ASSESSMENT OF THE STATUS OF MANGROVE VEGETATION AND THEIR DEGRADATION IN RUFIJI DELTA IN TANZANIA

BY

LEONARD PETER

(10361135)

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN GEOGRAPHY AND RESOURCE DEVELOPMENT

JUNE, 2013

DECLARATION

I declare solemnly that this research work has never been presented to any university / institution. It is mine and to the best of my knowledge. All other works apart from mine which were used have been fully acknowledged.

SIGNATURE: ……...................................

DATE: ………………………………..

LEONARD PETER (10361135)

(STUDENT)

SIGNATURE: …………………………

DATE: ………………………………

DR. EMMANUEL MORGAN ATTUA

(PRINCIPAL SUPERVISOR)

SIGNATURE: …………………………

DATE: ………………………………

DR. ALEX BARIMAH OWUSU

(CO-SUPERVISOR)

DEDICATION

This research is dedicated to the Almighty God, St. Augustine University of Tanzania, the Gallagher's family (Ireland), and my loving, caring and industrious parents whose efforts and sacrifice have made my dream of having this degree a reality. Words cannot adequately express my deep gratitude to you. I pray you will live long to reap the fruits of your labour.

ACKNOWLEDGEMENT

I thank the Almighty God for his immense love and protection through my success. I acknowledge your great provisions, protections and support throughout the duration of this course. I heartily express my genuine thanks to St. Augustine University of Tanzania, Rev. Fr. John Gallagher SMA, and my family for their moral and material supports they gave me during my study at this university.

I cannot but sincerely appreciate the constructive suggestions, criticisms and encouragement of my supervisors in persons of Drs. Emmauel M. Attua and Alex B. Owusu. I also genuinely show my appreciation towards them for their tolerance and readiness to correct me whenever I went wrong. I really convey my heartfelt gratitude to Mr. Jacob Doku Tetteh for his moral and material supports he provided me in the RS and GIS Laboratory.

It is impossible to credit all the lecturers at the department of Geography and Resource Development who have directly or indirectly contributed to this study. However, I specially wish to thank Prof.Owusu (Head of department), Prof. Yankson, Prof. Songsore, Prof. Addo, Prof. Gyasi, Prof. Asiedu, Dr. Teye, and Mr. Kufugbe who provided help in many ways regarding my studies at the University from August, 2011 to June, 2013. I deeply thank my colleagues in persons of Eric Afornorpe, Charles Osei, Evans Yeboah, Musa Abudu, William Asamoah, Prince Amegbor, Saviour Zikpi, Joseph Mihaye, Vicent Asamoah, William Ofosu, Sarah Ehlinger, Hannah Somma Sono and Lucia Kafui. I will miss you all. I wish to thank my respondents who wisely responded accordingly.

In a special way, I thank Mr. Mbwambo (MNRT), Mr. Kitale (MMP), Mr. Baraka (TCMP), and all Village Executive Officers in the Rufiji Delta. Generally, without the help of those named and unnamed respondents, this research would not be completed. Thank you for your contributions.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

AOI – Area of Interest

DDT – Dichloro Diphenyl Trichloroethane

EIA – Environmental Impact Assessment

ENVI – Environment for Visualization of Images

ETM+ – Enhanced Thematic Mapper

FAO – Food and Agriculture Organisation

FBD – Forest Beekeeping Department

FGD – Focused Group Discussion

GCP – Ground Control Point

GIS – Geographic Information Systems

GPA – Global Programme of Action for Protection of the Marine Environment from Land-based Activities

GPS – Global Positioning System

ICM – Integrated Coastal Management

IMS – Interim Management Statement

MACEMP – Marine and Coastal Environmental Management Project

MDM – Minimum Distance to Mean

ML – Maximum Likelihood

MMP – Mangroves Management Project

MNRT – Ministry of Natural Resources and Tourism

MSS – Multi-Spectral Scanner

NBS – National Bureau of Statistics

NBS – National Bureau of Statistics

NDVI – Normalized Difference Vegetation Index

NEMC – National Environmental Management Council

NGO – Non-Governmental Organisation

NIR – Near Infrared

NORAD – Norwegian Agency for Development

PCA – Principal Component Analysis

RdMFR – Rufiji delta Management Forest Reserve

REMP – Rufiji Environmental Management Project

RGB – Red Green Blue

ROI – Region of Interest

RS – Remote Sensing

RUBADA – Rufiji Basin Development Authority

RUBEP – Rufiji Bee Project

RUMAKI – Rufiji Delta Mafia Island and Kilwa District

TCMP – Tanzania Coastal Management Project

TM – Thematic Mapper

TNC – Tanzania National Census

TSCR – Tanzania State's Coast Report

UNEP – United Nations Environment Programme

UNESCO – United Nations Educational, Scientific and Cultural Organisation

URT – United Republic of Tanzania

USGS – United States Geological Survey

UTM – Universal Transversal Mercator

VEO – Village Executive Officer

VPO – Vice President's Office

WEO – Ward Executive Officer

WGS – World Geodetic System

WIOMSA – Western Indian Ocean Marine Science Association

WWF – World Wide Fund for Nature (Formally known as World Wildlife Fund)

LIST OF FIGURES

Figure Page

LIST OF TABLES

Table Page

ABSTRACT

Mangroves are among the most degraded ecosystems in the World. This study focused on assessment of the status of mangroves and their degradation in Rufiji Delta. It was guided by the following objectives: to determine the types of use of mangrove resources in Rufiji Delta, estimate the extent of mangroves cover degradation, identify the factors causing mangrove resources degradation and investigate coping strategies of local communities for management of mangrove resources in the study area.

Remote sensing was used for land cover change detection, and Landsat images data of 2000 and 2011 were analysed. Findings indicated that the bareland increased by 7412.8 ha (2.62%), *Rhizophora* dominant improved by 3076.47 ha (1.09%), *Sonneratia* almost pure stands enhanced by 1998 ha (0.71%), *Sonneratia* dominant amplifies by 129.06 ha (0.05%), *Heritiera* almost pure stands increased by 900.45 ha (0.32%), and *Heritiera* dominant added 3872.1 ha (1.37%) between 2000 and 2011. Whereas, *Avicennia* dominant decreased by -1962.9 ha (-0.69%), *Avicennia* almost pure stands reduced by -1681.83 ha (-0.59%), mixture of *Avicennia* and *Ceriops* degraded by -15222.8 ha (-5.38%), and *Ceriops* dominant dropped by -2302.56 ha (-0.81%) within this period of time.

Pressures on mangroves in the Rufiji Delta are mostly human-induced , and it was inferred that direct causes of mangrove resources degradation include tree felling for firewood and building materials(poles and timber), clearance of mangrove areas for agriculture (rice farming), solar salt works, and human settlement (population increase). Other causes include reduction in fresh water flow (both surface and groundwater), flooding, storms, and heavy or increased sedimentation.

To reduce mangrove resources loss in the Rufiji Delta, it is important to focus not only on the management aspect but also to provide more economic alternatives and opportunities to the local communities that will discourage them from over-utilisation of

these resources. In addition, stakeholders (NGOs) should organise more progrmmes on awareness-raising for the people of Rufiji Delta with respect to sustainable use of mangrove vegetation. Further training programmes for various stakeholders especially the local community to address on sustainable mangrove vegetation use and the current widespread mangrove degradation should be implemented.

CHAPTER ONE: INTRODUCTION

1.1: Background to the Study

Studies have shown that there remain only few landscapes on the Earth surface which are still in their natural state. Due to anthropogenic activities, the Earth surface is being significantly altered in some manner and man's presence on the Earth and his use of land had had a profound effect upon the natural environment, thus, resulting into an observable pattern in the land cover over time. It has been reported that global mangrove distributions have fluctuated throughout human history. The area covered by mangroves is influenced by a complex interaction between land position, rainfall hydrology, sea level, sedimentation, subsidence, storms and pest-predator relationships (Dale *et al*., 2009; McLeod *et al*., 2006).

In addition to the above, high population pressure in coastal areas has led to the conversion of many mangrove areas to other uses and numerous case studies describe these mangrove losses over time. Nevertheless, information on the current status and trends in the extent of mangroves at the global level is scarce (FAO, 2006). A study conducted by FAO (2006), indicates that global mangrove area currently equals about 15.2 million hectares, with the largest areas found in Asia and Africa, followed by North and Central America (FAO, 2006).

An alarming 20%, or 3.6 million hectares of mangroves, have been lost since 1980(FAO, 2006). More recently, the rate of net loss appears to have slowed down, although it is still disturbingly high. About 185,000 hectares were lost every year in the 1980s; this figure dropped to some 118 500 ha per year in the 1990s and to 102 000 ha per year (-0.66%) during the 2000–2005 period, reflecting an increased awareness of the value of mangrove vegetation (FAO, 2006).

Although, mangroves are often used for the collection of wood forest products and as a source of subsistence for local populations, removal of wood and non-wood forest products is rarely the main cause of the loss of mangroves. Human pressures on coastal ecosystems and the competition for land for aquaculture and agriculture are largely the causes of decline in mangrove areas as found in Asia, the Caribbean and Latin America (FAO, 2006).

In the last five decades, worldwide mangrove areas have fallen across all regions. Different data sources or survey methods make estimates more problematic, as many nations have high variations of mangrove change (Alongi, 2002). The present annual rate of loss is estimated at just over 2% per year (Valiela *et al.*, 2001). The most recent and comprehensive global assessment of mangrove distribution was conducted by the Food and Agriculture Organization (FAO) of the United Nations which assessed trends from 1980 to 2005. In the 1980s and 1990s the greatest amount of loss occurred, while in the period of 2000 to 2005 the rate had fallen significantly across all regions (FAO, 2007).

Some projections estimate that worldwide mangrove areas will decline by a further 25% by 2025, particularly in developing nations (McLeod et al, 2006). Estimates of mangrove areas vary from several million hectares to 15 million ha worldwide (FAO and UNEP 1981). The most recent estimates suggest that mangroves presently occupy about 14,653,000 ha of tropical and subtropical coastline (Wilkie and Fortuna 2003). Over the last 50 years, about one-third of the world's mangrove forests have been lost (Alongi, 2002).

The greatest human threat to mangroves is the establishment of shrimp aquaculture ponds (Alongi, 2002). Because mangroves are often viewed as wastelands, many developing countries are replacing these forests with agricultural land and/or shrimp aquaculture production (Franks and Falconer 1999). Shrimp aquaculture accounts for the loss of 20% to 50% of mangroves worldwide (Primavera, 1997). World original area lost per year is 2.07% (Valiela *et al.*, 2001).

In the African continent, mangroves cover 3.2 million hectares about 19% of the global coverage. According to the UNEP (2006) they are distributed in three major coastal regions; Western Atlantic (1.5million ha, 49%), Central Atlantic (0.4 million ha, 14%), and Eastern Indian Ocean (1.2 million ha, 37%). In the western Atlantic coastal region of Africa, mangroves stretch from Mauritania in the north-western section of the Atlantic coast to Senegal in the Saloum Delta, Lower Casamance through Guinea Bissau, South Guinea, to the Gulf of Guinea flanking the coastlines of West and Central Africa from Liberia to Angola (UNEP, 2006).

Nigeria has the largest mangroves in Africa located in the Niger delta with up to 1.0 million ha of mangrove stands in this area and plays a critical role in supporting the region's rich wildlife (UNEP, 2006). Mangroves covered countries in eastern Africa include Somalia, Kenya, Seychelles, Tanzania, Madagascar, Mozambique and South Africa (UNEP, 2006). Climatic conditions are predominantly humid and tropical but changes to more temperate conditions towards Angola and South Africa (UNEP, 2006).

In Africa, there is little variation in phyto-geographical distribution of mangroves species across the continent. West Africa and Central Africa have three families with six species including: *Avicenniaceae* (*Avicennia germinans* referred to as white mangroves); *Combretaceae* (*Laguncularia racemosa, Conocarpus erectus*); and *Rhizophoraceae* (*Rhizophora harrisonii, Rhizophora mangle, Rhizophora racemosa* usually called red mangroves). *Rhizophora racemosa* is very dominant in this region with characteristic long and straight poles in pure stands especially in tidal estuaries. While *Rhizophora harrosonii* and *Rhizophora mangle* are small trees and shrubs respectively. In Eastern Africa there are 10 species of mangroves, the dominant species being *Rhizophora mucronata, Ceriops tagal* and *Avicennia marina* (Semesi, 1998) occupying a total of 1.1million ha (Spalding *et al.*, 1997).

African mangroves have been subjected to enormous pressures and threats within the past decades with great losses. For example, over 20% -30% of the mangroves in West and Central Africa have been lost in the past 25years (Ajonina and Usongo, 2001; Ajonina *et al.*, 2005). This is through many factors especially urbanization, urban infrastructural development, quarrying, salt and sand extraction, pollution from industries, agro-chemicals, petroleum and gas exploitation, absence of appropriate legislation, deforestation for fish smoking (Ajonina and Usongo, 2001; Ajonina *et al.*, 2005).

During the past decades, substantial areas of mangrove in West Africa have been converted to other land uses such as the production of salt and rice (FAO, 2005). The shrimp farm industry has been less developed than in other regions, but a few countries have undertaken this activity (e.g. Guinea). Other causes of mangroves loss on this coast are the over-exploitation of resources and urban; and tourism development. In contrast, awareness of the services and benefits provided by mangroves is growing in most western African countries.

Despite this positive note, mangroves in West and Central Africa still have to face major threats, particularly the ever-increasing human pressure on coastal lands (e.g. Cameroon, Guinea and Sierra Leone), the lack of sustainable resource management (e.g. the Congo), and the absence of adequate legislation for mangrove protection , for instance in Cameroon (FAO, 2005). Pollution is also an increasing threat in several countries like Cameroon, Democratic Republic of Congo and Ghana (FAO, 2005).

East Africa mangroves also face additional threats from shrimp aquaculture, the underlying root causes of mangroves degradation in East Africa are associated with population pressure, poor governance, economic pressure in the rural and urban centres, poverty status of local communities, and unequal distribution of resources (FAO, 2005). In addition, factors such as sea level rise and increased sedimentation have affected the fringing mangroves in East Africa (FAO, 2005). These have led to shortage of firewood and building materials, reduction in fisheries and increased coastal erosion, loss of livelihood and increased in poverty (Abuodha and Kairo, 2001). According to a recent assessment of global mangroves, Eastern Africa region has lost approximately 8% of its mangroves cover in the last 25years on average approximately 3,000 ha per year (FAO, 2005).

In Tanzania, mangroves occur almost along the entire coastline of the country which spans for over 1000km from the border with Kenya in the North to the border with Monzambique in the South (Semesi, 1992). About 50% of mangrove area is confined in the Rufiji Delta which is the single mangrove forest in the Eastern Africa region. Other important mangrove areas include the river estuaries and sheltered lagoon of Tanga, Pangani, Wami, Ruvu and Mtwara.

A research conducted by Semesi (1992), reports that the total area covered by mangroves is about 115, 475 ha including those of the Island of Mafia. This account for only 0.3% of the total forested land in Tanzania. However, shortly over a decade later, Wang *et al* (2003) indicates decline area coverage of mangroves to about 108, 138 hectares. According to the Tanzania State's Coast Report of 2003, Mangroves in Rufiji District (Rufiji Delta) covered 49,799 ha in 1990. After a decade later, mangroves in this district were found covering 48,030 ha (URT, 2003).

1.2: Problem Statement

Mangroves are very important for various reasons, including the provision of a large variety of wood and non-wood forest products; coastal protection against the effects of wind, waves and water currents; conservation of biological diversity, including a number of endangered mammals, reptiles, amphibians and birds; protection of coral reefs, sea-grass beds and shipping lanes against siltation; and provision of habitat, spawning grounds and nutrients for a variety of fish and shellfish, including many commercial species (FAO, 2006).

In Tanzania approximately 150 000 people earn their livings from mangrove vegetation. The Rufiji Delta is the largest estuarine mangroves forest in Tanzania. It contains nearly half of the mangroves in Tanzania. It is one of the most ecologically important areas in this country. It supports a large number of other plants and animals indigenous to mangroves, thus, presenting a unique ecological unit. The literature indicates that approximately 49,799 and 48,030 hectares of mangroves existed in Rufiji district in 1990 and 2000, respectively (Wang *et al.*, 2003).

Despite the fact that, mangrove ecosystems have tremendous value for coastal communities and associated species, they are being drastically degraded by human activities at an alarming rate. Human threats to mangroves include the over-exploitation of mangrove vegetation by local communities, conversion into large scale development such as agriculture (rice cultivation), salt extraction, market oriented policy, energy sources (fuel wood, charcoal) urban development and infrastructure, and diversion of freshwater for irrigation (UNEP, 1994). With the dramatic increases in population in the Rufiji Delta, farmers are cultivating more rice in the delta. This is because the delta has alluvial soil condition that is most suitable for growing rice.

Although, literature indicates that mangroves in Tanzania are reserved by law, legally declared as reserve forests (Holmes, 1995), the capacity to effectively enforce this law has remained a challenge, thus, the mangroves have not been spared. Despite increased awareness about the importance of mangroves and mangrove replanting efforts, which have been promoted by Non-Government Organisations (NGOs), the condition of the mangrove vegetation of Rufiji Delta continue to decline considerably.

Little was found in the literature on the extent of mangrove vegetation degradation or loss of mangroves taking place in the Rufiji Delta . Data on the extent of harvesting of mangrove products in the delta is scanty and inconsistent, but project officials believe legal harvesting is high, and illegal harvesting is even higher (Kulindwa, *et al*., 2001). There is a management plan, but it is not followed effectively (Stedman, 1998). Therefore, this study assessed the status of mangrove vegetation and their degradation in Rufiji Delta. Literature indicates that the local communities living within the mangroves are the primary users of mangrove vegetation.

1.3: Research Questions

i) What are the major mangrove species and their uses in Rufiji Delta?

ii) To what extent are mangroves degraded in the study area?

iii) What major factors are causing mangroves degradation in Rufiji Delta?

iv) What strategies are used by local communities for managing mangrove vegetation?

1.4: Research Objectives

The main objective of the study was to assess the extent of degradation of mangrove vegetation in the Rufiji Delta. The specific objectives were to:

i) Identify the main mangrove species and their usage of mangrove in Rufiji Delta.

ii) Estimate the extent of mangroves cover degradation in the study area from 2000-2011.

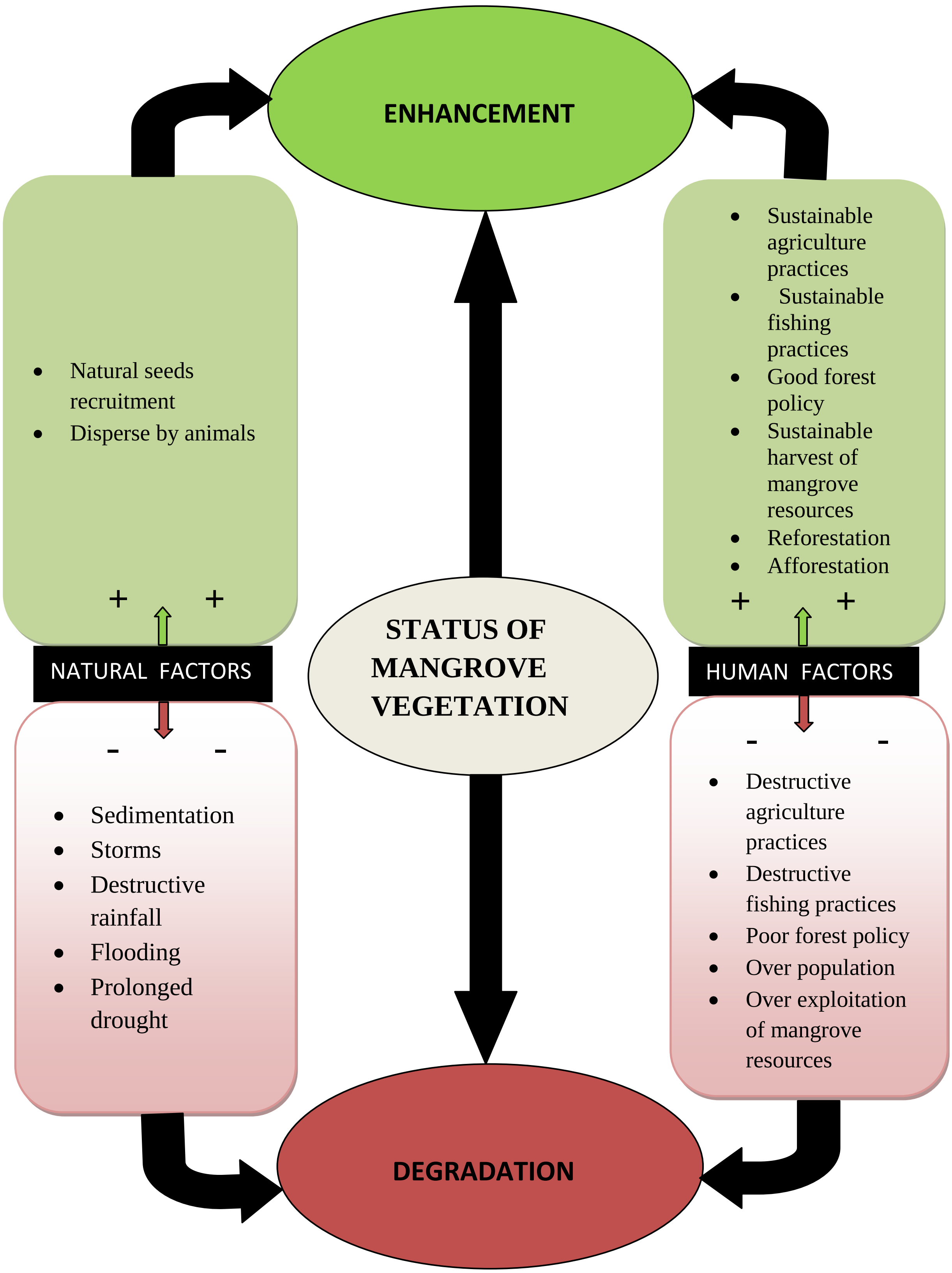
iii) Ascertain the main factors causing mangrove vegetation degradation.

iv) Investigate the strategies used by local communities for management of mangrove vegetation.

1.5: Research Propositions

i) Increase in population correspondingly decrease mangrove vegetation cover in Rufiji Delta.

ii) Mangrove vegetation degradation in Rufiji Delta is as a result of non-enforcement of forest policy and rules in Rufiji Delta.



1.6: Figure 1: **Conceptual Framework Explaining Changes in Mangrove Vegetation**

Source: Author's construct, 2013

The status of mangrove vegetation of a region is an outcome of natural and human factors in time and space. Mangrove vegetation been restored naturally by seeds recruitment and by animal dispersal. Furthermore, man's activities such as sustainable agriculture practices, sustainable fishing practices, and good forest policy have led to enhancement of mangrove vegetation in the world. In addition, anthropogenic practices like sustainable harvest of mangrove vegetation, reforestation, afforestation, among others greatly contribute to mangrove vegetation enhancement.

On the other hand, land is becoming a scarce resource in coastal areas due to immense agricultural and demographic pressure. Therefore, mangrove vegetation have been tremendously reduced over the years due to natural and anthropogenic threats. Although, policy measures in Tanzania and other places are in place to conserve mangrove vegetation, implementation on the ground has not been effective. Also, the conversion of mangrove forests to agriculture and salt pans reduces the amount of mangrove vegetation available to the community. Communities directly depend on fishing as their primary source of income and food becomes poorer as fewer and fewer fish are caught.

Lack of livelihood opportunities and need for increased cash requirement to satisfy the day to day survival needs of their families, the communities are forced to destroy mangroves for expansion of farmlands for rice cultivation. Moreover, gathering of mangroves for poles and firewood which can be sold and as housing materials is rampant among the settlers within the mangrove areas. Furthermore, natural factors such as sedimentation, flooding, storms and prolonged drought lead to mangroves depletion. Hence, information on mangrove vegetation and possibilities for their optimal use is essential for monitoring and managing to meet the increasing demands for basic human needs and welfare resulting out from changing demands of increasing population.

1.7: Research Rationale

In general, the aim of monitoring and managing of any forest is to find a way to ensure its sustainability. Rufiji Delta is more mangroves forested area (50%) of total mangrove vegetation found in Tanzania. Moreover, literature indicates that it is one of the overexploited, because it is close to the pole market centres in Dar es Salaam and Zanzibar (Semesi, 1992). To understand why degradation of mangrove vegetation is dangerous and should be discontinued means that credit must first be giving for the role they play and their impact on the ecosystem. The increase demand for mangrove vegetation in the Rufiji Delta and big cities such as Dar es Salaam and Zanzibar has led to their degradation.

This has resulted in increased mangrove trees consumption for other purposes, modification and alteration in the status of their coverage over time without any detailed and comprehensive attempt to evaluating these changes. Mangroves cover deforestation as been practiced in this area, present multiple societal and environmental problems; and the effect and consequence of mangrove resources degradation is likely to jeopardize life.

1.8: Organisation of the Study

This study is presented in six chapters. Chapter one involves the background of the study, problem statement, research questions, and objectives of the study. Propositions, conceptual framework, and rationale of the study are also presented in this chapter. Relevant literature are captured in chapter two whereas, study area is described in chapter three. The methodology employed to achieve the objectives of the study is described in chapter four. Chapter five is made up of the status of mangrove vegetation and their degradation in the Rufiji Delta. Summary, conclusions, and recommendations are captured in chapter six.

CHAPTER TWO: LITERATURE REVIEW

2.1: Global Distribution of Mangrove and Change

Mangroves are evergreen forest between the land and sea, found essentially in intertidal zones and occupying large tracts along sheltered coasts (Tomlinson, 1986), estuaries and in deltas where they are influenced by tides and widely differing conditions of salinity and rainfall regimes. A "mangrove" has been defined as a "tree, shrub, palm or ground fern, generally exceeding more than half a meter in height, and which normally grows above mean sea level in the intertidal zones of marine coastal environments, or estuarine margins" (Duke 1992). The term "mangrove" can refer to either the ecosystem or individual plants (Tomlinson 1986). For the purpose of this study, mangroves refer to vegetation (plants).

They are usually defined in terms of the distribution of characteristic tree species and found in brackish water on the margin between land and sea but with other definitions of ecological zones. Mangrove forests generally embody two different concepts. The first refers to an ecological group of evergreen plant species belonging to several botanical families but possessing marked similarities in their physiological characteristics and structural adaptation and having similar habitat preferences. The second concept implies a complex ecosystem of plant and animal communities (Kunstadter *et al.*, 1986).

The mangrove system is very dynamic, where changes take place regularly, and within the range of mangrove habitats, most major species grow within a given set of conditions. Mangroves are salt-tolerant forest ecosystems of tropical and subtropical inter-tidal regions. They occur in sheltered coastline areas such as small bays, estuaries, lagoons, creeks and sea channels separating islands and certain locations where the soil conditions are favourable such as mud flats and swamps.

Mangroves survive water logging due to periodic submergence by tides, high solar radiation and strong winds. Being ecologically complex, strictly unique habitat, highly resourceful with vulnerable, ecosystems exhibiting peculiar morphological and anatomical adaptations mangroves have attracted consent from people over last few decades. The mangrove ecosystem is complex, comprising of various species of plants, animals and micro organisms both marine and brackish water, and its structure and functioning is regulated by various environmental factors.

The people living in coastal areas are dependent on these forests as their primary source of income generation, fuel, food, medicine, and other basic necessities such as timber for housing and roofing materials. Wise management of these resources is therefore essential for their sustainable use and for socio-economic welfare of the coastal inhabitants. With the increase of coastal population, mangrove ecosystem is being endangered. Increased coast storms, land erosion, high salinity, and loss of biodiversity will occur unless we approach the problem from different views (Ohn, 2004).

It has been identified that one hundred and twenty-four countries located between 30°N and 30°S are home to highly productive mangrove ecosystems (FAO, 2007). They cover up to 75% of the tropical and subtropical shorelines (Giri *et al.,* 1996; Spalding, 1997). Studies also have indicated that the halophytic evergreen woody mangroves typically fringe the transition zone between land and sea in intertidal coastal regions, estuary, and reef environments, which are characterized by strong winds, varying inundation, high temperatures, and anaerobic muddy soil (Kathiresan *et al*., 2001; Lugo *et al.,* 1974).

Mangroves growing within equatorial regions achieve their maximum biomass. These favourable conditions enable an optimal lush growth, with tree canopies reaching a height of 30–40 m (FAO, 2007; Tomlinson, 1986). Because of the lower temperature level, the amount of biomass declines with increasing latitude (Alongi, 2002; Blasco *et al.,* 1996). Under less favorable environmental conditions, mangroves form isolated patches of dwarf-stunted habitus, with canopies reaching a height of 1–2 m. It is assumed that the total area of mangroves covers between 167,000 km^2 (Valiela *et al.,* 2001) and 181,000 km^2 (Spalding, 1997).

2.2: Mangrove Degradation and Causes

Globally, mangroves today are altered principally by both natural and anthropogenic factors. Hence, in order to use mangrove vegetation optimally, it is not only necessary to have the information on existing mangrove cover but also the capability to monitor and manage the dynamics of mangrove vegetation resulting out of both changing demands of increasing human and natural forces acting to shape the landscape. Mangroves are under threat from human activities at the present time. They are being destroyed at an alarming rate that could potentially lead to many different types of environmental catastrophe, not only at the local level but also globally.

The extent of forest vegetation is the first measure of sustainable forest management. It relates to the overall goal of maintaining adequate forest of various forest types within a country or region. The aim of monitoring the extent and characteristics of mangrove vegetation is to understand and reduce unplanned degradation, restore and rehabilitate degraded forest landscapes. Information on the extent of forest has formed the backbone of all global forest assessments and continued to be a major topic in assessing forest.

The most commonly quoted statistics from the global forest assessments continue to be the global rate of degradation and the net loss of forest area. Approximately 75% of sheltered tropical coasts worldwide were once occupied by mangroves (Chapman, 1976), but today this figure is said to be reduced to 25%. Published data in fact report that between 5% and nearly 85% of original mangrove extent has been lost, particularly during the second half of the 20th century (Burke *et al.*, 2001).

Table 1: A Summary on the Extent of Mangroves from 1980 to 2005 in hectares

STATUS	**1980**	**1990**	**2000**	**2005**
World	18,794,000	16,925,000	15,740,000	15,231,000
Africa	3,670,190	3,427,520	3,217,957	3,160,105
Tanzania	152,000	140,000	127,2000	125,000
Rufiji Delta	51,568	49,799	48,030	

Sources: TSCR, URT (2003) and FAO (2006)

The globally determining factor of mangrove loss is affected by the conversion of mangrove areas into shrimp farms (Dahdouh-Guebas, 2002; Primavera, 2005 and 2006). The share of aquaculture-based business is still very high in developing nations (Seto *et al.*, 2007). This portion accounts for a global mangrove loss of more than 50% (Walters *et al.*, 2008). Industrial lumber and wood chip operations (Walters *et al.*, 2008), increasing human populations, industrialization, and agriculture have caused dramatic forest loss as well (Gilman *et al.*, 2008). In addition to the natural progression and succession stages of the ecosystem, a significant amount of the loss is triggered by natural forces, such as tsunamis, cyclones (Chan, 2009), and the threat of global warming (Krauss *et al.*, 2008). The related reduction in mangrove-related services and product delivery imposes serious limitations on the local residents (Walters *et al.*, 2008).

Anthropogenic and natural threats have an effect on marine life and on terrestrial biological diversity, as well as on adjacent ecosystems, such as sea grass beds and coral reefs (Krauss *et al.*, 2008). As a consequence of the loss of mangroves, the natural tidal system is altered or totally disturbed: tidal creeks are blocked, fisheries decline, sedimentation rates decrease, and toxic waste pollution, such as antibiotic impact from aquaculture grows (Thu *et al.*, 2007). Additional problems include salinization of coastal soils, increased erosion, land subsidence, land degradation, and extended exposure of coastlines to wave surges (Thu *et al.*, 2007).

Reforestation and rehabilitation programs geared toward the sustainable use of mangroves have been successful to some extent (Meza *et al.*, 2003). One of the most important and global-acting programmes is the Ramsar Convention on Wetlands. This is an inter-governmental treaty, which provides the framework for national action and international cooperation for the wise use of wetlands and their resources (http://www.ramsar.org/). Important sites, such as the Sundarbans, the world's largest area of mangroves, are affiliated with this programme.

Mangroves have been extensively studied for decades by botanists, ecologists and marine scientists (Macnae, 1968; Chapman, 1976; Saenger *et al.*, 1983; Tomlinson, 1986; Kathiresan and Bingham, 2001; Lacerda, 2002). Yet, it was not until the 1980s and early 1990s that significant research attention was brought to bear on the human interactions with these unique-forested wetlands (FAO, 1985; Hamilton *et al.*, 1989; FAO, 1994; Cormier-Salem, 1999). Earlier works were mostly descriptive, documenting the status and uses of mangroves by coastal communities (e.g., Walsh, 1977; Taylor, 1982; Christensen, 1982; Kunstadter *et al.*, 1986; Field and Dartnall, 1987; Diop, 1993; Lacerda, 1993). By contrast, recent research on mangroves is more analytical, examining humans as ecological agents of disturbance and change in mangrove vegetation.

Population pressure is typically greatest along the coast, so it is not surprising that human influences on the world's mangrove forests are significant and growing. Moreover, mangroves have been cleared and degraded on an alarming scale during the past four decades (Valiela *et al.*, 2001; Wilkie and Fortuna, 2003; Duke *et al.*, 2007), yet they remain an important source of wood and food products, and provide vital environmental services for coastal communities throughout the tropics (Balmford *et al.*, 2002). These values still receive relatively little attention or recognition from government policy-makers and the development community, and the myriad of influences people have on these mangrove forests which are overlooked by many mangrove researchers.

Non-timber forest products are recognized as important economic resources, particularly to rural and marginalized communities (Vedeld *et al.*, 2004). Many coastal communities in the tropics are characterized by relative geographic isolation, chronic poverty and significant dependence on the harvest of marine and coastal resources for their livelihood (Kunstadter *et al.*, 1986). The majority of people living in or near mangrove areas derive their principal income from fishing and related activities.

The direct harvest of mangrove wood and plants is really a full-time occupation for them, but many of them rely on these products to meet subsistence needs for fuel and construction materials, and for others the harvest and sale of mangrove forest products is an important income supplement (Christensen, 1982; FAO, 1985, 1994; Kunstadter *et al.*, 1986;Diop, 1993; Lacerda *et al.*, 1993; Spalding *et al.*, 1997; Glaser, 2003; Walters, 2005a; Lopez-Hoffman *et al.*, 2006; Ro¨nnba¨ck *et al.*, 2007a).

The two most widespread uses of mangrove wood are for fuel and construction. Many common mangrove tree species, e.g., *Rhizophora* species produce wood that is dense, hard and often rich in tannins (FAO, 1994; Bandaranayake, 1998). Such wood burns long and hot, and so is highly attractive for making charcoal or consuming directly as firewood (Brown and Fischer, 1918; Chapman, 1976; Christensen, 1982, 1983b; Taylor, 1982; Bhattacharyya, 1990; Ewel *et al.*, 1998a; Walters, 2005a; Dahdouh- Guebas *et al.*, 2006a). The harvest of mangrove for fuel wood is widespread throughout the coastal tropics.

Although, this is less common today because of the ready availability of alternative fuels, like natural gas and electricity, and policies aimed at discouraging mangrove cutting (Lacerda *et al.*, 1993; Naylor *et al.*, 2002; Walters, 2003). Nonetheless, remote coastal communities in many parts of the tropics continue to depend heavily on mangrove wood for domestic fuel wood consumption, and commercial markets that sell mangrove charcoal to nearby towns and urban centers are not uncommon (Untawale, 1987; Walters and Burt, 1991; Alvarez-Leon, 1993; Allen *et al.*, 2000; Dahdouh-Guebas *et al.*, 2000b; Glaser, 2003)

Mangrove wood is widely used in coastal communities for residential construction (posts, beams, roofing, and fencing) and to make fish traps/weirs (Adegbehin, 1993; Alvarez-Leon, 1993; Rasolofo, 1997; Ewel *et al.*, 1998a; Semesi, 1998; Kovacs, 1999; Primavera *et al.*, 2004; Walters, 2004). Fronds from the mangrove ‘‘nipa’’ palm (Nypa fruticans) are particularly valued in Southeast Asia for use in roofing and as thatch in walls and floor mats (Aksornkoae *et al.*, 1986; Fong, 1992; Basit, 1995; Spalding *et al.*, 1997;Walters, 2005a). Mangrove wood is also used in some countries for building boats, furniture, wharf pilings, telegraph poles, construction scaffolding, railway girders and mine timbers (Walsh, 1977; Mainoya *et al.*, 1986; Adegbehin, 1993; Bandaranayake, 1998; Primavera *et al.*, 2004; Lopez-Hoffman *et al.*, 2006).

2.3: Managing Mangrove Land Cover

Mangrove vegetation are unusual environments in that they are located between dry land and shallow marine and brackish water. This characteristic introduces complexities to planning and management because of competing and overlapping interests in mangrove lands and their resources. In short, mangroves are valuable coastal lands to various forest users and land developers, each one having incentive to claim and control access through degrees of privatization. But this tenure dynamic changes because marine and estuarine waters in mangroves as elsewhere are typically viewed as open access transportation corridors for fishing boats, and the diverse fish and crustaceans within these waters are usually treated as a common property resource available for harvest by local fishermen.

These complexities are often mirrored in government policy. Until recently, most governments considered mangroves to be relatively worthless swamp lands, so rational policy guiding their management has in most cases been late in coming. Being part land and part sea, jurisdictional ambiguities are often present. For example, regulation of mangrove forest lands in the Philippines has historically fallen under the legal jurisdiction of both the Department of Environment and Natural Resources (formerly the Ministry of Forests), whose mandate was to protect and sustainably manage these as forests, and the Department of Agriculture, whose mandate was to promote brackish water aquaculture development in these same areas (Primavera, 2000a, 2005; Walters, 2003).

Thus, government decisions concerning mangroves were often made with ‘‘the right hand not knowing what the left hand was doing’’ (Primavera, 1993, p. 168). Similar problems of jurisdictional ambiguity over mangroves have been documented in Ecuador (Meltzoff and LiPuma, 1986), India (Bhatta and Bhat, 1998; Dahdouh-Guebas *et al.*, 2006a), Thailand (Vandergeest *et al.*, 1999), Sri Lanka (Dahdouh-Guebas *et al.*, 2000a, b), Indonesia (Armitage, 2002) and Brazil (Glaser and Oliveira, 2004). But such ambiguities go beyond government policy and affect informal understandings and customary rules concerning access and use of mangroves by different users.

Customary use of mangroves is typically characterized by common access rights, with different uses overlapping but to a large degree accommodating one another (Bhatta and Bhat, 1998; Walters, 2004). Conflict in such situations can arise, for example, where customary boat access or seine fishing rights become impaired by the construction of a dyke or the planting of mangrove trees (Walters, 2004), or where resident mangrove fishers and wood users are forced to compete with outsiders for the same resources (Glaser and Oliveira, 2004). The potential for such conflict is exacerbated where large tracts of mangrove are leased to private interests who displace common access users (Bailey, 1988; Dewalt *et al.*, 1996; Stonich and Bailey, 2000; Walters, 2003, 2004; Hoq, 2007).

The issue of shrimp farming is particularly problematic because the large profit potential of these operations creates incentive for corruption of legal mechanisms that might otherwise protect the forests and/or interests of local users (Meltzoff and LiPuma, 1986; Bhatta and Bhat, 1998; Stonich and Vandergeest, 2001; Armitage, 2002; Dahdouh-Guebas *et* *al.*, 2002). In short, conflict is more likely to emerge in the absence of shared understandings about rules of access, clear government regulations, and effective means of enforcement and dispute resolution. Government policy on mangrove vegetation has a tremendous impact on the socio - economic well being of local people. It is necessary to protect the livelihood security of local people for ensuring ecological security of mangrove vegetation in a sustainable manner.

2.4: Application of RS Technology in the Analysis and Management of Mangrove Landscape

The study of mangrove vegetation requires research with respect to the high spatio-temporal dynamism in land cover patterns (marine and coastal changes), in order to assess and predict the extent of anthropogenic impacts or environmental changes. This includes changes in population structure of floral and faunal assemblages, in biodiversity and ecosystem functioning, and in the complexity of their regulation (termed 'biocomplexity'), and in ethnobiological uses. An excellent tool that is increasingly important in the detection, description, and quantification and monitoring of those changes is remote sensing (RS) in combination with geographic information systems (GIS).

The applications of RS and GIS provide various guidelines for the sustainable management of tropical coastal ecosystems, including mangrove forests. It shows how new digital remote sensing technology can be integrated in long-term studies that combine past and present in order to make predictions about the future, and, if necessary, to indicate action to prevent degradation. Remote sensing and GIS have been used to study mangrove forests (e.g. Ramachandran *et al.*, 1998). Also in the study of larger mangrove assemblages, data with a high spatial resolution may reveal relevant details on vegetation structure dynamics (Dahdouh-Guebas *et al.*, 2000b). Such results may be used to predict future changes in vegetation structure (Dahdouh-Guebas, 2001).

A study by Venema *et al* (2005) notes that proper mangroves forest monitoring and management can only be achieved by using remote sensing techniques and creating spatial representations such as maps to know the exact locations and extent of degradation. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). It is also an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest.

Remote sensing is defined by Lillesand and Kiefer (1987) as the science of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with object, area, or phenomenon under investigation. Remote sensing has been determined to be a cost-effective approach to document changes over large areas and even geographic regions and it has been of immense help in monitoring the changing pattern of vegetation (Lunetta *et al.*, 2004).

In some instances, land cover change may result in environmental, social and economic impacts of greater damage than benefit to the area (Moshen, 1999). Therefore, data on vegetation cover change are of great importance to planners in monitoring the consequences of vegetation change on the area. Such data are of value to resources management and agencies that plan and assess vegetation cover patterns and in modeling and predicting future changes. An intensive study by Macleod *et al* (1998) lists four aspects of change detection which are important when monitoring natural resources. These are: detecting the changes that have occurred, identifying the nature of the change, measuring the area extent of the change and assessing the spatial pattern of the change.

The basis of using remote sensing data for change detection is that changes in mangrove cover result in changes in radiance value, which can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computer power. A wide variety of digital change detection techniques have been developed over the last two decades. Coppin *et al* (1996) summarize eleven different change detection algorithms that were found to be documented in the literature by 1995. These include: Mono-temporal change delineation, delta or post classification comparisons, multi dimensional temporal feature space analysis, and composite analysis. Others are image differencing, multi-temporal linear data transformation, change vector analysis, image regression, multi-temporal biomass index NDVI, background subtraction, and image rationing.

Shosheng and Kutiel (1994) investigated the advantages of remote sensing techniques in relation to field surveys in providing a regional description of vegetation cover. The results of their research were used to produce four vegetation cover maps that provided new information on spatial and temporal distributions of vegetation and allowed regional quantitative assessment of the vegetation cover.

Apart from that, Arvind *et al* (2005) carried out a study on land use land cover mapping of Panchkula, Ambala and Yamunanger districts, Hangana state in India. They observed that the heterogeneous climate and physiographic conditions in these districts has resulted in the development of different land use land cover in these districts. An evaluation by digital analysis of satellite data indicates that majority of areas in these districts are used for agricultural purposes. The hilly regions exhibit fair development of reserved forests. It is inferred that land use land cover pattern in the area are generally controlled by agro-climatic conditions, ground water potential and a host of other factors.

Another interesting study on change detection is that of Adeniyi and Omojola, (1999) in their land use land cover change evaluation in Sokoto – Rima Basin of North – western Nigeria based on Archival Remote Sensing and GIS techniques. They used aerial photographs, LANDSAT MSS, SPOT XS/Panchromatic image Transparency and Topographic map sheets to study changes in the two dams (Sokoto and Guronyo) between 1962 and 1986. This work revealed that land use / land cover of both areas was unchanged before the construction while settlement alone covered most part of the area. However, during the post dam era, land use/land cover classes changed but with settlement on earth, affecting the ability of the biosphere to sustain life. Human have become ever more adapt at appropriating and altering the earth's resources for their needs. Intensification and diversification of land use and advances in technology have led to rapid changes in biogeochemical cycles, hydrological processes and landscape dynamics.

The use of remote sensing techniques has great advantages because of their characteristics in the application to monitoring, evaluating and forecasting any change in vegetation. By using remote sensing techniques, the user can grasp the present situation, evaluate processes such as land degradation trends in macroscopic range, and also provide a scientific basis for the prevention and administration of vegetative change. Change detection as defined by Hoffer (1978) means revealing any changes in temporal effects such as variation in spectral response and involves situations where the spectral characteristics of the vegetation or other cover type in a given location change over time. Singh (1989) described change detection as a process that observes the differences of an object or phenomenon at different times.

Generally, many change detection techniques have been developed to detect vegetation change using remote sensing data (Cakir *et al.*, 2006). However, despite the wide diversity of algorithms currently available, all of these techniques can usually be separated into two main categories: post-classification change detection and pre-classification spectral change detection. Post-classification methods involve the independent thematic classification of two different images taken on two different dates. Thematic maps are then further compared and analyzed to map any types of changes uncovered (Jensen, 1996). Pre-classification spectral change detection involves the analysis of transformed images from two different dates.

The transformation of different date images is the product of several specialized operations, among them multi-date image differencing, principal component analysis (PCA), normalized difference vegetation index (NDVI) differencing, among others. The transformed image contains spectral information about the changes taking place within the imagery, which then requires further processing to develop thematic change maps. NDVI differencing is one of the most commonly applied pre-classification change detection techniques (Cakir *et al.,* 2006; and du Plessis, 1999). It utilizes NDVI images in which vegetated areas are spectrally enhanced using ratios or differences between red and near-infrared bands within an image by taking advantage of the different absorbance and reflectance characteristics of vegetation in those bands (Jensen, 1996).

Also areas of change can be identified through subtraction of the NDVI image of one date from the NDVI image of another date. In the resultant NDVI difference image, changes can be detected at the lower-end and higher-end tails of the NDVI difference-image pixel distribution histogram. However, several studies such as of (Klintenberg *et al.,* 2007; Cakir *et al.,* 2006; du Plessis, 1999) have shown that NDVI techniques produce limited discriminating abilities in areas less dominated by vegetative ground cover types.

CHAPTER THREE: STUDY AREA

3.1: Location and Size

The researcher conducted this study in the Rufiji Delta in Tanzania. This delta is located between latitudes 8˚ 20′ 00″, 7˚50′ 00″S and longitudes 39˚10′ 00″, 39˚10′ 00″E. Moreover, it is about 250miles south of the Tanzania’s business capital Dar es Salaam. It is the largest delta in East Africa and it contains the largest estuarine mangrove forest on the Eastern seaboard of the African continent. The Rufiji Delta covers 53,255 ha (Semesi, 1989) and forms part of the Rufiji River basin which extends for some 177,000 km^2 (RUBADA, 1981a). As a result of deposition of sediment carried by the Rufiji River towards the coast, the shoreline has shifted seaward and presently protrudes some 15 km into the Mafia channel (Semesi, 1989).

The north-south extent of the delta is 65 km and its depth inland is approximately 23 km. The Rufiji Delta is divided into three parts namely; Northern Delta which is more forested (17,555.7 ha) comprises 16 villages (about 50% of all villages). The central Delta which is 15,172 Ha forested comprises 9 villages. The southern delta has a total area of 13,526.7 ha; it also comprises 9 villages. The estuary and delta of the Rufiji River seem to be in a state of dynamic equilibrium. The geometry and the course of the several tidal branches changes continuously by sediment deposition and erosion. The morphological conditions are disturbed by changing hydraulic features, such as fluctuating discharges, varying intrusion of salinity, and changes in sediment transport (RdMFR, 2011).

The Rufiji Delta mangroves are the home for migratory wetland birds such as curlew, sandpipers, crab plovers, roseate terns and Caspian terns. Nile crocodiles also share the Rufiji Delta with hippopotamus, otters, and Sykes monkeys. The delta covers extensive intertidal flats, seagrass beds, and sandbars, all ecologically interlinked with the Rufiji River. Yellowfin, wahoo, kingfish, dorado, and red cod swim these waters. Several tidal channels and countless creeks dissect the mangrove swamps through which tidal controlled water flows between mangrove swamps and the Indian Ocean (RdMFR, 2011).

The annual floods of the Rufiji River force fresh water out into the delta, lowering the degree of salinity in the channels. The islands of the delta have been built principally by the mangroves, which via accumulating washed-in silt and their own production of detritus; raise the ground level to form dry land. The Rufiji Delta is one of the most ecologically important areas in Tanzania. The delta supports a large number of other plants and animals indigenous to mangroves, thus presenting a unique ecological unit (Semesi, 1989).

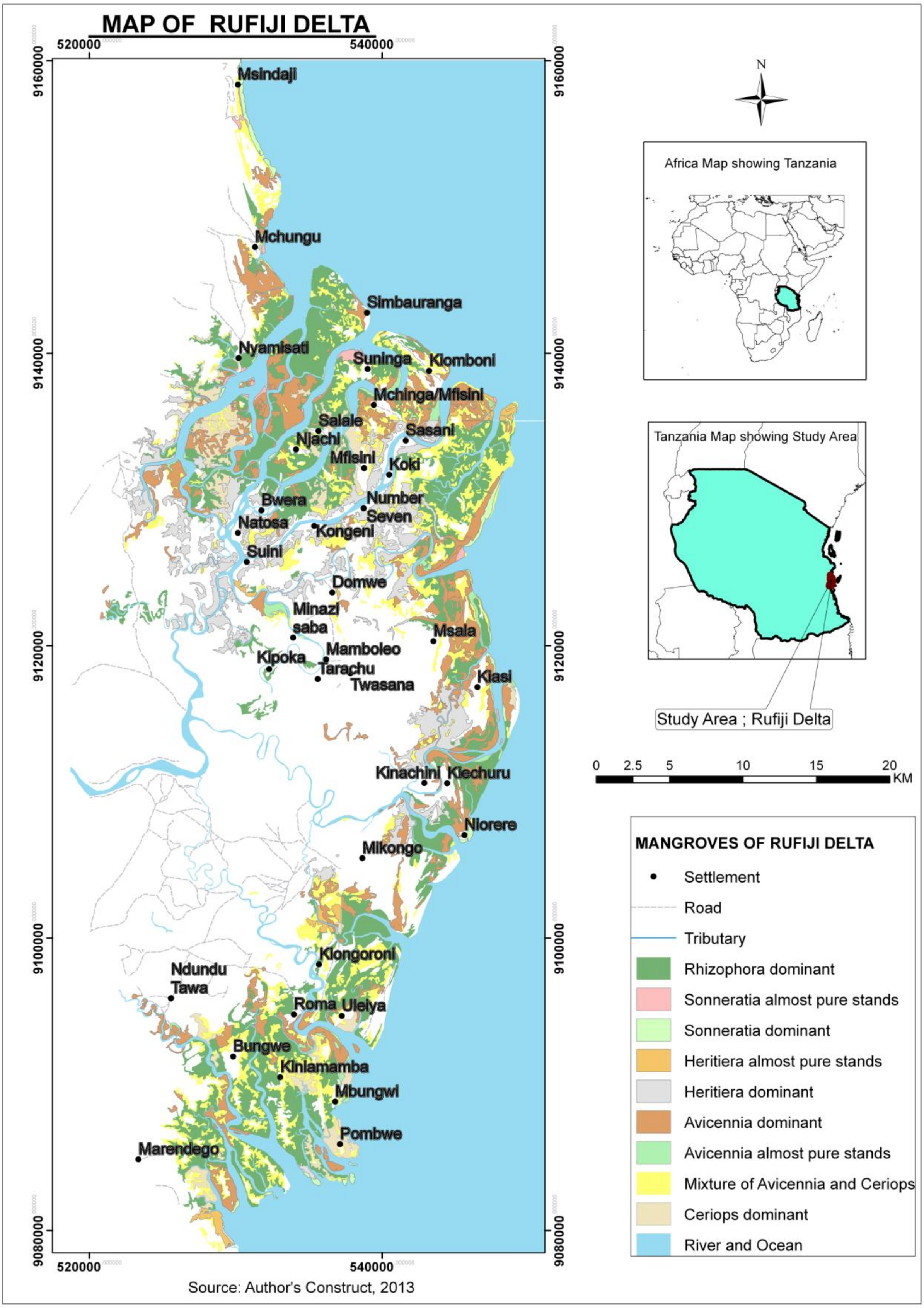


Figure 2: Study Area Map showing Mangrove Vegetation

3.2: Physical Geography

3.2.1: Climate

The climate is hot and humid and influenced by the North-east and South-east monsoon winds which blow from October to March and April to September respectively. However, the climate is unpleasant between May and October (Semesi, 1989).

3.2.2: Geology and Soils

In the Rufiji Delta, the land is not stable (Semesi, 1989). Banks are scoured by the river currents and silt deposited again at the convexities of curving water channels (Semesi, 1989). The rain-swollen river deposits its detritus load on reaching the slack waters in its delta and rapidly builds up new mud banks (Semesi, 1989). The Rufiji Delta is 23km wide and 65km long protrudes 15km into the Mafia channel (Semesi, 1989). It is overlain by superficial alluvial material mainly sand, silt and clay resulting to a large degree from suspended sediments transported from the Rufiji basin (Semesi, 1989).

Deposition of sediments at the middle of channels is still increasing; small islands are created and some channels are blocked (Semesi, 1989). The sediments have an impact on transport in the delta because larger vessels can now no longer pass through most channels, or passage is only possible during high tides (Semesi, 1989).

3.2.3: Drainage Patterns

The Rufiji River is the largest river in Tanzania (Semesi, 1989). It has three main tributaries, that is, the Great Ruaha, Kilombero, and Luwengu rivers (Semesi, 1989). The delta is also influenced by tides which reach about 25km upriver (Semesi, 1989). The delta is traversed by numerous deltaic branches of the Rufiji River (Semesi, 1989). There are about 43 islands in the delta (Semesi, 1989).

3.3: Mangrove as the Dominant Vegetation

The Rufiji Delta is divided in three parts, namely: northern delta, central delta and southern delta (RdMFR, 2011). The forested area in the northern delta has changed from 24,555.5ha in 1991 to the present 17,555.7ha due to rice farming, poles, among others (RdMFR, 2011). The central delta has an area of 15,172ha while the southern delta has a total area of 13,526.7ha (RdMFR, 2011). The mangrove vegetation of the Rufiji Delta often occurs in more or less pure stands (RdMFR, 2011). In situations where stands of mixed species composition occur, a single species still tends to dominate (RdMFR, 2011). Based on this criterion, the following nine classes of mangrove vegetation were distinguished (RdMFR, 2011).

3.3.1: *Rhizophora* Dominant

Rhizophora dominant, with *Avicennia*, *Ceriops*, *Sonneratia*, *Bruguiera*, *Heritiera* and/or *Xylocarpus*. *Rhizophora* dominant in muddy soils, the most favourable substrate for this species, and often form extensive pure stands. On sandy soils, however, the species fails to compete with others. Numerous stilt roots make the *Rhizophora* zone almost impenetrable. *Bruguiera* is relatively less abundant in the mangroves of Rufiji Delta and is often found as narrow zone between *Rhizophora* and *Ceriops* zones or mixed with them.

3.3.2: *Sonneratia* Almost Pure Stands

Sonneratia alba forms pure stands in areas which are flooded daily by tides. Such areas are found on the seaward side of the coast, where the substrate is usually soft, fine silt and mud. Walking across this zone is extremely difficult because of the large peg root and the softness of the substrate. Except in depositional areas where the species is a pioneer colonizer, old trees dominate because little harvesting takes place in this zone.

3.3.3: *Sonneratia* Dominant

Sonneratia dominant, with *Avicennia, Bruguiera* and/or *Rhizophora* commonly found inland on some tidal channels that do not receive substantial freshwater inputs. *Sonneratia* found growing together with species listed above. It grows on depressions which are flooded daily by tides contrary to the other species listed above which are found on slightly raised portions.

3.3.4: *Heritiera* Almost Pure Stands

Heritiera littoralis, a riverine mangrove species, grows only in habitats with low salinity, thus, it is restricted to areas in the vicinity of river mouths. Such sites are usually only flooded by spring high tides, and usually the substrate is firmer compared to those on which other mangrove species are found.

3.3.5: *Heritiera* Dominant

Heritiera dominant, with *Avicennia*, *Bruguiera* and/or *Rhizophora* are found in areas where there is freshwater influence. Typically, the substrate is irregular and not flat; the area is heterogeneous and more than one species exists.

3.3.6: *Avicennia* Dominant

Avicennia dominant, with *Rhizophora*, *Bruguiera*, *Heritiera*, *Ceriops* and/or *Xylocarpus*. *Avicennia* torelate high ranges of salinity and varied flooding regimes. It grows on a compacted substrate, sand flat and/or on newly deposited sediments. It does poorly on muddy soils which tend to dominanted by *Rhizophora* and *Ceriops*. When mixed with other species, it is commonly associated with *Ceriops* and *Xylocarpus*. *Xylocarpus* is often found mixed with *Avicennia,* and it grows on raised portions where flooding takes place only for a few days a month and where there is freshwater influence.

3.3.7: *Avicennia* Almost Pure Stands

Avicennia pure stands occur on depositional areas where the species is a pioneer colonizer and on the sandy flats to the landward side where salinity fluctuations are too high to support the growth of other mangrove species. On the seaward side the species attains large sizes whereas on the landward margin is present as bushes only.

3.3.8: Mixture of *Avicennia* and *Ceriops*

Forests with mixed vegetation of *Avicennia* and *Ceriops* are found on slightly raised grounds where flooding occurs only during spring tides. The substrate is usually firm during low tides. Conditions are less favourable for fast growth and as such the trees are short with yellow leaves, and stand density is often low.

3.3.9: *Ceriops* Dominant

Ceriops dominant, with Rhizophora, *Avicennia* and/or *Bruguiera*. *Ceriops* is largely found on the landward side of the *Rhizophora* zone. It becomes dominant more frequently in areas where mud is thin and relatively higher grounds than the *Rhizophora* zone

3.4: Population

People have lived in the Rufiji Delta for many years at places where spring tides permit sand islands to remain dry, and obtain the necessities of life by cutting mangroves and fishing (Semesi, 1989). Historically, the delta people have been in contact with various traders who visited the coast of Tanzania, including Arabs, Portuguese, Indians, Germans and English (Semesi, 1989). Among these Arabs were most prominent and the main item taken from the delta was mangrove poles (Semesi, 1989).

In 1988 the population in the Rufiji Delta was 33,000 and had a growth rate of 1.3% (Semesi, 1994) whereas, in 2002 the population was 42,615 with a growth rate of 1.9% (NBS, 2002). The people live in villages and belong to *Wandengereko*, *Wambwera, Wanyagatwa*, among others and mostly are Moslems (Semesi, 1994). The divorce and remarriage rate is relatively high (Semesi, 1994). It had a total of 34 villages and the number of women in the villages is considerably higher than that of men (Semesi, 1994).

Table 2: Population of the Rufiji Delta in 2002

SN	Ward	Male	Female	Total	Number of Households	Average Size
1	Mtunda	3,756	3,970	7,726	1,740	4.4
2	Ruaruke	4,059	4,422	8,481	1,690	5
3	Salale	4,264	4,071	8,335	1,694	4.9
4	Mbuchi	3,095	3,333	6,428	1,474	4.4
5	Kiongoroni	2,582	2,602	5,184	1,083	4.8
6	Maparoni	3,176	3,285	6,461	1,365	4.7

Source: NBS, URT (2002)

However, there is a new ward formed recently called Mwambao.

3.5: Economy

The economy of the people in the Rufiji Delta includes agriculture, fishing, trade, handcrafts, among others (Semesi, 1989). Most men and women are farmers and the main food crops produced are rice, sorghum, millet and cassava (Semesi, 1989). Men engage more in fishing as compared to women (Semesi, 1989). Apart from intertidal mollusks which are collected by women and children, fish is the main source of protein. Fish is an important source of income not only for fishermen but also for many people engaged in their processing and trading. Opportunities for employment and other income generating activities such as beekeeping, honey harvesting, carpentry and bicycle repair not relating to mangroves exploitation are very few (RdMFR, 2011).

3.6: Political Systems and the Decision Process

The approval of the Forest Act (2002), which became operational following publication of the Forest Regulations provides diversity of management options and expands the range of potential forest managers to include individuals, groups, villages, local and national governments. It also makes possible a range of management options in which roles are shared between forest owners and users. The concept of participatory forest management (PFM), a central strategy of Tanzania's Forest Policy (1998), Forest Act (2002) and NFP (2001), was conceived as a mechanism for transferring forest ownership and management from the central to village government. In general, forest and wildlife laws and regulations exist to guide harvest of mangrove resources in Rufiji Delta.

Licenses for harvesting and transporting forest products are normally issued by authorized forest officers stationed in the districts and are valid for 30 days (URT, 2003). Traders in forest products are also required to pay annual registration fees to the MNRT in addition to business license to local authorities (URT, 2003). Forest Product Royalty Rates are set by the Forest and Beekeeping Division of the MNRT (URT, 2003). The rates are updated regularly depending on market forces. To control legal trade on flora and fauna, checkpoints are normally established at strategic administrative boundaries for monitoring poles and timber trade, and collecting revenue (URT, 2003).

CHAPTER FOUR: METHODOLOGY

4.1: Research Strategy

A mixed method (quantitative and qualitative) was used in this study. The main purpose for using this method is that, both quantitative and qualitative data can cross validate each other around a common reference, that is, quantitative evidence checks qualitative statements (Fitzpatrick and Boulton, 1994). Triangulation explores the dynamics of complex social phenomena by highlighting the multi-layered and often contradictory nature of social life (Devine and Heath, 1999:49).

4.2: Data and Data Sources

Data were gathered from both primary and secondary sources. Primary data were collected from ten (10) villages, five within the Rufiji Delta (Salale, Simbauranga, Minazi saba, Kiongoroni and Msimbe) and other five around the Delta (Msindaji, Mchungu, Nyamisati, Kikale and Ndundutawa). On the other hand, secondary data were derived from books, journals, articles, published and unpublished papers. Rufiji Delta mangrove vegetation base map from the MNRT and population records from the NBS, all in Tanzania were obtained. Also, archival satellite images (2000 and 2011) were ordered from USGS website and downloaded. Secondary data collection was done in order to understand the rationale of supporting evidences in terms of past situations and trends as well as the constraints in the development efforts of policy, rules and regulations on how mangrove vegetation accessed and their management.

4.3: Data Collection

The data collection was conducted in the Rufiji Delta. Data collection techniques included 10 focused group discussions (FGDs), with groups ranging from 6-8; only one FGD in every sampled village was conducted. In-depth interviews (10 respondents form MNRT and NGOs), and 180 questionnaires were administered. In addition to the above mention data collection techniques, direct observation was employed to facilitate understanding of the situation and also cross-check the information provided by the respondents.

The study also involved the use of ten (10) key informants from MNRT, NGOs, and old people who have a historical perspective. They explained about the past and present status of mangrove vegetation real situation in their villages with respect to socio-economic activities. Discussing with different household groups facilitated to get unique information on mangrove vegetation. Moreover, information on how villagers accessed mangrove vegetation in the past and present time was also gathered.

Only one person per household was given a questionnaire to fill or involved in a FGD to avoid repetition from members of the same household who could, however, would have been inconsistent with their answers. The questionnaires and FGDs were administered and conducted respectively in Kiswahili (national language). A guide (Village Executive Officer) facilitated moving around the delta reducing possible hostility, facilitating a comfortable reception and a fluent conversation with the respondents in the visited households. The information gathered was then filled out in questionnaire schedules in English.

The questionnaire involved questions that sought to provide general information about the respondents. Questions posed reveals the way of forest life of the members of the community; that is, how they conducted the various activities in the delta and what kind of preferences they had as well as questions aimed at bringing out the respondents' opinions concerning various issues. The questionnaire had a semi-structured nature with short multiple- choice questions as well as some open-ended questions. The former of which mainly aimed at narrowing down the answer categories to facilitate and enhance data analysis.

The FGDs and interviews often began by assessing the understanding of the term mangrove vegetation to ensure that the respondent and interviewer were talking about the same concept and subject matter. In situations where cultural inhibitions limited or prevented the respondents from answering certain questions, visual observation was substituted as a method to acquire information. In addition, direct observation was important to visually check and complete the respondents answer. Some of the uses of mangrove vegetation were quite easily observable, e.g. making furniture, cooking utensils, fishing traps, canoes and sailboats, and in building houses. This observation technique provided supplementary information to the gathered in the FGDs and interviews.

The few problems met during the collection of data were related to sensitivity of certain issues. Given the current policy of mangrove vegetation exploitation in Tanzania, the entire subject has become a sensitive one. Questions dealing with mangrove poles and timber harvesting often result in a lot of suspicion, which made the gathering of information complicated. Often, it took a long conversation to win the confidence of the respondents so that they felt comfortable enough to answer questions. To obtain sensitive demographic data, village leaders (Village Executive Officers) were approached.

4.3.1: Population Size

According to the 2002 Tanzania National Census, the population of Rufiji Delta was 42,615 (NBS, 2002) The Rufiji Delta comprises 34 villages, 16 villages are found in the northern delta, 9 in the central delta, and other 9 in the southern delta (RdMFR, 2011).

4.3.2: Sample Size and Sampling Techniques

This study comprises a sample of 200 respondents. The study used ten (10) villages from which the 190 respondents were obtained. Five villages were chosen within the delta for this study through purposive sampling method basing on their location, i.e. inside and/or around the delta. The same method was used to obtain other five villages around the delta. A total of nineteen (19) households were selected from each chosen village using simple random sampling (i.e. taking every 4th household). A questionnaire was administered to each of them. Also a group range of 6-8 respondents in every selected village were purposively selected based on gender, age, income, occupation and education for a FGD. Again, using the purposive sampling technique ten (10) informants were chosen from MNRT, TCMP, and NGOs for an in-depth interview.

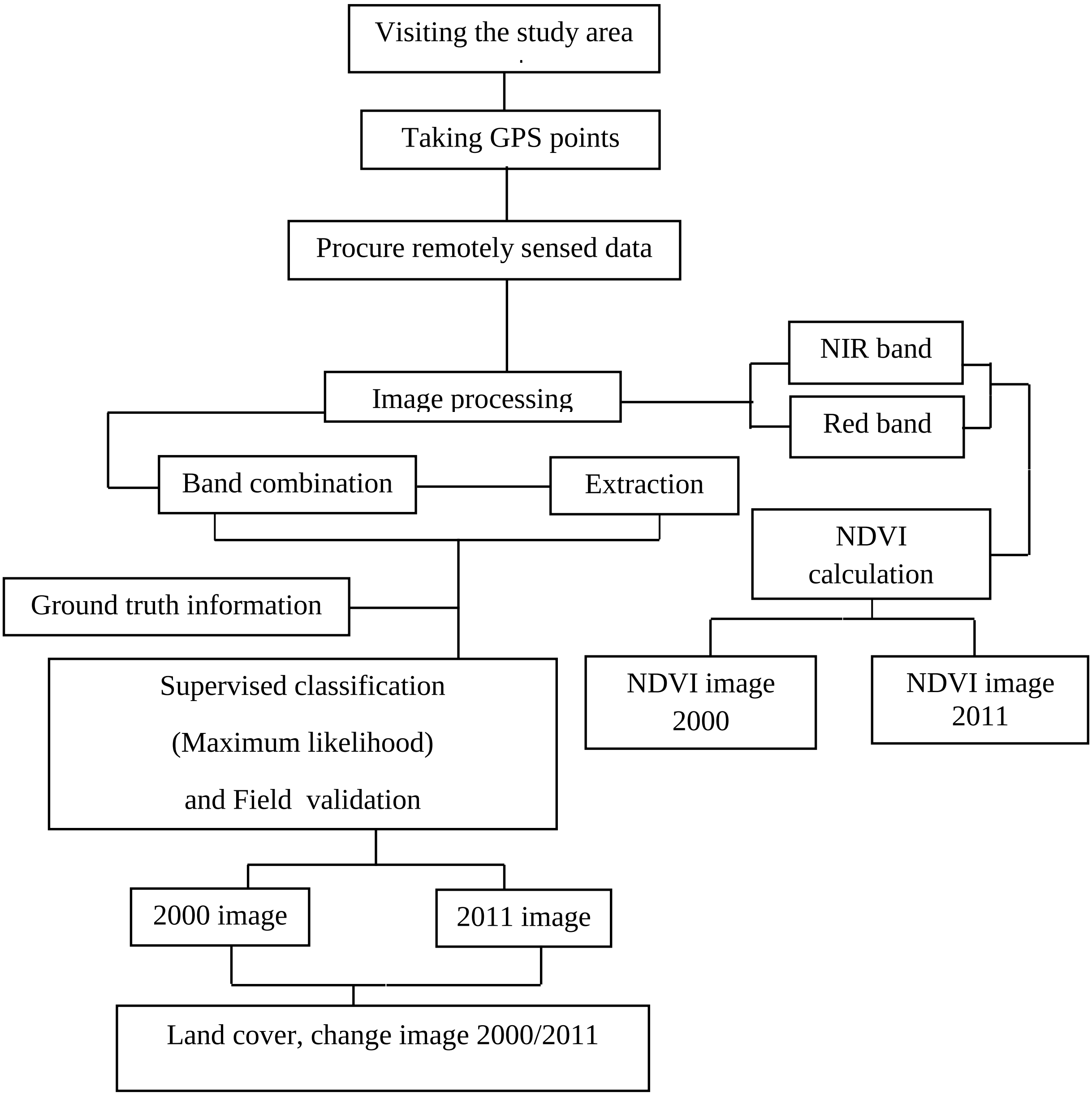


Figure 3: Flow Chart of Methodology

4.3.3: Remote Sensing Data

In all two Landsat images were acquired. Images dated 30th June, 2000 (Landsat7 ETM+) of path 166 and row 065 (representing the upper part), and lower part of path166 and row 066 were ordered and downloaded from the USGS website. Also, images on 7th July, 2011 (Landsat5 TM) consisting of the same path and rows of both upper and lower parts were procured. The upper and lower parts were used because one part could not cover the whole of

Rufiji Delta. The four Landsat images scenes have cloud cover less than 10% and resolution of 30 by 30 metres.

Table 3: Remote Sensing Data Characteristics

Satellite	Sensor	Bands	Date of acquisition	Spatial resolution
Landsat 7	ETM^{+}	Mid-Infrared Near-Infrared Red (5, 4, 3)	30th June 2000	30m
Landsat 5	TM	Mid-Infrared Near-Infrared Red (5, 4, 3)	7th July 2011	30m

4.3.4: Image Processing/Image Restoration and Enhancement

Image restoration is an attempt to remove known value distortions in the image. These can include radiometric and geometric error that degrades image quality. While image enhancement refers to techniques which are applied to remotely sensed data to improve the appearance of an image for human visualisation and analysis. The two general enhancement algorithms are image filtering, and band ratioing. These techniques are very useful when trying to locate objects on an image or improve the detail that can be seen when beginning the process of image classification.

4.3.4.1: Image Calibration

One of the important aspects of imagery preparation/processing that should always be performed before classification of images is calibration. Calibration is used to convert Landsat TM and ETM^{+} digital numbers to spectral radiance or exoatmospheric reflectance (reflectance above the atmosphere) using published post- launch gains and offsets. It eliminates variables on the image that can skew or alter the final output, ultimately rendering more predictable colour to the image. Thus, when an image is properly calibrated it provides the user with more accurate image that requires little or no correction (Chander et al, 2009) In calibration of images, parameters were set. The first image is from Landsat satellite sensor 7, acquired on 30th June, 2000 with sun elevation of 47.087451˚ for the upper part and 45.896030˚ for the lower part.

The calibration type was reflectance and L_{Min} and L_{Max} were set for each band. Whereas, the second image is from Landsat satellite sensor 5, obtained on 7th July, 2011 with sun elevation of 45.4386055˚ for the upper part and 45.65333108˚ for the lower part. Also, the calibration type was reflectance and L_{Min} and L_{Max} were set for each band. L_{Min} is the spectral radiance at the calibrated and quantised (QCAL) scaled radiance in units of digital numbers, i.e: it is the spectral radiance at QCAL while L_{Max} is the maximum quantised calibrated pixel value (corresponding to L_{Min}), in digital numbers, i.e: it is the spectral radiance at QCAL= $QCAL_{Max}$ (Chander *et al.*, 2009).

4.3.4.2: Band Combination (5, 4, 3)

This 5, 4, 3 band combination provides information and colour contrast for detecting vegetation and bare soil. Band 5 (1.55-1.75 µm, mid-infrared), is very sensitive to moisture and is therefore used to monitor vegetation and soil moisture. Band 4 (0.76-0.90 µm, near infrared), since water absorbs nearly all light at this wavelength water bodies appear very dark. This contrasts with bright reflectance for soil and vegetation so it is a good band for defining the water/land interface. Band 3 (0.63-0.69 µm, red), since vegetation absorbs nearly all red light (it is sometimes called the chlorophyll absorption band) this band can be useful for distinguishing between vegetation and soil and in monitoring vegetation health.

4.3.4.3: Band Ratioing (4/3)

This technique was used to remove brightness differences in the images caused by topography and/or seasonal changes in the solar elevation angle. This ratio isolated vegetation from other land cover classes. It enhanced vegetation and bare land because vegetation exhibits reflectance in near infrared region (NIR: 0.76 — 0.90µm), and strong absorption in red (RED: 0.63 — 0.69µm) region. Therefore, this ratio uniquely defines the distribution of vegetation. The higher the tone, the greater the amount of vegetation present. Band ratios have important uses in environmental remote sensing; however, deciding which two bands to ratio is not an easy task. There has been extensive research done to show how bands to ratios can be used to reveal important relationships on an image for application in vegetation studies

4.3.4.4: Image Filtering

The method which was used to filter the images is called convolution. This technique applies a 3×3 pixel filter to a single band producing a 'convolved' output image. Convolution was used to change the spatial frequency characteristics of images; thus, sharpening images edges with high frequency filter, and alternatively, smoothing the images with a low frequency filters.

4.3.4.5: Cloud Mask

Typically, the Earth's surface is covered by clouds at any given time, where a cloud is defined as a visible mass of condensed water droplets or ice crystals suspended in the atmosphere above the Earth's surface. In remote sensing, clouds are generally characterised by higher reflectance and lower temperature than the background. A thick opaque cloud blocks almost all information from the surface or near surface, while a thin cloud has some physical characteristics similar to other atmospheric constituents.

It is often possible to find a cloud free Landsat image for a given area, a completely cloud-free image was not available for the location of interest and acquisition time. The images of 2000 and 2011 were acquired with Enhanced Thematic Mapper (ETM^+) and Thematic Mapper (TM) respectively. Both images had cloud cover although the TM imagery had lower cloud cover as compared to the ETM^+ imagery. In this case clouds mask (Fmask 2.1) was applied to both images and were successfully removed. The limitation was that the researcher was unable to replace the masked areas with pixels from corresponding cloud-free image.

4.3.4.6: Image Mosaicking

Mosaicking is the art of combining two or more images into a single composite image. The subsetted images were mosaicked using ENVI 4.7. ENVI provides automated placement of georeferenced images within a georeferenced output mosaic.

4.3.4.7: Extraction/Image Subsetting

The raw images displayed in RGB below were extracted. Subsetting involves the process of clipping an area of interest (AOI) from parent imagery. As a result, subsetting was done to crop the area of interest (Rufiji Delta) region before the classification for both 2000 and 2011years.

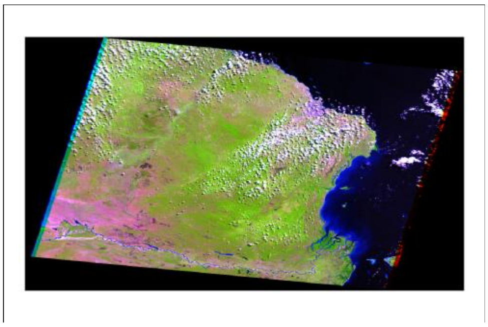


Figure 4: The Upper Part Raw Image

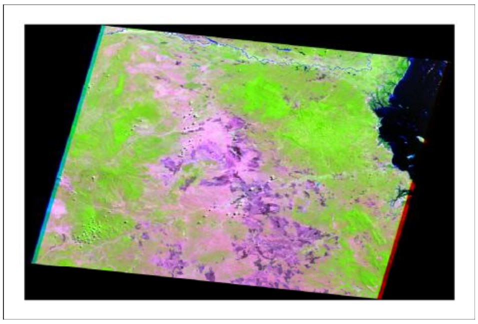


Figure 5: The Lower Part Raw Image

Source: USGS (2000 and 2011)

4.3.5: NDVI Calculation

The normalized difference vegetation index (NDVI) was performed to aid the classification for estimating vegetation cover from the reflective bands of satellite data. The

NDVI, the normalized difference of brightness values from the near infrared (NIR) and visible red (RED) bands, was calculated by the following formula:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

For Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) imageries, Band 4 contains the near infrared data and Band 3 represents the visible red information.

4.3.6: Development of a Classification Scheme

Based on the prior knowledge of the study area and a reconnaissance survey in the Rufiji Delta, a classification scheme was developed. The classification scheme developed gives a rather broad classification where the land cover was identified by codes.

Table 4: Land Cover Classification Scheme

Codes	**land cover categories**
100	*Rhizophora* dominant 80%
101	*Sonneratia* almost pure stands 95%
102	*Sonneratia* dominant 80%
103	*Heritiera* almost pure stands 95%
104	*Heritiera* dominant 80%
105	*Avicennia* dominant 80%
106	*Avicennia* almost pure stands 95%
107	Mixture of *Avicennia* and *Ceriops* 75%
108	*Ceriops* dominant 80%
109	Other vegetation
110	Bareland
111	Waterbody

4.3.7: Image Classification

Image classification is the process of assigning the pixels (picture elements) to different classes. Usually each pixel is treated as an individual unit composed of values in several spectral bands. By comparing the pixels with one another and with those of known identity, it is possible to group similar pixels into classes that match the information category of interest. These classes form regions on the image and after classification these are presented as a mosaic or parcel, each identified by a colour or a symbol (Ramachandra *et al.*, 2008). One of the main steps in image classification is the partitioning of the feature space (Kerle *et al.*, 2004).

Basically, there are two types of classification. These are supervised and unsupervised classification. In case of supervised classification, classification is realised by an operator who defines the spectral characteristics of the classes by identifying sample areas (training areas). It also requires that the operator be familiar with the AOI. Furthermore, the operator needs to know where to find the classes of interest in the area covered by the image. This information is derived from general area knowledge or from dedicated field observation (Kerle *et al.*, 2004).

There three most commonly used classifiers in supervised classification. These are: Parallelepiped or the box decision rule classifier, which characterises each class by a range of values on each band. The range is defined by the minimum and maximum values of the training sites. It then classifies all the pixels, which fall within this range. If a pixel does not fall within this range then it is left unclassified. It is called Parallelepiped because the opposite sides are parallel. It is also known as the Box classifier due to the fact that when the lower and upper limits are used, they define a box-like area in the feature space (Kerle *et al.*, 2004).

Another one is the Minimum Distance to Mean (MDM). This is based on training site data which characterises each class by its mean position on each band. All the pixels which have the same value are assigned to their respective classes and the unassigned pixels are then assigned to that class to which it is nearer. The next is the Maximum Likelihood (ML) classifier. It uses the information from a set of training sites which are based on their mean, variance and covariance data of the signatures to estimate a probability that a pixel belongs to each class (Ramachandra *et al.*, 2008).

In an unsupervised classification, the software itself classifies the image into many groups or clusters based on the prominent spectral reflectance values of each pixel. These groups or clusters will then have to be identified as a land cover by the analyst, with the help of the baseline maps or ground truth data (Ramachandra *et al.*, 2008). There are several methods that are applied in this type of classification and their main purpose being to produce spectral groupings based on certain spectral similarities.

Classification of an image was carried out by applying a classification algorithm. The choice of algorithm depended on the purpose of the classification, the characteristics of the image and training date. For the purpose of this study, supervised parametric classification using the ML classifier was used. This is because ML is the best classifier (Ramachandra et al, 2008). It also provides an estimate of overlap areas based on statistics. This method is different from parallelpiped that uses only maximum and minimum pixel values as a result overlap between classes occurs (ERDAS IMAGINE 9.2, Help-Online Documentation).

In addition to the above, the ML decision rule is based on the probability that a pixel belongs to a particular class. The basic equation assumes that these probabilities are equal for all classes, and that the input bands have normal (Gaussian) distributions. ML algorithm considers not only the mean or average values in assigning classification, but also the variability of brightness values in each class while MDM classifier does not take the class variability into account; i.e. some clusters are small and dense while others are large and disperse (ERDAS IMAGINE 9.2, Help-Online Documentation).

4.3.7.1: Supervised Classification and Field Validation

In case of supervised classification, signatures of different land cover types/classes were identified. These are called training sites. In all, 195 points were picked using the GPS in the study area through field visits. The ground control points (GCPs) were collected using

GARMIN GPS etrex Legend HCx (error ± 5 m) which marks the latitude (Northings) and longitude (Eastings) of the points taken in UTM projected coordinates. In executing the supervised classification, 120 GCPs were randomly selected from all GCPs collected above and an additional of 10 points picked for cloud masking.

Approximately, 10 GPs for every land cover class were used as signatures in Erdas Imagine 9.2. The points were selected such that it could be easily identified and located on the satellite imagery and distributed uniformly all over the ROI. Based on this criterion, the GCPs for each mangrove type, water body (rivers and ocean), bareland as well as masked-cloud areas were picked. As supervised classification was based on the samples of land cover classes, the actual quality was checked and quantified afterwards. For validation of the results, a total of 65 GCPs from which 5 GCPs for each land cover class were used to confirm the classification result. These aided the accuracy assessment and generation of report. It must be noted, however, that for the 2000 supervised classification, same total number of points were extrapolated from an existing map of that year of the study area for each land cover class.

4.3.8: Calculation of Vegetation Change Detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Change detection is an important process in monitoring and managing natural resources (e.g. mangrove vegetation) because it provides quantitative analysis of the spatial distribution of the AOI.

4.3.9: Data Analysis

All collected data both primary and secondary were useful in terms of research questions and research objectives for this study. Data collected were analysed using Remote Sensing and GIS software namely; ENVI 4.7, ArcGIS 9.3, and ERDAS IMAGINE 9.2 for land cover post classification and change detection. Methods of data analysis which were adopted in this study include: Calculation of the area in hectares of the resulting land cover classes for each study year (2000 and 2011) then converting into percentage and subsequently comparing the results (Change detection). Maximum likelihood classifier was applied.

4.3.10: Problems and Modifications

Calculation of the area in hectares was used for identifying change in the land cover classes. Furthermore, the comparison of land cover class statistics assisted in identifying the percentage change, location and nature of change between 2000 and 2011. In achieving this, the first task was to develop a table showing the area in hectares and the percentage change for each year (2000 and 2011) then measured against each land cover class. In addition to the above, a table showing the area in hectares and the percentage to what changes into what was developed.

The percentage change to determine the trend of change was then calculated by dividing observed change by sum of changes multiplied by 100.

$$\text{(Trend) Percentage change} = \frac{\text{Observed change}}{\text{Sum of change}} * 100$$

In addition, the annual rate of change was obtained. This was done by taking the percentage change divided by 100 and multiplied by the number of study year 2000 – 2011 (11years).

Both the 2000 and 2011 Rufiji Delta population figures were estimated from the 1988 and 2002 population figures of Rufiji Delta respectively using the Rufiji district recommended growth rates of 1.3% and 1.9% as obtained from the Tanzania National Census of 1988 and 2002 respectively. The first task to estimating the population figures was to multiply the annual growth rate of each year by the census figures of its base year, while subsequently dividing same by 100. The result was then multiplied by the number of years (2000 and 2011) being projected for, the result of which was then added to the base year population (1988 and 2002). This is represented in the formula below;

n = r* Po/100 (1)

Pn = Po + (n * t) (2)

Pn = estimated population (2000, 2011)

Po = base year population (1988 and 2002 population figures)

r = annual growth rate

n = annual population growth

t = number of years projecting for

The formula given for the population estimate was developed by the researcher

Table 5: Population Figures of Rufiji Delta in 1988 and 2002

Base year	**Base year population figures**	**Annual growth rate**
1988	33,000	1.3%
2002	42,615	1.9%

Sources: Semesi (1994) and NBS (2002)

Table 6: Population Figures of Rufiji Delta in 2000 and 2011

Study year	**Study year population figures**
2000	38,148
2011	49,902

Source: Researcher's estimates

4.3.11: Data Presentation

The output data were represented using tables, graphs, charts, and maps. These were done by using Microsoft Excel 2007 in producing the charts and graphs. ENVI 4.7 was used for image calibration, stacking, and mosaicking while the supervised classification as well as the change detection analyses were performed in ERDAS IMAGINE 9.2. The final presentations of the maps were carried out in Arc GIS 9.3.

CHAPTER FIVE: STATUS OF MANGROVE VEGETATION AND THEIR DEGRADATION IN THE RUFIJI DELTA

5.1: Socio - Economic Background of Respondents

Demographic variables are important for appreciating the status of mangrove vegetation. The main aim of determining the respondents' characteristics was to document their understanding on mangrove vegetation and their degradation in the Rufiji Delta. The respondents' socio-economic background include; sex, age, marital status, level of education, place of birth and occupation.

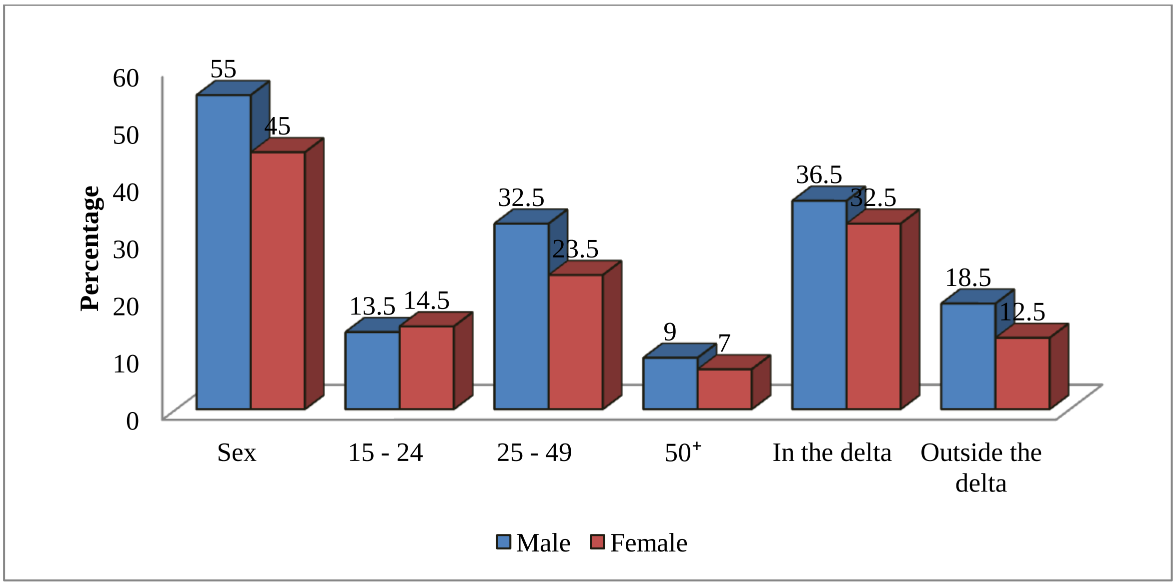


Figure 6: Sex, Age Category, and Place of Birth of Respondents in Percentage

Sex is an important variable in a given situation which is variably affected by any social or economic phenomenon. Hence, this variable was investigated for this study, and the respondents included both male and female. When the data computed into percentage, it was found that male respondents were 110 (55%) while female were 90 (45%). Similarly, both women and men face similar economic constraints in the study area. The findings indicate that women concentrated their harvesting closer to settlements and/or easily accessible areas, because of physical limitations. On the other hand, men harvested over a wider range and in a more selective manner. This is because of the higher frequencies of harvesting and number of visits to harvesting sites by women over men.

Age of the respondents is one of the most important characteristics in understanding their views about the particular problems. Higher age indicates level of maturity of individuals in that sense age becomes more important to examine the response. Respondents were from 15 years and above because they are more matured and perceive enough to understand the base of the study. Thus, this research excluded children whose age group rages between 0 to 14 years.

Respondents were grouped into three different age categories notably; 15 to 24 years (youth), 25 to 49 years (adults) and 50 and above (elders) (NBS, URT, 2002). Majority (112 = 56%) of respondents who participated in providing information were aged from 25 to 49 years old, followed by those aged between 15 to 24 years old (58 = 29%) and very few (30 =15%) were from 50 and above years old. The mixture of respondents' age groups aided in documenting different perceptions on mangrove vegetation degradation and coping mechanisms that are practised by different age group in the study area.

Respondents aged between 15 to 24 years constituted the group of people (youth) that engaged in production. This group generated an understanding of the prevailing situation of mangrove vegetation degradation in the study area. Representative aged between 25 to 49 (adults) years were very useful in expressing their views of the changes happening on mangrove vegetation in their villages. Above all, respondents aged 50 and above years, they were very useful in telling stories regarding to the changes on mangrove vegetation over years. By using different respondents from different age groups, it was easy to gather useful information that are important as regards to mangrove vegetation and their degradation reduction hence, sustainable mangrove vegetation in and surrounding the Rufiji Delta.

An individual place of birth is likely to have effects on his or her perceptions towards a particular problem. The person when migrates to some other place becomes a new comer to that particular place. As new comer he or she has to face many problems with regards to his or her day to day living. Therefore, the variable whether the respondent is a migrant or not was investigated by the researcher.

The findings show that most of the respondents (138 = 69 %) were native to the area, having lived there for at least three generations while the remaining (62 = 31%) had moved to the delta from other places. A respondent at Kiongoroni said that mangrove selling activity forced him to live in the delta from Mahenge. The movement of people to the Rufiji Delta from different places among other reasons could be attributed to their reliance on mangrove vegetation for their livelihood.

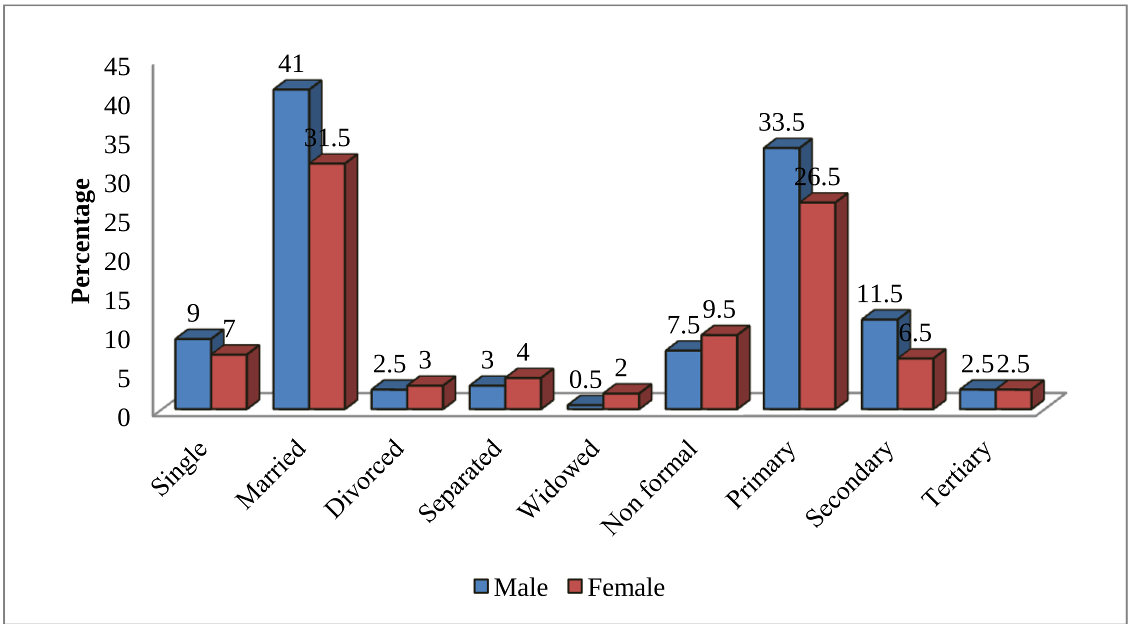


Figure 7: Marital Status and Level of Education of Respondents in Percentage

Furthermore, perceptions and attitudes of the person can also differ by the marital status of the persons because the marriage might make the persons little more responsible and matured in understanding and giving the responses to the questions asked. It was discovered that majority (145) of respondents captured were married constituting 72.5%. The singles (never married) who were 25 making 12.5% and those separated were 14 equivalents to 7%. Divorced (11) only constituted 5.5%, and lastly widowed (5) who constituted 2.5%. These findings indicate that most of the people in the Rufiji Delta are married and as a result will reproduce more to increase their population and their quest for survival and development. This eventually leads to over-dependence on mangrove vegetation, hence, their depletion.

Education is also one of the most important characteristics that might affect the person's attitudes and the way of looking and understanding any particular social phenomena. In a way, the response of an individual is likely to be determined by his or her educational status and therefore it becomes imperative to know the educational background of the respondents. Hence the variable 'educational level' was investigated by the researcher and the data pertaining to education is presented below.

In terms of level of education, most of the respondents (120 = 60%) especially from age group of 15-24 years had attained primary education. 34 respondents (17%) indicated that they had no formal education, and these were mostly from the age group of 50 years and above. Some of them only attended Islamic education (Madrasah). Only 36 = 18% had secondary education, all of these were in the age group of 15-24. This implies that in the last two decades there were no or few secondary schools in the study area. However, recently there have been a number of secondary schools around the delta.

Contrary to expectations, the findings did not show any respondent resident of Rufiji Delta who had tertiary education. Only 10 (5%) key informants from MNRT and NGOs indicated that had tertiary education. Such findings imply that, there is total reliance on mangrove vegetation in the study area. In addition, this also have an implication that there is a great possibility that the methods used on mangrove vegetation utilization in the area of study are of low quality. This also attests to earlier observations (Shemdoe, 2001; Shemdoe *et al.*, 2009; and Ngwara *et al.*, 2008) which reports natural resources use in Tanzania where majority of communities had attained low level of education which hindered them from using state of art technology in their activities.

Person's occupation(s) do have a bearing on his or her personality and also the ways of looking at the problem before him. The quality of life is also determined by an individual's occupation and the incomes he derives from it. Occupation of an individual also socializes him or her in a particular fashion which in turn reflects his or her pattern of behaviors and his/her level of understanding of particular phenomenon. In other words the person's response to a problem possible determined by the type of occupation he is engaged in and hence variable occupation was investigated by the researcher.

As regards to the main occupations of respondents in the Rufiji Delta, it was observed that majority of them indicated peasant, fisherman/fisherwoman, selling mangrove poles, timber, charcoal, salt producer, and crafts. Other respondents have a combination of their occupations, i.e. they are peasant and fisherman/fisherwoman, and peasant and retailer.

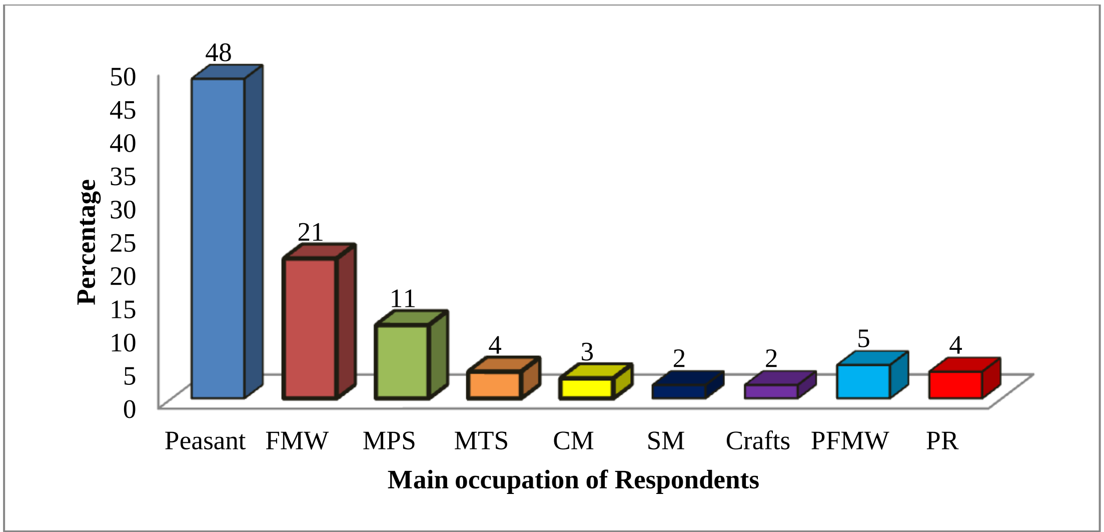


Figure 8: Main Occupation(s) of Respondents in Percentage

Key:

FMW – Fishermen and Fisherwomen

MPS – Mangrove Poles Seller

MTS – Mangrove Timber Seller

CM – Charcoal Making

SM – Salt Making PFMW – Peasant, and Fishermen and Fisherwomen

PR – Peasant and Retailers

5.2: Level of Mangrove Resources Utilisation

The findings show that the Rufiji Delta mangrove forest is heavily exploited for both the export market and local use (Semesi, 1989). Historically, mangrove poles from the Rufiji Delta have been traded since ancient times for house and boat building; an export market has long existed in the Arabian Peninsula and Gulf States (Semesi, 1989). The results reveal a general pattern that the main uses of mangrove vegetation include poles for house construction, timber for boat construction, firewood, charcoal, local medicine, dyes, craftsmanship, and others.

Table 7: Mangrove Vegetation and Uses in Rufiji Delta.

Biological name	**Common name Swahili name**	**Uses**
Lumnitzera racemosa	*Mkandaa-mwitu, Mkandaa-dume*	Structural poles, fuel
Xylocarpus granatus	*Mkomafi, Mtonga*	Construction timber, fuel, fruits (food, medicine), boat
Xylocarpus moluccensis	*Mkomafi*	Construction, fuel
Ceripos tagal	Yellow mangrove *Mkandaa*	Structural poles, dye, fuel
Rhizophora mucronata	Red mangrove/*Mkoko, Mkaka*(exported)	Fuel, basketry, fish-traps pole, timber
Sonneratia alba	*Mlilana,Mpira,Mpia*	Boat, timber, fish-net floats
Heritiera littoralis	*Mkungu, Msikundazi*	Construction, fuel, timber
Avicennia marina	White mangrove *Mchu*	Timber, poles, fodder, dye, perfume, medicine
Bruguiera gymnorrhiza	Black mangrove *Mkifu, Muia*	Structural poles, fish smoking

Source: RdMFR (2011)

The results show that both men and women engage in harvesting mangrove vegetation. For men, the main uses of mangroves are house construction (poles), boat/dhow construction (timber), and charcoal. While women harvest the mangroves mainly for firewood. Other utilization of mangrove vegetation by both men and women include medicine, dyes, basketry, fruits (food), among others. In harvesting mangrove vegetation, a number of constraints are encountered. These include bitten by snakes and struck by mangrove trees. One of the respondents, a resident at Mchungu village added by saying "*a number of cases have been reported that people have died by being bitten by snakes and been struck by heavy tree*".

All respondents (200 = 100%) are aware that mangrove vegetation are legally protected in Rufiji Delta. Some respondents indicated that "*to access mangrove vegetation now you need a letter from the MNRT, but two decades ago, it was not strict as it is today*". However, 150 (75%) of these respondents acknowledged that there is high illegal access of mangrove vegetation because of poverty level of the people; thus, most of them cannot afford to pay for permit.

5.2.1: Poles

The largest and most significant use of mangroves is in the form of poles used for house construction. Harvest of poles from mangroves was found to be an economic activity taking place in the study area. Certain species are preferred over others namely: *Ceriops tagal*, *Rhizophora mucronata,* and *Bruguiera gymnorrhiza*. These are favoured because of their ability to grow tall and straight and each of these species occupies a particular place within the framework of a house. *Bruguiera gymnorrhiza* is preferred for the rooftops rather than for walls because it produces long yet strong enough poles for the roof.

In addition, this species is cited as not lasting very long in the soil as it does not withstand moisture and saline soils. On the other hand, the most resistant to the soil conditions cited above is *Rhizophora mucronata*. This is preferred for walls and especially the thicker supportive poles and corner pillars of a house. *Ceriops tagal* poles are much thinner and thus used as *fito* for creating an interweaving network in the walls and roofs. They are also used to make other house like structures such as shrines, cooking sheds outside the main house, and animal sheds and pegs.

Looking at the construction of a house from the utilization classes' point of view, it can be summarized that the *boriti* are thick poles that go deep into the ground and that they are the main supports for the walls. At each side of the wall they are crossed by the *fito.* The fillings of the walls consist of traditional clay or cemented dead coral rock, whether or not they are furnished with a more modern plaster treatment, depending on financial means of the person. It was observed that the latter provides a polished look exactly like that of a plastered modern brick house constructed with cement and stone or concrete bricks.

The ceiling is made of *nguzo* and *boriti,* the former being thicker and heavier than the latter, which could be closely packed or evenly spaced out at one-foot intervals. The roof is composed of *pau* and *mazio,* which are long poles meeting at a common apex or at the same level at the top depending on the roof design. Finally, the *vigingi* are used to support the roof extension that formed a kind of veranda just outside the main door and is used as a cool or dry sitting area.

The most common roof fillings are dried coconut leaves woven into a thatch called *makuti*. This material insulates the house adequately from the hot daytime sun. The *makuti* are placed in an overlapping manner directly onto the grid of mangrove poles and tied with strings made from some indigenous inland creepers, dried coconut leaves split into thin strips, and split roots of *Rhizophora mucronata.* From direct observations, it can be estimated that 90% of the houses in the Rufiji delta are of the traditional design, with a bare instead of a cement floor.

Figure 9: Houses in Rufiji Delta Built Using Mangrove Poles

Mangrove poles business depends on market demand and availability. For a long period of time, mangrove poles which are logged and sold or preferred by customers are those found in group A namely; *Rhizophora mucronata, Ceriops tagal and Bruguiera gymnorrhiza.* Class B are those mangrove species which are not common in the market, therefore, they are lowly demanded poles, currently, they are very plenty. They include *Avicennia marina and Heritiera littoralis*.

Although, the management plans hinges around joint management, with active participation of local communities it has side effects which make legal cutting rather complicated (Turpie, 2000). Legal commercial cutting of mangrove poles involve getting permission from the Ward and Village Executive Officers of the area concerned, then taking the permit to the forest officer to get a license, and finally, making payments to all three parties. Because of the capital required for permits, most permits are in the hands of traders from large centres, outside the Rufiji Delta who employ local people to do the cutting. Most harvesting is reported to be illegal, unselective and unsustainable.

5.2.2: Timber

Timber cutting was also reported to be one of an economic activity taking place in the Rufiji delta. The timber trade was reported to be externally driven by its demand from business traders from Dar es Salaam and other major centers who transport and export them abroad. The use of mangroves as timber is the most important one, either for house or boat construction. Simple one-man canoes are carved from heavy *Avicennia marina* logs. Larger vessels like the traditional dhows are built with ribs from *Sonneratia alba* logs.

The paddles and oars to propel these boats forward are made from *pau* of *Bruguiera gymnorrhiza, Ceriops tagal,* or *Rhizophora mucronata,* the key features of these poles being their length and straight shape. During the Inventory exercise of 2011 to the area, illegal logging activities were observed in the delta. The logging operations employ strong people and therefore often involve young men. Therefore, it can be concluded that unsustainable mangrove forest for timber extraction has caused mangrove vegetation degradation in the delta

5.2.3: Firewood and charcoal

The research findings reveal that firewood and charcoal are the main sources of fuel in the Rufiji Delta. Fuel wood by far is the first major source of fuel contributing about 80% of the total households energy used in the study area. While charcoal contributes 15% of the total households used in the delta. Other less important sources of fuel include kerosene (5%), and electricity (0 %). However, at Nyamisati village, it was found that some people use solar energy and generators.

It was reported that, fuel wood is generally collected by women, although, men occasionally assist (especially in big occasions). In the delta (eg. Salale, Simbaulanga, Minazi saba, Kiongoroni, and Msimbe) fuel wood is mainly collected from the mangrove forests while in villages around the delta (eg Nyamisati, Mchungu, Msindaji and Kikale and Ndundutawa) fuel wood is both collected from mangrove forests and woodland. Surprisingly, respondents reported that mangrove wood make better fuel wood than woodland wood. Charcoal, however, is often made from miombo woodlands from the floodplain but it is rarely used as a substitute for firewood.

5.2.4: Traditional medicine

It was mentioned that a number of diseases are cured from traditional herbs which are from mangrove vegetation. For instance, a leaf extract is used as medicine for hernias. Medicinal products are mainly made from the bark of mangrove stems, which are crushed and blended with other ingredients or plant extracts before being boiled. Tree stems of different ages yield medicines for different ailments. *Rhizophora mucronata* (*Mkoko*) roots are often valued for their curative properties for constipation, fertility-related or menstruation disorders. *Xylocarpus granatum* (*Mkomafi*) fruits are used as an ointment to soothe aching muscles and limbs resulting from injury.

5.2.5: Dyes

From findings, tanning compounds are produced from the bark of *Rhizophora mucronata* stems, applied to the insides of canoes and boats and valued for their preservative quality. In the study area, dyes are also used to seal up the tiny pores in trays woven from reeds and palm leaves, used for storing flour from cereals, and to decorate sleeping mats, baskets, and trays. The insecticide application of mangroves is reported to come mainly from green *Avicennia marina* logs which are very smoky when burnt, keeping away mosquitoes and other biting night insects.

Their slow burning makes them also popular with honey collectors and fishermen as they sit out on the beach at night, awaiting the right tide amplitude to set out fishing. However, the fishermen report that sometimes they prefer to set the entire tree ablaze beginning with a hole at the base of the stem. These fishermen’s fires are not extinguished until the entire tree is burnt out.

5.3: The Extent of Mangrove Cover

This objective of research forms the basis of all the analysis carried out in this chapter. The results are presented in form of maps, charts and statistical tables. They include the static, change and projected land cover of each class.

5.3.1: Mangrove Species in the Rufiji Delta

Table 8: List of Mangrove Species found in Tanzania

Mangrove species	**Family**	**Local name**
1 *Avicennia marina*	*Verbenaceae*	Mchu
2 *Bruguiera gymnorrhiza*	*Rhizophoraceae*	Msinzi
3 *Ceriops tagal*	*Rhizophoraceae*	Mkandaa
4 *Heritiera littoralis*	*Sterculiaceae*	Msikundazi
5 *Lumnitzera racemosa*	*Combretaceae*	Mkandaa dume
6 *Rhizophora mucronata*	*Rhizophoraceae*	Mkoko
7 *Sonneratia alba*	*Sonneratiaceae*	Mlilana
8 *Xylocarpus granatum*	*Meliaceae*	Mkomafi
9 *Xylocarpus molluccensis*	*Meliaceae*	None

Source: Wang *et al* (2003).

On the question of mangrove species found in the Rufiji Delta, it was interesting to note that in all ten sampled villages of this study all respondents were able to list some of them according to their local names. There are similarities between the mangrove species mentioned by respondents in this study and those listed by Wang *et al* (2003), who listed nine mangrove species found in Tanzania. In addition, there is one new mangrove species which was identified during the inventory exercise of April 2011 not reported in previous management plan of the Rufiji Delta. Thus, increasing the number of mangroves species found in Mainland Tanzania from the well known nine species to 10 species. This new species is known as *Xylocarpus molluccensis* (*mkomafi dume*).

In the area of study, different levels of knowledge on mangrove species became evident when respondents were interviewed. Firstly, experts, as they were referred to by others, who, when interviewed, were able to identify mangrove species using different physiognomic and morphological traits of the plants (e.g. roots, leaves, flowers, and propagules). Secondly, those who had a good working knowledge on the mangrove vegetation could distinguish different mangrove species through the rooting system alone.

These two first groups constituted the majority of respondents (148 = 74%). Thirdly, those (37 = 18.5%) who had a fair idea and could acknowledge the existence of different species, but could almost never go beyond visually naming at least three species that were present in the Rufij Delta. Fourthly, respondents (15 = 7.5%) who had no idea at all about different mangrove species, who knew what mangroves were though, could not distinguish individual mangrove species characteristics, therefore, much less name them.

The second research question was to look at the extent of mangrove cover in the study area. In response to the question, "Compared to last eleven years are mangrove species more degraded presently?" The overall answer, to this question was positive. That is to say, 180 (90%) of the respondents who completed the questionnaire, interviews, and FGDs agreed that presently mangrove species have degraded tremendously as compared to the last eleven years. This is because of cutting them for poles, timber, and rice farming just to mention a few. A respondent at Minazi saba village justified by saying that "*one can take almost five hours to harvest a score (20 poles) for house construction while previously it was possible for just an hour.*" This statement suggests that previously, there were abundance of mangroves but because of over utilization resulting in fewer mangroves, it takes a long time to get the score.

On the other hand, a minority of 20 (10%) of the respondents indicated that there is no change on mangrove species in the last eleven year. They defended their position by saying that "*they always get what they need and at any time*". Surprisingly, no respondent denied the knowledge about mangroves, meaning, all people in the area are aware of the status of mangrove species. What was seen to be lacking is the sustainable utilisation of these resources. Responses on mangrove species degradation in percentage currently as compared to the past eleven years in Rufiji Delta are summarized below.

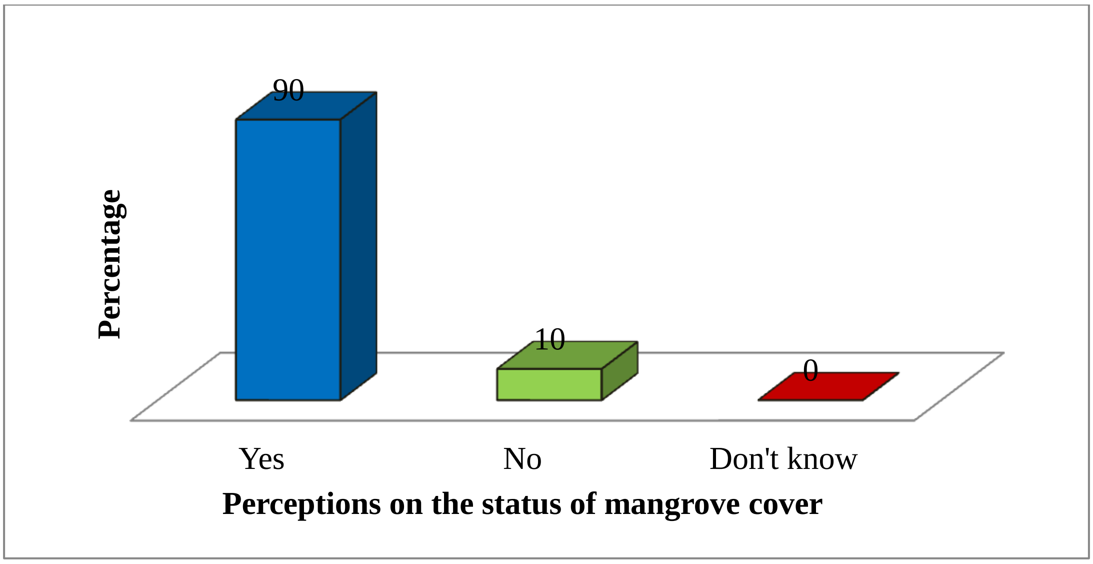


Figure 10: Perceptions of Respondents on the Status of Mangrove Cover in Percentage

When respondents were asked to give estimation on the loss of mangrove cover for the past eleven years, the responses were as follows; 116 (58%) very high, high 58 (29%), moderate 12 (6%), low 4 (2%), very low 6 (3%), and do not know 4 (2%). Looking at these responses, 174 (87%) of respondents mentioned high and very high. This means that the mangroves cover are under high threat in the area. Unless immediate initiatives should be taken by the government in collaboration with the stake holders (NGOs and local community), the mangrove cover will be over-exploited to the extent that regenerating them will take so many years to achieve.

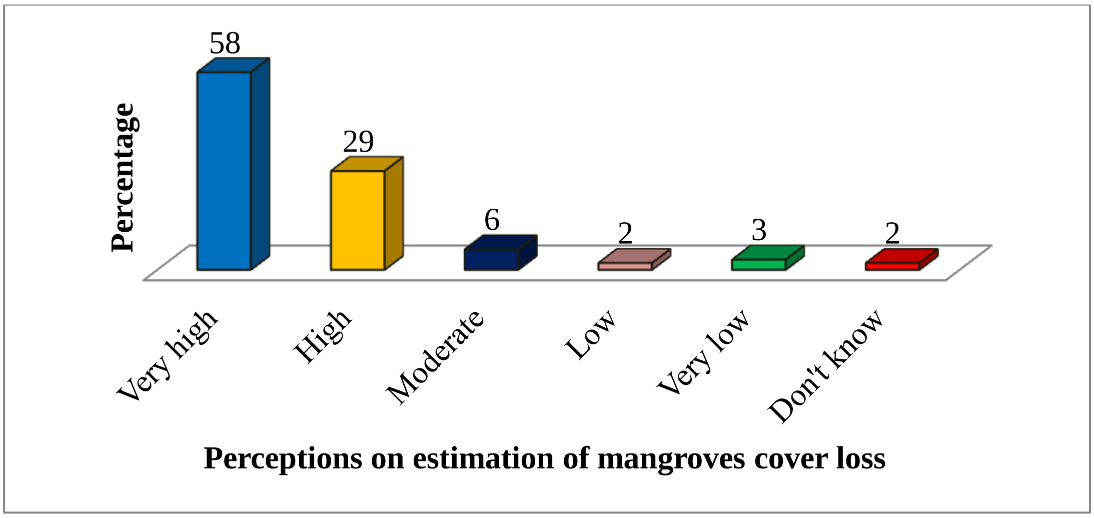


Figure 11: Perceptions of Respondents on Estimation of Mangrove Cover Loss in Percentage

The results above agree with the study done by the Rufiji Delta Inventory Team in February 2011 which reveals that there is a decrease of 1,769 ha of mangrove vegetation in every ten years. The decrease of 1,769 ha is due to expansion of agricultural activities. People are still breaking new grounds for rice farming; and unsustainable mangrove timber and pole cutting in the delta. In addition, another factor leading to mangrove species degradation mentioned is the dynamics of flooding and prolonged drought along the Rufiji river flood plains (Inventory team, February 2011). This finding is also in agreement with the findings by Wang *et al* (2003), who used Remote Sensing to study mangrove change along the Tanzania coast which shows that the Rufiji Delta mangrove species are degrading tremendously over the years.

5.3.2: Land Cover Maps of Rufiji Delta

Land cover can be referred to the physical material at the surface of the earth. Land covers include vegetation, bareland and water. Land cover maps provide information to help managers best understand the current landscape. To see change over time, land cover map for several different years are needed. With this information in the study area, coastal managers can evaluate past management decisions as well as gain insight into the possible effects of their current decisions before they are implemented. Furthermore, land cover data and maps help to predict and assess impacts from sea level rise and changes with effects in the environment or to the connections in socio-economic changes such as increasing population

5.3.2.1: Land Cover Map of Rufiji Delta, 2000

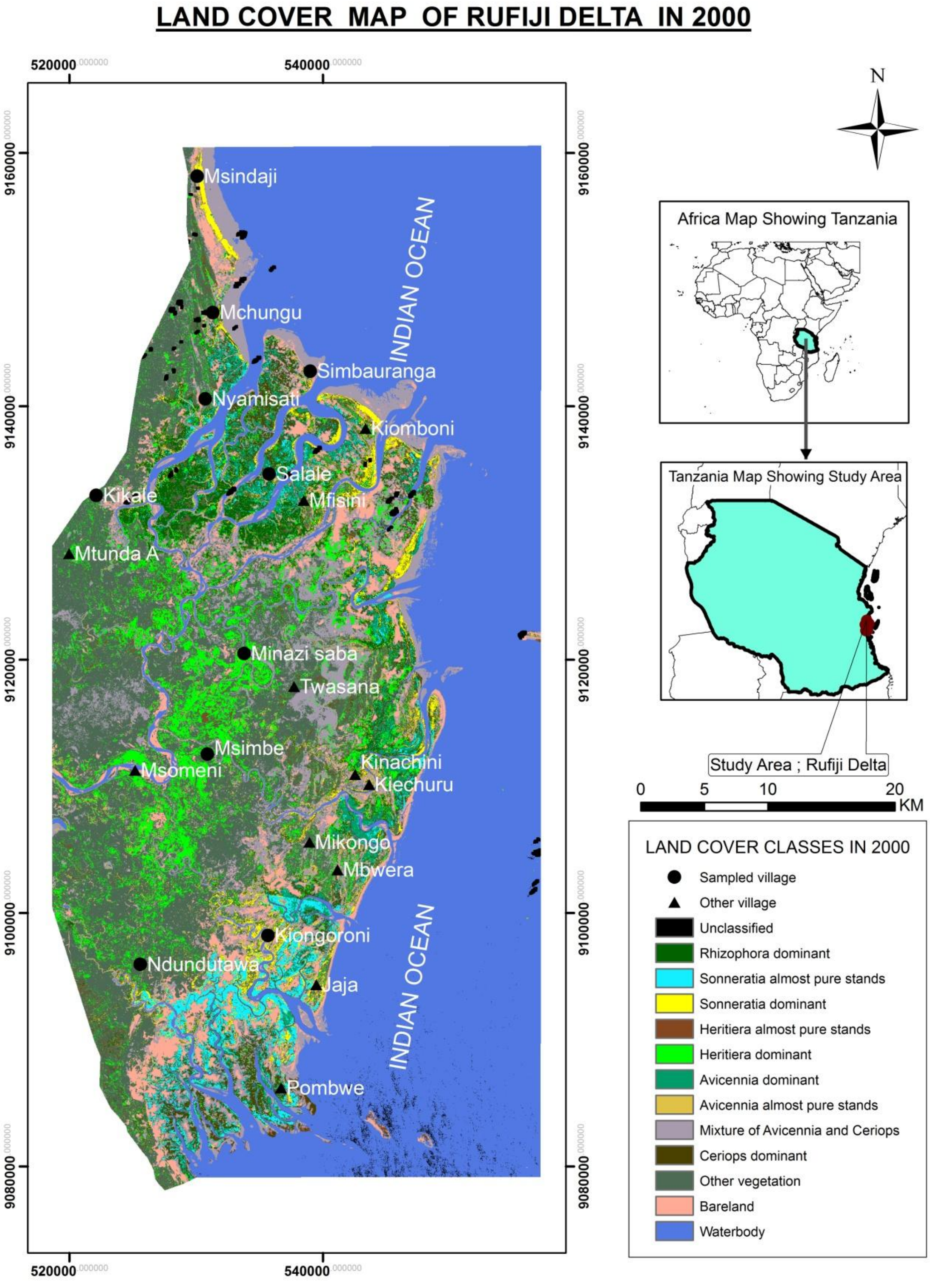


Figure 12: Land Cover of Rufiji Delta in 2000

Table 9: Accuracy Assessment Results from Maximum Likelihood Supervised Classification Training Class Performance, 2000

Land cover class	Rh	Sop	Sod	Hep	Hed	Avd	Avp	MAC	Ced	Other vegetation	Bare land	Water body	Unclassified	Total Samples	Error of Commission (%)	User's Accuracy (%)
Rh	**5**	0	0	0	0	0	0	0	0	0	0	0	0	5	0	100
Sop	0	**5**	0	0	0	0	0	0	0	0	0	0	0	5	0	100
Sod	0	0	**5**	0	0	0	0	0	0	0	0	0	0	5	0	100
Hep	0	0	0	**5**	0	0	0	0	0	0	0	0	0	5	0	100
Hed	0	0	0	0	**5**	0	0	0	0	0	0	0	0	5	0	100
Avd	0	0	0	0	0	**5**	0	0	0	0	0	0	0	5	0	100
Avp	0	0	0	0	0	0	**4**	1	0	0	0	0	0	5	20	80
MAC	0	0	0	0	0	0	0	**4**	1	0	0	0	0	5	20	80
Ced	0	0	0	0	0	0	0	0	**5**	0	0	0	0	5	0	100
Other vegetation	0	0	0	0	0	0	0	1	**0**	4	0	0	0	5	20	80
Bare land	0	0	0	0	0	0	0	0	0	**0**	**5**	0	0	5	0	100
Water body	0	0	0	0	0	0	0	0	0	0	0	**5**	0	5	0	100
Unclassified	0	0	0	0	0	0	0	0	0	0	0	0	**5**	5	-	
Total Samples	5	5	5	5	5	5	4	6	6	4	5	5	5	65		
Error of Omission (%)	0	0	0	0	0	0	0	33.3	16.7	0	0	0	-			
Producer's Accuracy (%)	100	100	100	100	100	100	100	66.7	83.3	100	100	100				

Overall Classification Accuracy (62/65*100) = 95.4% Overall Kappa Statistics (X100) = (0.9500*100) = 95

Key

Rh – *Rhizophora* dominant

Sop –*Sonneratia* almost pure stands

Sod – *Sonneratia* dominant

Hep – *Heritiera* almost pure stands

Hed – *Heritiera* dominant

Avd – *Avicennia* dominant

Avp – *Avicennia* almost pure stands

MAC – Mixture of *Avicennia* and *Ceriops*

Ced – *Ceriops* dominant

Overall Accuracy is the number of correctly classified pixels (ie. The sum of diagonal cells in the error matrix) divided by the total number of pixels checked

Kappa Statistic is a measure of map accuracy that is used to evaluate different sources (image data) or methods for the generation of spatial data.

Error of Omission refers to those sample points that are omitted in the interpretation result

Error of Commission refers to incorrectly classified samples

The User Accuracy is the probability that a certain reference class has also been labeled that class

The Producer Accuracy is the probability that a sampled point on the map is that particular class.

Table 9 shows the results from the ML supervised classification, 2000. All samples representing *Rhizophora* dominant, *Sonneratia* almost pure stands, *Sonneratia* dominant, *Heritiera* almost pure stands, *Heritiera* dominant, and *Avicennia* dominant classes were correctly classified yielding a classification accuracy of 100% each. For *Avicennia* almost pure stands 4 samples were correctly classified producing a classification accuracy of 80%. While one was observed as a mixture of *Avicennia* and *Ceriops* giving the accuracy of 20%. Similarly, 4 samples were correctly classified as a mixture of *Avicennia* and *Ceriops* class making up an accuracy of 80% for this class. But one was captured as *Ceriops* dominant yielding the classification accuracy of 20% for this class.

Ceriops dominant, other vegetation, bareland, and waterbody classes revealed the same results. This means, all their samples were correctly classified giving the classification accuracy of 100% each. To sum up, a total of 65 samples were used for the accuracy assessment. Out of these 65 samples, 62 were correctly classified, while 2 samples were classified differently. Above all, an overall accuracy of 95.4% and Kappa statistics of 95% were obtained.

5.3.2.2: Land Cover Map of Rufiji Delta, 2011

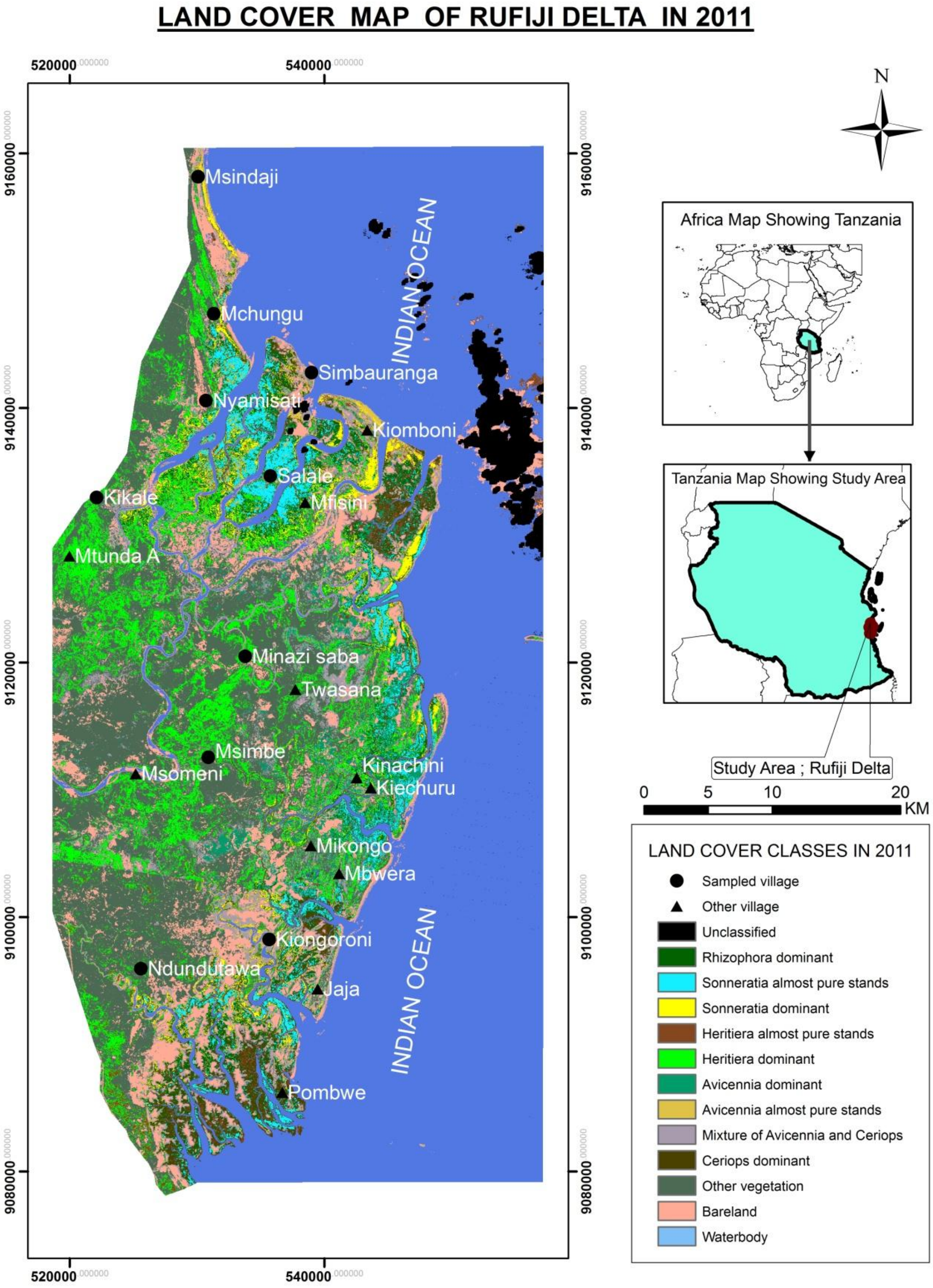


Figure 13: Land Cover of Rufiji delta in 2011

Table 10: Accuracy Assessment Results from Maximum Likelihood Supervised Classification Training Class Performance, 2011

Land cover class	Rh	Sop	Sod	Hep	Hed	Avd	Avp	MAC	Ced	Other vegetation	Bare land	Water body	Unclassified	Total Samples	Error of Commission (%)	User's Accuracy (%)
Rh	**5**	0	0	0	0	0	0	0	0	0	0	0	0	5	0	100
Sop	1	**4**	0	0	0	0	0	0	0	0	0	0	0	5	20	80
Sod	0	0	**4**	1	0	0	0	0	0	0	0	0	0	5	20	80
Hep	0	0	0	**5**	0	0	0	0	0	0	0	0	0	5	0	100
Hed	0	0	0	0	**5**	0	0	0	0	0	0	0	0	5	0	100
Avd	0	0	0	0	0	**5**	0	0	0	0	0	0	0	5	0	100
Avp	0	0	0	0	0	0	**4**	1	0	0	0	0	0	5	20	80
MAC	0	0	0	0	0	0	0	**4**	0	0	1	0	0	5	20	80
Ced	0	0	0	0	0	0	0	0	**5**	0	0	0	0	5	0	100
Other vegetation	0	0	0	0	0	0	0	0	0	**5**	0	0	0	5	0	100
Bare land	0	0	0	0	0	0	0	0	0	0	**5**	0	0	5	0	100
Water body	0	0	0	0	0	0	0	0	0	0	0	**5**	0	5	0	100
Unclassified	0	0	0	0	0	0	0	0	0	0	0	0	**5**	5	-	
Total Samples	6	4	4	6	5	5	4	5	5	5	6	5	5	65		
Error of Omission (%)	16.7	0	0	16.7	0	0	0	16.7	0	0	0	0	-			
Producer's Accuracy (%)	83.3	100	100	83.3	100	100	100	83.3	100	100	83.3	100	-			

Overall Classification Accuracy (61/65*100) = 94%   Overall Kappa Statistics (X100) = (0.9301*100) = 93

Table 10 indicates the results from the ML supervised classification, 2011. For *Rhizophora* dominant class, 5 samples were correctly classified producing the classification accuracy of 100% of this class. In *Sonneratia* almost pure stands, 4 samples were classified correctly yielding a classification accuracy of 80% each. One was identified as *Rhizophora* dominant making up an accuracy of 20%. Looking at *Sonneratia* dominant, 4 samples were classified correctly producing the accuracy of 80%, whereas, one was found as *Heritiera* almost pure stands yielding the accuracy of 20% of this class.

In the case of *Heritiera* almost pure stands, *Heritiera* dominant and *Avicennia* dominant, all samples were classified correctly producing the accuracy of 100% each. For *Avicennia* almost pure stands, and a mixture of *Avicennia* and *Ceriops*, 4 samples were correctly classified giving the accuracy of 80%. Whereas in *Avicennia* almost pure stands one was identified as a mixture of *Avicennia* and *Ceriops* making up the accuracy of 20% for this class but other in a mixture of *Avicennia* and *Ceriops* was seen as *Ceriops* dominant giving a classification accuracy of 20% .

Similar results were observed for *Ceriops* dominant, other vegetation, bareland and waterbody classes. In each class, 5 samples were correctly classified producing the classification accuracy of 100% each. Generally, a total of 65 samples were used for accuracy assessment. Out of these 65, 61 samples were correctly classified while 4 samples were misclassified. An overall accuracy and Kappa statistics of 94% and 93% were obtained respectively.

5.3.2.3: Land Cover Distribution in Rufiji Delta between 2000 and 2011

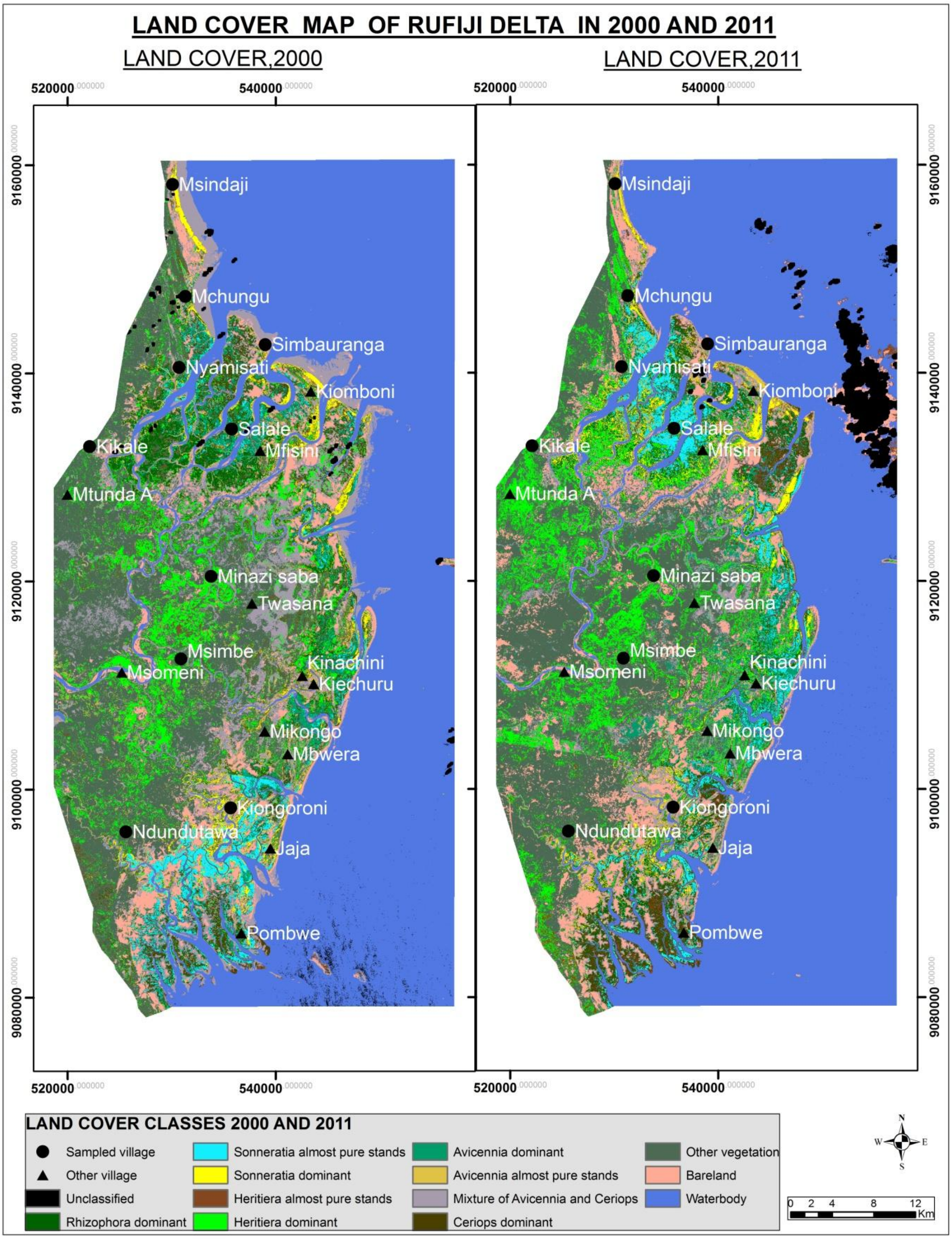


Figure 14: Comparison of Land Cover Distribution in Rufiji Delta between 2000 and 2011

The static land cover distribution for each study year as derived from the maps are presented in the table below

Table 11: Land Cover Distribution in Rufiji Delta in 2000 and 2011 in Hectares and Percentage

Land cover classes	**2000(ETM⁺)**		**2011 (TM)**		**Land cover change**	
	Area (ha)	**Area (%)**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**
Unclassified	1634.94	0.58	5651.55	2.00	4016.61	1.42
Rhizophora dominant	5428.44	1.92	8504.91	3.01	3076.47	1.09
Sonneratia almost pure stands	6056.1	2.14	8054.19	2.85	1998.09	0.71
Sonneratia dominant	4317.57	1.53	4446.63	1.57	129.06	0.05
Heritiera almost pure stands	4623.12	1.63	5523.57	1.95	900.45	0.32
Heritiera dominant	15914.5	5.63	19786.6	7.00	3872.1	1.37
Avicennia dominant	7172.55	2.54	5209.65	1.84	-1962.9	-0.69
Avicennia almost pure stands	4694.31	1.66	3012.48	1.07	-1681.83	-0.59
Mixture of *Avicennia* and *Ceriops*	30041.5	10.62	14818.7	5.24	-15222.8	-5.38
Ceriops dominant	7983.99	2.82	5681.43	2.01	-2302.56	-0.81
Other vegetation	53799.6	19.02	53200	18.81	-599.2	-0.21
Bare land	10492.7	3.71	17905.5	6.33	7412.8	2.62
Water body	130697	46.21	131061	46.33	364	0.12
TOTAL	**282856**	**100.00**	**282856**	**100.00**	**-**	-

From Table 11, the status of each land cover category for each year (2000 or 2011) is displayed. In 2000, *Sonneratia* dominant occupied the least class with 4317.57 ha (1.53%) of the total coverage, followed by *Heritiera* almost pure stands class occupying 4623.12 ha (1.63%). *Avicennia* almost pure stands occupied 4694.31 ha (1.66%) of the total coverage while *Rhizophora* dominant covered 5428.44 ha (1.92%). Looking at *Sonneratia* almost pure stands in the same year, its coverage was 6056.1 ha (2.14%).

Avicennia dominant comprised 7171.55 ha (2.54%) whiles *Ceriops* dominant occupied 7983.99 ha (2.82%). Furthermore, Bareland coverage was 10492.7 ha (3.71%). *Heritiera* dominant total area was 15914.5 ha (5.63%) and a mixture of *Avicennia* and *Ceriops* as the third largest class covered 30041.5 ha (10.62%). Other vegetation as the second largest class occupied 53799.6 ha (19.02) and lastly, Waterbody occupied the largest area covering 130697 ha (46.21%).

However, the pattern of land cover distributions in 2011 is not the same as in 2000. In this year, *Avicennia* almost pure stands covered the least area with 3012.48 ha (1.07%). *Sonneratia* dominant had the second least coverage of 4446.63 ha (1.57%). *Avicennia* dominant occupied 5209.65 ha (1.84%) of the total coverage and *Heritiera* almost pure stands was seen as having 5523.57 ha (1.95%) whiles *Ceriops* dominant occupied 5681.43ha (2.01%) in the same year. *Sonneratia* almost pure stands had acreage of 8054.19 ha (2.85%).

Also, *Rhizophora* dominant occupied 8504.91 ha (3.01%) of the study area. Furthermore, a mixture of *Avicennia* and *Ceriops* in the same year covered 14818.7 ha (5.24%), whiles bareland enclosed an area of 17905.5 ha (6.33%). *Heritiera* dominant occupied 19786.6 ha (7%) whereas other vegetation maintained its position as the second largest class occupied a total area of 53200.4 ha (18.81%). Finally, waterbody had a largest coverage of 131061 ha (46.33%).

5.3.3. Location and Nature of Change in Land Cover in Rufiji Delta, 2000 – 2011

The role of change detection is to determine "what is actually changing to what", thus, which land cover class is changing to the other. This information will reveal both the desirable and undesirable changes and classes that are "relatively" stable overtime. It serves as a vital tool in the monitoring and management decisions of various land cover types including those that are found within the Rufiji Delta.

5.3.3.1: Location of Changes in Land Cover Classes within the Rufiji Delta, 2000-2011

In terms of change, the main emphasis is on the mangrove vegetation, other vegetation and bareland. Figure 14 shows this change between 2000 and 2011. Generally, the observation here is that there seems to exist a drastic decrease of mangrove vegetation with an increase of bareland in the delta specifically, around Msindaji, Nyamisati, Minazi saba, Twasana and Ndundutawa villages. A possible explanation for this might be due to communities heavily depending on mangrove vegetation for their livelihood (e.g. clearing mangrove vegetation for rice farming). This dependency also initiates land transformations by the felling of mangrove vegetation for construction purposes or conversion of mangrove habitats to land uses like settlement, consequently, causes biotic losses.

Population growth and development in the study years (2000 and 2011) estimated by the researcher as 38,148 and 49,902 respectively might have caused an increase in the anthropogenic pressure on the environment. It was observed that over-harvesting of existing mangrove vegetation and expanding new settlement are problems currently recognised by both the local government and the local community. Increase in demand for wood products and easily available market for mangrove timber in Zanzibar and external market (Arab world) through Zanzibar market has created serious challenges in mangrove forest management. This has resulted in a serious illegal timber harvesting and transportation.

In 2002, the Mangrove Management Project facilitated villagers in the delta to form Village Natural Resources Committees (VNRCs).The committee has ten members and is responsible for natural resource matters including protection, harvesting, supervision and planting of mangroves. Surprisingly, it was found that these committees are not adequately effective due to lack of good governance and effective cost-benefit sharing mechanisms. This also contributes to poor management of mangrove resource in the study area.

In addition, legal instruments used in effecting involvement of local people have been through National Forest Policy of 1998, Forest Act No. 14 of 2002 and its Regulation of 2004. At the community level where necessary, by-laws are formulated, as provided by Act No. 7 of 1982, to address the conditions and requirements of managing the reserve. For effective management, instruments like Memorandum of Understanding (MoU) or Memorandum of Agreement (MoA) are necessary instruments between and among the collaborating parties. It was identified that as for the time of the study, there was no approved MoU, MoA, or bye-laws between the management of Rufiji Delta Mangrove Forest Reserve and respective stakeholders (local community). This does not give villagers strength and motivation to participate effectively in conservation, thus, leading to mangrove vegetation degradation.

It was also observed that heavy erosion in some parts of the study area (e.g Simbauranga) which is thickest along the seaward edge and in traces along the river channels contributes to mangrove vegetation loss for the past 11years. The study findings also provide strong evidence that the exposed seaward edges of mangrove forests investigated are quite vulnerable to climate change factors. The main factors likely creating threats on these areas are sea level rise and increasing frequency and severity of storm surges or wave action. Sea level rise alone would likely cause only minor and very gradual pressure on seaward edges.

However, when combined with increased wave activity and high water events, these climate change factors appear to have caused drastic and extensive coastal erosion and loss of mangrove vegetation in the study area. Although, the pattern seems to be uniform, there exists more decrease of other vegetation with the increase of Bareland around Msomeni and Ndundutawa villages.

On the other hand, there exist mangrove vegetation replacement in some parts of the delta, specifically around Nyamisati and Salale which were previously dominated by other mangrove types now being occupied by *Sonneratia* almost pure stands. This result may be explained by a number of factors. The observed increase in mangrove vegetation could be attributed to awareness creation on mangrove restoration to the local communities by MNRT and NGOs that interact in the management and conservation of RdMFR.

These NGOs include RUMAKI, REMP, WIOMSA, IMS, FAST, WWF, RUBEP, TCMP, TAMPA and UNESCO. The findings indicate that sensitization and awareness meetings that were conducted in all 34 villages focused mainly on role of VNRCs, villagers and FBD staff in the management of mangroves. VNRCs members were trained on various management approaches including record keeping, law enforcement, report writing and beekeeping.

Furthermore, there are other possible explanations to reduction of Bareland in the Rufiji Delta. One of them might be the effort to rehabilitate degraded mangroves area in 1994 to 2005 under NORAD funding support in which a total of 840 ha were planted in the area of study. This programme was specifically done at Kikale, Pindanikile, Twasalie, Salale, Mawanda, Maunga, and Nyamisati villages. After the end of the NORAD programme in 2005, more planting of mangroves continued, where a total of 112 ha were planted from MACEP funding support.

Moreover, RUMAKI funding for climate change mitigation activities was also used for expanding planted area where a total of 88 Ha were planted. Furthermore, the National Forest Programme supported by plating of 250 ha in the Rufiji Delta. There is also a slight increase (Table 11) in waterbody coverage of 0.12% from 2000 to 2011; however, this probably could have been more if portions of the 2011 subsetted image had not been masked due to cloud cover.

5.3.3.2: Nature of Change in Land Cover Classes in Rufiji Delta, 2000 - 2011

Looking at the nature of change under stability i.e. areas with no change and instability i.e. areas with loss or gain by each class between 2000 and 2011 particularly in the change of the hectares as observed in Table 11 above. Stability seems to be a relative term as no class is actually stable during this period. Generally, between 2000 and 2011, *Rhizophora* dominant gained by 3076.47 ha (1.09%). Also, *Sonneratia* almost pure stands increased by 1998.09 ha (0.71%) while *Sonneratia* dominant enlarged by 129.06 ha (0.05%). *Heritiera* almost pure stands amplified by 900.45ha (0.32%). Similarly, *Heritiera* dominant gained by 3872.1 ha (1.37%).

However, the results showed that *Avicennia* dominant decreased by 1962.9 ha (0.69%) while *Avicennia* almost pure stands has a loss of 1681.83 ha (0.59%) but a mixture of *Avicennia* and *Ceriops* reduced by 15222.8 ha (5.38%). It was also observed that *Ceriops* dominant decreased by 2302.56 ha (0.81%) while other vegetation reduced by 599.2 ha (0.21). On the other hand, bareland increased by 7412.8 ha (2.62%) and waterbody also showed a gain of 364 ha (0.12%).

5.3.4: Land Cover Classes Change Matrix in Rufiji Delta from 2000 to 2011

Table 12: Land Cover Change Detection of Rufiji Delta between 2000 and 2011 in Histogram (Pixels)

		2011												
	Land cover classes	Rh	Sop	Sod	Hep	Hed	Avd	Avp	MAC	Ced	Other vegetation	Bareland	Waterbody	**Class total**
2000	Rh	**15054**	4444	9581	1601	14978	3537	2859	3223	555	1876	0	2548	**60256**
	Sop	17319	**26657**	5883	1713	265	1029	2336	654	11246	95	3	47	**67247**
	Sod	3961	1669	**16400**	3249	4358	948	8717	3359	2799	452	23	1855	**47790**
	Hep	1924	566	2550	**5527**	16559	1042	2327	4855	2531	1357	2231	9850	**51319**
	Hed	4616	2765	971	3184	**53726**	11495	757	11804	2073	9004	253	76177	**176825**
	Avd	20690	33396	2312	2387	1650	**5417**	1833	1625	9907	90	11	187	**79505**
	Avp	2095	370	2515	2442	8295	1609	**3971**	10053	667	2264	144	17713	**52138**
	MAC	6701	2525	2037	17597	8315	15239	6185	**79945**	11124	45349	65302	73109	**333428**
	Ced	21293	16753	5845	10060	1159	4734	2108	2306	**20809**	226	3096	157	**88546**
	Other vegetation	120	161	149	618	1500	1590	1273	16209	151	**73745**	7273	13655	**116444**
	Bareland	30	28	8	5508	369	126	68	1603	845	16357	**1364731**	948	**1390621**
	Waterbody	219	13	940	7028	107818	10962	981	28474	56	47749	447	**393086**	**597773**
	Class total	**94022**	**89347**	**49191**	**60914**	**218992**	**57728**	**33415**	**164110**	**62763**	**198564**	**1443514**	**589332**	3061892
	Class change	78968	62690	32791	55387	165266	52311	29444	84165	41954	124819	78783	196246	0
	Image difference	-33766	-22100	-1401	-9595	-42167	21777	18723	169318	25783	-82120	-52893	8441	0

Table 13: Land Cover Change Detection of Rufiji Delta between 2000 and 2011 in Hectares

	2011													
	Land cover classes	Rh	Sop	Sod	Hep	Hed	Avd	Avp	MAC	Ced	Other vegetation	Bareland	Waterbody	**Class total**
	Rh	**1354.86**	399.96	862.29	144.09	1348.02	318.33	257.31	290.07	49.95	168.84	0	229.32	**5423.04**
	Sop	1558.71	**2399.13**	529.47	154.17	23.85	92.61	210.24	58.86	1012.14	8.55	0.27	4.23	**6052.23**
	Sod	356.49	150.21	**1476**	292.41	392.22	85.32	784.53	302.31	251.91	40.68	2.07	166.95	**4301.1**
	Hep	173.16	50.94	229.5	**497.43**	1490.31	93.78	209.43	436.95	227.79	122.13	200.79	886.5	**4618.71**
	Hed	415.44	248.85	87.39	286.56	**4835.34**	1034.55	68.13	1062.36	186.57	810.36	22.77	6855.93	**15914.25**
	Avd	1862.1	3005.64	208.08	214.83	148.5	**487.53**	164.97	146.25	891.63	8.1	0.99	16.83	**7155.45**
2000	Avp	188.55	33.3	226.35	219.78	746.55	144.81	**357.39**	904.77	60.03	203.76	12.96	1594.17	**4692.42**
	MAC	603.09	227.25	183.33	1583.73	748.35	1371.51	556.65	**7195.05**	1001.16	4081.41	5877.18	6579.81	**30008.52**
	Ced	1916.37	1507.77	526.05	905.4	104.31	426.06	189.72	207.54	**1872.81**	20.34	278.64	14.13	**7969.14**
	Other vegetation	10.8	14.49	13.41	55.62	135	143.1	114.57	1458.81	13.59	**6637.05**	654.57	1228.95	**10479.96**
	Bareland	2.7	2.52	0.72	495.72	33.21	11.34	6.12	144.27	76.05	1472.13	**122825.79**	85.32	**125155.9**
	Waterbody	19.71	1.17	84.6	632.52	9703.62	986.58	88.29	2562.66	5.04	4297.41	40.23	**35377.74**	**53799.57**
	Class total	**8461.98**	**8041.23**	**4427.19**	**5482.26**	**19709.28**	**5195.52**	**3007.35**	**14769.9**	**5648.67**	**17870.76**	**129916.26**	**53039.88**	**275570.3**
	Class change	7107.12	5642.1	2951.19	4984.83	14873.94	4707.99	2649.96	7574.85	3775.86	11233.71	7090.47	17662.14	0
	Image difference	-3038.94	-1989	-126.09	-863.55	-3795.03	1959.93	1685.07	15238.62	2320.47	-7390.8	-4760.37	759.69	0

Table 14: Land Cover Change Detection of Rufiji Delta between 2000 and 2011 in Percentage

		2011												
	Land cover classes	Rh	Sop	Sod	Hep	Hed	Avd	Avp	MAC	Ced	Other vegetation	Bareland	Waterbody	**Class total**
	Rh	**16.01**	4.97	19.48	2.63	6.84	6.13	8.56	1.96	0.88	0.94	0.00	0.43	**100.00**
	Sop	18.42	**29.84**	11.96	2.81	0.12	1.78	6.99	0.40	17.92	0.05	0.00	0.01	**100.00**
	Sod	4.21	1.87	**33.34**	5.33	1.99	1.64	26.09	2.05	4.46	0.23	0.00	0.31	**100.00**
	Hep	2.05	0.63	5.18	**9.07**	7.56	1.81	6.96	2.96	4.03	0.68	0.15	1.67	**100.00**
	Hed	4.91	3.09	1.97	5.23	**24.53**	19.91	2.27	7.19	3.30	4.53	0.02	12.93	**100.00**
	Avd	22.01	37.38	4.70	3.92	0.75	**9.38**	5.49	0.99	15.78	0.05	0.00	0.03	**100.00**
2000	Avp	2.23	0.41	5.11	4.01	3.79	2.79	**11.88**	6.13	1.06	1.14	0.01	3.01	**100.00**
	MAC	7.13	2.83	4.14	28.89	3.80	26.40	18.51	**48.71**	17.72	22.84	4.52	12.41	**100.00**
	Ced	22.65	18.75	11.88	16.52	0.53	8.20	6.31	1.41	**33.15**	0.11	0.21	0.03	**100.00**
	Other vegetation	0.13	0.18	0.30	1.01	0.68	2.75	3.81	9.88	0.24	**37.14**	0.50	2.32	**100.00**
	Bareland	0.03	0.03	0.02	9.04	0.17	0.22	0.20	0.98	1.35	8.24	**94.54**	0.16	**100.00**
	Waterbody	0.23	0.01	1.91	11.54	49.23	18.99	2.94	17.35	0.09	24.05	0.03	**66.70**	**100.00**
	Class total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	0
	Class change	83.99	70.16	66.66	90.93	75.47	90.62	88.12	51.29	66.85	62.86	5.46	33.30	0
	Image difference	-35.91	-24.74	-2.85	-15.75	-19.26	37.72	56.03	103.17	41.08	-41.36	-3.66	1.43	0

With specific reference to which land cover class is changing to the other between the year 2000 and and 2011, Table 12 and Table 13 show the histogram and the area in hectares respectively, which were then converted into percentage (Table 14). Looking at individual land cover class within the period of 11 years, *Rhizophora* dominant maintained an area of 1354.86 ha (16.01%) and lost 4068.18 ha (52.83%) to other mangrove classes, other vegetation, bareland and waterbody. On the other hand, it gained a total area of 7107.12 ha (83.99%) from other land cover classes, thus, produced an image difference of -3038.94 ha (-35.91%).

In the same period of time, *Sonneratia* almost pure stands retained a coverage of 2399.13 ha (29.84%) but decreased by 3653.1 ha (60.46%) to other mangrove classes, other vegetation, bareland and waterbody. However, it received 5642.1 ha (70.16%) from other land cover classes and gave the image difference of -1989 ha (-24.74%). From 2000 to 2011, *Sonneratia* dominant maintained 1476 ha (33.34%), while lost 2825.1 ha (48.18%) to other mangrove classes, other vegetation, bareland and waterbody. At the same time it gained 2951.19 ha (66.66%), hence, showed the image difference of -126.09 ha (-2.85%).

Heritiera almost pure stands had 497.43 ha (9.07%) between 2000 and 2011. Although, results indicated a loss of 4121.28 ha (33.69%) to other land cover classes, it also received 4984.83 ha (90.93%) from them, and displayed the image difference of -863.55 ha (-15.75%). Within this period, *Heritiera* dominant maintained 4835.34 ha (24.53%). Though, it allowed a loss of 11078.91 ha (65.36%) to other land cover classes, it also gained 14873.94 ha (75.47%) from other vegetation, bareland and waterbody, thus, indicated the image difference of -3795.03 ha (-19.26%).

Avicennia dominant between 2000 and 2011 had 487.53 ha (9.38%). Despite the fact that it lost 6667.92 ha (68.76%) to other vegetation, bareland and waterbody, it received 4707.99 ha (90.62%) from these land cover classes and showed the image difference of 1959.93 ha (37.72%). *Avicennia* almost pure stands retained 357.39 ha (11.88%), whereas, it decreased by 4335.03 ha

(29.68%) to other land cover categories. At the same time as it increased by2649.96 ha (88.12%) from them, hence indicated the image difference of 1685.07 ha (56.03%).

Furthermore, from 2000 to 2011, a mixture of *Avicennia* and *Ceriops* maintained an area of 7195.05 ha (48.71%) but also indicated a loss of 22813.47 ha (149.18%) to other vegetation, bareland and waterbody. However, it received 7574.85 ha (51.29%) from them and showed an image difference of 15238.62 ha (103.17%). *Ceriops* dominant within this period had 1872.81 ha (33.15%) while experienced the decrease of 6096.33 ha (86.59%) to other land cover types. Within these 11 years, it gained 3775.86 ha (66.85%) other land cover classes, thus, indicated the image difference of 2320.47 ha (41.08%).

Moreover, other vegetation maintained a total area of 6637.05 ha (37.14%) but allowed a loss of 3842.91 ha (21.81%) to mangrove classes, bareland and waterbody. It also received 11233.71 ha (62.86%) from mangrove types, bareland and waterbody, hence, showed the image difference of -7390.8 ha (-41.36%). bareland maintained 122825.79 ha (94.54%) and lost 2330.1 ha (20.43%) to other land cover classes. It received 7090.47 ha (5.46%) from them and finally gave an image difference of -4760.37 ha (-3.66%). Finally, waterbody in this period maintained an area of 35377.74 ha (66.70%) whereas it decreased by 18421.83 ha (126.37%) to other land cover classes at the same time it gained the area of 17662.14 ha (33.30%), therefore, it indicated the image difference of 759.69 ha (1.43%).

5.3.5: Vegetation Change Detection in Rufiji Delta, 2000-2011

Change detection is a process that measures how the attributes of a particular area have changed between two or more time periods (Lu *et al.*, 2003). In general, the problem concerns both detecting whether or not a change has occurred, or whether several changes might have occurred, and identifying the times of any such changes. In this study, it involved satellite imagery of the area (Rufiji Delta) taken at different times (2000 and 2011). This was done to function as a guide towards mangrove vegetation management in the area of study.

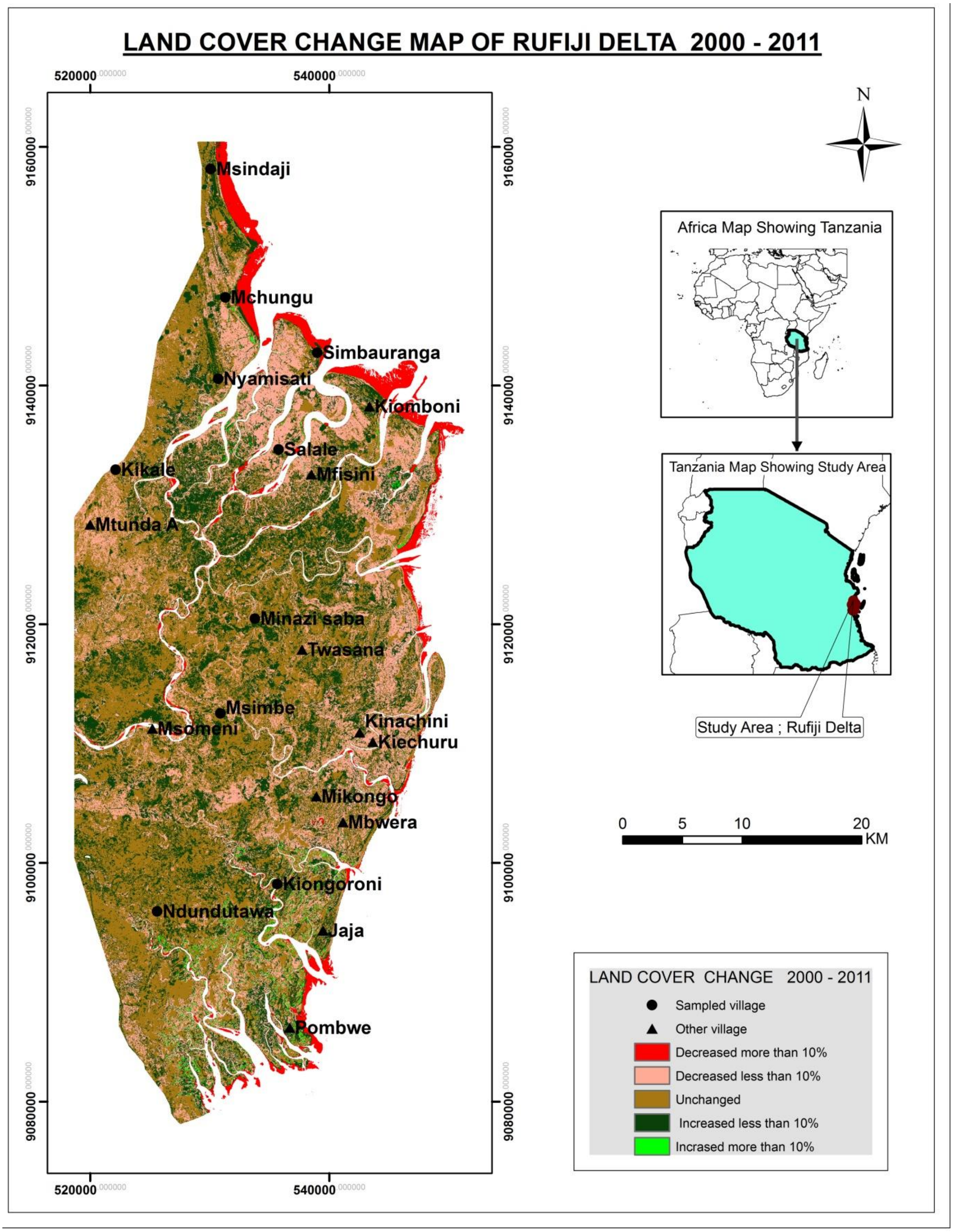


Figure 15: Land Cover Change Map of Rufiji Delta, 2000-2011

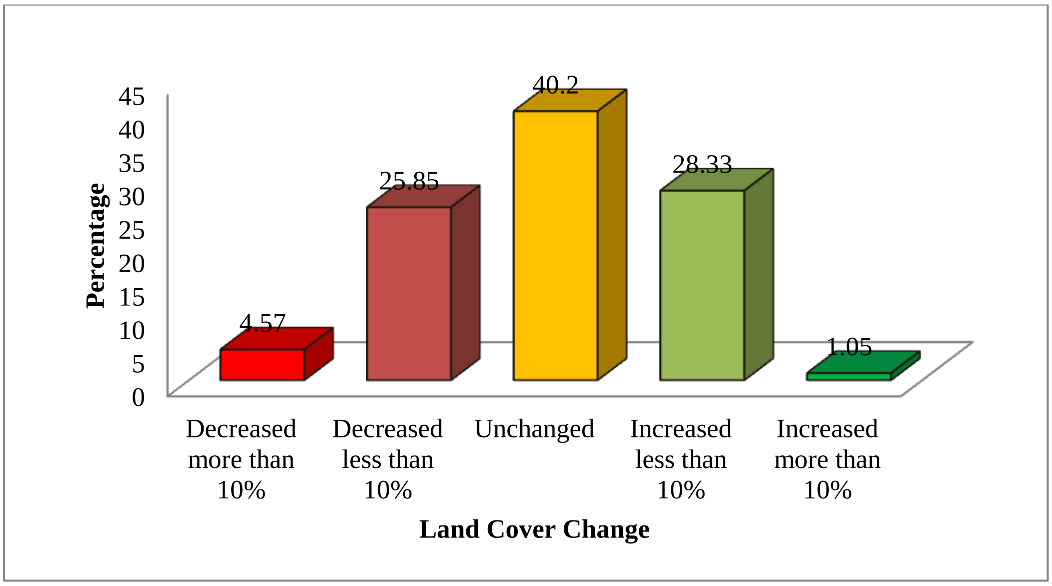


Figure 16: Land Cover Change Detection of Rufiji Delta, 2000 – 2011 in Percentage

The spatial distribution of land cover changes and the variations that had occurred in Rufiji Delta between 2000 and 2011 are shown in Map 5. The analysis showed that during this period, specifically, along the coast and river areas land cover have decreased more that 10% by 6887.97 ha (4.57%) of the total area. This might be due to soil erosion, abrasion by sea waves, and human activities carried along water bodies have lead to land degradation. It was also inferred that land cover around Nyamisati, Kikale, Mtunda A, Simbauranga, Salale, Kiechuru, Kinachini, among others have decreased less than 10% by 38943.72 ha (25.85%). The results reflect the main reasons for this might be due to illegal felling of mangrove vegetation, shifting cultivation, and population increase leading to settlement expansion has caused land cover depletion.

The analysis indicated that there is a uniform distribution of unchanged land cover in the area of study within 2000 and 2011. However, this was seen to be more dominated by other vegetation class especially areas around Mchungu and Ndundutawa where there are forest reserves as compared to mangrove vegetation classes. The area covered by unchanged vegetation was found to be 60574.5 ha (40.20%) being the largest coverage. This might be due to the fact that people do not greatly rely on this land cover type as compared to mangrove vegetation.

However, observations on the results clearly proved that at the same time, there has been increased in land cover by less than 10% by 42691.23 ha (28.33%) in land cover distributed almost to the entire delta. Similarly, land cover in the Rufiji Delta has increased more than 10% by 1574.55 ha (1.05%). This is specifically, around rivers at Pombwe, Jaja and Kiongoroni villages. Same results also were observed along rivers near Nyamisati, and some parts close to Mchungu village. The possible explanation to this might be due to the activities which are conducted by the MNRT and NGOs interacting with the community in managing mangrove forest in the area.

5.4: Factors Causing Mangrove Resources Degradation

Many researchers have reported that the value of mangrove vegetation has gone unrecognized for many years and the forests are disappearing in many parts of the world. These impacts are likely to continue, and worsen, as human populations expand further into the mangroves. Thus, mangrove systems require intensive care to save threatened areas. So far, conservation and management efforts lag behind the destruction; it is suggested that there is still much to learn about proper management and sustainable harvesting of mangrove forests (Kathiresan and Bingham, 2001). Numerous research findings have indicated that even where efforts have been made to slow the destruction, remaining forests have a number of problems. In some areas, the health and productivity of the mangroves have declined significantly.

The causes of these tragic losses differ from habitat to habitat but are generally tied directly or indirectly to human activities. Therefore, individual study is required to determine the most effective remedial measures. Where degraded areas are being regenerated, continued monitoring and thorough assessment must be done to help in understanding the recovery process (van Speybroeck, 1992). This knowledge will help to develop strategies to effectively rehabilitate degraded mangrove habitats over the world.

The findings shows that the major anthropogenic pressure on the Rufiji Delta are associated with the socio-economic activities such as agriculture (farming), fishing and various local and external commercial trades. Most of these activities have taken different shapes during the course of time, and are currently pausing significant negative effects to the future sustainability of the mangrove resources present in the area of study. The future trends on these activities are considered to be a function of demographic change.

The general response given by respondents in answering the question: “Do you think the mangrove vegetation in Rufiji Delta are being degraded?” was that (190 = 95%) of them agreed. The remaining (10 = 5%) disagreed because the mangroves vegetation are available to them at any time they need them. Generally, they all mentioned factors such as mangrove cutting for poles, timber, firewood, and charcoal pause threats in the study area.

They also added factors such as destructive agriculture, destructive fishing, urbanisation, tropical storms, mangrove species, diseases, biological pests and parasites, prevention of freshwater flow and tidal flow, and pollution. Moreover, factors including; sedimentation, salinity, floods, climate change, market failure, conflict interests, lack of institutional coordination, inadequate capacity for enforcement of policies and rules, poverty and lack of economic alternatives, lack of alternative material of construction/ fuel, and tourism were listed.

5.4.1: Destructive Agriculture Practices

The research findings conducted in June-July, 2012, indicated that agriculture especially rice cultivation is one of the main activities conducted in the Rufiji Delta. Almost every household involves in it for food and cash. It was found that more than 50% of respondents are peasant farmers and most of them engage in unplanned agriculture (Figure7).

In addition to rice cultivation, villages surrounding the delta such as Nyamisati and Mchungu also engage in cashew nuts and cassava cultivation.

These findings concur with a significant number of previous studies conducted in the study area which reveal that the Rufiji Delta has been and is still an area of great agricultural potential (Bantje, 1979, 1980; Kajia, 2000; Ochieng, 2002). Historical record reports more than 20 occasions of serious food shortages and famines between 1880 and 1980 in Rufiji District (Bantje, 1980). It is generally believed that the export of agricultural products was probably the dominant trend during the 19^{th} Century. During those “good olden days”, the agricultural production in most villages produced beyond self-sufficiency to create surplus for export outside tribal boundaries (Ochieng, 2002).

Today, the old trend has significantly changed. The present agricultural production in Rufiji Delta is not even enough for subsistence. Ochieng (2002) notes that, today no exports of foodstuffs are reported and food remains the main expenditure item as quantities of food crops produced are inadequate to cover all the household needs of food and cash. Despite the dwindling trends of agriculture, various studies indicate that, agriculture is still the main occupation of many households in the Rufiji Delta. It is estimated that today, more than 90% of households in the Rufiji Delta consider agriculture as their main occupation (Ochieng, 2002). The agricultural system of the Rufiji Delta has for a long time been influenced by a combination of both rainfall and flooding (Bantje, 1980; Ochieng, 2002).

Findings indicated that growing demand for fertile ground and wetlands for paddy farms in Rufiji district has led farmers to continuously clear mangrove forests in the Rufiji Delta, adversely affecting the ecosystem. One of the most pressing issues driving mangrove forest loss in the study area was observed to land conversion. For instances, clearing of mangrove vegetation for rice farms, conversion to salt pans, and conversion to aquaculture ponds. It was found that poor agricultural practices contribute to the loss of mangrove vegetation, as well as associated problems such as siltation.

Shifting cultivation was a major agricultural system in Rufiji Delta for some decades ago but now has become less common as the land shortage has worsened, although, it is still a threat. It was mentioned that under shifting cultivation, yields are initially high in newly opened rice field in the mangroves, but decline after the third year, and the field is abandoned due to weed invasion by the seventh year. This practice leads to the clearing of mangroves every time a new field was opened. Shifting cultivation is still a threat in the study area today.

In the Rufiji Delta, farmers have been moving away from the increased salty rivers where most rice fields are located, further out into the delta in search for fresh water and better land. For example, it was evidenced that saline intrusion has forced farmers at Nyamisati village in Salale ward to move to areas such as Bunga, Mchinga and Mfisini soil is still very fertile. It was also found that some are encroaching on protected mangrove swamps in their search for new fertile fields. Thus, scramble for land has created conflict between the Rufiji Delta residents and the government authorities who want to stop local people invading protected sites.

A peasant farmer at Mchungu village said "*we have experienced one of the lowest crop yields in our history this year. Imagine one hectare hardly gives you 15bags of rice these days, whereas we used to get up to 30bags of rice before*". According to this respondent, the situation has forced farmers to clear some mangrove trees in the delta to find fertile land where they can plant rice seedlings. In addition, a peasant farmer at Nyamisati village said that she has got good harvests in her new rice field this year and she was able to pay fees for her daughter. "*If we do not look for new lands, how are we going to feed and educate our families?"* She asked.

At Salale, it was found that, most peasant farmers who have relocated their fields have to travel long distances to the new rice fields they have carved out of the mangrove forests. As a result, they often build temporary accommodation in which they stay during the main farming season. When I interviewed, the manager of the donor-founded Mangrove Management Project (MMP) run by the MNRT at Kibiti, the manager said "*we are trying to educate the Rufiji Delta dwellers on the need to protect the forest around them that is why we are encouraging them to replant mangrove trees in their paddy fields".* In October, 2011, the MMP conducted a five day eviction exercise in a bid to protect mangrove forests from further destruction and degradation due to increased human activities.

The decision to remove paddy peasant farmers from protected land in the mangrove forests caused uproar. Villagers whose temporary huts were stables argued that they and their ancestors had used and at times lived in the mangrove forest for generations. One of the respondents, who had a farm in the delta, defends the decision by local dwellers to cultivate rice in unprotected forest zones by saying that, *"we respect the government that is why no one has dared to touch those areas traditionally known as protected forests like Kikale and Msindaji. That does not include the whole of Rufiji Delta".*

Villagers now fear their dwindling rice fields, coupled with government disruption of their forest farming activities. This will force many of them to depend on food handouts currently. "*We invested massively in rice, but because of salt water, our fields are turning red"* said a peasant farmer at Simbauranga village. *"We can barely see the salt content in the soil, yet there is nothing we can do but vacate the fields……Now the government says we have invaded its forests, where can we go?"* he queried. About the evictions, the government has relaxed its law enforcement efforts, at least for the time being is allowing peasant farmers to continue their activities while it collects more data on their environmental impacts. Unless the government completes its data collection within a short time, a great degradation is going to occur on mangrove vegetation.

This finding is in agreement with Stedman's (1998) findings which state that agriculture is an important activity in the Rufiji Delta. About over 70 % in Rufiji Delta consider farming their first priority. Main crops grown include paddy rice, cassava, cashew nut, coconut, maize, banana, simsim, millet, sweet potatoes, fruits, vegetables, and legumes. In the Rufiji Delta, cultivation of rice is very important for the survival of the people, to the extent that farmers believe "without paddy cultivation, many people would have died here". Rice is harvested twice a year in some of the areas. In the Rufiji Delta, farms are much smaller and fragmented. Peasant farmers stated that they expanded their farms because they needed to increase incomes, to get more yields, and to be able to support their families.

Thus, Stedman's study (1998), indicates that at a local level, expansion of agricultural area is a direct cause of habitat change. New farms are being opened up in the Rufiji Delta although such expansion is illegal because the government has prohibited further clearing. It was reported that peasant farmers are advised by the government to plant mangroves in their paddy farms and are allowed to cultivate them until the mangroves have grown up, then, must vacate the area. This policy has garnered strong criticism from the peasant farmers. A peasant farmer at Mfisini said, *"we are really surprised by this government, we do not know what they are thinking about us. We are required to plant mangroves in our paddy farms, will they send us food in the future?*" The peasant farmers have not been told by the government where to go after the mangroves in their rice fields have grown up.

These findings seem to be consistent with other researches which found that crabs found in the sediment affect rice seedlings. Farmers respond by using DDT to kill the crabs

(Semesi, 1991), but it also kills other species. Farmers in the Rufiji Delta continue to use DDT perhaps due to lack of alternatives for dealing with the problem or due to ignorance of its effects. Agriculture is also affected by natural processes. For example, Rufiji River changed course some years ago, resulting in changed patterns of erosion, deposition, and salt penetration into different parts of the delta.

Some rice farmers reacted to these changes by clearing mangroves and introducing rice into areas that now experience less salinity (Sandlund, *et al.,* 1997). Those involved in the destruction of the delta come from the villages and some individuals are believed to have been employed by Dar es Salaam based 'big shots' to open new rice fields.

Figure 17: Stands of *Heritiera* in previous years for Rice Cultivation in the RdMFR

Source: Wagner *et al* (2010)

5.4.2: Destructive Fishing Practices

Fishing is another important economic activity in the Rufiji Delta. In this delta, fishing is carried in the estuaries and in shallow inshore waters along the coast. The marine catches are generally constant throughout the year as the fishers have the options of fishing finfish as well as prawns. Rufiji Delta is the most important wild prawn fishing area in Tanzania. It was found that about 26% of the respondents involved, make a living in fishing.

It was also observed that, both men and women are involved in fishing and the majority of the fishermen and fisherwomen use nets, although traditional traps and hooks are also used. Comparing fishermen and fisherwomen in the study area, it was seen that fishing by men is mostly done by using dug-out canoes, using 2-ply gill nets, 15 m long by 1.5 m deep, with meshes of 2-2½ inches. According to the stage of the fishing cycle, the prawns are fished by men from open rivers, estuaries, lagoons, shallow tidal creeks and mudflats.

In FGDs, it was reported that most of the fishing is concentrated during the spring tides. The average daily catch of prawn is estimated at 2.5 tons which gives an estimate of about 1000 tons per year. This research found that fishing done by women near the seashore only targets for locally valued small pelagic shrimp, known locally as udavi and it is done using hand held nets. The shrimp caught are sun-dried and sold to visiting traders. It is estimated that approximately 18,000 sacks of shrimp are sold annually. These results differ from Fottland and Sorensen (2001), who indicates an average catch of prawn at 3 tons which gives approximately to more than 1000 tons annually, shrimp approximated to 20,000 sacks sold per year.

Although, findings ranked fishing as number two in order of importance in the study area, this finding differs from Hogan *et al* (1999), who found that, there are some villages (around some of the permanent water bodies) fishing is ranked as the first important activity. This may be attributed to two main factors: firstly, agriculture is generally below subsistence level, and secondly, fishing is the main source of getting animal protein needs.

Figure 18: Fish catch

Figure 19: Two fishing boats

Source: Kipalanga (2008)

The results of this study show that the use of dynamite or explosives for fishing is the most immediately destructive human activity in the marine environment in Rufiji Delta. The respondents reported that many fishermen from the main urban centres such as Dar es Salaam own boats, procure dynamite and hire crews to catch fish by dynamiting. Dynamite fishing is a very destructive fishing method used mainly in shallow waters of less than 10m deep. It was observed that this method destroys the basis for reef fish productivity by indiscriminately killing juveniles and adult fish alike and at the same time reducing the reef to rubble.

Moreover, trampling during collection of octopus, shellfish, sea cucumber and seaweed in intertidal or shallow sub-tidal areas are also causing damage throughout the Eco-region. Particularly, the research findings showed that the reef flat, which provides important habitat for larval and juvenile stages of fish and other organisms, is gradually destroyed and the biodiversity of the area degrade. One unanticipated finding was that, trawling is an efficient and less destructive fishing method when operated in deep waters. However, commercial and semi-commercial fishing vessels often operate their vessels, at depths of less than 20 m up and down East Africa's coast. This is not only harmful to sea grass beds and soft benthic communities but also disturbance to micro-habitats and sediment structure.

The encroachment of prawn trawlers into shallow areas has created tension between artisanal fishermen and commercial fishermen over fishing territories and rights. Artisanal fishermen complain about the destruction of artisanal fishing gear and the damage to the sea floor by industrial trawlers. They also blame large-scale commercial fishing vessels for the destruction of their fishing gear, encroachment into their fishing territory and being responsible for over-fishing.

Furthermore, the findings indicated that fishing methods such as beach seines and small mesh size nets are also destructive to the environment in which they are applied, regardless of how limited their operations are. Also, it was observed that, many of the local fishermen in the Rufiji Delta use stake traps made from the roots of *Rhizophora mucronata*. With this technique, a large part of small channel is blocked by planting wooden stakes in a V-shape so that fish are stranded during low tide. It was seen that this process is destructive because it affects the roots of the plant and may kill the entire plant. Also, these traps are woven together so tightly that even juvenile fish are trapped.

A fisherman in Rufiji Delta said, *"there is a shortage of fish catches due to the fall of the sea level, as a result a lot of areas covered by water before are now covered by mud water"*. He added by saying "*previously, the ocean began from Mahenge about 2kilometres from Mchungu where currently the ocean begins*". Another respondent said that *"the effects are obvious; buying fish here (Nyamisati) is more expensive than in Dar es Salaam".* This shows that there is a depletion of the resources, which should not be allowed at any cost.

Another possible explanation for this was the FGD conducted to respondents (fishermen)who were complaining that fish catches are declining sharply and that they have to go further out to the deep waters, which is an indication that fish numbers have declined in shallow waters. In addition, the fishermen complain that catches now consist of juvenile fish, a further indication of over-fishing and habitat degradation.

5.4.3: Population and Settlement.

Several theories have emerged that explain the impact of population on the use of natural resources (Stedman, 1998). Local population growth may directly affect use of resources and influence the rate of habitat change. Although, the relationship between population size and growth and biodiversity loss is complicated, the use of a variety of indicators make it possible to explain the effect of population growth on natural resources. For example, it is evident that countries with high population densities have converted relatively more land to agricultural use. This study therefore, is tempting to follow this line of argument to explain the degradation of mangrove vegetation in the Rufiji Delta. However, due to the paucity of data on population trends, one must be careful with the conclusions.

Data collected from the study area suggests that in 1988, the population of the Rufiji Delta was 33,000 (Rufiji Environmental Management Project, 1998; Semesi, 1994, and Fottland and Sorensen, 1996) and the Rufiji district's annual growth rate was 1.3% (NBS, 1994). For 2000 the Rufiji Delta population was estmated as 38,148 (Researcher's estmate). Tanzania National Censu of 2002 indicates that the population of Rufiji Delta in 2002 was 42,615 and the Ruiji district's annual growth rate was 1.9% (NBS, 2002). Thus, the 2011 Rufiji Delta population was estmated to 49,902 (Researcher's estmate).

Population increases and settlement in the Rufiji Delta are often linked with mangrove vegetation degradation. Demand from increased population as well as settlement has been identified as driving activities that threaten mangrove vegetation such as mechanical logging, pit-sawing, charcoal burning, fuel-wood gathering, cutting mangrove poles for housing and selling. This study shows that immigration exceeds emigration in the study area. The ethnic groups immigrating to the area include; Nyamwezi, Ha, Zigua, Matumbi, Ngindo, Mang'ati, among others.

However, Stedman (1998) suggests that one must be careful with these conclusions in the case of the Rufiji Delta in Tanzania, because what emerges is that historically poor management has contributed more significantly to increased depletion of mangrove vegetation than population pressure. What is surprising is that Stedman (1998) indicates that the human settlement in the Rufiji delta is larger than in the other deltas (Ruvu and Wami) in Tanzania. This implying that the population in the study area is increasing tremendously.

5.4.3.1: Poles

In the area of study, it was found that a mangrove management plan has been instituted in place (Semesi, 1991) to control the harvest of mangrove products (including mangrove poles). This management plan has identified zones in which various activities could be undertaken. Zone I are mangrove forest under total protection, which is about 31% (1,657.5 ha). Zone II (59% or 31,522 ha) are protected forest. Zone III (8.3% or 4,437.7 ha), and Zone IV (1.3% or 718.3 ha) is development area. Harvesting area in this management plan is 15,163.1ha. One hectare of mangrove vegetation could produce 300 poles of class I and II in terms of quality. The same hectare could also produce 400 poles of class III and IV. The remaining mangroves will be utilised for fuel wood, 1hectare can produce $10m^3$.

Table 15: Estimated Poles per hectare in the Rufiji Delta

Class	**Poles per hectare**	**Quality**
I and II	300	1^{st} Class poles
III and IV	400	Average quality poles
Fire wood	$10m^3$	–

Source: RdMFR (2011)

Studies including that of Turpie (2000), indicate that although, the management plans hinges around joint management, with active participation of local communities it has side effects which make legal cutting rather complicated. Legal commercial cutting of mangrove poles involve getting permission from the WEO and VEO of the area concerned, then taking the permit to the forest officer to get a year license, and making payments. It was reported that because of the capital required for permits, most permits are in the hands of traders from large centres, outside the Rufiji Delta who employ local people to do the cutting. Kulindwa *et al* (2001) findings seem to be consistent with this study which also found that most harvesting is reported to be illegal, unselective and unsustainable.

The major commercial agents in this trade order between 20 – 100 scores at a time and can cut 100 – 1000 scores per month (Turpie, 2000). The mangrove cutters are paid about US$ 2 per score by their clients (Turpie, 2000) which is a very low price compared to the market value. The cutters have little bargaining power, as there are always other cutters willing to do the job for less payment. It is estimated that about 126,000 scores are exported annually, out of which only 14,565 scores are from licensed traders (Turpie, 2000).

Selective harvesting of quality trees for particular purposes is a common practice, village natural resources committees and the MMP staff jointly supervises harvesting. Legal mangrove pole and fuel wood harvesting is monitored and recorded by mangrove management zonal office. However, an unanticipated finding was that illegal pole cutting continues in the area of study, this finding accord with earlier observations by the 2011 inventory exercise conducted by FBD which showed similar results.

The Rufiji District Forestry officer said 38 hectares were cleared illegally between January and September 2011 bringing the total to 98 hectares of mangroves that have been destroyed in the last four years. He also mentioned that the Rufiji Delta originally covered more than 53,000 hectares but controlling the destruction has not been an easy task. He added by saying lack of speedboats coupled with the limited number of rangers to patrol the Rufiji River basin, has complicated efforts to save the mangroves, a natural system that acts as a sieve for rivers not to pollute seas. "*Illegal loggers have gone high technology; using mobile phones to alert their colleagues in the field when officials were either on patrol or approaching them"*, he said.

Figure 20: Mangrove Poles Harvested Illegally in the RdMFR

Source: RdMFR Inventory data, February (2011)

5.4.3.2: Timber

Another important finding was that mangrove forest degradation is caused by unsustainable mangrove timber extraction. Therefore, it was observed that illegal harvesting and subsequent trading of mangrove produce such as timber continues in the area of study. The Rufiji District Forest Officer said *"worse still, logs from the cleared land are burnt to ashes"*. Villages surrounding the area include; Saninga, Salale, Simbauranga, Kiomboni, Nyamisati, Mtunda and Nganyanga.

Figure 21: A pile of *Xylocarpus* Timber Illegally Harvested in RdMFR

Source: RdMFR Inventory data, February (2011)

5.4.3.3: Charcoal

The study concluded that, although commercialization of wood resources provides tangible monetary benefits to rural communities, it also contributes to the resource depletion that will ultimately threaten their long-term survival. The present study notes that to a large extent the growth of charcoal trade to Dar es Salaam and other urban centers is influenced by the higher tariff rates of electric energy in Tanzania. Due to the high tariff rates of electricity most people in urban centers, prefer charcoal and kerosene for cooking to electricity. Thus, unless some measures are undertaken to significantly reduce the cost of electric energy, the growth of this trade is expected to increasingly pose more pressure on the mangrove forest and woodland resources in Tanzania.

5.4.3.4: Salt - Making

In the study area, mangroves have been cleared and replaced with solar evaporation pans for the production of salt. In some areas of the Rufiji Delta, it was generally reported that mangroves are used for fuel wood in the salt production process. However, current statistics on this activity is scarce.

5.4.4: Lack of Alternative Materials for Construction/Fuel

Over 90% of respondents indicated that lack of alternatives for building materials such as cement, timber and iron sheets (which are sold at a higher price) to replace or substitute mangrove poles tends to exacerbate over-harvesting problems in Rufiji Delta. Some respondents stated that mangrove poles are most preferred because they are cheap, durable and easily available. It was observed that; majority of the delta dwellers cannot afford those alternative materials for construction due to their poverty status. Applying the direct observation method, most of the huts or houses in the study area constructed by poles, mud and grasses. Only a few were seen to be of modern materials.

With regard to this observation, very few people can afford these alternative construction materials. However, few opportunities have been sought to address the issue of alternatives for mangrove poles, and policies have failed to set the actual value for the poles, such that, they are regarded to be very cheap. Increased demand for firewood and charcoal is often linked to few affordable alternatives for energy that put further pressure on the mangrove vegetation. The findings showed that lack of affordable alternatives is compounded by the fact that the Forestry Policy does not address the issue of alternatives for mangrove poles. Therefore, unless the government takes immediate initiatives to provide or reduce the prices for construction materials in Tanzania degradation of mangrove vegetation is likely to continue in the study area.

5.4.5: Poverty and Lack of Economic Alternatives

The issues of mangrove vegetation degradation in the Rufiji Delta are often closely connected to poverty and general lack of alternative economic activities. There are several possible explanations for this result. Most rural poor coastal people rely on natural resources around them for their livelihood. In order for households to survive they engage in actions that rapidly deplete mangrove vegetation. There also exists a vicious cycle between poverty and environmental degradation. Poverty and inequality leaves the disadvantaged members of the community with marginal lands for farming. Combined with bad farming practices, soil erosion is enhanced and this eventually leads to siltation of inshore habitats.

This socio-economic situation present in the study area is seen to be a major challenge to the prospect of sustainable mangrove vegetation utilisation. In the face of declining marine resources, rather than switching out of fishing to other forms of livelihood, the narrow income generation base compels resource users to adopt ever more environmentally unfriendly techniques. To make matters worse, education opportunities in the study area are very poor (Figure 7). If sustainable mangrove vegetation use is to become a reality, local communities in the Rufiji Delta urgently need technical assistance to broaden their income base and develop new sustainable sources of revenue.

Surprisingly, there are limited commercial infrastructures and high transaction costs for travel (low volumes, poor quality and poor roads and limited processing facilities) are considered to contribute to low levels of income and intense mangrove vegetation exploitation. In Tanzania the issue of poverty is closely connected to a general lack of alternative economic activities. This research found that most people in the study area rely on natural resources around them for their livelihood. In order for the households to survive they engage in actions that rapidly deplete these local resources. A large percentage of the Rufiji Delta dwellers are poor compared to most districts in mainland Tanzania. Most of them live a predominantly hand -to-mouth lifestyle based on exploitation of marine resources, coconut and cashew production and subsistence agriculture.

5.4.6: Inadequate Capacity for Enforcement of Policies and Rules

Another major issue in Tanzania was identified in this study is the lack of capacity to enforce rules and regulations. Many of the country policies have emphasized the issue of control and prohibitions even though without the means and capability to carry these out.

Retrenchments of government staff involved in enforcement of regulations and policing marine resource has been one of the key factors in reduced monitoring and enforcement. Effective monitoring and enforcement work requires a good communication system. Often, the distribution of revenues from natural resources is uneven between the central government and the districts where the resources are to be found.

In the area of study, it was observed that there are few staff assigned to its supervision. They are supported by one boat crew and two watch men who are on temporary basis. Moreover, there is only one boat at Nyamisati mangrove centre that serves all purposes as regards to monitoring of mangroves in the Rufiji Delta. The evidence from this result suggests that more staff are required to inevitably manage Rufiji Delta mangrove Forest Reserve. In Tanzania, local governments, which are supposed to finance some of their own activities, are facing financial and leadership problems. The District Councils do not have funds for recurrent expenditures such as fuel and field allowances for the officers who are sent to do monitoring.

5.4.7: Lack of Institutional Coordination

After interviewed the mangrove forest director at MNRT and the TCMP officer on the relationship that exists among management units, both commented that at the national level, there exist conflicting objectives among government ministries and departments, be it land for salt making or tourism, forestry and fisheries. This has also contributed to the loss of mangrove vegetation and continues to pose threats. They also added that, the country's forestry policy, hence, the Forestry Department, encourages sustainable management of forests. At the same time the Department of Fisheries, under the same Ministry of Natural Resources and Tourism (MNRT), sanctions a prawn farming project in the Rufiji Delta, aimed at economic growth. In such cases inconsistency in policies and mandates occur, such that maximization of one objective threatens the mere existence of the other.

Furthermore, it was reported that the recent shift of environmental matters to the Vice President's Office (VPO) has not produced significant changes in the management of natural resources. Recent developments concerning the Rufiji Delta prawn farming project proposal have revealed the hopeless position NEMC occupies. One would like to look upon it as the watchdog for environmental protection matters with some clout in influencing environmentally correct behaviour among various stakeholders. Instead, it is just a "toothless dog", with only the advisory role without necessarily its advice being taken seriously. Technical opinions are still yet to be given their fair share in influencing decisions.

5.4.8: Conflicting Interests

Another possible explanation for mangrove vegetation degradation in the study area is lack of effective management of conflicting interests of the various institutions involved in the management of the natural resources exacerbates the problems associated with institutional coordination. For instance, in the mangrove area including the Rufiji Delta in Tanzania, there are several institutions involved, including those responsible for mining (mineral prospecting and salt making), land use (Ministry of lands), forestry (Ministry of Natural Resources and Tourism), environment (Vice President's Office) and local governments (represented by the newly established Ministry of Local Governments). The interplay of activities influenced by policies and regulations from these institutions often conflict with each other due to different immediate objectives and lack of harmonization of policies in order to achieve a much wider objective of sustainability.

In addition, no overall authority exists which coordinates institutional mandates such as the issuing of licenses (for fishing, harvesting of mangroves and salt making) and land titles. Such issues may concern the Division of Forestry, the Division of Lands, the Division of Fisheries, the Ministry of Water and the Ministry of Energy and Minerals simultaneously. The National Environmental Management Council (NEMC) which was established in 1983 is charged with among others, the duty of coordination. However, inadequate personnel, equipment, funds as well as the tendency by some departments or ministries to protect their areas of interest have prevented NEMC to perform its duties effectively.

5.4.9: Market Failure

It is somewhat surprising that only 9 (5%) of the administered questionnaires did not mention this factor. 171 (95%) of them mentioned it, and commented that in Tanzania, investment, particularly foreign investment, is looked upon as important in facilitating economic growth through transfer of modern technology for efficient production, which would otherwise not be available to the country due to shortage of capital. Today, foreign investments are more important due to the fact that they have networking advantage to the world market.

Well-functioning markets are efficient mechanisms for allocating scarce resources among competing uses over time. However, many markets do not function well. Much of the mismanagement and inefficient use of natural resources such as mangroves, biodiversity and the wider environment is attributable to malfunctioning and distortion of their markets, and also the mere lack of market in some cases. Interviewed manager of MMP, at Kibiti added by saying that, market failure has contributed significantly to the decline of many of the marine and coastal biodiversity resources by leading to over-fishing and over-harvesting of mangroves in Tanzania, that in turn, have contributed to the ecological disruption. A Strong evidence of this factor was found when one of the respondents in one of the FGDs conducted at Kiongoroni stated that the prices at which the fisheries and mangrove products are sold at the export and national markets are low, as the environmental and social costs of harvesting the marine resources are ignored.

Only private costs (capital, labour, materials and management) are considered as factors of production. With low costs of production and increasing output prices, due to high demand, profitability is generated even when catches are low and exploitable material is scarce in the ecosystem. An implication of this is the possibility that the low price stimulates excessive demand for fish and other marine products, which in turn stimulate over-harvesting, processing and distribution, and undermines sustainable exploitation of the mangrove vegetation.

A reasonable approach to tackle this issue could be to balance these costs and benefits by doing a well-rounded analysis, which integrates all sectors and stakeholders to be able to determine the social, economic and environmental costs and benefits before any major decision is made. Such a decision can be assisted by well executed Environmental Impact Assessment (EIA). However, the EIA processes in the Tanzania have limited in its formalization if it exist at all.

5.4.10: Mangrove Species

It was generally reported that mangrove species sometimes poses a problem, when it is introduced as an exotic species. However, evidence on this was scarce. This finding is in agreement with that found in the nipa palm, (*Nypa fruticans*) introduced from Singapore to Nigeria in 1906 to control coastal erosion. However, the palm spread extensively and replaced the native mangrove species like *Rhizophora* in Nigeria. Hence, the Federal Ministry of Environment of Nigeria has developed the '*Nypa* Palm Control programme' to control the invasive species.

5.4.11: Pollution

Pollution issues have been highlighted as significant in Tanzania. However, pollution in Rufiji Delta was identified throughout the estimation of mangrove loss/modification of ecosystem as one of the prime source of the degradation of the habitat. But reports establish that the information available is insufficient at this point to conclude on a clear cause and effect relationship. There are no systematic studies about the actual sources, kind and levels of pollutants in marine waters. What is known is that the main sources are land-based, especially from coastal cities, agriculture, mining and port activities.

The presence of biocides, drained from agricultural areas, may be harmful to both flora and fauna of the delta. According to Semesi (1989), DDT application on farms leads to the death of non-target animals including fish and prawns. The increasing application of agricultural chemicals in the catchment area increases the level of nutrients and/or toxins in the estuarine water and affects the ecology of the delta.

4.4.12: Sedimentation

Sediments are material of varying size of mineral and organic origin. The process of deposition of sediment from a state of suspension or solution in a fluid is called sedimentation. Natural sources of sediments transported to the sea include erosion of bedrock, soil and decomposition of plants and animals (UNEP and Gems Water Programme, 2006). Natural sediment mobilization is an important process in the development and maintenance of coastal habitats, including mangroves, dunes and sand barriers (UNEP/GPA 2006a). However, anthropogenic activities or those which are carried out by man, often change the processes of erosion and sedimentation as well as modifying the flow of rivers and the amount of sediments it can carry.

The effects of changes to sedimentation patterns depend on whether the change results in an increase or decrease in sediment availability. Both effects have various physical and chemical consequences for water quality and aquatic ecosystem health (UNEP/GPA 2006a, UNEP and Gems Water Programme, 2006). Increased sedimentation in the study area through the Rufiji River has smoothen marine communities and in severe cases, completed burial leading to suffocation of corals, mangrove stands and seagrass beds. It has also caused to intrusion of many toxic organic chemicals, heavy metals and nutrients which were physically and/or chemically absorbed by sediments.

Increase of sediment loading to the marine environment caused to increased deposition of these toxic substances that result in further negative impacts such as eutrophication. On the other hand, decreased sedimentation in the area of study has lead to degradation of an ecosystem by starving it of the elements needed to sustain production since sediments often carry a variety of minerals, nutrients, and organic matter; increased velocity of the water has caused erosion downstream and caused damage to coastal and marine ecosystems and human settlements.

5.4.13: Salinity Water

This study found that high level of salinity in the mangroves has lead to high concentrations of salt in tissues which has severely damaged metabolic processes, leading to death of mangroves in the study area. How do mangrove plants prevent this? Some mangrove species like the *Avicennia* are salt secretors. The common salt concentration in the sap is high at about one-tenth that of sea water. Salt is partially excluded by the roots and the salt is excreted by the salt glands by the plant expending energy.

Other mangrove plants like *Bruguiera*, *Rhizophora* or *Sonneratia* species are non-secretors. They can selectively absorb only certain ions (electrically charged atom(s) and/or group of atom(s) which a salt becomes on going into solution) from the solutions they come into contact with by a process called ultrafiltration. However, even with this, exclusion is not complete. Some salt is lost by transpiration through the leaf surface or accumulates in some cells of the leaf. Suggestions have even been made that some species deposit a good part of the excess salts in the old leaves which are shed.

5.4.14: Floods

Floods have been an integral part of mangroves and the human experience since the beginning of agricultural practices when the first permanent settlements were built along the river banks. Seasonal floods deliver valuable topsoil and nutrients to farmland and bring life to otherwise infertile regions of the world. In contrast, flash floods and large floods are responsible for more deaths. In the Rufiji Delta, it was generally reported that a lot of mangroves have been destroyed by flood water. From the results, although, there were areas that recorded a decrease in mangrove cover, generally it appeared that there were no serious set-backs in mangrove vegetation development.

5.5: Strategies for Management of Mangrove Vegetation

Respondents reported to have developed a number of coping strategies in their communities that are useful in counteracting the effects of mangrove resources degradation for improving their livelihoods. The mentioned coping mechanisms include:

5.5.1: The Rufiji Delta Fishing Communities.

Change in fishing time-communities have developed the tendency of fishing when at dark (as during the night) and when there was light (as at day time), change in fishing gears from the use of simple fishing tools to the use of complicated sustainable fishing tools, and going fishing in the deep water where in the past the local fishers did not use to go. They are also engaged in agricultural activities during the time when fish catch had decreased, mainly during the North East Monsoon (*Kaskazi)* Wind. Due to decline in mangrove species, fishes are dried using the sun. There is also a change from open smoking to indoor smoking of fish as a way of drying them. This is due to the fact that open-smoking use a lot of firewood which has been a problem because of mangrove species depletion. Therefore, there is the shift from fishing to other economic activities.

5.5.2: The Rufiji Delta Peasant Farmers/ Farming Communities

It was reported that peasant farmers in the the Rufiji Delta engage in growing drought resistant crops such as millet, sorghum, cassava , among others. They also practice mixed cropping.

5.5.3: Introducing Alternative Income Generating Activities

On the question of household members belonging to a local association, committee, NGO or any social group, this study found that all respondents belonged to one or two local association(s). Generally, these associations deal with; beekeeping, livestock keeping, fishing, and loans. These associations were identified as main opportunities not only to boost the households' generating income but also to improve food security of the families.


Figure 22: Livestock alongside delta villages Figure 23: Beekeeping in Rufiji Delta

Source: Kipalanga (2008)

5.5.4: Boundary Consolidation

Terrestrial Forest Reserves and Nature Reserves in Tanzania mainland boundaries are usually consolidated by establishment and installation of beacons. The situation is different in mangrove forests. The boundaries of mangrove forest reserves in Tanzania mainland are prescribed as "the land between the high water mark and the low water mark of the spring tide of the Indian ocean" (RdMFR,2011). Based on the above boundary definition all saline areas and area with mangrove trees automatically fall within mangrove forest reserve.

The study found that one of the activities that are implemented by MMP in RdMFR is to install sign boards adjacent to the mangroves in order to create awareness on the extent of the mangrove reserve, educate and remind the people on laws and regulations governing mangrove reserve.

5.5.5 Forest Protection

It was found that forest patrols are conducted by FBD staff in collaboration with the adjacent communities through Village Natural Resource Committees usually comprised ten members of villagers. Other patrols are conducted by the Marine Forest Surveillance Unit; a special section created for the purpose of strengthening forest protection. This Unit conducts patrols in the open sea and makes regular follow-ups on illegal forest resources on transit by ocean. Village Natural Resources Committee has the mandate to conduct self-organized patrols in areas adjacent their village.

5.5.6 Forest Restocking and Natural Regeneration

Areas which have been degraded due to rice farming, efforts have been made to rehabilitate them. The areas planted under NORAD support from the year 1995/96 to 2004/2005.

Table 16: Mangrove Areas Planted under NORAD support from the year 1995/96 to 2004/2005

Village name	**Year and area in hectares**							**Total**
	1995/1999	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	
	ha	ha	ha	ha	ha	ha	ha	
Kikale	160	60	100	25	40			385
Pindamikila			100		40		80	220
Twasalie			95	70				165
Salale		40			20		25	85
Mawanda				100			10	110
Maunga			35	15			15	65
Nyamisati				15	20	25	10	70
Total	**160**	**100**	**330**	**225**	**120**	**25**	**140**	**1100**

Source: RdMFR Inventory Data (2011)

CHAPTER SIX: SUMMARY, CONCLUSION, AND RECOMMENDATIONS

6.1: Summary

Mangrove forests globally cover about 15.2 million hectares straddling coastlines in 123 tropical and subtropical countries (Spalding *et al.,* 2010). Although, mangroves are able to grow on sand, peat, rock and coral, the most extensive and luxuriant forests are often associated with muddy soils usually found along deltaic coasts, in lagoons and along estuarine environments (Saenger, 2002). Mangrove forests are among the most productive ecosystems and offer a variety of goods and services.

Ecosystem goods refer to products, which can be extracted from an ecosystem for direct or indirect human utilization such as seafood, timber, honey, biomass fuels, and medicines, among others. Ecosystem services refer to the conditions and processes through which ecosystems and the species that make them up sustain and fulfill human life (Daily, 1977). Such services include nutrient recycling; sediment accretion and moderation of hydrological processes, among others are thus, the life-support functions at the foundation of the ecosystem.

Change detection with satellite imagery has become necessary as a result of increasing versatility in manipulating digital data. Land cover change may result in environmental, social and economic impacts of greater damage than benefit to the area (Moshen, 1999). Therefore, data on land cover change are of great importance to planners in monitoring the consequences of its changes in Rufiji Delta. Such data are of value to mangrove vegetation management and agencies that plan and assess mangrove cover patterns and in modeling and predicting future changes.

In estimating the extent of vegetation cover and the degradation in the study area, results showed that between 2000 and 2011, land cover occupied a total area of 150672 ha (100%). Out of the total coverage, a total area of 6887.97 ha (4.57%) of land cover decreased by more than 10% (Figure 16). At the same time same, land cover in this period decreased less than 10% by 38943.72 ha (25.85%). These results indicate that despite all efforts taken by the MNRT, NGOs, and the Rufiji Delta communities in enhancing mangrove vegetation in the study area, degradation continues to spread (Figure 15).

Findings also showed that the bareland increased by 364 ha (2.62%) between 2000 and 2011(Table 11). Although, results indicated the decrease in land cover, some land cover were unchanged between this period covered the area of 60574.5 ha (40.20%). On the other hand, land cover indicated the increase of less than 10% by 42691.23 ha (28.33%) whereas some showed they increased more than 10%, covering 1574.55 ha (1.05%) of the total area. Pressures on mangroves in the Rufiji Delta are mostly human-induced. The area of mangroves that has been degraded for the past 11years was 364 ha (2.62).

It was inferred that direct causes of mangrove resources degradation include tree felling for firewood and building materials(poles and timber), clearance of mangrove areas for agriculture (rice farming), solar salt works, and human settlement (population increase). Other causes include reduction in fresh water flow (both surface and groundwater), flooding, storms, and heavy or increased sedimentation.

The identified coping strategies in the communities are useful in counteracting the effects of mangrove vegetation degradation for improving their livelihoods. These include; change fishing gears (fishing communities) from the use of simple fishing tools to the use of complicated sustainable fishing tools, going fishing in the deep water where in the past the local fishers did not use to go. Farming communities engage in growing drought resistant crops such as millet sorghum and cassava. In addition to the above, people were found belonging to a local association, committee or NGO as a means of alternative income generating activity. It was also found that to some extent mangrove vegetation are protected through Village Natural Resource Committees and mangrove vegetation restocking mostly is done by different stakeholders such as RUMAKI, REMP, MMP, WIOMSA, IMS, WWF, RUBEP, TCMP, MACEMP, and UNESCO.

6.2: Conclusion

In this study, the main focus was on assessment of the status of mangrove vegetation and their degradation in Rufiji Delta. The research was guided by two propositions, namely; increase in population correspondingly decrease mangrove vegetation in Rufiji Delta, and mangrove vegetation degradation in Rufiji Delta is as a result of non-enforcement of forest policy and rules in the study area. RS in combination with GIS was applied as a tool for land cover change detection in the Rufiji Delta between 2000 and 2011.

The overall land cover changes were derived from the paired maps (Refer figure 14) over the past 11 years. One must bear in mind that those maps reflect land cover conversions "transitions from one land cover class to another". In comparing the 2000 and 2011 Rufiji Delta land cover maps, the most visible changes are in the pattern and distribution of *Sonneratia* almost pure stands and the bareland, particularly, in the north-east and south-east of the Rufiji Delta. The expansion of the bareland is driving other land cover classes in the study area leading to habitat loss and decline in habitat quality. Moreover, a number of other changes were observed in data analysis. Generally, there has been a loss of land cover class to another within this period.

Furthermore, land cover change detection results revealed that a total area of 45831.69 ha (30.42%) of the total coverage had decreased by less or more than 10%. Whereas, an area of 60574.5 ha (40.20%) remained unchanged between 2000 and 2011 (Figure 16). However, it was investigated that a total of 44265.78 ha (29.38%) increased by less or more than 10% in the area of study.

Conclusively, a clear look on the assessment of the status of mangroves vegetation in the Rufiji Delta inferred that population increase (Table 6) and inadequate capacity for enforcement of mangrove policy and rules, thus, clearing mangrove vegetation as a result of settlement expansion and rice farming has caused degradation of mangrove vegetation in the study area. At policy level, it is acknowledged that, the majority of Tanzanian livelihoods depend on natural resources (MNRT, 1998a; URT, 2000). However, proven experience has shown that the quality and quantity of Tanzania natural resources, in particular coastal forests, is dwindling due to unwise utilisation of resources.

Therefore, the findings are in favour of the propositions postulated in this research that increase in population correspondingly decrease mangrove vegetation in the area of study, and mangrove vegetation degradation in Rufiji Delta is as a result of non-enforcement of forest policy and rules in the study area.

6.3: Recommendations

This study has identified several uses of mangrove species and key factors that threaten or cause mangrove vegetation degradation in Rufiji Delta. The following are some of the recommendations that address those key issues. In order to reduce mangrove vegetation loss in the Rufiji Delta, it is important to focus not only on the management aspect but also and more importantly, to provide more economic alternatives and opportunities to the local communities such as reduce prices for materials for construction that will discourage them from over-utilisation of mangrove vegetation. This will require immediate action from the central government because some of the alternatives, including farming and fishing, demand improvement in infrastructure support. Also, negotiations between the MNRT and local authorities and the people must be undertaken to identify suitable areas for farming.

Through what has been found in this, there is a great need by the MNRT to reassess its forest (mangroves) policies and rules regarding to population increase leading to increasing demand and drains on resources, and commit itself that permits on poles and timber hervest procedures are respected by all parties.

Not all the farmers in the Rufiji Delta can access alternative areas for farming. Therefore, it is recommended that farmers in villages such as Salale , Kikale, Maparoni, Kiongoroni, among others in Rufiji Delta be allowed to continue to use their existing land for farming and that the decision to plant mangrove trees on the farms be reconsidered. Alternatively, if these people have to be moved, plans for new settlement have to be openly discussed and known to them before they are told to vaccate. Although, this is an issue that requires immediate attention, negotiation must be carried out among the MNRT, villagers, and the Rufiji District council. These negotiations are important because the MNRT has already prohibited further expansion of farms and demands that existing farms be planted with mangrove trees.

Furthermore, it has been observed that many of the villagers and land users in the study area are not fully aware of the interdependence between their activities, such as harvesting of mangrove poles, and the health of the marine environment. In many cases, people are concerned with their survival needs, and strive to meet them at any cost. It is therefore, suggested that the stakeholders (NGOs) should organise more progrmmes on awareness-raising for the people of Rufiji Delta with respect to sustainable use of mangrove vegetation. This is not something new; further training programmes for various stakeholders especially the local community to address on sustainable mangrove vegetation use and the current widespread mangrove degradation.

REFERENCES

Abuodha, P.A. and Kairo, J.G. (2001). Human-Induced Stresses on Mangrove Swamps along the Kenyan Coast. *Hydrobiologia*. Vol. 458, pp. 255-265.

Adegbehin, J.O. (1993). Mangroves in Nigeria.In: Diop, E.S. (Ed.). Conservation and Sustainable Utilization of Mangrove Forests in Latin America and African Regions (Part 2: Africa). Mangrove Ecosystem Technical Reports 3. Tokyo. International Society for Mangrove Ecosystems and International Tropical Timber Organization.

Adeniyi P.O. and Omojola A. (1999). Land Use Land Cover Change Evaluation in Sokoto – Rima Basin of North Western Nigeria Based on Archival of the Environment (AARSE). Geoinformation Technology Applications for Resource and Environmental Management in Africa. 14-172.

Ajonina, G.N. and Usongo, L. (2001). Preliminary Quantitative Impact Assessment of Wood Extraction on the Mangroves of Douala-Edea Forest Reserve Cameroun. *Tropical Biodiversity*. 7 (2) 3: 137-149.

Ajonina, P.U.; Ajonina, G.N.; Jin, E.; Mekongo, F.; Ayissi, I.; and Usongo, L. (2005). Gender Roles and Economics of Exploitation, Processing and Marketing of Bivalves and Impacts on Forest Resources in the Douala-Edaa Wildlife Reserve, Cameroon. *International Journal of Sustainable Development and World Ecology*. 12 (2005):161- 172.

Aksornkoae, S.; Piebprom, S.; Saraya, A.; Kongsangchai, J. (1986). Mangrove Resources and the Socio-Economics of Dwellers in Mangrove Forests in Thailand. In: Kunstadter, P., Bird, E.C.F., Sabhasri, S. (Eds.), Man in the Mangroves, Tokyo, United Nations University. pp. 11–43.

Allen, J.A.; Ewel, K.C.; Keeland, B.D.; Tara, T.; Smith III, T.J. (2000). Downed Wood in Micronesian Mangrove Forests. *Wetlands*. 20, 169–176.

Alongi, D.M. (2002). Present State and Future of the World's Mangrove Forests. *Environmental Conservation*. 29 (3): 331-349.

Alvarez-Leon, R. (1993). Mangrove Ecosystems of Columbia. In: Lacerda, L.D. (Ed.). Conservation and Sustainable Utilization of Mangrove Forests in Latin America and African Regions (Part 1: Latin America). Mangrove Ecosystem Technical Reports 2.Tokyo, International Society for Mangrove Ecosystems and International Tropical Timber Organization.

Armitage, D. (2002). Socio-Institutional Dynamics and the Political Ecology of Mangrove Forest Conservation in Central Sulawesi, Indonesia. *Global Environmental Change*. 12, 203–217.

Balmford, A., Bruner, A.; Cooper, P.; Costanza, R., Farber, S.; Green, R.E.; Jenkins, M., Jefferiss, P.; Jessamy, V.; Madden, J.; Munro, K.; Myers, N.; Naeem, S., Paavola, J.; Rayment, M.; Rosendo, S.; Roughgarden, J.; Trumper, K.; Turner, R.K. (2002). Economic Reasons for Conserving Wild Nature. *Science.* 297, 950 - 953.

Bandarayake, W.M. (1998). Traditional and Medicinal Uses of Mangroves. *Mangroves and Salt Marshes.* 2: 133–148.

Bantje, H. (1979). The Rufiji Agricultural Systems: Impact of Rainfall, Floods, and Settlement. BRALUP Research Paper, No.62.

Bantje, H. (1980). Floods and Famines: A Study of Food Shortage in Rufiji District. BRALUP Research Paper, No.63.

Basit, M.A. (1995). Non-wood Forest Products from the Mangrove Forests of Bangladesh. In: Beyond timber: Social, Economic and Cultural Dimensions of Non- wood Forest Products, Report 1995/13. Rome, Food and Agriculture Organization of the United Nations.

Bhatta, R., Bhat, M. (1998). Impacts of Aquaculture on the Management of Estuaries in India. *Environmental Conservation*. 25, 109–121.

Bhattacharyya, J. (1990). Uses, Values, and Use Values of the Sundarbans. *Agriculture, Humam Values*. 7, 34–39.

Blasco, F.; Saenger, P.; Janodet, E. (1996). Mangroves as Indicators of Coastal Change. *Catena*. 27, 167-178.

Brown, W.H.; Fischer, A.F. (1918). Philippine Mangrove Swamps. Bulletin No. 17, Bureau of Forestry. Manila, Department of Agriculture and Natural Resources.

Burke, L.; Kura, Y.; Kassem, K.; Revenya, C.; Spalding, M.; and McAllister, D.(2001). Pilot Analysis of Global Ecosystems, Coastal Ecosystems. Washington D.C, World Resources Institute.

Cakir, H.I.; Khorram, S.; and Nelson, S.A.C. (2006). Correspondence Analysis for Detecting Land Cover Change. *Remote Sensing of Environment*. 102: 306-317.

Chan, H.T. and Baba, S. (2009). Manual on Guidelines for Rehabilitation of Coastal Forests Damaged by Natural Hazards in the Asia-Pacific Region. Okinawa, International Society for Mangrove Ecosystems (ISME) and International Tropical Timber Organization (ITTO).

Chander, G.; B. Markham; and D. Helder. (2009). Summary of Current Radiometric Calibration Coefficients for Landsat MSS, TM, ETM^+, and EO-1 ALI Sensors. *Remote Sensing of the Environment*. Vol. 113, pp. 893-903.

Chapman, V. J. (1976). Mangrove Vegetation. *J. Cramer, Veduz*

Christensen, B. (1982). Management and Utilization of Mangroves in Asia and the Pacific. FAO Environment. Paper No. 3. Rome, Food and Agriculture Organization.

Christensen, B. (1983b). Mangroves: What are They Worth?. *Unasylva*. 35, 2–10.

Coppin, P. and Bauer M. (1996). Digital Change Detection in Forest Ecosystems with Remote Sensing Imagery. *Remote Sensing Review*. Vol. 13, pp, 207-234.

Cormier-Salem, M.C. (1999). The Mangrove: An Area to be Cleared for Social Scientists. *Hydrobiologia*. 413, 135–142.

Dahdouh-Guebas, F.; C. Mathenge; J.G. Kairo; N. Koedam (2000b). Utilization of Mangrove Wood Products around Mida. *Economic Botany*, 54(4). 513-527.

Dahdouh-Guebas, F.; Collin, S.; Lo Seen, D.; Ro¨nnba¨ck, P.; Depommier, D.; Ravishankar., Verheyden, A.; De Genst, W.; Hettiarachchi, S.; Koedam, N. (2000b). Four Decade Vegetation Dynamics in Sri Lankan Mangroves as Detected from Sequential Aerial Photography : A Case Study in Galle. *Bulletin of Marine Science*. 67, 741–759.

Dahdouh-Guebas, F. (2001). Mangrove Vegetation Structure Dynamics and Regeneration. Ph.D. Dissertation, Brussels, Vrije Universiteit Brussel.

Dahdouh-Guebas, F. (2002). Remote Sensing and GIS in the Sustainable Management of Tropical Coastal Ecosystems, Environment, Development and Sustainability. Special Issue. Dordrecht, *Kluwer Academic Publishers*. Vol. 4(2), pp, 93–112.

Dale, D. A.; Cohen, S. A.; Johnson, L. C.; Schuster, M. D.; Calzetti, D.; Engelbracht, C. W.; Gil de Paz, A.; Kennicutt, R. C.; Lee, J. C.; Begum, A.; Block, M.; Dalcanton, J. J.; Funes, J. G.; Gordon, K. D.; Johnson, B. D.; Marble, A. R.; Sakai, S.; Skillman, E. D.; van Zee, L.; Walter, F.; Weisz, D. R.; Williams, B.; Wu, S.-Y.; Wu, Y. (2009). The Spitzer Local Volume Legacy: Survey Description and Infrared Photometry. *The Astrophysical Journal*, Volume 703, Issue 1, pp. 517-556.

Devine, F and S. Heath (1999). Sociological Research Methods in Context. Basingstoke: Macmillian.

Du Plessis W. P. (1999). Linear Regression Relationships between NDVI, Vegetation and Rinfall in Etosha National Park, Namibia. *Journal of Arid Environments.* 42, 235-260.

Duke, N.C. (1992). Mangrove Floristics and Biogeography. In: A.I. Robertson and D.M. Alonghi,(Eds.). Tropical Mangrove Ecosystems, Coastal and Marine Estuarine. Series 41, Washington, DC, American Geophysical Union.

Duke, N.C.; Meynecke, J.-O.; Dittmann, S.; Ellison, A.M.; Anger, K.; Berger, U.; Cannicci, S.; Diele, K.; Ewel, K.C.; Field, C.D;, Koedam, N.; Lee, S.Y.; Marchand, C.;

Nordhaus, I.; Dahdouh-Guebas, F. (2007). A World Without Mangroves?. *Science*. 317, 41–42.

Elmore, A.J. and G.P. Asner (2005). Satellite Monitoring of Vegetation Phenology and Fire Fuel Conditions in Hawaiian Drylands. *Earth Interactions*. 9 (21):1- 21.

Erdas imagine 9.2, Help- Online Documentation. Copyright© 1991-2008, Leica Geosystems Geospatial Imaging. LLC Worldwide Headquarters 5051 Peachstreet Corners Circles Norcross, GA 30092-2500, USA.

Erftemeijer, P. L. A and O. Hamerlynck (2005). Die-Back of the Mangrove Heritiera littoralis Dryland in the Rufiji Delta (Tanzania) Following El Nino Floods. In *Journal of Coastal Research*. 228-235.

Eslami-Andargoli, L.and Dale P., (2009). Mangrove Expansion and Rainfall Patterns in Moreton Bay, Southeast Queensland, Australia. *Estuarine, Coastal and Shelf Science*. 85(2), 292-298.

Ewel, K.C.; Twilley, R.R.; Ong, J.E. (1998a). Different Kinds of Mangrove Forests Provide Different Goods and Services. *Global Ecology, Biogeography*. 7, 83–94.

FAO and UNEP. (1981). Tropical Forest Resources Assessment Project. Roma, Forest Resources of Tropical Asia, Africa and America.

FAO (2007). The World's Mangroves 1980-2005. No, 153, FAO Forestry Paper. Rome, Food and Agriculture Organisation of the United Nations.

FAO (1994). Mangrove Forest Management Guidelines. FAO Forestry Paper 117. Roma, Food and Agriculture Organization of the United Nations.

FAO (2005). Status and Trends in Mangrove Area Extend Worldwide. Working Paper No. 64. Rome, Forest Resource Division.

FAO (2006a). Global Forest Resources Assessment 2005. Progress towards Sustainable Forest Management. FAO Forestry Paper 147. Rome (www.fao.org/ forestrysite/fra2005).

FAO (2006). Global Forest Resources Assessment. Main Report. Progress Towards Sustainable Forest Management. FAO Forestry Paper 147, Rome.

Farnsworth, E.J. and Ellison, A.M. (1997). The Global Conservation Status of Mangroves *Ambio*. 26, 328–334.

Field, C.D. and Dartnall, A.J. (1987). Mangrove Ecosystems of Asia and the Pacific: Status, Exploitation and Management. Townsville, Australian Development Assistance Bureau and Australian Committee for Mangrove Research.

Fitzpatrick and Boulton (1994). Qualitative Methods for Assessing Health Care. *Quality in Health Care.* 3, 107-113.

Foell, J.; Harrison, E. ; Stirrat, R.L. (1999). Participatory Approaches to Natural Resource Management – The Case of Coastal Zone Management in the Puttalam District. Summary Findings of DFID-Funded Research 'Participatory Mechanisms for Sustainable Development of Coastal Ecosystems' (Project R6977). School of African and Asian Studies. University of Sussex, Brighton, Falmer.

Fong, F.W. (1992). Perspectives for Sustainable Resource Utilization and Management of Nipa Vegetation. *Economy*, *Botany*. 46, 45–54.

Fottland,H and Sorensen,C. (2001). Issues Related to the Establishment of Prawn Farms in Tanzania, with example of Rufiji Delta. Catchment Forest Project, 96.4. Accessed on 10th March 2013 on http://www.uit.no/semut/cfp/rep/CFP964m.html.

Franks, T. and Falconer, R. (1999). Developing Procedures for the Sustainable Use of Mangrove Systems. *Agriculture, Water Management*. 40:59-64.

Fromard, F.; Vega, C.; Proisy, C. (2004). Half a Century of Dynamic Coastal Change Affecting Mangrove Shorelines of French Guiana. A Case Study Based on Remote Sensing Data Analyses and Field Surveys. *Marine Geology*. *208*, 265-280.

Gang, P.O. and Agatsiva, J.L. (1992). The Current Status of Mangroves along the Kenyan Coast: A Case Study of Mida Creek Mangroves Based on Remote Sensing. *Hydrobiologia*. 247: 29-36.

Gibbons,P. (1997). Prawns and Piranhas, The Political Economy of the Tanzania's Private Sector Marketing Chain. *Journal of Peasant Studies*. 25(1), 1-86.

Gilman, E.L.; Ellison, J.; Duke, N.C.; Field, C. (2008). Threats to Mangroves from Climate Change and Adaptation Options, A Review. *Aquatic Botany*. 89, 237-250.

Giri, C.P.; Kratzschmar, E.; Ofren, R.S.; Pradhan, D.; Shrestha, S (1996). Assessing Land Use/Land Cover Dynamics in Two Identified ―Hot Spot‖ Areas. In Proceeding of The 17th Asian Conference on Remote Sensing, 4–8 November. Colombo, Oudomxay Province of Lao P.D.R. and Mekong Delta of Vietnam.

Glaser, M. (2003). Interrelations Between Mangrove Ecosystem, Local Economy and Social Sustainability in Caete Estuary North Brazil. *Wetland Ecology Management*. 11, 265–272.

Glaser, M. and Oliveira, R. (2004). Prospects for the Co-management of Mangrove Ecosystems on the North Brazilian Coast: Whose Rights, Whose Duties and Whose Priorities?. *Natural Resource Forum*. 28, 224–233.

Hamilton, L.S.; Dixon, J.A.; Miller, G.O. (1989). Mangrove Forests: An Undervalued Resource of the Land and of the Sea. In: Borgese, E.M., Ginsburg, N., Morgan, J.R. (Eds.). Ocean Yearbook 8, Chicago, University of Chicago Press.

Hemeleers, L.; Koedam, N.; Dahdouh-Guebas, F. (2009). Global Ecology of Mangroves: A Survey Analysis of Diversity, Functionality, and Degradation of Mangrove Ecosystems. In: Mees, J. *et al.*, (Ed.) (2009). Book of Abstracts: An Overview of Marine Research in Belgium, Special Publication. 43, pp,70.

Hoffer, R. M. (1978). Biological and Physical Considerations in Applying Computer-Aided Analysis Techniques to Remote Sensor Data. In: Swam PH, Davies SM (Eds. i.). New York, McGraw- Hill.

Hogan, A.R; Nandi,R.X.L; Mtiga,M.O; Chirwa,E.B; Kilonzo,P ; Peter, J. (1999). Selection of Pilot Villages, A Report on the Rapid Appraisal Methodology used and the Election made, Together with Eleven Individual Village Profiles. REMP Technical Report. No. 2.

Holmes, J. (1995). Natural Forest Handbook for Tanzania. Forest Policy, Planning and Utilization, Faculty of Forestry, Morogoro, Sokoine University of Agriculture. Volume II, pp, 362.

Jensen J.R. (1996). Introductory Digital Image Processing. A Remote Sensing Perspective. New Jersey, Prentice-Hall.

Kaija,Y.S. (2000). Assessment of the Effects of Rice Farming in the Mangrove Forests of the Rufiji Delta, Mainland Tanzania. MSc Thesis in Ecological Marine Management, Faculty of Science. Brussels, Free University of Brussels.

Kathiresan, K.; Bingham, B.L. (2001). Biology of Mangroves and Mangrove Ecosystems. *Advances in Marine Biology*. 40, 81–251.

Kathiresan, K and Bingham, B.L. (2010). Biology of Mangrove and Mangrove Ecosystems. *Advances in Marine Biology*. 40: 81-205.

Kerle, N. ; Janssen, L. L. F.; Huurneman, G. C. (2004). Principal of Remote Sensing (Ed). An Introductory Textbook. ICT. Enschede.

Kipangala A. (2008). Marine and Coastal Environment Management Progressive Report. Dar es Salaa.

Kovacs, J.M. (1999). Assessing Mangrove Use at the Local Scale. *Landscape, Urban Planning*. 43, 201–208.

Krauss, K.W.; Lovelock, C.E.; Mckee, K.L.; Lopez-Hoffman, L.; Ewe, S.M.L.; Sousa, W.P. (2008). Environmental Drivers in Mangrove Establishment and Early Development, A review. *Aquatic Botany*. 89, 105-127.

Kulindwa, K; Sosovele,H.; Mgaya, Y.D. (2001). Socio-Economic Dimensions of Biodiversity Loss in Tanzania. Dar es Salaam, Dar es Salaam University Press.

Kunstadter, P., Bird, E.C.F., Sabhasri, S. (1986). Man in the Mangroves, Tokyo, United Nations University.

Kunstadter,P.; Eric,C.F.; and Sanga,S. (1986). Socio-Economic Situation of Human Settlement in Mangrove Forests. Tokyo, The United Nations University.

Lacerda, L.D. (1993). Conservation and Sustainable utilization of Mangrove Forests in Latin America and African Regions. (Ed.). (Part 1: Latin America). Mangrove Ecosystem Technical Reports 2. Tokyo, International Society for Mangrove Ecosystems and International Tropical Timber Organization.

Lacerda, L.D. (2002). Mangrove Ecosystems: Function and Management. (Ed.). New York, Springer.

Lacerda, L.D.; Conde, J.E.; Bacon, P.R.; Alarcon, C.; D'Croz, L.; Kjerfve, B.; Polania, J.;Vanucci, M.(1993). Mangrove Ecosystems in Latin America and the Caribbean: A Summary, In: Lacerda, L.D. (Ed.). Conservation and Sustainable Utilization of Mangrove Forests in Latin America and African Regions (Part 1: Latin America). Mangrove Ecosystem Technical Reports 2. Tokyo, International Society for Mangrove Ecosystems and International Tropical Timber Organization.

Lamparelli, C.C.; Rodrigues, F.O.; Orgler de Moura, D. (1997). Long-Term Assessment of An Oil Spill in a Mangrove Forest in S˜ao Paulo, Brazil. In: B. Kjerfve; L.D. de Lacerda and E.H.S. Diop (Eds.). Mangrove Ecosystem Studies in Latin America and Africa. Paris, UNESCO.

Lillesand, T. M. and Kiefer, R. W. (1987). Concepts and Foundations of Remote Sensing in Remote Sensing and Image Interpretation. Chapter 1, New York: John Wiley.

Lopez-Hoffman, L.; Monroe, I.E.; Narvaez, E.; Martinez-Ramos, M.; Ackerly, D.D. (2006). Sustainability of Mangrove Harvesting: How Do Harvesters' Perceptions Differ from Ecological Analysis?. *Ecol. Soc.* 11(2) art. 14.

Lu, D.; Mausel, P.; Brondizio, E.; and Moran, E. (2003). Change Detection Techniques. *International Journal of Remote Sensing*. 25(12):2365.

Lugo, A.E.; Snedaker, S.C. (1974). The Ecology of Mangroves. *Annual Review of Ecology Systematic*. 5, 39-64.

Macleod and Congalton (1998). A Quantitative Comparison of Change Detection Algorithms for Monitoring Ealgrass from Remotely Sensed Data. *Photogrammetric Engineering and Remote Sensing*. Vol. 64, No 3, pp. 207-216.

Macnae, W. (1968). A General Account of the Fauna and Flora of Mangrove Swamps and Forests in the Indo-West-Pacific Region. *Advances in Marine Biology*. 6, 73–270.

Mainoya, I. R. (1986).The Use of Mangroves and Their Products by the Local Community in Tanzania. In: I.R, Mainoya and P.R Siegel (Eds.). Status and Utilisation of Mangroves, Proceeding of a Workshop on Save the Mangroves Ecosystem in Tanzania. 21st -22nd February, 1986. Dar es Salaam, University of Dar es Salaam.

Mainoya, J.R.; Mesaki, S.; Banyikwa, F.F. (1986). The Distribution and Socio-Economic Aspects of Mangrove Forests in Tanzania. In: Kunstadter, P., Bird, E.C.F., Sabhasri, S. (Eds.). Man in the Mangroves. Tokyo, United Nations University.

McLeod, E. and Salm, R. V. (2006). Managing Mangroves for Resilience to Climate Change. Gland, Switzerland, The World Conservation Union (IUCN) 2.

Meltzoff, S.K. and LiPuma, E. (1986). The Social and Political Economy of Coastal Zone Management: Shrimp Mariculture in Ecuador. *Journal of Coastal Zone Management*. 14, 349– 380.

Meza Diaz, B. and Blackburn, G.A. (2003). Remote Sensing of Mangrove Biophysical Properties: Evidence from a Laboratory Simulation of the Possible Effects of Background Variation on Spectral Vegetation Indices. *International Journal of Remote Sensing*. 24, 53-73.

Ministry of Natural Resources and Tourism (2003). Forest Act of 2002. School of Oriental and African Studies. United Kingdom. *Journal of African Law*. 47, 1, 133-135.

Ministry of Natural Resources and Tourism (1998). National Beekeeping Policy. Dar es Salaam, Tanzania.

Moshen A. (1999). Environmental Land Use Change Detection and Assessment using Multi-Temporal Satellite Imagery. Zanjan University.

National Bureau of Statistics (2002). Statistics for Development. Tanzania 2002 Population Census. United Republic of Tanzania.

Naylor, R.L.; Bonine, K.B.; Ewel, K.C.; Waguk, E. (2002). Migration, Markets and Mangrove Resource Use on Kosrae, Federated States of Micronesia. *Ambio*.31, 340–350.

Ochieng, C.A. (2002). Research Master Plan for the Rufiji Flood Plain and Delta, 2003-2013. REMP Technical Report, No.28.

Ohn, U. (2004). Mangrove Reforestation in the Coastal Area of Myanmar. Yangon, Forest Resource Development and Conservation Association.

Pettorelli, N.; J.O. Vik; A. Mysterud ; J.M. Gaillard ; C.J. Tucker ;N.C. Stenseth (2005). Using the Satellite Derived NDVI to Assess Ecological Response to Environmental Change. *Trends in Ecology and Evolution.* 20 (9): 503-510

Primavera, J.H. (1997). Socioeconomic Impacts of Shrimp Culture. *Aquaculture, Res*. 28, 815-827.

Primavera, J.H. (1993). A Critical Review of Shrimp Pond Culture in the Philippines. *Rev. Fish. Sci*. 1, 151–201.

Primavera, J.H. (2000a). Development and Conservation of Philippine Mangroves. *Institutional Issues, Ecology and Economy*. 35, 91–106.

Primavera, J.H. (2005). Mangroves, Fishponds, and the Quest for Sustainability. *Science.* 310, 57–59.

Primavera, J.H. (2006). Overcoming the Impacts of Aquaculture on the Coastal Zone. *Ocean Coastal Management*. 49, 531-545.

Primavera, J.H.; Sadaba, R.B.; Lebata, M.J.H.L.; Altamirano, J.P. (2004). Handbook of Mangroves in the Philippines. Man and the Biosphere ASPACO Project SEAFDEC, Panay, Aquaculture Department (Philippines) and UNESCO.

Ramachandran, S.; Sundaramoorthy, S.; Krishnamoorthy, R.; Devasenapathy, J.; and Thanikachalam, M. (1998). Application of Remote Sensing and GIS to Coastal Wetland Ecology of Tamil Nadu and Andaman and Nicobar Group of Islands with Special Reference to Mangroves. *Current Science*. 75 (3), 236–244.

Ramachandra, T.V ; Savitha, G. (2008). Vegetation Analysis in Uttara kannada District using GIS and Remote Sensing Techniques. The Ministry of Environment and Forests Government of India ENVIS Technical Report: 24.

Rasolofo, M.V. (1997). Use of Mangroves by Traditional Fishermen in Madagascar. *Mangrove and Salt Marshes*. 1, 243–253.

Rehder, J.B. and Patterson, S.G. (1986). Mangrove mapping and monitoring. In: Symposium on Remote Sensing for Resources Development and Environmental Management. Enschede, The Netherlands.

Ro¨nnba¨ ck, P.; Crona, B.; Ingwall, L. (2007a). The Return of Ecosystem Goods and Services in Replanted Mangrove Forests, Perspectives from Local Communities in Gazi Bay, Kenya. *Environmental Conservation*. 34, 313–324.

R¨onnb¨ack, P. (2001). Mangroves and Sea food Production. Akademitryck AB, Edsbruk, The Ecological Economics of Sustainability.

Roberts, R. W. and Ruara, W. W. (1967). Lamu Mangrove Inventory. Nairobi,Kenya, Forest Department.

Rufiji Delta Management Forest Reserve (2011). Inventory Exercise Team

Rufiji Environmental Management Project (1998). Strengthening Voices for Better Choices in Tanzania. Helping Stakeholders Overcome the Obstacles to Better Forest Governance Locally and Nationally. Gland, Switzerland. International Union for Conservation of Nature.

Saenger, P. (2002). Ecological Assessment of Mangroves in Egypt. Field Report for FAO Project.TCP/EGY/0168(A) FAO. Rome.

Saenger, P., Hegerl, E.J.; Davie, J.D.S. (1983). Global Status of Mangrove Ecosystems. Commission on Ecology Papers No. 3. Gland, Switzerland, World Conservation Union (IUCN).

Saenger, P.; Hegerl, E.J.; Davie, J.D.S. (1983). Global Status of Mangrove Ecosystems. *Environmentalist.* 3 (Suppl.3), 88.

Sathirathai, S. and Barbier, E.B. (2001). Valuing Mangrove Conservation in Southern Thailand. *Contemporary Economic Policy*. 19(2), 109–122.

Semesi, A.K. (1989). The Mangrove Resources of the Rufiji Delta, Tanzania. Paper Presented at a Workshop on Marine Science in East Africa, 4th -16th November, 1989. Institute of Marine Science, University of Dar es Salaam.

Semesi, A.K. (1992). Developing management Plans for the Mangrove Forest Reserves of the Mainland Tanzania. *Hydrobiologia.* 247: 1-10.

Semesi, A.K. (1998). Mangrove Management and Utilization in Eastern Africa. *Ambio.* 27(8), 620–626.

Semesi, A.K. (1991). Management Plan for Mangrove Eco-system of Tanzania Mainland. Vol.11: Mangrove Management Plan of all Coastal Districts. Dar es Salaam, Ministry of Tourism, Natural Resources and Environment, Forest and Bee- Keeping Division.

Seto, K.C.; Fragkias, M. (2007). Mangrove Conversion and Aquaculture Development in Vietnam. A Remote Sensing Based Approach for Evaluating the Ramsar Convention on Wetlands. *Global Environmental Change.* 17, 486-500.

Shemdoe, R. S. (2001). Understanding Community Based Adaptation Strategies to Climate Variability in Fishing of Rufiji River Basin in Tanzania. *African Journal of History and Culture*. Vol. 4(2), 17-26.

Shemdoe, R. S.; Kikula, I. S.; Van Damme, P. (2009). Traditional Tillage Systems as Drought Adaptation Strategies of Smallholder Farmers. The Case of Semi-Arid Central Tanzania. *Nature and Culture*. 4(2), 191-207.

Shunula, J.P. (2002). Public Awareness, Key to Mangrove Management and Conservation, The Case of Zanzibar. *Trees*. 16, 209–212.

Singh, A. (1989). Digital Change Detection Techniques using Remotely Sensed Data. *International Journal of Remote Sensing*. Vol. 10, No.6, p: 989- 1003.

Spalding, M (1997). The Global Distribution and Status of Mangrove Ecosystems. *International News Letter Coastal Management*. 1, 20-21.

Spalding, M., Blasco, F. and Field, C. (1997). World Mangrove Atlas. Okinawa, The International Society for Mangrove Ecosystems.

Spalding, M.; Kainuma, M.; Collins, L. (2010). World Atlas of Mangroves. London, United Kingdom. Earth Scan Publishing.

Stedman-Edwards, P. (1998). Root Causes of Biodiversity Loss. Analytical Approach. Micro Economic for Sustainable Development Programme Office. Washington DC. WWF for Nature.

Stonich, S., Vandergeest, P. (2001). Violence, Environment, and Industrial Shrimp Farming. In: Peluso, N.L., Watts, M. (Eds.). Violent Environments, Ithaca, New York, Cornell University Press.

Tack, J.F. and Polk, P. (1999). The influence of Tropical Catchments upon the Coastal Zone. Modelling the Links between Groundwater and Mangrove Losses in Kenya, India and Florida. In: D. Harper and T. Brown(Eds.). Sustainable Management in Tropical Catchments. London, John Wiley and Sons Ltd.

Tassan, S. (1987). Evaluation of the Potential of the Thematic Mapper for Marine Application. *International Journal of Remote Sensing*. 8(10): 1455-1478.

Taylor, F.J. (1982). The Utilization of Mangrove Areas in Thailand and Peninsular Malaysia. *Journal of Southeast Asian Studies*.13, 1–8.

TCMP, (2000). Pwani Yetu. The News Letter of the Tanzania Coastal Management Partnership Issue No.10, December 2000.

Thanikachalam (1998). Application of Remote Sensing and GIS to Coastal Wetland Ecology of Tamil Nadu and Andaman and Nicobar Group of Islands with Special Reference Mangroves. *Current Science*. 75(3): 236-244.

Thu, P.M.; Populus, J. (2007). Status and Changes of Mangrove Forest in Mekong Delta: Case study in Tra Vinh, Vietnam. *Estuary Coastal Shelf Science*. 71, 98-109.

Tomlinson, P.B. **(**1986). The Botany of Mangroves. Cambridge, UK, Cambridge University Press.

Tomlinson, P.B. (1986). The Botany of Mangroves. Melbourne, VIC, Australia,Cambridge University Press.

Tomlinson, P.B. (1986). The Botany of Mangroves. Ontario , Canada , UNEP and Gems Water Programme, 2006. Water Quality For Ecosystem and Human Health, Cambridge University Press.

UNEP, (2003). Mangroves of Eastern Africa. UNEP-Regional Seas Programme/UNEP-WCMC.

UNEP (2007). Mangroves of Western and Central Africa. UNEP-Regional Seas Programme/UNEP-WCMC. *http://www.unep-wcmc.org/resources/publications/*.

UNEP, (1994). Assessment and Monitoring of Climatic Change Impacts on Mangrove Ecosystems. UNEP Regional Seas Reports and Studies N° 154, Environmental Programme, Nairobi, Kenya, United Nations.UNEP; World Bank and WRI (2003), World Resources (2002-2004). Decisions for the Earth Balance, Voice and Power. Washington DC, World Resources Institute.

UNEP and GERMS Water Programme (2006). Water Quality for Ecosystem and Human Health. Ontario, Canada.

UNEP/GPA (2006a). The State of the Marine Environment: Trends and Processes. The Hague www.http://en.wikipedia.org/wiki/Sediment, Retrieved on 10th June 2013.

United Republic of Tanzania (2003). Tanzania State of the Coast Report. The National Integrated Coastal Management Strategy and Prospects for Poverty Reduction, Dar es Salaam.

Untawale, A.G. (1987). Exploitation of Mangroves in India. In: Field, C.D., Dartnall, A.J. (Eds.). Mangrove Ecosystems of Asia and the Pacific: Status, Exploitation and Management, Townsville, Australian Development Assistance Bureau and Australian Committee for Mangrove Research.

United States Geological Survey (2000 and 2011). Rufiji Delta Landsat Images

Valiela, I.; Bowen, J.L.; York, J.K. (2001). Mangrove Forests: One of the World's Threatened Major Tropical Environments. *Bioscience*. 51, 807–815.

Van Speybroeck, D. (1992). Regeneration Strategies of Mangroves along the Kenyan Coast. In: Jaccarini, V and Martens,E (Eds.). The Ecology of Mangroves and Related Ecosystems, Kluwar, Netherlands, Academic Publishers.

Vandergeest, P.; Flaherty, M.; Miller, P. (1999). A political ecology of shrimp aquaculture in Thailand. *Rural Sociology*. 64, 573–596.

Vedeld, P.; Angelsen, A.; Sjaastad, E.; Berg, G.K. (2004). Counting on the Environment. Forest Incomes and the Rural Poor, Environmental Economics Series Paper No. 98, Washington, DC, World Bank.

Walsh, G.E. (1977). Exploitation of *Mangal*. In: Chapman, V.J. (Ed.). Wet Coastal Ecosystems. New York, Elsevier Science, pp. 347–362.

Walters, B.B. (2003). People and Mangroves in the Philippines: Fifty years of Coastal Environmental Change. *Environmental Conservation*. 30, 293–303.

Walters, B.B. (2004). Local Management of Mangrove Forests: Effective Conservation or Efficient Resource Exploitation? *Human Ecology*. 32, 177–195.

Walters, B.B. (2005a). Patterns of Local Wood Use and Cutting of Philippine Mangrove Forests. *Economic Botany*. 59, 66–76.

Walters, B.B.; Burt, M. (1991). Integrated Management of Common Property Fuel Wood Resources from Natural and Plantation Forests. CANARI Communication No. 35, September 1991. Paper Presented at the IDRC Workshop on Common Property Resources. St. Lucia, Winnipeg, Canada, Caribbean Natural Resources Institute.

Walters, B.B.; Rönnbäck, P.; Kovacs, J.M.; Crona, B.; Hussain, S.A.; Badola, R.; Primavera, J.H.; Barbier, E.; Dahdouh-Guebas, F. (2008). Ethnobiology, Socio-Economics and Management of Mangrove Forests: A Review. *Aquatic Botany*. 89, 220-236.

Wang, Y.; Bonynge, G.; Nugranad, J.; Traber, M.; Ngusaru, A.; Tobey, J.; Hale, L.; Bowen, R. and Makota, V. (2003). Remote Sensing of Mangrove along the Tanzania Coast. *Marine Geodesy*. 26: 35– 48.

Wilkie, M.L., Fortuna, S. (2003). Status and Trends in Mangrove Area Extent Worldwide. Working Paper FRA 63. Forest Resources Division, Forestry Department, UN-Food and Agriculture Organization.

WWF, (2001). The Root Causes of Biodiversity Loss in the Eastern African Marine Ecoregion. Macro economics Program Office.

www.ramsar.org. Retrieved on 20th February, 2013.

Xiao, X.; S. Hagen,; Q. Zhang; M. Keller ; B. Moore III (2006). Detecting Leaf Phenology of Seasonally Moist Tropical Forests in South America with Multi-Temporal MODIS Images. *Remote Sensing of Environment*. 103: 465-473.

Zhang, X.; M.A. Friedl; C.B. Schaaf; A.H. Strahler; J.C.F. Hodges; F. Gao; B.C. Reed ; A. Huete (2003). Monitoring Vegetation Phenology using MODIS. *Remote Sensing of Environment*. 84: 471-475.

APPENDIX 1

QUESTIONAIRE ON ASSESSMENT OF THE STATUS OF MANGROVE VEGETATION AND THEIR DEGRADATION IN RUFIJI DELTA IN TANZANIA.

Name of Interviewer…………………………….. Date………………………………

Questionnaire Code……………………… Household Code………………………………

Village Name……………………………………………

Coordinates: Latitude………………. Longitude……………… Elevation……………….

This questionnaire is part of a research which will be conducted at the University of Ghana, Legon; Department of Geography and Resource Development in fulfillment of the award of Master of Philosophy Degree in Geography and Resource Development. The research is solely for academic purpose. For ethical and confidential reasons, I will not write your name on this questionnaire form and besides, your anonymity is guaranteed.

Please tick and / or write responses where necessary.

SECTION A (Socio-Economic Background of Respondents)

1. Which age category do you belong?

1	15 - 24	
2	25 - 49	
3	50 and above	

2. What is your sex?

1	Male	
2	Female	

3. What is your marital status?

1	Single	
2	Married	
3	Separated	
4	Divorced	
5	Widowed	

4. Where were you born?

1	In the Rufiji Delta	
2	Outside the Rufiji Delta	

5. What is your highest level of education?

1	Non formal education	
2	Primary education	
3	Secondary education	
4	Tertiary education	

6. What is your main occupation?

1	Peasant	
2	Fisherman/fisherwoman	
3	Mangrove poles dealer	
4	Mangrove timber dealer	
5	Salt producer	
6	Charcoal producer	
7	Others, specify	

SECTION B (Utilisation of Mangrove Vegetation)

7. How do you use mangrove vegetation?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

8. What are the most commonly harvested mangrove species presently?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Why?………………………………………………………………………………………

…………………………………………………………………………………………………

…..………..………………………………………………………………………………

…..……………………………………………………………………………………

9. What are the least harvested mangrove species presently?

……………………………………………………………………………………………

………..………………………………………………………………………………

………………..……………………………………………………………………

……………………...………………………………………………………………….

Why?…………………………………………………………………………………

……..

...............……………………………………………………………………………

…………………...…………………………………………………………………..

………………………..………………………………………………………………

10. Who are engaging in harvesting mangrove vegetation?

1	Male	
2	Female	
3	Both	

If male, what are mangrove vegetation used for?

……………………………………………………..……………………………………

……………………………………..………………………………………………………

……………………………...…………………………...……………………………………

……………………………………..………………………………………………………

If female, what are mangrove vegetation used for

……………………………………..………………..……………………………………………

………………………………………………...………......……………………………………

………………………………………………………...……………...…………………………

…………………………………………………………..………………..............................

……………………………………………………………………………………………….

If both, specify the uses

…………………………………………………………………………...………………

…………………………………………………………………..……………………………

……………………………………………………………..…………………………………

…………………………………………………………………………...…………………

……………………...………………………………………………………………………

11. On what basis are mangrove vegetation accessed?

1	Legally	
2	Illegally	
3	Both	

12. a) Has the basis for accessing mangrove resources changed for the past eleven years?

1	YES	
2	NO	
3	DO NOT KNOW	

b) What changes have occurred in uses and access to mangrove vegetation for the past eleven year?

…………………………………………………...…………………………………………

………...…………………………………………………..………………………………

……………....…………………………………………………...………………………

……………………..………………………………………………...…………………

13. a) Have there been significant changes in your income in the last eleven years?

1	Yes	
2	No	

b) If Yes, What is the income used for? (List main uses)

i)………………………………………………..……………………………………….

ii)……………………………………………………..………………………………….

iii)…………………………………………………………………………………….

iv)……………………………………………………..……………………………….

v)…………………………………………………………………………………….

14. Has the mangrove vegetation affected to your livelihood positively or negatively?

Explin.………………………………………………………..……………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

………………………………………………………………………………………….

15. What are the challenges you face during exploitation of mangrove vegetation?

……………………………………………………………………………………………

………..…………………………………………………………………………………

………………...……………………………………………………………………….

……………………….……………………………………………………………….

……………………………………………………………………………………………

SECTION C (Extent of Mangrove Cover Degradation)

16. Mention the mangrove species that you know.

……………………………………………………………………………………………

………..………………………………………………………………………………..

…………………..…………………………………………………………………….

……………………….……………………………………………………………….

…………………………………………………………………………………………..

17. Compared to the past eleven years, are mangrove species more degraded presently?

1	YES	
2	NO	
3	DO NOT KNOW	

Why?

…………………………………………………………………………………………...

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

18. How can you estimate the loss of mangrove cover for the past eleven years?

1	Very high	
2	High	
3	Moderate	
4	Low	
5	Very low	
6	Do not know	

SECTOIN D (Factors causing Mangrove Vegetation Degradation)

19. a) What do you think are the direct causes of mangrove vegetation degradation?

i)……………………………………………………………………………………………

ii)…………………………………………………………………………………………

iii)…………………………………………………………………………………………..

iv)…………………………………………………………………………………………

v)…………………………………………………………………………………………

vi)………………………………………………………………………………………

b) What do you think are the indirect causes of mangrove vegetation degradation?

i)……………………………………………………………………………………………

ii)………………………………………………………………………………………

iii)…………………………………………………………………………………………

iv)…………………………………………………………………………………………

v)…………………………………………………………………………………………

vi)…………………………………………………………………………………………

vii)…………………………………………………………………………………………

viii)………………………………………………………………………………………

SECTION E (Strategies of Local Communities for Management of Mangrove Vegetation)

20. In your own opinion, what are the main problems in the area?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

21. What things would you like to change or improve?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

22. Indicate how you cope with the shortage of each.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………..…………………………………………………………………………………

………………..………………………………………………………………………………

……………………………..……………………………………………………………………

………………………………..…………………………………………………………………

…………………………………..……………………………………………………………

23. Have any attempts been made to control mangrove resources degradation?

1	YES	
2	NO	
3	DO NOT KNOW	

Why?……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………..

24 a) Are there laws, rules or regulations (formal or informal) that affect how the

household manages mangrove vegetation?

1	YES	
2	NO	

b) If YES, are these rules enforced?

1	YES	
2	NO	

25. a) Do household members belong to a local association, committee, NGO, or any

social group?

1	YES	
2	NO	

If Yes, since when?

....……

…………………………………………………………………………………………….

If No, why not?

………..…………

………………………………………………………………………………………………..

b) What are the benefits of being part of the group(s)?

………………………………………………………………………………………………

………..……………………………………………………………………………………….

………………………………………………………………………………………………

…………………………..………………………………………………………………….

…………………………………………………………………………………………….

26.Do you have access to new information/knowledge on mangrove vegetation management?

1	YES	
2	NO	

If Yes, by who?

....

....

....

....

....

If No, why?

....

....

....

....

....

APPENDIX 2

INTERVIEW GUIDELINE FOR MINISTRY OF NATURAL RESOURCES AND TOURISM AND NON-GOVERNMENTAL ORGANIZATIONS

The following instrument seeks the views of the MNRT and NGOs on mangrove resources management.

1. Briefly explain, the historical background of mangroves management
2. How long has your organization been working in managing mangrove vegetation in Rufiji Delta?
   - i) How stakeholders/actors involved in planning, implementation and monitoring process, and government policies?
   - ii) What was the situation of mangrove vegetation before your NGO started?
   - iii) What is the future prospect of mangrove vegetation?
3. How does the concept of local participation evolve in mangrove vegetation management?
   - i) What is local meaning and understanding of the concept ‘participation’?
   - ii) How are communities consulted or informed about forest (mangroves) policies and rules in Rufiji Delta?
   - iii) What is your perception about local participation towards sustainability of mangrove vegetation?
   - iv) In your opinion, do you think participation of an individual or group of people belonging to many NGOs leads to active participation in mangrove vegetation management? Give reasons
   - v) What mechanisms have been put in place to ensure local participation in managing mangrove vegetation?
   - vi) How such mechanisms evolved?

vii) To what extent the implementation of the mechanisms enhanced the performance of community in managing mangrove vegetation?

4. Is there any mangrove policy, laws, rules or regulations?
   i) What is the level of policy, laws, rules or regulations implementation?
   ii) How is it mainstreamed within your organization and communities?
5. Why local participation in community mangrove management, what are motives for participation?
6. What is the level of local participation in community managed mangrove vegetation?
7. How local community involved or represented in prioritizing, planning and decision making process?
8. What is the level local participation in community meetings?
9. How can you rate the community's willingness to manage mangrove vegetation?
10. What are the main challenges of local participation and sustainability in community mangrove vegetation management?
11. Challenges for local participation
    i) Challenges for sustainable mangrove vegetation
12. What are specific roles of your organization in managing mangroves?
13. What are your policies regarding the mangrove vegetation management in Rufiji Delta?
14. How is your organization support the community through participatory approach?
15. What roles do the MNRT perform in the managing mangrove resources?

APPENDIX 3

FOCUSED GROUP DISCUSSIONS GUIDELINES FOR THE LOCAL COMMUNITY

1. What do you understand by the terms mangrove and mangrove vegetation?
2. Discuss on the historical background of mangroves vegetation in Rufiji Delta
3. Are mangrove vegetation degraded over the past 11 years?
4. How do you rank the rate of degradation of mangrove vegetation?
5. How are you involved in managing mangrove vegetation?