IMPACT OF LAND USE CHANGE ON SHORELINE EROSION AND MANGROVE DYNAMICS IN WATAMU MIDA CREEK, KENYA

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ABSTRACT

Watamu Mida creek coastal area is a major attraction site for tourists and also a source of income for the local people. The key identified anthropogenic pressures in the mangrove forest are; encroachment into the forest (from a growing number of hotels, cottages and private holiday houses) and, high dependence from the surrounding villages which has resulted in clearing and selective cutting. The shoreline is also equally affected by human induced change such as physical alteration of the beach through clearing the vegetation, development close to the High Water Mark, and the construction of sea walls. This research assessed the impact of land use change on mangrove dynamics and shoreline erosion as well as the main driving factors that cause these changes in Watamu Mida creek. The study had four objectives; (i) to assess the land use change and, mangrove dynamics (ii) measure the rate of shoreline change and define the drivers, (iii) determine the natural and human induced drivers of land use change, mangrove dynamics and shoreline change (iv) assess the role of relevant government and community level polices on land use and shoreline management.

This study used old aerial photographs (1969 and 1989), current high resolution satellite images World view (2010) and ground truthing to analyze the patterns and dynamics of Mida creek mangrove forest changes, shoreline erosion rates and land use change over 41 years between 1969-2010. The data were generated for the mangrove cover by on screen visual digitizing and interpretation using the mosaic aerial photographs and satellite image. In order to assess the biomass of the mangrove, a non-destructive method was used to collect data on 25 sample plots and 934 trees were measured to estimate the above ground biomass and carbon stock of the forest. This study also investigated the trend of shoreline changes, and the factors

attributed to these changes. The Digital Shoreline Analysis System (DSAS) in ArcGIS environment was used to create transects and statistical analyses for the shoreline. The 9.8 km long Watamu shoreline was divided into 245 transects with 40 meter spacing in order to calculate the change rates. To identify the primary driving forces of land use change, a multiple regression model was used. For the household questionnaires, a stratified random sampling method was used. The household survey included 60 respondents from different resource users groups and villages.Five Focused Group Discussions (FGDs) were conducted with representatives of the community and eleven Key informants interviews were conducted with the key leading government office representative's, non-governmental organization, hoteliers, and old residents along the beach.

The greatest land use change rate observed between 1969 and 1989 was in, miscellaneous coastal vegetation cover at 2.5%, while coastal bush experienced a significant negative change rate of -6.5%. The main land use changes observed between 1989 and 2010 were; increasing coastal bush, an expansion of town and urban areas, hotels, and private holiday houses. The results of the mangrove analysis showed a decline in mangrove cover (16%) between 1969 and 1989, while between 1989 and 2010 an increment in mangrove cover (9%) was observed. The total above ground biomass and carbon estimated was 296.14 $ton \cdot ha^{-1}$ and 148.07 $ton \cdot ha^{-1}$ respectively. Mida creek mangrove forest is largely dominated by the presence of; *Rhizophora mucronata* and *Ceriop tagal* and the regeneration of these two species is very high. The result of shoreline erosion from WLR indicated a mean of -0.89 m/year where 69.7% of transects fall under erosion and 30.3% accretion. Shoreline erosion was mainly attributed to anthropogenic factors. These include; construction near the High Water Mark, defensive structures and sea walls, and, destruction of

vegetation along the beach front. The main drivers of land use change were human population growth and policy. The research found that the policy instrument review of the existing policy and legal framework indicated a number of gaps and opportunities for the protection of the coastal environment in the study area.

The most unique aspect of this research was that it has analyzed a 41 year period of human and naturally induced changes in the study area through a combination of GIS/RS tools and community/key informant interviews, enabling a robust triangulation of the results to be made. As a result the research recommendations provided a firm foundation for improved County/multi stakeholder management in the Watamu Mida creek area. The integrated methodology developed as part of this paper offers other researchers a clear pathway for future comparative studies.

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List of Abbreviations and Acronyms

CDA	Coast Development Authority
DBH	Diameter at Breast Height
DSAS	Digital Shoreline Analysis System
EPR	End Point Rate
EMCA	Environmental Management Co-ordination Act
FGD	Focus Group Discussion
GIS	Geographical Information System
GOK	Government of Kenya
GPS	Global Positioning System
HWM	High Water Mark
HWL	High Water Line
ICZM	Integrated Coastal Zone Management
ICAM	Integrated Coastal Area Management
KMFRI	Kenya Marine and Fisheries Research Institute
KFS	Kenya Forest Service
KWS	Kenya Wildlife Service
MCCC	Mida Creek Community Conservation
NEMA	National Environmental Management Authority
NGOs	Non-Governmental Organizations
NSM	Net Shoreline Movement
UNEP	United Nation Environmental Program
UNIDO	United Nation Industrial Development Organization
WLR	Weighted Linear Regression
WIOMSA	Western Indian Ocean Marine Sciences Association
WMA	Watamu Marine Association

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Over the next century, land-use and land-cover changes are likely to be the most significant challenges facing the Earth (Gutman et al., 2004). For instance, Hansen et al, (2004) pointed out that, the expansion and intensification of human land use in recent decades has resulted in major changes in biodiversity. A range of processes influence the speed of change, the distribution, and the types of land use and land cover change (Solomon, 1994). The two main land use change drivers are biophysical factors such as topography, soil types, drainage patterns, climate and availability of natural resources and, socioeconomic drivers, such as change in population, technological change, policies and legislation (Hansen, 2007). The Watamu Mida creek area selected for this research exhibits the above mentioned pressures and for future sustainable tourism and marine resource use, it is essential to understand the key causes and drivers of change.

Land is the most fundamental natural resource since it provides virtually all the food we use today. It is also essential to provide space on which to live (Susan et al., 1991). Land use is the interaction between human beings, and the land and its resources. It is also the way in which human beings utilize the land and its resources; such as farming, mining, and lumbering. Growing human populations exert pressure on the landscape as demands increase for resources such as food, water, shelter, and fuel. Land use change is a sign of human activities and at the same time environmental processes over time and space (Olson et al., 2004). As Polyakov and Zhang (2008) stated, in most cases land use change results in negative externalities such as congestion, air and water pollution, loss of biodiversity, wildlife habitat fragmentation, and increased flooding.

Land use practices generally develop over a long period under different environmental, political, demographic, and social conditions. Over the last 20 years, increasing human population, economic development and emerging global markets have driven unprecedented land-use change (UNEP, 2007). In order to better understand the impact of land use change, the factors affecting land use, and the changes that occur over a period of time, must be fully examined. The availability of Geographical Information Systems and Remotely taken images makes the study of land use and cover change possible.

Spatial analysis of land use provides historical, environmental and societal information (Olson et al., 2004). The advent of remotely sensed data from satellites has provided a basis for quantifying rates of land use change around the world and its consequences on biodiversity (Hansen, et al., 2004). For instance, the information that comes from remote sensing provides measurement of shoreline changes in response to storm erosion (Elisabeth and Louis, 2007). Furthermore, the availability of high resolution satellite images and remote sensing technology allow a more favourable way to study and manage coastal and marine areas (UNEP, 1989). For quantifying these changes in the Watamu Mida creek study area, the available aerial photographs and satellite images were used to create a historical mosaic suitable for studying land use and land cover changes.

A significant proportion of the human population depend heavily on coastal and marine ecosystems for their livelihood. Coastal areas are a unique natural environment where strong interactions take place between land, sea and atmosphere (UNESCO, 1997).Coastal areas are important for the numerous benefits that they bring, such as; fish, oil, minerals, salt and construction materials as well as services such as; shoreline protection, sustaining biodiversity, transportation, recreation and

tourism (Ireland et al., 2004). Coastal areas are also home for the world's population and are increasingly being inundated with people (Don Hinrichsen, 1990). A report by National Academic of Science, (2007) indicated that, nearly two-thirds of the world's population nearly 3.6 billion people live on or within 100 miles of a coastline. Coastal and marine ecosystems which include tropical rainforest, estuarine and near-shore areas as well as the open ocean, are among the most productive, yet most highly threatened ecosystems in the world (Ireland et al., 2004). Today, many coastal ecosystems are under extreme anthropogenic pressure (Hoorweg and Muthiga, 2009).Coastal changes and their rate of change are of great concern to scientists, policy-makers and the general public (Stephen et al., 2005).

Coastal areas of developing countries are vulnerable due to high population density, and livelihood dependence on natural resources (Marcus et al., 2007). For example in Bangladesh, there is demand for expansion of all current land uses, while the need for new exploitation is also emerging with an increased population density (Asib Ahmed, 2011). Furthermore people in coastal areas are exposed to several types of natural hazards such as the tsunami which occurred in December 2004, (Marcus et al., and 2007). A study in the coastal zone of SE Asia shows large tracts of the coastal zone which had been occupied by mangroves during the past decades, have now been cleared to accommodate increasingly intensive forms of land-use for human benefit such as settlement, transport infrastructure, agriculture and aquaculture (Thampanya et al., 2006). In recent decades, most of Kenya's coastal ecosystems have come under severe anthropogenic pressure leading to physical alterations and land use changes resulting in; shoreline erosion, siltation and hydrological modifications, causing damage to, or loss of, coastal and marine habitats (Hoorweg et al., 2006). This study

aims to quantify a number of the above mentioned adverse effects on the tourism sector in the Watamu Mida creek coastal area of Kenya.

In Kenya, tourism and its supporting activities are becoming increasingly important to local economy (Kairu, and Nyandwi, 2000). In the last three decades, rapid development in the tourism industry has taken place along the coastal zone. Watamu beaches for example, are bordered by more than 25 hotels and an increasing number of residential houses bordering the Marine Park and Marine Reserve (Weru et al., 2001).Many of these developments along the beach are experiencing increasing coastal erosion problems such as damage on the property, uprooted trees and severely affected hotel and private property beach fronts (Field survey and personal observation Oct 2012-2014). A recent study at the Bamburi site revealed that erosion (of the plain beach sand at the backshore) has increased significantly over the last 20 to 40 years and the shore has retreated by about 150–200 m during the last 20 years (WIOMSA, 2010). Sea walls increase reflected wave energy, leading to the erosion and flattening of the adjoining beaches, as near Mtwapa north of Mombasa, where walls have been built to protect shoreline properties (Kairu and Nyandwi, 2000). Moreover, beach clearing and levelling can lead to increased beach erosion (Weru et al., 2001). Based on the field observations in October2012-2014, some hotels along the Watamu beach have levelled and cleared the beach in order to get a better view of the sea. Kenya's coastal and marine environment is also threatened by naturally occurring processes, such as coral bleaching, sea-level change and beach erosion from long shore currents (Hoorweg, 2006).Watamu Mida creek coastal area also facing both environmental and anthropogenic threats.

Mida creek is an important sea bird haven due to the presence of mangroves, yet human habitation is still a controversial issue (Weru et al., 2001). Traditionally,

mangrove forests provide the coastal human population with a variety of goods and services on which the poorer strata of society depend strongly (Thampanya et al., 2006).Mangroves support numerous species and serve to protect the coastline from storms, but despite their importance, a substantial proportion of mangrove forests have been lost due to human activities in recent decades (Allsopp et al., 2009). Mangroves contribute to important ecosystems services in Kenya's coastal areas by protecting the coastline and farms against erosion and produce goods and services that are of environmental, ecological and economic importance to human society (Abuodha and Kairo, 2001). However mangrove degradation at the Kenyan coast has occurred at an increasing rate as the result of growing subsistence needs (Hoorweg, 2006). This is observed along the Watamu Mida creek area.

The communities in Watamu Mida creek area generate their income directly or indirectly from tourism related activities. Activities which provide revenue are direct employment from hotels and private residents, self-employment through activities such as; boat operation, curio vending, and safari selling. Fishing also plays a major role in generating direct income for these communities. This research focused on the Watamu Mida creek coastal area of Kilifi County which has one of the highest tourist visitor numbers on the north coast and is located bordering a Marine Protected Area and a Marine Reserve. General objective of the current study was to assess the impact of land use change on shoreline erosion and mangrove dynamics in Watamu Mida creek for informed decision making and improved natural resource management.

1.2 Statement of the problem

Kenyan coastal ecosystems (comprising; mangrove forests, coastal marshes, seagrass beds, sand dunes and coral reefs), especially within the Watamu Mida creek area, have undergone severe anthropogenic pressures such as physical alteration and land use change to meet the subsistence and economic needs of the local population, and demands of the modern economy (Hoorweg and Muthiga, 2009). This has led to shoreline erosion, siltation and hydrological modifications, resulting in damage to, or loss of, coastal and marine habitats (GOK, 2009), including a substantial loss of mangrove forests (Abuodha and Kairo, 2001). In Kenya,the issue of shoreline changes, and the risk of coastal erosion has been the subject of national reports (WIOMSA, 2010). The increasing dependence of the coastal community on the mangrove forest such as use of mangrove poles for house construction, and firewood collection, is putting pressure on the adjacent marine life since the land productivity is relatively low.

The problem is further aggravated by the development of unplanned urban settlements in marginal lands, and poor enforcement of the Land Planning Act and the Environmental Management Coordination Act (EMCA) regulations at major tourist destinations along the coast (GOK, 2009). The natural resources on which the communities depend are thus declining culminating into a high level of ecosystem degradation and poverty. Notwithstanding the impact of shoreline change and human induced land use changes, habitat degradation over the years has not been scientifically explored and quantified and there has been limited emphasis on integrating local knowledge.

1.3 Justification

The WatamuMida Creek study site was selected for this research for a number of significant reasons. It has been recognized as a world biosphere site by UNESCO, and nationally by the Government of Kenya for its rich marine and coastal biodiversity with part of the area designated as a National Park another part under the status of a National Reserve. It is one of the most frequently visited coastal tourism destinations on the Kenyan coast with current annual visitor numbers reaching above 300,000 per annum (COAST Project, 2013). It is also a high priority turtle breeding and nesting area (GOK, 2010a). The Creeks within the Mida area hold significant mangrove stands (Tychsen, 2006).In addition, Mida Creek area has been designated as one of the most Important Bird Areas (IBA) in Kenya (Weru et al., 2001). Finally, from a socio-cultural perspective it contains a diverse mix of traditional coastal communities (with their own historical cultures) and a modern international visitors and investor economy, creating a complex challenge for local planning and policy formulation and decision making

In order for this coastal destination to be sustainably preserved for Kenya's future citizens as well as its international clientele, urgent research is needed to better understand the shoreline changes and mangrove dynamics which will determine its future economic and conservation values.

There is a lack of information at local government and within coastal communities on the actual effects of land use and shoreline changes resulting from increased human activity within the Watamu Mida study site. The research methodology selected in this study allowed for a scientific study of land use and cover changes over 41 year period to be quantified and mapped. While this period of historical coverage was largely determined by the availability of suitable aerial photography, it does represent

a very fundamental part of the first 52 years of Kenya's independence which in turn reflects a massive change in human population within the study site. Understanding local knowledge as well as human induced impact on biophysical resources within such coastal areas is also an important element if local stakeholders are to become practically involved in designing appropriate integrated coastal area development strategies and decisions. As a result informed decision making and execution of appropriate integrated coastal area natural resource conservation strategies, the research will help promote sustainable development in the area.

1.4 Overall objective

To assess the influences of land use change on shoreline and mangrove dynamics for better and improved local natural resource management.

1.5 Specific objectives

- To determine changes in land use and mangrove dynamics between the period of 1969-2010.
- To measure the rate of shoreline change and define the drivers of shoreline erosion and accretion.
- To determine the natural and human-induced drivers of land use changes, mangrove dynamics and shoreline changes.
- To assess the role of relevant government and community level policies and strategies on land use and shoreline management.

1.6 Research questions

1. How has land use and mangrove population dynamics changed from 1969-2010 on the sea front?
2. What is the rate of shoreline change?
3. What are the drivers of shoreline erosion and accretion?

4. What are the natural and human induced drivers of land use change, mangrove dynamics and shoreline erosion?
5. How effective are government and community level policies and strategies on natural resource conservation vis-à-vis current land use change?

1.7 Organization of the thesis

The first chapter introduces the main subject matter and continues with statement of the problem, overall and specific objectives and research questions of the thesis. Chapter two explains the concept of land use change and its main driving factors and the impact on the environment. This chapter also covers the impact of the land use change on the coastal resources such as mangrove and shoreline. The role of policy and governance influencing the coastal areas of Kenya is reviewed in this chapter. Chapter three present the location of the study area and the approaches and methodology used for each specific objectives i.e. land use changes, mangrove cover change and biomass estimation, assessment of shoreline erosion and socioeconomic assessment to identify the main driving forces of land use change and its impact on shoreline and mangrove. The change in mangrove cover and the biomass estimation is covered in Chapter four. Chapter five cover the shoreline change rates and the main driving factors of shoreline change. The main land use change observed from 1969-2010 as well as the impact that followed on mangroves and shoreline erosion fully discussed in Chapter six. Chapter seven describes the gaps and opportunities observed on the existing policy framework and also assess the level of perception and attitude of all stakeholders in Watam Mida creek area. The last chapter highlights the research findings and possible research area for further studies and recommendations based on the outcome of the research.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Land use and land cover change

Land use refers to the uses of land for various purposes, such as wildlife habitat, forest, agriculture, and settlements (Asib Ahmed, 2011). Ever since the beginning of agriculture, the human population and the consumption of resources have increased steadily throughout the world (Ricardo et al., 2003). These result in the conversion of forest and natural areas into agricultural land, pastureland and settlement areas. Over the next century, land-use and land-cover changes are likely to become one of the most significant challenges facing the Earth (Gutman et al., 2004). Hansen, et al, (2004) pointed out that, the expansion and intensification of human land use in recent decades is resulting in major changes in biodiversity. As stated by Turner et al. (1995), historical land use and land cover change has happened predominantly in response to population growth, technological advances, and economic opportunity. This shows that human beings and their activities take the biggest portion of responsibilities in the conversion or modification of the natural environment. This is due to the fact that the growing human population demand cannot be satisfied without alteration or conversion in land use and land cover.

Agarwal et al. (2000) indicated that on a global scale nearly 1.2 million km^2 of forest and woodland and 5.6 million km^2 of grass land and pasture have been converted to other uses during the last three centuries. A parallel study by Munasinghe and Shearer (1995) indicated that, human induced land use change such as land clearing, agricultural intensification, and urbanization, is currently the most significant factor of global change and its effects are already with us. However, land use change is also the backbone of economic development and supports the livelihood of billions of people by providing most of their economic and social benefits (JunJie Wu, 2008).

2.1.1 Drivers of land use changes and the resulting impact

The presence of mankind on earth and his modification of a landscape have a profound effect on the patterns of land use and land cover change (Mariappan et al., 2010). Land use change is the reflection of human activities and environmental processes over time and space (Jennifer et al., 2004). The effect of this anthropogenic process have already been observed in many parts of the earth's system: climate, hydrology global biodiversity, and the fundamental sustainability of lands (Gutman et al., 2004). For example recent research in East Africa has shown six factors which are responsible for land use changes. These are: government policies, laws and regulations, economic factors, population growth and migration, changes in land tenure arrangements, access to markets and environmental conditions (Jennifer et al., 2004). According to a report by UNEP (2007), increasing human population, economic development and emerging global markets have driven unprecedented land-use change.

Several recent studies have been made to identify the main causes of land use and land cover changes and their consequences. Many researchers divide the drivers of land use changes into; direct and indirect drivers, or natural and anthropogenic processes (Lambin, and Helmut, 2007, Lambin et al., 2001, Ricardo et al., 2003, Jennifer et al., 2004). According to Lambin, and Helmut , (2007), the direct causes of land use change explain how and why local land cover and ecosystem processes are modified directly by humans, while the indirect causes explain the fundamental forces behind these local actions. Land use change is always caused by multiple factors, driving forces can be slow variables such as salinity in irrigation water, or fast variables, such as climatic variability associated with El Nino oscillations (Lambin et al., 2001).Biophysical factors such as climate variation, flooding, vegetation

succession and fire can be the cause for land cover change. According to Turner et al. (1995), climate variations may change land cover globally, while volcanic eruption and change in river channels or sea level have more localized impacts. Generally, the biophysical drivers do not cause major land use change although some consequently may affect land use decisions (Hansen, 2007).

Several land use change studies have noted that the main driving factors for land use change are anthropogenic factors (Lo and Gunasiri, 2014, Campbell et al., 2003, Misana et al., 2012, Yagouband Reddy, 2006). For instance a study on Mount Kilimanjaro indicated major land use change occurred on the slopes of the mountain as the result of demographic, social, cultural, economic, political, institutional and infrastructural developments (Misana et al., 2012). A study by Campbell et al. (2003) stated that over the past 50 years factors such as economic, demographic and political practices have changed the patterns of land use along East Africa's ecological landscapes Yet another study in Abu Dhabi specified human induced change such as manmade island development, reclamation, and urban and industrial development activities along the coastline can be attributed to the observed land use change and reduction of wetlands(Yagouband Reddy, 2006).Considering the vulnerability of the coastal environment expansion of urban areas and modification of shorelines causes a threat to the biodiversity of the marine environment. A study on the impact of land use change in Taiwan found human induced land use change mainly resulting from an expansion of industrialization changed the natural environment of coastal areas (Lo and Gunasiri, 2014).

Anthropogenic and natural drivers of land use and cover change have a huge impact on the environment and its supporting ecosystems. Some of the direct effects of land use change are habitat loss and fragmentation, soil degradation, species introductions,

and changes in vegetation (Garu et al., 2003). The change in land use have brought increases in production of farm and forest products to secure and support the livelihoods of human population nevertheless, have often resulted in land degradation, loss of biodiversity and disturbance of biophysical cycles, such as the water and nutrient cycles (Holmgren et al., 2006). Osemeobo (1993) studies on impact of rural land use in Nigeria found out that, uncontrolled bush burning, unplanned human interference with the soils and changing land tenure systems increasingly caused the extinction of wild fauna and flora in these natural ecosystems. Land use change and fragmentation has not only affected the natural environment but also the wildlife habitats (Osemeobo, 1993). For example a study in America revealed that fragmentation of farm and forestland, and the increased development near wildlife habitats has escalated the conflicts between people and wildlife (Miller and Brian, 2002). A similar study in Kenya indicated the change in land use patterns had an impact on wildlife-based tourist activities as the cultivation on mountain slopes and in swampland reduced the access of wildlife to browsing areas and reduces surface water resources (Campbell et al., 2003).

2.1.2 Anthropogenic factors leading to ecological imbalance

Understanding land use and land cover dynamics in an area plays a significant role in helping to take corrective measures against ecological destruction. Land use and land cover change besides affecting the current and future supply of land resources, are also important sources for many other forms of environmental change. Turner et al. (1995) pointed out that the knowledge of land use change has become more and more important in order to analyze environmental processes and problems, such as; uncontrolled urban development, deteriorating environmental quality, loss of prime agricultural lands, expansion of agriculture into areas that consist of fragile

ecosystems such as wetlands and steep hillsides, and high value natural biodiversity hotspots for example, humid tropical forests. This has been particularly important, as changes in land use become more rapid affecting the livelihoods of different societies. High dependence on agriculture and the need to provide food for a rapidly expanding populations has resulted in the use of marginal land for cultivation and added pressure on cultivable land. Expansion of the cultivable land has caused a number of land cover changes including; deforestation, overgrazing, and inappropriate agricultural practices. This is true of the majority of developing countries, for example most African countries have rural economies and depend heavily on their natural resources for food, fuel wood, and primary commodity exports. The Watamu Mida creek area is no exception, and depletion of these resources (e.g. mangroves) could result in a rapid decline in living standards. Thus understanding the patterns and trends in land use and land cover changes and their impact is essential in order to understand the cause of many of today's environmental and livelihood concerns within the study site.

2.2 Mangroves

Mangroves are distinctive ecological units (FAO, 1994) and grow along coastlines in the inter-tidal zone between land and sea (Allsopp et al., 2009). Mangroves support coastal ecosystems by providing environmental ecosystem services and critical ecological functions, affecting both inland and oceanic resources (Kauffman, and Donato, 2012). Mangrove ecosystems exchange matter and energy with the adjacent marine and terrestrial ecosystems (Gang and Agatsiva, 1992). These forests are nutrient-rich environments which support a variety of food chains and function as a nursery and feeding ground for fish and invertebrates (Hoorweg and Muthiga, 2009, Allsopp et al., 2009, Hinrichsen D., 1990, Taylor et al., 2003). Mangroves play a protective role against detrimental climatic impacts (Leni, et al., 2011). They also

support numerous species and serve to protect coastlines from storms (Allsopp et al., 2009) by breaking the storm-waves and dampening the tidal currents, and the sediments they trap help to build the coastline against the forces of erosion (UNEP 1984). In addition to protecting the coastline from natural hazards, mangrove forests provide goods and services that are of economic, ecological and environmental value to man (Hoorweg and Muthiga, 2009). In many developing countries, the survival of coastal communities is largely dependent upon the sustainable harvest of seafood, and the cultivation of fish and crabs in mangroves (Hinrichsen D., 1990). Several studies have shown that, despite the numerous uses of mangrove forests they have been overexploited and converted to other land uses. According to a report by FAO (1994), the world's mangroves are losing their habitats as the result of; diversion and damming of rivers, expansion of agricultural activities on the intertidal zone, and the conversion of the mangrove forest into industrial and development areas. Based on the report of UNEP-WCMC (2003) topsoil erosion from agricultural and grazing land is becoming one of the key components that cause change in the characteristics of mangroves in the countries of East Africa. For instance, Kirui et al. (2012) study indicated, between 1985 and 2010 Kenya lost 18% of its mangroves at an average rate of loss of 0.7% yr^{-1} due to conversion pressure, over-exploitation or pollution (GOK, 2009).

Mida Creek holds substantial mangrove stands (Tychsen, 2006) it is also an important sea bird haven. Traditionally, mangrove forests provide the coastal human population with a variety of goods and services on which the poorer strata of society depend strongly (Thampanya et al, 2006).However mangrove degradation at the Kenyan coast has occurred at an alarming rate as the result of growing subsistence needs (Hoorweg

and Muthiga, 2009). This is observed along the Watamu-Mida creek area (Cohen et al., 2013, Weru et al., 2000, Gang and Agatsiva, 1992, Hirsch and Mauser, 1992).

In Mida Creek in particular, several agricultural land use practices in and around the creek influence the mangrove ecosystem along the coast (Gang and Agatsiva, 1992). Furthermore, the mangrove forests of Mida Creek are showing signs of over-exploitation and degradation because of logging, settlement and selective harvesting of large trees (Weru et al., 2000). A study by Kairo et al., (2002) indicted the anthropogenic influence on the species composition of mangrove forest in Mida Creek. Recent assessment of biomass estimation in Mida Creek by Cohen et al., (2013) confirms the level of forest degradation due to illegal and poorly managed logging activities.

Mangroves grow on muddy and anaerobic soils which suffer from tidal inundation; as a result they show a distinctive pattern of biomass allocation (Komiyama etal., 2005). A consistent assessment and research on biomass accumulation in mangroves is necessary in order to use the resources such as; yield of commercial products from forests, and for the development of silvicultural practices (Kairo et al., 2009).Estimation of biomass is significant in describing the status of mangroves, and as an essential component of carbon sequestration estimation (Kirui, et al., 2006). Measurements of stem diameter and sometimes height are used to estimate tree biomass and carbon stock using allometric equations (Kauffman and Donato, 2012) Komiyama et al. (2005) defined allometry as a powerful tool for estimating tree weight from independent variables such as trunk diameter and height that are quantifiable in the field.

As stated by several authors (Cohen et al., 2013, Kuyah et al, 2012, Kairo, 2009, Komiyama et al, 2005, and Chave et al., 2005), in order to use mangrove forests

sustainably and improve management, it is important to estimate the amount of above ground biomass accumulation. Furthermore, it is important to monitor mangrove changes through an assessment of forest structure (Kairo et al., 2002). Kenya is mandated to develop a greenhouse gas inventory for the land based emissions for UNFCCC reporting. Since the mangrove forests are treated as a unique forest category, there is the need to develop a historical dataset to show changes in these biomass stocks. Additionally, shoreline vegetation may be affected by erosion and/or accretion and since the study site is experiencing both high levels of shoreline erosion (refer Chapter 5) as well as increasing use from recreational tourism, it is essential to be able to analyse the outcome of shoreline erosion.

2.3 Shoreline erosion

A shoreline is defined as the interface between the land and the sea (WIOMSA, 2010) and the immediate position of the land–water line at one instance in time (Boak and Turner, 2005). Because of the active nature of water bodies and the coastal land, the shoreline is constantly changing (Paterson et al., 2010). Shoreline change depicts the way in which the position of the shoreline moves with time (WIOMSA, 2010). Several studies point out that two main factors can be responsible to change a shoreline, these are; human activities along the shore or natural processes (Richmond, 1997, Keqizhang et al., 2004, Boak and Turner, 2005, Hanslaow, D.J., 2007, Paterson et al, 2010). An example of a natural process can be sea level rise (SLR), change from storms and climate (Keqizhang et al., 2004) extreme weather events, including an increase in the intensity and frequency of waves on the shoreline and beaches (Pearson et al., 2005). Williams and Gutierrez (2009) pointed out that a sea-level rise is one of the most important impacts for shoreline change, and may cause variations in waves, currents and sediment availability in most US coastal areas. Shorelines can also move landwards through the process of erosion; or seawards by sediment

accretion (WIOMSA, 2010). Shoreline change can also be used as a good indicator of possible coastal erosion and the best indicator for describing coastal erosion is the shoreline retreat rate (Boak and Turner, 2005).

Coastal areas are one of the most distinct and dynamic parts of the earth's ecological system (UNESCO, 2003).Coasts offer a range of benefits by providing food, raw materials, income from recreational activities and economic development. Coastal areas consist of a range of highly productive ecosystems such as; coral reefs, mangroves, coastal lagoons and creeks, estuaries and deltas, and sea grass beds (UNESCO 1997).Coastal zones have become focal points for the growing human population following expansion of urbanization, industry and tourism activities (Hoorweg and Muthiga, 2009).

Many beaches around the world are subject to problems associated with beach erosion and recession (Hanslaow, D.J., 2007). Paterson et al, (2010) defines Shoreline erosion as the group of natural processes including; weathering, abrasion, erosion, and transportation, by which material is worn away from the earth's surface. In Kenya, Hoorweg and Muthiga (2009) reported that the coastal environment is influenced by naturally occurring processes such as erosion and sedimentation carried out by the Sabaki River. In addition to these natural processes, human action to control and mitigate erosion and maintain navigation channels can change the shoreline (Williams and Gutierrez, 2009). According to Richmond (1997), human actions such as the destruction of mangrove forests, seagrass beds, and coral reefs caused by tourism development can increase the exposure of the coast to wave actions which may lead to erosion. A study in the US by Hapke et al. (2010) showed that activities such as shoreline stabilization structures causes change in; coastal processes, sediment

transport, and shoreline position. In Kenya for example, a study by Kairu and Nyandwi, (2000) showed, that in the last three decades rapid development in the tourism industry has taken place on beach fronts which have experienced increasing coastal erosion problems. Another study along the Kenyan coast by Government of Kenya, (2010a) indicated that in the built up areas, erosion in some cases has been exacerbated by human interference, through the construction of sea walls. Sea walls increase reflected wave energy, leading to erosion and flattening of the adjoining beach. An example of the effect of sea walls can be seen at Mtwapa in Kenya, where walls have been built to protect shoreline properties (Kairu and Nyandwi, 2000). According to a study by Government of Kenya, (2010a) coastal areas are showing clear signs of damage and degradation due to over-exploitation, land use changes which has led to erosion, siltation and hydrologic modifications. The results observed were; loss of coastal and marine habitats, fish landing sites, beaches, turtle nesting areas, and damage to properties adjacent to the shoreline. Erosion is moderate to severe in parts of Watamu beach area (Government of Kenya, 2010b), and with increasing tourist numbers visiting and staying at hotels and resorts, it is important to better understand the implications of manmade structures erected to protect these shorelines.

According to Moore et al. (2006), several coastal areas are heavily populated and have been observed as continuously changing hence, shoreline change analysis research has become a common goal of most coastal management plans. Furthermore, shoreline change analysis has become a suitable tool to understand temporal and spatial trends of beach erosion and accretion triggered by natural and human impacts (Limber et al., 2007). Therefore, understanding the process causing shoreline change and quantifying the shoreline change rate is crucial for better coastal area

management. Fortunately today tools such as Geographical Information Systems and Remote Sensing are readily available to assist in the accurate assessment of such problems.

2.4 Role of Geographical Information System (GIS) and Remote Sensing (RS) in natural resource management

Geographical Information System (GIS) and Remote Sensing (RS) have become vital tools for improved natural resource management and informed planning. As indicated by Andrew et al., (1997) remote sensing data are helpful to carry out inventories of land, and the associated temporal information required to monitor sustainable land management practices. For example remote sensing data such as satellite images and aerial photographs can provide data to generate baseline information on natural resources (Rao, 2000). Satellite imagery is very valuable in order to provide information on land cover and land use, during environmental events such as floods, hurricanes and forest fires (Horning, 2004).A good example of the use of remote sensing data is the example of improving emergency response through decisions based on the normalized difference vegetation index (NDVI), which is a tool that was used to indicate biomass status in 1997, enabling the Government of Kenya to import extra grain to avoid food shortages caused by drought (Andrew et al., 1997).

GIS supports the handling of huge spatial data sets such as raster images and vector data sets (point, line and polygon data). For example, using GIS it is possible to model the relationship between land degradation status and the associated driving factors (Bridges et al., 2001). GIS also help to relate information gathered from local knowledge with scientific spatially referenced data in order to develop community based land and resources mapping (Quan et al., 2001). The idea of participatory GIS in which the community participate in order to map the existing natural resources is becoming a common practice in many developing countries. GIS provides a platform

to integrate information gathered from local knowledge with spatially referenced data on natural resources such as forestry, vegetation, and land cover land use information (Rao, 2000). In general, GIS in combination with remote sensing is being used by several disciplines to; study historical land use land cover changes, to map population distributions, for soil mapping, for rangeland management, for monitoring wetland and coastal environments, and to identify shoreline changes rates.

Several studies used GIS and RS tools to study the change in a shoreline. A study by Restrepo et al. (2012) confirmed the use of historical aerial photos and satellite imagery to provide information on erosion hazards on Colombia Island. A parallel study in Tanzania pointed out the importance of RS and GIS tools for monitoring the shoreline environment and resources (Makota et al., 2004). Yet another study of shoreline change in Ghana indicated the significance of using medium resolution multi spectral satellite imagery to map and monitor the change on a shoreline (Appeaning Addo et al., 2011). The utilization of GIS and RS tools makes it easier to assess past or present shoreline changes accurately and help assists planners to come up with a better shoreline management approach. Looking to the future, such tools can also help policy makers and local governments in improved decision making through the provision of reliable and up to date spatially analyzed information.

2.5 Institutional frameworks, policy and governance influencing coastal areas in Kenya

Coastal areas receive economic development in the form of tourism, agricultural, and industrial development (Salam et al., 2000). Primarily the seashore provides attractive scenery, distinctive resources and creates a good opportunities for tourism development (IGAD, 2007). The impact of tourism related activities on a given shoreline needs careful management and protection. Human activities affecting the oceans require integrated planning to ensure that development goals, strategies, and

projects will not negatively affect the marine life and the surrounding inhabitants (Kimball, 2001). Coastal area management and conservation requires a universal approach to address issues relating to impacts coming from development on coastal resources and use within a given area (PAP/RAC 2005). Integrated Costal Area Management (ICAM) and/or Integrated Coastal Zone Management (ICZM) are the two common approaches found in much of the literature on coastal areas. According to a report by GOK (2009), ICZM is a management system for wise and sustainable utilization of coastal zone resources. Based on the study of Kairu and Nyandwi (2000) the primary objective of ICAM is to achieve sustainable development of coastal and marine areas, and reduce the vulnerability of the ecosystems, while maintaining ecological processes and biological diversity in coastal and marine areas. Apart from these two approaches, a good legislative environment which enables, laws and policy guidelines to be formulated and applied, are useful for better use and management of coastal areas.

There are a number of international treaties to protect the natural resources of the ocean and the coastal environment. Some of these treaties are: The UN Convention on the Law of the Sea which was adopted in 1982. This provides the legal basis for protection and sustainable development of the marine environment and its coastal resources (Salam et al., 2000).The 1995 Convention on Biodiversity (CBD), Jakarta Mandate on marine and coastal biological diversity which provides for the sustainable use of marine and coastal living resources. The 1972 Convention concerning the protection of the world and natural heritage (World Heritage Convention) (Kimball, 2001). Kenya has signed several international and multilateral environmental agreements in order to protect its coastal areas (GOK, 2009).

There are also national land Acts and land policies which directly or indirectly affect the coastal areas of the country. For example, the Physical Planning Act No.6 of 1996 of the Laws of Kenya which came into force on 28th October 1998 is a legislative framework for systematic national land use planning (Weru et al., 2001). However, according to the new Land Policy document (2009), the land question within the Coast region is potentially explosive owing to its peculiar historical and legal origins. A report by WIOMSA (2010) also emphasized the problem associated with the existing coastal development policies and practices which exacerbate the risks to coastal communities associated with shoreline change, erosion and inundation. There is also a problem of overlapping and uncoordinated jurisdictions which leads to duplication of effort and wasted resources among different sectors (e.g. the Forestry and Wildlife Sectors, GOK, 2009).

In Kenya there are 77 Acts which address the conservation and management of the environment (UNESCO, 1997). Except the Coast Development Authority Act 1990, and Environmental Management and Coordination Act (EMCA) 1999, there are no direct Acts, regulations or policy documents which address the issue of coastline resource use and management. Most of the regulations regarding coastal areas are scattered through a range of resource and sectorial specific Acts and policy documents. Some of the Acts which directly or indirectly address the issues of coastal area management appeared to be duplicated, have overlapping mandates and/or have a system of weak penalties (GOK, 2009). A study in the West Indian Ocean countries namely Kenya, Tanzania and Seychelles revealed that these countries do not have an inclusive legal framework designed towards general beach management (WIOMSA, 2009). The same document indicated that in cases of Kenya there is only one instrument EMCA 1999 for regulation of developments along the shoreline. Other

issues such as shoreline change and guideline policies towards land use planning along the shoreline were not addressed by EMCA 1999.

2.5.1 Existing policies/legislation in Kenya and their relevance to shoreline management

In this section some of the Acts which directly or indirectly affect coastal resource management and conservation were reviewed. The document review was undertaken to show where overlapping and conflicting mandates for managing marine and coastal issues exist and what opportunities for improved coordination can be grasped by the mandated institutions. Kenya has a range of national environmental legislation that has been created, however much of this legislation is decades old and no longer sufficient to manage current pressures. Marine and coastal ecosystems have therefore degraded, with protected areas not being exempt (UNIDO COAST Project, 2013).

2.5.1.1 Physical planning Act 1998

The draft Physical planning Act 1998 empowered the Local Authorities under section (29) of the Act 'to reserve and maintain all land planned for open spaces, parks, urban forests and green belts'. Under section (30) of the Act it is specified that, 'no other licensing authority shall grant license for commercial or industrial use or occupation of any building without a development permission granted by the respective local authority'. Section 36 stated the requirements of environmental impact assessment (EIA) for projects that cause potential damage on the environment.

2.5.1.2 Draft Physical Planning Bill, 2014

Physical Planning Act, 2014 is a 'Bill for an Act of Parliament to provide a legal framework for the planning, use, management, regulation and development of land, to repeal the Physical Planning Act, 1998. Under this Act, Section (12) (2), issues of the protection of wetland, and mangrove forests it states; 'The Commission shall ensure

that any public land that has been identified for allocation does not fall within any of the following categories, forest and wild life reserves, mangroves, and wetlands or fall within the buffer zones of such reserves'.

2.5.1.3 Coast Development Authority Act 1990

Coast Development Authority Act, 1990is an 'Act of Parliament to provide for the establishment of an Authority to plan and co-ordinate the implementation of development projects in whole of the Coast Province and the exclusive economic zone'. This Act specifically states the mandates of the Authority to carry out surveys and research, and come up with alternative uses of the natural resources, such as agriculture, tourism and also to make sure that the planned development projects promote socioeconomic development to the coastal area.

2.5.1.4 The Tourism Act 2011

The Tourism Act 2011 is an 'Act of Parliament to provide for the development, management, marketing and regulation of sustainable tourism and tourism-related activities and services'. Some of the tasks of the Minister are provided under Regulation (122) sub section (1). The Minister has the responsibilities of providing licenses, classification of tourism activities, regulation, restriction and control of tourism related activities and services, and managing the shoreline.

2.5.1.5 Environmental Management and Coordination Act 1999 (EMCA)

The Environmental Management and Coordination Act (EMCA) 1999 is an 'Act of Parliament to provide for the establishment of an appropriate legal and institutional framework for the management of the environment'. In this Act under Sections 54 and 55 issues of coastal area management, conservation and guidelines, and regulation on the protection of the resources are incorporated. Specifically under Section (55) subsection (2) and (3) it is stated that the Authority i.e. NEMA together

with the key institutions working in the area, has the responsibility to prepare a survey of the coastal area and to report every two years. Based on this report, it is to prepare an integrated coastal management plan. Some of the survey reports include; an inventory of the state of the coral reefs and mangroves, an assessment of effects of coastal erosion in the area, an evaluation of the source of coastal pollution and degradation.

2.5.1.6 Environmental Management and Coordination Regulation, 2009

According to EMCA Wetlands regulation, 2009, under Section (14) the obligation of land owners and users are stated as, 'every owner or user of land which is adjacent to a wetland shall, with advice from the Authority, have a duty to prevent the degradation or destruction of the wetland'. Under the same regulation Section (17) the overall principles and guidelines on the utilization and protection of all wetlands are indicated. This regulation includes not only wetlands, but additionally river banks, lake shores and sea shore management. Some of the principles which are directly relevant for coastal areas are; the requirements of an EIA for any kind of project, sustainable use of shores, and the importance of developing an inventory of degraded shorelines and their conservation measures. The present study provides up to date spatial information on the status of the Watamu Mida shoreline in this context.

2.5.1.7 Forests Act, 2005

Forests Act, 2005 is an 'Act of Parliament to provide for the establishment, development and sustainable management, including conservation and rational utilization of forest resources for the socio-economic development of the country'. The Forests Act, 2005 under Section (32) (3) states, 'No cutting, grazing, removal of forest produce, hunting or fishing, shall be allowed in a nature reserve except with the

permission of the Director granted in consultation with other conservation agencies, which permission shall only be given with the object of facilitating research'. Section 33 subsection (1) indicates the requirement of permission from the Board through the conservation committee in order to use the forest under nature reserve for conservation, utilization for cultural, religious or any other purposes.

2.5.1.8 Wildlife Conservation and Management Act, 2013

The Wildlife Conservation and Management Act, 2013 is an 'Act of Parliament to provide for the protection, conservation, sustainable use and management of wildlife in Kenya'. The use and conservation of marine resources is indicated under Section (32) subsection (2) of the Act which specifies, the need to use a zoning system in marine conservation areas where, 'extraction or no extraction zones in respect of marine resources, protection of nesting, breeding and foraging areas, no take areas in respect of fisheries and any other purposes with respect to specified human activities within the zone'.

2.5.1.9 The National Land Policy, 2007

The primary objective of this policy is stated; 'to secure rights over land and provide for sustainable growth, investment and the reduction of poverty'. Under Section 134 the issue of the protection and management measures of coastal resources such as; islands, shoreline and other marine life including fragile ecosystems are incorporated. Section 135 specifically indicates the need to consider 'development activities in all islands and front row beaches shall take into account concerns of public access to beaches, and the fragility of the ecosystem,' hence the need to put in place firm management guidelines for coastal areas. Section 187 specifies the issue of ownership of beachfronts by foreigners either holding freehold or leasehold tenure. This has

caused some challenges such as access to the beach by the public, free movement along the seaside, and reduction in fish landing sites, as well as complications to control developments along the beach.

2.6 General strategies to improve coastal areas in Kenya

In Kenya there are four Marine National Parks which was established in 1968 and known to be the oldest in West Indian Ocean Region covering an area of 54 Km^2 and five Marine National Reserves cover 898 Km^2 (ASCLME, 2012). However there is still no clear coastal management plan such as an Integrated Costal Area or Zone management plan or legislation to give direction or regulate on the use of the coastal areas. In 1993 a Regional Workshop and Policy Conference on ICAM for Eastern Africa was held in Arusha, Tanzania. Countries who participated in the regional workshop agreed on a policy document which required individual countries to develop their own national ICAM programmes for sustainable utilization of their coastal resources (UNSECO, 1997). In 1994 Kenya commenced a process to start ICZM in selected demonstration areas in; Nyali, Bamburi and Shanzu. The objective of this project was to address the urgent coastal problems in these selected demonstration areas.

After the introduction of the EMCA Act 1999, ICZM became institutionalized in Kenya through the preparation of "an Integrated National Coastal Zone Management Plan" based on detailed survey of coastal resources and uses (GOK, 2009). This State of the Coast Report has been prepared in compliance with the provisions of the EMCA (Sec 55), which mandates NEMA to prepare an ICZM plan, and review such a plan every two years. According to the report of ASCLME (2012) following the EMCA 1999, quite a number of coastal development projects have now been subjected to an Environmental Impact Assessment (EIA) process.

In the recent past, the National Environment Management Authority (NEMA) prepared a document which describes the current circumstance of Kenya's coastal and marine environment. The document was supposed to assist as a baseline for the development of an ICZM plan for Kenya (GOK, 2009). Other reports which specifically focused on shoreline management and strategies have been prepared by NEMA for all coastal areas of Kenya as part of the plan to tackle the negative impacts of human induced shoreline erosion. This shoreline management strategy document was prepared for each of the 29 sediment cells (section of coastline with similar morphological characteristics) which describes the status of each shoreline (GOK, 2010). The document provides information on the biophysical settings of the shoreline such as coastal morphology, ecology and socioeconomic aspects such as population density, and tourist facilities along the shoreline.

A recent effort to improve the management and conservation of the Watamu Malindi National Park and Reserve is the 10 year (2011-2021) management plan for the Malindi Watamu marine Conservation Area (MWMCA). The plan has been prepared through a collaborative effort involving a wide array of stakeholders including; Kenya Wildlife Service (KWS), Wildlife Society of Kenya, Kenya Marine and Fisheries Research Institute (KMFRI), AROCHA-Kenya, Kenya Forest Service, Fisheries Department, Beach Management Units (BMUs) for Malindi and Watamu, and Boat Operators (KWS draft document, 2011). The main objective of the management plan is to come up with a general framework or approach for the conservation and management of the Watamu Malindi coastal area through resource use zones representing; core protection, partially protected, multiple use and livelihood intervention zones.

As compared with terrestrial ecosystems, marine environments are more complex because of their wider range of functions (Jones et al., 2011). This diverse environment needs protection, improved governance and implementation guidelines to manage the resources. There are many Acts and legislation which directly or indirectly address issues of land use and shoreline management (Section 2.4.1). There have been documents and strategic plans prepared to improve the current status of the shoreline and land use specifically in coastal areas. However, the coastal areas still are under huge pressure from; the growing population, urbanization and uncontrolled tourist related developments. Therefore, assessment of the existing Acts and policies, reviewing what has been done in the past, and providing up to date time series data and analysis from the present study, will help the ongoing efforts of coastal area management planning by providing new information on the weaknesses and strengths of such instruments, thus leading to their revision and improvement.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The study area

The study was conducted between 2013 to 2015 in Watamu Mida creek Kilifi County, in Coast Province, Kenya (Figure1). The study area covered approximately 60 square kilometers. Mida creek is a biologically important and complex tidal marine multi-habitat ecosystem supporting the adjacent local communities by providing foods, building materials and tourist revenues (Weru et al, 2001).The Creek expands across an area of 32 square kilometers. According to the population census of 2009, the population of the study area is 67,215 with estimated growth rate of 3.05% (GOK, 2009). The study area falls under the Agro-ecological zone identified as Coastal Lowlands, with cashew nuts and coconuts being the characteristic main crops (Foeken, 1994).

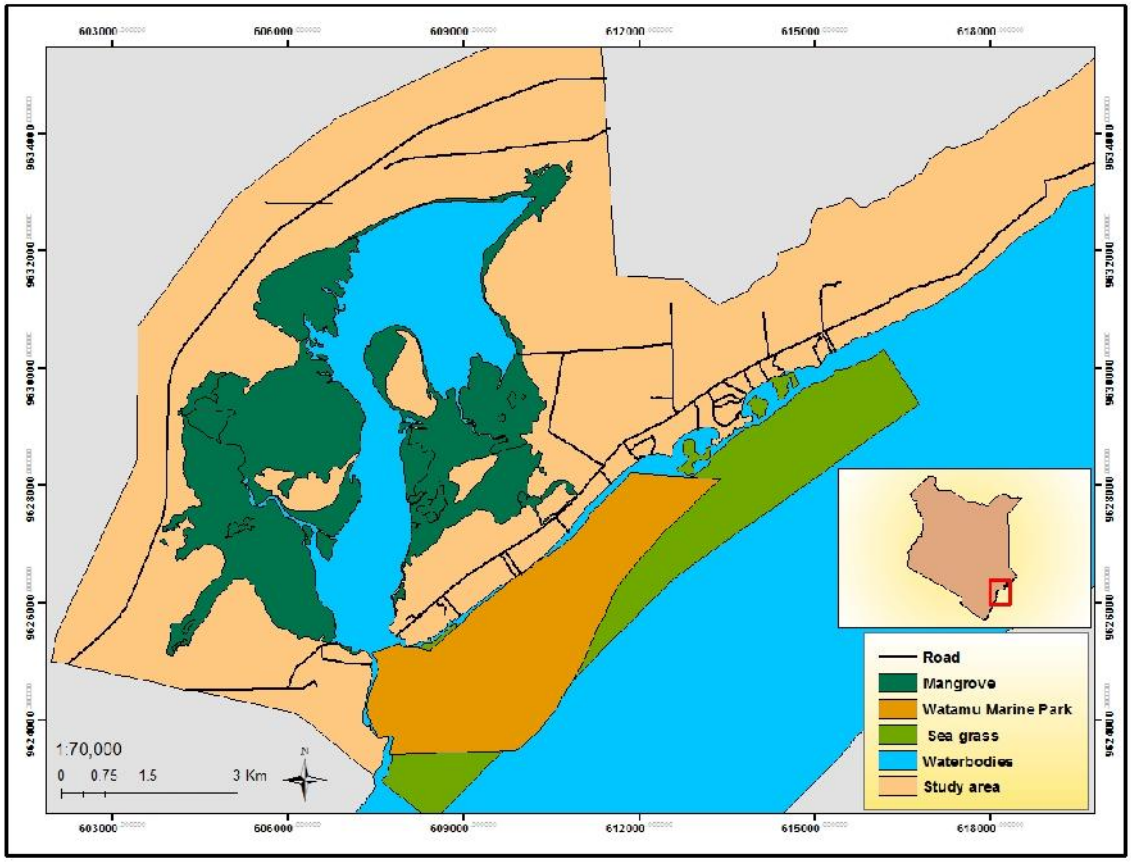


Figure 1. Location map of the study area

The coastal climate of Kenya is influenced mainly by large-scale pressure systems of the Western Indian Ocean and monsoon winds. Rainfall occurs during two distinct periods; the long rains between March and May and the short rains usually between October and December with mean annual rainfall that ranges from 500-900mm (GOK, 2009). The rainfall pattern around Mida creek and Watamu areas is bimodal where the long rains occur in April to June with a peak in May (Gang and Agatsiva, 1992) (Figure 2 and 3).

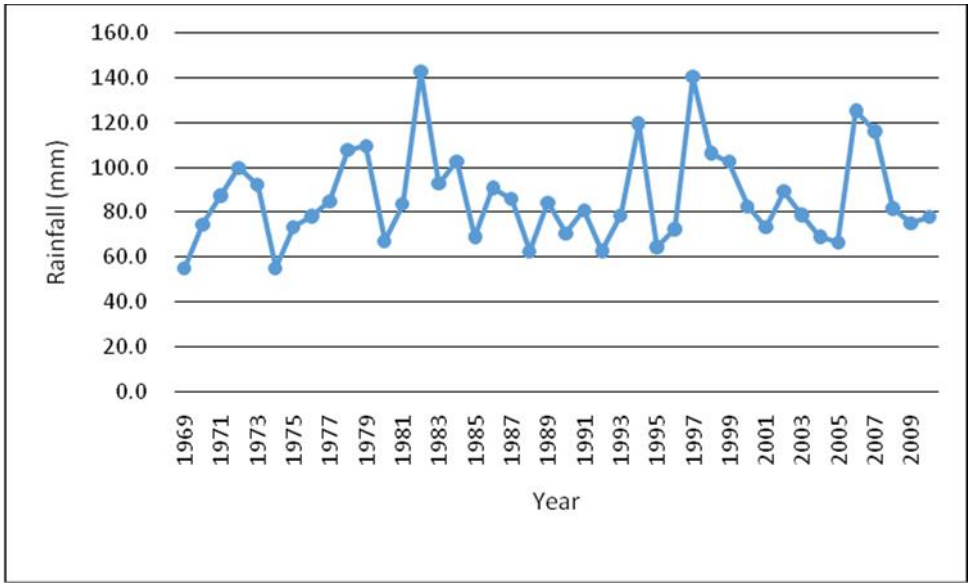


Figure 2. The trend of rainfall distribution in the study area (Source Kenya Metrological Service)

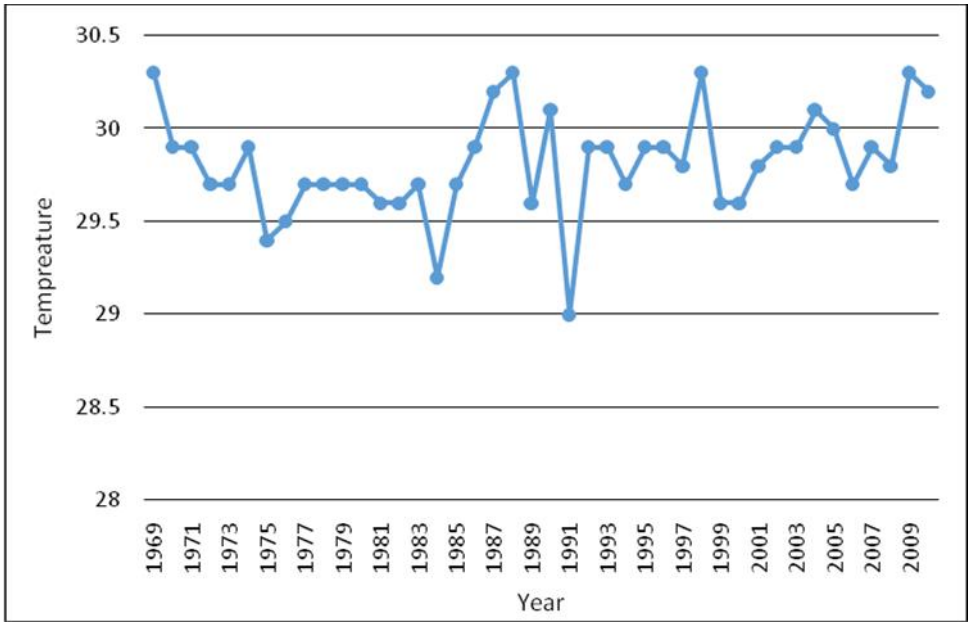


Figure 3. The trend of temperature in the study area (Source Kenya Metrological Service)

Regarding tidal ranges (height difference between high tide and low tide), for the entire coast of East Africa spring tidal range is 2-4 m (Richmond, 1997). According to a report by Government of Kenya (2009), coastal areas of Kenya have mixed semi-diurnal tides with two tidal cycles every 24 hours. In an unpublished report by

Bennett (1997), he divided the status of the Watamu tide variation into two, whereby the highest tide recoded was on a spring tide up to 4 m, while neap tides were recorded as less than 1.5 m.

According to a UNEP report (1998), the principal soil types in the area include coastal sands and brown clay soils. Soils of the mangroves swamps around Mida Creek are poorly drained, deep and excessively saline, olive to greenish grey loam to clay, and often with sulfidic material (Gang and Agatsiva, 1992).

3.1.1 Land use

There is not much written about detailed classification of land use within the study area. However a report by GOK, (2009) classified the land use type of the coastal areas of Kenya into four main categories; livestock ranches in the hinterland, agricultural settlement schemes, private land along the coastline, and undesignated government land. National parks and reserves constitute important components of the coastal ecosystems, and are major tourist attractions. The study area includes two National Parks and one national reserve. In most of the villages, except those near the shoreline and urban areas (such as Watamu village), rural settlement with mixed cash crop trees is the main land use type(Gang and Agatsiva, 1992). The main cash crop trees are; cashew nuts, mangoes, and coconuts. More recently *Cassurina sp* trees are being grown in most villages to meet the high demand for construction poles. Other land use types are; residential plots, and big hotels with urban settlement in the hinterland. Business and commercial areas including local markets are becoming a more important land use type.

3.1.2 Shoreline

According to a study by Tychsen, (2006), Kenyan beaches are characterized in to two groups: i) gentle to steep sandy beach without protection from a reef and, ii) gently sloping beaches sheltered behind a fringing reef. The shoreline that extends from Malindi to Mida creek is sheltered by a continuous fringing reef with a white sandy texture (GOK, 2010a). In addition this beach is a calcareous sand of marine origin (Tychsen, 2006). The Watamu Marine National Park and reserve border the shoreline. The shoreline is also an attractive tourist area including a number of tourist hotels, resorts and residential plots. There is a trading centre for curio sealers, safari sealers and boat operators. The shoreline near Mida creek is identified as a high priority turtle nesting area (GOK, 2010a). The beach is a nesting place for Hawksbill and olive Ridley turtles (Tychsen, 2006). However the turtle nesting sites and the newly hatched young are threatened by natural causes such as; high tides, wind, rain and manmade factors including; beachfront development, artificial light from hotels, and noise pollution (Thomas, 2006). The shoreline is exposed to erosion during the Southeast monsoon from September to May.

3.1.3 Socio-economic activities

In many of the Kenyan coastal areas tourism is the main socioeconomic activity supporting the local economy, providing the majority of the people with a livelihood. The most notable tourism related activities include: tourist hotels, guesthouses and lodges, beach traders, curio vendors, boat tour operators, sport fishing, snorkeling and diving (UNIDO COAST project 2013, and GOK 2009). Villagers near the mangrove forest and the creek earn their living from fishing, mangrove harvesting (GOK, 2009) and ecotourism activities within the mangroves (such as mangrove boardwalks and bird watching). The tourism industry such as hotels and private residents are the major

employers for the local people (COAST project, 2013). In the hinterland fishing and agriculture are the main principal livelihood contributors. In most of the villages in Watamu and Mida creek artisanal fishing is the main source of income for the local communities (Gang and Agatsiva, 1992). According to a study by Muthiga (2009), 30-80 percent of households depend on fishing using gills nets. Tourism related activities offered opportunities such as direct employment, business and trade for local dwellers, but are also important as buyers of products from the agricultural sector (GOK, 2009). There are also some efforts by the community groups to use the Mida creek mangrove areas as a source of income through promoting ecotourism activities. Currently the two main ecotourism sites are at Mida and Dabaso boardwalks which run through the mangrove forest and are managed by these community groups.

3.1.4 Mangrove forest

Mangrove forest along the Kenyan coast is found largely on the northern coast around; Lamu, the Tana and Sabaki river estuaries, and smaller wetlands occurs along semi-perennial and seasonal rivers such as Mida Creek (GOK, 2010). The mangrove of Mida creek is separated naturally by the main creek (Kairo et al., 2002) and has habitats which comprise mangrove forest, sand flats, rock outcrops, sea grass beds, coral growths and deep water (Dahdouh et al., 2000). Gang and Agatsiva (1992) observe the presence of seven mangrove species in Mida Creek. Another study by Kairo et al., (2002) in the same area confirmed the presence of seven mangrove species in which; *C.tagal, R.mucronata* and *A. marina* are the dominant species. A study by Hirsch and Mauser, (1992) indicated the total area of mangroves in Mida creek as 1,600 ha whereas, Gang and Agatsiva (1992) reported the total mangrove cover 1,500 ha. The mangrove forest in Mida creek supports a diversity of plants and

animal life, For example, both indigenous and migratory birds use the mangrove backwaters, sandpits and small islands as a resting place (Hirsch and Mauser, 1992). The area is also a nursery ground for fish and shrimps (Tychsen, 2006). It is also a source of livelihood for the local community with poles being harvested for house construction (Dahdouh et al., 2000), fuel for domestic cooking, and charcoal making (GOK, 2010). Some employment opportunities and income for the local communities are derived from tourist visits (Hirsch and Mauser, 1992).

3.2 Study approach

The research integrates information using GIS and remote sensing, from three time periods covering; 1969, 1989 (aerial photographs) and, 2010 (satellite image), to determine where land use change, shoreline erosion and mangrove forest dynamics have occurred (Figure 4). The anthropogenic drivers of land use changes, shoreline change, and the status and dynamics of the mangrove forest and its biomass per hectare were quantified. The main drivers of land use change and shoreline erosion were assessed using household questionnaires, key informant interviews and focus group discussions.

Secondary data on natural and anthropogenic causes of shoreline and land use changes were gathered from relevant government and NGO offices. Population data which show the trend for the last 40 years within the study area was collected from the Kilifi County statistics office.

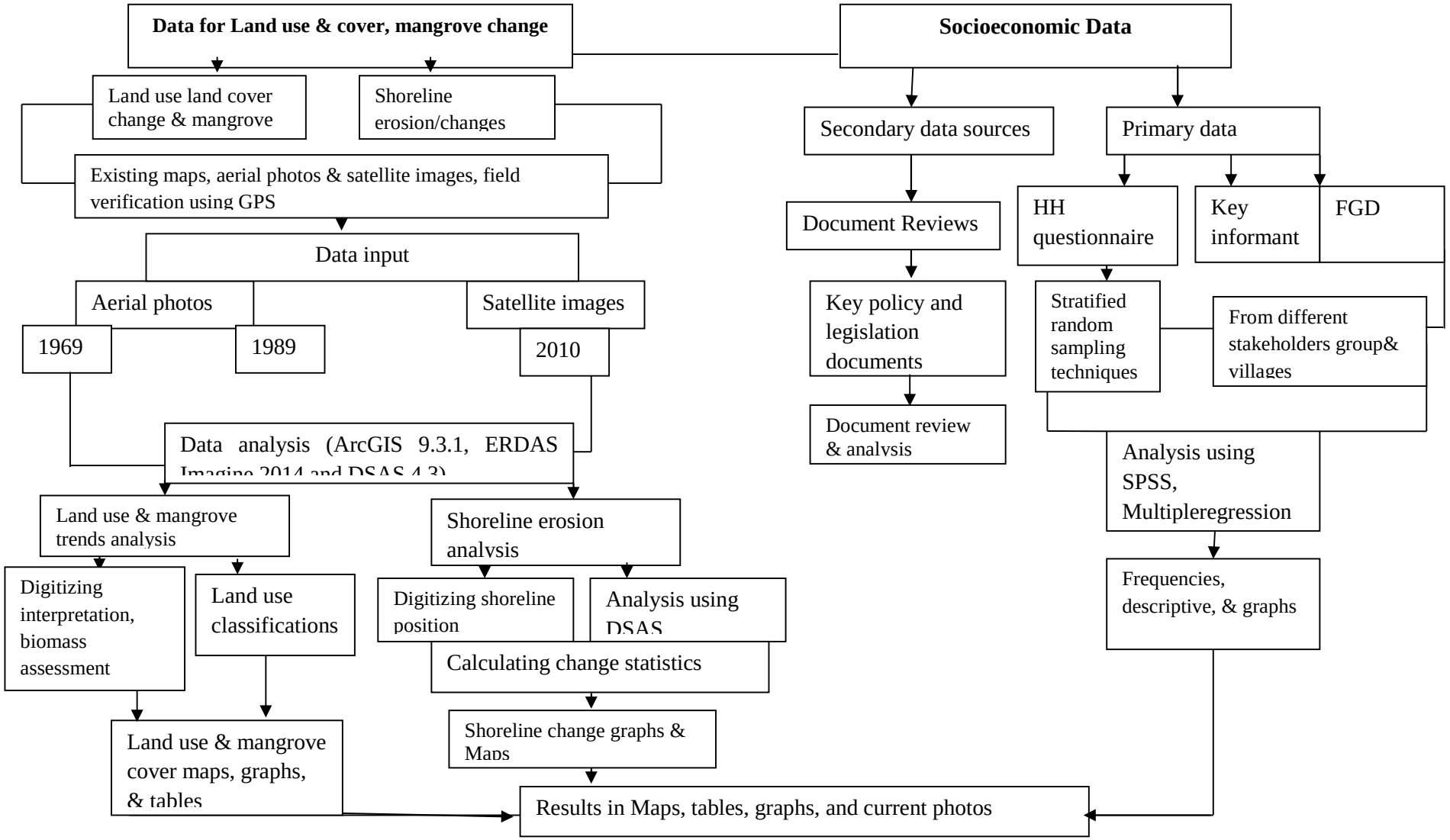


Figure 4.General Flow charts for methodology

3.2.1 Methods of data collection and analysis

The land use, mangrove assessment and shoreline change was assessed using remote sensing and GIS software. The use of remote sensing and GIS technologies enables the provision of data for larger areas to be more rapidly analysed and allows comparison of time series data (Elisabeth and Louis, 2007). The use of remote sensing technology can be of great help to study and manage coastal and marine areas (UNEP, 1989) because changes in the vegetation which are induced by land use changes are easy to detect due to the clarity of the reflectance differences between the sea and the land.

3.3 Data compilation

The land use data in Watamu Mida creek study area were based on over 40 years' of time series aerial photographs and satellite imagery (Table 1).To determine change in land use, the information was extracted from the aerial photographs of 1969, 1989 and an orthorectified 2010 World View satellite image (0.5mresolution). In total 23 scanned photographs (digital photographs) at 800 dip resolution were acquired from the Survey of Kenya office. The aerial photographs had a scale of 1:60,000 and 1:50,000 for 1969 and1989 respectively.

Table 1 Data source for land use and cover change, mangrove and shoreline

Aerial photographs & satellite images	Area	Year and date of data acquisition	Spatial resolution	Data acquired
Aerial photograph	Watamu Mida creek	February, 1969	1:60,000 (approximately 6 m resolution)	Survey of Kenya
Aerial photograph	Watamu Mida creek	February 1989	1:50,000 (approximately	Survey of Kenya

			5 m resolution)	
Spot satellite image	Watamu Mida creek	January 2002	2.5 (meter)	Planet Action
WorldView satellite image	Watamu Mida creek	February 2010	0.5 (meter)	UNIDO COAST project
Topographic map	Watamu Mida creek	1972	1: 50,000	Regional Center for Mapping of Resources for Development
Field verification using GPS	Mida creek mangroves, Watamu beach fronts & several	Oct 2012 Oct-Nov 2013 Oct 2014		

3.3.1 Georeferencing

The aerial photographs obtained from the Survey of Kenya was raw data (without any geo spatial referencing information). Hence in order to prepare these for analysis the photos were rectified using Ground Control Points (GCP) taken from the autorectified images. The orthorectified and mosaic 2010 World View image and Spot image 2003 with (2.5m) resolution served as master images for the orthorectification of the older aerial photographs. Both these images were orthorectified by the suppliers. The Universal Transverse Mercator (UTM) geographic projection WGS84 zone 37 South was used to georeference the 1969 and 1989 aerial photographs and to harmonize the old aerial photographs and the 2010 image. The orthorectification and georeferencing was prepared using ERDAS IMAGINE software, 2014 version. Both 1969 and 1989 aerial photographs were brought into ERDAS IMAGINE 2014 through conversion from GeoTIFF file format to image formats. This process helped to easily proceed to use the aerial

photographs to compute statistics, and change projections. The georeferencing was performed in the IMAGINE Auto Sync Workstation. First a new IMAGINE Auto Sync project was created and then the Spot image 2003 was added into the software interface (view). Finally the 1969 aerial photographs were added to the view. The Ground Control Points (GCP = tie points) were collected manually using identifiable features such as existing roads. Then the Auto Sync process used these GCPs to align the raw aerial photographs by automatically generating additional GCPs to align the photos to the georeferenced Spot image. The same process was repeated to georeference the 1989 aerial photos and later both sets of aerial photographs were orthorectified using the 2010 image. The total root mean square errors for georeferencing the two aerial photographs were ±2m.

3.3.2 Mosaic

A mosaic is a process to combine two or more images or photographs to produce one complete merged image file. For this study MosaicPro an application in ERDAS IMAGNE mosaic toolbox was used. Through using this software the multiple georeferenced and rectified aerial photographs of 1969 and 1989 were combined into a single Ortho-mosaic output. On screen visual interpretation and digitizing was then undertaken to prepare; the land use maps, mangrove cover and, shoreline change rate maps. Additionally, the aerial photographs and the satellite images were spatially enhanced using radiometric and photography enhancement tools in ERDAS IMAGINE.

3.3.3 Land use change data analysis

Using the mosaic aerial photographs of 1969 and 1989, training sites were collected on ERDAS EMAGINE using signature editor tools. Once the signatures were collected a supervised classification was performed. However, since the old aerial photographs have a single band and low spectral resolution the majority of the classes were misclassified, and it was difficult to use other image analysis tools in both ERDAS and ArcGIS software to improve the classification. Hence to improve the land use classification a combined methodology was used. The output of the supervised classification was used as a basis for visual interpretation and classification. In the study of land use and land cover classifications, it is common to use visual interpretation, computerized classification or a combination of the two (Horning N., 2004). Land use types were visually digitized and delineated following their; texture, pattern, tone and shape using ArcGIS.9.3.1 software. The 1972 topographic map legend (Key) which was also prepared using the 1969 aerial photographs was used to identify some of the main land cover types from the 1969 aerial photographs but difficult to identify all the cover types. Thus, later during field verification, some known features were identified on the ground to verify this classification. The land use change for 2010 satellite image was also visually interpreted and digitized on screen. All screen digitization were done at a scale of 1: 5,000 for uniformity and to provide detail and precision. After the necessary editing and cleaning of the data in ArcGIS, a preliminary land use map classification for 1969, 1989 and 2010 was verified in the field. During the field verification some features such as the mangroves, and the mixed cash crop farming/settlement areas which were identified on the photographs were cross checked through a ground truthing exercise. A simple random

sampling method was used to collect the GPS points in combination with the household survey. During the household survey in each village the following information was collected: the vegetation cover, settlement patterns and information related to the land use history at individual and village levels, the kind of trees grown and vegetation cover in the past and now, the land use change observed and the reason, the crops type grown in the area in the past and in the present time. Other related land use/cover information was gathered using semi structured and open ended questionnaires in order to improve the preliminary image interpretation and classifications. The village level information provided a crosscheck to the changes observed from the remote sensing materials (Roeder and Hill, 2009).The GPS points and photos taken during the survey also helped to improve the classification for the 2010 map. To improve the accuracy of the land use cover classification over one hundred ground control points were also taken both in the hinterland and along the beachfront. Original vegetation cover such as coastal bush, identified by households who had lived in the area for many years were identified, the names of old trees were recorded, and GPS points taken to overlay on the preliminary maps. In addition, a number of ground level pictures were taken for the 2010 land use map verification. Finally, GPS points of historical information (e.g. ruins) were gathered through households who had lived in the area for over 40 years, and this helped to improve the old aerial photographs land use cover classifications. All the GPS points gathered together with this historical information were overlaid on the classified land use and cover map to check the accuracy. Furthermore, for the 2010 land use classification, the land use map was exported to Google Earth (2012) and overlaid to check its accuracy.

In summary, based on intensive field verification (from 2012-2014), aerial photo and satellite image interpretation, the previous and current land use and cover types information gathered from household surveys and, the 1972 topographic map (legend/Key), 13 land use and cover classes were identified for 1969. The classes increased to 15 for 1989, and 19 classes for the year 2010. Some of the current land use types are defined in (Table 2) below. Additional comparative literature was also reviewed.

3.4 Accuracy assessment

For this study a combination of approaches were used to prepare the land use cover change maps, the mangrove cover maps and the shoreline erosion rates. The historical black and white aerial photographs of 1969 and 1989 were not suitable to use further image analysis such as supervised classifications as they are not multispectral data. However it was possible to identify the patterns of land use and cover, settlements and farming, forests such as the mangroves and coastal forest, and beach fronts clearly on the aerial photographs. Moreover the GPS points collected in all the villages and the land use history gathered during the household survey together with the more recent high resolution imagery helped to improve the accuracy of the current day land use cover classifications. According to the US Geological Survey (2011) procedures, classification accuracy should be checked against the real ground status to compare classification values.

The mangrove forest biomass assessment also allowed the researcher to gather additional information on the adjacent villages around the mangroves, and on the vegetation cover

bordering the mangroves. All this intensive field work, together with prior knowledge of the study area by the researcher helped to improve and validate the accuracy of the classification.

Table 2 Description of land use and land cover classifications

Land use and cover types	Descriptions of land use and cover classifications	Pictures of the current land use and land cover types
Miscellaneous coastal vegetation	Coastal vegetation cover dominated by old big indigenous trees	
Thickets with trees	Mainly coastal bush with big old trees	
Coastal bush with trees	Dominated by coastal bush with the presence of few old trees	 
Forest	Coastal Forest	

Settlement with mixed cash crops	Farm settlements with cash crop trees such as; mango, cashew nuts, coconuts and other indigenous trees together with seasonal crops such as maize, and a small number of livestock	 
Mangrove forest	All mangrove forest in the study site	 
Residential plots	Private plots along the beach with residential and holiday houses and thick vegetation cover	 

Seasonal Swamp	Area regularly flooded during rainy season	 
Beach	Areas adjacent to hotels and covered by white sand and used as a recreational area	 
Town	Areas composed of built-up areas under intensive use with residential, commercial and business centers and institutional facilities and other infrastructure.	
Barren land	Land which is not covered by	

	any vegetation at the time of the image acquisition and field verification (for the current period)	
Settlement	Mainly houses and villages with little vegetation or tree cover and where there is expansion of built- up areas (in progress)	
Private holiday houses	Houses constructed for the purposes of rent and tourist accommodation	 

3.5 Rate of land use cover change analysis

The land use changes between the three periods were quantified to show land use change conversion for the 41 year period. The change rates of single land use type was quantitatively measured based on Peng *et al.,* (2008) procedures. This index is recognized as one of the most widely used indices for detecting the land use change rates: (Peng *et al*., 2008)

$$\mathbf{K1} = \frac{Ub - Ua}{Ua} \times \frac{1}{T} \times 100\%$$

Where *K*1 is land use dynamic degree, measuring the change rate of the target land use type; *Ua* and *Ub* are the area of the target land use type at the beginning and end of the study period respectively; and *T* is the study period, which is usually measured by units of a year. The index of *K*1 can concisely express the overall characteristics of the change of a certain land use type in the study period.

3.6 Mangrove cover analysis

In order to estimate the mangrove cover changes over the last 41 years (1969-2010), an aerial photographic mosaic for 1969 and 1989, and a high resolution (0.5 m) World view satellite image for 2010 were used to digitize the mangrove cover. The data were generated for the mangrove cover by on screen visual digitizing and interpretation using ArcGIS 9.3.1and ERDAS IMAGINE 2014 version software. The aerial photographs have a scale of 1:60,000 and 1:50,000 for 1969 and 1989 respectively, as a result it was not sufficient to categorize mangrove at species level. Therefore, the classification of mangrove was undertaken based on two categories; open canopy, and closed canopy forest. The rest of the classification area was assigned as mud flats and the Mida creek

water body. The preliminary classified maps were verified in the field (through ground truthing) using a GPS together with field observation sunder taken during the biomass assessment exercise (Figure 5).

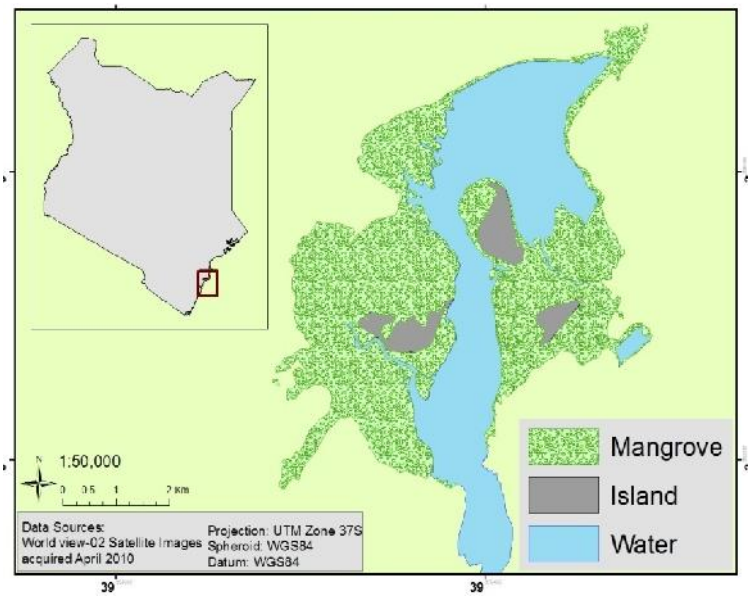


Figure 5: Mangrove areas

3.6.1 Above ground Biomass sampling

A non-destructive method of biomass estimation was done to record all the trees within a 10 m x 10 m quadrat sample. Using the quadrat, tree measurements for biomass data were taken from the two stratum of mangrove cover type: open canopy mangroves and closed canopy mangroves, both of which occur within the National Reserve. In each stratum, 25 sample plots were randomly distributed on 10 m x 10 m plots. In each plot tree Diameter at Breast Height (DBH) which was 1.3 m above the ground (where the highest prop-roots reach) was measured using a diameter tape. Tree height was measured using a Laser Ace for each mangrove tree to a minimum diameter of 7 cm (Figure 6). For saplings and seedlings qualitative methods were used to enumerate species within 3 m x 3

m, and 1 m x 1 m, subplots at the center of each main plot for determination of species regeneration. The minimum distance between the plots was 50 m (Figure 7).

Figure 6: Mangrove biomass data collection (height and DBH) collection

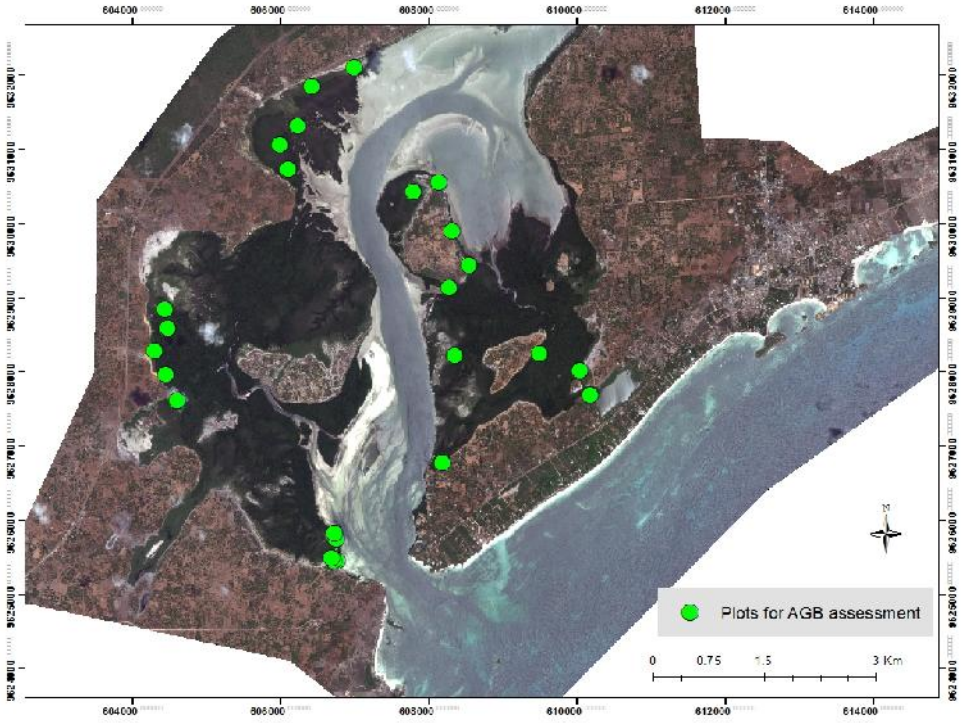


Figure 7: GPS points depicting plots to collect above ground biomass field data

3.6.2 Allometric equation for above ground biomass estimation

This research used a non-destructive method to calculate the above ground biomass of the mangrove by measuring the height and DBH of sampled trees. The biomass of the mangrove forest can be assessed indirectly from measurements of DBH at a height of 1.3 m above ground and the tree height (Kairo et al., 2009). There was no allometric equation found to assess above ground biomass for all mangrove species in Kenya. Hence, published allometric equations developed for mangrove species by Komiyama et al., (2005) (above Ground Biomass = $0.251*\rho*(D)^{2.46}$ were used to assess and estimate the above ground biomass of the Mida creek mangrove forest. To get a comparison on above ground biomass estimation, other equations were also used including; Chave et al, (2005), (above Ground Biomass= exp (-2.977+ln (ρ D^2H) = $0.0509*\rho D^2H$), Where ρ = wood density, D= Diameter at breast height (DBH), H= Height) and Kirui, et al, (2006) ($y= 0.8069DBH^{2.5154}$). Values of biomass data were allocated to each mangrove species using the tree inventory data and applied to each allometric equation. The equations have a coefficient of determination (R^2) of 0.98 (Komiyama et al., 2005) and a standard error of 12.5% (Chave et al., 2005).

At local level, the allometric equation published in Kenya was the one developed by Kirui et al. (2006) and has been applied only to *R. mucronata* which grows naturally. This is currently the only allometric equation developed for a mangrove species which grows in a natural environment in Kenya. An allometric equation developed for predicting the total above ground biomass at Gazi bay (which is some 100 kms south of the study site) was $y= 0.8069DBH^{2.5154}$ ($r^2= 0.98$, $p<0.05$). This study uses the local

equation for *R.mucronata* for the purpose of comparison with the general allometric equation developed by Chave et al. (2005) and Komiyama et al. (2005) to measure above ground biomass for *R. mucronata*. For data analysis and graphical presentations of the findings, IBM SPSS version 19 was used.

The wood density for each species of mangrove was taken from Bosire et al. (2012) (Table 3) which has been developed for this region. The allometric relationships of the four dominant mangrove species (*C.tagal, R. mucronata, B. gymnorrhiza, and A. marina)* in Mida Creek were studied for the two variables of (DBH^2H), and (ρ) (DBH). A number of different literature on the measurement of above ground biomass show the use of DBH^2 H, DBH, wood density (ρ) or DBH alone (Chave et al., 2005,Komiyama et al., 2005, Leni,et al., 2011, Kirui et al.,2006) . According to the study of common allometric equations by Komiyama et al., (2005) in order to attain a common allometric relationship, it is necessary to include wood density (ρ) with a given value for each specific species in the equation. For this study in order to avoid possible bias on the results of the estimation of biomass, trees with high DBH values from all species were eliminated. Using Komiyama et al. (2005) general equation, the maximum DBH limit was 49.0 cm.

Table 3 Specific wood density of major mangrove species in the West Indian Ocean

Species	Density (g/cm^3)	Standard Error
C. tagal	1.1	0.0
B gymnorrhiza	1.3	0.1
X. granatum	0.8	0.1
S. alba	0.8	0.0
A. marina	0.9	0.0
R. mucronata	1.1	0.1
H. littoralis	0.8	0.1

Source: Bosire et al., (2012)

To estimate the carbon stock of the mangrove forest, a conversion factor of biomass to C which is C=0.55 * biomass (total) as recommended by (FAO, 2004) was used. According to this FAO (2004) report, this coefficient is frequently used when making assessments of biomass and carbon stock in the current land use.

3.7 Shoreline erosion

The sources of shoreline data were geo referenced and mosaic aerial photographs, satellite images, topographic maps, field observations with knowledgeable local community representative and GPS points. The aerial photographs had a scale of 1:60,000 and 1: 50,000 for 1969 and 1989 respectively. The satellite image used for 2010 was World View with 0.5 m resolution.

3.7.1 Shoreline extraction

The shoreline change data were extracted from aerial photographs of 1969, and 1989 and the satellite image of 2010 using ArcGIS.9.3.1 software (Figure 8). The shoreline change rate measurement followed the approach used by (Hanslow 2007, Thieler et al., 2009, Borrelli 2009, and Fletcher et al., 2012) which includes: digitizing a shoreline on georeferenced images, and quantifying rates of shoreline change.

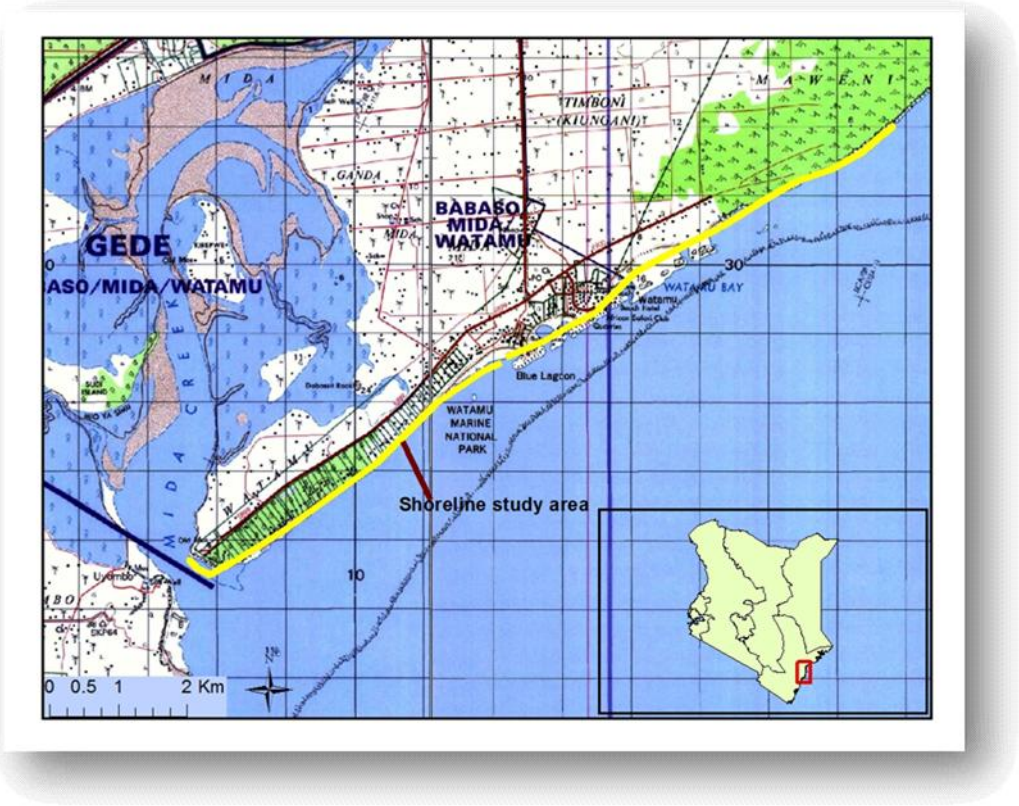


Figure 8: Location map of the Watamu shoreline (the yellow line)

Several literature suggest the use of; the High Water Line (HWL) or shoreline indicators such as a debris line; the wet/dry line and; change from low-marsh to high-marsh vegetation along marshy shorelines to delineate shoreline change (Crowell et al., 1991, Borrelli, 2009, Boak and Turner). According to Crowell et al. (1991) the HWL is the best indicator of the land-water interface for historical shoreline studies. Based on this approach the shoreline was digitized onscreen using the HWL indicator from the aerial photographs and from the 2010 satellite image using ArcGIS software. Additionally, GPS points collected in November 2013 and October2014 along the shoreline following the HWL were used to define the current shoreline.

3.7.2 Shoreline data analysis

A geo-database was created in ArcGIS for the digitized shoreline positions with attribute tables for all shorelines which comprised; year, ID, shape and uncertainty (measurement and sampling errors) (Figure 9). The historical change in shoreline was analyzed using a Digital Shoreline Analysis System (DSAS 4.3) computer software which is an extension for ArcGIS. The Digital Shoreline Analysis System (DSAS) computes rate-of-change statistics from multiple historic shoreline positions residing in a GIS (Thieler et al., 2009).

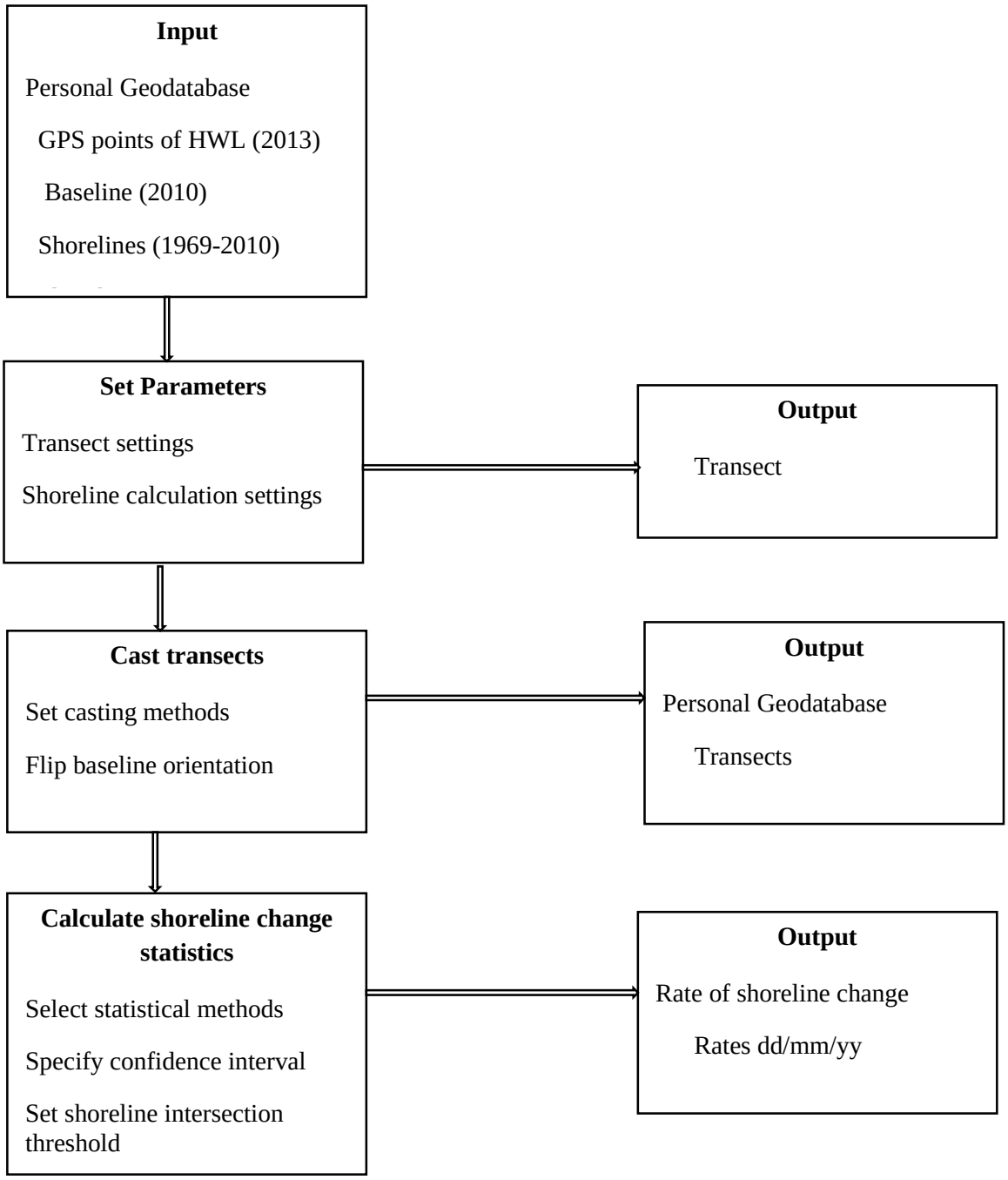


Figure 9: Flow Diagram illustrating the steps followed for Shoreline data collection and analysis

Three statistical methods were used to calculate the rates of shoreline change from 1969-2010. The methods were End Point Rate (EPR), Net Shoreline Movement (NSM), and

Linear Weighted Regression (WRL). In the DSAS work flow the EPR is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline (Thieler et al, 2009). The NSM reports the total distance between the oldest and youngest shoreline (Thieler et al, 2009). In the computation of rate-of-change statistics for shorelines, greater emphasis is placed on data points for which the position uncertainty is smallest.

$$w = 1/ (e^2) \quad (1)$$

Where

e = shoreline uncertainty value

The weight (w) is defined as a function of the variance in the uncertainty of the measurement (e) (Thieler et al, 2009)

The uncertainty field of the shoreline feature class is used to calculate a weight. In conjunction with weighted linear regression rate, the standard error of the estimate (WSE), the standard error of slope with user-selected confidence interval (WCI), and the R-squared value (WR2) are all obtained (Thieler et al, 2009).

The error or uncertainty that comes from using a number of different sources of data were calculated based on a number of studies (Crowell et al., 1991, Fletcher et al., 2012, Laura and Javier, 2013). Using the approach by Laura and Javier, (2013) three main sources of errors were identified: image resolution error (R), geo-referencing error (G), and a physical component of the error or shoreline proxy (D). Fletcher et al (2012), suggests the

inclusion of digitization error, hence this variable was also included in the following formula (Ed):

$$Ep=\sqrt{G^2 + R^2 + D^2 + Ed^2} \quad (2)$$

Where

G= Geo-referencing error, R= Image resolution error, D= Shoreline proxy error, Ed= Digitization error.

Using the above formula, the uncertainty corresponding to each individual image was ±4.6 m and ±2.4 m for the aerial photographs and satellite image respectively.

3.7.3 Field verification

Two ground truthing exercises were conducted in the study area during 2013 and 2014to assess areas which were affected by erosion with the help of a local community guide. During the survey all vegetation cover along the beach was identified and the information recorded together with the specific location using a GPS. A number of GPS points were also collected by walking along the beach during low tide following the HWM (Figure 10). At the same time digital photos were taken to improve knowledge of specific points along the Watamu shoreline. After the preparation of the preliminary analysis of shoreline change results, an additional field verification was conducted in October 2014. During this time Focused Group Discussion and key informant interviews were conducted with: curio sellers, boat operators, fishermen, safari sellers, local longtime residents, and hoteliers in order to get information about the possible drivers of shoreline change in Watamu. All these groups of people have long term experience in the area as

they work or live along the shoreline and beachfront. The 2010satellite image was printed in colour for Focused Group Discussions to help the participants to identify areas which were affected by erosion /accretion and high intensity touristic activities along the beach. All this qualitative information was compared with the results from the statistical analysis of shoreline erosion and accretion rates.

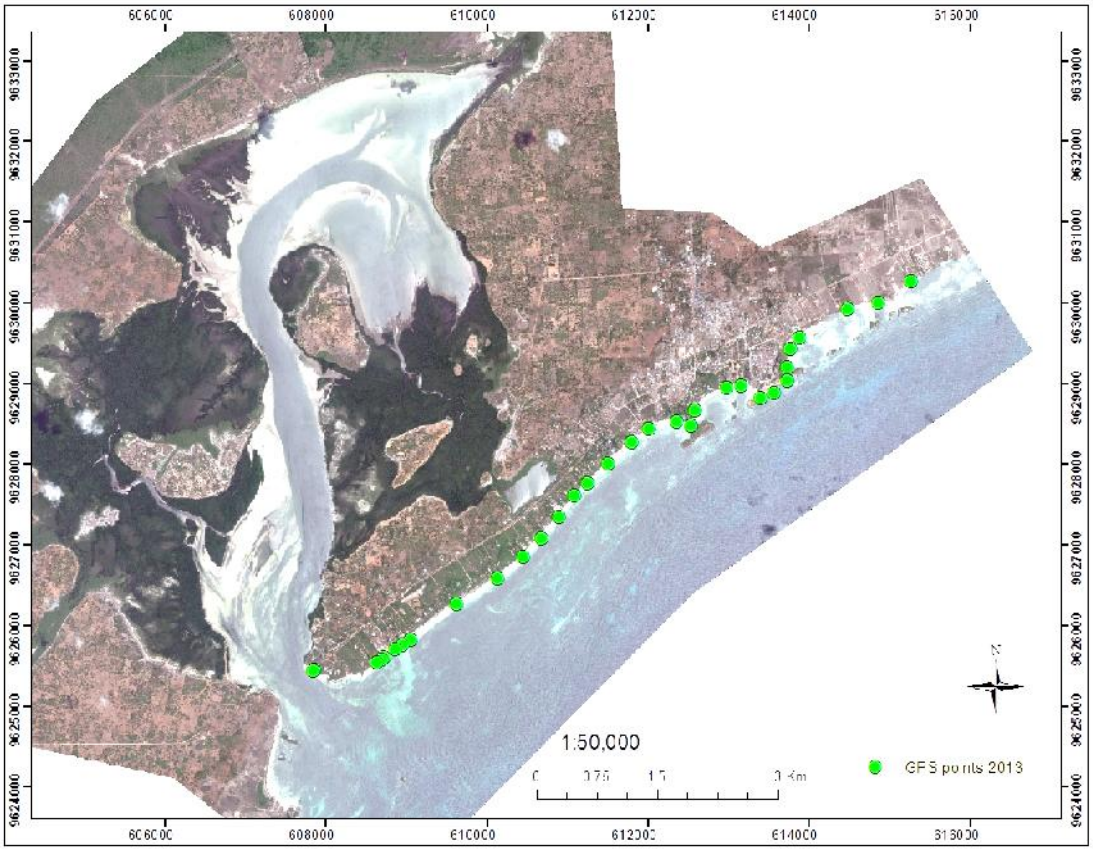


Figure 10: GPS points taken in 2013 following the High Water Mark overlaid on the satellite image of 2010

3.8 Socioeconomic data collection and analysis

In order to better understand the drivers of land use change, shoreline erosion and mangrove dynamics, a socioeconomic assessment was conducted using household questionnaires, Focused Group Discussions and key informants interview. The

information was gathered from local resources users of the study area based on the land use change, shoreline erosion and mangrove change dynamics results which were analysed from the GIS/RS preliminary analysis. The main local resource users in the study area are; fisherman, curio sellers, boat operators, safari sellers, tour guides, diving institutions, beach operators, hoteliers, longtime residents along the beach, NGOs, community conservation groups and, women groups. The villages for the household survey were selected from the Creek mangrove adjacent villages, and those close to the shoreline areas including the islands. The names of the villages in which the survey was conducted were: Watamu, Dabaso, Chafisi, Mida, MidaMajaoni, Kadaina, Jacaranda/Kanaina, Kisiwani, Dongokundo, and Kirepwe.

3.8.1 Sampling size and sampling methods

For the household questionnaires, a stratified random sampling method was used. The household survey included 60 respondents from different resource users groups and villages and included: fisherman, boat operators, tour guides, beach operators, community conservation groups and women groups. A sample of 10% of the household were selected from the total population with Margin Error of +/-5% and 95% of confidence interval (Watson, 2001).The list of households from each of the villages were collected and households were randomly selected from each group. The household questionnaires were at first tested on 20 households selected randomly from other villages. Based on the outcome of the test the questions were corrected and improved. The questionnaires were translated in Kiswahili before the actual household survey. The researcher conducted the survey together with a local person who spoke the two local

language (Kiswahili and Giriama) and English. The research was conducted in each household compound and/or work location i.e. along the beach.

The questionnaire for the household survey consisted of a series of closed and open-ended questions designed to obtain information on: the history ofthe land use type and shoreline erosion, species of mangroves and their uses both past and present, the history of land use in terms of farming activities, the kind of crop/cash crop trees planted and the current status of land and mangroves, extreme environmental events such as rainfall, or tide surges, that may have contributed to the land use and shoreline changes. Moreover to assess the opinion of the respondents the questionnaire included five main socioeconomic drivers of land use change namely: natural, demographic, institutional, political and economic factors.

3.8.2 Focused Group Discussions and key informants

Prior to the household survey and Focused group discussions, a community meeting was held in Dabaso village and 20 community representatives attended the meeting. The purpose of the meeting with the community was to present the preliminary findings of the land use change and mangrove dynamics outputs (maps) and to discuss with the community the objectives of the research. Based on the information, comments and suggestions of the community, key government offices, community based resource user groups and individuals who could assist in the research were identified. At the same time the questions prepared for the Focused Group Discussion were tested. The target group for the Focused Group Discussion were mainly elderly community representatives. Based on the preliminary maps of the specific changes in land use, mangrove dynamics and shoreline changes, key topics (natural factors such as rainfall, tide, population pressure,

economic factor, institutional factor and policy related factors) associated with drivers of changes were discussed with key informants and different stakeholders among the resource users. Five Focused Group Discussions (FGDs) were conducted with representatives of the community including; fishermen, boat operators, tour guides, safari sellers, beach operators, curio sellers, and community forest conservation groups. Eight to ten participants attended the Focused Group Discussions in each session. During the Focus Group Discussion preliminary maps of the land use and cover change and, results of shoreline analysis were provided as props to the groups to assist their discussions. Eleven Key informants interviews were conducted on a one to one basis with the key leading government office representatives from: Kenya Wildlife Service, Kenya Forest Service, National Environment Management Authority, and non-government offices such as; Watamu Marine Association, Local Ocean Trust, and A Rocha Kenya, and hoteliers (Turtle Bay Beach Club which is a leading hotel for environmental best practices and conservation), Garoda Resort and residents along the shoreline. The Key informants interviews questions were pre prepared on areas that needed further clarification and more detailed historic information.

Additional information about the trends of population data were gathered from the Kilifi County office. Biophysical data including; tide, rainfall, and temperature data were gathered from Mombasa KMFRI offices in order to assess the natural causes of shoreline changes over the years. Additional relevant unpublished strategic plan documents from KWS and other offices, prepared by Government of Kenya, were reviewed and used in the write up.

3.8.3 Data analysis

The socioeconomic data were analysed and computed using IBM SPSS version 19 (Statistical package for social sciences) and Excel 2013. The variables from the household questionnaires were selected for summarizing and organizing the data in such a manner to show the main drivers of land use changes, mangrove dynamics and shoreline changes. For these purposes the data were analyzed using; frequencies, descriptive statistics and a multiple regression model within Excel 2013.

The information gathered through Focus Group discussion (FGD) and key informants was summarized and organized into themes to discuss the drivers of land use and shoreline changes. The information gathered through Focused Group Discussions (FGD) and key informants interviews were transcribed, coded and the data organized in inductive categories using *ATLAS.ti* (version 7) qualitative data analysis software and IBM SPSS statistics (version 19).

3.8.4 Model linking land use and cover change with driving forces

In the study of land use and land cover change one can use a combination of approaches depending on the level and scale of the study. In order to understand and assess the biophysical and human causes of land use cover change there are several approaches and models to link land use cover change with the main driving forces. Some of the most common models used are: Driving forces-Land Change, Driving forces-Actor-Land Change, Driving forces/Actor-Land Change, and Actor-Land Change (Hersperger et al., 2010). Some studies integrate social and biophysical variables to represent drivers of land

use change cover (Walsh et al., 1999) while others combined socioeconomic household data and remote sensing data to understand the process of land use change (Roeder and Joachim, 2009 and Fox 2003).The current study used Driving Forces-Land Change model with one dependent variable (the spatial analysis of land use change) and several independent variables (population data, rainfall data and policies) in combination with qualitative data drawn from; a household survey, Focused Group Discussion and Key Informant interviews, to gather historical information related with changes in mangroves, land use and the shoreline. Qualitative data gathered from key informant interviews and at household level can help to better understand and answer some of the information gaps that emerge during classification (National Research Council, 2005). Moreover, the approach used in the study clarified and improved on the land use cover classification of the 1969 and 1989 aerial photo mosaics through the use of GPS points. Data captured at each household were used to garner further information about the household and their use of the land, including identifying remnants vegetation cover, for example identifying old trees as a reference to cross check the earlier classification.

3.8.5 Description of Variables

In many studies of land use and land cover change the main drivers of change are assessed using different factors such as natural factors (rainfall), economic factors (for example agricultural expansion combined with improvement in infrastructure), institutional factors (such as the land tenure system), political factors (for example policies), population and cultural factors and technological factors (for example change in the mechanization of agricultural activities) (Serneels and Lambin, 2001, Tsegaye et al., 2010, Misana et al., 2012 and Belaye et al., 2014). For this study driving factors such as

natural (rainfall), population (demographic), and policy (institutional) variables were incorporated in the analysis as independent variables. The land use change results from the GIS and RS analysis were taken as the dependent variable. The results from 1969-2010 was interpolated in hectares for each year of the analysis. For the independent variable, average rainfall data for each year from 1969-2010 were calculated. For population data the national censuses data for the years 1969, 1999, and 2009 were taken and for each decade year the population data were interpolated for the purpose of the analysis. Policy documents were checked for each year and whenever a policy existed it was coded as =1, and where not available =0, for each year from 1969-2010. To determine the main drivers or factors of land use change, a multiple regression analysis was used (Table 4). Multiple regression analysis can identify how well a set of variables are able to predict a particular outcome (Julie, 2005). Using the model each of the drivers which significantly affect the land use changes were identified.

Table 4 Description of variables used in the multiple regression model

Variable	Description	Type of measurement
Dependent variables		
LUC	Area of land use change	Continuous (the GIS output and interpolated values of each land use change in hectares for each year 1969-2010)
Independent Variable		
RF	Rainfall	Continuous (average rainfall values for each year)
DF	Demographic Factors (population)	Continuous (population data from 1969-2010)
PF	Policies Factors	Dummy (1=present , 0=otherwise)

3.9 Review of existing policy documents

A policy instrument analysis of the existing policy and legal instruments was necessary to see what gaps and opportunities existed for the protection of the coastal environment in the study area. Except for the Coast Development Authority Act 1990, and EMCA 1999, there were no direct Acts, regulations or policy documents which address the issue of coastline resource use and management in Kenya. Most of the regulations regarding coastal areas are scattered in a range of resource and sectoral specific Acts and policy documents. For the purpose of this study; Acts, Regulations and Policies directly or indirectly affecting the use of resources such as the mangrove forest, the shoreline, and land adjacent the mangrove forest, and hinterland were reviewed and included in the literature review.

Key Acts and legislative documents relating to marine and coastal protection were reviewed. These were: Physical planning Act 1998, Draft Physical Planning Bill 2014, Coast Development Authority Act 1990, The Tourism Act 2011, Forest Act 2005, Wildlife Conservation and Management Act 2013, Environmental Management and Coordination Act 1999 (EMCA), Environmental Management and Coordination (Wetlands, River Banks, Lake Shores and Sea Shore Management) Regulation 2009. In order to understand what challenges exist for implementation of these Acts, eleven Key informant interviews were conducted with government office representatives, from: Kilifi County NEMA office, Kilifi County Physical planning office, Mombasa Coast Development Office, Mombasa NEMA, Environmental Impact Assessment office. Representatives of government and non-government offices working in the research area

such as; KWS, KFS, Watamu Marine Association (an umbrella organization of several local communities -WMA), Local Ocean Trust, and A Rocha Kenya were also included as part of the key informant interviews. Five Focused Group Discussions (FGDs) were conducted with representatives of the community. Eight to ten participants attended the Focused Group Discussions in each session. In addition to these FGDs, questions related to existing polices, their implementation and the level of awareness of the related Acts and Regulations within the community were included in a household survey to gather more information. The information gathered through Focused Group Discussion (FGD) and key informant interviews were transcribed, coded and input into *ATLAS.ti* (version 7) qualitative data analysis software and IBM SPSS statistics package (version 19). The qualitative results were presented using; frequencies, descriptive statistics, graphs and tables, and organized along themes within the write up.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Assessment of above ground biomass estimation and mangrove cover changes in Mida creek

4.1.1 Above ground biomass

From the 25 sample plots a total of 934 trees were measured. In addition several saplings and seedlings of mangrove species were recorded. Based on the data gathered on the sample plots, the mangroves forest composed of five main mangrove tree species namely *C.tagal, R.mucronata, B.gymnorrhiza, A.marina, and X.granatum*. Quantitative measurements were not carried out on regeneration, nevertheless, an observation and count in the field showed the dominance of *C.tagal* and *R. mucronata* seedlings and saplings actively growing (Figure 11).

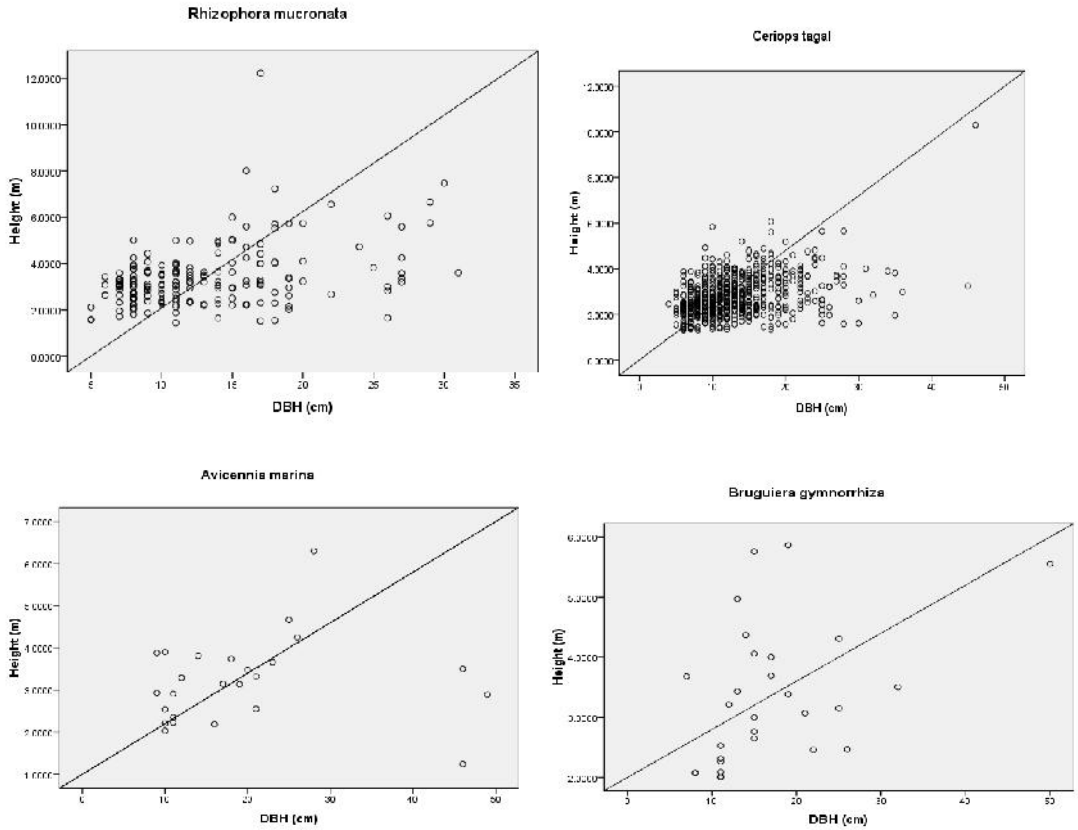


Figure 11: Scatter graph showing height versus dbh

The relative dominance of *C. tagal* and *R. mucronata* was 69.3% and 22.8% respectively Relative dominance by basal showed that *A. marina*, *B. gymnorrhiza*, and *R. mucronata*have the highest DBH with the maximum DBH of 148(cm). Whereas *B. gymnorrhiza* had the tallest tree among the sample mangrove trees with the mean height of 16.6(m) and there were 41 trees with DBH>40 cm.

4.1.2 Above ground biomass and carbon estimation

From the four species of mangroves trees, *C. tagal* and *R. mucronata* had the highest biomass and carbon stock as it is the dominant species by basal and relative abundance in all the sampling plots (Table 5). The results of the biomass depicted that the equation by Chave et al., (2005) gave lower above ground weights compared with Komiyama et al

(2005). The result of above ground biomass for *R. mucronata* using the allometric equation developed by Kiruiet al., (2006) also shows a higher result compare with the two common equations (Table 5).

Table 5: Above Ground Biomass and carbon storage per species in Mida creek mangrove

Mangrove Species	Average above ground biomass (ton ha^{-1})	Average carbon stocks (ton ha^{-1})
C. tagal	26.1	13.1
R. mucronata	27.1	13.5
B. gymnorrhiza	3	1.5
A. marina	2.9	1.4

The above ground biomass estimated using the equation developed by Chave et al., (2005) which includes three variables with the parameter of diameter (DBH), wood density (ρ) and height (H) was less ($R^{2)}$value for all four species compared with the result with Komiyama (2005) and Kirui et al., (2006) (Figure 12,13,14 and 15).Significant correlation was observed using the general equation by Komiyama et al., (2005) DBH and (ρ) as explanatory variables where used (correlation is significant at 0.01 level) (R^2=0.96, R^2=0.93,R^2=0.99 and R^2=0.95) was observed for *A.marina, B.gymnorrhiza, C. tagal* and *R.mucronata* respectively. For this study the local equation developed for *R.mucranata* by Kirui et al., (2006) using DBH estimated the highest above ground biomass(135 t/ ha) . For this study the result showed that above ground biomass was best estimated using (DBH) as a parameter.

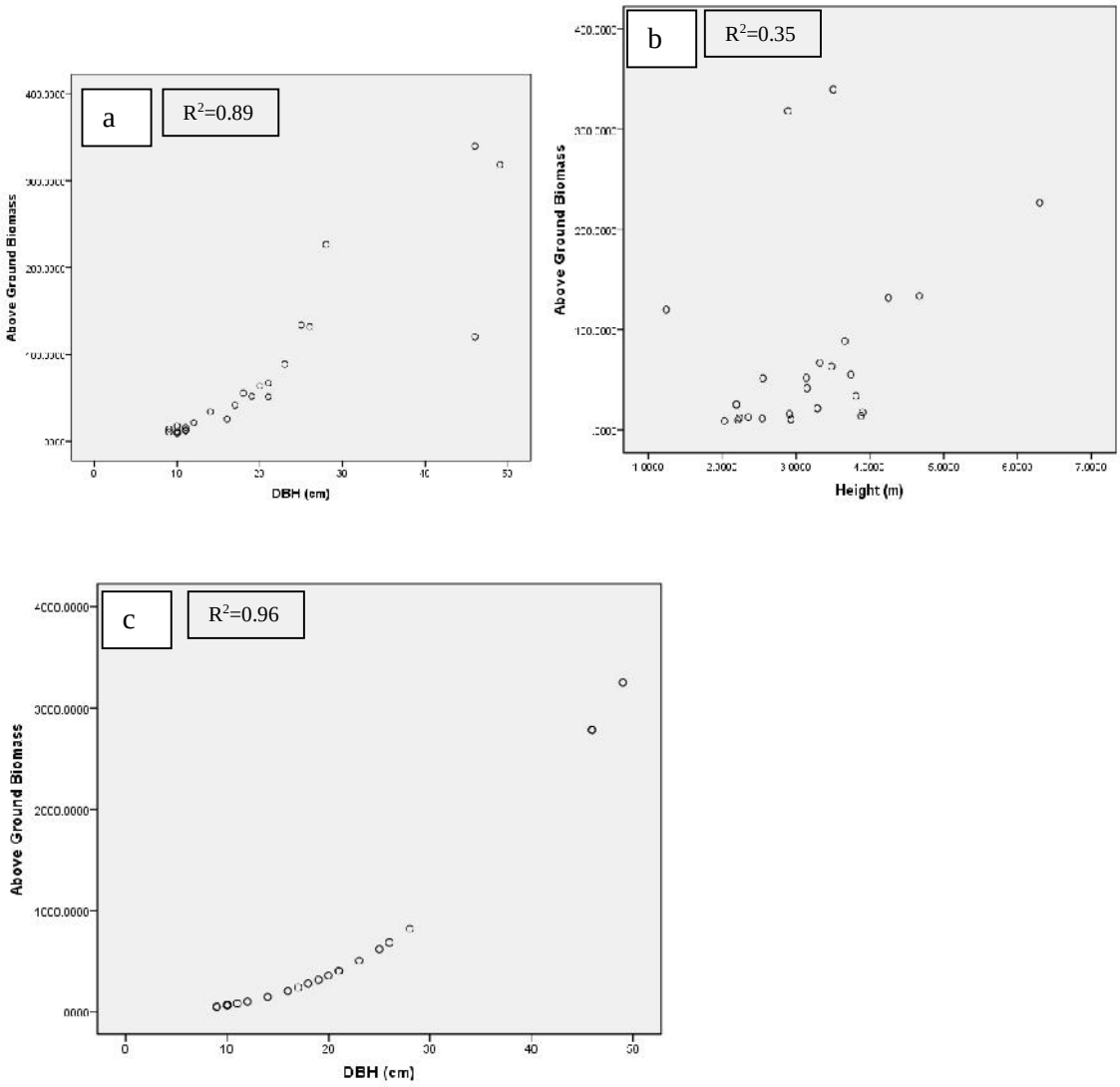


Figure 12: Scatter plots for A. marina showing: (a) the relationship between DBH and above ground biomass estimated using Chave et al., 2005. (b) the relationship between H and above ground biomass estimated using Chave et al., 2005. (C) the relationship between DBH and above ground biomass estimated using Komiyama et al., 2005

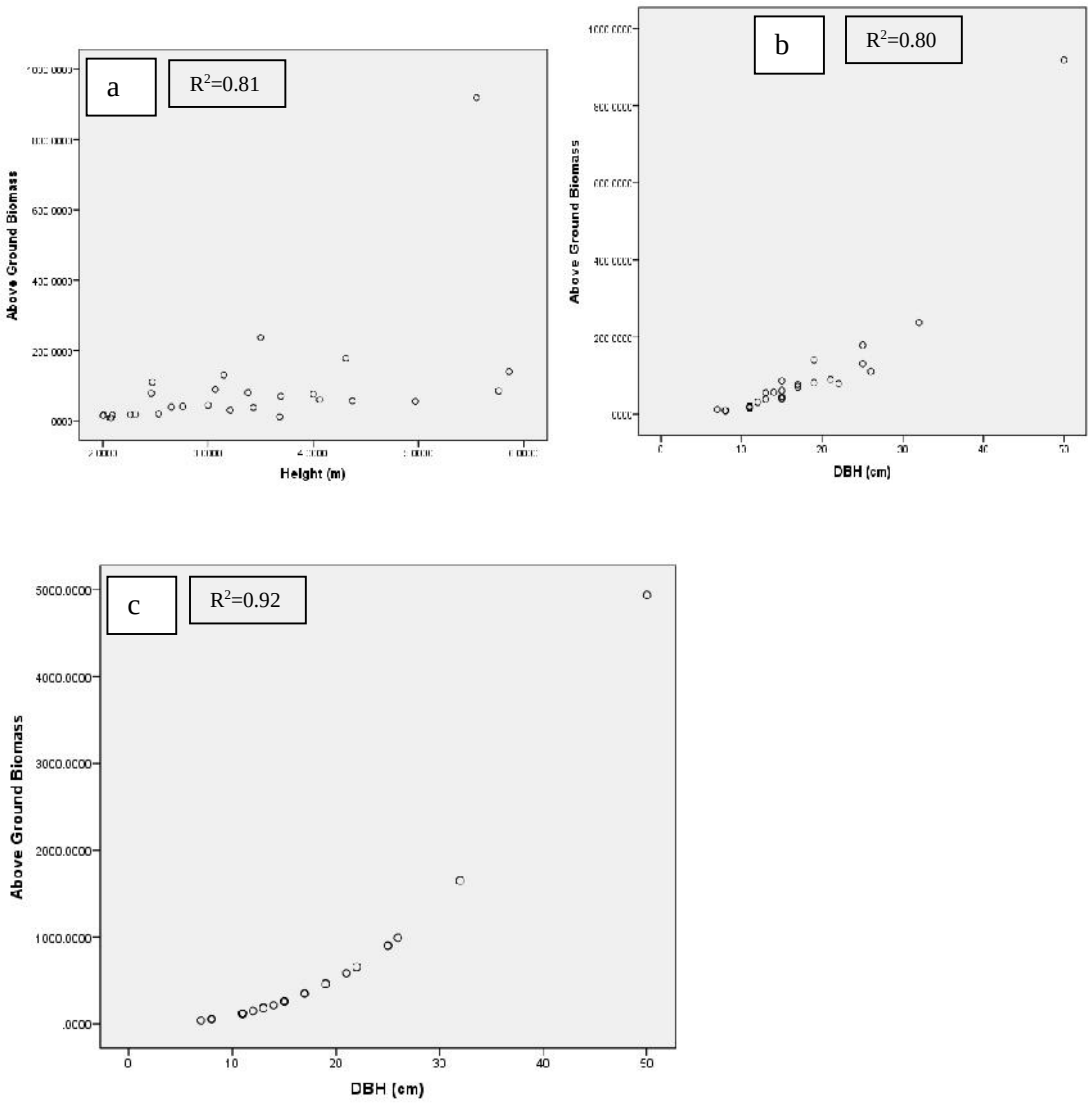


Figure 13: Scatter plots for B.gymnorrhiza showing: (a) the relationship between DBH and above ground biomass estimated using Chave et al., 2005. (b) the relationship between H and above ground biomass estimated using Chave et al., 2005. (C) the relationship between DBH and above ground biomass estimated using Komiyama et al., 2005

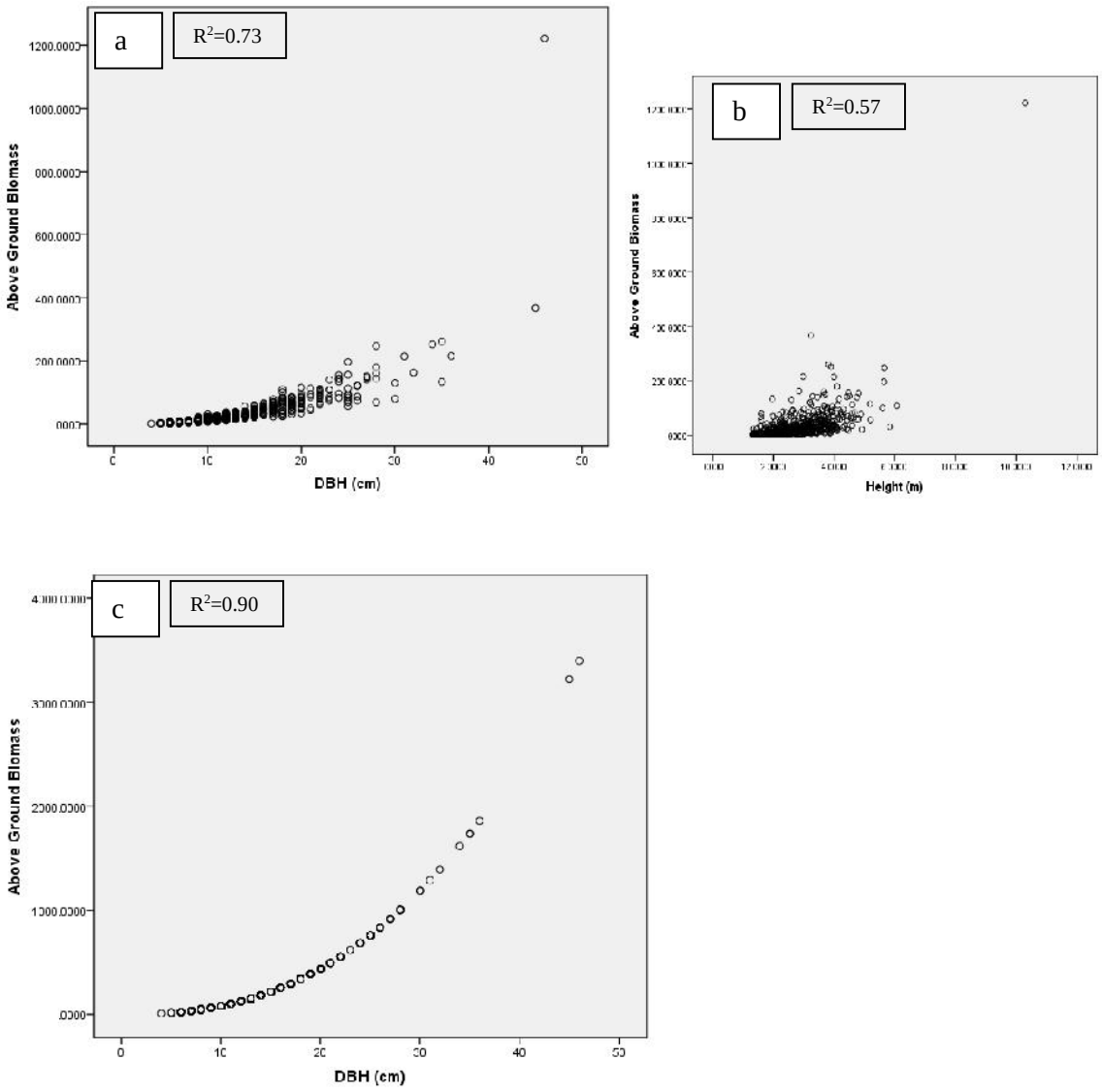


Figure 14: Scatter plots for C.tagal showing: (a) the relationship between DBH and above ground biomass estimated using Chave et al., 2005. (b) the relationship between H and above ground biomass estimated using Chave et al., 2005. (C) the relationship between DBH and above ground biomass estimated using Komiyama et al., 2005

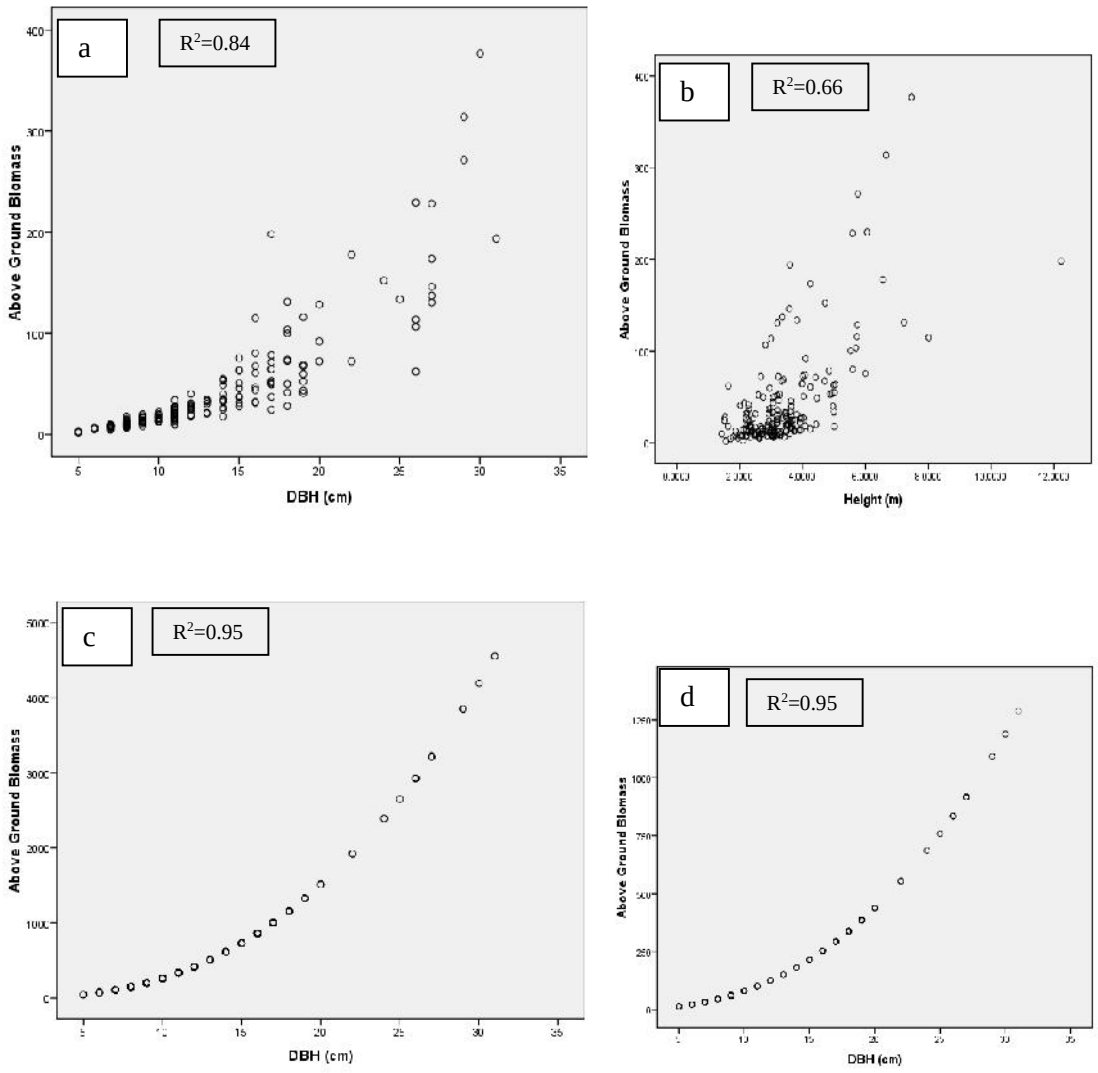


Figure 15: Scatter plots for R.mucronata showing: (a) the relationship between DBH and above ground biomass estimated using Chave et al., 2005. (b) the relationship between H and above ground biomass estimated using Chave et al., 2005. (C) the relationship between DBH and above ground biomass estimated using Komiyama et al., 2005 (d) the relationship between DBH and above ground biomass estimated using Kirui et al, (2006)

4.1.3 Mangroves cover change over the 41 years period

The mangrove cover was found to have declined by (16%) in the last 41 years when comparing the 1969 cover with1989. However the most recent cover record (2010) showed an increment of 165.5 ha when compared with the 1989 cover. Hence the highest

cover loss was observed between 1969 and 1989, which was -337.8 ha (Table 6) and (Figure 16, Figure 17 a, b, c).

Table 6: Mangrove cover change over the years

	Time series		
Area per ha	1969	1989	2010
Total mangrove cover	2072.2	1698.4	1863.9
Cover loss	-	-337.8	-208.3
Change against 1969 (%)	-	-16.3	-10.1

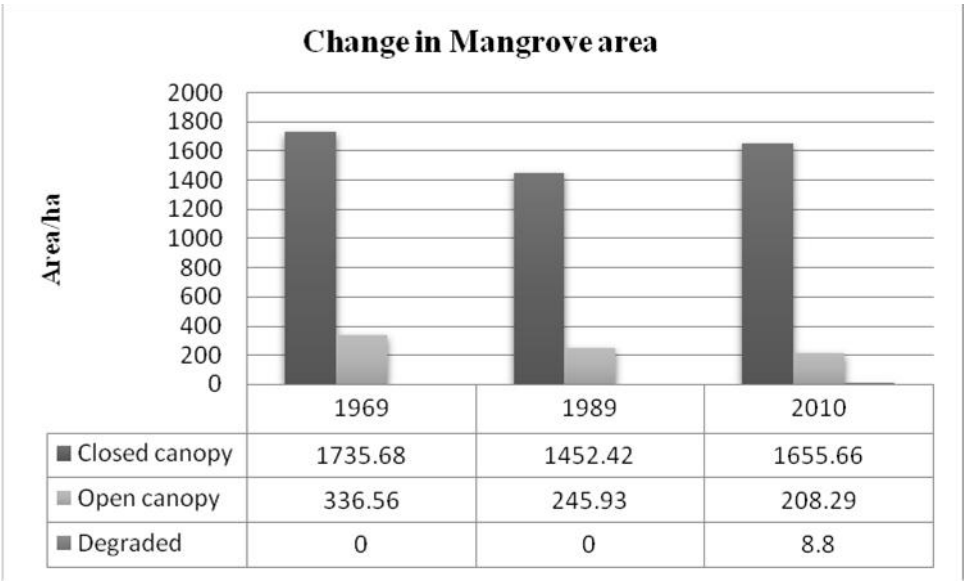
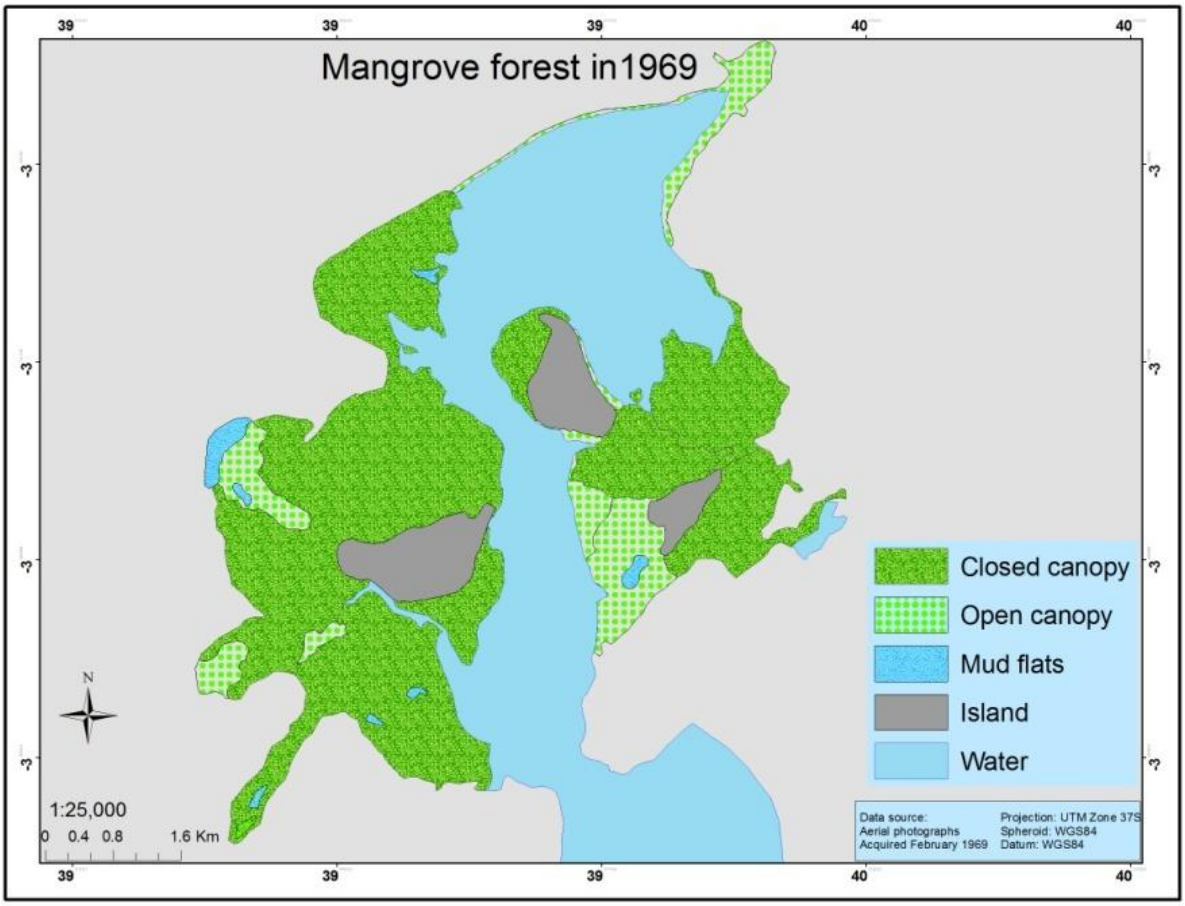
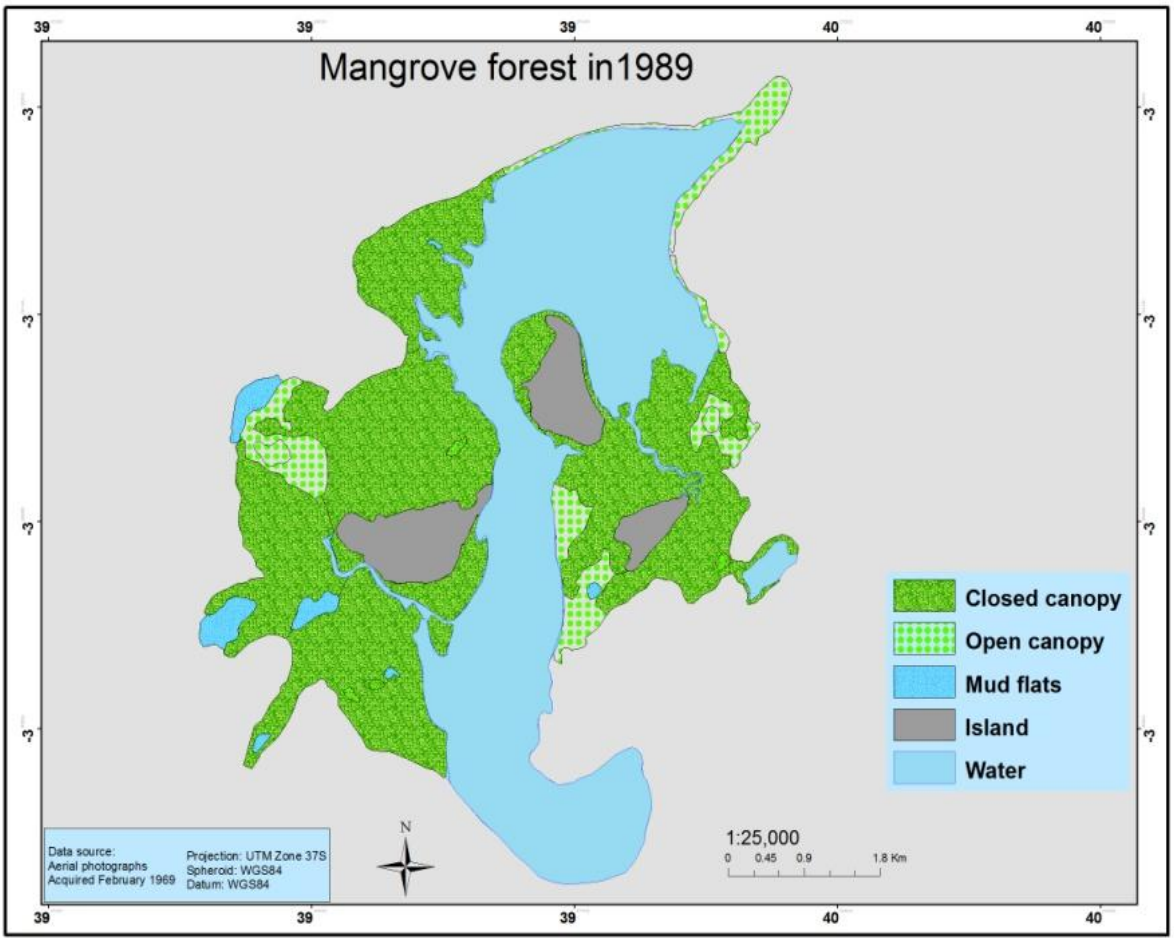


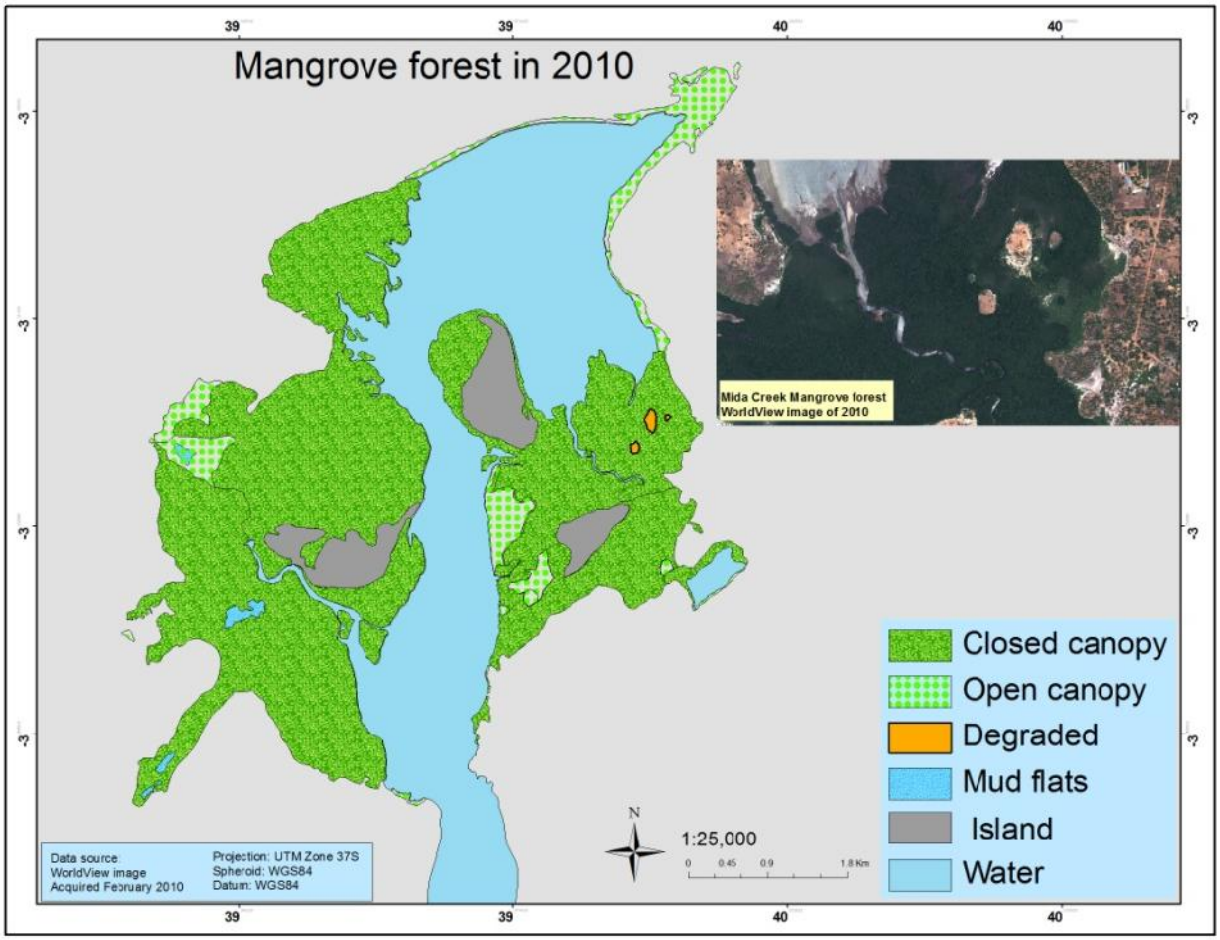
Figure 16: Change in Mangrove area between 1969, 1989, 2010


Mangrove forest in1969
39
40
-3
N
1:25,000
0 0.4 0.8 1.6 Km
Closed canopy
Open canopy
Mud flats
Island
Water
Data source:
Aerial photographs
Acquired February 1969
Projection: UTM Zone 37S
Spheroid: WGS84
Datum: WGS84

(17, a)


Mangrove forest in1989
39
40
-3
Closed canopy
Open canopy
Mud flats
Island
Water
N
1:25,000
0 0.45 0.9 1.8 Km
Data source:
Aerial photographs
Acquired February 1969
Projection: UTM Zone 37S
Spheroid: WGS84
Datum: WGS84

(17, b)



(17, c)

Figure 17: Mangrove cover map of 1969, 1989, and 2010

The above ground biomass estimated for each year was based on the total area of mangrove cover (obtained from aerial photographs and satellite image analysis) multiplied by the total biomass estimate for 2013. This gave the following above ground biomass results; 613,661.3 ton (1969), 502,964.2 ton (1989) and 551,975.3ton (2010) (Figure 18). The change in the biomass between 1969 and 1989 was 110697.1ton while the change in biomass between 1969 and 2010 was 61686 ton.

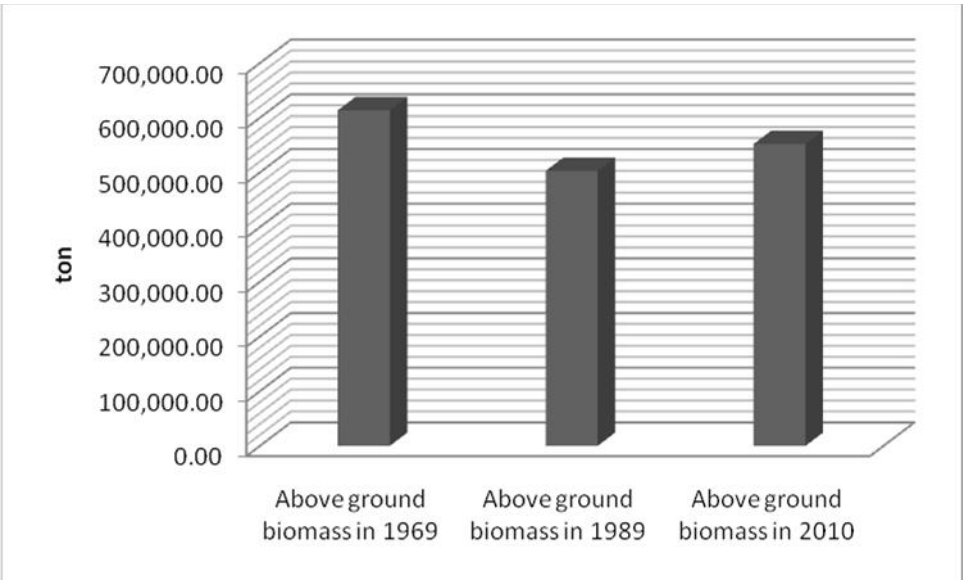


Figure 18: Estimated above ground biomass from 1969-2010

4.1.4 Mangrove cover change trends

In 1969, Mida Creek mangrove forest covered 2072.2 ha. This cover declined by 16% during the 20 years period of 1969-1989. The decline in the mangrove forest cover could be due to expansion of the settlement around the mangrove forest which increased the use of mangrove poles as a source of building materials. The mangrove forest in Mida Creek is surrounded by 11 villages. Abuodha and Kairo, (2001) indicated a high dependence on mangroves by coastal populations for firewood, charcoal, poles for boats and housing. The land use activities in and around the Creek have also influenced the mangrove forest (Gang and Agatsiva, 1992). A study by Kairo et al. (2002) showed the contribution of the anthropogenic influence for the decline in mangrove forest for the last three decades in Mida Creek. Another possible reason for the decline of the mangroves could be the export of building poles and charcoal produced from mangroves in the past. During data collection household questionnaires were conducted in the Mida Creek area (Oct-Nov,

2013) for another study to identify the historical land use change in the area. During this survey many respondents mentioned mangrove harvesting for export in the past by those who had licenses to harvest mangroves mainly as a sources of building materials. This was confirmed by Dahdouh et al. (2000) reported that the decline in the mangroves of Kenya were mainly due to mangrove harvest for export to Middle East countries. According to a study by Hirsch and Mauser, (1992), in the period of 1966-1970 an amount of 45,677scores (1score= 20poles) of mangroves were exported from Kenya to the Middle East. According to a report by Ravilious and Green (2003), mangrove forest has declined to the point that export-quality poles are no longer found in many coastal areas of Kenya.

The decline in cover loss reduced in the period of 1989-2010 could partly be a result of the ban on export of mangroves in 1982 (Hirsch and Mauser, 1992). According to a study by Kirui et al., (2013), in the period between 2000 and 2010 mangroves along Kenyan coastal areas observed the lowest rate of loss due again to a presidential ban on the harvesting of mangroves for the domestic market. In the present study the result of 2010 mangrove cover has improved compared with the 1989 however another cover type appeared which showed the level of degradation in the mangrove forest (Figure 19).Kairo et al., (2002) study confirmed the high magnitude of human disturbance of the mangrove forest at Mida Creek. Dahdouh et al., (2000) stated the primary reason for observed change in the forest was due to decline in overall number of trees. The other possible pressure for mangrove forest in Mida Creek could be the growing number of hotels, cottages and private holiday houses. This has been observed on the field that some new

residential private houses are in close proximity to the mangroves forest, some cleared the forest to get a better view of the sea. In 1992 there were 7 big Hotels in Watamu Mida Creek area (Hirsch and Mauser, 1992).Currently there are 23 hotels and over 18 different lodges and guest houses and several private residence or holiday houses (COAST project, 2013). The image of 2010 revealed a complete clearance of some areas within the forest which confirmed during the Oct-Nov, 2013 field work. This new degraded area covered 8.8 ha of land.

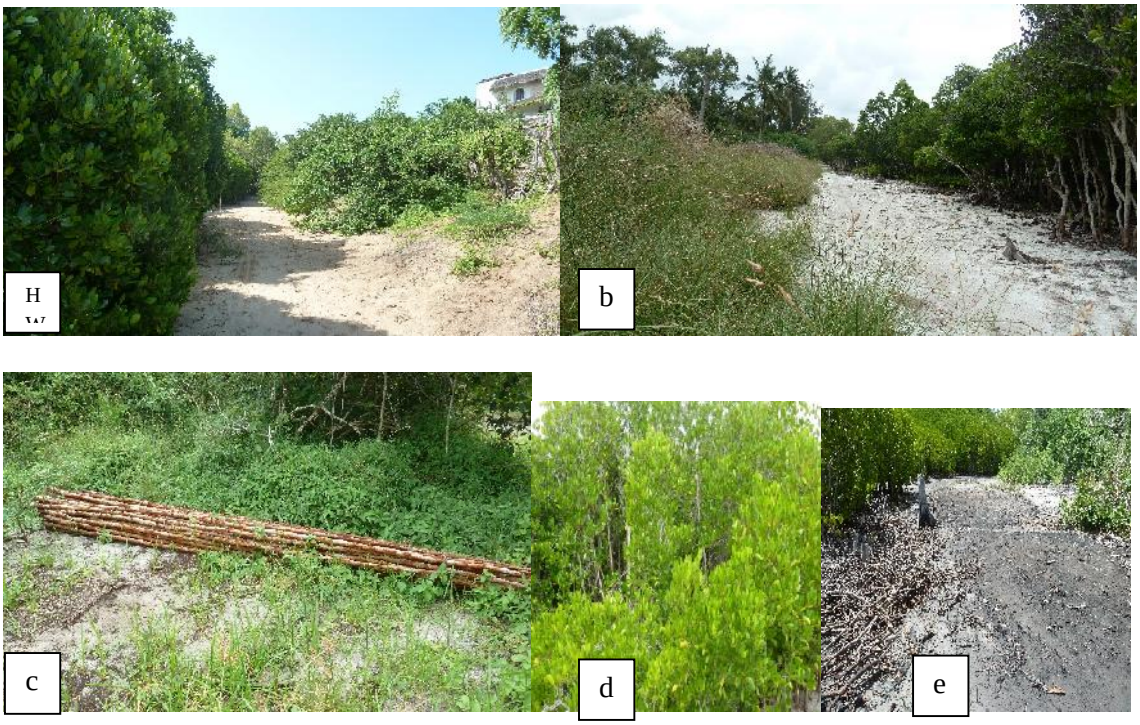


Figure 19: Mangroves under pressure: a) Residential settlements are occurring nearer to the mangrove forest over time; b) local settlement areas are often directly adjacent to the mangrove forest; c) mangrove poles ready for collection and transport to market; and d) relatively undisturbed mangrove stand e) an example of a degraded mangrove area.

This study found out the overall trends of the mangrove cover for the last 41 years, and in general the current mangrove cover had improved since 1989 as compared with 2010 (1452.5 ha to1655.7 ha).On the other hand, it was observed that there was selective cutting of mangrove poles mainly; *C.tagal, B.gymnorrhiza*and *R.mucronata*. These species are targeted mainly for house construction as the poles are long and straight (Dahdouh et al., 2000). Gang and Agatsiva (1992) also observed the high intensity of cutting of *C.tagal* and *X.granatum* for poles.

4.1.5 Above ground biomass estimation

Very few studies are available on the estimation for above ground biomass in a natural mangrove forest in Kenya. Hence, it was not easy to compare findings of the present study above ground biomass for *C.tagal, A.marina*, and *B. gymnorrhiza* species with other studies at local level. Many of previous studies in Kenya have focused on replanted mangrove forests (e.g. Langat (2006), plantation of *B.gymnorrhiza*, Kairo et al (2008)plantation of *R.mucronata,* Tamooh et al, (2009)plantation of *R.mucronata,* Kairo et al, (2009)plantation of *R.mucronata, A.marina*, *C.tagal, S.alba*). However, the use of different equations can also yield variation in biomass estimation (Kauffman and Donato, 2012). For instance, two above ground biomass estimation studies for *R. mucronata* species at Gazi Bay, Kenya, in a primary forest came out with a different result 515t/ha (Slim et al, 1996) and, 452.02t/ha (Kirui et al., 2009). The differences in these results could be because of; varying sample size, variation in wood density, ecology, plant age, and the type of forest i.e. primary or planted (Cohen et al., 2013, Kairo et al., 2009, Kirui et al., 2006, Tamooh et al., 2009 and Komiyama et al., 2008). Comparison of above

ground biomass estimation from Kenya and South East Asia with the current study is presented in (Table 7).

Table 7: Comparison of different above ground biomass for the four mangrove species in this study with other studies

Study	Region	Species	Height range (m)	Stem diameter (cm)	Above ground biomass	No oftrees N=
Komiyama (1999)	South East Asia	C. tagal(secondary)	-	-	92.24t/ha	77
Slim et al (1996)	Kenya	C. tagal (Natural)	3.0	-	40.1t/ha	-
Kirui (2006)	Kipini Kenya	R.mucronata (Natural)	2.8-16.1	2.3-23.6	0.6-383.7 (kg Dw)	15
Kirui (2006)	Kipini Kenya	A.marina (Natural)	3.9-11.7	2.5-15.8	4.6-71.4 (kg Dw)	28
Kirui (2006)	Gazi Bay Kenya	A.marina (Natural)	2.1-11.3	3.7-21.8	7.2-127.3 (kg Dw)	51
Gang and Agatsiva (1992)	Kenya Mida Creek	R.mucronata C. tagal B.gymnorrhiza X.granatum			11,832kg/ha 24,178kg/ha 1029kg/ha 514kg/ha	23 47 2 1
Cohen et al (2013)	Kenya Mida Creek	All tree species (Natural)	1.5-17.7	2.5-58	0.116(Mega tonn)	14
This study	Mida Creek (Natural)	C. tagal B.gymnorrhiza R.mucronata A.marina	1.3-10.3 2.0 -5.8 1.5-12.2 1.3-4.6	5-46 7-49 5-31 9-49	130t/ha 15.1t/ha 135t/ha 14.5t/ha	640 30 193 26

Kg DW= above ground biomass is given in Kg dry weight. The above ground biomass comparison results for Kirui (2006), was taken from Cohen et al (2013).

In a similar biomass estimation study in Kenya, Kirui et al., (2006), found out that the use of diameter as the independent variable can best estimate the biomass of *R. mucronata*. The above ground biomass estimated by Kirui et al., (2006) for *R. mucronata* at Gazi Bay was 452.02 t/ha which was much higher than in the present study for the same species(135t/ha) using the same equation. Both Komiyama et al., (2005) and Chave et al., (2005) general equation obtained lower above ground estimation of *R.mucronata* (i.e. 39.5 and 8.3t/ha) respectively.

Most studies have only had small sample sizes compared with the current study. This could explain the variation in results in addition to other factors which have been mentioned above. There was a limitation in finding the appropriate equation for this study as there is no local allometric equation developed using evidence at local level. In most biomass estimation studies, researchers develop an equation using destructive methods and compare the result with existing general equations. In the current study the main objective was to estimate the mangrove cover change for the last four decades and biomass estimation was based on a non-destructive method.

In regard to species domination, the results in this study agreed with a previous study by Gang and Agatsiva (1992). In their study of the status of mangroves in Mida Creek, they found high dominance of *C. tagal* and *R. mucronata* and higher seedling growth in these two species. The present study also found the same dominance of these two species both at seedling and sapling stages. Another study in Mida Creek by Kairo et al., (2002) also confirmed the dominance of *R. mucronata* and *C.tagal*, and a high tendency towards the dominance of *C. tagal*. According to a study by Kairo et al., (2002), the reason for the

dominance of these two species and the high number of seedlings and saplings in the Mida Creek mangroves was as the result of a stronger anthropogenic pressure which may have resulted in C. tagal becoming more dominant. In addition, other studies revealed that the composition of the regenerated species depends on the species mix of the neighboring population (Kairo et al., 2001), the stability of the soil to hold the seeds and young trees, and the germination percentage of seeds and propagules (Hirsch and Mauser, 1992).

4.2 Assessment of shoreline change in the period 1969-2010 in Watamu area

4.2.1 Shoreline changes

The Watamu shoreline that covers 9.8 km was digitized from 1969 and 1989 aerial photographs and 2010 satellite image (Figure 20). A total of 245 transects were generated with 40 m spacing and an average change rate calculated from 1969 to 2010.

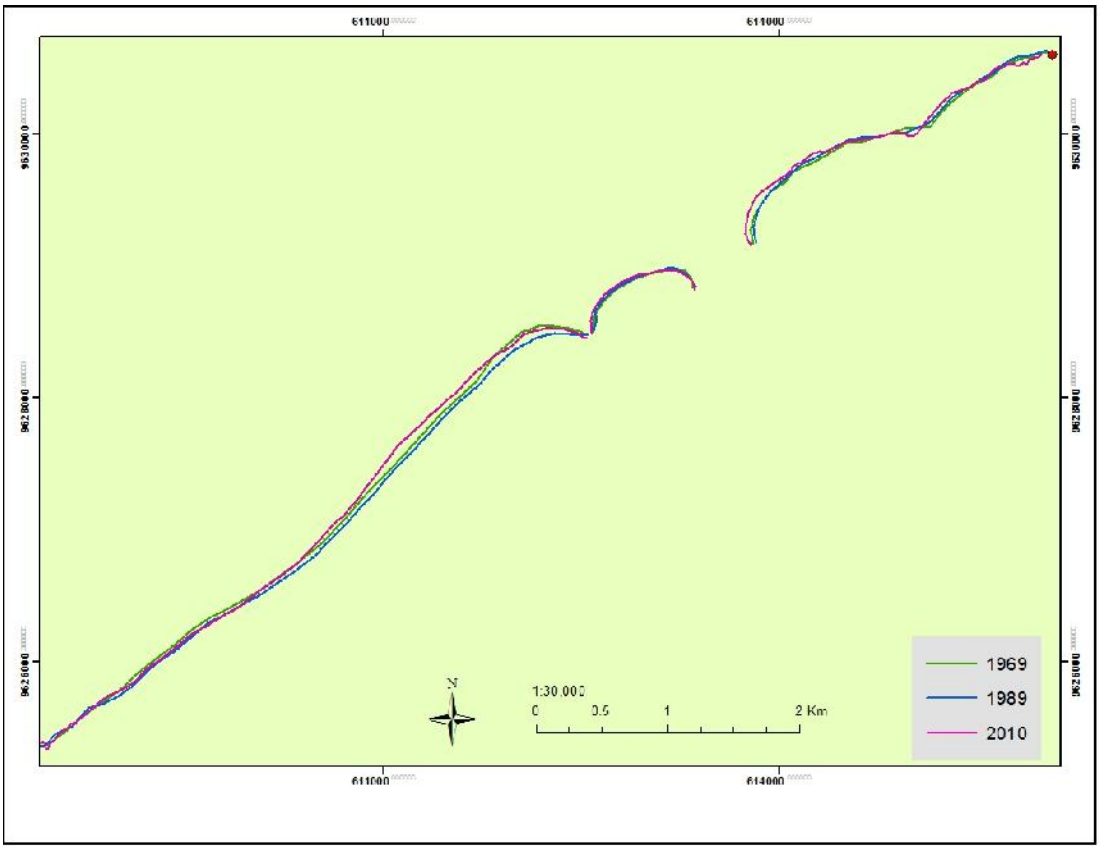


Figure 20: Extracted shorelines

The shoreline analysis for the period 1969-2010 revealed that most of the beachfront underwent erosion with accretion observed in small patches. The WLR shoreline analysis for the beachfront showed a mean of -0.89 m/year where 69.7% of transects fall under erosion and 30.2% accretion (Table 8). This analysis gives emphasis on data points for which the position uncertainty was smaller. The EPR and NSM analysis revealed mean shoreline change of -0.7m/year and -30.3m/period respectively from1969 to 2010 (Table 8). The mean shoreline movement from 1969 to 2010 was -30.3m/year with a standard deviation of 19.4. Both EPR and NSM results showed 158 transects or 64.4% experienced erosion, and 87 transects or 35.5% with accretion (Figure 21 and 22).

Table 8: Overall shoreline change rates from 1969 to 2010

Shoreline Statistics	Shoreline change (m/year and m/period)	
	Erosion	Accretion
End point rate (EPR) (m/year)	-0.74	0.47
Weighted linear regression (WLR) (m/year)	-0.89	0.41
Net shoreline movement (NSM) (m/period)	-30.3	19.5

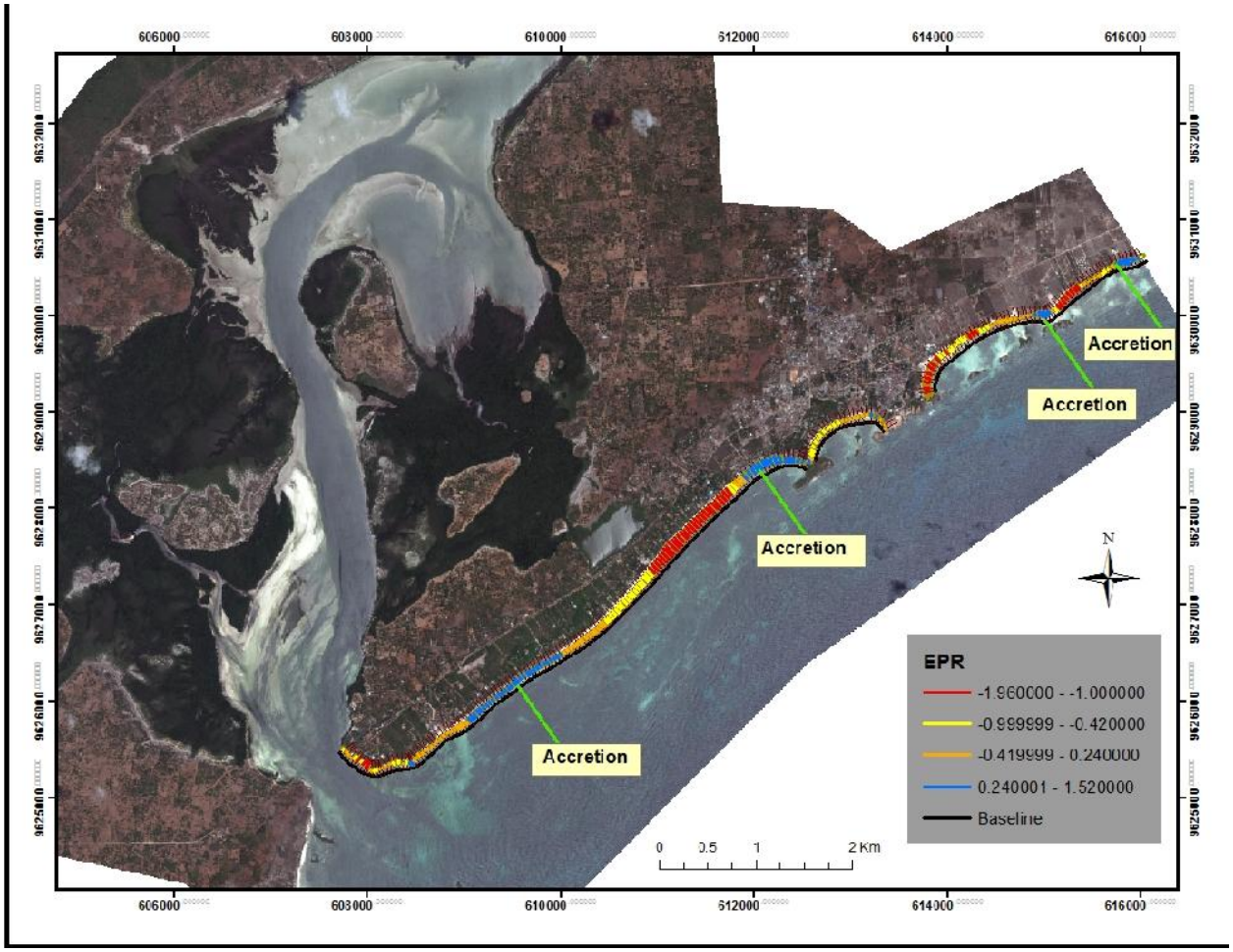
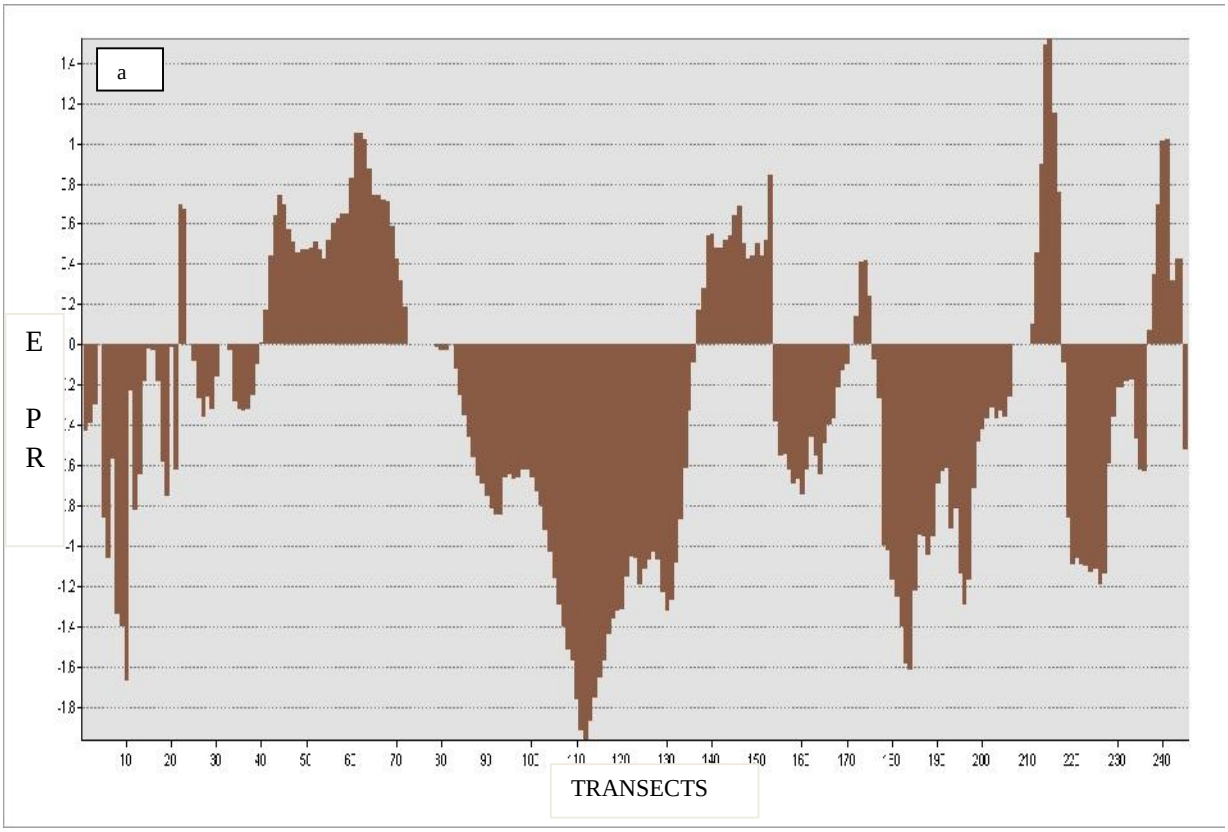


Figure 21: Rate of shoreline change (EPR m/year) along the shore from 1969-2010(all negative signs shows erosion)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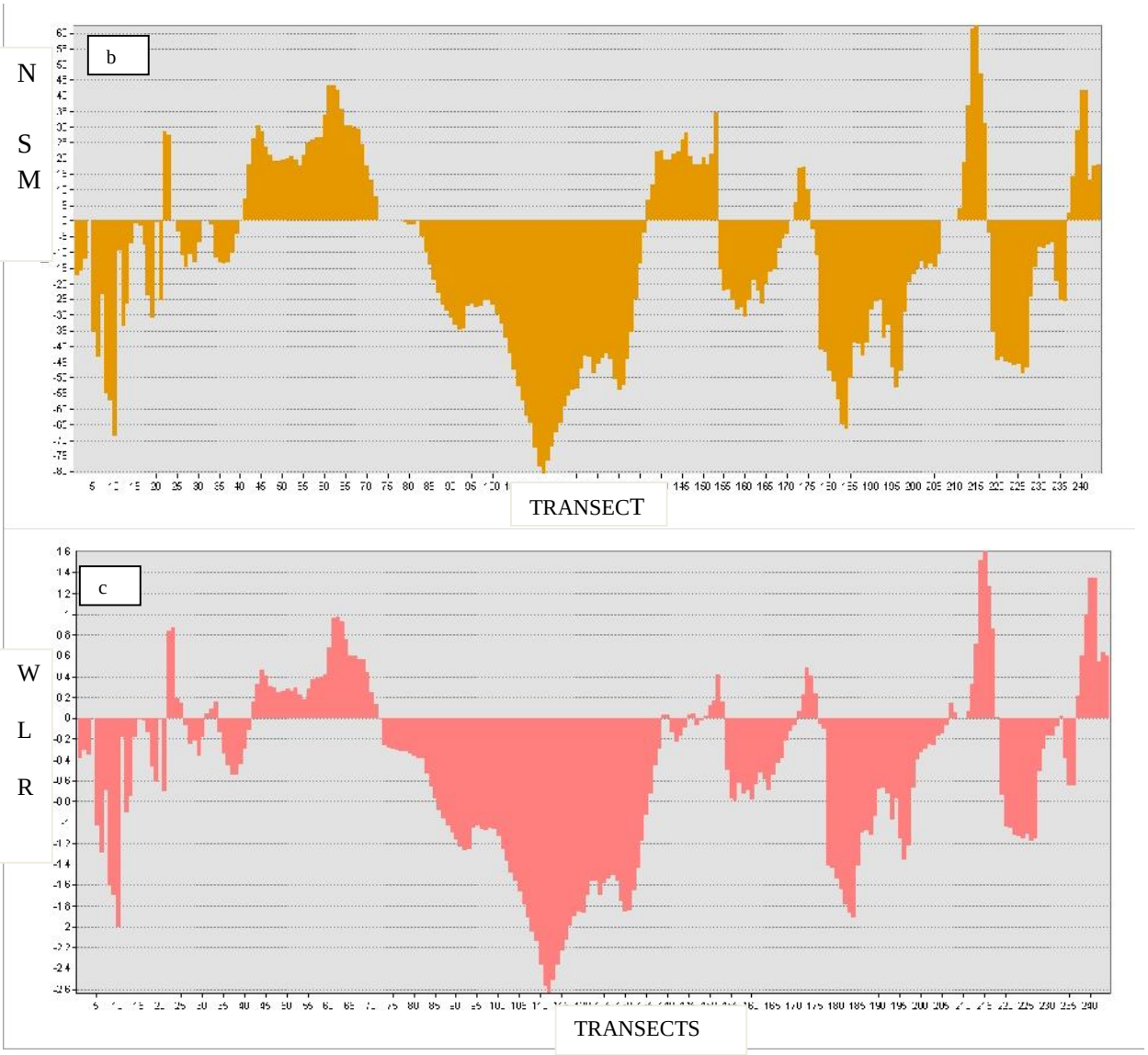

Figure 22: Graphs of the shoreline changes 1969-2010, (a) End Point Rate (EPR), (b) Net Shoreline Movement (NSM) (c) Weighted Linear Regression (WLR). The EPR and WLR units are in m/year, while NSM is m/period. Most of the graph is in the negative area (i.e. below the line) which indicates shoreline erosion.

4.2.2 Shoreline change trends

The result from the three shoreline analyses (EPR, WLR, and NSM) showed that the shoreline had retreated (in general) along the Watamu beach over the last 41 years

(Figure 23 and Table 9). The shoreline was divided into sections comprising 50 transects each. Section S1 and S2 at the beginning of the Mida Creek entrance show a mean change of -0.25 and -2.1 m/year respectively (Figure 23 and Table 9). This result agreed with the EPR shoreline change analysis rates except that some of the area under EPR showed some accretions. Major erosion (retreat) was observed in S3 with the WLR mean of -1.32. The EPR analysis and the information gathered during ground truthing has shown similar shoreline erosion in this section. Section S4 and S5 also showed shoreline erosion though the rate of change was not as high as S4 (Figure 23 and Table 9). According to Thieler et al, (2009), the R^2 statistic has a dimensional index that ranges from 1.0 to 0.0, the smaller the variability of the residual values around the regression line, the better the prediction. Hence the R^2 for the current study indicated values less than 1 which was a good prediction.

Table 9: Weighted Linear Regression (WLR) from 1969 to 2010

Section number	Transect number	Mean	WR2 (R^2)	St. Deviation
S1	1-49	-0.25	0.5	0.57
S2	50-100	-0.21	0.4	0.69
S3	101-149	-1.32	0.5	0.82
S4	150-200	-0.65	0.8	0.61
S5	201-245	-0.01	0.6	0.77

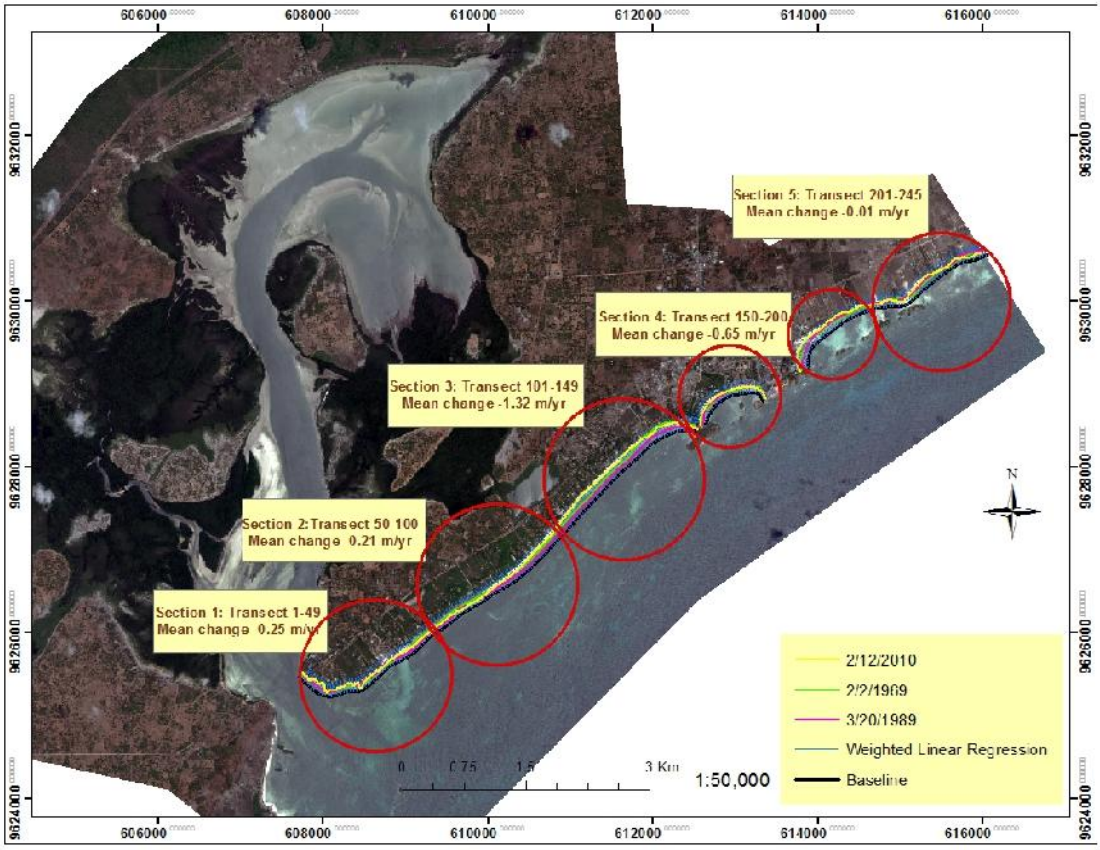

Figure 23: WLR mean Shoreline change rates by sections (transects) from 1969-2010 (presentation adopted from Chaaban et al., 2012)

4.2.3 Shoreline change rates

Numerous studies have used the ArcGIS extension DSAS to calculate long term shoreline erosion change rates (Borrelli 2009, Hapke et al.,2010, Appeaning et al., 2011, Fletcher et al., 2012). In Kenya there was a research in Bamburi, Mombasa, using an alternative methodology based on beach width measurements and a hydrodynamic parameters which showed the exposure of the shoreline to erosion (Mwakumanya et al., 2009). The outcome of this study was similar with that of Fletcher et al., 2012. Based on Fletcher et al's., (2012) study on historical shoreline change in the Hawaiian Islands (1928-2006),

long-term rates from all transects on the three islands are -0.11 ± 0.01 m/yr and 70% of transects indicate a trend of erosion. Another study in Keta, Ghana, using the same methodology came up with an erosion rate change ranging from 0.1 to 15.4 m/yr and accretion rates ranging from 0.1 to 21m/yr from a period of 25 years (Appeaning et al., 2011). However in each of these studies results from the analyses can differ depending on both the natural and human factors that cause variation in shoreline changes in each context.

4.2.4 Main driving factors of shoreline change

Assessment of shoreline change rates showed a trend of shoreline erosion along Watamu coastline. Most of the beach underwent erosion while some part of the beach accreted during the study period. The observed patterns of erosion and accretion along the Watamu shoreline resulted from both natural and human impacts. Most of the shoreline was exposed to natural shoreline phenomena such as waves, tides and periodic storm surges. It was noted that during the southeast monsoon (from May to September) the shoreline showed signs of greater erosion, which was evidenced from uprooted trees and severely affected hotel and private property beachfronts (Figure 24 and 25).The shoreline from Section 1 to Section 3 (S1-S3), was exposed during the southeast monsoon where the waves exert a strong alongshore influence on the beach causing movement of shoreline materials from one location to another. These findings confirm, a wider trend along the Kenyan coast, concerning the southeast monsoon as reported (Government of Kenya, 2010 (a)).

Another natural factor which attributed to shoreline erosion in the study area was the fine sandy nature of the beach material which make it easily susceptible to erosion during periodic surges (Figure 25). Watamu beach has a fringing reef coast consisting of sandy beaches and reef limestone (Government of Kenya, 2010(b)).Coastal areas which are dominated by unconsolidated sediments are more susceptible to coastal erosion (IOC-UNEP- WMO-SAREC, 1994).

Source: Field study 2013-2014

Figure 24: Indicators of shoreline erosion in the study area. Pictures taken in; 2012, 2013 and 2014.

Source: Field study 2013-2014

Figure 25: Watamu beach front along the Long beach where the beach is covered by natural riparian vegetation and few tree species including Cocos nucifera, Casuarina equisetifolia and Pomoea pes-caprae, (photo taken during southeast monsoon period)

Human impacts such as; areas where the riparian vegetation was cleared to expand the recreational beachfront and to get a better view of the sea, construction of sea walls to control shoreline erosion, and building developments near the HWM are all considered to be major contributors to shoreline erosion (Figure 26). Along the beach several tourist hotels and expensive residential/holiday houses were observed, with some of these being built just a few meters away from the High Water Mark (HWM) making them susceptible to flooding during spring tides (Figure 26). Studies conducted by IOC-UNEP-WMO-SAREC, (1994), indicated that; Diani, Shelly beach, Nyali, Bamburi, Kikambala, Watamu and Malindi coastal tourist centers are located on level (I) that is 0-5 meter above sea level and level (II) 5-10 meter above sea level.

Source: Field study 2013-2014

Figure 26: some of expensive investments near the HWM

The Survey Act (Cap 299) of Kenya, provides a set-back of not less than 60 meters above HWM (Government of Kenya, 2010(a)). However the reality on the ground proved that this set-back was not applied to some of the tourist hotels and houses (Figure 27). As reported in the shoreline change rate analysis Section 3 (S3) demonstrated marked erosion, this result agrees with other similar shoreline studies. For example a study in the Caribbean revealed that the shoreline has been significantly altered by human action such as coastal infrastructure (Restrepo et al., 2012). Another study in Ghana confirmed the impact of increased population along the coast followed by rapid urban development have been the main driving force for coastal erosion (Appeaning et al., 2011). A study of Bamburi beach, Kenya, also confirmed the anthropogenic activities such as recreational activities resulting in a trampling effect of the beach sediment aggravates shoreline erosion as the sediment gets loosened and carried away by the stronger waves (Mwakumanya et al., 2009).

Source: Field study 2013-2014 and (e) Taken from Watamu Marine Association office

Figure 27: (a) Construction near HWM, (b) Impact of recreational activities along the beach, (c, d) construction of sea walls ,(e) (2007) ,(f) (2014) clearing of riparian vegetation and natural dune

It was observed during field verification the construction of sea walls to combat shoreline erosion had caused major shoreline erosion and property damage in adjacent plots on the beachfront (Figure 28). Other studies have also confirmed the impacts of such sea walls, for example a study in Diani, Bamburi and Kikambala, revealed beach erosion and rapid

degradation of the beach resources as the result of sea walls (IOC-UNEP- WMO-SAREC, 1994). A study by Kairu and Nyandwi (2000) reported the impact of sea walls as the cause for the increase in reflected wave energy leading to the erosion and flattening of adjoining beach areas. A study in America by Hapke et al., (2010) indicated that the emplacement of shoreline protection structures such as; seawalls, bulkheads, and barrages can result in erosion of the beach.

Source: Field study 2013-2014

Figure 28: Adjacent properties affected by erosion displaced by sea walls and other fortifications.

Information gathered during Focused group discussions with community representatives and longtime residents (through key informant interviews) confirmed how different

human induced activities and developments along the beachfront had caused shoreline erosion as well as destruction of turtle nesting grounds. Respondents also mentioned that the night lights from some tourist hotels have disorientated newly hatched sea turtles, leading to lower survival rates. Watamu beach is a high priority turtle nesting area (Figure 29), and according to a report by the UNIDO COAST project (2014), five species of sea turtles can be found in the study site.

Source: Field study 2013-2014

Figure 29: (a) Turtle nesting areas marked by Kenyan Wildlife Services (b) turtle nesting site on a private beach plot (c, d) A good example of beach bank rehabilitation in Watamu

4.3 Land use and cover change in Watamu Mida creek area

4.3.1 Land use and cover change from 1969-2010

The land use and cover types in the study area were categorized into six main classes' namely coastal vegetation (bush, scrub, and thickets), mangrove and coastal forest, farmland with settlements, residential houses, and sea water bodies, (sandy beach, tide flats and mudflats). The mangrove forest is a source of livelihood and ecotourism activities for the surrounding communities while, the beach, and forest, serves as a main touristic recreational area. There are two boardwalk within the mangrove forest run by the community as part of ecotourism activities which support the locals. For the year 1969, 13 land use types were classified while, for 1989 15 were classified, and in 2010, 19 land uses were identified. The total area of land use mapped for 1969, 1989 and 2010 was 11,207.9 ha, 11,181.3 ha, and 11,235.7 ha respectively (Figures 30, 31, and 32). The slight variations on the total area of the study was due to variability and coverage of the aerial photographs and satellite image for each year.

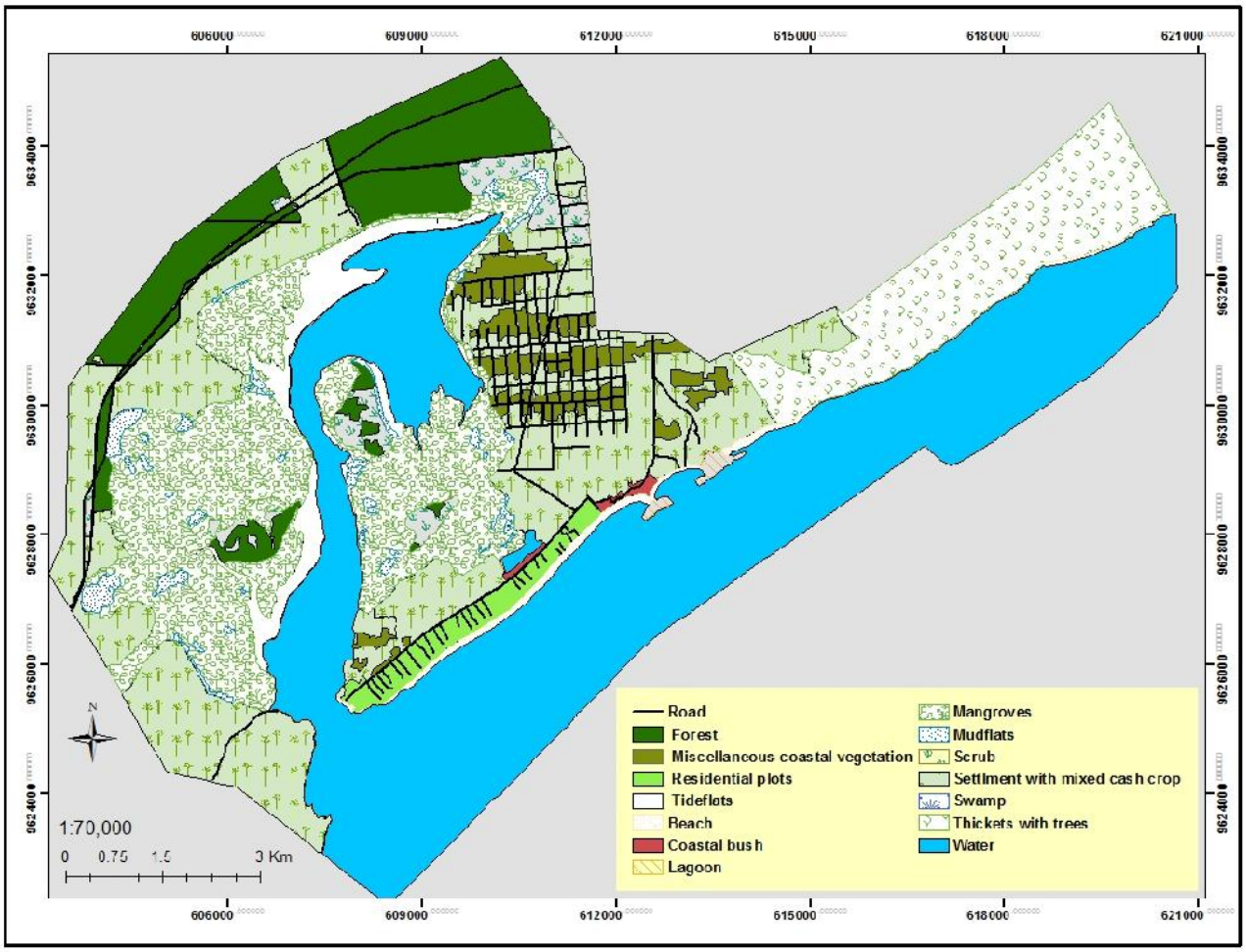

Figure 30: Land use and cover map of the study area in 1969

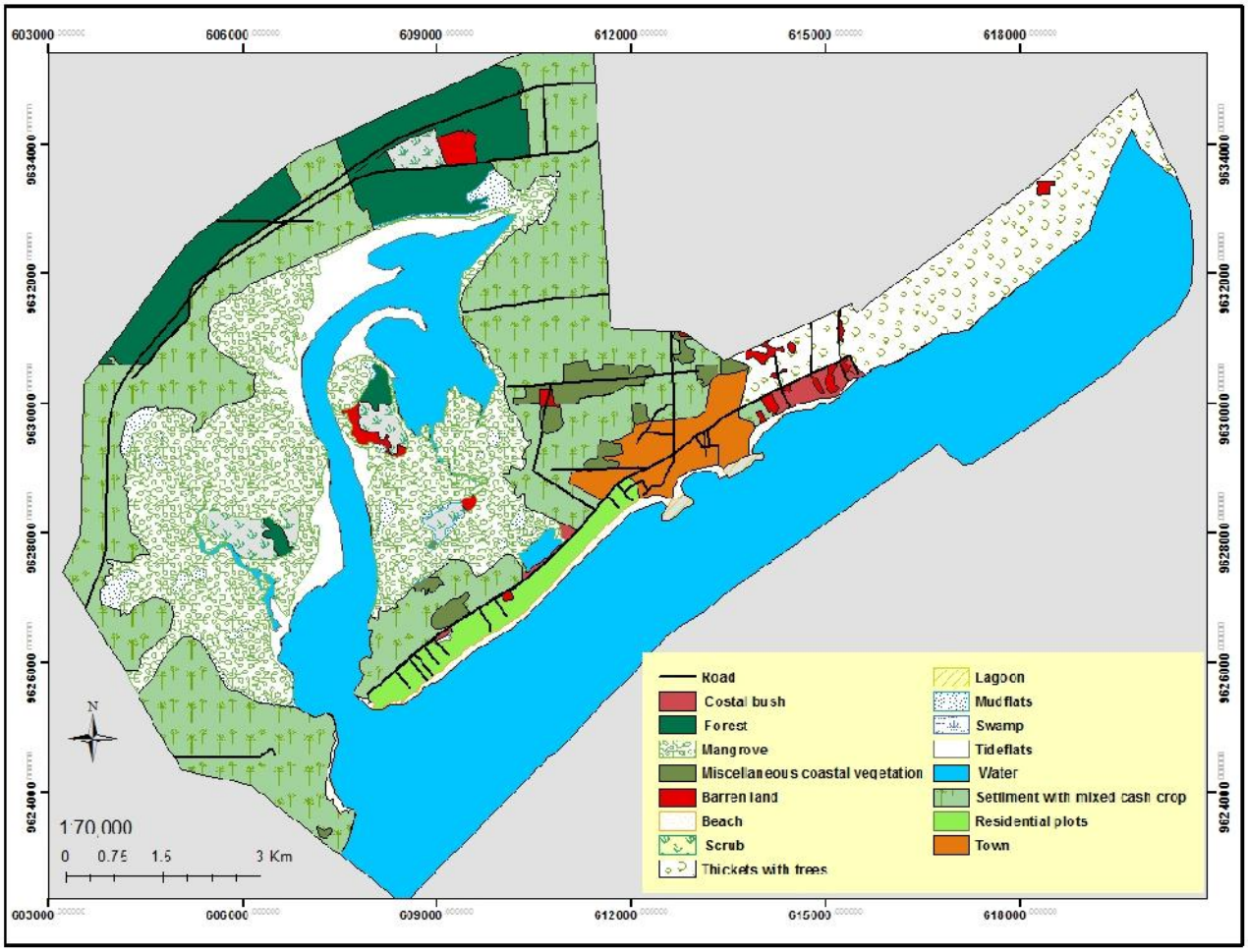

Figure 31: Land use and cover map of the study area in 1989

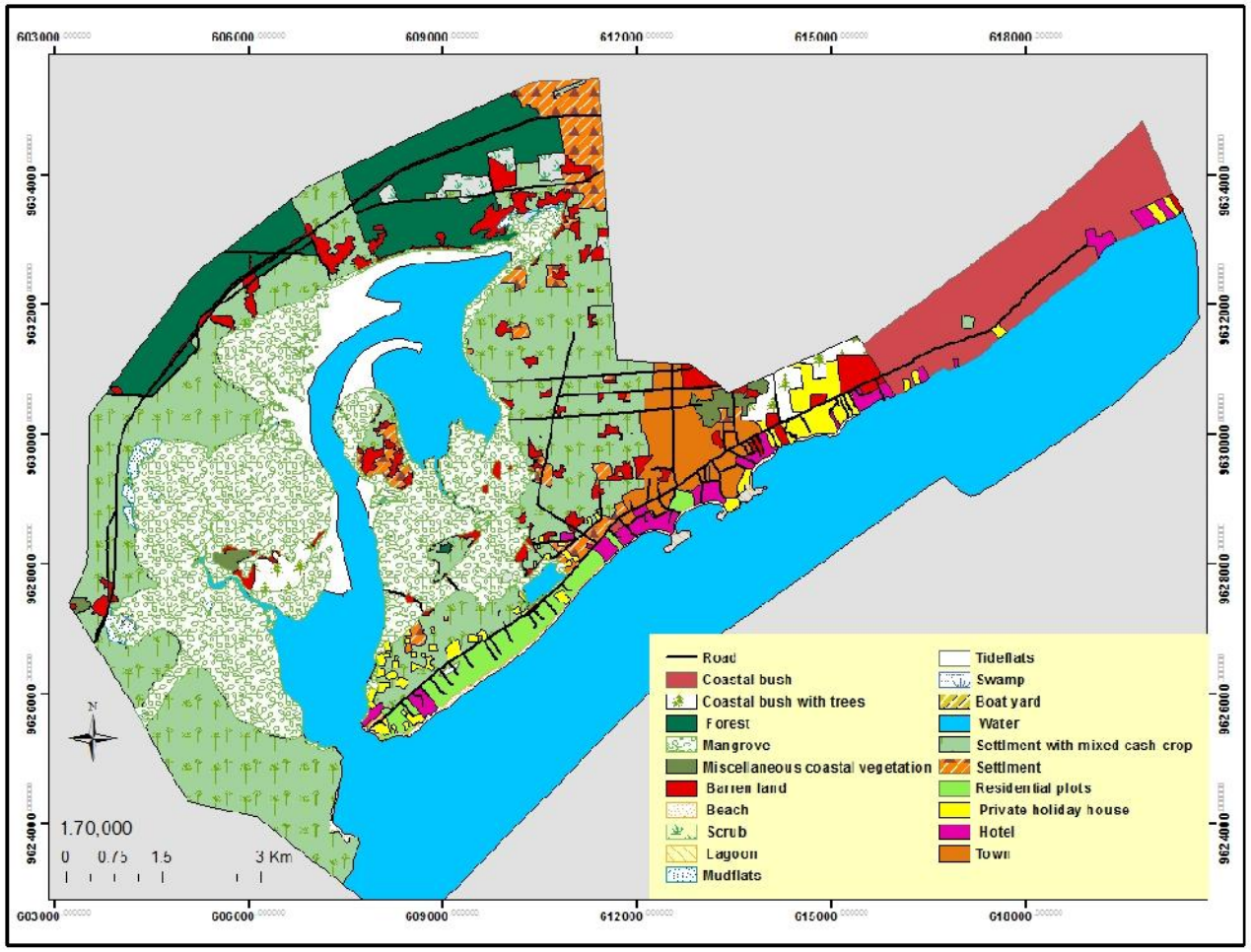

Figure 32: Land use and cover map of the study area in 2010

Ii is evident that conversion of land from one use to another, as well as the emergence of new land use types was common from 1969 to 2010 (Table 10). In 1969 settlements with mixed cash crop (2358.6 ha) were the main land use in the area followed by mangroves (2072.2 ha), thickets with trees (889.1 ha) and forest (855.6 ha) with the sea water accounting for 33.5% of the total area. The land use change analysis (comparison between 1969 and 1989) showed a decline in vegetation covers including mangrove forest and emergence of new land use in 1989. As mangrove forest decreased by 3%, there was emergence of urban centers (239.6 ha) and barren land (92.7 ha). The 2010

land use map displays conversion of areas initially covered with thickets and trees to urban centers, barren and bushes. For example, thickets with trees which covered (773.1 ha) in 1989 converted into other land use type such as town, barren land, and costal bush with few old trees. The land use types observed in 2010 were expansion of settlements without any cash crop trees, and an increasing number of private holiday houses, and hotels.

Table 10: Land use and cover area from 1969-2010

Land use and cover type	1969		1989		2010		Change computation (%)	
	(ha)	%	(ha)	%	(ha)	%	1969-1989	1989-2010
Scrub	213.6	1.9	154.1	1.37	69.8	0.62	1.4	2.6
Miscellaneous coastal vegetation	325.7	2.9	161.3	1.44	52.2	0.46	2.5	3.2
Coastal bush	23.3	0.21	53.6	0.47	582.2	5.18	-6.5	-46.9
Thickets with trees	889.1	7.93	773.1	6.91	-		0.7	4.8
Forest	855.6	7.63	644.5	5.76	635.8	5.65	1.2	0.06
Mangrove	2072.2	18.48	1719.8	15.38	1872.9	16.66	0.9	-0.4
Settlement with mixed cash crops	2358.6	21.04	2611.1	23.35	2230.7	19.84	-0.5	0.7
Residential plots	179.3	1.59	189.8	1.69	159.5	1.41	-0.3	0.8
Seasonal Swamp	1.4	0.01	1.7	0.01	2.3	0.02	-1.1	-1.7
Tide flats	309.1	2.75	344.2	3.07	274.3	2.44	-0.6	1.3
Mud flats	141.6	1.26	174.7	1.56	59.1	0.52	-1.2	-3.2

Beach	78.9	0.79	88.1	0.78	42.1	0.37	-0.6	2.5
Water body (Ocean)	3759.5	33.54	3933.1	35.17	3981	35.43	-0.2	-0.01
Town (business centers, settlement, infrastructure, different facilities)			239.6	2.14	252.7	2.24		-0.3
Barren land			92.7	0.82	353.1	3.14		-13.4
Coastal bush with trees					112.1	0.99		
Settlement					260.1	2.32		
Hotel (along the beach)					127.1	1.13		
Private holiday house					168.7	1.5		
Total	11,207.9	100	11,181.3	100	11,235.7	100		

4.3.2 Land use change rate

The main land use changes between 1969 and 1989 were; decline of scrub land, miscellaneous coastal vegetation, coastal bush, thicket with trees, and mangroves whereas the new type of land use that emerged during this period were town and barren land. The largest land use change rate observed between 1969 and 1989 was in miscellaneous coastal vegetation at 2.5% while coastal bush experienced the significant change rate with -6.5%. Areas covered by scrub, forest, mangrove, experienced change rates of 1.4%, 1.2%, and 0.9% respectively. The main land use changes observed between 1989 and 2010 were increasing coastal bush, an expansion of town and urban

areas, hotels, and private holiday houses. Furthermore, there was decline in miscellaneous coastal vegetation and total conversion of thickets with trees to other land use types observed during this period. In the period between1989 to 2010 the highest decline was observed in coastal bush (-46.9%), thickets with trees (4.8%) and barren land (-13.4)

4.3.3 Main drivers of land use and cover changes

The results of multiple regression model estimates showed that the major determinants of land use change were population ($p<0.05$, actual p-value 0.000 (4.27418E-66), and policy ($p<0.05$, actual p-value 0.000 (8.89021E-09) although rainfall was not significant ($p=0.656461979$). The multiple regression analysis results depicted that the estimates were significant ($p<0.05$) as predictors of the observed changes in land use. The R value was $R^2=0.9820$ and Adjusted $R^2 =0.9806$.

Land use in Watamu Mida Creek coastal area has experienced rapid change during the last 41 years (1969-2010) following the increasing tourist flow and expansion of tourist facilities and urbanization. According to the information gathered during the household survey, during the colonial administration , there were settlement schemes where each settler were given 12 Acers of land with an obligation to plant cash crops, cleared the boundaries of the plots and to leave the remaining part of the plot under old trees and bushes. This information agrees with the history of settlement schemes along the Kenyan coastal area. According to Hoorweg (2000) in 1938, 850 families settled on a 4,000 ha of land near Gede. The farmers were given 12 acres (4.8 ha) of land. A recent study by Carter (2013), indicated that most of the villages were legally established after the 1950s

land resettlement schemes. In his study Hoorweg (2000) reported the division of each of the 12 acres of farmland as; “six acres for annual crops, three acres for perennial crops such as coconut, palms, cashew nut trees and fruit trees, and three acres for fodder crops, miscellaneous trees and the home compound”. Respondents stated that in some villages they used to grow maize, sesame, cotton, peas, cassava and beans. After independence the plots which used to have a similar patterns in 1969 changed with new land uses including a decline in miscellaneous coastal vegetation, an expansion of settlement, conversion of land into towns and clearance of natural vegetation including a; decline in the forest and mangrove areas. Both the 1989 and 2010 land use change map and the information obtained from the household survey showed that there was an increasing intensity of land use during this period.

A number of factors have been reported to work either individually or in combination to cause land use change and conversions. Jan (2005) attributed land use change to interaction between socioeconomic, institutional and environment. A study in Tanzania by Misana et al., (2012) showed that land use change was driven by a combination of different factors such as demographic, institutional, economic, government policies, and sociocultural, technological and infrastructural factors. Other research in Northern Ethiopia pointed out that government policy was amongst the main socioeconomic drivers of land use change (Tsegaye et al, 2010). In the current study land use change was significantly (‘p’ value of <0.000) affected by population and policy. While assessment of respondent’s opinions indicated the key drivers of change in land use to be economic (62%) and population (22%).

Coastal development in association with an expanding tourism industry has contributed to high demand for land to build hotels, private holiday houses, businesses and service centers. As the tourism industry expanded many people from other parts of the country have migrated in search of job opportunities to the Watamu Mida creek area. As the number of hotels increased, the town expanded, areas which used to be covered by coastal bush, thickets with trees, and forest started to decline and were converted for other land uses. Based on the census data of 1969, 1989, 1999 and 2009, the population of Watamu Mida area has substantially grown; 21,032, 50,258, 75,414 and 101,689 over the respective time period. The increasing human population brought about land fragmentation with the original settlement schemes being sub divided and distributed to other family members including younger generations.

Areas which were previously left to grow natural trees and bushes and grazing areas have been converted into settlements and often are also used to grow cash crop trees such as coconuts and *Casuarina equisetifolia* trees. Due to increasing demand of poles arising from the hotel industry, areas covered by coastal bushes and old trees have been converted to *Casuarina equisetifolia* tree, thereby replacing the old cashew nuts trees. This in turn reduce the amount of land which was under cultivation and cash crop trees between 1969 and 1989. Furthermore, the expansion of infrastructure led to clearance of more areas under coastal vegetation and forest. In addition because of the growing number of tourist in the study area the number of people migrating to Watamu in search of business and job opportunities has increased. Based on the report by Government of Kenya (2009), migration to the coastal region is due to employment opportunities, and

the growth of tourism industry. According to Bridges et al. (2001) population growth and changes are main driving factors for the change in the natural resources bases including the quality of the land itself. The influx of settlement is mainly attributed to immigration of people to Watamu area in search of business and employment opportunities. This has led to the former farmland mixed cash crop areas being converted into settlement areas in order to accommodate the increasing demand of housing for the people who came looking for job. As the household survey respondents confirmed, the productivity of the land has declined and farmers particularly in the vicinity of the shoreline started selling their land to foreigners in order to raise money to support their family needs. This trend has been observed in villages such as; Watamu, Dongokundu, Blue bay, and Jacaranda. Other village are now also beginning to experience similar changes although these are not yet as extreme as the above mentioned villages.

In Jacaranda area the land was mainly covered by coastal bush with tickets and old trees before the expansion of settlements and hotels. For example, the dominant tree types that used to cover this area as mentioned by the respondents were; *Azadirachta indica, Afzelia quanzensis, Balanites wilsoniana,* and *Ficus sansibarica*. However, this land cover type has been slowly cleared and the old trees cut down for use as a source of firewood and charcoal making. As respondents of the household survey and the Focused Group Discussion confirmed, the expansion of urban areas and growth in human population has led to increased demand for firewood and charcoal. Most of the respondents agreed that there were originally lots of big trees and they started to observed significant changes occurring in the land use as from the early 1990s. Presently some part of the area is used for coral mining because of the high demand of construction materials from nearby big

tourist hotels (Figure 33). Several big tourist hotels and private holiday houses are being built in Jacaranda village replacing the old coastal vegetation cover.

Figure 33: Coral mining in Jacaranda area

4.3.4 Impact of land use change on shoreline erosion and change

The change in land use had an impact on shoreline changes as well. The beach front plots were owned by private residential houses mainly (foreigners) for a long time. The southern parts of the beach front is adjoined by approximately 50 residential houses and the Marine Park .These plots were mainly covered by old trees; and coastal bushes which protected the area from erosion. Most plots in this residential area were 8 to 12 acres in size. Currently many of the plots have been converted into very big hotels and several private holiday houses complexes. Some of the beach front (mainly occupied by big hotels), has been leveled in order to get a better view of the sea. Areas which used to be thick coastal bush were cleared and replaced by ornamental trees or left without vegetation cover. The vegetation cover on the sandy beach acts as beach stabilizer by protecting the beach from erosion. Some beach front hotels have built sea walls in order to protect the property from erosion but this has only aggravated the erosion in places

along the beach. Richmond (1997) stated that environmental degradation such as clearance of mangrove forests for beach access, and up-rooting of near shore sea grass beds for touristic activities has become a feature of the tourism sector in most East African countries.

An impact of coastal land use change on a shoreline study in Taiwan (Lo and Gunasiri, 2014), indicated the effects of expansion of settlement and urbanization resulted in negative effect to the position of shoreline. Some villages such as Jacaranda further to the north, which used to be mainly covered by coastal bushes before the expansion of hotels are now rapidly being converted into big hotels and private houses. In this village, the beach front is mainly hard coral rock with pockets of sandy beach. Much of the original vegetation cover (Table 11) has been cleared and the land close to the beach is fenced or under construction with new hotels or private houses.

Table 11: Some of the tree species along the beach front and behind hotels or private houses

Number	Tree species	Status
1.	*Sideroxylon Inerme*	Dominant
2.	*Bourreria petiolaris*	Dominant
3.	*Drypetes natalensis*	
4.	*Zanthoxylun chalybeun*	
5.	*Garcinia livingstonei*	
6.	*Flocourtia indica*	
7.	*Salvadora persica*	
8.	*Cusuarina equisetifolia*	
9.	*caesalpina boundue*	

10.	*Pomoea pes-caprae*	Habitat along the beach
11.	*Euclea natalensis*	
12.	*Ochna thomasiana*	
13.	*Cola minor*	
14.	*Vitex mombassae*	
15.	*Combretum illiarii*	Climber
16.	*Grewia plagiophylla*	Dominant
17.	*Gardenia volkensii*	
18.	*Elleodendron schweinfurthianum*	
19.	*Suregada zanzibarensis*	
20.	*Mimusobs Obtusfolia*	
21.	*Afzelia quanzensis*	
22.	*Deinbollia borbonica*	
23.	*Xymenia americana*	
24.	*Bridellia cathartica*	
25.	*Cuzzonia zimmermanii*	
26.	*Balanites wilsoniana*	
27.	*Azadirachta indica*	Habitat

Source: Field data (2012-2014)

4.3.5 Impact of land use change on mangrove forest

As the human population number increases the demand for building materials, poles, and fire wood increases. As a result of the mangrove forest decline it has also affected the main source of livelihood of the surrounding community. The total area of mangrove has

shown a reduction in Kenya since 1985 (Kirui et al., 2012). A study by Kairo (2002) and Dahdouh (2000) in Mida Creek confirmed a significant decline and disturbance of mangrove forest over the last 20-30 years mainly for poles used for house construction. In this research based on the analysis of the 2010, encroachments in to the mangrove forest have been observed. This encroachment was both by local people and foreign private holiday house owners (Figure 34). As the unpublished five year management plan prepared by KWS (2005) indicted, there is an indication of over exploitation of mangrove forest; and decline with the number of big trees disappearing as the result of logging, settlement and selective harvesting of poles in Mida creek area. Even though there was a slight increment of mangrove forest and adequate rate of recruitment of mangrove seedlings and saplings as observed in this study, areas adjacent to the villages were affected either by direct cutting of mangroves, (Mida, Kadaina, and Kirepwe) grazing (Mida) or encroachments (Dongokundo and Dabaso)(Figure 34).

Figure 34: Private Holiday house and local village encroachment to the mangrove forest

4.4 Policy framework and perceptions: the viewpoints of communities, hoteliers, and non-governmental organizations

4.4.1 Perceived benefits and disbenefits of tourism sector

Watamu National Park and Reserve has one of the highest number of tourists and visitors in any destination in Kenya. The main tourist attractions in the area are; the hospitality of the people, the Marine Park and Reserve, marine life (including turtles and corals), ocean sports, snorkelling, fishing, and the culture of the community. However there are several environmental and social challenges that are likely to affect the future of the tourism industry (Table 12).

Table 12: Positive and negative contribution of tourism sector in Watamu Mida Creek

Some of the positive effects of tourism	N	Mean	Percentage	Std.Devation
Employment creation	53	1.08	88.3	.385
Increase in income because of tourist visits	28	2.25	46.7	.518
Benefits from the improvements of infrastructure	10	2.40	16.7	.843
Increase sale of curios	25	2.40	41.7	.645
Employment in private households	24	2.42	40	.504

Some of the negative effects of tourism	N	Mean	Percentage	Std.Devation
Loss of fish landing sites	18	2.1	30	.676
Conflicts between resources users	11	2	18.3	.775
Social problems (drug use, prostitution, school dropouts)	54	1.3	90	.614

Loss of community land	25	2.4	41.7	.651
Reduced access to public beach	22	2.4	36.7	.727
Loss of community culture and values	24	2.3	40	.794

The main environmental challenges observed during the course of the research were; beach erosion which resulted from uncontrolled building development, rubbish dumping, destruction of corals (sometimes resulting from excessive visitor numbers), overfishing, use of illegal fishing gear, illegal cutting of mangrove poles to fulfil the high demand coming from hotel expansion and increasing human habitation, and loss of turtle nesting and hatching places along the beach. Some of the social challenges that were observed are; a high dependency on the tourism sector, lack of alternative livelihoods, increasing human population and in-migration, high dependency on the natural resources of the area focusing on fishing and mangrove resources, high unemployment during the tourist low season, high dropout of students from schools in order to try to benefit from tourism, increasing use of drugs by the youth, prostitution, increasing levels of poverty, and cultural degradation resulting from the aforementioned items.

4.4.2 Perceptions of existing policies and regulations among community members, hoteliers, and non-governmental organizations

At community level

Respondents were asked to list some of the Acts and Regulations related with mangrove protection, fishing, shoreline and the Marine Park and Reserve areas. Among the households 40% of them were aware of some the regulations in the Forest and Fishery Acts, whereas 21% of the respondents identified some of the rules related with the

Marine Park and Reserve. Out of the 60 households interviewed only one person knew about the physical planning Act, and none of them were aware of the EMCA regulations or about the need of an EIA before the implementation of any project (Figure 35). At household level none of the survey respondents mentioned about the setback rules of the High Water Mark along the beach and near the mangrove forest. Whereas during Focused Group Discussions the participants indicated they were aware of the 30 m set back rule (in areas adjacent to the Marine Park), and stated the current development trend near or below the High Water Mark along the shoreline as one of the reasons for the shoreline erosion.

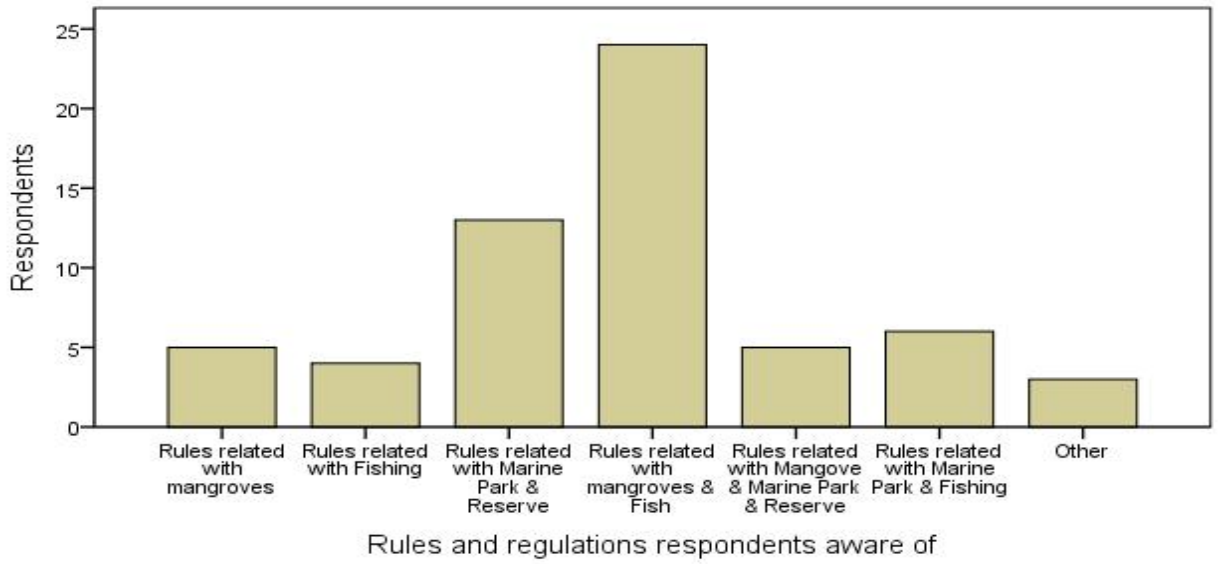

Figure 35: some of the rules and regulations of which the community were aware concerning mangroves, marine reserve and park

The community in Watamu Mida Creek area were highly dependent on the natural resources and marine life for their livelihood. Although tourism sector is the main income earner, its existence depends largely on the healthy environment of the shoreline and its natural beauty. Community expectations from the leading government institutions in; enforcing laws and regulations on areas of new developments, illegal cutting of mangroves, controlling overfishing, sharing the income collected from the Marine Park and other touristic activities, is very high. Generally the level of awareness on the regulations and some of the "dos and don'ts" in the use and management of these

resources amongst the community was good. According to the household survey results, 96.7 % of the community members were aware of some of the existing rules and regulations of natural resources in the Marine Park and Reserve (e.g. those relating to fishing and mangrove use). The household survey results revealed that although over 40 percent of the respondents knew about some of the Acts and Regulations, the majority of them agreed that the level of compliance was very weak (Figure 36).

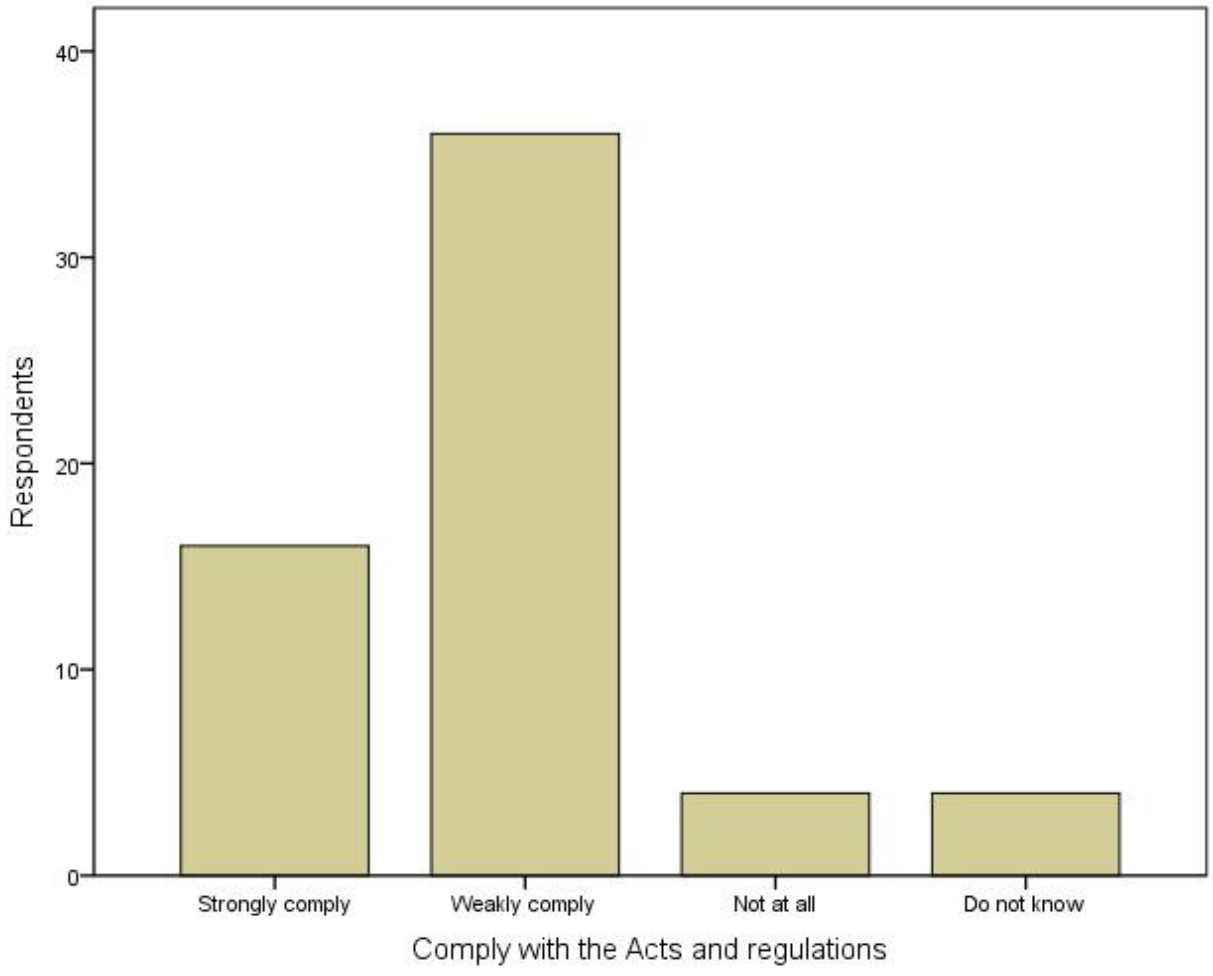

Figure 36: Household pereception on levels of compliance with the existing laws, rules and regulations

The respondents also showed that they were aware of some of the observed degradation and depletion of resources (Table 13). During the Focused Group Discussions they reported some of the threats to; mangrove forest, shoreline, fishing, sea turtles and generally the marine life. They also suggested possible solutions for the main challenges facing the environment (Table 13).The following Table summarizes the five Focused Group Discussions with different local resource users groups in the community on what were raised as a threats and suggested community recommendations.

Table 13: Threats to mangrove and shoreline

Main threats of the coastal environment and recommendations by the community in Watamu Mida Creek			
Threats of mangrove	Recommendations	Threats of shoreline	Recommendations
▪ Illegal cutting ▪ Natural factors (e.g. flooding some years back) ▪ Poor law enforcement ▪ Lack of knowledge ▪ Population increase ▪ High level of poverty and unemployment ▪ High demand of construction poles ▪ Expansion of villages ▪ Fishermen dig the roots of the mangroves to get fish bait	▪ Awareness creation on the conservation and management of mangroves and shoreline ▪ Alternative or diversify livelihood activities ▪ Planting more trees to reduce the pressure on mangrove trees ▪ Stop over exploitation of natural resources ▪ Strong law enforcement from all institutions ▪ Create more community conservation groups ▪ Support from government institution for	▪ Beach erosion ▪ Climate change ▪ Tourist related activities along the shoreline eg development near the shoreline ▪ Land use change ▪ Lack of management plan ▪ Development close to the shoreline ▪ Clearing vegetation from the beach to get a better view ▪ Levelling the beach to get a better view ▪ Natural factor such as deposition of sand and mud from the adjacent areas	▪ Support community from the fees collected from the Marine Park ▪ Community involvement in upcoming projects and investments ▪ Better communication and working environment with leading government institutions ▪ Community needs to be vigilant on all illegal activities and report to authorized offices ▪ Education to all resources users and to those that work to protect the environment ▪ Involve those engaged in illegal use of resources in conservation activities ▪

	community conservation groups ▪ Community participation and involvement in the conservation and management of the mangrove forest		

Source: Five Focused Group Discussion with the representatives of local community resource users group

Hoteliers and non-governmental organizations

There were notable non-governmental organizations in Watamu such as the Watamu Marine Association (WMA), A Rocha Kenya, and Local Ocean Trust who were working in the conservation and protection of the mangroves and marine life and also supporting the community in many ways in the sustainable use and conservation of the environment. Out of a total of 25 hotels there were a few (for example; Turtle Bay Beach Club and Hemingways Watamu) who are working together with community conservation groups to protect the environment. They were involved in the promotion of ecotourism, recycling and contributing towards supporting the local communities through maintaining; roads, schools, clinics and supporting community conservation groups. Both the hoteliers and nongovernmental organizations (NGOs) had expectations from the mandated government institutions for strong law enforcement in order to reverse the destruction of mangrove forests and marine life. The following diagram summarized the main issues raised by key

informants interviewed from hoteliers and NGOs concerning the main drivers of change in the mangroves and along the shoreline (Figure 37).

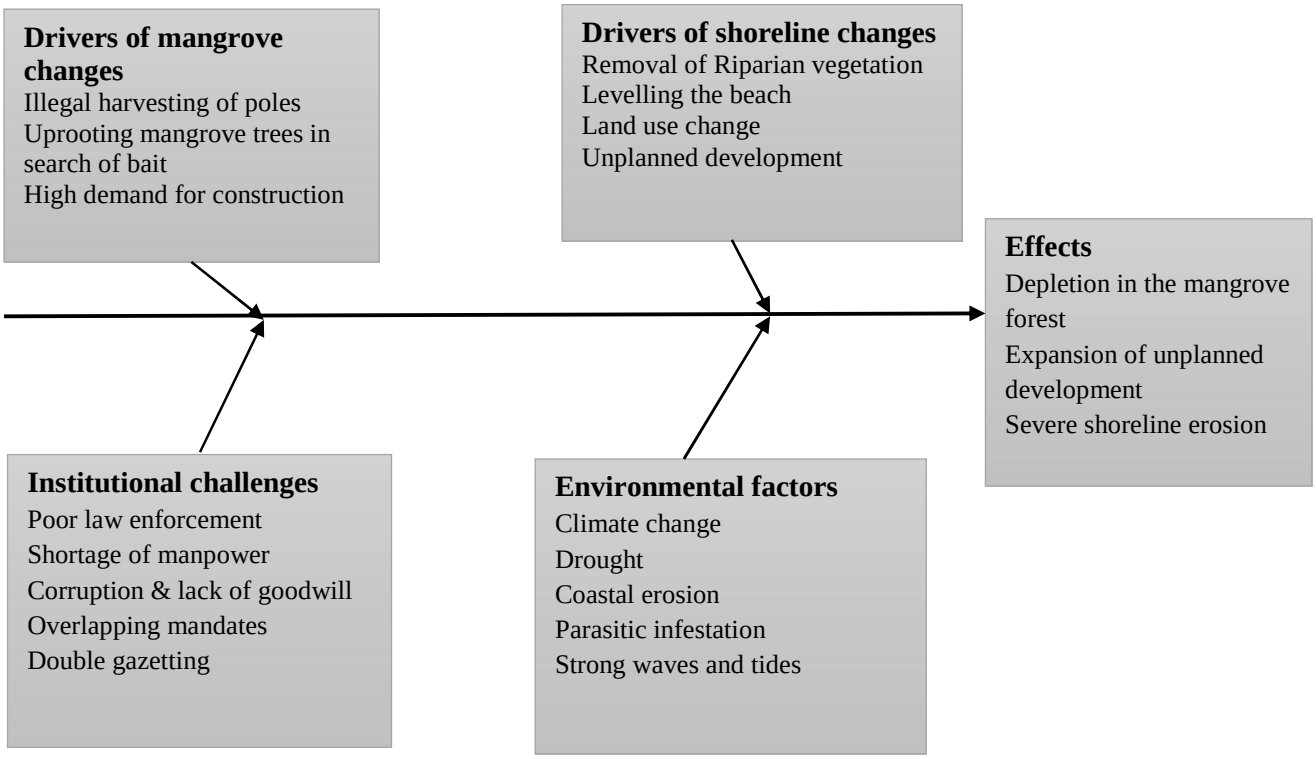

Figure 37: Hoteliers and non governmental organizations perception on the effectsof threats on coastal resources

The hoteliers and NGOs provided some suggestions in order to improve the management and conservation of the shoreline and mangrove forest. Among them were; increasing community involvement to protect the mangrove forest, such as joint patrolling with community representatives and Kenya Forest Service and Kenya Wildlife Service rangers, recruitment of community guards to look after the resources, creating a sense of

ownership and trust amongst the community in the use and conservation of the mangrove forest, training and awareness raising programs for the local community to emphasize the importance of sustainable utilization of resources. The other areas that needed improvement were: law enforcement capacity by the institutions with research mandates, capacity building for the staff in the leading government institutions, increasing the number of rangers, and regular stakeholders meetings on the conservation and management of the mangroves and marine life. The key informants suggested to create a centralized management unit with representatives from; Kenya Wildlife Service, Kenya Forest Service and local communities to improve the overall management. Kenya Wildlife Service also needs to inform tourists or visitors before they go out to visit the Marine Park on what is allowed and not allowed so that damage on the environment will be minimal. There is also a need to create awareness among local community members who work in the Marine Park so that they can become watchdogs for the environment and report on any damage that is caused by visitor or tourist.

4.4.3 Challenges observed in the implementation of laws, and regulations

Existing Acts and regulations, and institutional challenges for controlling shoreline development

Key institutions responsible for the protection and management of mangrove forest and marine life, including the Marine Park and Reserve were; Kenya Wildlife Service, Kenya Forest Service, Coast Development Authority(CDA), Fisheries Department and Kenya Marine and Fishery Research Institution (KMFRI). From these key institutions, Kenya Wildlife Service and Kenya Forest Service take the major responsibility to administer and

protect the Marine Park and Reserve which includes the mangrove forest. Kenya Wildlife Service has the mandate to conserve and manage the wildlife in the Marine Park and Reserve. The obligation to enforce laws and regulations related to marine and terrestrial parks and reserves is the responsibility of this institution. However the institution does not have enough manpower to patrol the Marine Park and Reserve, they also have a problem to control the unplanned development along the beachfront and in mangrove adjacent areas where encroachment and illegal cutting of the mangroves can occur.A recent research finding in a similar case indicated thatKenya Wildlife Service challenges to enforce the regulation of protection within the riparian zone that has an area 30 meters from the highest water mark (Carter, 2013).Kenya Wildlife Service as institution cannot alone stop unplanned development near the High Water Mark (HWM) or encroachment in the mangrove forest by private developers. In such instances, it must work with National Environment Management Authority. According to the Environmental Management Co-ordination Act Wetlands regulation (2009), section (17) indicates the overall principles which are relevant for coastal areas, such as the requirements of an Environmental Impact Assessment (EIA) for any kind of project, sustainable use of shoreline, and the importance of developing an inventory of degraded shorelines and their conservation measures. National Environment Management Authorityhave the responsibility to request the developer to bring an EIA report before they actually allow the construction to begin. The developer or investor also has the responsibilities to discuss with all stakeholders and get their acceptance. However sometimes the EIA will not be done correctly, lack of commitment and willpower to stop an unplanned development which can harm the environment. On a parallel note a report by WIOMSA

(2010) pointed out that the EMCA (1999) does not have policy guidelines, regulations or proper management plan for coastal land use and shoreline changes. The Physical planning Act (1998) also empowers the Local Authorities under section (29) of the Act, 'to reserve and maintain all land planned for open spaces, parks, urban forests and green belts'.

There have been cases where the developer came with permission from National Environment Management Authority head office without the knowledge of the County office or without any discussion with the local stakeholders or any other relevant institutions such as Kenya Wildlife Service or Kenya Forest Service. In such cases it was difficult for the mandated institution in the area to stop any development which potentially could affect the shoreline and/or the mangrove forest. However there were cases where such developments had been stopped with the help of all stakeholders (including local government institutions), as in the case of the Blue Lagoon headland development. In this case a developer put up a fence (Figure 38) and started a development without consulting the community or any other stakeholders. This headland is an important part of the shoreline and needs to be left alone to protect the lagoon from strong winds and waves. This research noted however that the fence put up by the developer has still not been demolished.

Figure 38: Illegal development on Blue lagoon headland

Existing Acts and regulations and institutional challenges for mangrove conservation

The mangrove forest reserve had been 'doubly gazetted' at the national level as both a Forest and Marine Reserve. Internationally, it is also recognised as part of a biosphere area under UNESCO. Under Kenya's Forest Act, (2005) section 41 (1) it states that; 'All indigenous forests and woodlands shall be managed on a sustainable basis for purposes of, river line and shoreline protection, habitat for wildlife in terrestrial forests and fisheries in mangrove forests, sustainable production of wood and non-wood products'. Kenya Forest Service allows the local community who live adjacent to the mangrove forest use of mangroves for harvesting poles for house construction, and subsistence firewood collection. Nevertheless, the same Forest Act under section (32) (3) states, 'No cutting, grazing, removal of forest produce, hunting or fishing, shall be allowed in a nature reserve except with the permission of the Director granted in consultation with other conservation agencies, which permission shall only be given with the object of facilitating research'. This section of the Act clearly contradicts with section 41 (1) which allows sustainable use of mangrove forest within the Reserve. To harvest mangrove poles

a license is required from the Forestry Department which costs 3,000 Ksh per annum per license (Mauser and Hirsch, 1992). However, obtaining a license takes a lot of time and as the result people undertake illegal harvesting of mangroves (Dahdouh et al., 2000).

On the other hand, according to the Wildlife Conservation and Management Act, (2013) section 36 sub section (3), it states that; 'a marine conservation area shall adopt a system of zoning that caters for multiple use of marine resources for extraction or no extraction zones in respect of marine resources.' Kenya Wildlife Service do not allow extraction of mangrove forest within the reserve. The main challenge here is both Kenya Wildlife Service and Kenya Forest Service have responsibilities for the conservation and management of the mangrove forest. Kenya Wildlife Service does not allow any extraction of mangrove forest in the reserve areas, while Kenya Forest Service allows sustainable use of mangrove forest by local communities within the same area. Such overlapping mandates creates a gap in the conservation approach which local people continue to exploit to the detriment of the mangrove forest. As was stated in Chapter Four (Assessment of mangrove forest cover change and biomass), the mangrove tree species such as; *C.tagal, B.gymnorrhiza* and *R.mucronata are* targeted for construction of houses and with increasing demand from the hotels and private houses. The magnitude of the destruction of the mangrove forest is increasing over time. This is partly because of the lack of coordination in the management and conservation of the two mandated institutions.

Other challenges faced by Kenya Forest Service include; insufficient staff establishment, and hence lack of capacity for law enforcement, limited work facilities and tools (e.g.

there is no boat for patrolling the marine areas). The other challenge is the continued community dependency on the mangrove forest. The community view mangroves as a community resource and not as an environmental service to protect the area and sustain the marine ecology. They depend on the mangrove forest to get poles to build their houses. In some villages mangrove trees such as *Avicinia marina* is are used as a browse by livestock during the dry season. The other emerging threat to the mangrove forest is charcoal making. This was not reported in the past, but now it is becoming a problem. This is mainly because of the high dependence on income from tourism, and the recent reduction of tourist flows in the Watamu area has created high unemployment which in turn has resulted in increased exploitation of mangroves and over fishing in the Mida creek. Global events such as international security issues (e.g. Somalia) and the West Africa outbreak of Ebola have also affected tourism. There is a common expression by the local people that, 'during low tourist season everybody becomes a fisherman.'

Environmental Management and Co-ordination Act (EMCA) (1999) and institutional challenges

National Environment Management Authority (NEMA) is another key institution with a direct mandate for implementing rules and regulation within the coastal area and marine environment under the Environmental Management and Co-ordination Act (EMCA) (1999). The Act under section 42 subsection (1) states the need to submit environmental impact assessment reports and get written authorization of the Director-General before any development can take place along the coast. Section 55 subsection (1) also states that, 'The Minister may, by notice in the Gazette, declare an area to be a protected Zone and in

consultation with the relevant lead agencies prepare a survey of the coastal zone and an integrated national coastal zone management plan.' National Environment Management Authority has some challenges in the implementation of these regulations. The first one is lack of enough trained manpower in order to go out to assess projects and inspect unplanned developments. For example a report by Government of Kenya (2009) stated that no construction is allowed within 30m from the high water mark in the Marine Protected Area, however the field survey revealed that there are several buildings within the high water mark range. As parallel research by Carter (2013) reported, Kenya Wildlife Service also do not have a clear document which shows the demarcation of the riparian area and as a result it was difficult to stop the developers in the tourism sector from encroaching. This is a very big gap which hinders the implementation of regulations along the shoreline. There is also lack of manpower assigned at County office level to enforce the EMCA regulations.

Under the EMCA 1999 regulations Section 42 subsection (3) states, 'National Environment Management Authority by notice in the Gazette, issues general and specific orders, regulations or standards for the management of river banks, lake shores, wetlands or coastal zones and such orders, regulations or standards may include management, protection, or conservation measures in respect of any area at risk of environmental degradation.' However, the influences of human activities such as clearing of the shoreline vegetation cover, leveling the beach to get a better view of the sea and uncontrolled construction of sea walls to halt shoreline erosion is observed as continuing along the shoreline. In addition to this, despite the 60 meters set-back above the High Water Mark (Government of Kenya, 2010(a)) outside of the Marine Park, again several

tourist hotels, private houses and residential/holiday homes were observed within the high water mark range along the shoreline. This has resulted in shoreline change and severe erosion which is causing damage on the shoreline and on these properties.

Another problem is political influence. It was reported by National Environment Management Authority office as one problem that sometimes a project will get approval without the knowledge of the local County office. The headquarter office in Nairobi may sign and approve a project, and following this action the County officer will have no power to stop the project. A further challenge is a gap within the EMCA (1999) Act itself which states that 'a temporary building can remain with a warning', and this regulation is very difficult to enforce. Sometimes a developer, knowing the Act, will put up temporary structures for example along the shoreline, and then obtain permission from the physical planning unit for construction without National Environment Management Authority approval. The other challenge is lack of awareness of the need for an EIA by the general public. If a building or project commences without any EIA and National Environment Management Authority office is later notified about it, then the office has the power to stop the project. If National Environment Management Authority finds that the project has a negative environmental effect it has the authority to stop the project. A good example of the Act working is the aforementioned project on Blue lagoon headland

Physical Planning Act and institutional challenges

The physical planning unit at the County has the mandate to give approval for a development. The Physical Planning Act, 2014, Section (12) (2) states, 'The Commission shall ensure that any public land that has been identified for allocation does not fall

within any of the following categories, forest and wild life reserves, mangroves, and wetlands or fall within the buffer zones of such reserves'. However, the physical planning unit do not have a copy of the land use plan for Watamu Mida Creek area, this is because the area is considered as a Marine Reserve and National Park. The Physical planning unit is also under a different department, and there is also a problem of trained manpower and capacity in the area. As a result plans may be approved without staff ever visiting the development site. An example here is the issue of Dongokundo village (adjacent to the mangrove forest) where land use conversion is currently observed. In this village several previous farmland and small household plots have been converted into big private holiday houses. According to the physical planning unit in Kilifi County, a Master Plan for all areas along the north coast including the Watamu Mida Creek is under preparation.

The other office which is equally responsible in the tourism sector is the tourism office. According to the Tourism Act 2011 the Minister has the responsibilities of, 'providing licenses, classification of tourism activities, regulation, restriction and control of tourism related activities and services, and managing the shoreline'.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Watamu Mida creek is one of the main tourist destinations at the coast and supports many of the local communities who are largely dependent on the income from the tourism sector and the natural resources of the area. This coastal area needs protection and special consideration because it is a very fragile environment which can be negatively affected if a proper management plan has not been put in place. Currently the area is under a lot of pressure arising from; the growing human population and in-migration from other parts of the country, heavy reliance of the local community on the mangrove forest, fishing and agriculture, and also from the expanding tourism industry which requires an attractive natural coastline to sustain investment as well as heightened security issues (arising from Kenya's involvement in Somalia).

This research has assessed the impact of land use change on shoreline erosion and mangrove dynamics from 1969 to 2010 and identified the main drivers of these changes. The research provided a detailed information on mangrove cover, updated the current status of species composition and regeneration, and analyzed above ground biomass. This study also scientifically quantified shoreline erosion rates and indicted beachfronts highly susceptible to erosion. It also identified the main factors causing this erosion which will help to control unplanned development and improve the existing regulations and policies regarding shoreline management. The present study also provides detailed information on the current and historical coverage of the different land use and cover types over a 41

year period, and such information should become an input for the current preparation of the land use Master Plan for the Watamu Mida creek area. The research also reviewed the existing policy and legal framework and identified various challenges for the mandated institutions in law enforcement. A review of the available Acts and polices specifically regarding shoreline protection and mangrove conservation was undertaken highlighting the challenges of each institution. There is a need for the mandated institutions to come together to review areas where there are overlapping mandates on the management and use of these resources. In addition the study also incorporate the opinion and knowledge of all local stakeholders who work and live in the area in order to triangulate what the problems are, and what needs to be done in future, in order to come up with a more sustainable and practical management plan. The study suggested a number of practical recommendations for the future conservation of; the mangrove forest, the protection of the shoreline through improvements to the existing policies for sustainable management of the coastal environment in Watamu Mida creek.

This research also highlights the use of remote sensing and Geographical Information System tools to measure and quantify shoreline erosion rates along the Watamu shoreline. The results should help stakeholders to take informed decisions to protect the shoreline from being eroded and further degraded. The methodology used to measure the shoreline change rates and assess the land use change and mangrove dynamics is applicable to other parts of the coast in Kenya. These tools and techniques should form a key part of any methodology to assist improve land use planning to minimize future negative impacts of land use change on the shoreline. The major conclusions from the thesis are summarized under each specific objective below.

Specific objective one

Determine changes in land use and mangrove dynamics between the periods of 1969-2010.

The impact of land use change in Watamu Mida creek area as assessed in this study revealed a decline in most coastal vegetation cover types from 1969 to 2010. These included; mangroves and conversion of land use types which were under miscellaneous coastal vegetation or coastal bush and thickets with trees into; settlement, urbanization and tourist facilities such as hotels and holiday houses. The expansion of urban areas, hotels and private holiday houses resulted in the conversion of land cover which was dominated by old trees and cash crop trees such as; coconut, palms, cashew trees, fruit trees, and fodder crops. A considerable increase in barren land, town, private holiday houses and hotels was observed between the periods 1989 to 2010.

The research identified that mangrove cover had declined by (16%) between 1969 and 1989. However the most recent cover record (2010) showed an increment of 165.5 ha when compared with the 1989 cover data. Hence the highest cover loss was observed between 1969 and 1989, which was -337.8 ha. This study compared a number of general equations to derive biomass and carbon values for the Mida creek mangrove forest. The above ground biomass estimated for each year was: 613,661.3 ton (1969), 502,964.2 ton (1989) and 551,975.3 ton (2010). Therefore the change in the biomass between 1969 and 1989 was 110,697.1 ton while the change in biomass between 1969 and 2010 was only 61,686 ton. This study identified the overall trends of the mangrove cover for the last 41 years, and in general the current mangrove cover has improved since 1989 as compared

with 2010 (1452.5 ha to 1655.7 ha). On the other hand, it was observed that there is selective cutting of matured mangrove poles mainly; *C. tagal, B. gymnorrhiza*and *R. mucronata,* leading to a decline in these species.

While there remain technical questions about the value of each equations used, it is clear that the study has highlighted a number of specific lines of enquiry for further study. These lines of enquiry will need to be thoroughly investigated if this important site is to be maintained both to maximize future use by local communities, as well as sustain the biodiversity and tourism values for future generations.

Specific objective two

Measure the rate of shoreline change and define the drivers of shoreline erosion and accretion.

Watamu beach is one of the key tourist beach destinations in Kenya with stunning white beaches and a large variety of bird and marine life. The livelihood of the local people also largely depends on income generated from different tourism activities. This study has demonstrated that almost 69% of the beachfront has undergone erosion in the period 1969-2010. The use of DSAS to calculate long term shoreline change was found to be very useful. A study of this kind is very valuable in helping to provide evidence for strategic coastal management planning and for future policy interventions.

Both natural and anthropogenic factors were observed to contribute to shoreline erosion and accretion. However, the influence of human actions on accelerating shoreline erosion is a major concern. Construction of hotels or houses near the High Water Mark, sea defense structures or sea walls to combat beach erosion, high trampling effects on the

beach due to tourism activities, and destruction of vegetation along the beachfront were all observed to be aggravating shoreline erosion. These can all be easily observed when comparing areas covered by; indigenous coastal vegetation, under rehabilitation/ protection, and without coastal defensive structures.

In Kenya there are several parliamentary Acts and supporting legislation to protect and conserve riparian areas and marine environments. However, there is a problem of law enforcement and lack of monitoring specifically on the 60 meter set-back regulation to prevent construction within such areas. Therefore, it will be advantageous if all institutions with responsibilities for such coastal areas were to work in collaboration so as to keep the coastline and its marine life and resources from further damage and erosion. Rehabilitation of the shoreline with indigenous coastal vegetation is a good practice which needs to be replicated along the beach where major shoreline erosion is a problem. The implication of the study is there should be a multi stakeholder discussion on the aesthetics of Watamu as a major tourist destination, focusing on different shoreline protection practices, namely building of sea walls or, rehabilitation using natural vegetation protection techniques.

Specific objective three

Determine the natural and human-induced drivers of land use changes, mangrove dynamics and shoreline changes.

The research found that the change observed in land use and conversion was mainly due to an increase in human population, migration from the other part of the country in search of employment and, business opportunities arising from the ever increasing tourism

industry in the area. Population and policy were found out to be the major driving forces of changes in land use. The general trend observed in the study area indicated a rapid change in land use and conversion of remnant coastal vegetation cover and farmland settlements into tourism facilities such as; private houses, resorts and hotels. This has led to some uncontrolled developments which have negatively affected the coastal environment and reduced the area under local settlement. These trends have led to further fragmentation of land, and degradation of the vegetation cover in the area. In addition there has been a loss of cultural values which were attached with the farmland settlement land use type. Currently quite a number of old farmlands have been sold to foreigners and the land is being converted into resorts and holiday houses.

The impact of land use change was also observed along the coastline of Watamu. The study indicated increasing pressure from tourism related developments which harm the general environment including marine life such as sea turtles. Some beach front hotels have leveled the beach to get a better view, coastal vegetation has been cleared and replaced by ornamental trees or left without vegetation cover, which has exposed the sandy beach to increased erosion. The land use change in Watamu Mida creek has also put pressure on the remaining mangrove forest. As settlement has expanded, villages adjacent to the mangrove forest have encroached into the mangrove reserve. Another threat to the mangroves has come from a number of holiday houses which have cleared the mangroves in order to get a better view of the sea. The increasing demand for building materials such as poles and firewood, also puts a high pressure on the mangrove forest.

The majority of the community in Watamu Mida creek area earn their livelihood from tourism related activities such as; safari sailing, curio vending, providing boats for tourists, boardwalks in the mangroves, providing local services to tourists, and direct employment from hotels. The growing tourism industry has also contributed towards the national Gross Domestic Product (GDP) of the country and it should be encouraged. The implication of the study is there is a need to have a clear management and implementation plan, which considers the current conservation status of the coastal environment in balance with the needs of the local people.

Specific objective four

Assess the role of relevant government and community level policies and strategies on land use and shoreline management.

Policy instrument review of the existing policy and legal framework indicated a number of gaps and opportunities for the protection of the coastal environment in the study area. Except the Coast Development Authority Act 1990, and Environmental Management Co-ordination Act 1999 there are no direct Acts, Regulations or policy documents which address the issue of coastline resource use and management in Kenya. Most of the regulations regarding coastal areas are scattered in a range of resource and sectorial specific Acts and policy documents.

When it came to the institutional settings, there was lack of coordination and overlapping mandates between, or amongst, institutions on the same resources use and management, lack of law enforcement, political influence, lack of manpower in these same institutions, lack of a clear management plan for the area. These conditions created gaps in the

existing Acts which hampers implementation and results in a lack of practical guidelines for officers on the ground. Several hotels have been built along the shoreline (within the setback measures or the high water mark), and some hotels have built seawalls to reduce the effect of erosion yet there is no regulation to control such construction.

The outcome of the study is that, mandated institutions in the area such as; the Kenya Wildlife Service and Kenya Forest Service, as well as other offices like, the National Environmental Management Authority (NEMA) and the Ministries of Tourism, and Fisheries Department, have responsibilities to make sure that tourism developments are carried out without compromising the environmental, cultural values and social diversity of the area. Policies and regulations which are not currently implemented need to be updated based on the current pressure-state situation, and there should be strong law enforcement and strict regulation to control any unplanned developments along the coast and in the neighboring hinterland. This study recommends firm action needs to be taken to control unplanned and unregulated changes before it is too late.

5.2 Recommendations

1. There is a need to have a resource management plan with community involvement which demonstrate the responsibilities of each institution in the plan and the roles of all stakeholders in implementation. There is also a need to have much fuller discussion with the surrounding eleven local communities to decide what future management is best for the biodiversity conservation, tourism potential and community interest/needs in the Mida creek area.

2. There also needs to be a way to share the profits coming from Park fees with the community to ensure they will consider the resources as their own for future protection.
3. Consideration needs to be given to methods to involve the community members to protect mangroves. For example they can work hand in hand with Kenya Forest Services rangers, support community initiatives in planting mangroves, and consider an approach which reduces the high dependency on mangroves and, fishing.
4. Diversification of the livelihoods of the community and searching for new markets for the products they grow should be encouraged. Support for the agricultural sector so that the locals earn income from hybrid cash crop trees (such as fruit trees) needs to be considered. Other livelihood diversification activities such as; poultry, and beekeeping need to be promoted within the area. Promotion of community based ecotourism activities by targeting local tourists within the country also needs to be expanded.
5. Awareness creation programs for the community in the protection of resources as well as cultural values of the area, and finding a way to get school leavers involved for example in training in; hospitality, tourism related activities, vocational training, encouraging entrepreneurship and providing micro finance funding are all options worthy of consideration. These alternatives if developed, will ensure that the youth will have alternative livelihoods during the low tourist seasons.

6. There is a need to consider alternative land uses (e.g. planting of *Cassurina sp*.) in order to meet the increasing demands for building poles and timber, both within local village communities as well as in the expanding hotel and private residence markets. Institutional mandates between Kenya Forest Service and Kenya Wildlife Service need to be fully clarified with urgency, in order for the above management plans for the area to be both approved and supported by these government agencies.

7. The Kenya Wildlife Service needs to inform tourists, tour operators and other stakeholders who have direct relation with the tourism and natural resource sectors about ways to reduce negative environmental impacts. The office needs to improve communication of its activities and educational materials need to be distributed to all the visitors and made available in all hotels, emphasizing respect for the local environment and culture. The involvement of hoteliers in the conservation and protection of the marine and terrestrial resources is critical.

8. The mandated institution (NEMA) needs to stop developments beyond the shoreline side of the high watermark and the construction of seawalls bordering the high water mark. Several hotels along the Watamu shoreline have already been affected by erosion as the result of unplanned construction and development near the high watermark. There is a need to have a comprehensive land use plan and regulatory mechanism particularly for areas which are rapidly

developing in the Watamu Mida Creek area. The plan needs to take into account the growing population pressure and the expansion of tourism sector.

5.3 Future Areas for research

This research has examined the dynamics of the mangrove forest from 1969 to 2010 and estimated the status of the biomass in Mida Creek. There is need for further study on the biodiversity value versus economic value as the outcome of this would have direct implications for an improved management plan for the area. Further study can also be undertaken on each specific species to understand why there appears to be a changing ecology within this mangrove forest with a trend towards the predominance of *C. Tagal* and *R. macronata*. There is also a need for a much fuller discussion with the surrounding eleven local communities to decide what future management is best for the biodiversity conservation, tourism potential and community interest/needs in the area. Finally there is also a research need to identify best alternative livelihood options which can support local communities in a sustainable way especially during low tourism seasons.

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ANNEXES

Household Questionnaires

Part I-General background information

Date: _____

Name of the village _____ County _____

Name of Respondent _____

Name of the interviewer _____

1. Age _____
2. Gender: (1) Male (2) Female
3. Highest education attained

(1) Primary education (2) Secondary education (3) Tertiary education

(4) Informal education (5) none of the above

4. How long have you been living/working here (years)_____?

(1) Less than 40 (2) more than 40 years

5. Total number of family members :Total_____ F: _____ M:_____

6. GPS (coordinate)N: _____E: _____Elevation_____ (m)

PART 2: Livelihood activities

7. What are the livelihood activities that you depend on (*tick all applicable livelihood activities, and rank the top most 3 in order of importance*)

Livelihood activities	Tick all that applies	Rank the most 3 important activities (1=most important,

		2=second most, 3=third most)
Fishing		
Agriculture		
Tourism (*tour guide, boat operator etc.*)		
Livestock keeping		
Seaweed farming		
Beekeeping		
Fish vending (*fresh, fried, sundried, salted…*)		
Curio sellers		
Firewood/charcoal making		
Small-business (*shops/pharmacy….*)		
Craftsmanship (*boat making, carpenter, mason, plumber*)		
Lumbering (*timber and poles*)		
Safari sellers		
Employment (*with formal*		

monthly salary)		
Casual labourer (*in farms, building, factories etc*.)		
Other 1(*specify*)		
Other 2 (*specify*)		

PART: 3 Land use change, the drivers and impact

8. Have you observed any land use change for the last 40 years?

   (1) Yes (2) No

9. If yes what changes have you observed?

   _____

   _____

10. How would you describe the vegetation cover 20-40 years ago and now?

    1_____

    2_____

    3_____

    4_____

11. Since this time (specify the year), what have been the main land use changes which have occurred (specify each land use change with a year and the village where you see lots of change)

    _____

    _____

12. Have the changes affected your livelihood?

(1)Yes (2) No

13. If yes what impact on your household economy have these changes had?

_____

_____

14. In the Watamu-Mida Creek area, in your opinion, where have the most significant land use changes occurred? Please name the village and indicate on the map provided.

_____

_____

Of the factors listed below what have been the most influential that cause the land use change? Describe and explain for example:

	Factors which cause land use change	Most influential	Least influential	Describe the factors
1	Natural factors			
2	Demographic factors			
3	Institutional factors			
4	Political factor			
5	Economic factor			

PART: 4 Change in mangrove forest over the last 40 years

15. Is there any change on the mangrove forest for the last 40 years?

(1)Yes (2) No

16. If yes please explain how has the mangrove area changed since you first settled here (include parents/grandparents) in terms of cover and species variety in the following table?

Change in terms of	Put a tick mark	Details of changes observed
Cover		
Species type		
Area		

17. What brought about these changes? Please list

_____

_____

18. What did you use these mangroves for then, and now? (make a distinction between different types)?

	Mangrove type	Use then	Use now
1	Avicennia marina (Mchu/mtu)		
2	Bruguiera gymnorrhiza (Muia)		
3	Ceriops tagal (Mkanda)		
4	Lumnitzera (Kikanda)		
5	Rhizophora (Mkoko)		

6	Sonneratia (Mlilana/Mpia)		
7	Xylocarpus (Mkomafi)		

19. What do you consider to be the most important advantage of these mangroves (e.g. fishing, breeding sites, other fauna/flora, and livelihood activities) please explain?

    _____

    _____

20. Do you see any type/species of mangroves being endangered at this time (reduced markedly in area)? If so explain the reason and the type

	Mangrove type endangered	Reason
1	Lumnitzera (Kikanda)	
2	Rhizophora (Mkoko)	
3	Sonneratia (Mlilana/Mpia)	
4	Xylocarpus (Mkomafi)	
5	Lumnitzera (Kikanda)	

21. According to your understanding, name which islands that have been mostly damaged and the reason? *Indicate on the base map*

	Name of the island	Previous land use	Current land use	Reason for change
1.				

2.				
3.				
4.				
5.				

22. According to your understanding, name five mangrove areas (villages) that have been mostly damaged and why?

	Name of the village where you have mangrove resource	Strongly damaged	Fairly damaged	Reason for the damage
1.				
2.				
3.				
4.				
5.				

PART: 5 Change in shoreline and erosion/accretion over the last 40 years

23. In your opinion do you think there is any sea level change during the last 40 years?

(1)Yes (2) No

_____

_____

24. Did you see any change along the shoreline/beach for the last 40 years?
    (1)Yes (2) No

25. If yes what changes have you observed in the shoreline next to your house/village?

    _____

    _____

26. What do you think are the reasons for these changes?

    _____

    _____

27. When did you notice these changes (specify each site and time/year)?

	Name of the beach	Less than 20 years ago	More than 20 years ago	Reason for the change
1.				
2.				
3.				
4.				
5.				

28. What specific tree species were present at this site (along the shoreline) the time refers on the table above (less than 20 years ago or more than 20 years ago) and currently

	Historical tree species along the beach	Dominant tree species today
1.		
2.		
3.		
4.		
5.		

29. Where do you think the sea has cut into the land most (i.e. most land loss from erosion)? Please list the name of the beach/area

_____

_____

30. Why do you think this happened at that place?

_____

_____

31. Where do you think the land has moved out towards the sea (i.e. accretion)?

_____

_____

32. Why do you think this happened at that place?

_____

_____

33. Have you ever had to move or change the fish landing sites in Mida Creek or along the beach over the last 40 years?

    (1)Yes (2) No

34. If yes, why?

    _____

    _____

35. What changes and impacts did you see in general after the expansion of private house development and hotels along Watamu beach? Please rank your replay based on the following table.

Effect	Rank
Positive	
Employment creation a. In the hotels b. Self employment such as boat operation	
Income increase because of the increase in tourist or guests	
Benefits from the improvement of infrastructure	
Increase sale of agricultural produce	
Increase sale of curios	
Increase interest of visitors to see community and historical sites	
Employment in private households	
Employment in security services	
Negative	

Shoreline/beach erosion	
Loss of fish landing sites	
Decline in fish catch	
Conflicts between different users	
Social problems such as prostitutions, drug use, school drop outs	
Loss of community land	
Reduced access to beach	
Destruction of natural and community resources in the area	
Loss of community values and culture	

PART: 6 Institutional issues (governments and non governmental agencies)

36. Are you aware of government organization or NGOs working to support the management of marine and various land based resources in your locality?

    (1)Yes (2) No

37. If yes which organizations?

    _____
    _____
    _____

38. How do you evaluate the efforts made to protect both the resource on the land and marine?

	Name of GO or NGOs	On the land	Marine	Evaluation (1= being very effective, 2= being somewhat effective but needs improvement and 3= being Ineffective)
1				
2				
3				
4				
5				
6				

39. What's not achieved so far?

_____

_____

Are you aware of any government rules and regulations that influences land management in your locality?

(1)Yes (2) No

40. If yes please explain which one are you aware of?

_____

_____

41. What are the highest priority issues in your locality that needs intervention?

_____

_____

42. How would you suggest addressing these?

_____

_____

43. Do you believe that the mangrove and associated resources are managed effectively?

    (1) Yes (2) No

44. If no, list the main challenges in managing the mangroves and associated resources effectively

_____

_____

45. Are there any government laws or local by-laws for management of the Mida-Creek mangrove and the activities that take place in or around the creek (i.e. laws for fishing or tourism)?

    (1) Yes (2) No

46. If yes, please list them

_____

_____

47. If yes, how well do the people using the creek for fishing or tourism or any other activity, comply with the laws and regulations?

    (1) Strongly comply (2) Weakly complied (3) Not at all

48. Are there any kind of co-management that exists between government and coastal communities for managing the creek and the mangroves (or other resources)?

    (1) Yes (2) No

49. If yes, what are they, please explain!

_____

50. Do you think there is need to improve the management of the creek?
    (1) Yes (2) No

51. If yes, what do you think should be done to improve management of the creek in terms of strengthening the government's regulatory and institutional frameworks? Explain

CHECKLISTS FOR KEY INFORMANTS

Introduction questions for all key informants;

A. What is your name?
B. Where do you work and what is your position?
C. Please provide a contact number?
D. Please provide an email address?
E. What is your role in terms of managing the marine and coastal recourses in Watamu Mida (reefs/mangroves etc.)?

DISTRICT FISHERIES OFFICERS

1. How many fish landing sites do you have in this Watamu-Mida?

2. What are the most commonly landed fish species/types in this area for the last fisheries catch assessment survey?
3. What are the different types of fishing methods practiced in different fishing grounds (e.g. coral reef fishery, mangrove fishery, sea grass fishery, intertidal fishery, open water/deep sea fishery) in this area?

4. Are there any destructive fishing methods/practices in your area? If yes, what are they and where are they being practiced?

	Destructive fishing methods	Location

5. Describe the different aquaculture (crab fattening, fish farms, prawn farms etc.) in your area, in terms of:
    - What is cultured?
    - Where do they culture (*indicate in the map provided*)
    - Is it profitable to the coastal communities

6. Mention the main land-based activities undertaken in your area (farming (what?), tourism, forestry, etc.)

Main land based activities	Location/ Name of the place	Any damage to the area

7. Which land-based activities have major marine environmental impacts to your area?

8. Provide information on the location of rivers, and dumping points and describe the type of discharged material (wastes)

Location	Dumping site	Type of discharged material/wastes

9. Are there any cases of sea-based sources of marine pollution (include the operational and accidental discharges from tankers and other shipping vessels as well as the fishing boats)? Explain

10. Can you recall any incidence of the occurrence of natural threats such as storms or floods in your area? Explain briefly, where and when the incidence occurred and what the impact was.

Location	Natural treats	Impact

REGULATORY AND INSTITUTIONAL FRAMEWORK

1. Do you believe that the creek and associated resources are managed effectively?

2. What do you believe are the main challenges in managing the creek and the mangroves effectively?

3. Are there any government laws or local by-laws for management of the creek or the activities that take place on or around the creek (i.e. laws for fishing or tourism)?

    a. If yes, please list them.

    b. How well do the people using the creek for fishing or tourism or any other activity, comply with the laws and regulations?

    c. Do you think the laws should be changed to improve management of the creek?

4. Which government institution/s are responsible for management of the creek and marine resources?

5. How effective do you think the government institution/s are in managing the creek and the activities taking place around the reef?

6. What kind of community management or co-management arrangements exists between government and coastal communities for managing the creek?
    a. Do you think these arrangements are more or less effective than the government laws?

7. What do you think should be done to improve management of the creek in terms of strengthening the regulatory and institutional framework?

TOURISM OFFICERS

1. How many tourist hotels/guesthouses do you have in this area*?*

    - Indicate approximate capacity in terms of number of beds
    - Also indicate the number of tourists/guests for each season (low and high) per year (% occupancy)

2. Indicate the types, numbers and location of the dive centres and tour operators in this area.

Type of dive centres	Number	Location

3. Can you estimate the number of beach walkers/sun bathers per season (high - when and low - when) in your area of work
4. What are the main environmental challenges for the future tourism activities?

5. What changes did you observed along the beach side since you started working/living here?

REGULATORY AND INSTITUTIONAL FRAMEWORK

1. Do you believe that the beach, creek and associated resources are managed effectively?

2. What do you believe are the main challenges in managing the reef effectively?

3. Are there any government laws or local by-laws for management of the beach or the activities that take place on or around the beach (i.e. laws for fishing or tourism)?
    a. If yes, please list them.

    b. How well do the people using the beach for fishing or tourism or any other activity, comply with the laws and regulations?

    c. Do you think the laws should be changed to improve management of the beach and its resources?

4. Which government institution/s are responsible for management of the reef and marine resources?

5. How effective do you think the government institution/s are in managing the beach and the activities taking place around the beach?

6. What kind of challenges do the hotels have in carrying out their investment and business activities?

7. What kind of community management or co-management arrangements exists between government, coastal communities and hoteliers for managing the beach?

a. Do you think these arrangements are more or less effective than the government laws?

8. What do you think should be done to improve management of the beach in terms of strengthening the regulatory and institutional framework?

COUNTY COUNCIL AUTHORITY IN MALINDI

1. What is the administrative set up of your county? I.e. how your county is administratively divided? (*How many villages in Watamu-Mida area,*).
2. What is the total county population? (according to current census)

3. List and describe the livelihood economic activities which are done in your area?

4. Mention the main land-based activities undertaken in your area (farming, forestry fishing, tourism...etc)

5. Which land based activities have major marine and coastal environmental impacts to your area?

Land based activities	Marine environmental impacts

6. Describe the environmental challenges (*at land and ocean*) in your area

Environmental challenges	At land	At ocean

REGULATORY AND INSTITUTIONAL FRAMEWORK

1. Do you believe that the beach, creek, mangroves and associated resources are managed effectively?
2. What do you believe are the main challenges in managing the beach, creek and mangroves effectively?
3. Are there any government laws or local by-laws for management of the beach or the activities that take place on or around the beach (i.e. laws for fishing or tourism)?
    a. If yes, please list them.

    b. How well do the people using the beach and creek for fishing or tourism or any other activity, comply with the laws and regulations?

    c. Do you think the laws should be changed to improve management of the creek?

4. Which government institution/s are responsible for management of the beach and marine resources?

5. How effective do you think the government institution/s are in managing the beach and the activities taking place around the mangroves?

6. What kind of community management or co-management arrangements exists between government, coastal communities and hoteliers for managing the beach?
    a. Do you think these arrangements are more or less effective than the government laws?

7. What do you think should be done to improve management of the beach, mangroves and creek in terms of strengthening the regulatory and institutional framework?

Residents who lived along the beach for over more than 40 years

1. What is the total household number along your beach area (name of beach)

2. List and describe the livelihood economic activities which are done by residents along this beach

Name of the beach	Economic activities

3. (a) Describe the environmental challenges (*at land and ocean*) in your area

Environmental challenges	At land	At ocean

(b) What is the mitigation measures, e.g. law enforcements, community awareness etc. that are in place for the environmental problems mentioned above?

Mitigation measures taken	At land	At ocean

4. (a) Are there any environmental changes in the ocean (e.g. hotter/drier summers, more frequent storms, increased oil pollution, etc.) that people have noticed over the past 40years?

(b) Do people think any of these changes have affected fishing and tourism or any of their other livelihood activities?

If yes, explain

4. Are there any changes along the shoreline/beach over the last 40 years? If so what change did you observe? What are the main causes?

Name/ location of the beach	Change observed	Main causes

5. Are there any major land use change in Watamu-Mida creek area for the last over 40 years? If yes please list the change and major drivers/reasons of changes.

Name/ location of the beach or village land use change occurred	Land use change observed	Main causes

6. Are there any major change in the size and quality of mangrove forest for the last over 40 years? If yes please list the reason.
7. What were the species of trees dominated along the beach before the expansion of the hotel investment?

KWS officer

1. How many visitors do you record annually in Watamu Marine Park and the Reserve?

Year range	Number of visitors	Watamu Park	Watamu Reserve	Diving
1968-78				
1979-89				
1990-2000				
2001-2011				
2012 to current				

2. What are the main environmental challenges observed since the formation of the Park and Reserve?
3. How is KWS managing this challenge?
4. What are the main endangered species and marine resources?

5. What other positive and negative impacts of tourism on this area?

	Positive impact	Negative impact	Causes of change	Ranking of importance
Watamu Park				
Watamu Reserve				

REGULATORY AND INSTITUTIONAL FRAMEWORK

1. Do you believe that the beach, creek, mangroves and associated resources are managed effectively?

2. What do you believe are the main challenges in managing the beach, creek and mangroves effectively?

3. Are there any government laws or local by-laws for management of the beach or the activities that take place on or around the beach (i.e. laws for fishing or tourism)?
   a. If yes, please list them.

   b. How well do the people using the beach and creek for fishing or tourism or any other activity, comply with the laws and regulations?

c. Do you think the laws should be changed to improve management of the creek?

4. Which government institution/s are responsible for management of the beach and marine resources?

5. How effective do you think the government institution/s are in managing the beach and the activities taking place around the mangroves?

6. What kind of community management or co-management arrangements exists between government, coastal communities and hoteliers for managing the beach?
   a. Do you think these arrangements are more or less effective than the government laws?

7. What do you think should be done to improve management of the beach, mangroves and creek in terms of strengthening the regulatory and institutional framework?
8. Within the Mida-creek area there are overlapping mandates for management responsibilities between KWS, KFS and the local communities. How do you think this can be resolved in future?

NEMA Officer

1. Which land-based activities have major marine environmental impacts to your area?

2. Provide information on the location of rivers, and dumping points and describe the type of discharged material (wastes)

Location	Dumping site	Type of discharged material/wastes

3. Are there any cases of sea-based sources of marine pollution (include the operational and accidental discharges from tankers and other shipping vessels as well as the fishing boats)? Explain

4. Can you recall any incidence of the occurrence of natural threats such as storms or floods in your area? Explain briefly, where and when the incidence occurred and what the impact was.

Location	Natural treats	Impact

REGULATORY AND INSTITUTIONAL FRAMEWORK

8. Do you believe that the creek and associated resources are managed effectively?

9. What do you believe are the main challenges in managing the creek and the mangroves effectively?

10. Are there any government laws or local by-laws for management of the creek or the activities that take place on or around the creek (i.e. laws for fishing or tourism)?

    a. If yes, please list them.

    b. How well do the people using the creek for fishing or tourism or any other activity, comply with the laws and regulations?

    c. Do you think the laws should be changed to improve management of the creek?

11. Which government institution/s are responsible for management of the creek and marine resources?

12. How effective do you think the government institution/s are in managing the creek and the activities taking place around the reef?

13. What kind of community management or co-management arrangements exists between government and coastal communities for managing the creek?
    a. Do you think these arrangements are more or less effective than the government laws?

14. What do you think should be done to improve management of the creek in terms of strengthening the regulatory and institutional framework?
15. NEMA is responsible for leading an Integrated Coastal Zone Management Strategy in the area. Please explain how you are implementing this and who are the main partners?

NEMA Role	Partner Role	Strategic objective

KFS/ DISTRICT NATURAL RESOURCE OFFICERS

1. Which land-based activities have major marine environmental impacts to your area?

2. Provide information on the location of major tree plantation /natural forest cover and describe the contribution to environmental protection in the area?

Location	Tree cover/forest type	Environmental function

3. Can you recall any incidence of the occurrence of natural threats such as storms or floods in your area? Explain briefly, where and when the incidence occurred and what the impact was.

Location	Natural treats	Impact

4. What are the different roles between governments managed forest and community managed forest?

Forest Location/type	Government roles	Community roles

5. What is the status of the mangrove forest compared with 40 years ago (based on the data you have in your office)?
6. What are the major threats of the mangrove forest?
7. Which mangrove type is endangered and what is the reason?

Mangrove type	Cause of deforestation/endangered

8. Do you think the change in the shoreline/erosion is related with mangrove deforestation? If yes how?

REGULATORY AND INSTITUTIONAL FRAMEWORK

9. Do you believe that the creek and associated resources are managed effectively?

10. What do you believe are the main challenges in managing the creek and the mangroves effectively?

11. Are there any government laws or local by-laws for management of the creek or the activities that take place on or around the creek (i.e. laws for fishing or tourism)?

    a. If yes, please list them.

    b. How well do the people using the creek for fishing or tourism or any other activity, comply with the laws and regulations?

    c. Do you think the laws should be changed to improve management of the creek?

12. Which government institution/s are responsible for management of the creek and marine resources?

13. How effective do you think the government institution/s are in managing the creek and the activities taking place around the reef?

14. What kind of community management or co-management arrangements exists between government and coastal communities for managing the creek?

15. Do you think these arrangements are more or less effective than the government laws?

16. What do you think should be done to improve management of the creek in terms of strengthening the regulatory and institutional framework?
17. Within the Mida-creek area there are overlapping mandates for management responsibilities between KWS, KFS and the local communities. How do you think this can be resolved in future?

For NGOs who work around Watamu-Mida creek area

1. Which land-based activities (land uses) have major marine environmental impacts to your area?

2. Provide information on the location of major tree plantation /natural forest cover and describe the contribution to environmental protection in the area?

Location	Tree cover/forest type	Environmental function

3. Can you recall any incidence of the occurrence of natural threats such as storms or floods in your area? Explain briefly, where and when the incidence occurred and what the impact was.

Location	Natural treats	Impact

4. What are the different roles between government managed forest and community managed forest?

Forest Location/type	Government roles	Community roles

5. What is the status of the mangrove forest compared with 40 years ago (based on the data you have in your office)?

6. What are the major threats of the mangrove forest?

7. Which mangrove type is endangered and what is the reason?

Mangrove type	Cause of deforestation/endangered

8. Do you think the change in the shoreline/erosion is related with mangrove deforestation? If yes how?

9. What, if any, impact, have you seen from coastal tourism activities on the Watamu/Mida creek area which may not have been included in the above questions?

REGULATORY AND INSTITUTIONAL FRAMEWORK

10. Do you believe that the creek and associated resources are managed effectively (please list either negative/positive) ?

11. What do you believe are the main challenges in managing the creek and the mangroves effectively?

12. Are there any government laws or local by-laws for management of the creek or the activities that take place on or around the creek (i.e. laws for fishing or tourism)?

    If yes, please list them.

13. How well do the people using the creek for fishing or tourism or any other activity, comply with the laws and regulations (provide examples) ?

14. Do you think the laws should be changed to improve management of the creek (please specify which laws and how they should be modified)?

15. Which government institution/s are responsible for management of the creek and marine resources?

16. How effective do you think the government institution/s are in managing the creek and the activities taking place around the reef?

17. What kind of community management or co-management arrangements exists between government and coastal communities for managing the creek?

18. Do you think the above mentioned arrangements (question 17) would be more or less effective than the current management regime? Explain why?

19. What do you think should be done to improve management of the creek in terms of strengthening the regulatory and institutional framework?

20. Within the Mida-creek area there are overlapping mandates for management responsibilities between KWS, KFS and the local communities. How do you think this can be resolved in future?

21. Do you have any other ideas on how to improve collaboration between the various stakeholders within the Watamu-Mida creek area for future planning and implementation?

For Focus Group Discussion for different resource user groups:

Objective for each FGD discussion: to ascertain local stakeholder perspectives on land use change, shoreline erosion and mangrove dynamics and whether the drivers of these changes are human induced or 'naturally occurring'.

Six FGDs will be conducted using the primary set of questions below. Responses from these will then be triangulated for verification purposes.

1. After examining the maps of change provided by the researcher, please indicate what you as a group consider to be the main drivers (causes) of each of the above items (land use change, shoreline erosion and mangrove dynamics)
2. Please rank these drivers in order of importance, where the rank represents the degree of impact resulting from each specific driver.
3. Considering the last 40 years, in your opinion for each of the above items, please indicate any individual year, or sequence of years, when the speed of this change was most noticeable. Please explain your reasons in each case.
4. Looking towards the future, what do you consider to be the most important actions which you as a community can take to minimize future human induced changes in the above mentioned items? Please explain the reasons for your responses in each case.
5. Apart from actions which you as a community may take, who else may be responsible for undertaking such actions? Please explain the reasons for your choices in each case.
6. In every society there are always some people with specific knowledge about their environment, can you indicate who in your community is most knowledgeable about the natural environment and what indicators (measures or methods) are used for measuring changes noticed in this area?
7. If a significant change in the environment is noticed by one or more of your community members, how does this information get passed along to others in the community?

8. Does your community have a method/way of decision making which may be needed as a result of question number 7 above?
9. Within the Watamu-Mida creek area there are overlapping mandates for management responsibilities between KWS, KFS and the local communities. How do you think this can be resolved in future?
10. How well do the people using the Mida creek for fishing or tourism or any other activity, comply with the government laws and regulations (please provide examples)?
11. What changes and impacts did you see in general after the expansion of private house development and hotels along Watamu beach? Please rank the positive or negative effect based on the table provided below.

Multiple regression analysis result

Predictor variables	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
Intercept	11479.7751	37.43938939	306.6229255	4.27418E-66
Population	-0.012639739	0.000382387	-33.05482387	1.31553E-29
Policy	-185.339058	25.29190063	7.328000404	8.89021E-09
Rainfall	0.178351563	0.397814293	0.448328695	0.656461979