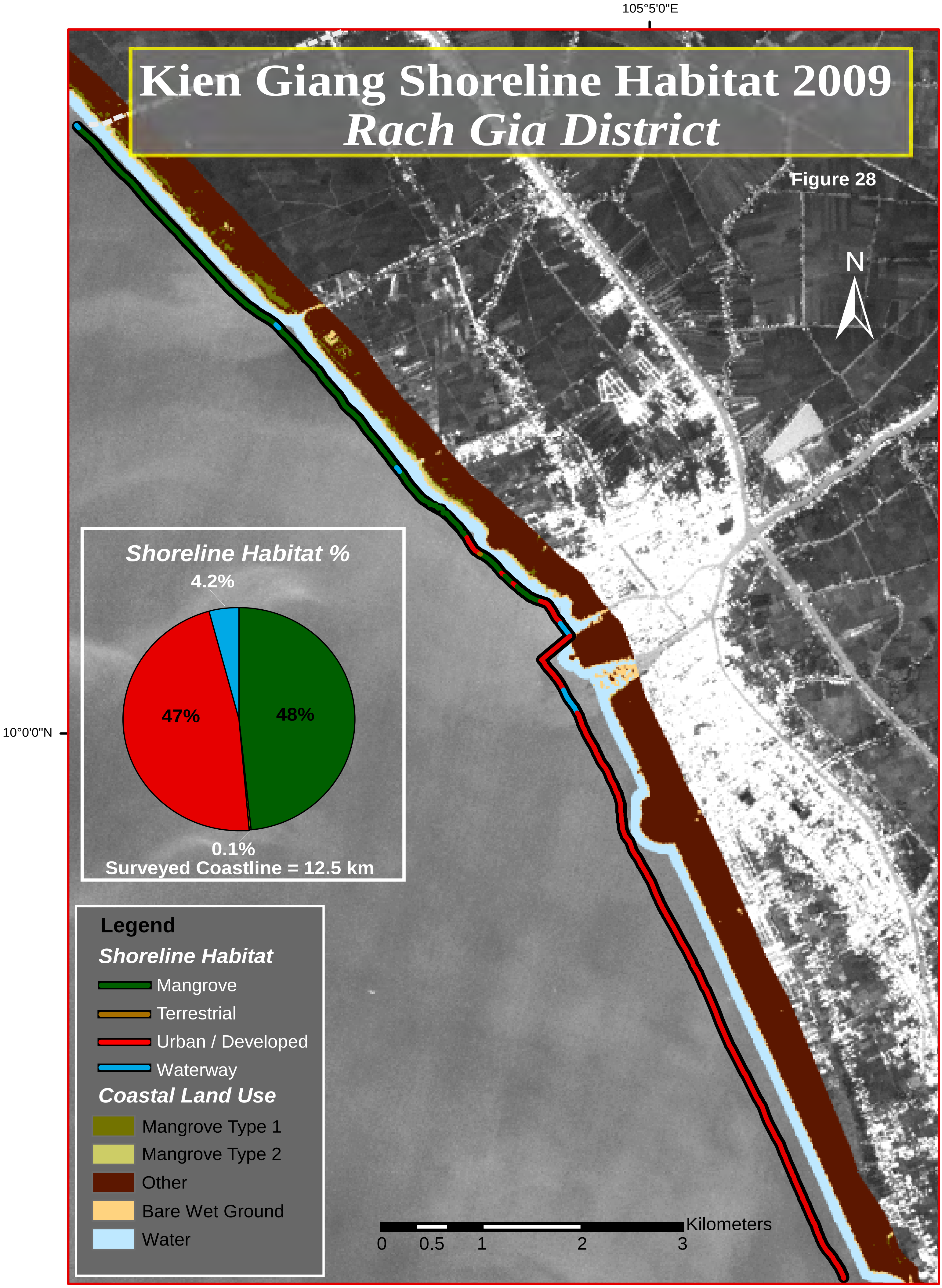


Kien Giang Shoreline Habitat 2009
Figure 25
104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Cam Pu Chia
Ha Tien
Kien Luong
Hon Dat
Rach Gia
Chau Thanh
An Bien
An Minh
Ca Mau
N
Shoreline Habitat %
2%
1.3%
7%
12%
2%
6%
5%
65%
Surveyed Coastline = 179.7 km
Legend
Shoreline Habitat
Mangrove
Terrestrial Fringe
Mixed Mangrove & Terrestrial
Sandy Beach
Rocky Shore
Urban / Developed
Waterway
River
0 3 6 12 18
Kilometers

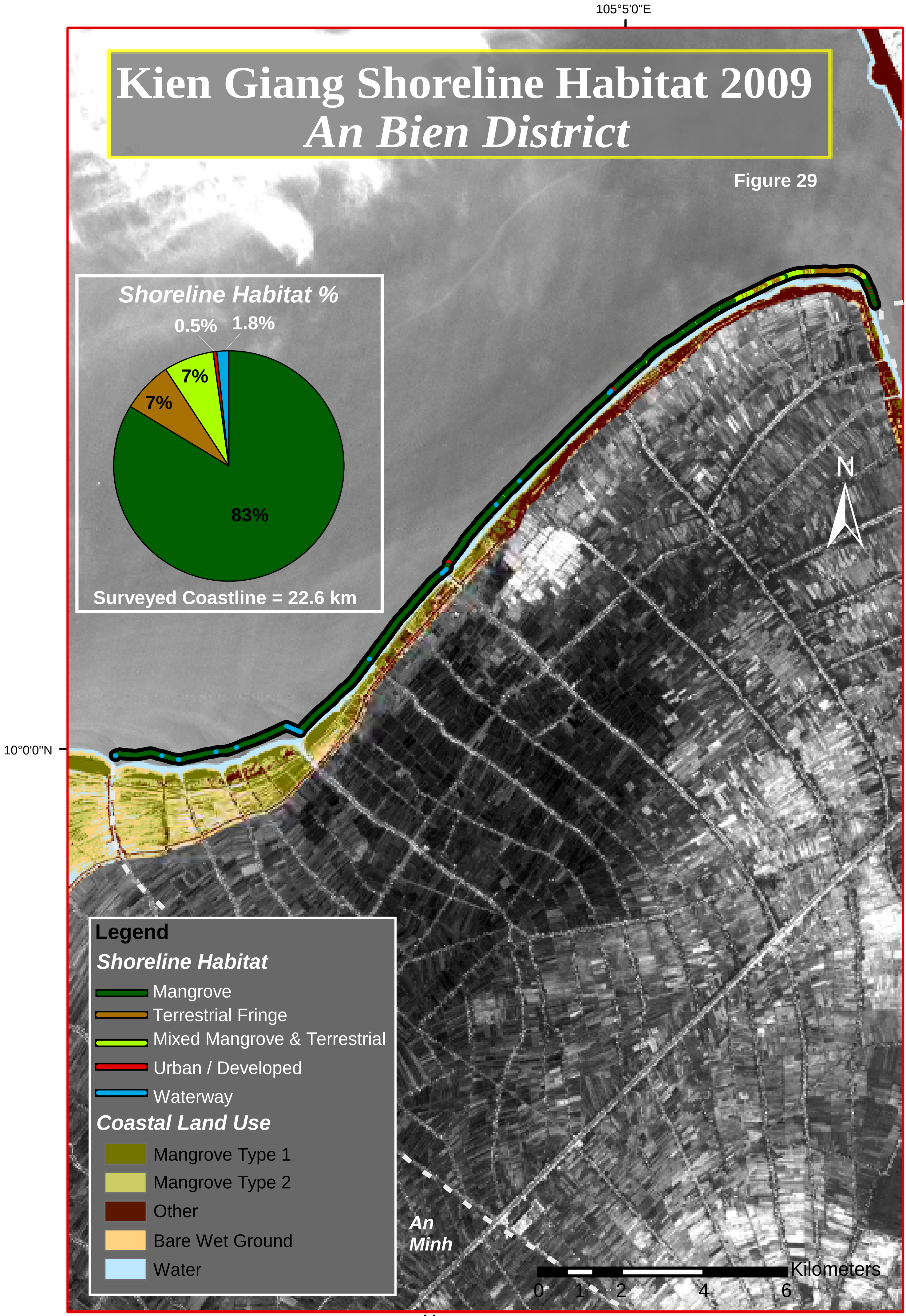

104°30'E
104°40'E
Kien Giang Shoreline Habitat 2009
Kien Luong / Ha Tien Districts
Figure 26
Ha Tien
Kien Luong
N
10°20'N
10°10'N
Shoreline Habitat %
1.7%
24%
39%
21%
7%
5%
2%
Surveyed Coastline = 56.7 km
Legend
Shoreline Habitat
Mangrove
Terrestrial Fringe
Mixed Mangrove & Terrestrial
Sandy Beach
Rocky Shore
Urban / Developed
Waterway
Kilometers
0 1 2 4 6

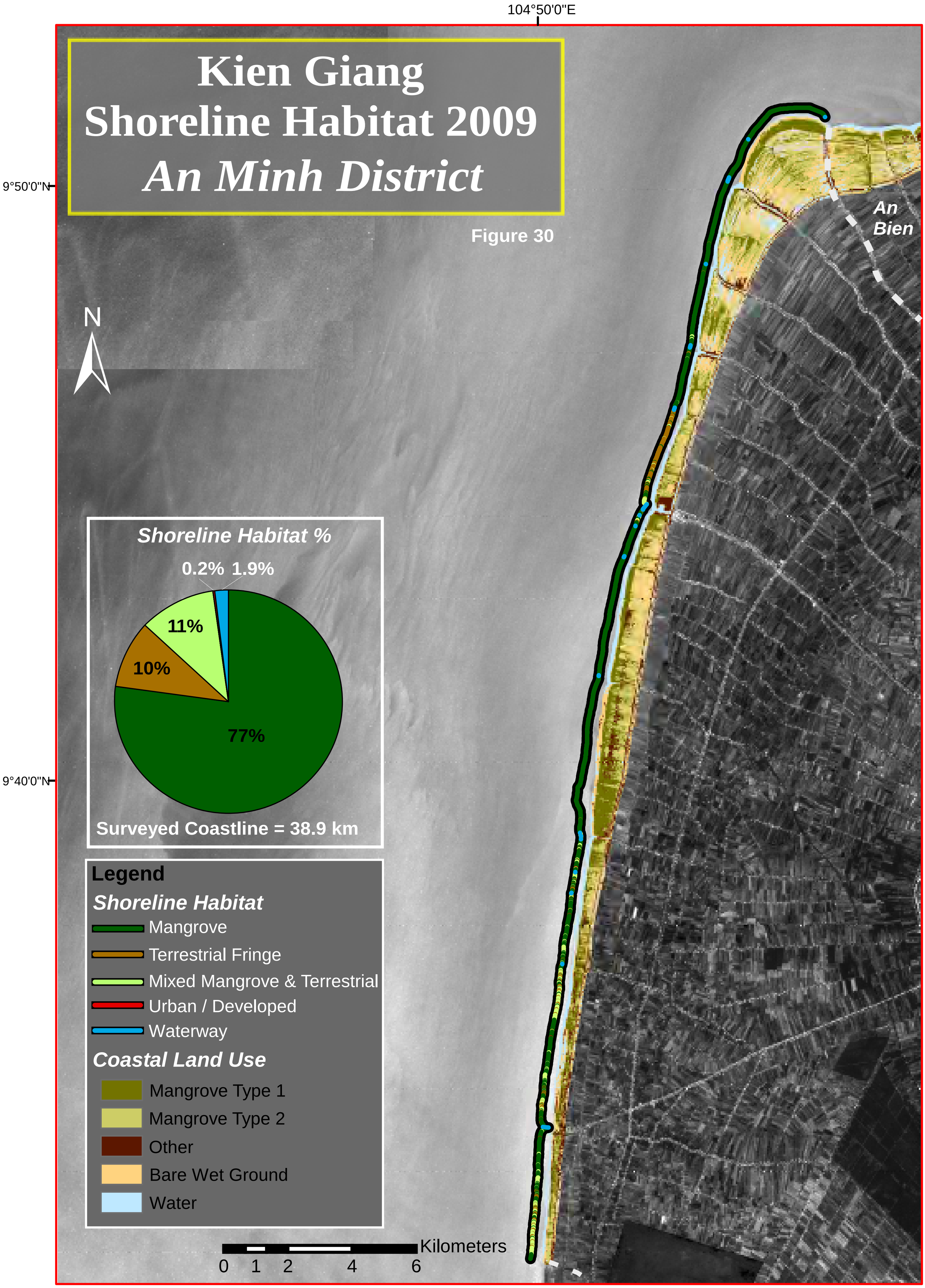


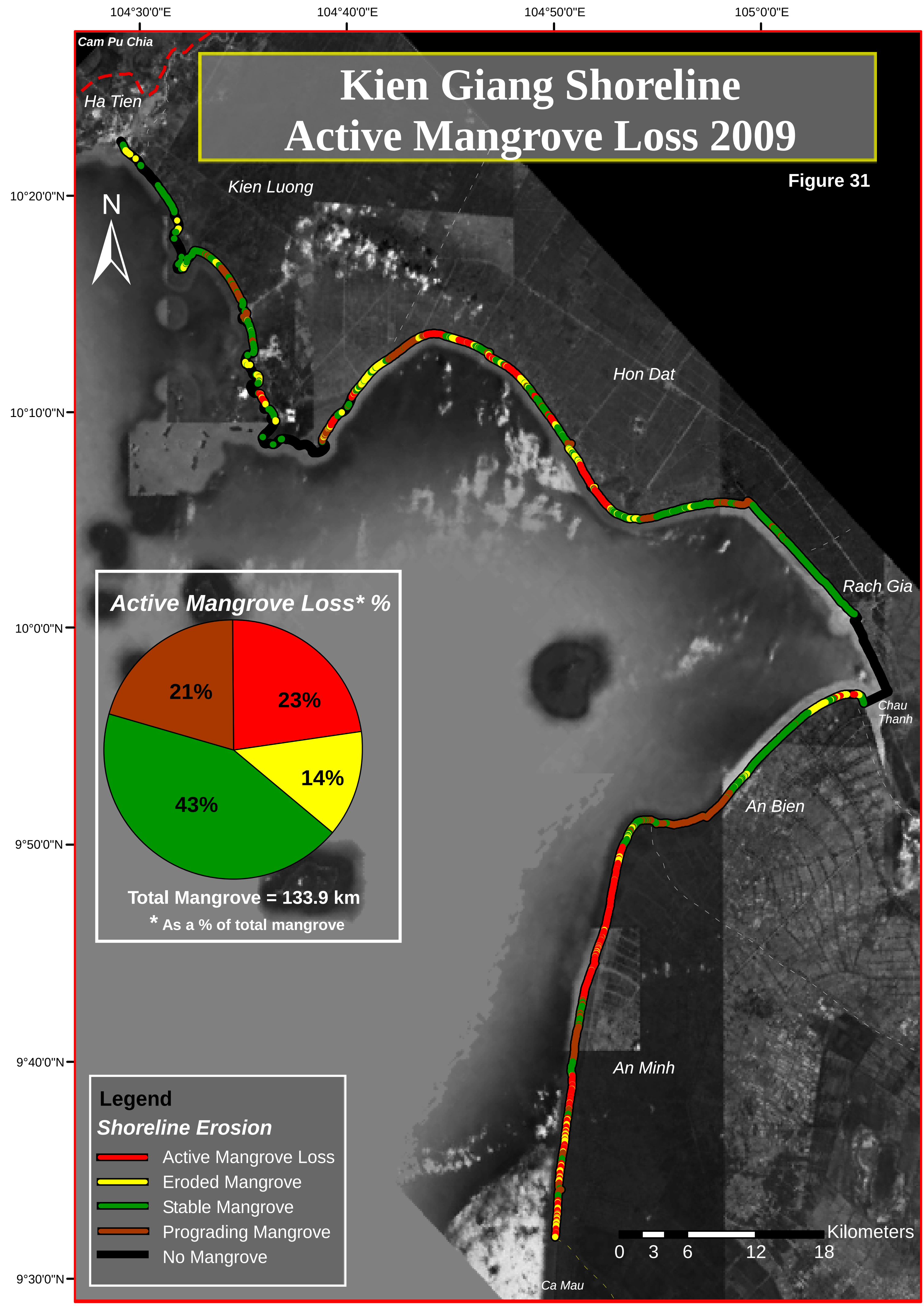
104°50'0"E
105°0'0"E
10°10'0"N
Kien Giang Shoreline Habitat 2009
Hon Dat District
Kien Luong
Figure 27
Shoreline Habitat %
0.4%
2%
2%
0.3%
2%
8%
86%
Surveyed Coastline = 46.7 km
N
Legend
Shoreline Habitat
Mangrove
Terrestrial
Mixed Mangrove & Terrestrial
Sandy Beach
Rocky Shore
Urban/ Developed
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0
1
2
4
6

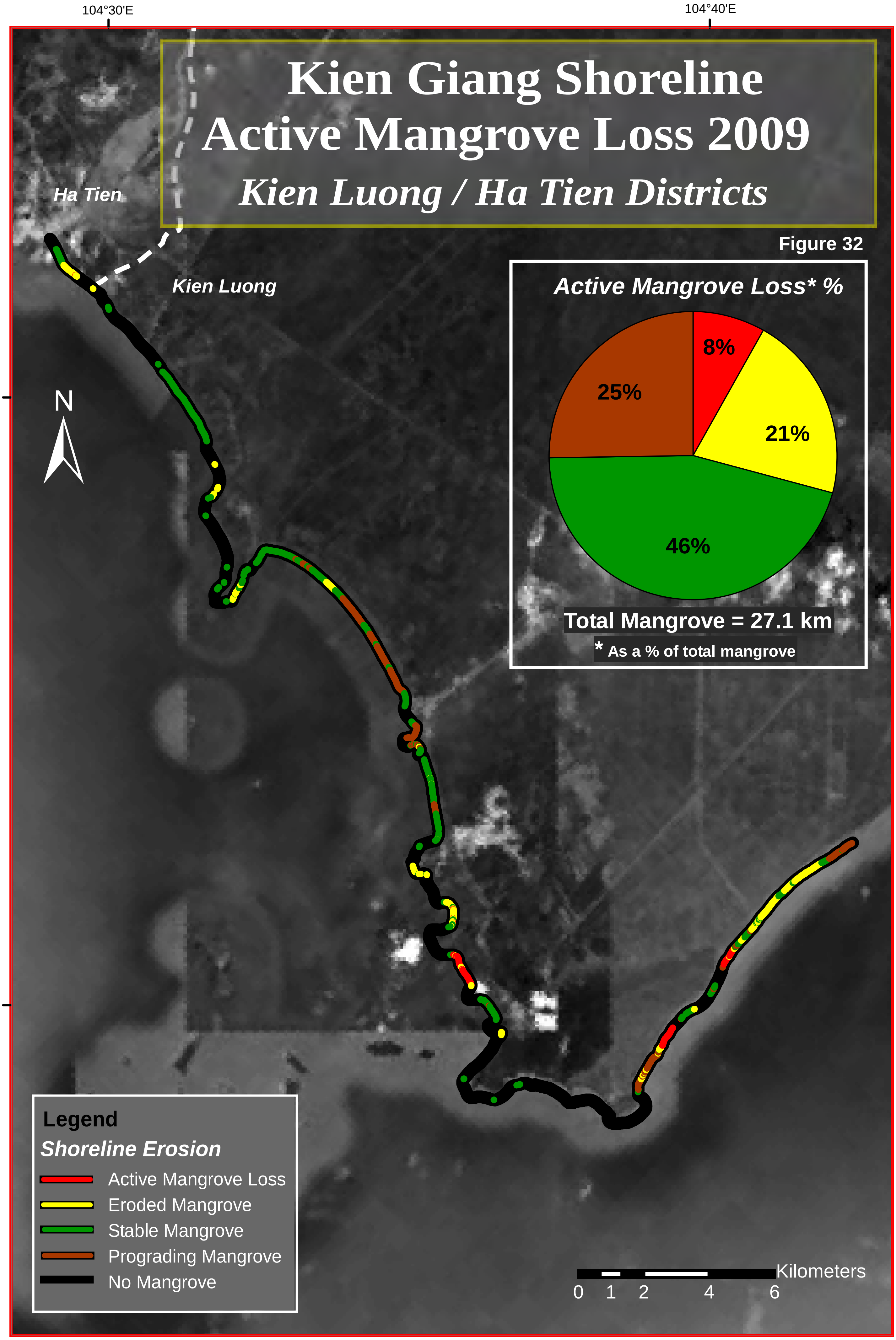


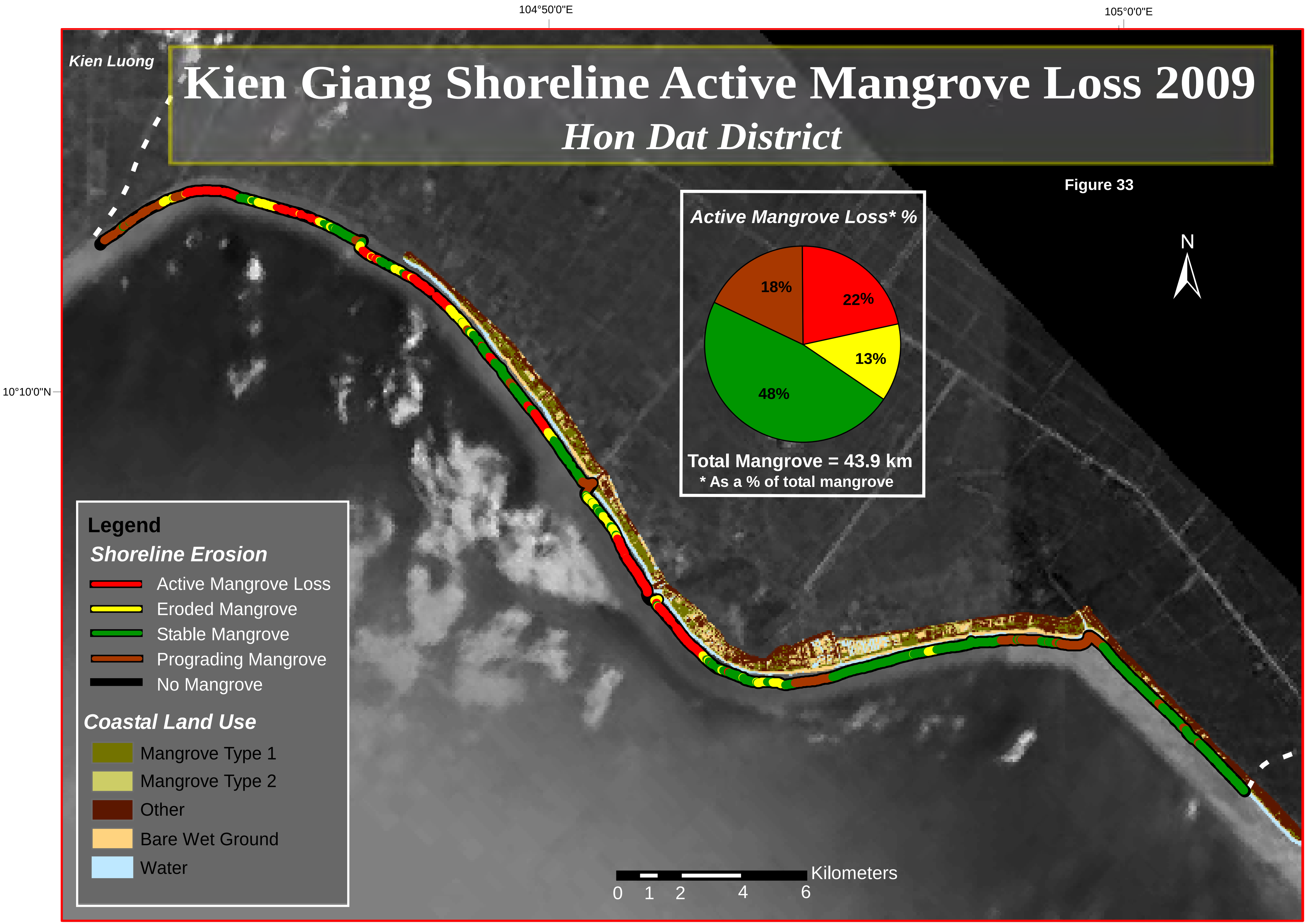
105°5'0"E
Kien Giang Shoreline Habitat 2009
Rach Gia District
Figure 28
N
10°0'0"N
Shoreline Habitat %
4.2%
47%
48%
0.1%
Surveyed Coastline = 12.5 km
Legend
Shoreline Habitat
Mangrove
Terrestrial
Urban / Developed
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
0
0.5
1
2
3
Kilometers

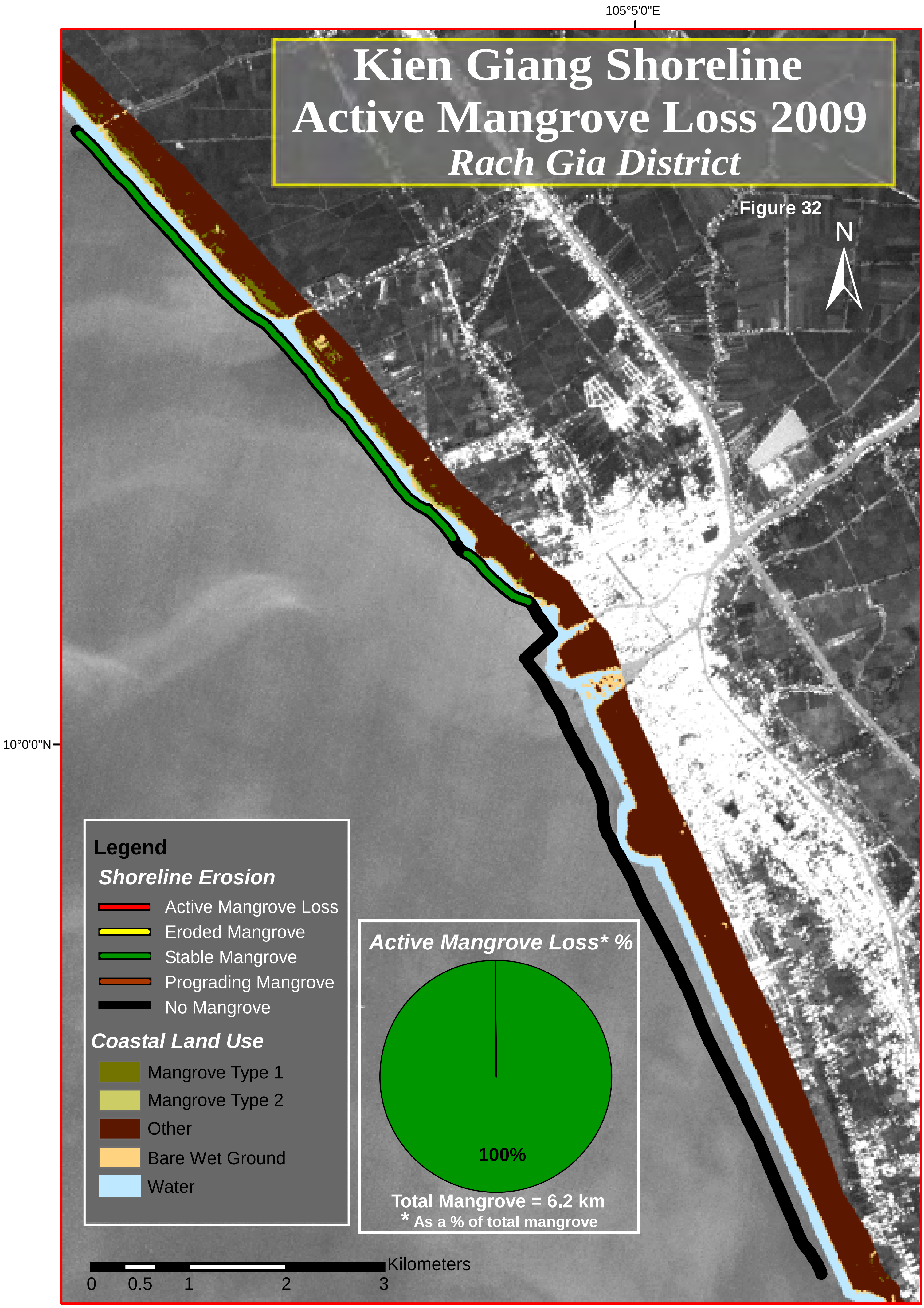

105°5'0"E
Kien Giang Shoreline Habitat 2009
An Bien District
Figure 29
Shoreline Habitat %
0.5%
1.8%
7%
7%
83%
Surveyed Coastline = 22.6 km
10°0'0"N
N
Legend
Shoreline Habitat
Mangrove
Terrestrial Fringe
Mixed Mangrove & Terrestrial
Urban / Developed
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
An Minh
Kilometers
0
1
2
4
6


104°50'0"E
Kien Giang
Shoreline Habitat 2009
An Minh District
Figure 30
9°50'0"N
9°40'0"N
N
An Bien
Shoreline Habitat %
0.2%
1.9%
11%
10%
77%
Surveyed Coastline = 38.9 km
Legend
Shoreline Habitat
Mangrove
Terrestrial Fringe
Mixed Mangrove & Terrestrial
Urban / Developed
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
0 1 2 4 6
Kilometers

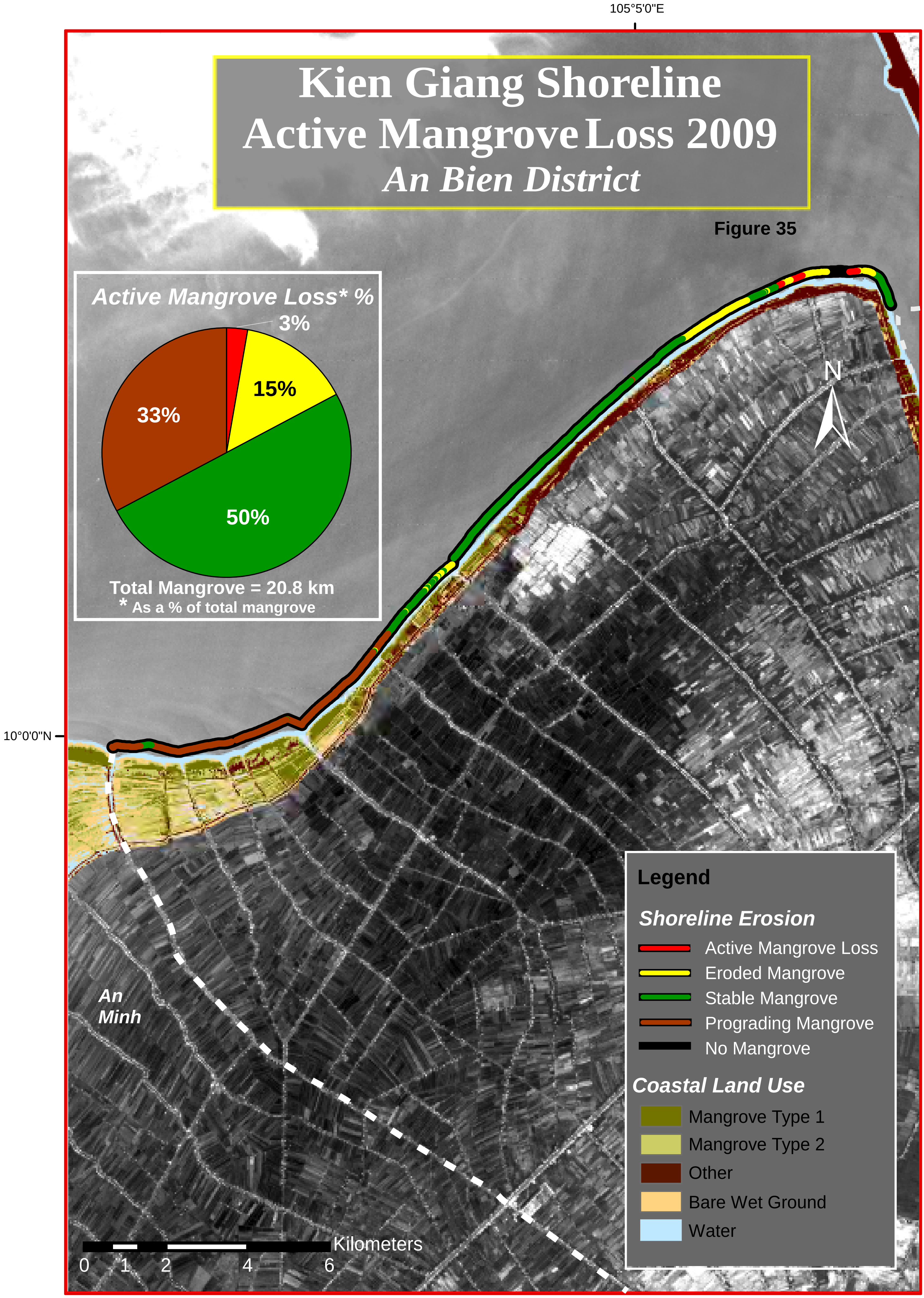

Kien Giang Shoreline
Active Mangrove Loss 2009
Figure 31
104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Cam Pu Chia
Ha Tien
Kien Luong
Hon Dat
Rach Gia
Chau Thanh
An Bien
An Minh
Ca Mau
N
Active Mangrove Loss* %
21%
23%
14%
43%
Total Mangrove = 133.9 km
* As a % of total mangrove
Legend
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
0 3 6 12 18
Kilometers

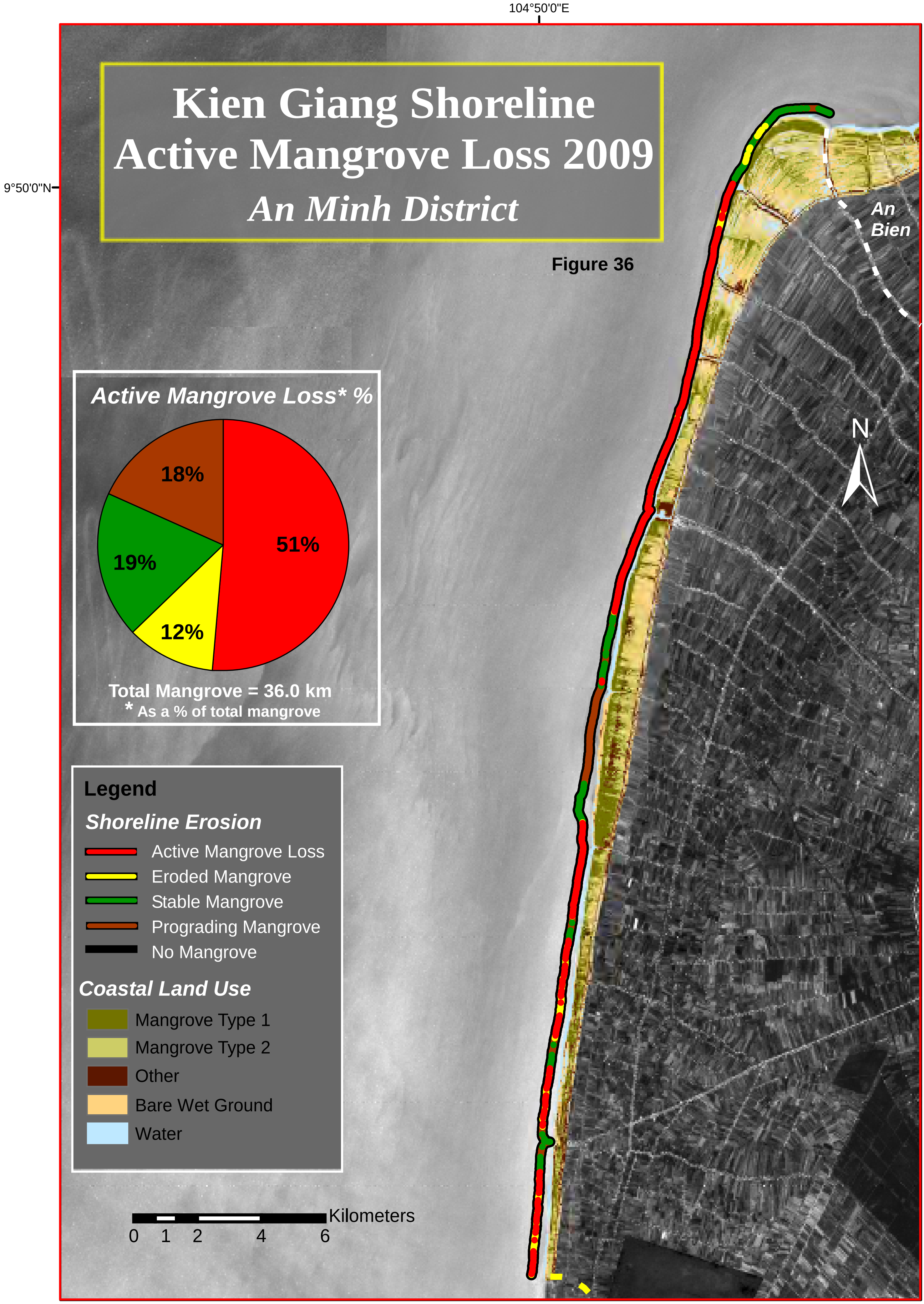

104°30'E
104°40'E
10°20'N
10°10'N
Kien Giang Shoreline
Active Mangrove Loss 2009
Kien Luong / Ha Tien Districts
Ha Tien
Kien Luong
N
Figure 32
Active Mangrove Loss* %
8%
21%
46%
25%
Total Mangrove = 27.1 km
* As a % of total mangrove
Legend
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
Kilometers
0 1 2 4 6


104°50'0"E
105°0'0"E
10°10'0"N
Kien Luong
Kien Giang Shoreline Active Mangrove Loss 2009
Hon Dat District
Figure 33
Active Mangrove Loss* %
18%
22%
13%
48%
Total Mangrove = 43.9 km
* As a % of total mangrove
N
Legend
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6

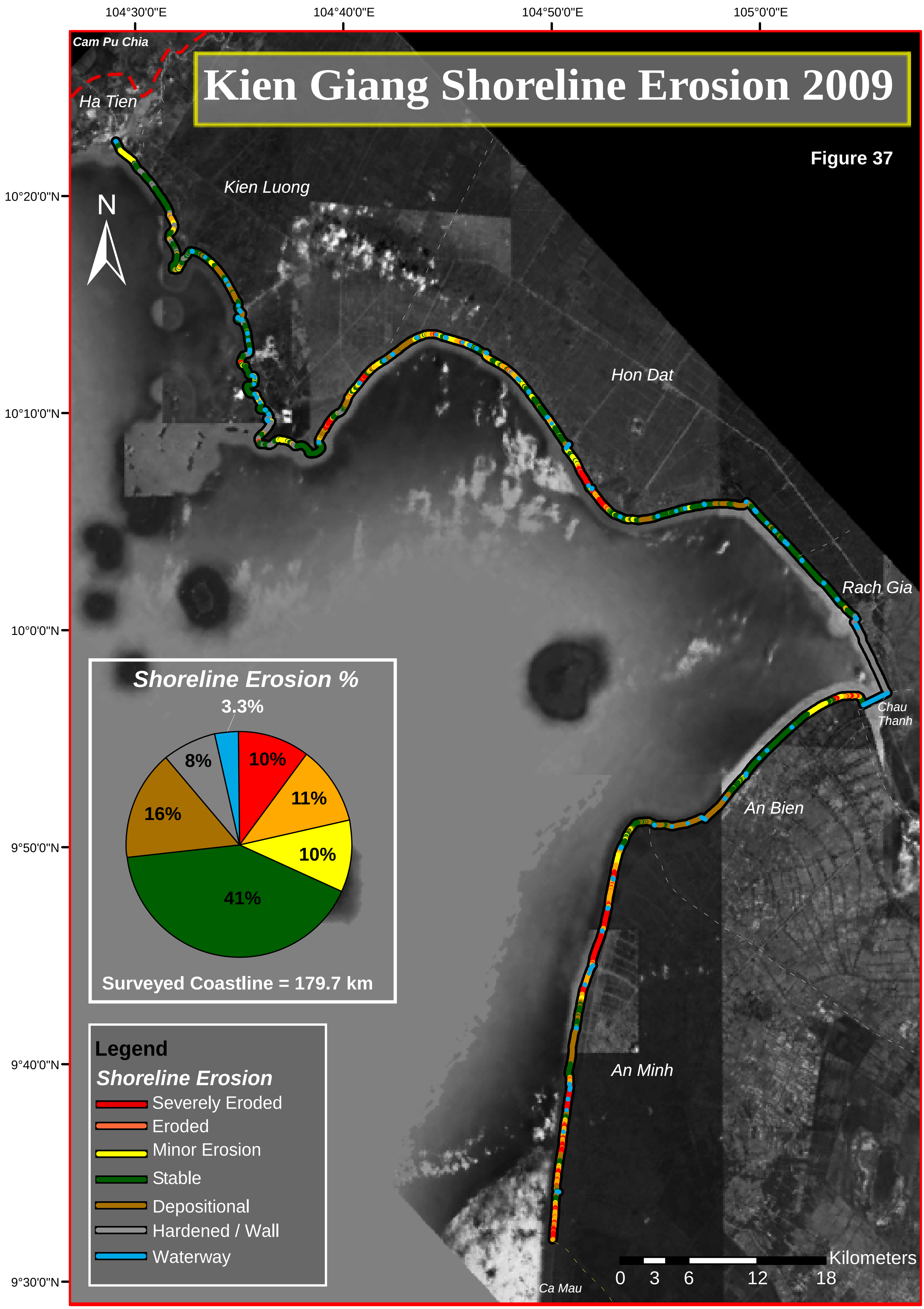


105°5'0"E
Kien Giang Shoreline
Active Mangrove Loss 2009
Rach Gia District
Figure 32
N
10°0'0"N
Legend
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Active Mangrove Loss* %
100%
Total Mangrove = 6.2 km
* As a % of total mangrove
Kilometers
0
0.5
1
2
3

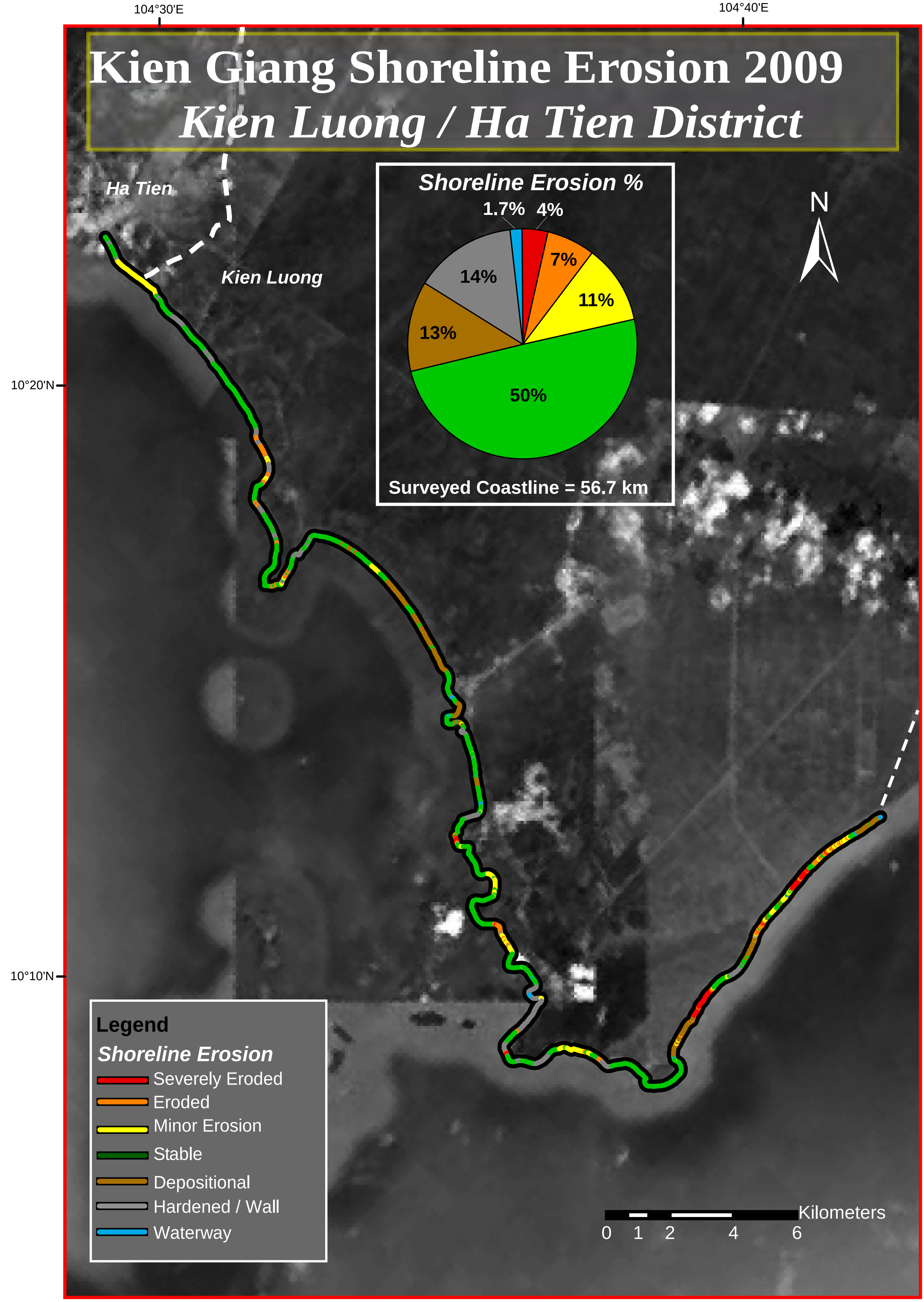

105°5'0"E
Kien Giang Shoreline
Active Mangrove Loss 2009
An Bien District
Figure 35
Active Mangrove Loss* %
3%
15%
33%
50%
Total Mangrove = 20.8 km
* As a % of total mangrove
N
10°0'0"N
An Minh
Legend
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6



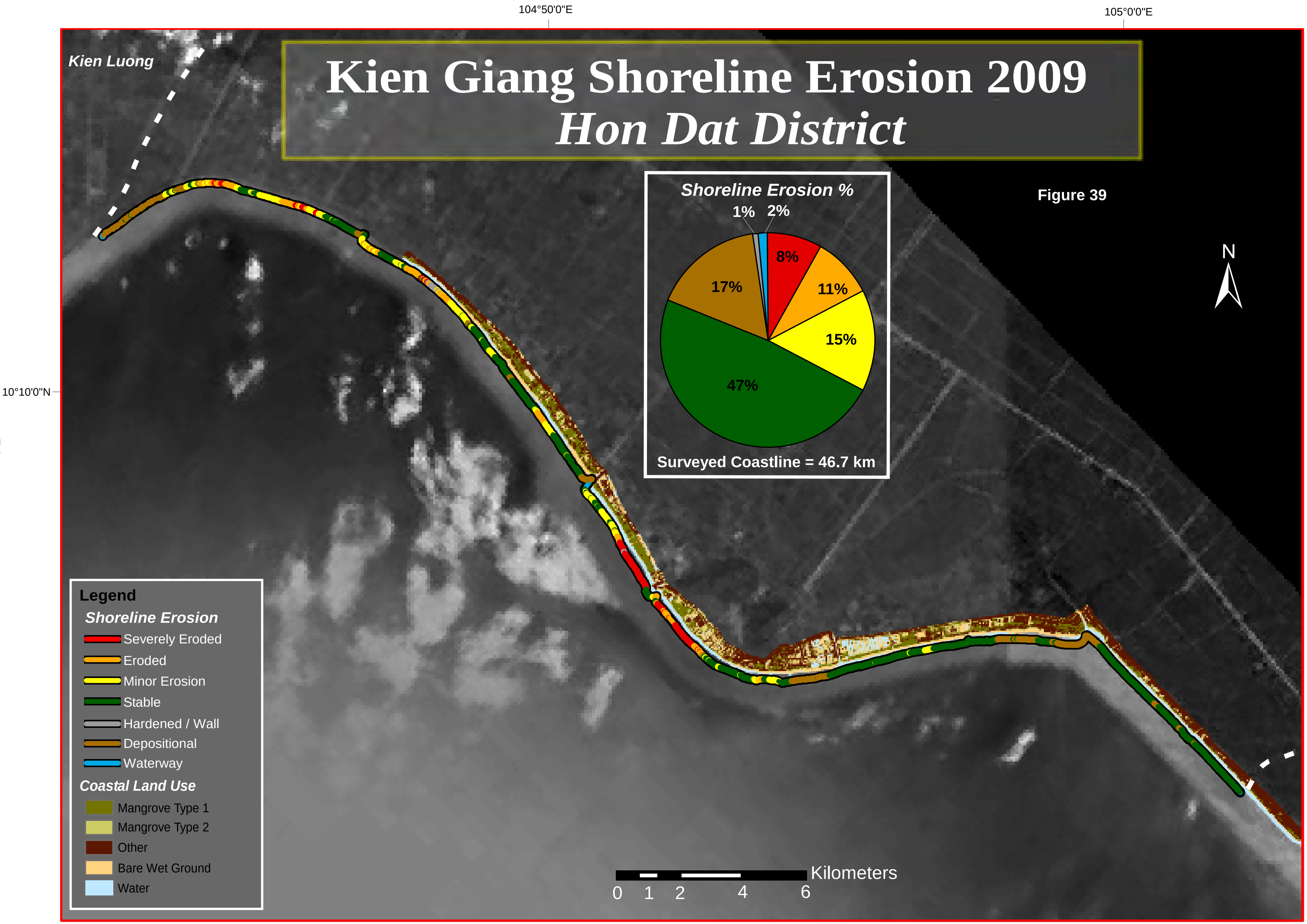
104°50'0"E
9°50'0"N
Kien Giang Shoreline
Active Mangrove Loss 2009
An Minh District
Figure 36
An Bien
N
Active Mangrove Loss* %
51%
18%
19%
12%
Total Mangrove = 36.0 km
* As a % of total mangrove
Legend
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
0 1 2 4 6
Kilometers

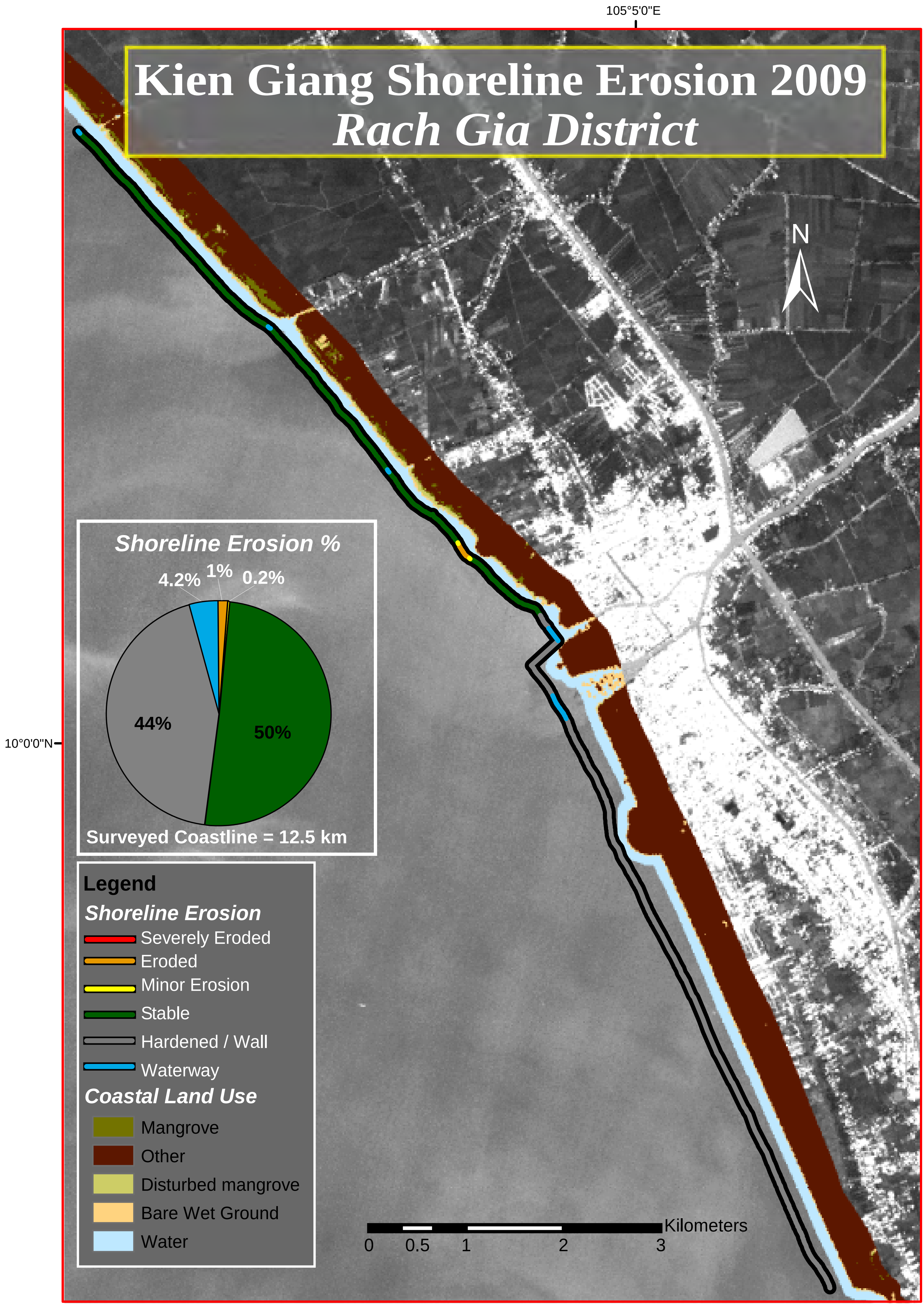


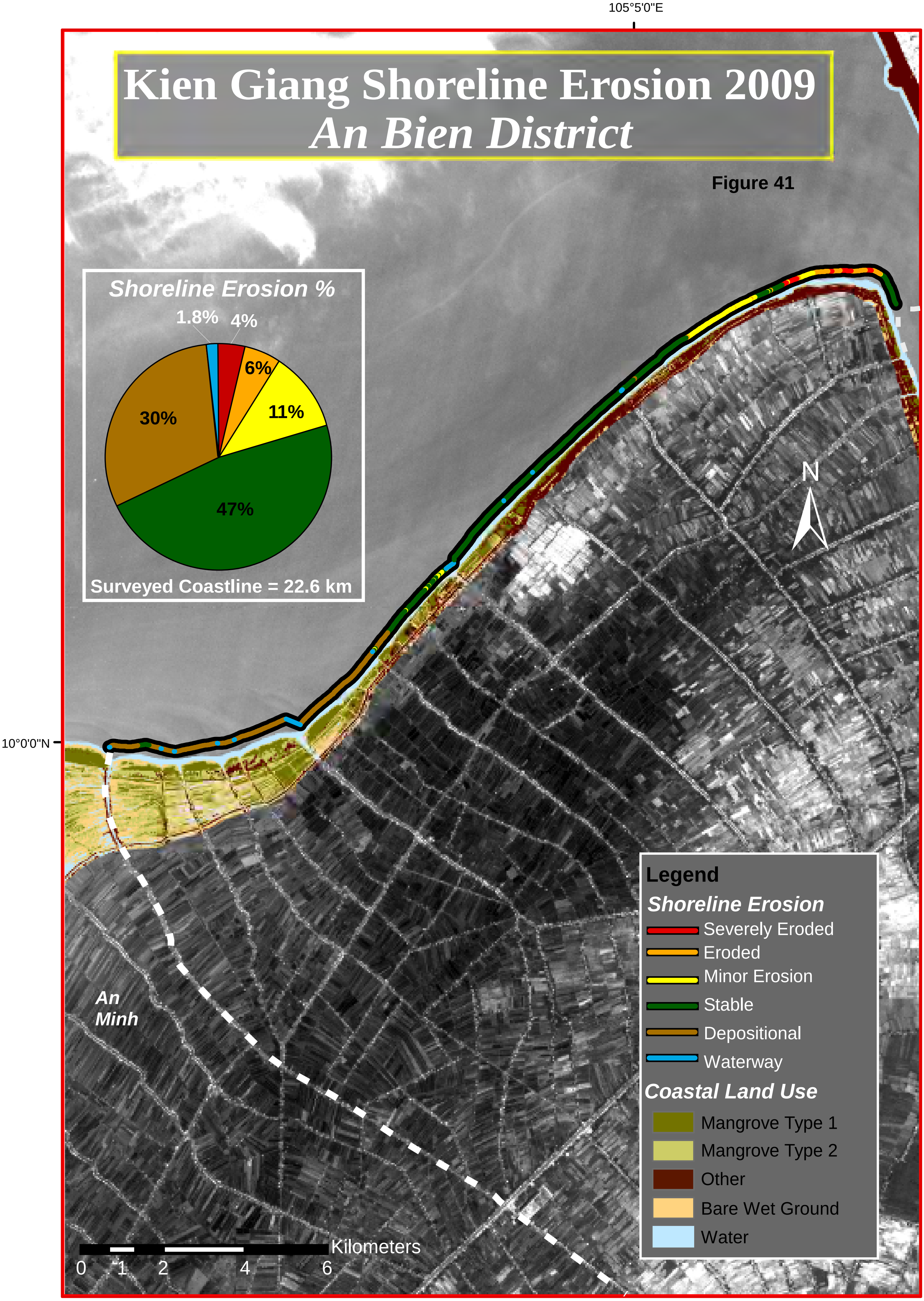
104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
Kien Giang Shoreline Erosion 2009
Figure 37
Cam Pu Chia
Ha Tien
Kien Luong
Hon Dat
Rach Gia
Chau Thanh
An Bien
An Minh
Ca Mau
N
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Shoreline Erosion %
3.3%
10%
11%
10%
41%
16%
8%
Surveyed Coastline = 179.7 km
Legend
Shoreline Erosion
Severely Eroded
Eroded
Minor Erosion
Stable
Depositional
Hardened / Wall
Waterway
Kilometers
0 3 6 12 18

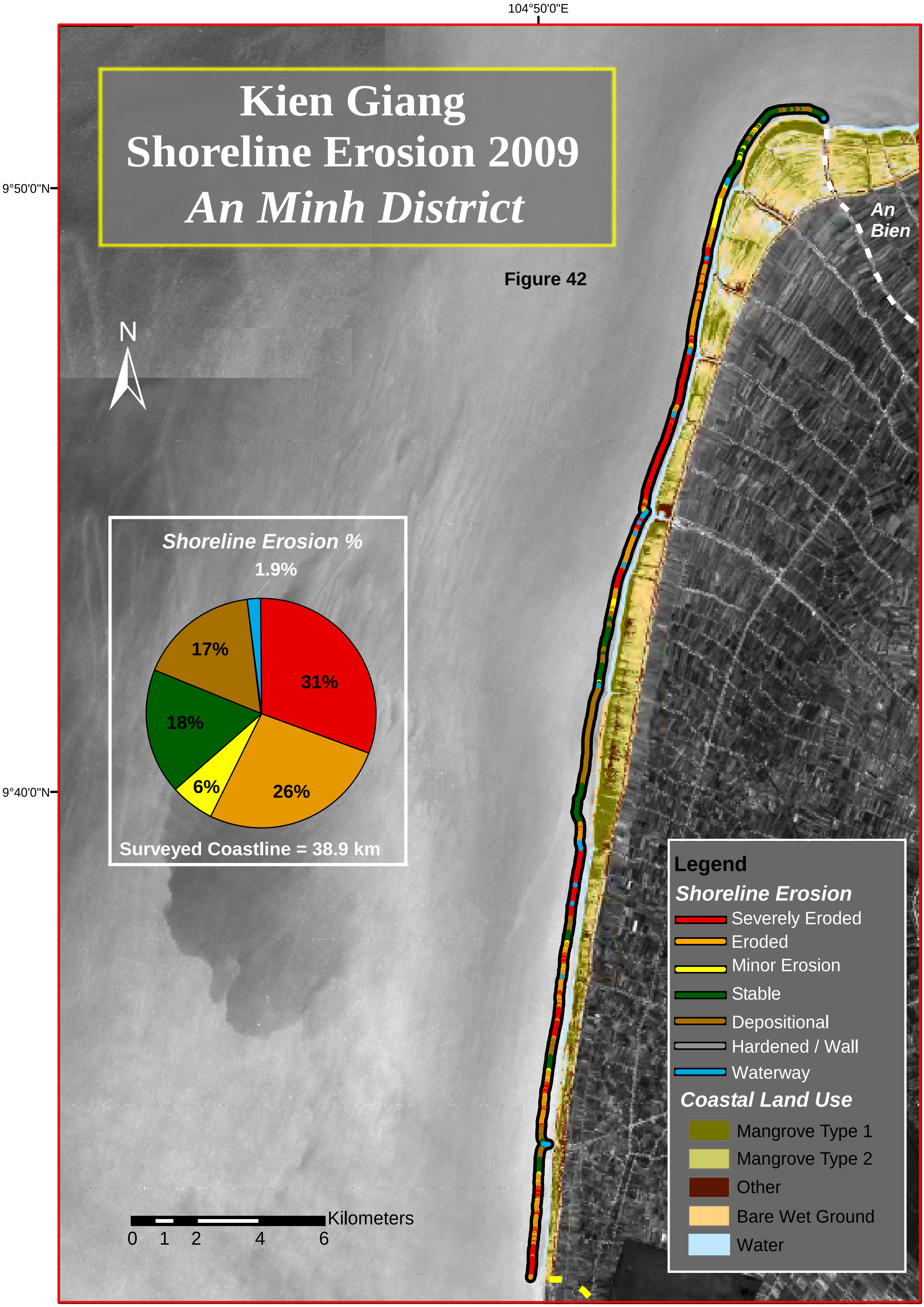


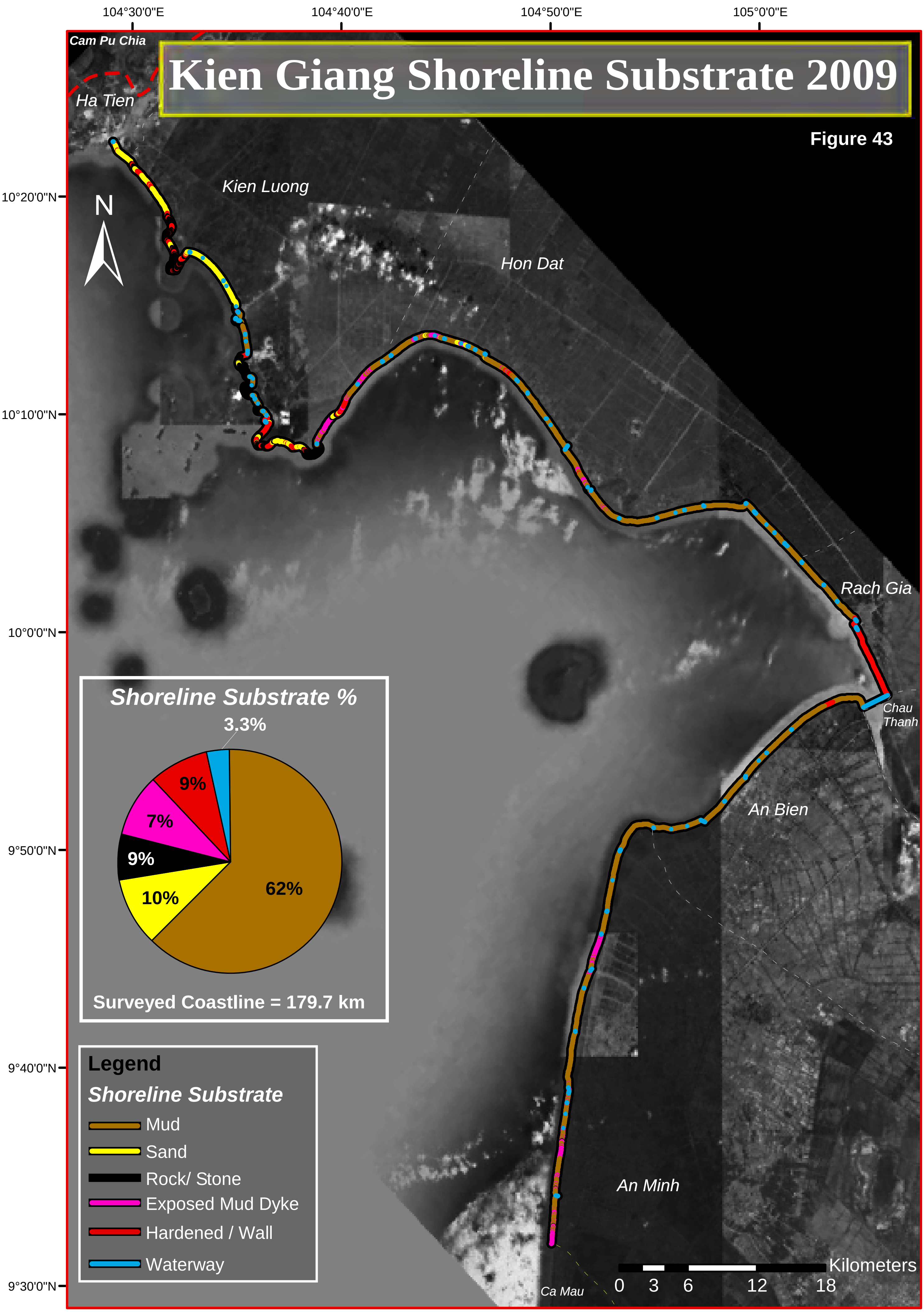
104°30'E
104°40'E
10°20'N
10°10'N
Kien Giang Shoreline Erosion 2009
Kien Luong / Ha Tien District
Ha Tien
Kien Luong
Shoreline Erosion %
1.7%
4%
7%
11%
50%
13%
14%
Surveyed Coastline = 56.7 km
N
Legend
Shoreline Erosion
Severely Eroded
Eroded
Minor Erosion
Stable
Depositional
Hardened / Wall
Waterway
Kilometers
0 1 2 4 6


Kien Giang Shoreline Erosion 2009
Hon Dat District
Figure 39
104°50'0"E
105°0'0"E
10°10'0"N
Kien Luong
N
Shoreline Erosion %
8%
11%
15%
47%
17%
1%
2%
Surveyed Coastline = 46.7 km
Legend
Shoreline Erosion
Severely Eroded
Eroded
Minor Erosion
Stable
Hardened / Wall
Depositional
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
0 1 2 4 6
Kilometers

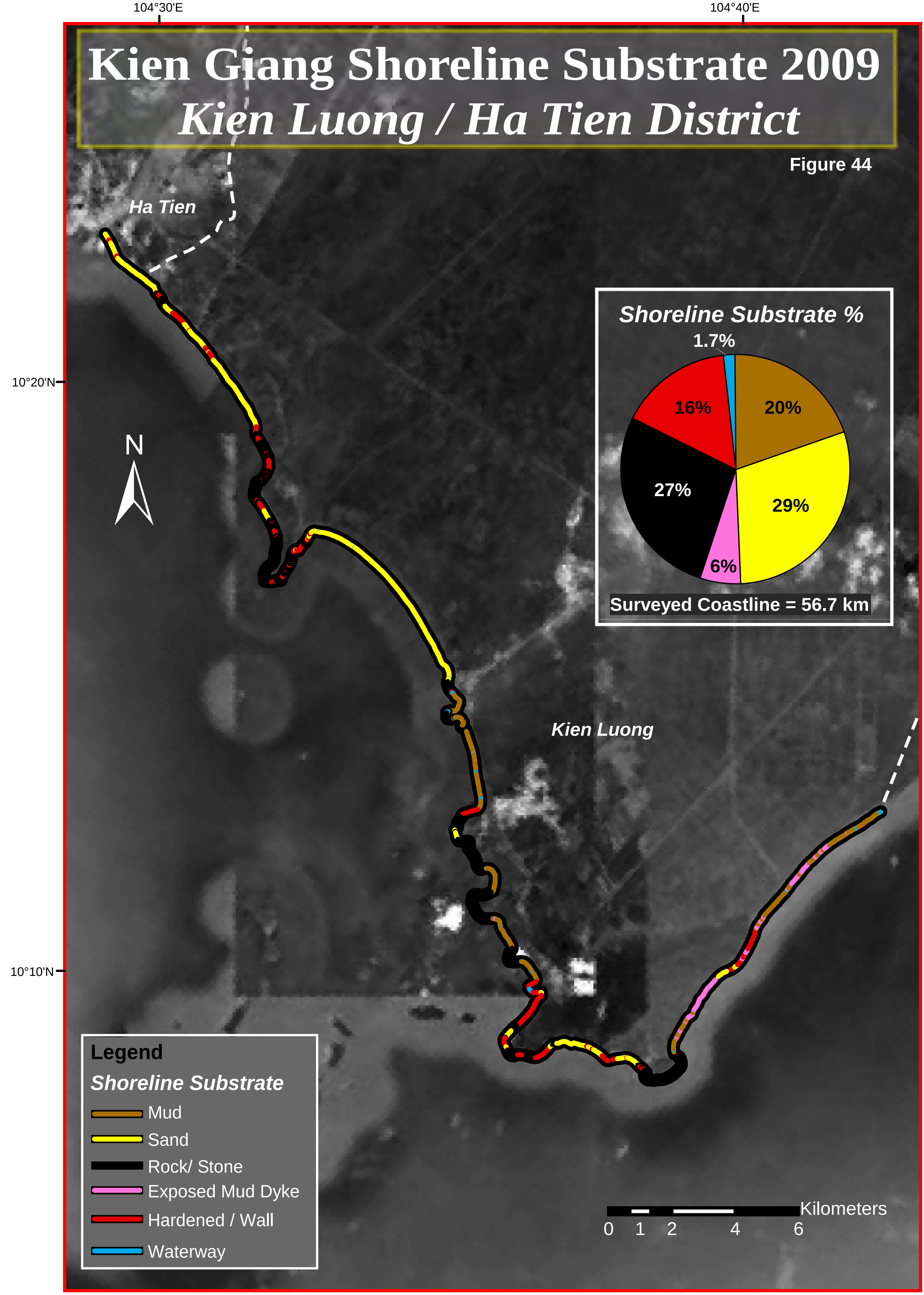

105°5'0"E
10°0'0"N
Kien Giang Shoreline Erosion 2009
Rach Gia District
N
Shoreline Erosion %
4.2%
1%
0.2%
44%
50%
Surveyed Coastline = 12.5 km
Legend
Shoreline Erosion
Severely Eroded
Eroded
Minor Erosion
Stable
Hardened / Wall
Waterway
Coastal Land Use
Mangrove
Other
Disturbed mangrove
Bare Wet Ground
Water
Kilometers
0
0.5
1
2
3

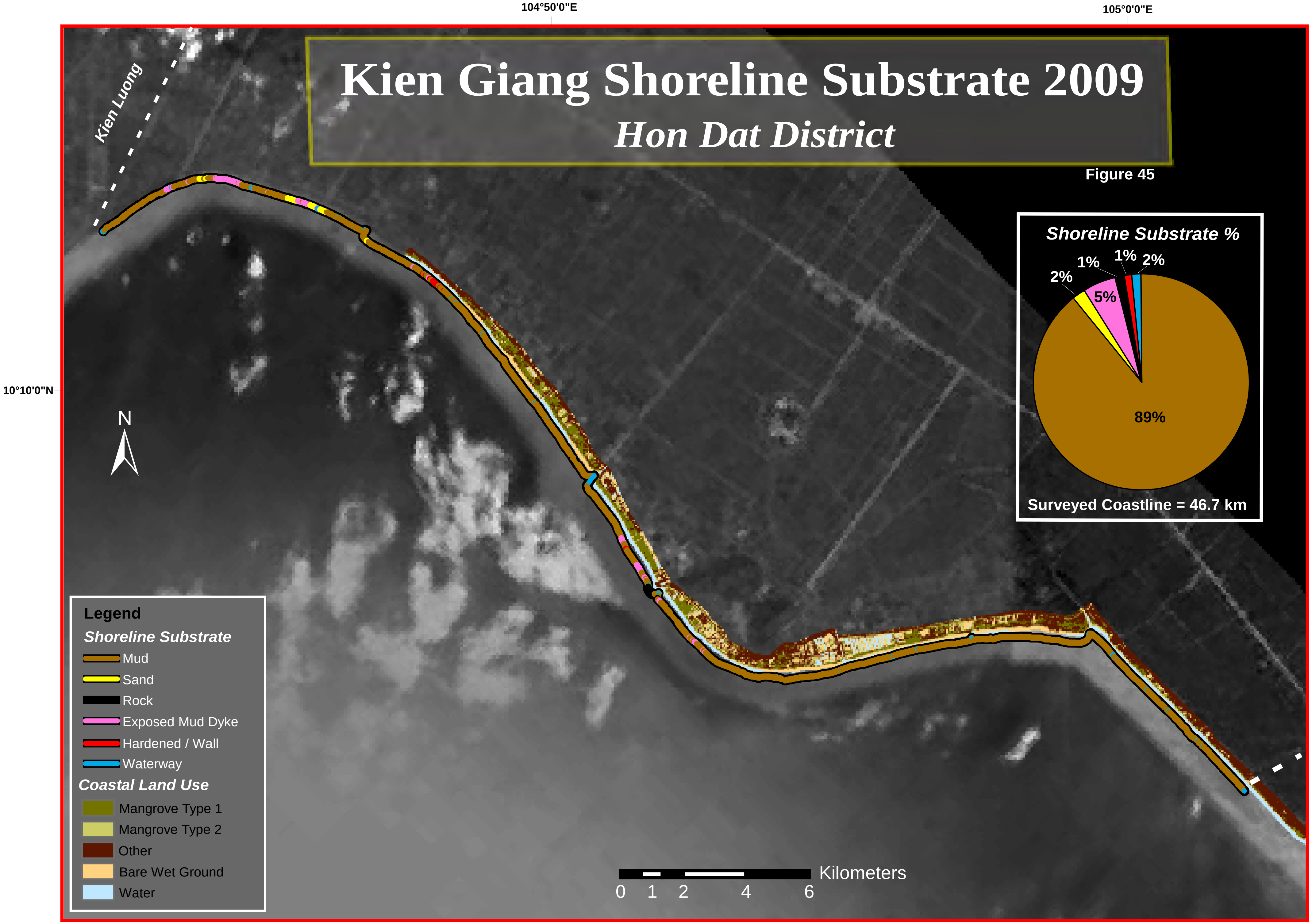

105°5'0"E
Kien Giang Shoreline Erosion 2009
An Bien District
Figure 41
Shoreline Erosion %
1.8%
4%
6%
11%
30%
47%
Surveyed Coastline = 22.6 km
10°0'0"N
N
An
Minh
Legend
Shoreline Erosion
Severely Eroded
Eroded
Minor Erosion
Stable
Depositional
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0
1
2
4
6


104°50'0"E
9°50'0"N
9°40'0"N
Kien Giang
Shoreline Erosion 2009
An Minh District
Figure 42
An
Bien
N
Shoreline Erosion %
1.9%
17%
31%
18%
6%
26%
Surveyed Coastline = 38.9 km
Kilometers
0 1 2 4 6
Legend
Shoreline Erosion
Severely Eroded
Eroded
Minor Erosion
Stable
Depositional
Hardened / Wall
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water

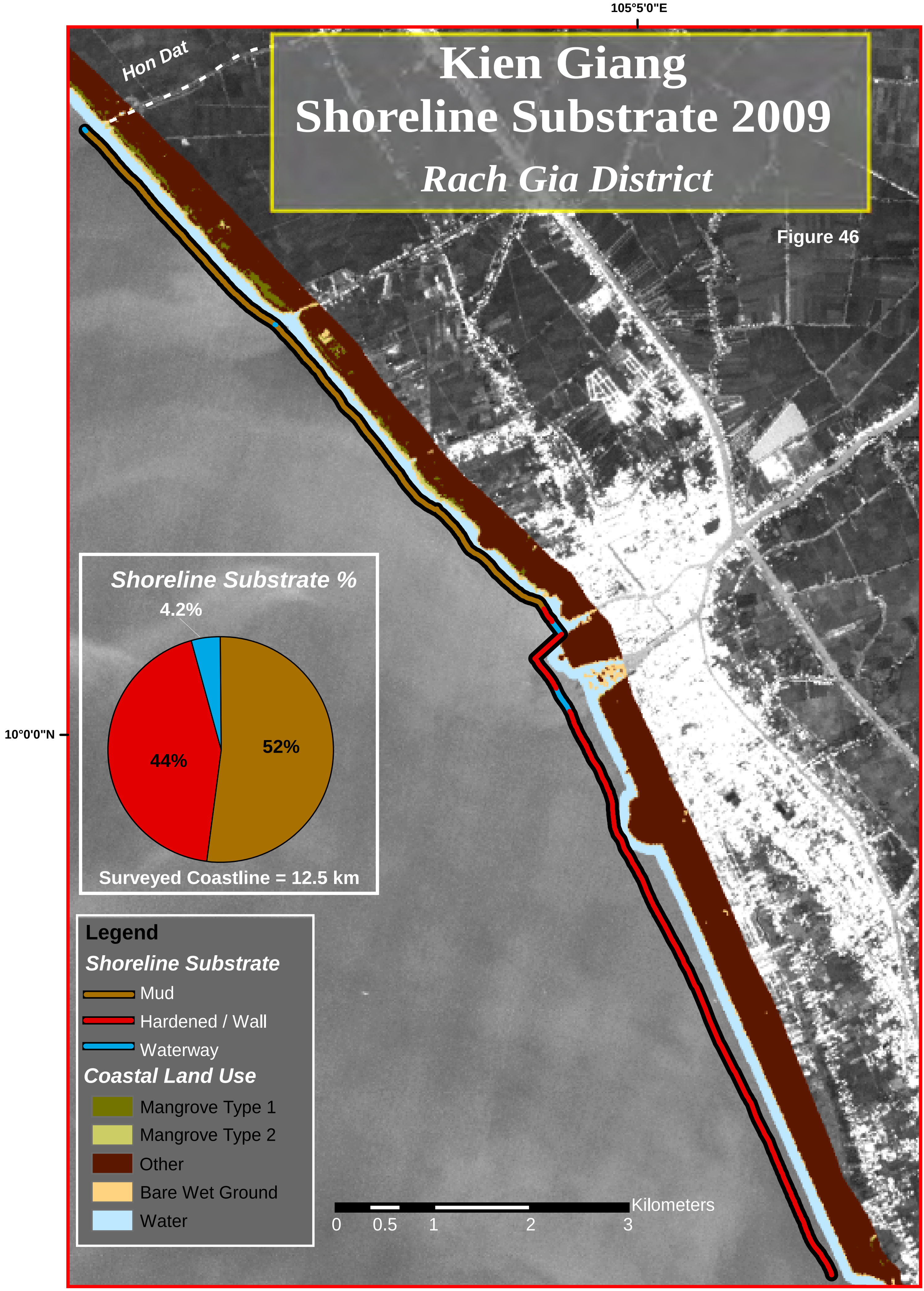


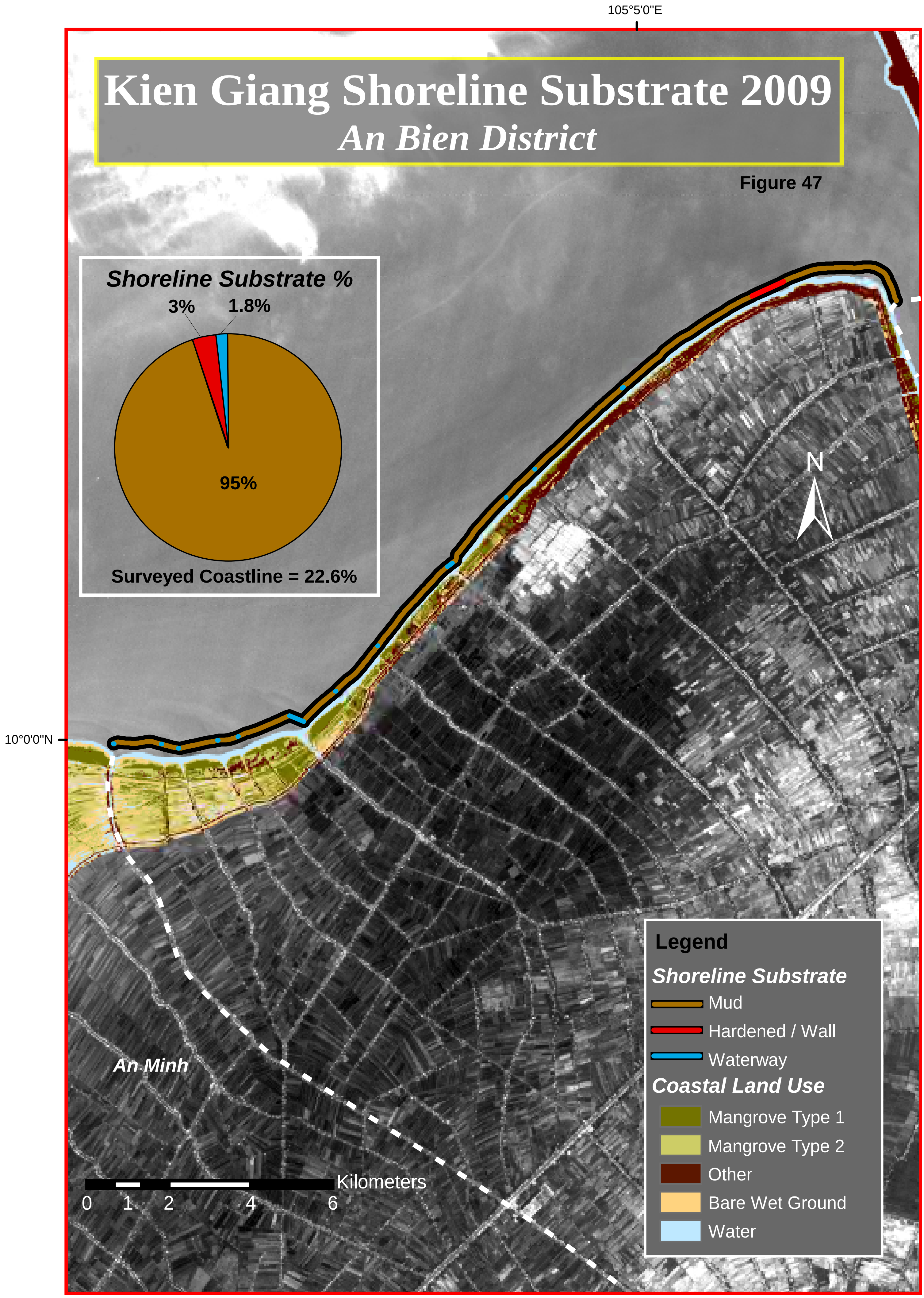
104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Cam Pu Chia
Kien Giang Shoreline Substrate 2009
Ha Tien
Figure 43
Kien Luong
N
Hon Dat
Rach Gia
Chau Thanh
An Bien
An Minh
Ca Mau
Shoreline Substrate %
3.3%
9%
7%
9%
10%
62%
Surveyed Coastline = 179.7 km
Legend
Shoreline Substrate
Mud
Sand
Rock/ Stone
Exposed Mud Dyke
Hardened / Wall
Waterway
Kilometers
0 3 6 12 18

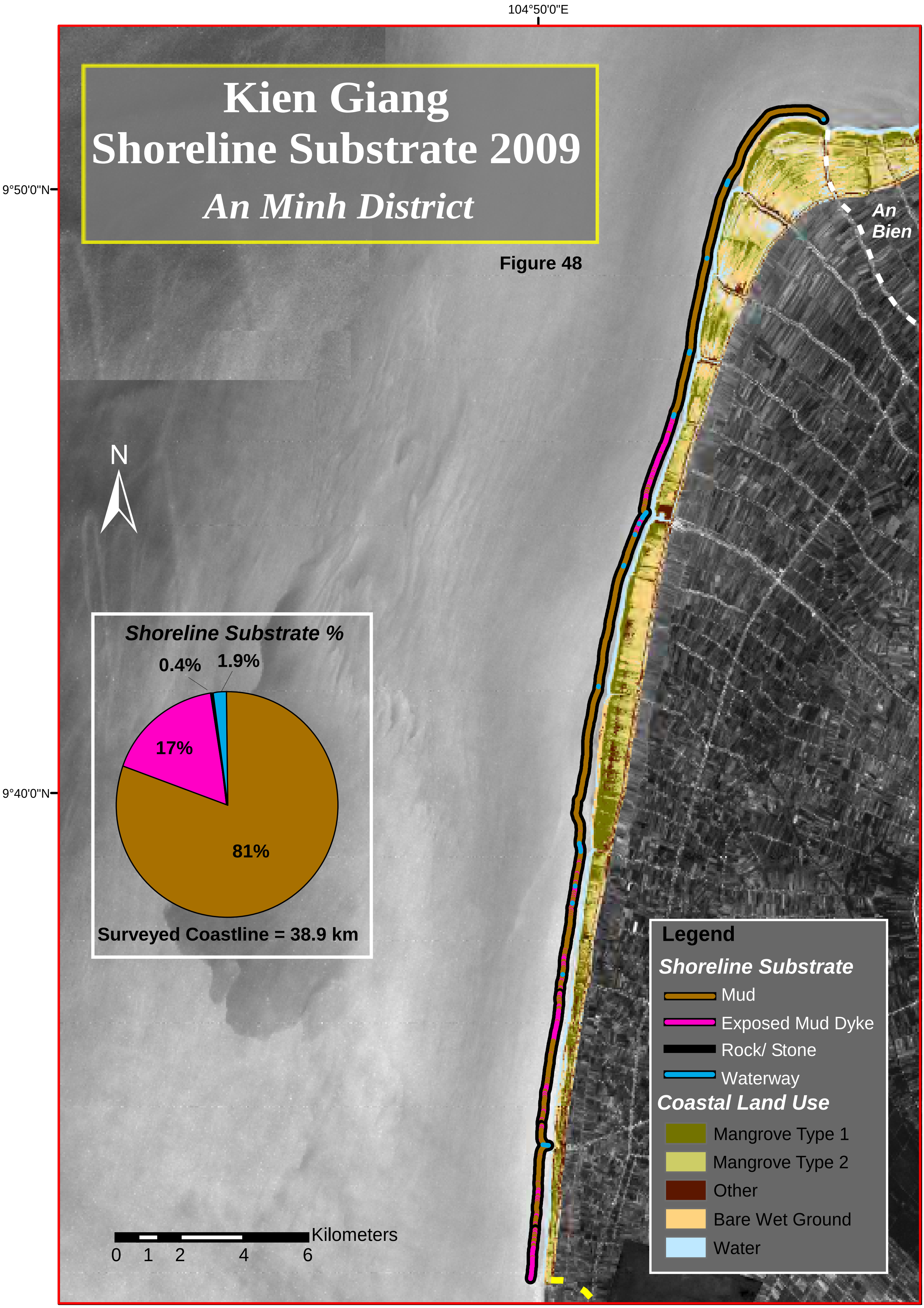

104°30'E
104°40'E
Kien Giang Shoreline Substrate 2009
Kien Luong / Ha Tien District
Figure 44
Ha Tien
10°20'N
N
Shoreline Substrate %
1.7%
16%
20%
27%
29%
6%
Surveyed Coastline = 56.7 km
Kien Luong
10°10'N
Legend
Shoreline Substrate
Mud
Sand
Rock/ Stone
Exposed Mud Dyke
Hardened / Wall
Waterway
Kilometers
0 1 2 4 6

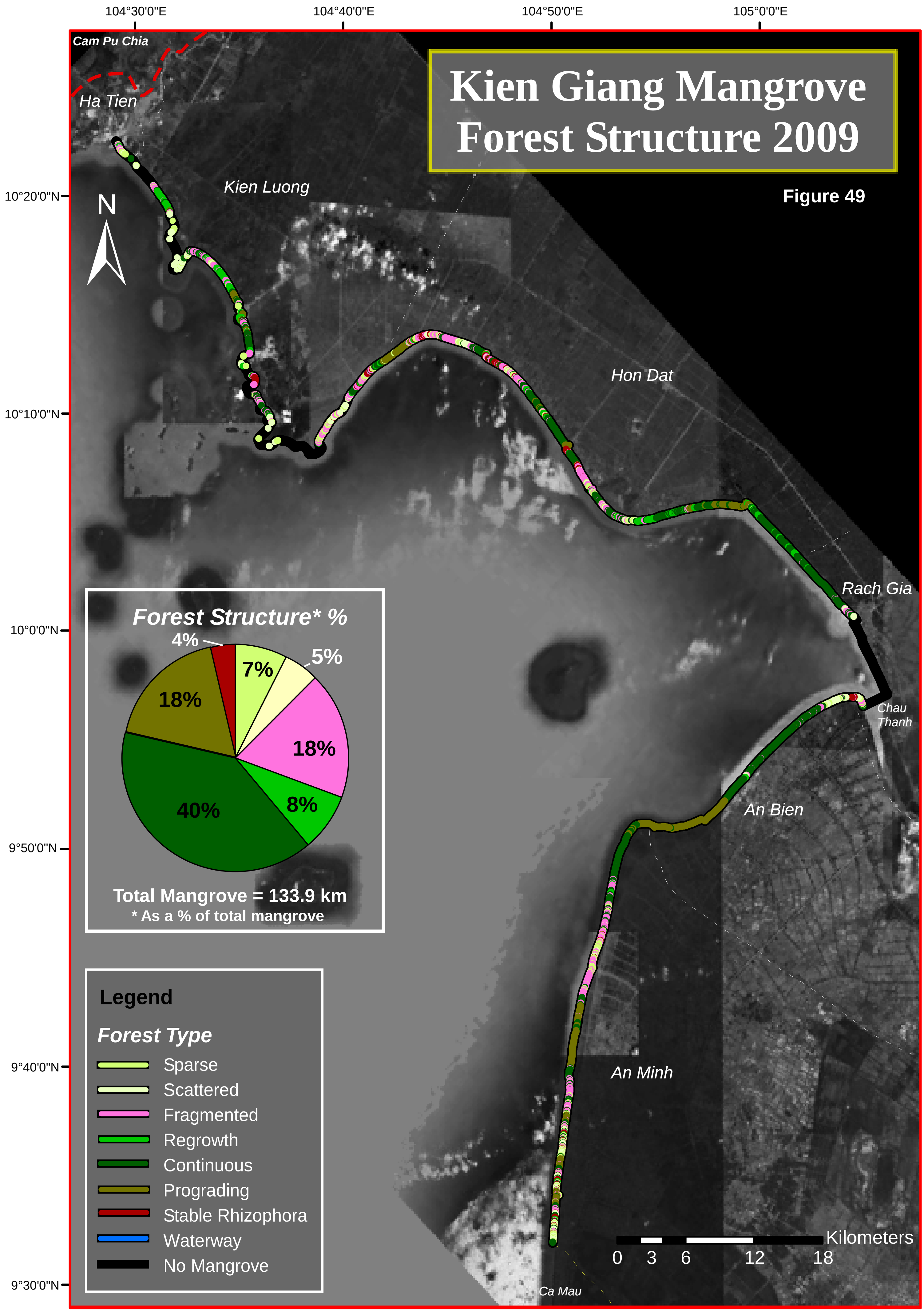


104°50'0"E
105°0'0"E
10°10'0"N
Kien Giang Shoreline Substrate 2009
Hon Dat District
Figure 45
Kien Luong
N
Shoreline Substrate %
1%
1%
2%
2%
5%
89%
Surveyed Coastline = 46.7 km
Legend
Shoreline Substrate
Mud
Sand
Rock
Exposed Mud Dyke
Hardened / Wall
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
0 1 2 4 6
Kilometers

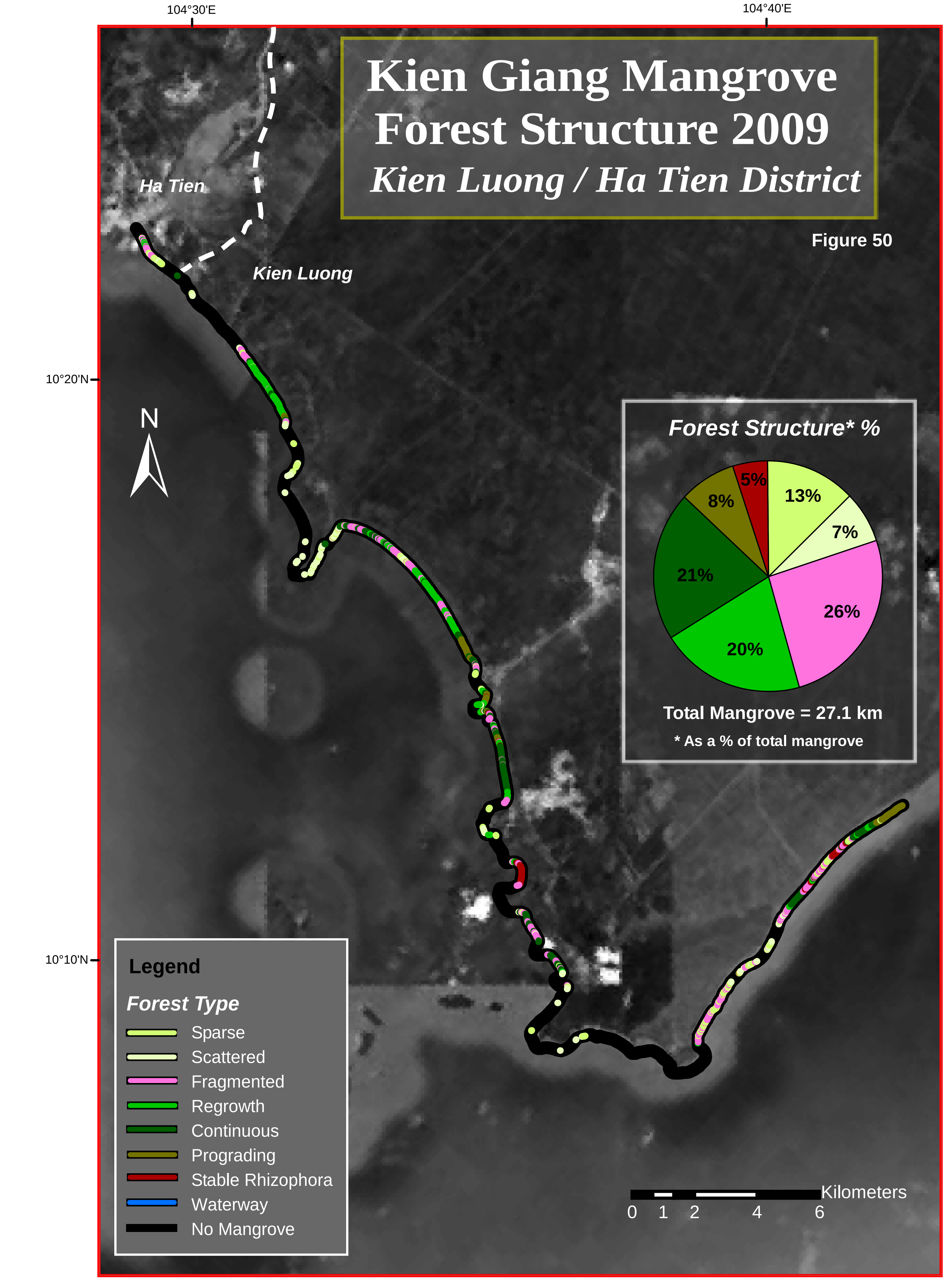

105°5'0"E
10°0'0"N
Kien Giang
Shoreline Substrate 2009
Rach Gia District
Figure 46
Hon Dat
Shoreline Substrate %
4.2%
52%
44%
Surveyed Coastline = 12.5 km
Legend
Shoreline Substrate
Mud
Hardened / Wall
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 0.5 1 2 3

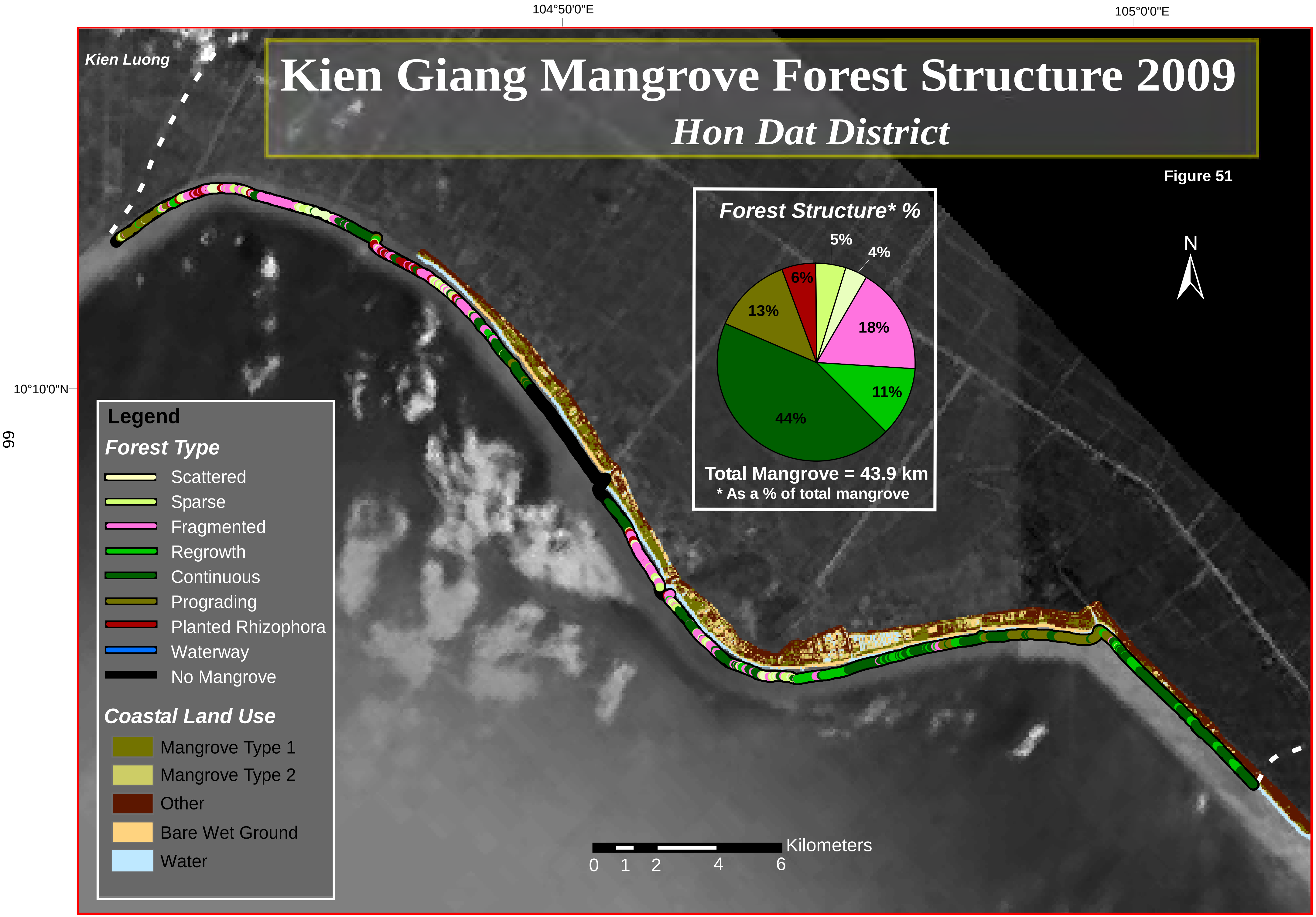

105°5'0"E
Kien Giang Shoreline Substrate 2009
An Bien District
Figure 47
Shoreline Substrate %
3%
1.8%
95%
Surveyed Coastline = 22.6%
N
10°0'0"N
An Minh
Kilometers
0
1
2
4
6
Legend
Shoreline Substrate
Mud
Hardened / Wall
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water

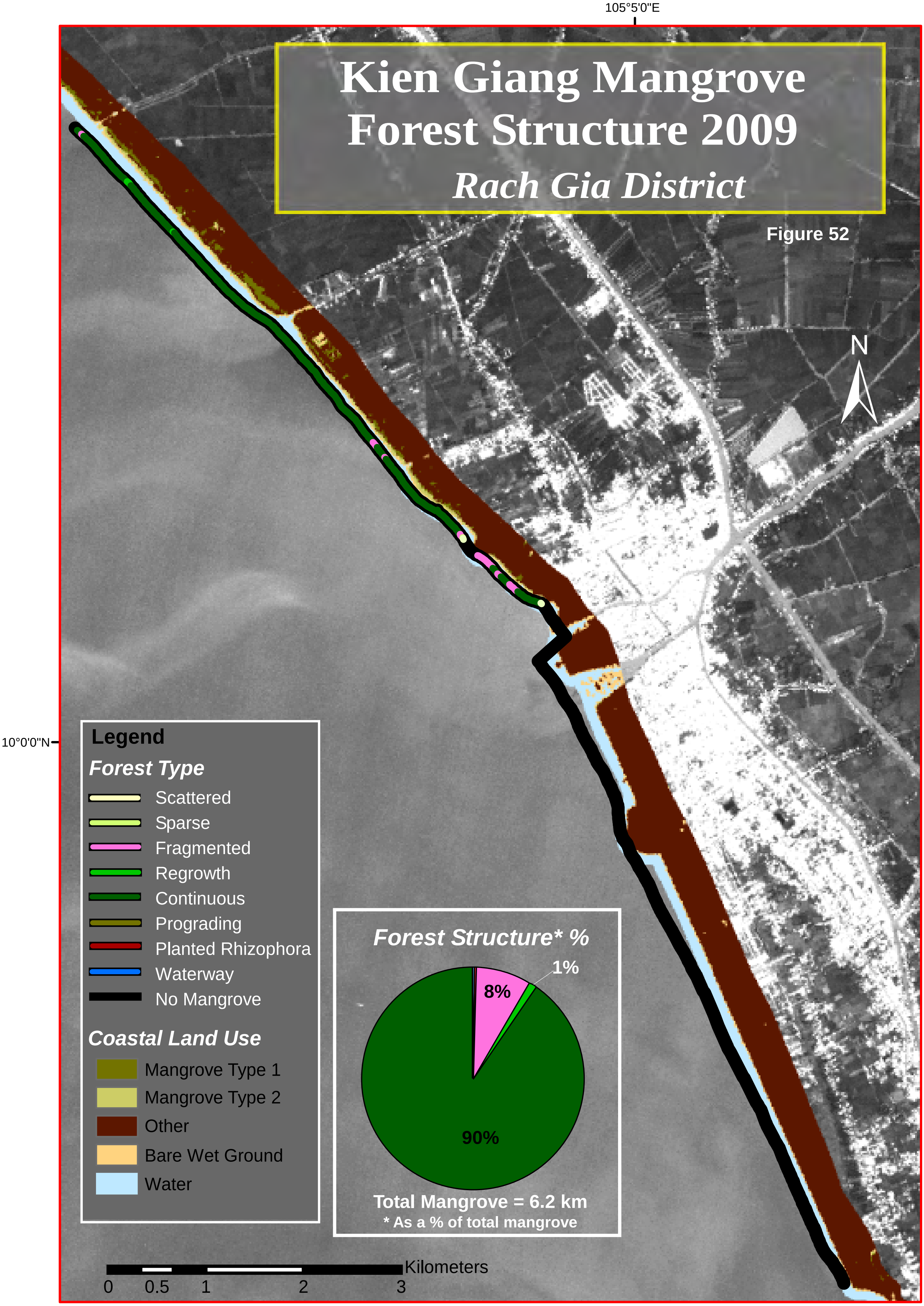

104°50'0"E
9°50'0"N
9°40'0"N
Kien Giang
Shoreline Substrate 2009
An Minh District
Figure 48
An
Bien
N
Shoreline Substrate %
0.4%
1.9%
17%
81%
Surveyed Coastline = 38.9 km
Kilometers
0 1 2 4 6
Legend
Shoreline Substrate
Mud
Exposed Mud Dyke
Rock/ Stone
Waterway
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water



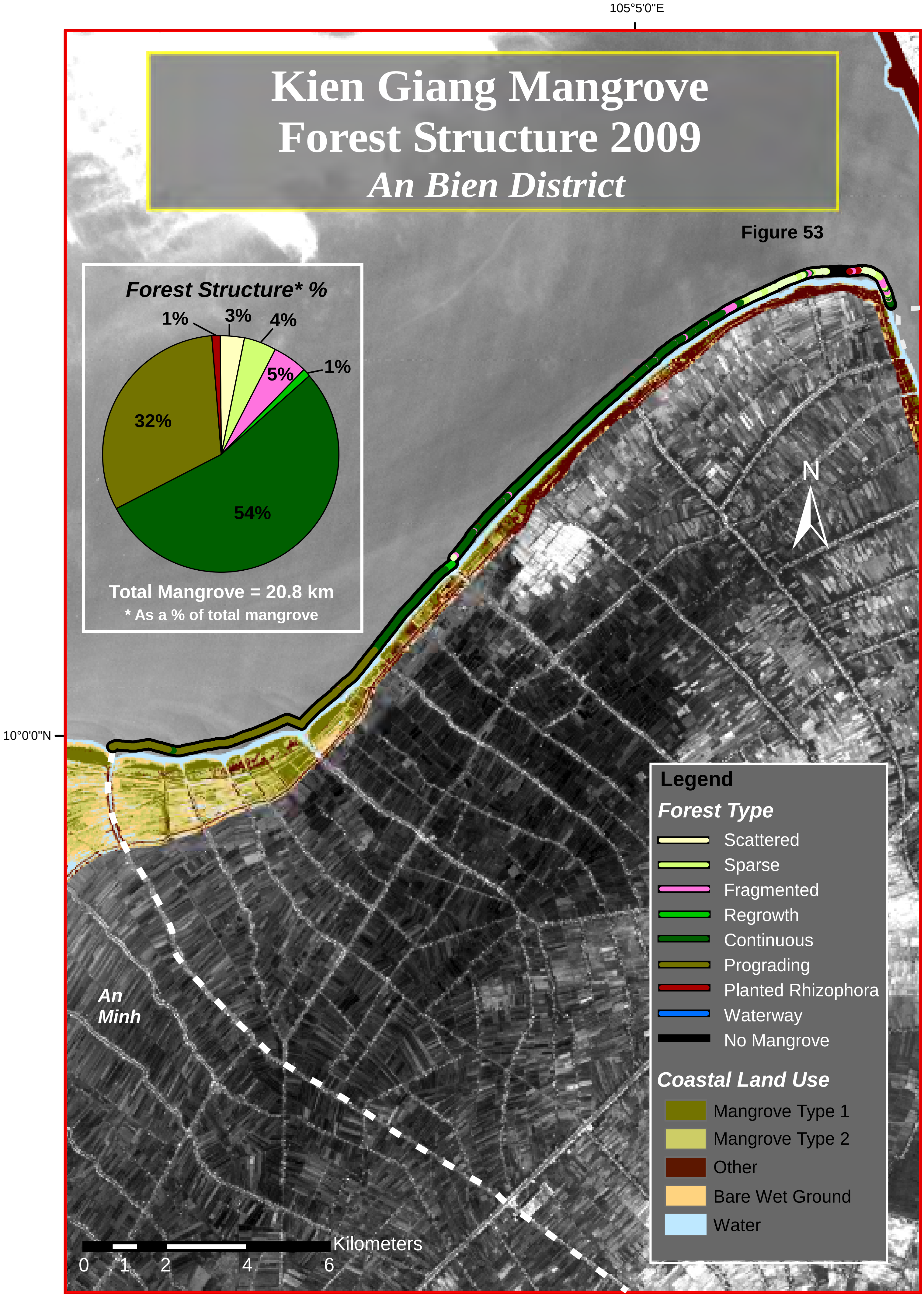
104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
Kien Giang Mangrove
Forest Structure 2009
Figure 49
Cam Pu Chia
Ha Tien
Kien Luong
N
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Hon Dat
Rach Gia
Chau Thanh
An Bien
An Minh
Ca Mau
Forest Structure* %
4%
7%
5%
18%
18%
8%
40%
Total Mangrove = 133.9 km
* As a % of total mangrove
Legend
Forest Type
Sparse
Scattered
Fragmented
Regrowth
Continuous
Prograding
Stable Rhizophora
Waterway
No Mangrove
0
3
6
12
18
Kilometers


104°30'E
104°40'E
Kien Giang Mangrove
Forest Structure 2009
Kien Luong / Ha Tien District
Figure 50
Ha Tien
Kien Luong
10°20'N
10°10'N
N
Forest Structure* %
5%
13%
8%
7%
21%
26%
20%
Total Mangrove = 27.1 km
* As a % of total mangrove
Legend
Forest Type
Sparse
Scattered
Fragmented
Regrowth
Continuous
Prograding
Stable Rhizophora
Waterway
No Mangrove
Kilometers
0 1 2 4 6

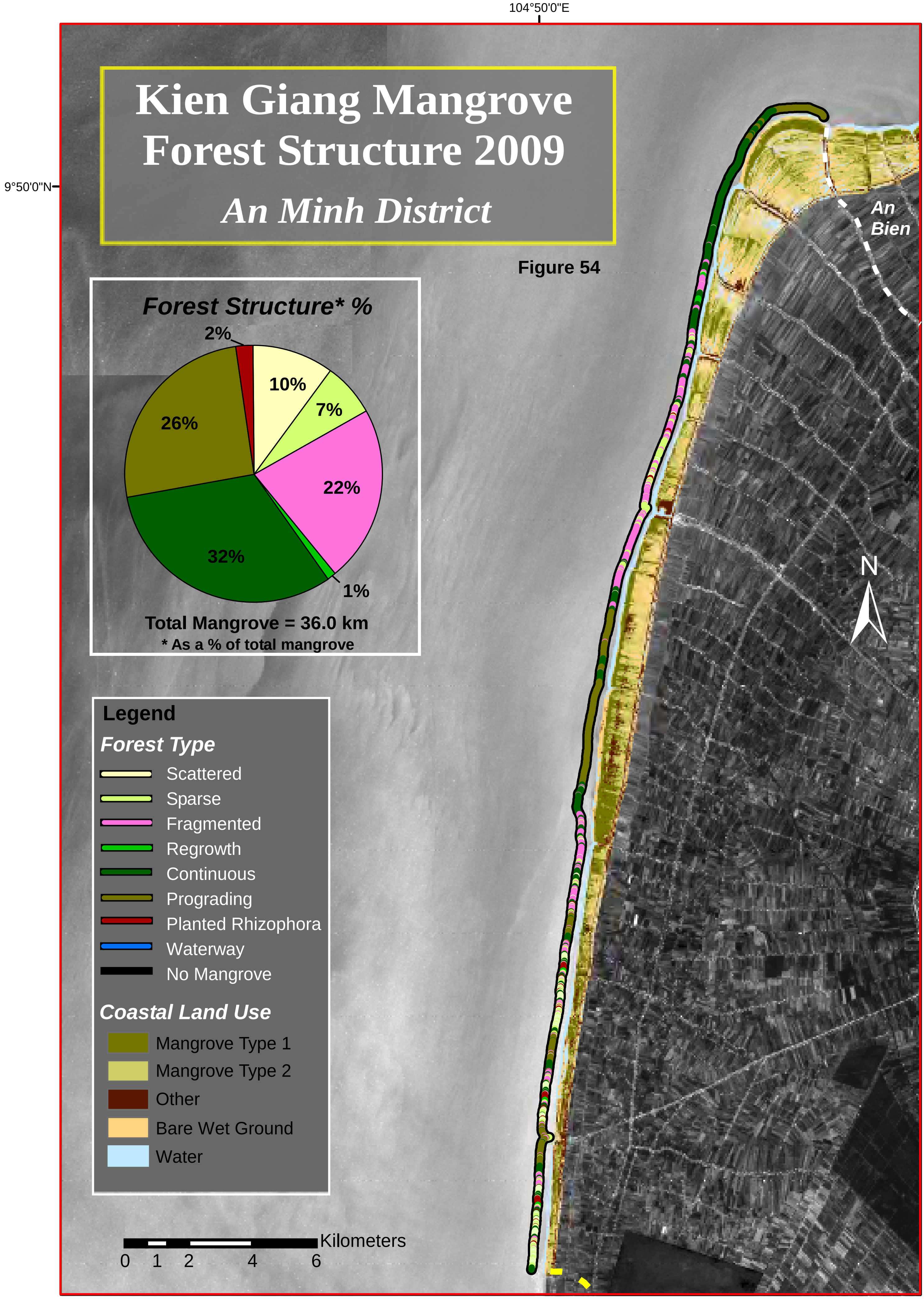

104°50'0"E
105°0'0"E
10°10'0"N
Kien Luong
Kien Giang Mangrove Forest Structure 2009
Hon Dat District
Figure 51
Forest Structure* %
5%
4%
6%
13%
18%
11%
44%
Total Mangrove = 43.9 km
* As a % of total mangrove
N
Legend
Forest Type
Scattered
Sparse
Fragmented
Regrowth
Continuous
Prograding
Planted Rhizophora
Waterway
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6



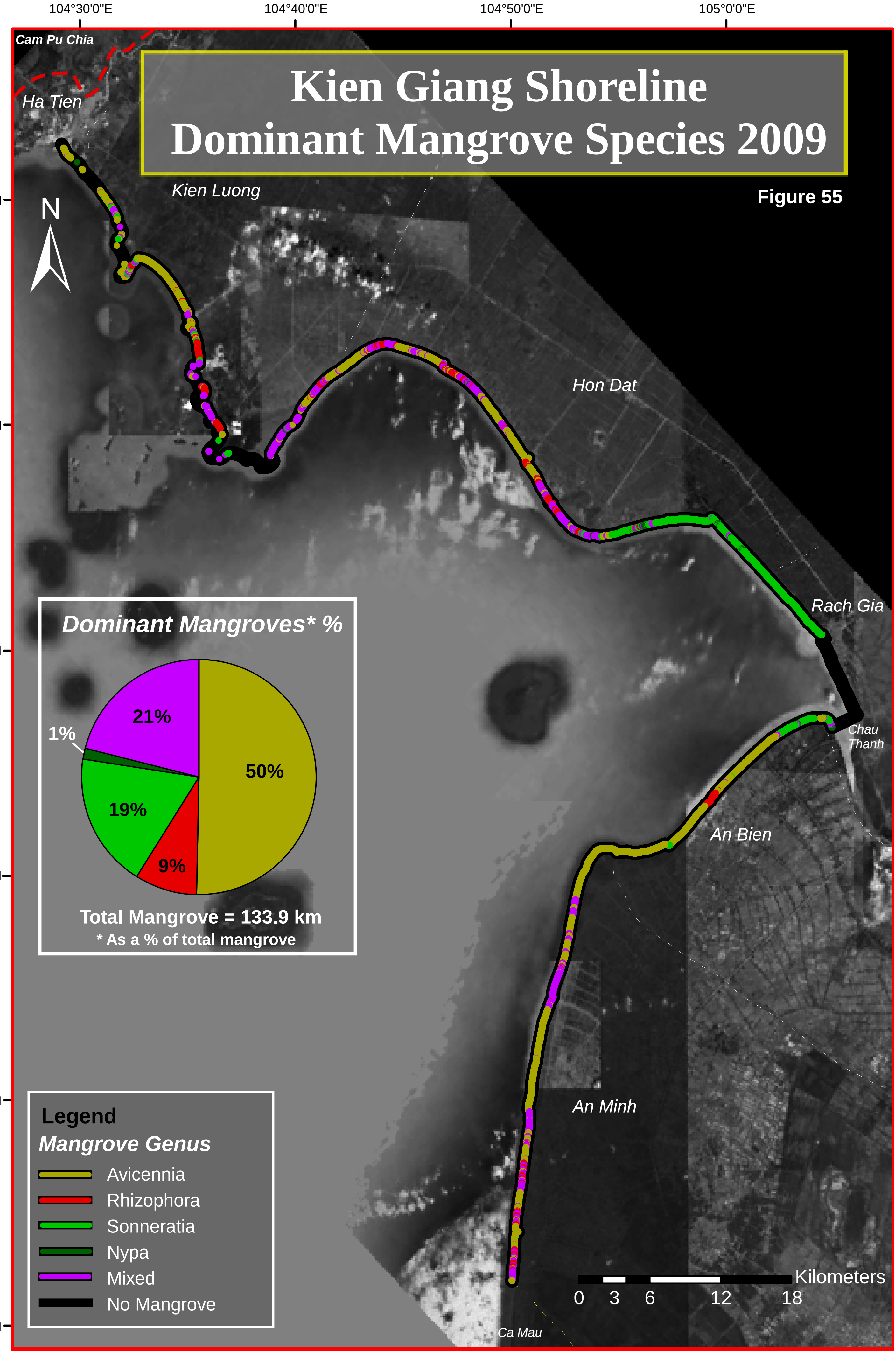
105°5'0"E
Kien Giang Mangrove
Forest Structure 2009
Rach Gia District
Figure 52
N
10°0'0"N
Legend
Forest Type
Scattered
Sparse
Fragmented
Regrowth
Continuous
Prograding
Planted Rhizophora
Waterway
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Forest Structure* %
1%
8%
90%
Total Mangrove = 6.2 km
* As a % of total mangrove
Kilometers
0 0.5 1 2 3

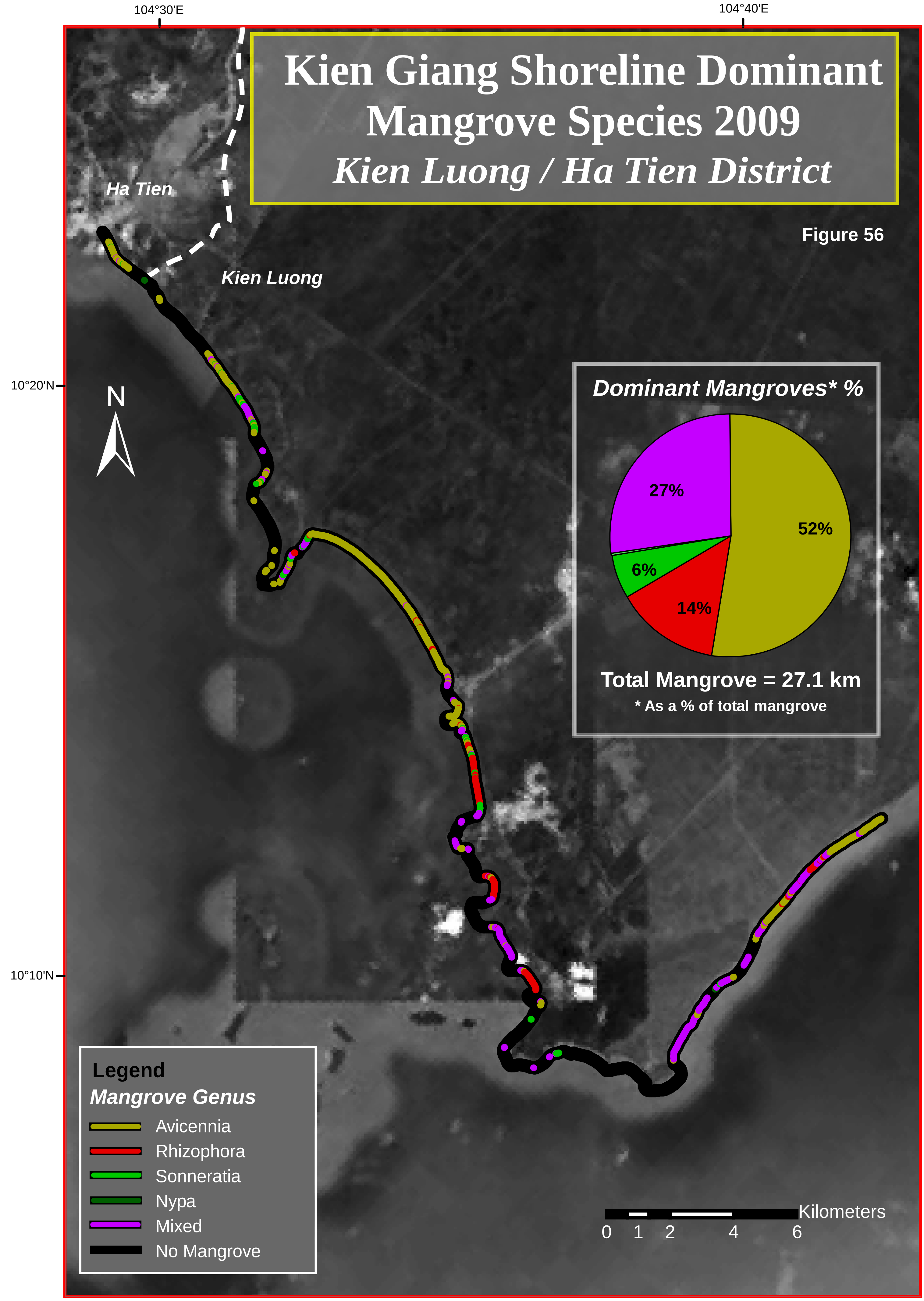


105°5'0"E
Kien Giang Mangrove
Forest Structure 2009
An Bien District
Figure 53
Forest Structure* %
1%
3%
4%
5%
1%
32%
54%
Total Mangrove = 20.8 km
* As a % of total mangrove
N
10°0'0"N
An Minh
Legend
Forest Type
Scattered
Sparse
Fragmented
Regrowth
Continuous
Prograding
Planted Rhizophora
Waterway
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0
1
2
4
6

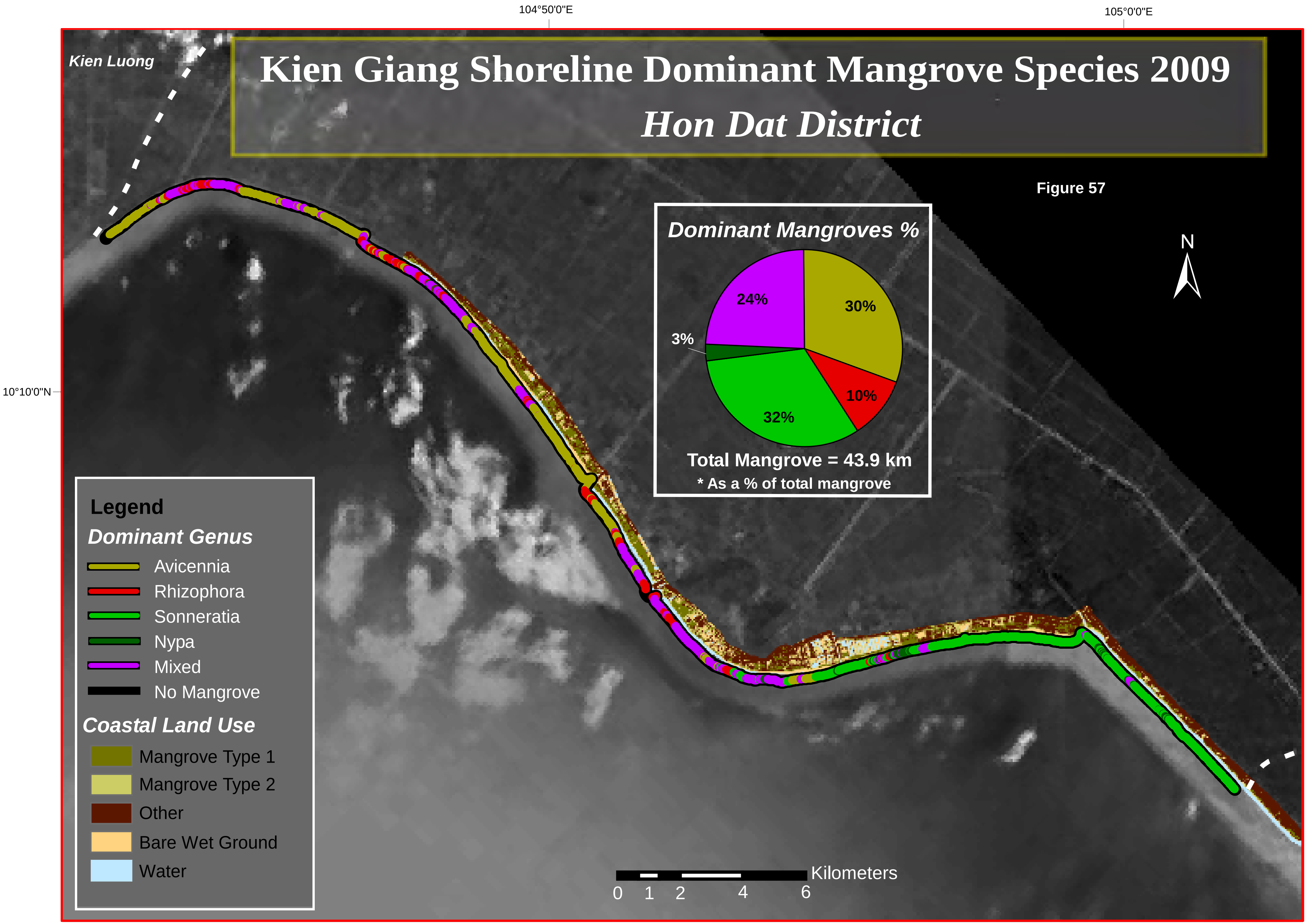


104°50'0"E
9°50'0"N
Kien Giang Mangrove
Forest Structure 2009
An Minh District
Figure 54
Forest Structure* %
2%
10%
7%
22%
1%
32%
26%
Total Mangrove = 36.0 km
* As a % of total mangrove
Legend
Forest Type
Scattered
Sparse
Fragmented
Regrowth
Continuous
Prograding
Planted Rhizophora
Waterway
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0
1
2
4
6
An
Bien
N

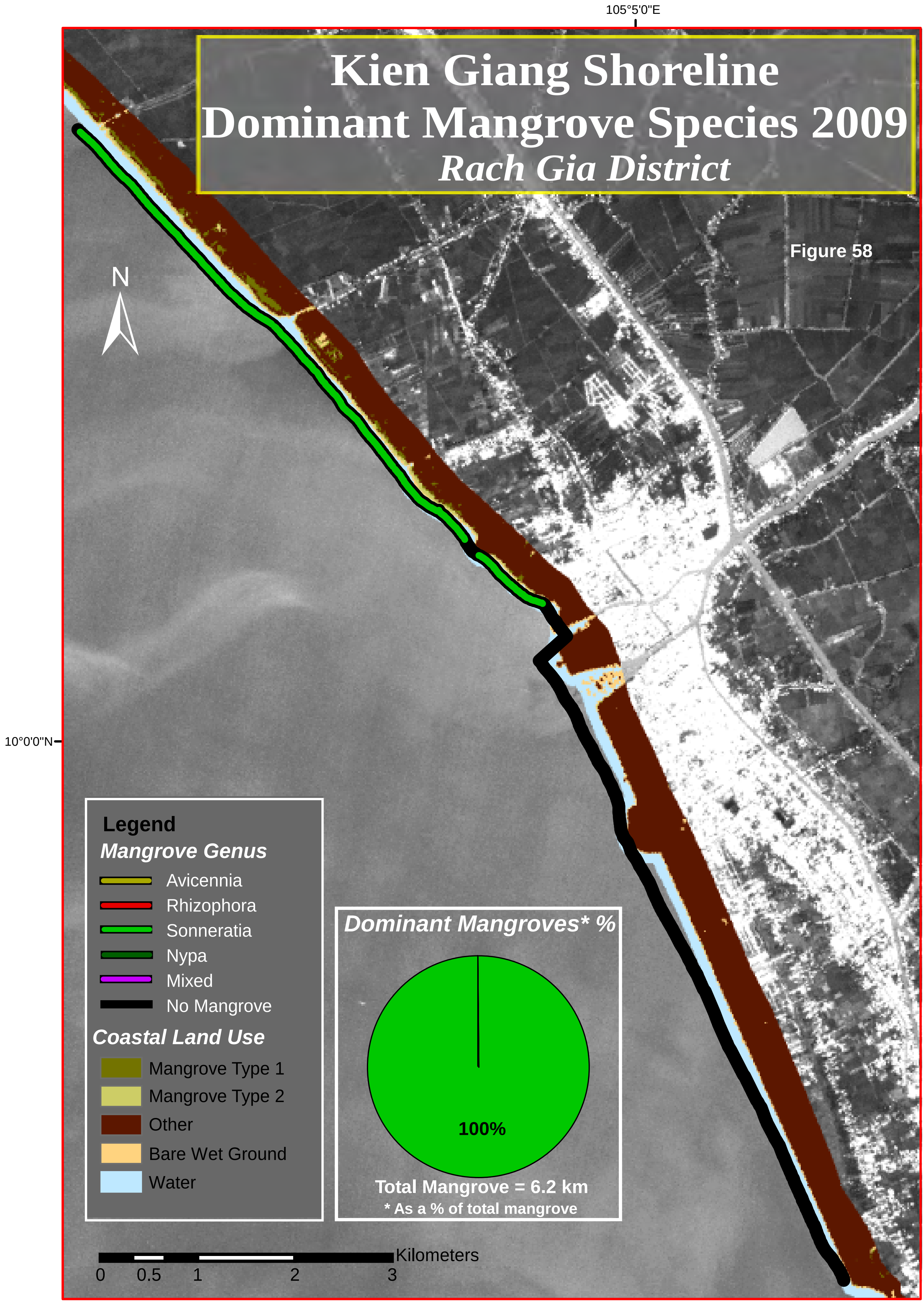

Kien Giang Shoreline
Dominant Mangrove Species 2009
Figure 55
104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Cam Pu Chia
Ha Tien
Kien Luong
Hon Dat
Rach Gia
Chau Thanh
An Bien
An Minh
Ca Mau
N
Dominant Mangroves* %
50%
21%
19%
9%
1%
Total Mangrove = 133.9 km
* As a % of total mangrove
Legend
Mangrove Genus
Avicennia
Rhizophora
Sonneratia
Nypa
Mixed
No Mangrove
Kilometers
0 3 6 12 18

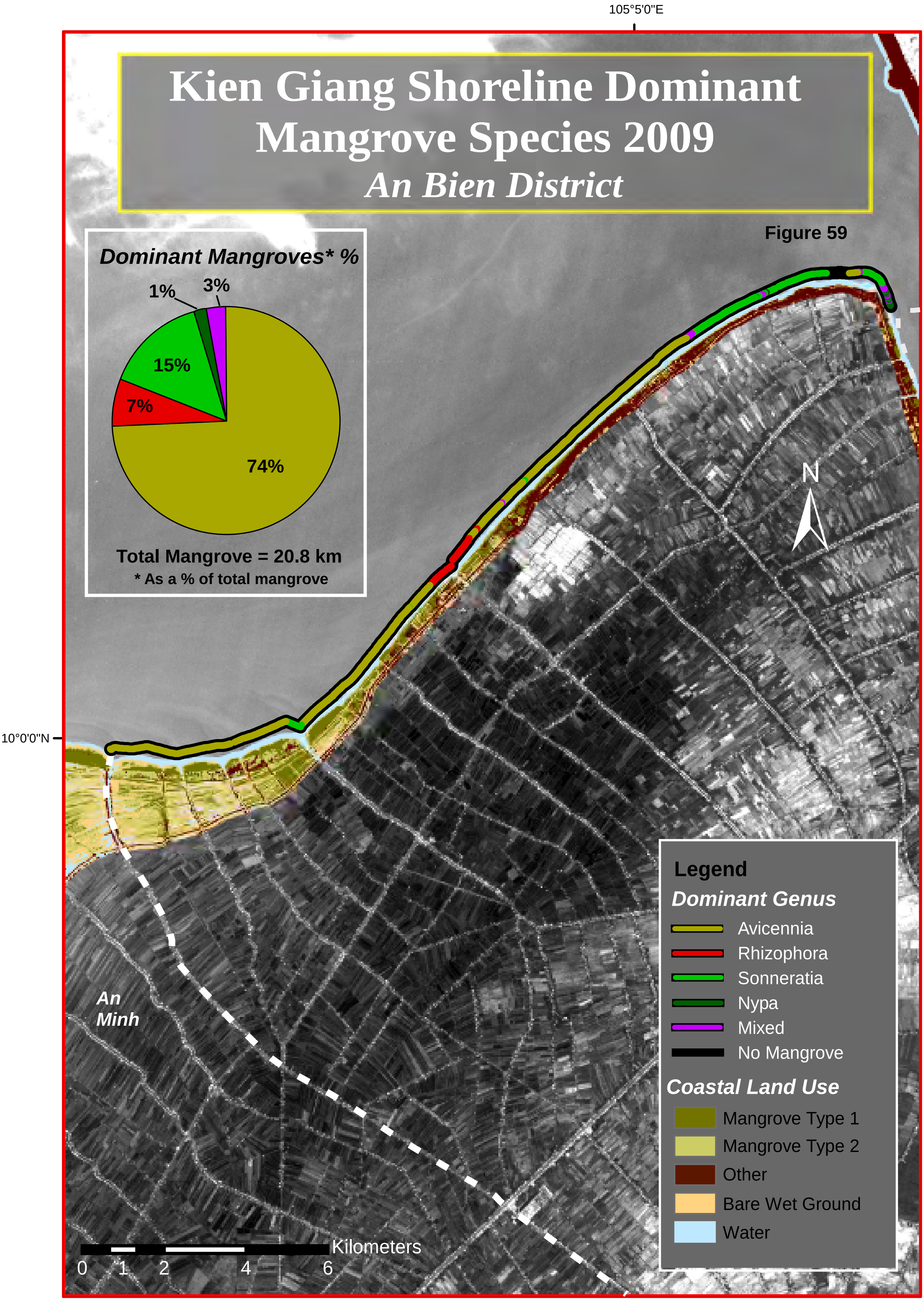


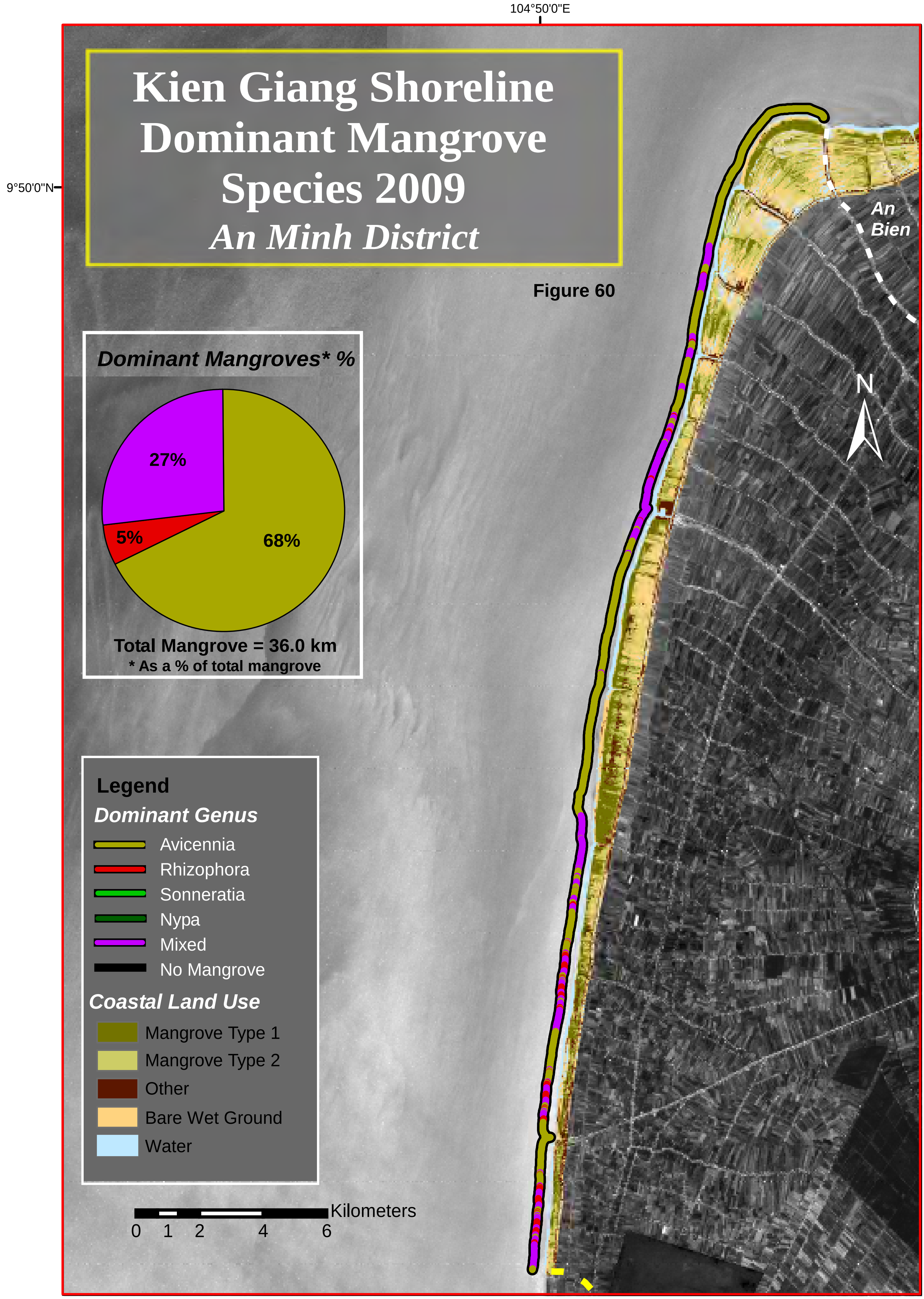
104°30'E
104°40'E
Kien Giang Shoreline Dominant Mangrove Species 2009
Kien Luong / Ha Tien District
Ha Tien
Kien Luong
Figure 56
10°20'N
10°10'N
N
Dominant Mangroves* %
27%
52%
6%
14%
Total Mangrove = 27.1 km
* As a % of total mangrove
Legend
Mangrove Genus
Avicennia
Rhizophora
Sonneratia
Nypa
Mixed
No Mangrove
Kilometers
0 1 2 4 6

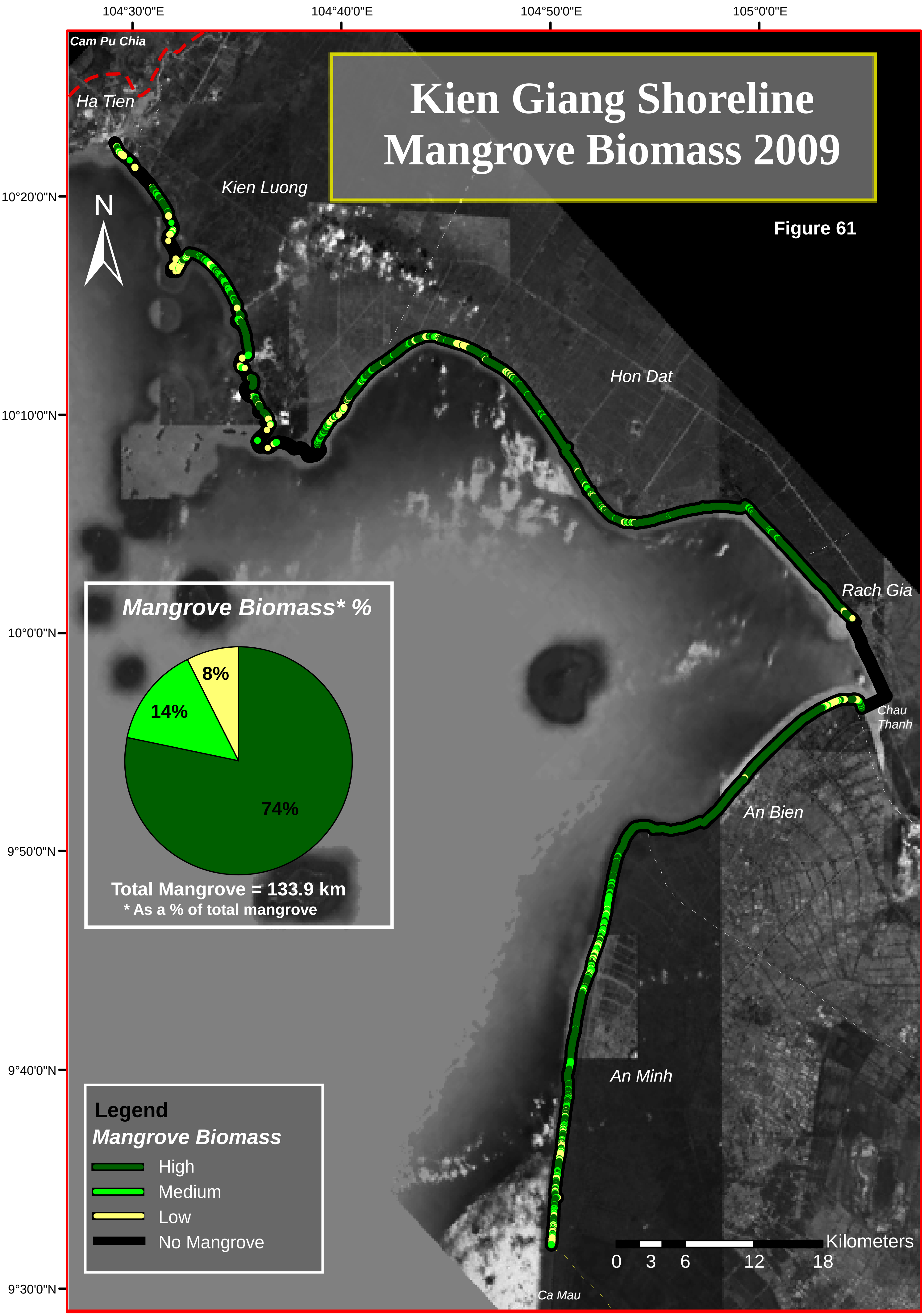


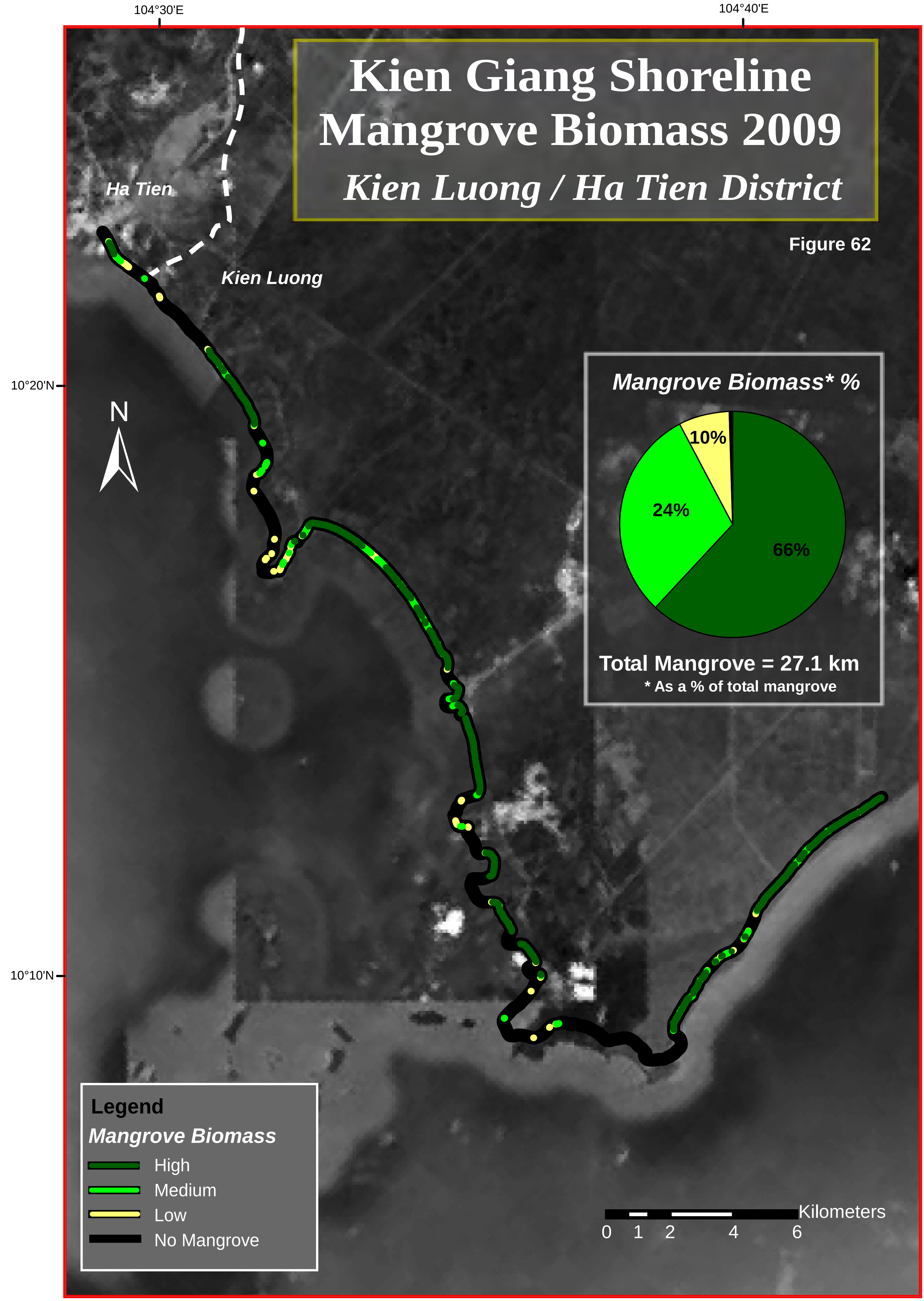
104°50'0"E
105°0'0"E
10°10'0"N
Kien Luong
Kien Giang Shoreline Dominant Mangrove Species 2009
Hon Dat District
Figure 57
N
Dominant Mangroves %
24%
30%
3%
10%
32%
Total Mangrove = 43.9 km
* As a % of total mangrove
Legend
Dominant Genus
Avicennia
Rhizophora
Sonneratia
Nypa
Mixed
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6

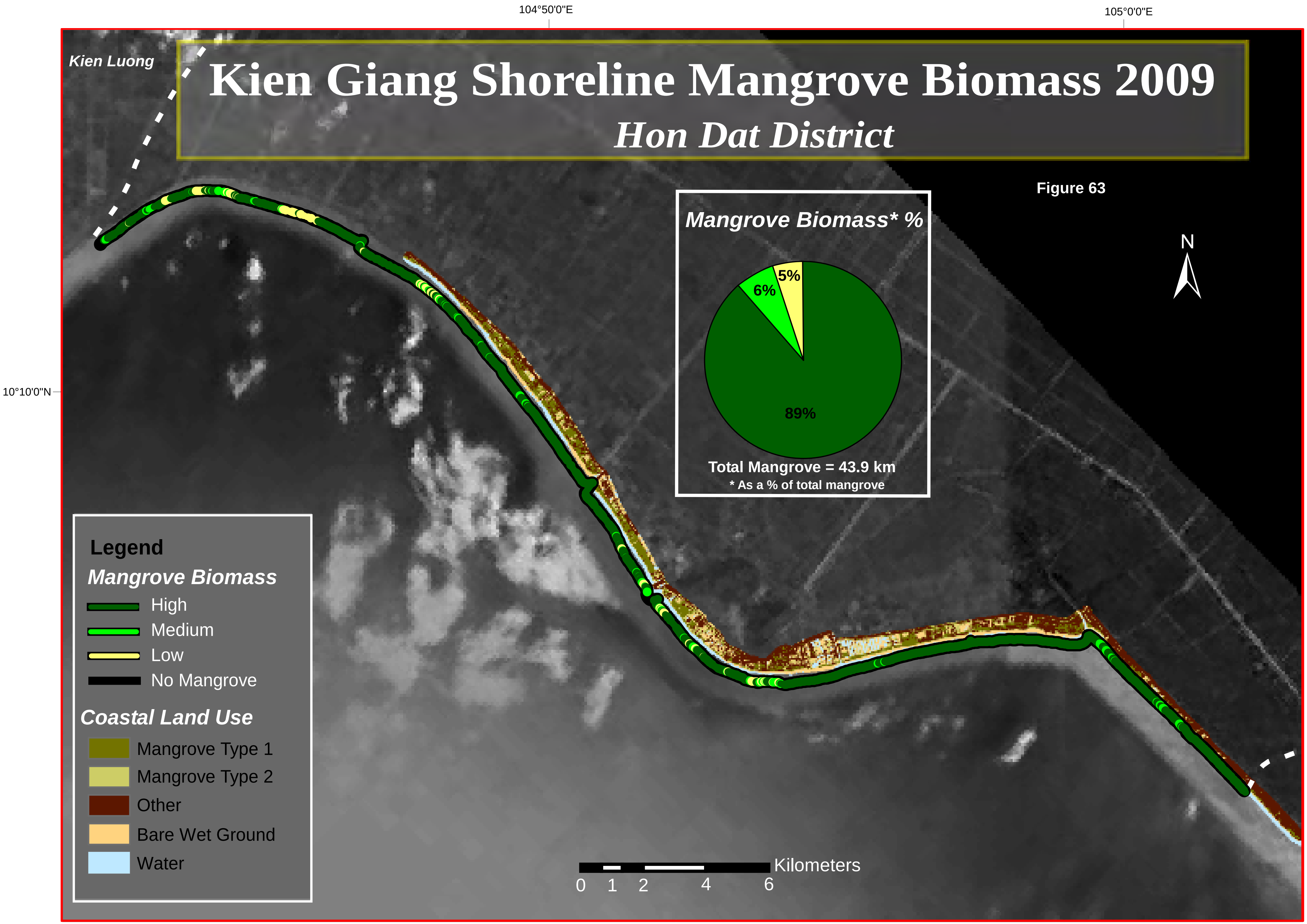

105°5'0"E
Kien Giang Shoreline
Dominant Mangrove Species 2009
Rach Gia District
Figure 58
N
10°0'0"N
Legend
Mangrove Genus
Avicennia
Rhizophora
Sonneratia
Nypa
Mixed
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Dominant Mangroves* %
100%
Total Mangrove = 6.2 km
* As a % of total mangrove
Kilometers
0 0.5 1 2 3


105°5'0"E
10°0'0"N
Kien Giang Shoreline Dominant Mangrove Species 2009
An Bien District
Figure 59
Dominant Mangroves* %
1%
3%
15%
7%
74%
Total Mangrove = 20.8 km
* As a % of total mangrove
N
An Minh
Legend
Dominant Genus
Avicennia
Rhizophora
Sonneratia
Nypa
Mixed
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6

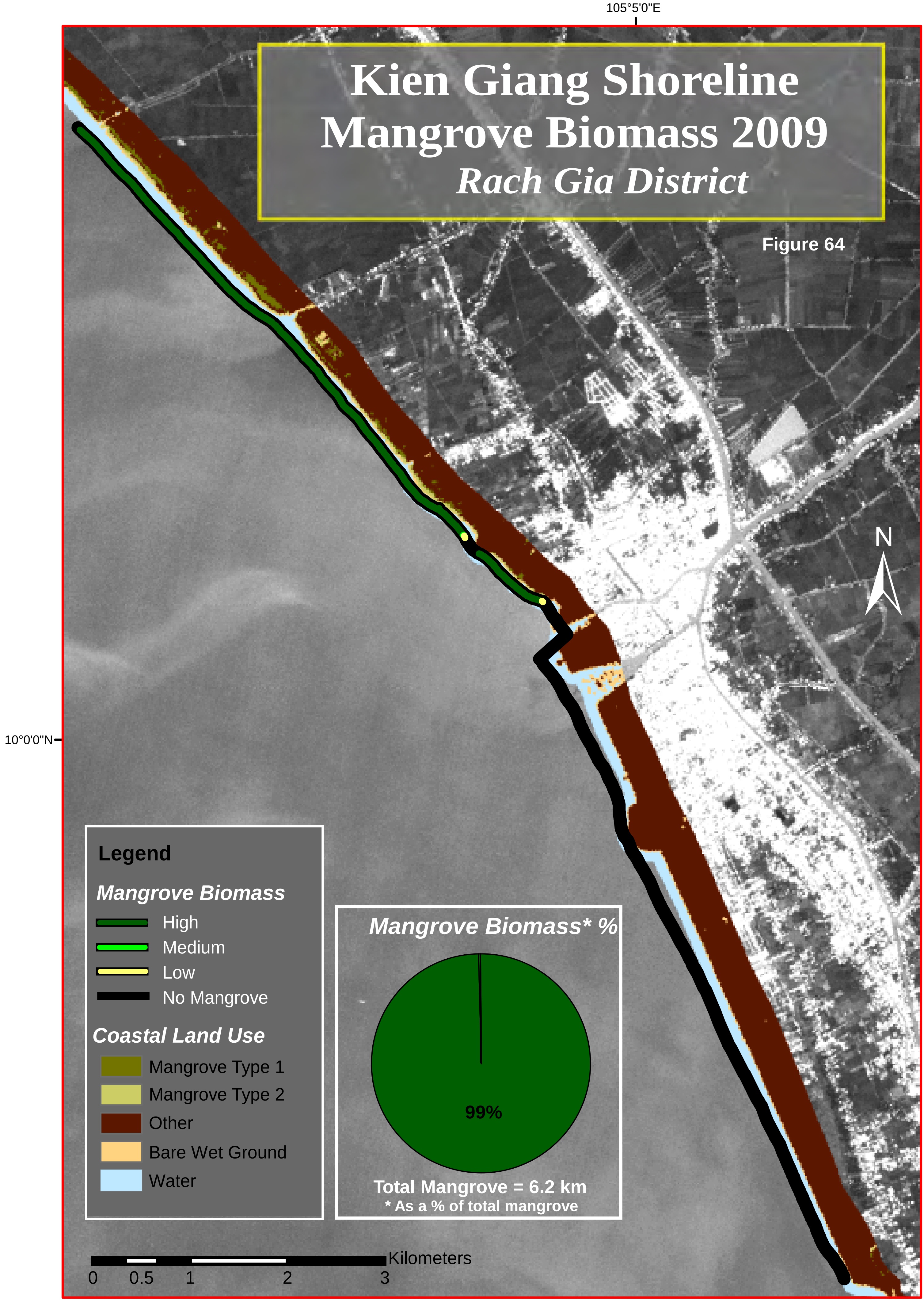

104°50'0"E
9°50'0"N
Kien Giang Shoreline
Dominant Mangrove
Species 2009
An Minh District
Figure 60
An
Bien
N
Dominant Mangroves* %
27%
5%
68%
Total Mangrove = 36.0 km
* As a % of total mangrove
Legend
Dominant Genus
Avicennia
Rhizophora
Sonneratia
Nypa
Mixed
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6


104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Cam Pu Chia
Ha Tien
Kien Luong
Kien Giang Shoreline Mangrove Biomass 2009
N
Figure 61
Hon Dat
Rach Gia
Chau Thanh
An Bien
An Minh
Ca Mau
Mangrove Biomass* %
8%
14%
74%
Total Mangrove = 133.9 km
* As a % of total mangrove
Legend
Mangrove Biomass
High
Medium
Low
No Mangrove
Kilometers
0 3 6 12 18

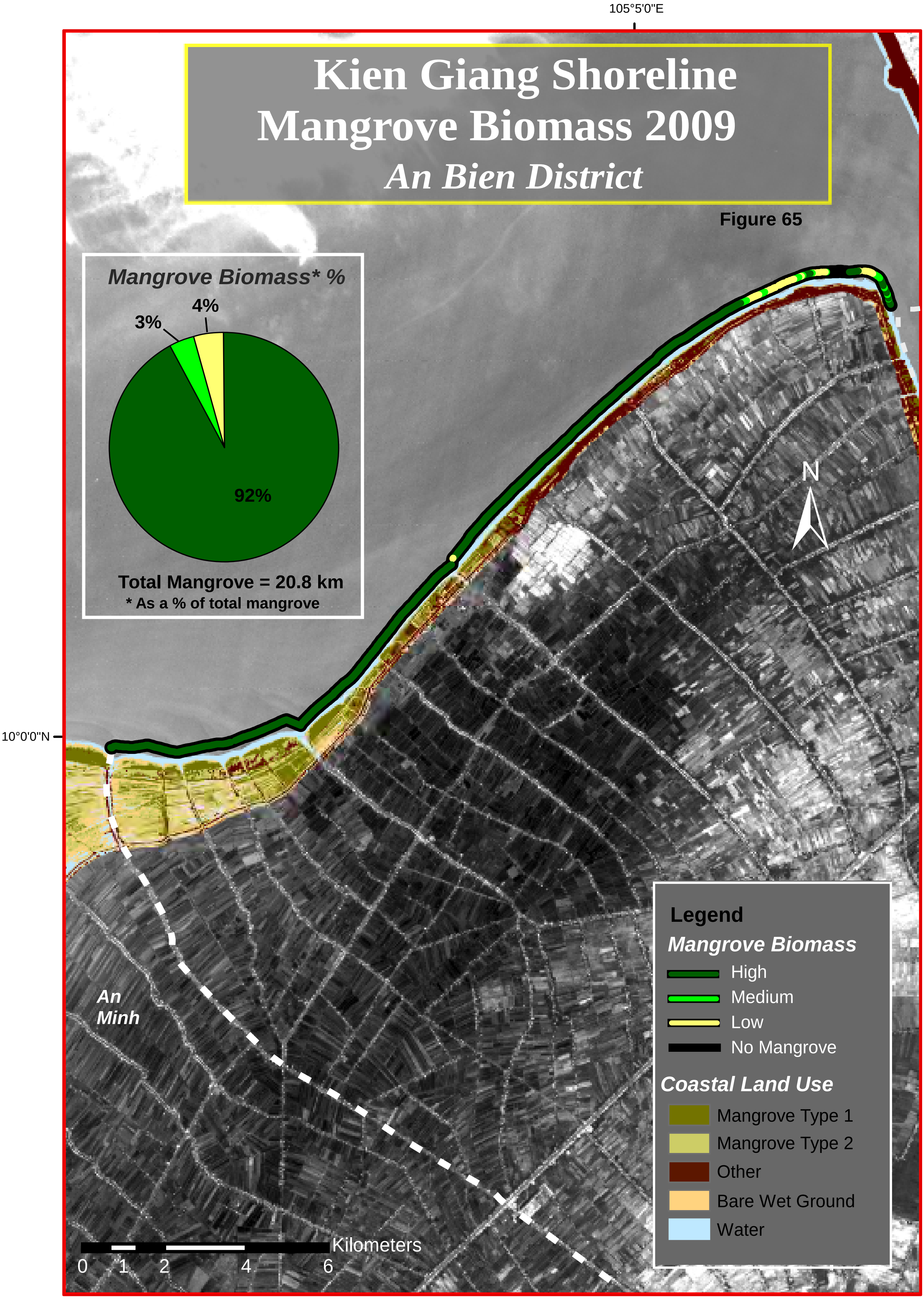

104°30'E
104°40'E
10°20'N
10°10'N
Kien Giang Shoreline
Mangrove Biomass 2009
Kien Luong / Ha Tien District
Figure 62
Ha Tien
Kien Luong
N
Mangrove Biomass* %
10%
24%
66%
Total Mangrove = 27.1 km
* As a % of total mangrove
Legend
Mangrove Biomass
High
Medium
Low
No Mangrove
Kilometers
0 1 2 4 6

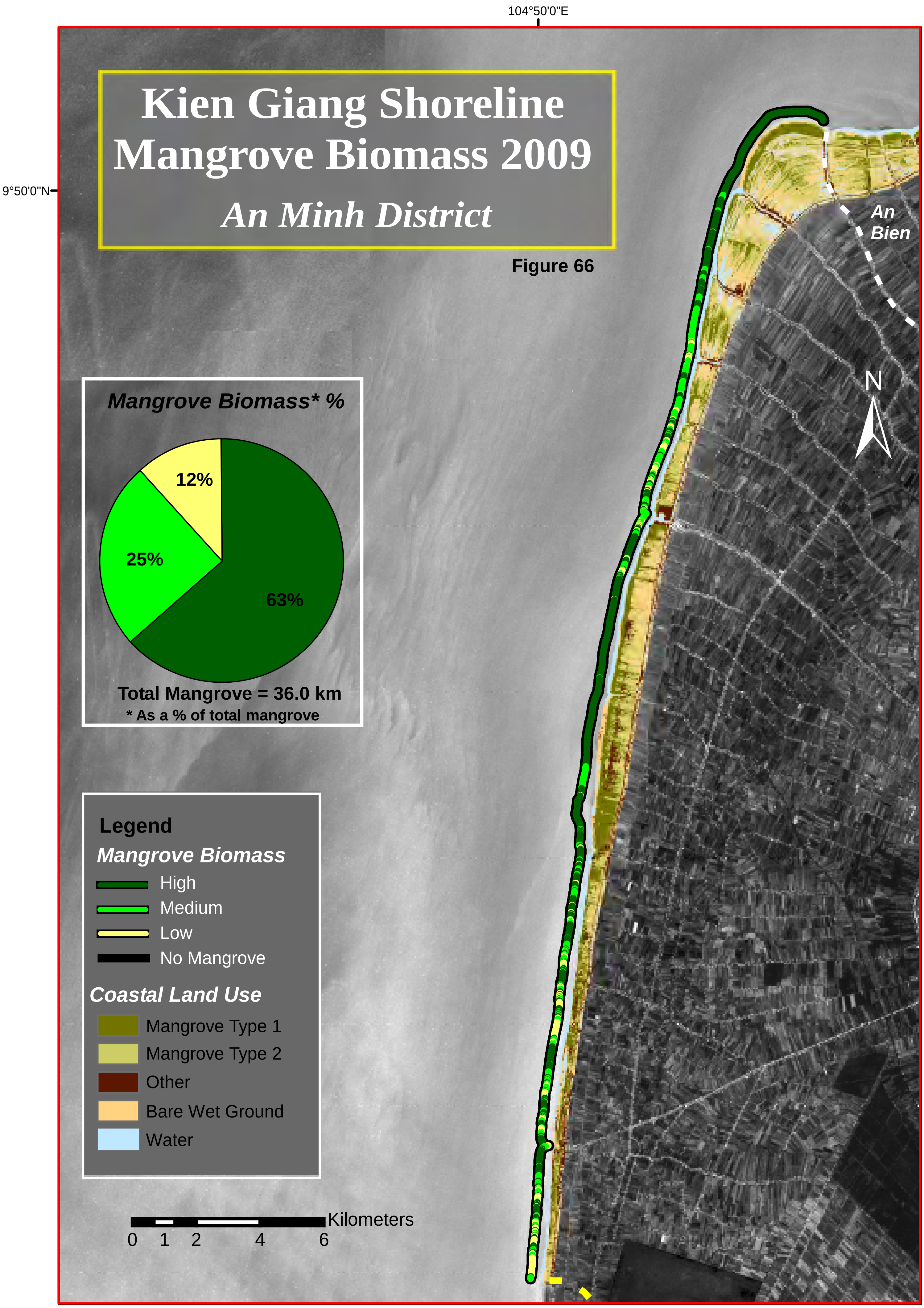


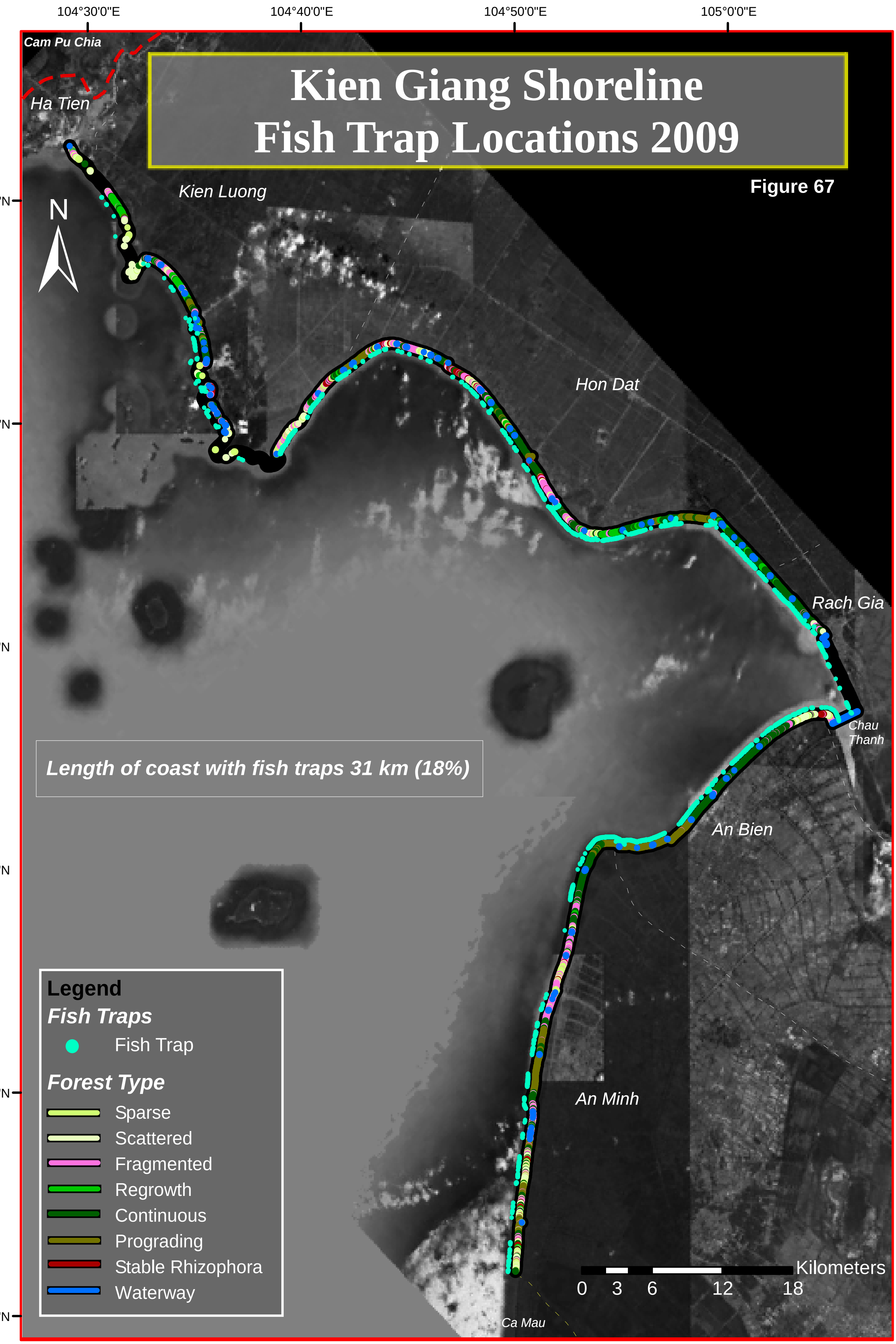
104°50'0"E
105°0'0"E
10°10'0"N
Kien Luong
Kien Giang Shoreline Mangrove Biomass 2009
Hon Dat District
Figure 63
Mangrove Biomass* %
5%
6%
89%
Total Mangrove = 43.9 km
* As a % of total mangrove
N
Legend
Mangrove Biomass
High
Medium
Low
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6



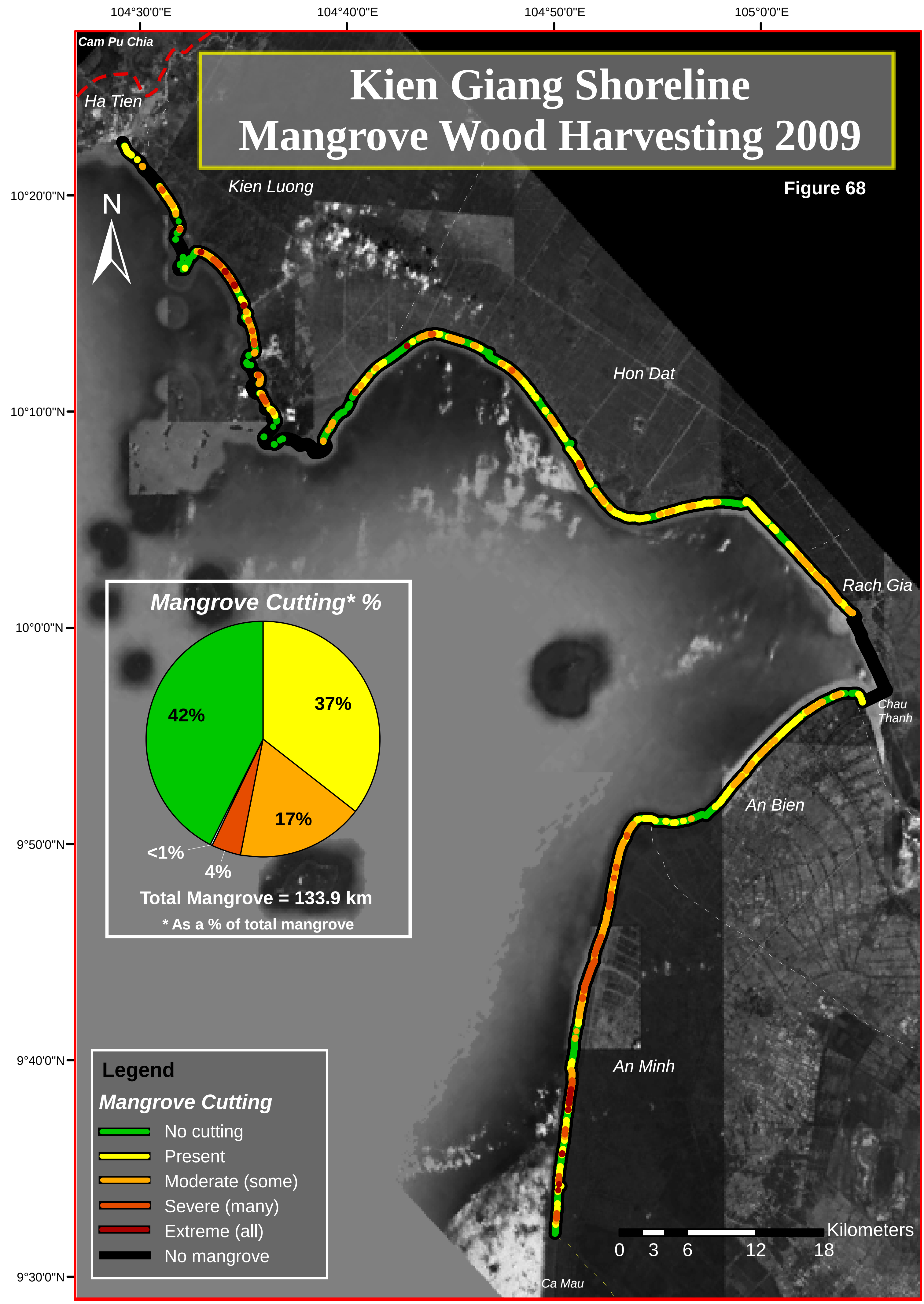
105°5'0"E
Kien Giang Shoreline
Mangrove Biomass 2009
Rach Gia District
Figure 64
N
10°0'0"N
Legend
Mangrove Biomass
High
Medium
Low
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Mangrove Biomass* %
99%
Total Mangrove = 6.2 km
* As a % of total mangrove
Kilometers
0
0.5
1
2
3


105°5'0"E
Kien Giang Shoreline
Mangrove Biomass 2009
An Bien District
Figure 65
Mangrove Biomass* %
3%
4%
92%
Total Mangrove = 20.8 km
* As a % of total mangrove
10°0'0"N
N
An Minh
Legend
Mangrove Biomass
High
Medium
Low
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6

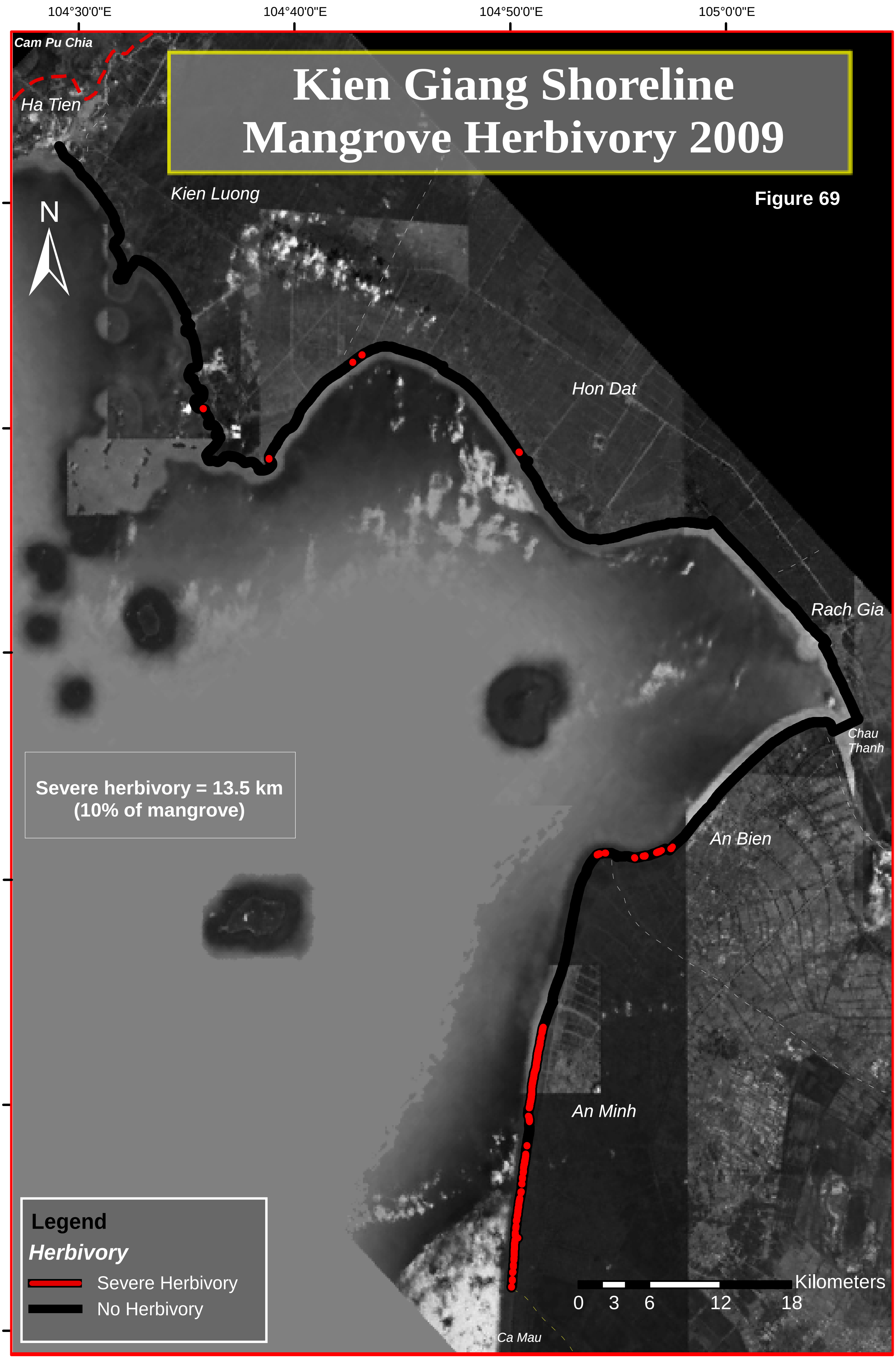

104°50'0"E
9°50'0"N
Kien Giang Shoreline
Mangrove Biomass 2009
An Minh District
Figure 66
An
Bien
N
Mangrove Biomass* %
12%
25%
63%
Total Mangrove = 36.0 km
* As a % of total mangrove
Legend
Mangrove Biomass
High
Medium
Low
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6



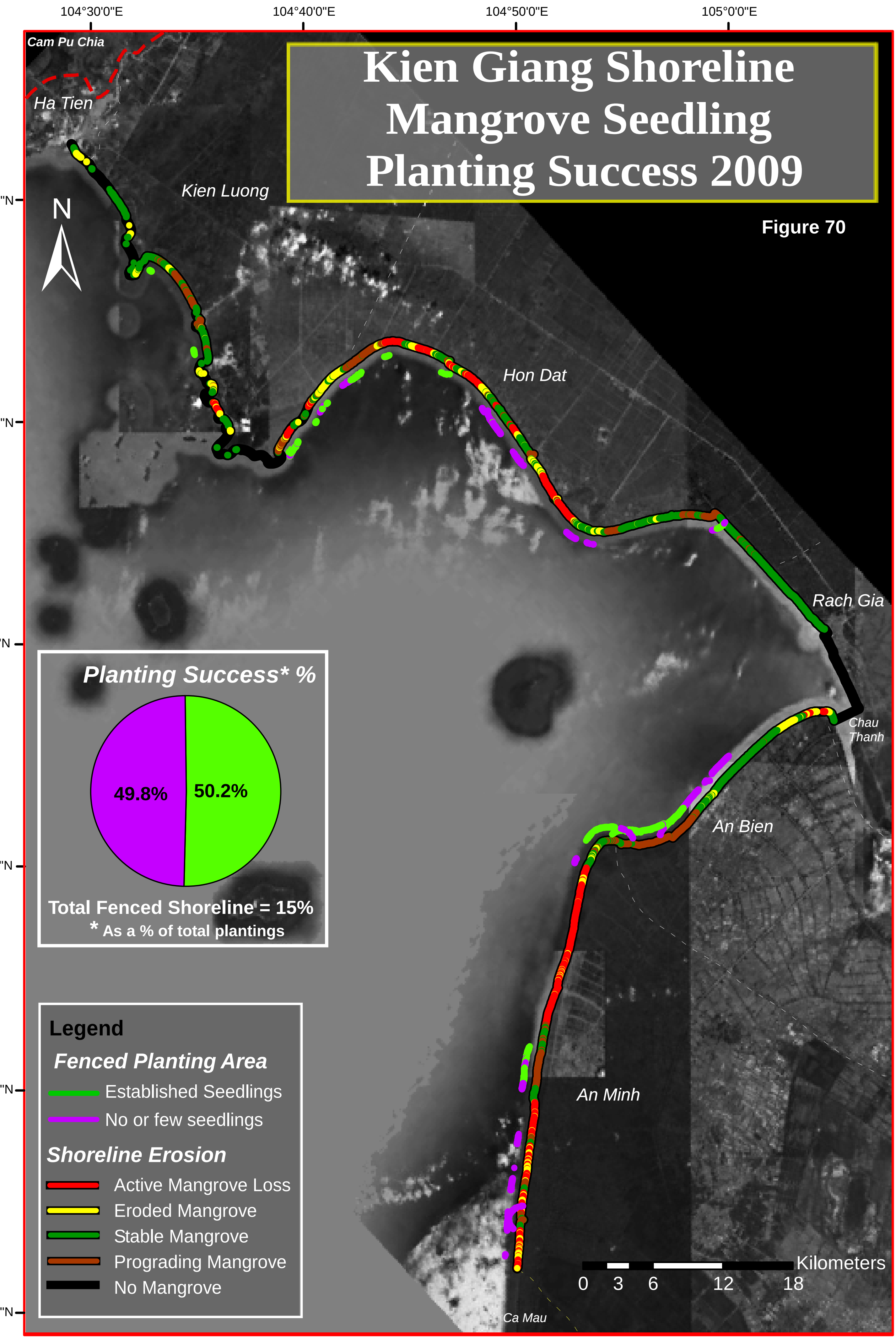
Kien Giang Shoreline
Fish Trap Locations 2009
Figure 67
104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Cam Pu Chia
Ha Tien
Kien Luong
Hon Dat
Rach Gia
Chau Thanh
An Bien
An Minh
Ca Mau
N
Length of coast with fish traps 31 km (18%)
Legend
Fish Traps
Fish Trap
Forest Type
Sparse
Scattered
Fragmented
Regrowth
Continuous
Prograding
Stable Rhizophora
Waterway
0 3 6 12 18
Kilometers

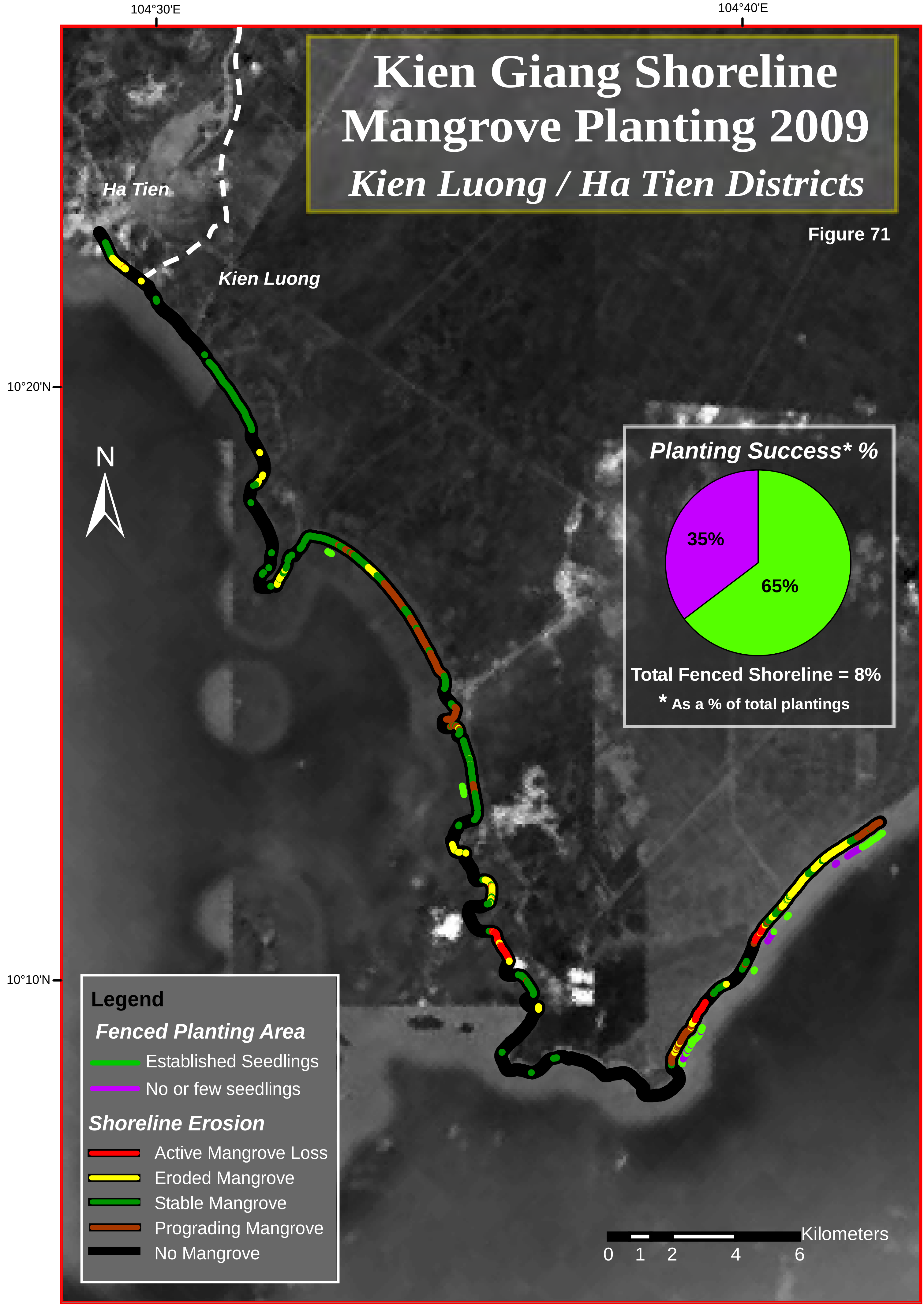


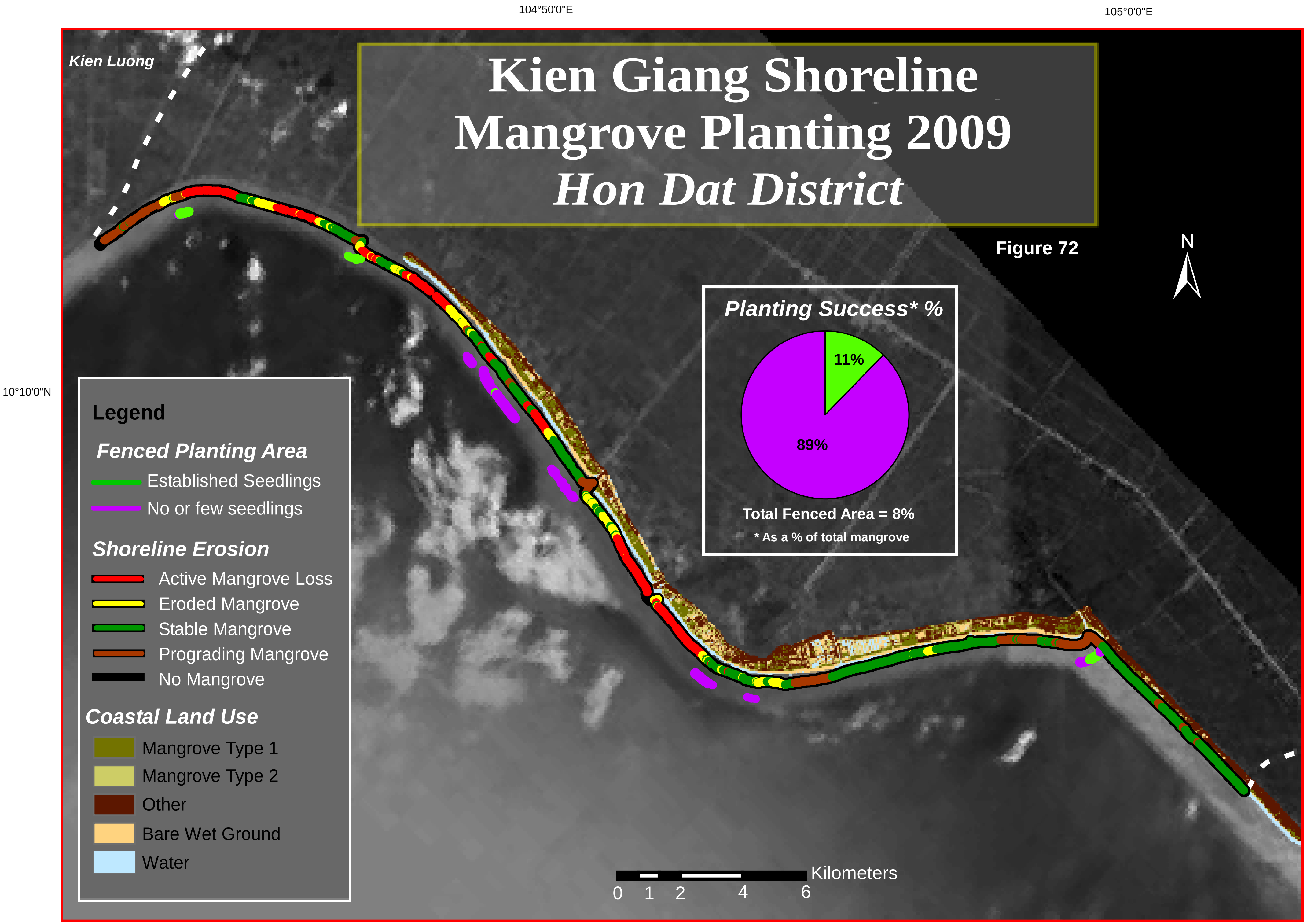
104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
Cam Pu Chia
Ha Tien
Kien Giang Shoreline
Mangrove Wood Harvesting 2009
Kien Luong
Figure 68
10°20'0"N
N
Hon Dat
10°10'0"N
Rach Gia
Mangrove Cutting* %
42%
37%
17%
<1%
4%
Total Mangrove = 133.9 km
* As a % of total mangrove
10°0'0"N
Chau Thanh
An Bien
9°50'0"N
An Minh
9°40'0"N
Legend
Mangrove Cutting
No cutting
Present
Moderate (some)
Severe (many)
Extreme (all)
No mangrove
Kilometers
0 3 6 12 18
Ca Mau
9°30'0"N



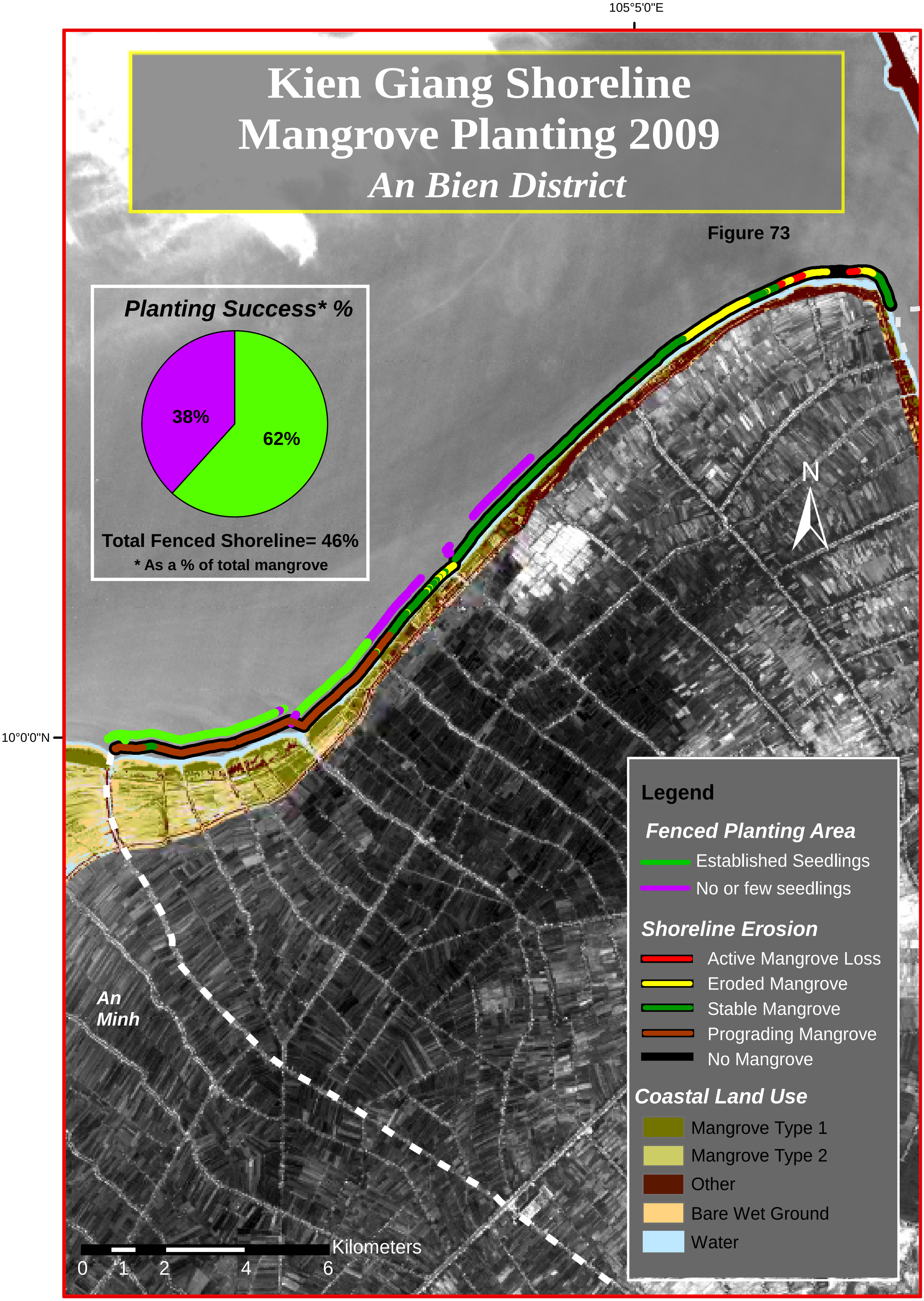
104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
Kien Giang Shoreline
Mangrove Herbivory 2009
Figure 69
Cam Pu Chia
Ha Tien
Kien Luong
Hon Dat
Rach Gia
Chau Thanh
An Bien
An Minh
Ca Mau
N
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Severe herbivory = 13.5 km
(10% of mangrove)
Legend
Herbivory
Severe Herbivory
No Herbivory
0 3 6 12 18
Kilometers

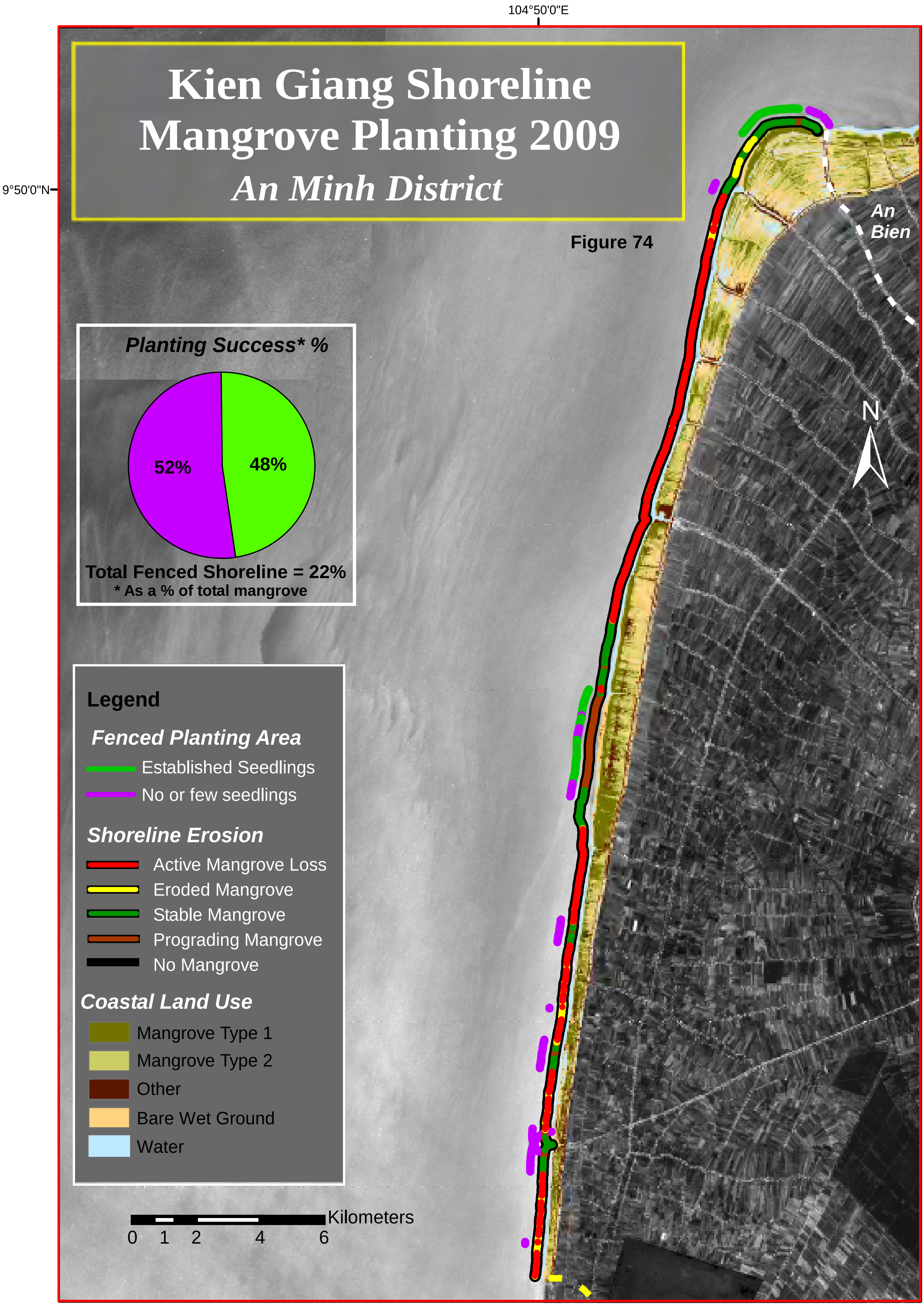

Kien Giang Shoreline
Mangrove Seedling
Planting Success 2009
Figure 70
104°30'0"E
104°40'0"E
104°50'0"E
105°0'0"E
10°20'0"N
10°10'0"N
10°0'0"N
9°50'0"N
9°40'0"N
9°30'0"N
Cam Pu Chia
Ha Tien
Kien Luong
N
Hon Dat
Rach Gia
Chau Thanh
An Bien
An Minh
Ca Mau
Planting Success* %
49.8%
50.2%
Total Fenced Shoreline = 15%
* As a % of total plantings
Legend
Fenced Planting Area
Established Seedlings
No or few seedlings
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
0 3 6 12 18
Kilometers


Kien Giang Shoreline
Mangrove Planting 2009
Kien Luong / Ha Tien Districts
Figure 71
104°30'E
104°40'E
10°20'N
10°10'N
Ha Tien
Kien Luong
N
Planting Success* %
35%
65%
Total Fenced Shoreline = 8%
* As a % of total plantings
Legend
Fenced Planting Area
Established Seedlings
No or few seedlings
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
Kilometers
0 1 2 4 6



Kien Giang Shoreline
Mangrove Planting 2009
Hon Dat District
Figure 72
Kien Luong
104°50'0"E
105°0'0"E
10°10'0"N
N
Planting Success* %
11%
89%
Total Fenced Area = 8%
* As a % of total mangrove
Legend
Fenced Planting Area
Established Seedlings
No or few seedlings
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6


105°5'0"E
10°0'0"N
Kien Giang Shoreline
Mangrove Planting 2009
An Bien District
Figure 73
Planting Success* %
38%
62%
Total Fenced Shoreline= 46%
* As a % of total mangrove
N
An Minh
Legend
Fenced Planting Area
Established Seedlings
No or few seedlings
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6


104°50'0"E
9°50'0"N
Kien Giang Shoreline
Mangrove Planting 2009
An Minh District
Figure 74
An
Bien
N
Planting Success* %
52%
48%
Total Fenced Shoreline = 22%
* As a % of total mangrove
Legend
Fenced Planting Area
Established Seedlings
No or few seedlings
Shoreline Erosion
Active Mangrove Loss
Eroded Mangrove
Stable Mangrove
Prograding Mangrove
No Mangrove
Coastal Land Use
Mangrove Type 1
Mangrove Type 2
Other
Bare Wet Ground
Water
Kilometers
0 1 2 4 6

3.5 Discussion

Outline of the Problem

Summary:

- Mangroves are extensive along the Kien Giang shoreline and have a high resource value, supporting local livelihoods in addition to natural ecosystem service provision.
- Shoreline erosion is a major threat to the valuable mangrove resource.
- Human activity, including unsustainable wood harvesting of mangrove forests is exacerbating shoreline erosion and severely limiting the ability of mangroves act as coastal stabilizers.
- Natural pressures further limit the resilience of shoreline mangrove forests to withstand coastal erosion processes, highlighting the need for management of anthropogenic pressures.
- Current strategies to replant mangroves could be improved to increase seedling establishment success and protect vulnerable coastline.

Shoreline mangrove extent

The shoreline survey identified that mangroves, although often limited in width, were extensive along the shoreline and represent a significant coastal resource. Mangroves were shown to be present along 74% (133km) of the Kien Giang coast (Figure 25). Of this mangrove extent, 60% of shoreline mangrove cover is intact, high biomass forest (Figure 61). The most extensive, high biomass mangrove shoreline cover was identified on the semi-protected coastlines of southern Hon Dat district, north Rach Gia district and An Bien district. These high biomass areas primarily consist of tall, dense Sonneratia and dense Avicennia forests.

Mangroves as a coastal resource

The shoreline mangrove areas were identified as being a valuable coastal resource which has tangible monetary value and direct association with coastal livelihoods. The primary resource value of mangroves in Kien Giang were identified from the shoreline survey as being a potential carbon store, fish habitat and a resource for building and construction.

High biomass fringing mangrove forest was identified as occurring along 60% of the shoreline. Despite being limited in width, this figure highlights that shoreline mangroves represent a sizeable carbon store. Based on mean estimates of biomass and carbon storage for Kien Giang mangrove forests outlined in section 4, if it is assumed that shoreline mangrove-forests are only on average 30m wide, this equates to 30,683 t ha^{-1} C, or 15% of total mangrove carbon store for Kien Giang.

Furthermore and perhaps more importantly, the shoreline mangroves were identified as being valuable fish habitat for edible and tradeable aquatic resources. Assessment of the presence of fish traps along the shoreline showed that 81% of all fish traps were associated with mangrove presence and 69% were associated with intact continuous forest (Figure 67).

From the shoreline survey it was also possible to identify areas of shoreline mangrove forest being used for wood harvesting (Figure 68). Wood harvesting of the shoreline mangrove was identified in 58% of mangrove forests, although it is expected that based on plot assessments, this figure is actually much higher. Of the forests being harvested, most cutting occurred in Avicennia (49%) and Sonneratia (19%) forests. However, of Sonneratia forest, cutting was observed in 65% of continuous forest. This suggests that Sonneratia is a target species for wood harvesting. From field observations, it was noted that as Sonneratia is the largest of the mangrove species, it was being used to create wooden boards. It was also observed being felled and coppiced to create habitat in association with fish traps. Planted and harvested Nypa fructicosa (Mangrove palm) was observed to be present along 6km of shoreline (Figure 55). This in itself represents a valuable mangrove resource as one Nypa frond can fetch up to 3000 VND at local markets.

From the shoreline survey it is apparent that shoreline mangroves are a valuable resource and significantly contribute to the livelihoods of coastal Vietnamese people. Further studies are required to fully quantify and appreciate the economic value of each resource, such as the fish catch associated with different forest types, wood value of each mangrove species and post-harvest wood use and Nypa productivity and harvesting intensity.

Mangroves under threat

Whilst mangroves are extensive along the Kien Giang coast and represent a significant resource, this valuable habitat is under threat from coastal erosion. 23% (30km) of shoreline mangroves are experiencing active mangrove loss (Figure 31). Shoreline erosion is most severe in An Minh district with 51% of mangrove areas experiencing active mangrove loss (Figure 36). Coastal erosion equates to a significant loss of mangrove area and has major implications for the capacity of Kien Giang mangroves to provide coastal defence under predicted scenarios of sea level rise. At a low estimate of shoreline erosion rates based on limited historical imagery available, shoreline erosion of 5m yr^{-1} results in a loss of 15 Ha yr^{-1} mangrove. In some areas, shoreline erosion has been estimated to be greater than 25m yr^{-1}, meaning this figure could be far greater. Of the actively eroding mangrove 56% (17km) is high biomass, continuous forest. In addition, a further 14% (18km) of mangrove areas are eroded, but not actively eroding. This suggests that these areas have in the past experienced erosion, possibly as a result of a one-off storm event, but are not threatened by daily coastal erosion processes. The presence of these non-actively eroding areas have several implications for management response to erosion. Firstly, they highlight that there are two distinct coastal erosion processes present along the Kien Giang coastline, daily erosion from small waves that causes consistent annual mangrove loss and erosion from infrequent one-off events. It is likely that shoreline erosion from these infrequent events could result in significant shoreline loss.

Further assessment of non-actively eroded areas from historical images is required to determine the time frame and scale of shoreline erosion resulting from one-off events. Secondly, non-actively eroded areas suggest that it is likely much more of the coastline is vulnerable to coastal erosion than is indicated by the presence of active erosion alone. An extensive analysis of shoreline erosion risk should be undertaken for the Kien Giang coastline to assess the risk of erosion resulting from a typhoon or large storm. This vulnerability highlights the importance of maintaining mangrove areas as a coastal defence, even in areas where active erosion is not present and appears unlikely. Fortunately however, it was observed that non-actively eroded areas were mostly recovering with mangroves prograding into shallow mud at the seaward margins. These areas represent the greatest opportunity for mangrove recovery. Direct mangrove planting in non-actively eroded areas could help prevent further erosion in the event of future one-off storm events.

It should be noted in any discussion of shoreline erosion, that erosion is a natural process and coastlines are naturally dynamic zones. In most natural circumstances shoreline erosion and mangrove loss is balanced by equal rates of sediment deposition and mangrove progradation across a temporal scale. In Kien Giang the current extent of mangrove loss (including non-actively eroded areas) outweigh prograding mangrove areas by 1.75:1. This suggests an overall loss of mangroves in the future. However, further studies of historical shoreline erosion and continued monitoring are required to examine past shoreline erosion rates and extent in comparison to the present assessment.

It is highly likely that extensive, uncontrolled wood harvesting and felling of shoreline mangroves is exacerbating shoreline erosion. 72% of actively eroding mangrove areas were recorded as being cut (Figure 68). Cutting in eroded areas was recorded as being significantly more severe than in non-eroded areas. In the case of An Minh District, 86% of actively eroding areas were cut and 100% of extreme cutting pressure recorded in Kien Giang, occurred in this district. The correlation between cutting and erosion does not suggest that cutting causes erosion, but it is likely to have a significant effect through forest fragmentation reducing the capacity of the forest to respond to coastal erosion processes. The recorded correlation is most likely the result of eroded areas being more easily accessed, owing to deeper waters at the shoreline edge. This is further supported by the results of the survey showing only 8% of cutting occurring in prograding forest, where the shoreline is shallow and muddy.

In addition to wood harvesting, a number of other natural and anthropogenic pressures were identified from the shoreline survey that are likely to further reduce the resilience of the mangrove forest to coastal erosion. Most notable of these pressures was the unexpected occurrence of severe herbivory on Avicennia from an unidentified caterpillar, causing extensive foliar leaf loss (Figure 75). This effect was observed in 10% of mangrove areas, mostly in An Bien and An Minh districts and in planted, prograding forest (Figure 69). The extensive damage to young planted Avicennia indicates that mixed species planting should be utilized to increase stand resistance to such an event.

Figure 75: Intense isect herbivory on mangrove trees is a fairly common occurance on the Kien Giang Shoreline. Inset (right): Unidentified caterpillar grazing on Mangrove leaves. Both photographs taken in An Minh District.

Other anthropogenic pressures identified from the shoreline survey that require management solutions were root burial associated with litter accumulation in Kien Luong district and direct mangrove removal for canal, dyke and industrial construction (1.7km). Root burial was observed to have killed an 800m section of mangroves near Hong Quao. Extensive litter accumulation was noted to be present on a further 7km (4%) of the coastline. Such extensive litter build up, resulting in mangrove death, has not been recorded anywhere else in the world and highlights the problem of plastic and refuse disposal in Vietnam. A large source of the plastic is likely to be the Rach Gia tip, which extends into the sea and was observed to be actively eroding.

Mangrove systems are well adapted to withstand natural pressures such as herbivory and storms and are therefore able recover after such events. However, with additional anthropogenic stressors present, the resilience and recovery potential of mangrove forests can be significantly reduced. The combination of natural stressors and direct anthropogenic pressures, it is unlikely that shoreline mangroves will be able to respond and recover to the additional stress associated with sea-level rise. It is therefore imperative that anthropogenic pressures are effectively managed and mitigated to prevent further extensive shoreline mangrove loss.

Threats to livelihoods

Shoreline erosion directly threatens the shoreline mangrove resource which has direct implications for the livelihoods of thousands of coastal inhabitants. In areas of severe erosion, homes, villages and aquaculture ponds are already being threatened. From the survey, 5km of aquaculture ponds were recorded as being breached and damaged by erosion. Additionally, 19 homes and villages were observed to have been abandoned or are directly threatened by coastal erosion. In the event of a storm surge resulting from a typhoon, it is likely that many more homes will be damaged and the loss of life is highly likely. The majority of abandoned and threatened homes and aquaculture were recorded along the An Minh coastline where erosion is the most severe (Figure 36).

Current Adaptive Strategies

The current management strategies implemented in Kien Giang Province to mitigate mangrove loss and prevent shoreline erosion are mangrove planting the construction of earthen walls. Based on the results of the shoreline survey, both strategies are limited in their success and could be improved and or modified.

Earthen dykes were observed to have been exposed by erosion along 24 km (13%) of coastline. Of the exposed dyke, almost 50% (11 km) were severely degraded or breached, with an additional 8 km of dyke currently eroding. These figures suggest that once total mangrove loss occurs in front of the earthen dyke, the dyke quickly degrades. The rapid degradation of exposed earthen dykes emphasises both the importance of the mangrove fringe in wave attenuation and shoreline protection and the ineffectiveness of earthen dykes as a strategy for coastal defence. The construction of the dyke may potentially exacerbate erosion, as mud dredged for dyke construction is often sourced from the seaward mangrove fringe, creating a deep channel and disturbing root structures.

A popular strategy to bolster mangrove shoreline defence is direct mangrove planting to encourage increased mangrove growth and forest density. In Kien Giang, these planting areas can be identified from a distinctive fence of crossed poles, hereby referred to as a planting fence, at the seaward edge of the planting area. The presence of planting fences were recorded during the shoreline survey. The success of the planting was assessed by observing the seedling density within the planting area. Planting fences were present along 27 km of coastline (15%) (Figure 70). Planting was predominatly of the Avicennia genus (82%) Of the planting area recorded, only 50% were identified as successful (Figures 70-74). Whilst it cannot be conclusively determined that the remaining 50% had failed, due to uncertainty surrounding whether they had been planted into, it does represent a seemingly low success rate. Most notable however was the location of the planting areas. 55% of mangrove planting occurs on prograding coastline, with a further 30% in front of stable mangrove areas (Figure 70-74). This indicates that most planting occurs on shoreline where it is least required; being the fragmented, eroding forest. However, these areas are also the most difficult to achieve planting success. Recommendations and strategies to enable planting in these areas are explored in section 5. One option for planting that is not currently being utilised but is important for mangrove recovery, is planting into eroded, but not actively eroding areas. As outlined above, these areas have possibly eroded as a result of a one-off storm event, but are no longer eroding. At present, < 1km (5%) of not-actively eroded areas of a total of 18 km have a planting fence. It is recommended that planting options for these areas be explored further. Enhanced recovery of the mangrove fringe through assisted planting may reduce the vulnerability of eroded areas to future storm events.

Management Recommendations

Current management strategies are failing to protect the mangrove resource. High levels of small scale local cutting and harvesting, larger scale conversion of mangrove areas to commercial aquaculture production and associated canal development have increasingly fragmented this valuable ecosystem. Fragmentation has significantly decreased the resilience of these plant communities to the natural pressures that exist on a semi-exposed coastline, such as waves, strong currents and wind. As such, large areas of mangrove have been lost to coastal erosion processes and much of the Kien Giang coastline is at risk of eroding in the near future. In some instances, coastal erosion has extended beyond the mangrove fringe and now threatens commercial enterprises and homes. This problem is only likely to become more severe under present climate change and sea-level rise predictions. The Mekong delta is considered to be one of the most at risk areas in the world due to its low elevation and high value for food production. Without appropriate action, the degradation of mangroves along the Kien Giang coastline will remove any effective vegetative buffer and expose the coastline to the effects of sea level rise which will threaten the livelihoods of thousands of people. A discussion of the potential solutions is included in chapter five of the current report.

4. Biomass and Carbon Estimations

Figure 76: Measuring plots for mangrove biomass estimates.

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4.1 Introduction

The purpose of this chapter is to synthesise plot based vegetation studies with satellite vegetation classification and mapping to provide the first estimate of regional-level biomass carbon stocks held within the mangrove forests of Kien Giang Province. Accurate mapping of carbon storage from optical satellite data, such as the SPOT imagery used in the current project, can prove problematic due to the difficulty in idenfying all types of forest degredation from satellite imagery (Fuller 2006; Gibbs *et al.* 2007). Through coupling SPOT imagery with ground-based observations, we provide novel data regarding mangrove biomass, and associated CO_2 storage, throughout Kien Giang province by scaling up plot based observations through vegetation mapping. This data synthesis provides valuable information given current discussions about financially valuing carbon stores in vegetation.

Recent focus on the storage of carbon by forest ecosystems that would otherwise be in the atmosphere has led to proposals to give sequestered carbon a financial value beyond the in-kind value they already have, either through large REDD mechanisms, voluntary carbon trading funds or via project funding. Even without a direct financial mechanism, the value of mangrove biomass is increased by the need to regulate atmospheric CO_2.

Contributions of plot based data to the wider project through supplying quantitative parameters such as species presence and height within plots will assist in the future development of clear vegetation units parameters used for mapping. In addition, observations and experience in identifying coastal erosion derived in field work has assisted shoreline condition assessments (Chapter 3; Shoreline Assessment), as well as informing management recommendations presented in Chapter 5 of the current report.

This chapter gives a general overview of the methods, results and implications regarding biomass and carbon estimations for the Kien Giang mangrove forests. For further detail and discussion please see the full document (Wilson 2010).

4.2 Background: Brief context on forests and carbon

Forest ecosystems are made up of carbon-based life forms in plants and animals (biomass), along with sometimes large amounts of leaf litter and living or dead organic material in the soil. Trees and shrubs make the bulk of above ground biomass in a forest, with the total biomass of a stand varying markedly depending on the climate and soil and, in the case of mangrove vegetation, the frequency and duration of tidal inundation. The age of the forest and its constituent trees is also a factor. In relatively young forests the carbon stored builds over time as the trees and forest grow. Soil carbon stocks also rise.

The relationship between the size of trees and their biomass is not linear – meaning that as the diameter and height of the tree increases its biomass increases in a disproportionally greater way. A typical mangrove tree may increase in dry biomass by greater than 5 times with every doubling of its trunk diameter of which about half is carbon. This means that a forest of thin trees, even if tightly packed, may have only a fraction of the biomass of a forest of wider spaced large trees. **It is the size of the trees and their density that is the principal determinant of stand biomass. The wood density of the tree further affects the carbon content of the plants and hence that of the stand of vegetation.**

All carbon in biomass derives ultimately from atmospheric carbon dioxide (CO_2) via plant growth. Removal of forest cover and the burning or rotting of cut biomass returns carbon to the atmosphere in the form of CO_2, or sometimes methane (CH_4) in the case of rotting. Hence forests are a standing store of sequestered atmospheric carbon, despite some turnover over on a daily basis. Some of the turnover (productivity) breaks down to return to the atmosphere, but other fractions enter food chains or are stored in the soil. Soil carbon can be stable for long periods. Sedimentary environments like mangrove ecosystems can facilitate the burial of biomass and sometimes form peat due to restricted breakdown of biomass in the wet soils. It follows that the degradation and disturbance of naturally-functioning wetlands can be a major cause of increased carbon emissions as soil carbon oxidises to the atmosphere (Ramsar Secretariat *et al* 2007).

4.3 Methods

Visits were made to Kien Giang in July-August 2009 and January 2010. Many observations on the nature and condition of the mangrove vegetation were made, along with the collection of plot-based data using a rapid field assessment methodology. The methodology was largely devised for this task (details in Wilson 2010).

A total of 41 plots were sampled (approximate localities in Figure 1; precise details in Wilson 2010), with the assistance of GTZ and Department of Agriculture and Rural Development (DARD) staff. These were long plots (2.5 m wide, long enough to include 30 trees of greater than 1.3 m high), and parallel to the shore. Numerous descriptive features of the vegetation collected in the plots, including:

- Species and vegetation types present.
- Heights (measured with a height pole), diameters at breast height (DBH = 1.3 m, except with *Rhizophora*, which were measured above the protuberances), canopy cover (using a canopy denistometer) and density of trees (number within the plot/plot size) to estimate biomass and carbon content.

- Seedling and small tree numbers in the first phase plots (number, species and heights in 1 m x 1 m quadrats at 5 m intervals inside the plot).
- Degree of cutting (number of cut stumps).
- Precise localities along with the summaries of the collected data for calibrating remote sensing.

Estimates of above ground biomass (AGB) were made using published allometric equations and one for Vietnam of Dr V. N. Nam, who made it available for this exercise. These equations are as follows:

- For *Avicennia*: AGB = $0.1292 * D^{2.4137}$ (Nam pers. comm., 2010)
- *For Ceriops*: AGB = $0.2079 * D^{2.407}$ (Nam pers. comm., 2010)
- For *Lumnitzera*: AGB = $0.075 * D^{2.3721}$ (Nam pers. comm., 2010)
- For *Rhizophora*: AGB = $0.3482 * D^{2.2965}$/Root weight = $0.0122 * D^{2.4959}$ (Nam pers. comm., 2010)
- Komiyama general: AGB = $0.251 * \rho D^{2.46}$/ Root weight = $0.199 * \rho D^{2.22}$ (Komiyama *et al*. 2005)
- *Nypa* palms: AGB = $0.029 * (\text{total frond length})^{2.013}$

Where D=trunk diameter in centimetres (at 1.3m above ground or immediately above the bulk of prop roots in *Rhizophora*); H =tree height in metres; ρ = wood density (dry weight/volume) in t m^{-2}. Root weight as an estimate of below ground biomass for species other than *R. apiculata* is based on the common allometric equation of Komiyama *et al.* (2005). This equation is not as statistically strict a relationship as above ground biomass (Komiyama *et al* 2005), however it can be useful to illustrate carbon storage potential below ground.

Conversion from biomass to carbon was achieved through dividing biomass by the carbon fraction of 50% (Gifford 2000), apart from with *R. apiculata,* where 49% was used based on Nam (pers. comm.). To convert standing carbon content to atospheric CO_2 equivalent, standing content was multiplied by 3.67.

Extrapolation of plot based data to estimate biomass and CO_2 storage in mangrove forests of Kien Giang Province

Plot locations were identified as either *mangrove type 1* or *mangrove type 2* based on geographic location within landuse maps developed in chapter 2 of the current project (Figures 11-15). The total number of plots within the mapped area was 22. Average biomass and total atmospheric CO_2 eqivalent storage per ha was calculated for each vegetation unit. To estimate total atmospheric CO_2 equivalent stored within mangrove forest, mangrove area (ha) was multiplied by mean total atmospheric CO_2 equivalent per ha for both *mangrove type 1* and *mangrove type 2* vegetation classes. As current satellite mapping (chapter 2, this report), is currently limited to ~70% of the coast of Kien Giang Province, total forest biomass and carbon storage figures were generated for both the known (mapped) area, and the estimated total mangrove area of Kien Giang. This estimation of 3500 ha is based on an extrapolation of the known area of mangrove from the mapped districts (see Chapter 2, this report).

4.4 Results

4.4.1 Quantitative Vegetation Description

The plots made up an area of 2773 m^2, containing 911 trees and shrubs taller than 1.3 m (genets) and a total of 1219 stems (ramets). There were 22 tree and shrub species taller than 1.3 m within the plots, plus four common species of understorey plant (two *Acrostichum* and two *Acanthus* species). This represents the majority of Kien Giang's recorded mangrove diversity.

Overall, the mean height of the trees above 1.3 m height in each plot ranged from 2.1 m to 11.2 m, with an overall mean of 6.2 m. The height of the tallest trees in each plot ranges from 5m to 16.9 m, with a mean of 10.1 m. A calculation of the tallest 'stratum' of trees in the plots gives a range of 2.4 m to 12.5 m, with an overall mean of 9.1 m. This represents an approximate canopy height as seen from an aerial photograph, albeit possibly with gaps present. The canopy cover of the plots ranged from 58% in a heavily cut site to a number of plots with 82 or 83%.

Tree diameter ranged from 2.3 cm to 14.2 cm, with an overall mean of 6.4 cm. The basal area of the plots[1] was summed, then expanded to a per hectare figure for comparison between plots (Wilson 2010), with a range from a very low 3.8 m^2 ha^{-1} to 54.7 m^2 ha^{-1} and an overall mean of the plot mean values of 22.5 m^2 ha^{-1} (Table 5)

Table 6 lists the tallest tree heights and diameters of mangrove species identified inside the plots. The average diameter at the top of cut stumps in the plots was 7.0 cm. The percentage of cut stumps to living stems varied from 0% (one plot only) to 450% in a heavily cut multi-stemmed *R. apiculata* plantation.

[1] 'Basal area' refers to the cross-sectional area of trees at the height of measurement, rather than at ground level.

Table 5: Summary details of mean mangrove tree height, diameter and basal area and quadratic mean diameter for all plots. Blue denotes *mangrove type 1* vegetation and grey denotes *mangrove type 2* vegetation as mapped in Chapter 2, this report. All other sites fall outside the currently mapped area.

Plot Number	Mean height of all stems (m)	Approximate canopy height (m)[1]	Mean diameter of all stems (cm)	Basal area (m^2 ha^{-1})
AB1	4.9	7.9	3.1	6.6
AB2	4.8	9.0	4.7	18.9
AB3	5.8	9.1	5.3	17.6
AB4	10.3	10.3	10.1	46.2
AM1	8.0	10.5	6.3	16.8
AM2	10.5	10.6	6.6	35.0
AM3	9.5	10.2	6.7	19.5
AM4	9.7	11.1	7.2	8.9
AM5	3.6	6.7	3.0	13.2
HQ1	3.8	7.0	3.4	5.0
HQ2	3.8	9.9	3.7	12.9
HT1	5.0	7.4	4.5	27.1
HT2	3.6	7.2	3.0	3.8
HT3	2.1	2.9	2.4	3.8
HT4	4.8	11.1	8.1	51.0
KL1	7.7	9.5	8.3	18.7
KL2	5.3	7.1	5.1	9.0
KL3	2.5	3.6	2.3	9.0
KL4	8.2	10.8	7.8	22.0
KL5	4.9	8.9	4.1	18.0
KL6	4.1	7.3	3.1	6.2
KL7	4.0	6.2	3.6	16.4
KL8	3.9	5.6	3.3	19.0
VQ1	6.8	16.4	10.4	38.4
VQ2	4.6	13	6.8	54.7
VQ3[1]	N/A	N/A	N/A	N/A
VQ4	7.2	14.0	10.3	36.8
VR1	9.9	11.0	13.4	23.5
VR2	6.6	11.8	5.6	28.8
VR3	10.8	11.5	14.2	34.5
VR4	8.8	10.1	13.6	34.5
VRy1	4.9	8.1	5.1	11.2
VRy2	11.2	8.3	12.3	22.6
VRy3	6.4	11.5	6.8	28.7
VRy4	7.4	10.2	6.7	52.6
VRy5	4.7	8.8	5.3	29.1
VRy6	5.6	7.4	6.3	18.2
VRy7	10.4	9.6	7.5	24.6
VRy8	4.6	12.0	8.0	23.3
VRy9	4.3	6.4	7.0	21.3
VRy10	3.8	5.5	4.6	13.9

[1] A manual calculation based on an assessment of the tallest trees across the plot (see text).
[2] Plot VQ3 is a *Nypa* only plot and so is not strictly comparable to the others.

Table 6: Maximum tree heights and their diameter for selected tree species within study plots

Species	Tallest height in plot (m)	Diameter of tallest tree in plots (cm at 1.3 m height)*	Plot name	Approx. max. height seen outside plots (m)
Avicennia alba	12.0	29.0	HT4	12-13
A. marina	11.5	15.6	KL1	None taller
Bruguiera cylindrica	10.0	15.7	KL1	None taller
B. gymnorhiza	3.8	3.5/2.9 (2 stems)	VQ2	11
B. sexangula	4.5	3.4	VRy1	6-7
Ceriops tagal	5.0	19.0	HT1	None taller
C. zippeliana	10.3	14.4	AM2	None taller
Excoecaria agallocha	8.75	7.3	VRy5	None taller
Lumnitzera racemosa	9	11.1	HT2	None taller
Rhizophora apiculata (apparently natural)	10.6	20.0 (above prop roots)	HQ2	15-16
R. apiculata (planted)	13.7	33.0 (above prop roots)	VRy3	None taller
R. mucronata	5.5	4.5 (above prop roots)	VRy2	12
Sonneratia caseolaris	16.9	37.6	VQ1	20-21
Sonneratia ovata	10.5	10.5	VRy6	None taller
Thespesia populnea	6.5	6.8	KL2	None taller
Xylocarpus granatum	9.5	31/29.5 (2 stems)	VRy7	None taller

* *Rhizophora* measured above prop roots.

4.4.2 Biomass and Carbon Analyses

Mean forest biomass for the forty plots where both above and below ground biomass was measured is 156.9 t DW ha^{-1}. If mapped vegetation units are considered in isolation, mean dry weight of total mangrove biomass (above and below ground) in *mangrove type 1* forest is 147 ± 24 t DW ha$^{-1.}$ (± std error), which is lower than total dry weight of *mangrove type 2* vegetation (191 ± 43 t DW ha^{-1} (± std error)).

The structural variability in Kien Giang's mangrove is shown in the range from a low above ground biomass (AGB) of 10 t dry weight (DW) ha^{-1} in riverine upper intertidal scrub vegetation in Ha Tien (Plot HT3) to a high AGB of 424 t DW ha^{-1} in a multi-stemmed *R. apiculata* plantation (Plot AB4) (Table 7). Two plots have an AGB equivalent to c. 300 t DW ha^{-1}. HT4 (309.2 t DW ha^{-1}) is a plot with relatively large (20 – 29 cm dbh) and dense *A. alba* trees and VQ2 (318 t DW ha^{-1}) is in tall *S. caseolaris* forest. Table 7 gives biomass and carbon estimates for the plots, expanded to a tonnes dry weight (DW) ha^{-1} basis.

Total atmospheric CO_2 eqivalent stored in one hectare of mangrove forest (both *mangrove type 1* and *mangrove type 2)*, was estimated based on all 40 plotswhere above and below ground biomass was calcuated as 282.1 ± 31 (t ha^{-1})[1]. Mean atmospheric CO_2 eqivalent stored in one ha of mangrove forest in *mangrove type 1* forest was estimated from plot measurements within the mapped area as 264 ± 43 (t ha^{-1})[1] (± std error). *Mangrove type 2* forest stored a higher amount of CO_2 with a mean value of 343 ± 78 (t ha^{-1})[1].

Table 7: Biomass and carbon estimates for mangrove plots in Kien Giang. Blue denotes *mangrove type 1* vegetation and grey denotes *mangrove type 2* vegetation as mapped in Chapter 2, this report. All other sites fall outside the currently mapped area. See text for more details.

Plot	AGB (t DW ha^{-1})	RW (t DW ha^{-1})[1]	Total biomass (t DW ha^{-1})	Total carbon content (t ha^{-1})	Total CO_2 equivalent (t ha^{-1})[1]
AB1	24.4	11.9	36.3	17.8	65.3
AB2	96.1	38.4	134.5	65.9	241.9
AB3	69.1	32.5	101.6	49.8	182.7
AB4	424.9	10.2	435.1	213.2	782.4
AM1	135.6	4.4	140.0	68.6	251.8
AM2	187.1	73.4	260.5	127.6	468.5
AM3	154.7	5.5	160.2	78.5	288.1
AM4	74.5	4.0	78.5	38.5	141.2
AM5	56.2	18.5	74.7	36.6	134.3
HQ1	25.0	6.6	31.6	15.5	56.8
HQ2	89.1	17.5	106.6	52.2	191.7
HT1	136.6	50.9	187.5	91.9	337.2
HT2	15.8	4.6	20.4	10.0	36.7
HT3	10.4	1.9	12.3	6.0	22.1
HT4	309.2	131.4	440.6	215.9	792.3
KL1	127.8	36.1	163.9	80.3	294.7
KL2	37.3	8.7	46.0	22.5	82.7
KL3	45.6	4.1	49.7	24.4	89.4
KL4	195.1	16.9	212.0	103.9	381.2
KL5	51.2	17.3	68.5	33.6	123.2
KL6	20.4	10.1	30.5	14.9	54.8
KL7	99.8	11.1	110.9	54.3	199.4
KL8	99.2	12.4	111.6	54.7	200.7
VQ1	203.5	72.2	275.7	135.1	495.8
VQ2	318.0	108.9	426.9	209.2	767.7
VQ3[2]	1.4	ND	NA	1.1 (above ground only)	2.3 (above ground only)
VQ4	174.8	66.4	241.2	118.2	433.7
VR1	235.2	14.3	249.5	122.3	448.7
VR2	101.6	37.5	139.1	68.2	250.1
VR3	145.5	48.2	193.7	94.9	348.3
VR4	83.1	34.4	117.5	57.6	211.3
VRy1	48.2	11.0	56.3	27.6	101.2
VRy2	71.0	37.5	108.5	53.2	195.1
VRy3	205.2	13.9	219.1	107.4	394.0
VRy4	124.6	61.2	185.8	91.0	334.1
VRy5	191.7	51.5	243.2	119.2	437.3
VRy6	133.3	45.5	178.8	87.6	321.5
VRy7	84.6	36.9	121.5	59.5	218.5
VRy8	212.2	11.6	223.8	109.7	402.5
VRy9	88.5	45.9	134.4	65.9	241.7
VRy10	132.4	14.7	147.1	72.1	264.5
Sums	**4903.2**	**1240.0**	**6275.6**	**3075.0**	**11285.4**
Means	**125.9**	**31.0**	**156.9**	**76.9**	**282.4**

[1] *Nypa* not included in RW data, sums or mean carbon figures.
[2] *Nypa* only plot estimated differently to other plots.

4.4.3 Estimated Carbon storage in Kien Gang's mangrove forests.

The high variability in the small mangrove areas of Kien Giang makes accurate expansion of biomass estimates across greater areas using remote sensing difficult. However, some estimates are neccessary to develop a standing budget for the province. Given current estimation of mangrove area of 3500 ha in Kien Giang province, carbon storage in mangrove forests of Kien Giang is 269089 ± 28120 tonnes (± 1 x SE), representing around 987556 ± 103201 t (± 1 SE) of atmospheric CO^2.

Based on both plot based data and vegetation mapping, Table 8 gives estimated total carbon content (t ha^{-1}) in *mangrove type 1 (M1), mangrove type 2 (M2)* and total mangrove forest (*M1 + M2)* in the mapped area of Kien Giang province (currently representing ~70% of the province, see Chapter 2, this report). This information is broken into each of the mapped regions.

Table 8: Total estimated carbon content held in *mangrove type 1, mangrove type 2* and total mangrove forests in each mapped region of Kien Giang. Error terms are single standard error.

	Mangrove Type 1 *(M1)*		Mangrove Type 2 *(M2)*		*M1 + M2*	
Region	ha	Carbon content (t ha^2)	ha	Carbon content (t ha^2)	ha	Total Carbon content (t ha^{-1})
Hon Dat	406	29161 ± 4765	387	362121 ± 8221	793	64795 ± 9140
Rach Gia	89	6407 ± 1047	104	9759 ± 2216	193	15812 ± 2230
Chau Thanh	27	1968 ± 322	32	3013 ± 684	60	4870 ± 687
An Bien	263	18904 ± 3089	255	23879 ± 5421	518	42358 ± 5975
An Minh	424	30439 ± 4974	549	51379 ± 11665	973	79495 ± 11214
Mapped regions total	**1210**	**86879 ± 14196**	**1328**	**124242 ± 28207**	**2537**	**207328 ± 29246**

Based on the carbon content of mangrove forest (Table 8), total atmospheric carbon equivalent held in mapped mangrove forests (*M1 + M2)* of Kien Giang is estimated as 760828 ± 107337 t (± 1 x SE). Total atmospheric carbon equivalent for the estimated complete area of mangrove forest in Kien Giang is 987556 ± 103201 t.

Synthesis of results:

- There is significant standing mangrove biomass in Kien Giang province, and hence carbon storage where the vegetation remains.
- For a given species, the size of trees contributes most to high biomass, although density) is also a factor.
- Wood density is a factor in biomass and carbon storage, with heavier timbered species being better stores for a similar size.

4.5 Discussion and implications of the biomass and carbon survey

To present a clear interpretaion of forest biomass and carbon storage in Kien Giang's mangrove forests, it is useful to compare figures both with other mangrove forests, as well as with tropical terrestrial forests. Mangrove forest biomass estimates from the 41 plots sampled during this project component revealed above ground biomass (AGB) to be only slightly lower than terrestrial tropical forest biomass. Mean AGB for mangrove plots was 126 t DW ha^{-1} compared with the IPCC's 180 t DW ha^{-1} for Asian tropical moist deciduous forest (IPCC 2006; Gibbs *et al.* 2007). The IPCC's biomass figures for forest types are based purely on above ground biomass, however it is well established that mangroves accumalate rates of below ground biomass in significantly greater proportions than terrestrial forests (Komiyama *et al.* 2008). The accumulation of below ground biomass in the roots of mangroves can contribute significantly to the overall forest biomass figure (Komiyama *et al.* 2008). Many plots in the present study have above to below ground biomass ratios of a little as 2:1 (Table 7). It is therefore likely that total biomass of Kien Giang mangroves, and of mangrove forests in general, is higher than terrestrial forest values than appears through consideration of above ground biomass only. This indicates that mangrove forest in Kien Giang can potentially exhibit biomass levels comparable with terrestrial forest, and show potentail as a worthwhile inclusion in a REDD scheme.

Carbon storage in Kien Giang mangrove forests is substantial. However, cutting was evident in the vast majority of the sites (all but one), and is a major influence on forest biomass and subsequent carbon storage. Greater protection and rehabilitation of areas currently subject to cutting will increase rates of carbon storage in Kien Giang mangrove forests. Mangrove forests with very high above ground biomass are commonly recorded in the literature (i.e. 460 t DW ha^{-1} in Malaysia, Putz & Chan 1986). These forests are generally primary forest (Putz & Chan 1986; Tamai *et al* 1986; Komiyama *et al* 1987, 1988), and analysis of primary forest biomass figures can therefore allow estimation of Kien Giang forest biomass were mangroves offered high protection from harvesting and other forms of human induced damage (i.e. conversion to aquaculture).

Above ground biomass is considered to be generally less than 100 t DW ha^{-1} in most secondary forests or concession areas (Poungparn 2003; Komiyama 2008), whilst primary mangrove forests in geographically comparable areas (Thailand and Malaysia) are commonly recorded to have biomass figures greater than 300 t DW ha^{-1} (Putz & Chan 1986; Komiyama *et al.* 1987). In Malaysia, primary stands *R. Apiculata* dominated forest were estimated to have above ground biomass figures of between 270 – 460 t DW ha^{-1} (Putz & Chan 1986), and in

Thailand primary *Rhizophora* forest has been recorded with biomass figures as high as 571.4 t DW ha^{-1} (Komiyama *et al.* 1987). Comparisons with these figures highlights the low biomass values recorded in the plots of Kien Giang (mean total biomass of Kien Giang = 156.9 t DW ha^{-1}). Biomass values in some plots were low, probably due both to the vegetation type and forest age. Sampling was taken from a range of vegetation including young forest, some significantly cut forest and scrubby vegetation during the present study. Species composition can also influence biomass figures, for example *A. alba* stands have low biomass due to their posoition at the colonising (frontal) edge of the mangrove forest. Mangrove forest biomass generally increases as you move away from the coast. (Fromard *et al* 1998; Komiyama *et al* 2008). However, overall the most obvious and significant impacts on forest biomass were related directly from cutting.

It is obvious that human influences on mangrove forest quality (such as cutting) substantialy impact the carbon storage potential of the forest (Figure 77). **To enhance the level of biomass, and subseqent carbon storage within mangrove forests in Kien Giang, efforts to protect the forest will be worthwhile.** We estimated current total forest biomass in Kien Giangs mangrove forests (based on extrapoloation of mangrove area mapping in chapter 2) to be 549114 ± 57385 t DW (± 1 std error of the mean). This corresponds to 269089 ± 28120 tonne of carbon storage. If, through protection, restoration and rehabilitation, mangrove forest biomass were to reach levels in line with primary forest biomass of nearby Thailand, total forest biomass could increase to as much as 1999900 t DW (given a total biomass level of 571.4 t DW ha^{-1}). **This in an increase of 1450785 t DW, which is more than 3.5 times the level of mangrove forest biomass we see today, with no increase in the area of mangrove in Kien Giang.**

Figure 77: Recent large scale cutting of mature *Sonneratia caseolaris* for coppicing. Note large stump in foreground. Cutting such trees has large biomass implications.

4.5.1 Protection and cutting

Maturity is a key factor in forest biomass. Much, if not nearly all, of the mangrove in Kien Giang is at a relatively young stage of development, even where current cutting is not intense. Factors such as past or ongoing cutting, regrowth after storm damage or the relatively recent colonisation of fresh mud may be influences. Changes in hydrology brought about by the construction of dykes and canals may have altered the distribution of mud. **Removal (cutting) of large trees results in a major reduction in standing biomass**. Although the removal of small trees may enhance the growth of those remaining in young forests, the removal of big trees diminishes biomass for a long time due to their contribution to biomass. To illustrate, the removal of a **single *R. apiculata* tree, 18 cm in diameter in the plot VR1, diminished the biomass by more than 15%**. The removal of large *S. caseolaris* trees can also be seen in standing biomass figures. Plot VQ4 has several large stumps present and a biomass of 174.5 t DW ha^{-1}, but the nearby VQ2 with only smaller stumps has an AGB of 318.2 t DW ha^{-1}.

Comprehensive and repeated cutting even of small to moderate size trees has the potential to reduce stand biomass (Figure 79). Forests with such a cutting history probably have at least 50% lower above ground biomass over a reasonable spatial scale than they would have if intact. Open patches and low thickets of species such as *Acanthus* and *Acrostichum* are present in places as artefacts of cutting (Figure 78 and can be seen as tree-less areas in Figure 80). There is considerable lost biomass potential within these areas.

Regardless of the reasons, with time and protection the mangrove forests will gain biomass and carbon storage. The largest trees seen of some species are shown in Table 3, showing the potential other trees may reach with significant increases in carbon sequestration in some cases. It follows that allowing trees to grow to maximal size is the way to maximise biomass. Typically, soil carbon levels increase with maturity as well (Alongi 2009).

Figure 78 (left): *Acrostichum* and *Clerodendrum* thicket and scattered trees, Plot VRy1, Vam Ray. This should all be forest. The very dense thicket can suppress tree regeneration. **Figure 79** (right): Stump of mature *Rhizophora apiculata* within mixed forest, An Bien. Cutting trees of this relative size noticeably affects standing biomass

4.5.2 Regeneration and restoration to enhance biomass

Given the value of mangroves and the possibility of financial support for carbon storage, it follows that enhancing the area and biomass of the mangrove area is desirable. Expanding the mangrove area seaward has been recognised in Kien Giang and elsewhere in Vietnam, including investigations in erosion zones in Kien Giang. Mangrove expansion for shoreline protection brings with it inevitable biomass benefit. However, there has been less recognition of the potential to enhance mangrove biomass within the existing mangrove area. **The best way to build biomass, and enhance carbon storage, is within the existing mangrove forests.** The net treed mangrove area in Kien Giang is smaller than the gross mangrove habitat due to aquaculture and to a lesser extent to unforested and largely unproductive 'wasteland' thickets (e.g. Figure 80). Protection where plants are already established will rapidly add to biomass and carbon stored, as productivity is high. This is particularly so as the forests in Kien Giang are relatively young in most places. Secondly, plant establishment is easier within the existing mangrove both in planting and in natural regeneration than in non-forested areas.

Figure 80: Degraded mangrove with unused aquaculture ponds, Kien Luong. Note a lack of tree cover and the eroding front of the mangrove. Erosion appears apparent even where mud extents out to sea (left of picture) (Image: Google Earth). The thickets in the non-treed areas may be suppressing regeneration.

Restoration will occur naturally with protection in areas with a biomass deficit resulting from human activities. Most restoration proposals focus on planting, although this is not always necessary. Regeneration is not limiting as evidenced by the number of seedlings and saplings. It is recommended that the potential for assisted natural regeneration be investigated in activities aimed at enhancing mangrove growth within the existing area. Mangroves establish and grow rapidly in good conditions and it is clear that this is the case in Kien Giang. In many areas there is great potential in natural regeneration if tidal conditions were enhanced. This includes existing and former aquaculture ponds and degraded land. Figure 81 shows where a breach of a wall immediately south of Hon Queo canal has reintroduced tidal flow, resulting in natural mangrove regeneration. The intervening period of a maximum of about 39 months has resulted in regeneration sufficiently large to be visible by remote sensing.

Figure 81: Apparent natural regeneration of mangrove vegetation following reintroduction of tidal regime to ponds, Hon Queo (Image: Google Earth).

Figure 82 shows young natural regrowth of *A. alba* at Vam Ray, in a abandoned aquaculture pond. Tidal flow is sufficient to instigate regeneration, which is rapid. Such regeneration is relatively low in biomass, similar to *A. alba* forest at the front of the mangrove, but will build over time. The advantages in natural regeneration are that it is low in resources compared to planting and that natural biodiversity is generated. The disadvantage compared to planting is that in good sites plantation growth is often faster.

Figure 82: Young natural regeneration of *Avicennia alba* in former pond, Vam Ray

Mangrove Planting: Rhizophora apiculata

Although large blocks of *R. apiculata* are not now found naturally on the Kien Giang coast, there has been good biomass gain in the planting programs dating to the early 1990s. The very high biomass of the plot AB4 (AGB = 424.9 t DW ha-^{1}) may be anomalous, but other stands unlikely to be older than 18 years are over 200 t DW ha^{-1}.

***Rhizophora apiculata* is the species of choice for plantings within the mangrove area.** The growth of *R. apiculata* is well studied in Asia, including in planted stands (e.g. Ong *et al.* 1995; Clough *et al.* 2000; Tan 2002; Komiyama *et al.* 2008; Alongi 2009). Some above ground biomass figures are given in Table 9. The figures found for Kien Giang are within the range of relative low to moderate figures in Thailand to high figures in Malaysia. The growth rates found by Tan (2002) are applicable to Kien Giang, as are biomass figures if the density is similar. Based on this and other work in the Mekong Delta (Clough *et al*. 1999 in Alongi 2002), **good quality *R. apiculata* stands at 35 years of age will be expected have an above ground biomass of about 325 t DW ha^{-1}.**

Clough *et al.* (2000) estimated an annual net primary production of *R apiculata* in the Mekong Delta by litter fall of 9.41 t DW ha^{-1} y^{-1} in a 6 year old stand and 18.79 t DW ha^{-1} y^{-1} in a 36 year old stand, showing good mangrove productivity and significant carbon input to the ecosystem.

Table 9: Some above ground biomass (AGB) figures from *Rhizophora apiculata* stands of known age.

Place	Age	AGB (t DW ha^{-1} y^{-1})	Source
Ca Mau, Vietnam	5	41.9	Tan (2002)
Ca Mau, Vietnam	10	143.4	Tan (2002)
Ca Mau, Vietnam	15	202.8	Tan (2002)
Ca Mau, Vietnam	25	277.6	Tan (2002)
Ca Mau, Vietnam	35	326.9	Tan (2002)
Thailand	3	65.4	Alongi (2009)
Thailand	25	344	Alongi (2009)
Thailand	15	159.0	Christensen
Malaysia	5	106.4	Alongi (2009)
Malaysia	18	352	Alongi (2009)
Malaysia	85	576	Alongi (2009)
Malaysia	20	114	Ong *et al.* (1995)

Planting within the existing mangrove, including in ponds, has been more successful than sea front plantings and *Rhizophora* plantings generate fast biomass, as a result of fast growth rates and dense timber.

4.5.3 Training and communication

A training session for GTZ staff and members of the Coastal Forest Protection Management Board was given as part of the current project component. Field based training in long plot methodology and biomass calculation was provided to Mr. Vo Van Duc (Hon Dat – Kien – Ha – Hai Coastal Forest Protection Management Board), Mr. Nguyen Minh Tri(An Minh – An Bien Forest Protection Management Board) and Mr. Huu To (GTZ Technical Officer) and Mr. Chu Van Cuong (GTZ Technical Officer). In addition, a detailed mathods manual regarding plot based methodology and employed in this project section was developed for future use by GTZ and associates. See Wilson (2010) for this documents.

5. Rehabilitation of eroded shorelines, environmental services and livelihood projects

Figure 83: Nursery for growing mangrove seedlings and preparing them for planting in both sea margin protection, and mangrove livelihood trials.

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5.1 Goals for our Assessments of Restoration and Livelihoods Projects

The chief goal addressed in this chapter is to provide advice, assistance or recommendations that might contribute to improved mangrove forest management in Kien Giang Province. Our objective is to assess alternate and complimentary strategies for coastal managers and landholders who must deal with rising sea levels and eroding shorelines. To be successful the strategy only needs to delay erosion loss, giving more time for communities to adjust and adapt in a more considered way.

One key component necessary to improve mangrove management is to increase awareness and appreciation of the great benefits to be gained from healthy and sustainable mangrove forests. Shoreline vegetation has significant intangible benefits. Healthy mangrove forests support the bulk of regional fisheries production and these same forests contribute to improved quality of coastal waters and hold and bind sediments, reducing erosion and loss of coastal lands.

To improve the capacity of mangroves to provide these important ecosystem services, mangrove areas need to be both enlarged and better maintained, specifically as the 'green barrier' along the sea edge that protects the coastal margin. While mangroves have multiple benefits, like increased fisheries production, it is their benefit towards coastal protection that needs to be officially recognised and fully supported. This is essential if the potential for mangroves to provide this benefit is to be realised. Official recognition is needed to ensure lands are allocated specifically for the task of hosting mangroves as shoreline stabilizors. Shoreline development needs to be kept to a minimum in these area, and appropriate strategies must be put in place to deal with anticipated increases in sea level.

5.2 Observations on Livelihood Projects and awareness raising

Throughout mainland Kien Giang, people are utilising mangrove forests and their many products. In coastal areas throughout the province local people seem aware of the key benefits to be gained from mangrove forests. Identified benefits derived from timber and thatch products, associated aquaculture, barriers to erosion on canals and seashores, and even aesthetic gardens are observed throughout the province.

Figure 84: Planting trials will consolidate various on-ground works to restore the Hon Dat sea wall and fringing mangrove defences.

In Ha Tien estuary in far northern Kien Gian there are large estuarine areas that are in the process of being divided up and turned into ponded crop lands of *Nypa* palms. This appears unique for Kien Giang, if not elsewhere in Vietnam. The going price of each frond is 3000 VND. A stack gets around 384,000 VND. Needless to say, whereever you look, there is a hive of industry surrounding the *Nypa* industry of Ha Tien. A study is needed to census these *Nypa* farmers of Ha Tien to learn about leaf harvest production rates, and production per hectare per year. This could be usefully be backed up with a scientific assessment of the same attributes, leaf production rates, biomass measures, and clump density.

Figure 85: Stacks of *Nypa* fronds ready to ship to market in Ha Tien.

It would be useful to compare crop production yields and infranstructure costs and outlays using similar calculations for rice production. The ready advantage in *Nypa* is that it is saltwater tolerant. There are also likely to be intangible benefits in their support of nearshore fisheries. These strategies should also be supported where they encourage local communities to value mangrove vegetation – and to derive direct benefits. In this way, people will have an investment in salt-tolerant crops, the knowledge to nurture mangrove vegetation, and the skills to promote a vegetated coastal defence that limits the rate of change and the progressive impact of sea level rise.

The linking of livelihood projects with the cultivation of the ‘hedge rows’, identified in section 5.3 as a possible method useful for rehabilitation projects, would be most useful. One great neccessity for successfully mangrove protectivion is to increase the popularity of rehabiliation projects amongst residents living adjacent to the mangrove forests. Uniting crop production with hedge row formation may provide one avenue to do so (for further detail see section 5.3).

In Phu Quoc, the opinion regarding the value of mangroves was found to be completely different from mainland Kien Giang. Mangrove forests are not used by the locals of Phu Quoc, and they are treated with considerable neglect. It seems that mangrove wetlands are seen only as areas of future development. Development is occuring rapidly in Phu Quoc due to the high level of tourism in the area. Many mangrove remnants and remains are evident around the island in the form of cut dead stumps and stagnant ponded areas which once were tidal but now have been cut off from the sea by ground work alterations. When promted, local residents expressed a view that mangroves are not valued in Phu Quoc. There is a real and urgent need to raise people's awareness of mangroves in this important district, which will lead to better management and conservation of these essential resources.

5.3 Observations on Restoration Projects, and recommendations for future efforts

Assessments of degraded and damaged shoreline were on-going during all field surveys. Shoreline surveys provide full quantification of extent and proportions of coastal areas affected by erosion and breaching of dykes, with 33% of the coast eroding, corresponding to 59.4 km of shoreline (Figure 86). In Chapter 2 mapping and remote sensing identified that in Hon Dat the coastline area is being lost at a rate as much as 24 m per year. Future mapping (where satellite imagery becomes available) will potentially identify further areas where coastline erosion is rapid and widespread (See chapter 2, this report for further detail). In additon to the current eroding areas, a further 59% of the coastline in Kien Giang province is considered to be at risk of future erosion due to factors including steep coastlines and low mangrove density.

Figure 86: Eroding coastlines threaten homes and livelihoods in many regions of Kien Giang province.

Pressures from both erosion and habitat transformation (development, cutting, conversion of aquaculture etc) has resulted in the mangrove area of Kien Giang being reduced to the point of being only a narrow fringe in many areas. Large scale efforts to re-establish mangroves at the coastal fringe through seedling planting, combined with restoration of mangroves at the landward margin are required to protect both the mangrove resource and the communities they support. This is well recognised, with most of the discussion on reinstating a wider mangrove barrier pertaining to seaward extension of the mangrove front. Such an extension is desirable in Kien Giang , despite the problems surrounding the establishment of mangroves on open coasts. The recent Prime Ministerial decision (667) on coastal dyke strengthening highlighted the current attention regarding these issues. This decision sets a desirable target of 500 m mangrove width, recognising the role played by mangroves in attenuating wave action. These strategies will ultimately increase carbon storage as well.

5.3.1 Shoreline Defence

Dyke construction

One solution has been to build dykes to keep the sea out (Figure 87). This seems like a relatively easy solution – but only if it works. Our observations show the construction and maintenance of these dykes needs to be improved, where they have collapsed and breached during periods of severe storms and large waves. Furthermore, dykes must also be accompanied by increasingly sophisticated water control systems for associated river canals. Unfortunately, as sea levels rise, the vulnerability increases exponentially of communities behind these 'high-maintenance' constructions. In additon, dredging of coastal areas to maintain and establish dykes and agricultural land adjacent to the coastline exacerbates the problems presented by rising sea levels through a reduction in the elevation of the warp zone and an increase of cross currents. These factors will prevent successful establishment of mangrove seedlings.

Figure 87: Mangrove destruction for the creation of a new dyke and canal, Kien Luong.

Mangrove Planting

Sea front mangrove plantings often do not thrive and many plantings have failed in Asia (e.g. Erftemeijer & Lewis 1999; Primavera & Esteban 2008). Sea front plantings undertaken in Kien Giang have only been partially successful, and have been costly in terms of money and time. In many areas the physical nature of the coastline has been altered dramatically due to erosion such that the construction of short-term barriers, coastal sediment replenishment and measures to increase the elevation of the warp zone, will be required to facilitate mangrove re-establishment at the coastal fringe. These srategies are currently being discussed and trialled in Kien Giang, however they are unproven on a broad scale. Success in mangrove planting should not be assumed if mud is present outside the mangrove. In fact, planting often fails even on accreting mudflats (Erftemeijer & Lewis 1999), although sometimes this is due to nonwater depth reasons such as insect attack. Suitable conditions are likely to foster natural regeneration eventually, but it is sometimes possible to plant mangrove seedlings at slightly greater mean water depth than in nature, as has been done in Kien Giang Province. Establishment and early growth are the most sensitive stages and planting may assist in passing through these stages, but there are limits.

The success of large-scale community planting can be partially quantified from our shoreline assessment during 2009 (see Chapter 3, this report). While a notable 27 km, or 15%, of the Kien Giang coast is fenced for planting, only 50% of these areas have successfully-established seedlings. Of further interest, fenced planting has only been undertaken in areas of little or no erosion. In other words, planting is evidently not being undertaken where it is needed most. As an example, the negative relationship between fenced areas and eroding coastline is shown in An Minh district (Figure 73, p 88), where 65% of the coastline is eroding. And, as for the rest of the province, where planting has been undertaken, it appears to be less than 50% successful. For the entire mainland coast of the province, approximately 58 km, or 32%, is affected by erosion and 23% of mangroves are actively eroding. These observations for the first time emphasise the great urgency in applying more effective shoreline management and rehabilitation in the region.

In addition to planting into eroded areas as recommended in section 3, it is also recommended that planting consist of a diversity of species. The recorded effects of herbivory in planted areas highlights the vulnerability of single species planting. Increased diversity is likely to enhance the resilience of planting efforts, it will also increase mangrove forest diversity along the coast. At present the majority of mangrove forest is dominanted by Avicennia (50%) and 82% of planting is Avicennia.


Figure 88: Recycled fish nets full of plastic bottles (left) could be used to provide protection to mangrove seedling planting areas where high wave action prevents seedlings becoming established (e.g right figure).

One suggestion to improve the success of seafront planting and rehabilitation is to use a **floating wave barrier to suppress erosive waves for at least ten years whilst mangrove vegetation becomes suitably large, dense and established.** This barrier might consist of a large floating boom constructed locally using recycled netting and plastic containers (Figure 88). The boom would be deployed and securely moored along the shoreline fronting the rehabilitation area.

Another reason for failed shoreline rehabilitation projects has been the lack of cultivation of 'edge' tree barriers. In any stable mangrove stand, it is only the trees immediately facing the sea edge that have any substantive capacity to resist shoreline erosion. Edge mangrove have altered growth structures with increased above ground root mass which raises the resilience of these edge trees to wave action. The removal of edge mangroves through erosion can therefore have significant lasting effects on the mangrove forest a the less resilient forest, previously protected by the fringing trees, quickly succumbs to further erosion from wave and current action. To prevent this situation arising, we suggest that ~3-6 **parallel 'hedges' (~3-4 established trees wide - ~30m) be established as 'hedge rows' along the coastal margin (**see Figure 89). Gaps between hedges might be shallow canals or ponds to prevent seedling growth, and hence encourage tree growth in a stucture resilient to wave action. These ponds, although somewhat narrower in width than hedges, might be used for fish cultivation. Or, if not ponds, these narrow strips between hedge rows might be designated sapling harvest zones – to be cleared approximately every 5 years, providing a link between livelihood and rehabilitation. In either case, strict monitoring is essential to ensure mangrove hedge trees are left intact and ready for their defensive role when the time comes. This is particularly relevant in consideration of the on-going consequences of climate change and sea level rise even after global communities learn to control carbon accumulation in the atmosphere. It is suggested that societies are locked into at least a century of rapid change and adaptation.

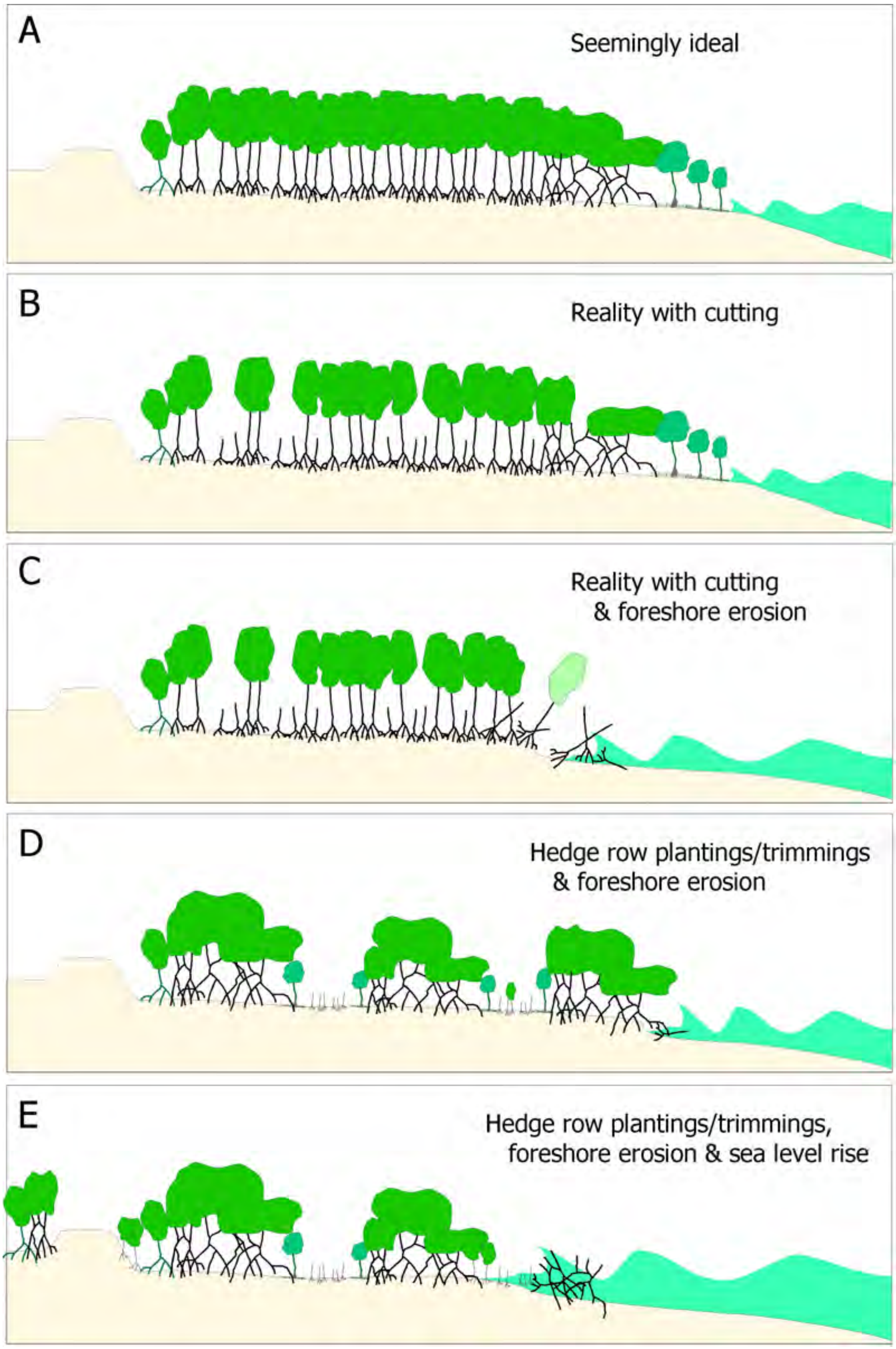

Figure 89: The mangrove-fringed shoreline is not often in an ideal condition (A), because of indiscriminate cutting and other direct human pressures (B). In locations with shoreline erosion, once specially-adpated 'edge' trees are lost, remaining trees offer little resistance and the shoreline recedes rapidly (C). A suggested solution is to nurture shoreline coastal defences with selected planting and cutting to develop 'hedge rows' parallel to the shoreline (D). Faced with rising sea level, these hedges always present a defensive barrier of 'edge' trees, which exhibit growth patterns reslient to wave and current action. As each is eventually overwhelmed, there is time to grow new rows behind. This action buys precious time for coastal communities to adapt.

In stabilising the sea edge against erosion, functional mangrove forests may only require wave-breaking structures to remain viable. However, in some areas it is likely that mangrove seedling establishment and alternative engineering solutions will not succeed under any circumstances. In these areas, it remains unlikely that generating a 200 m extension to the front of the existing mangrove (as discussed in Kien Giang) is possible. This needs to be further evaluated. Coastal retreat and landward mangrove regeneration must be accepted as the only viable long-term cost-effective solution to protect inland areas given sea-level rise predictions in these areas.

5.3.2 Management of mangrove harvesting

Cutting of mangrove forests for firewood has been identified as a significant threat to the ability of mangroves to provide their important services in coastal stabilisation. Minor harvesting of mangrove trees within the mangrove forest is very widespread, as is the collection of food and scavenging of debris. Observations on timber harvesting found cutting to be evident in every forest stand, principally of small size specimens for poles or perhaps firewood. Cutting is found even at the front of narrow eroded mangrove fringes (Figure 90), suggesting a disconnection between the needs or knowledge of locals in cutting trees and that of the protective role of mangroves.

Figure 90: Large *Sonneratia caseolaris* stump, Vinh Quang. This site is eroding.

Mangrove forest is commonly harvested by the poorest members of society in Kien Giang for use as firewood and building materials. To minimise the threat to fringing mangrove forest presented by mangrove harvesting, it will be neccessary to produce alternative sources of wood through the production of timber species such as the cannonball mangrove, *Xylocarpus granatum*. A potential trial mangrove plantation site that could be used to produce timber species like *Xylocarpus granatum*.

The locations of known large and productive seed trees for use in the development of farmed timber species will be important. During biodiversity surveys of Kien Giang province, a number of such locations were recorded (see Chapter 1). This information can be used to develop a a special database for future reference and collection of specific planting stock. Such a database will also be valuable in seedling planting efforts on the coastal fringe. Notable examples include: *Xylocarpus granatum* in Phu Quoc, *Rhizophora mucronata* in Hon Luong and *Lumnitzera littorea* to the north in Phu Quoc.

Based on the results of the shoreline survey it is recommended that wood harvesting be managed to limit removal and felling of trees in actively eroding and fragmented areas. One potential strategy is to explore rotational harvesting and to encourage wood collection from prograding forest and regrowth forest. These areas are the least likely to be impacted by erosion and have the greatest potential for recovery. At present, only 8% and 9% of total mangrove harvesting occurs in prograding and regrowth forest, respectively. A specific wood harvest management strategy should be developed for An Minh province, as these mangroves are experiencing the most intense harvesting activity and are the most at-risk of shoreline erosion that is likely to directly threaten homes and livelihoods.

As a proportion of forest type, high biomass, continuous, Sonneratia forest (11%) is the most threatened by wood harvesting with 65% of this forest type being cut. This forest type represents the few remaining stands of large mangrove trees and should be protected from cutting to provide shoreline protection and fish habitat to the areas directly north of Rach Gia. They also represent the forest type with the greatest carbon storage potential.

It is unlikely that any of the presented solutions will succeed unless appropriate management actions are taken to prevent the continued haphazard fragmentation and degradation of existing and restored mangrove areas (Figure 92). The prevention of such habitat destruction will require a number of key components;

1) The provision of **education at all levels** of community, local, provincial, national and international to highlight the scale and severity of the coastal erosion issue and highlight the value of mangrove forests for coastline protection and other ecosystem services.

2) **Regular year-to-year monitoring and assessment of shoreline condition and the success of various mitigation strategies**, including construction of dykes and planting, along the entire coastline.

3) The **faciliation of local management and protection of mangrove forests** by improving the direct monetary value of these valuable natural resources through the implementation of a REDD carbon storage scheme in conjunction with targeted livelihood projects.

4) The **provision of alternative sources of firewood and building materials** with the establishment of community plantation forests that can be accessed by the poorest members of the community. This selected harvesting might feasibly be linked with carefully applied shoreline rehabilitation projects.

5) The **implementation and trial of well-considered shoreline restoration strategies**, especially like the 'hedge row' planting strategy as a method that accommodates the inevitability of sea level rise. This method is notably planned as a strategy to slow down the rate of shoreline erosion, and to specifically 'buy time' for coastal communities to adapt and retreat in an orderly way.

Figure 91: Mangrove destruction through cutting continues throughout Kien Giang province due to lack of alterate sources of firewood and building material and limited understanding of the importance of mangrove habitats

At the local level of coastal management, it is not possible to prevent predicted rises in sea level. So, the most appropriate strategy needs to be both adaptation and defence. 'No action' will result in re-active and uncontrolled retreat from coastline areas with huge consequences accompanied by the loss of productive agricultural lands and massive displacement of people.

Planting efforts at the coastal fringe can no longer be undermined by continued mangrove degradation at the landward edge, and the subsequent reduced capacity of the ecosystem to naturally restore and buffer erosive forces. There are few non-mangrove sources of firewood and building materials available in Kien Giang Province as only small areas of natural melaleuca and terrestrial trees remain. This means areas that are eroding are still actively cut, perhaps even more so than other areas as erosion creates ease of access (Figure 91). This cutting exacerbates the shoreline erosion. Large scale planting efforts are further undermined by a perceived lack of protection and understanding of mangrove value amongst community members. In addition, a lack of some alternate income streams which may reduce mangrove degradation and fragmentation further intensifies the problem.

Education & Awareness

Education needs to highlight the scale, severity and consequences of the coastal erosion problem and the importance of mangroves at all levels to promote awareness of the issue that will encourage and facilitate local, provincial, national and international action.

On-ground works – what, how, where

- Provide protection to mangrove seedling planting areas through the establishment of short-term engineering solutions that reduce wave action and current forces for long enough such that trees can become established. Such barriers will also facilitate sediment deposition, further assisting mangrove establishment (Figure 90).

- Nurture coastal mangrove vegetation rehabilitation using a 'hedge row' defensive strategy (Figure 91) where local communities buy time by reducing the rate of shoreline retreat.

- In some cases, build up the elevation of the near-shore warp zone to reduce water depth to levels that enable successful mangrove establishment.

The series of maps presented in chapter 3 of the current report identifies that current mangrove planting efforts are focused on stable or depositional coastlines (Figures 25- 74). To improve the usefullness of mangroves as coastal defense, planting should be concentrated on actively eroding coasts. Figures 25 - 74, identify shoreline conditions throughout the province (eroding, stable, depositional etc.), and will be valuable tools in the selection of future sites for mangrove planting. Future analyses should identify and map specific locations where coastal retreat and mangrove restoration is neccessary. This information can be combined with identification of areas where additional efforts are needed to promote mangrove establishment, allowing informed site selection to concentrate seedling planting efforts.

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Centre for Mangrove Ecosystem Research, Hanoi

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Mangrove Ecosystem Research Centre/Division (MERC/MERD)
Suite 905, Building K1+ T11
136 Xuan Thuy, Cau Giay District, Ha Noi.

An english version of Prof. Hong's book 'Mangroves of Vietnam' (1993 IUCN publication) was purchased by Dr Duke.

References

Abuodha PA (2009) *Application and evaluation of shoreline segmentation mapping approaches to assessing response to climate change on the Illawarra Coast*, PhD thesis, the University of Wollongong, Australia.

Alongi DM (2009) *The Energetics of Mangrove Forests*. Springer, New York.

Cat NN, Tien PH, Sam DD & Binh NN (2006) Status of coastal erosion of Vietnam and proposed measures for protection, Regional technical workshop presentation: *Coastal protection in the aftermath of the Indian Ocean tsunami: what role for forests and trees?* 28 – 31 August 2006, Khao Lak, Thailand.

Carew-Reid J (2008) *Rapid Assessment of the Extent and Impact of Sea Level Rise in Viet Nam*, ICEM-International Centre for Environmental Management, Indooroopilly, Queensland, Australia.

Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Fölster H, Fromard F, Higuchi N, Kira T, Lescure J-P, Nelson BW, Ogawa H, Puig H, Riera B & Yamakura T (2005) Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia* **145**: 87-99.

Christensen B (1978) Biomass and primary production of Rhizophora apiculata Bl. in a mangrove in southern Thailand. *Aquatic Botany,* **4**: 43-52.

Clough B (1992) Primary productivity and growth of mangrove forests. In: Robertson, A., Alongi D., Eds. *Tropical Mangrove Ecosystems. Coastal and Estuarine Studies 41,* American Geophysical Union, Washington DC, US. pp 225-50.

Clough B (1998) Mangrove forest productivity and biomass accumulation in Hinchinbrook Channel, Australia, *Mangr. Salt Marsh* **2**:191-8.

Clough B, Tan DT, Phuong DX & Buu DC (2000) Canopy leaf area index and litter fall in stands of the mangrove *Rhizophora apiculata* of different age in the Mekong delta, Vietnam. *Aquatic Botany,* **66**: 311-20.

Duke NC (2008) *Mangrove and Climate change: Observations of two mangrove areas of Kien Giang province, including the districts of Hon Dat and An Minh*, Report to GTZ Kien Giang Biosphere Reserve Project, Centre for Marine Studies, University of Queensland.

Duke N, Meynecke J, Dittmann S, Ellison A, Anger K, Berger U, Cannicci S, Diele K, Ewel K, Field C, Koedam N, Lee S, Marchand C, Nordhaus I, Dahdouh-Guebas F (2007). A world without mangroves? *Science* **317**:41.

Duke NC, Wilson N, Mackenzie J & Nguyen HH (2009) *An Interim report on the current status of GTZ Kien Giamg Shoreline and management projects for periods up to July - August 2009*, Kien Giang Province, Vietnam, 45 pages.

Erftemeijer PLA & Lewis RR, III (1999) Planting mangroves on intertidal mudflats: Habitat restoration or habitat conversion? *ECOTONE VIII Seminar: Enhancing Coastal Ecosystem Restoration for the 21st Century, 23-28 May 1999.* Ranong & Phuket, Thailand.

Fargione J, Hill J, Tilman D, Polasky P, Hawthorne P (2008). Land clearing and the biofuel carbon debt. *Science* **319**:1235-1238.

Fearnside PM & Laurance WF (2004) Tropical deforestation and greenhouse gas emissions, *Ecological Applications* **14**: 982-986

Fromard F, Puig H, Mougin E, Marty G, Betoulle JL, Cadamuro L (1998) Structure above-ground biomass and dynamics of mangrove ecosystems: new data from French Guiana, *Oecologia* **115:** 39-53

Fuller DO (2006) Tropical forest monitoring and remote sensing: a new era of transparency in forest governance? *Singapore Journal Tropical Geography,* **27**: 15-29.

Gibbs HK, Brown S, Niles JO & Foley JA (2007) Monitoring and estimating tropical forest carbon stocks: makig REDD a reality, *Environemtnal Research Letters,* **2:** 1-13

Giesen W, Wulffraat S, Zieren M & Scholten L (2006) *Mangrove Guidebook for Southeast Asia*. FAO and Wetlands International, Bangkok.

Gifford RM (2000) *Carbon Contents of Above-Ground Tissues of Forest and Woodland Trees*. National Carbon Accounting System Technical Report No. 22. Australian Greenhouse Office, Canberra.

Gilman E, Ellison J & Coleman R (2007) Assessment of mangrove response to projected relative sea-level rise and recent historical reconstruction of shoreline position, *Environmental Monitoring and Assessment,* **124**: 105-130.

Government of Vietnam (2005), *National Action Plan for the protection and development of Vietnam's mangrove forest until 2015*, Agriculture Publishing House, Hanoi.

Hung HA & Tan DT (1999) *Sổ Tay Cây Cỏ Rừng Ngập Cà Mau.* Ca Mau Publishing House, Ca Mau.

IPCC (2006) *IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme* ed H S Eggleston, L Buendia, K Miwa, T Ngara and K Tanabe (Japan: Institute For Global Environmental Strategies)

Komiyama A, Ogino K, Aksornkoae S, Sabhasri S (1987) Root biomass of a mangrove forest in southern Thailand. Estimation by the trench method and the zonal structure of root biomass. Journal Tropical Ecology **3:** 97–108

Komiyama, A., H. Moriya, S. Prawiroatmodjo, T. Toma, and K. Ogino. 1988. Forest primary productivity. Pages 97–117 in K. Ogino and M. Chihara, eds. *Biological System of Mangrove*. Ehime University. 97–117.

Komiyama A, Poungparn S & Kato S (2005) Common allometric equations for estimating the tree weight of mangroves. *J. Trop. Ecol.* **21** (04): 471-77.

Komiyama A, Ong JE & Poungparn S (2008) Allometry, biomass and productivity of mangrove forests: a review. *Aquat. Bot.* **89**: 128–37.

Mazda Y, Magi M, Nanao H, Kogo M, Miyagi T, Kanazawa N & Kobashi D (2002) Coastal erosion due to long-term human impact on mangrove forests. *Wetlands Ecol. Manage.* **10**(1): 1-9.

Ong JE, Gong WK & Clough BF (1995) Structure and productivity of a 20-year-old stand of *Rhizophora apiculata* Bl. mangrove forest. *J. Biogeogr.* **22**(2-3): 417-24.

Pajak MJ & Leatherman S (2002) The high water line as shoreline indicator, *Coastal Research*, **18**(2): 329-337.

Poungparn S (2003) *Common allometric relationships for estimating the biomass of mangrove forests.* Ph.D. dissertation, Gifu University, 87 pp

Primavera J & Esteban J (2008) A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. *Wetlands Ecol. Manage.* **16**(5): 345-58.

Putz FE & Chan HT (1986) Tree growth, dynamics, and productivity in a mature mangrove forest in Malaysia, *Forest Ecology and Management* **17**: 211-230

Ramsar Secretariat *et al*. (2007) Ramsar Secretariat and Scientific and Technical Review Panel. *Provisional outcomes of an Expert Meeting*, 23 – 24 March, 2007, Gland, Switzerland. ramsar.wetlands.org/

Saenger P & Snedaker S (1993) Pantropical trends in mangrove above-ground biomass and annual litterfall. *Oecologia* **96**:293-329.

Saenger P (2002) *Mangrove Ecology, Silviculture and Conservation*. Kluwer Academic, Dordrecht, Netherlands.

Sam DD, Binh NN, Que ND & Phuong VT (2005) *Overview of Vietnam Mangrove forest*, agriculture publisher House, Ha Noi, Vietnam (in Vietnamese).

Soenen SA, Peddle DR, Hall RJ, Coburn CA, Hall FG (2010) Estimating aboveground forest biomass from canopy reflectance model inversion in mountainous terrain. *Remote Sensing Environment* **114:** 1325-1337

Tamai S, Nakasuga T, Tabuchi R & Ogino K (1986) Standing biomass of mangrove forests in southern Thailand. *Journal of the Japanese Forestry Society* **68:** 384-388.

Tan DT (2002) Biomass of *Rhizophora apiculata* forest. in *Forest Science and Technology Research Report Results Period 1996-2000*. (Ed. Forest Sciences Institute of Vietnam). Agricultural Publishing House, Hanoi**:** pp 165-72.

Thieler ER, Himmelstoss EA, Zichichi JL & Ergul A (2009) *Digital Shoreline Analysis System (DSAS) version 4.0, An ArcGIS extension for calculating shoreline change*, U.S. Geological Survey Open-File Report 2008-1278.

van der Werf GR, Morton DC, DeFries RS, Olivier JG, Kasibhatla PS, Jackson RB, Collatz GJ & Randerson JT (2009) CO_2 emissions from forest loss, *Nature Geoscience* **2:** 737-738

Wilson N (2010) *Biomass and regeneration of mangrove vegetation in Kien Giang Province, Vietnam*, A report for GTZ Kien Giang, Vietnam, pp 56.