



Review of Literature for a Climate Vulnerability Assessment in the RUMAKI Seascape, Tanzania

Madaka Tumbo ◆ Mwita M. Mangora ◆ Noah M. Pauline ◆ Baraka Kuguru

April 2015

Review of Literature for a Climate Vulnerability Assessment in the RUMAKI Seascape, Tanzania

Madaka Tumbo ◆ Mwita M. Mangora ◆ Noah M. Pauline ◆ Baraka Kuguru

Report Submitted to
WWF Tanzania Country Office
Dar es Salaam, Tanzania

April, 2015

Disclaimer

This report has been prepared as an output assignment commissioned by WWF Tanzania Country Office and has not been peer reviewed. Any opinions stated herein are those of the authors and do not necessarily reflect those of WWF and its donor agencies, or partners, nor those of the University of Dar es Salaam. Authors and their affiliation cannot guarantee the accuracy of the data and information included in this report. Correctness of the information presented herein is bound to the time of field consultations, review of literature and compilation of this report.

© 2015, WWF Tanzania Country Office, Dar es Salaam, Tanzania

Reproduction of this report for education and/or other non-commercial purposes is authorized without prior written permission provided the source is fully acknowledged. Any commercial purpose on this report is strictly prohibited without prior written permission from WWF Tanzania Country Office, Dar es Salaam.

Suggested citation:

Tumbo, M., Mangora, M.M., Pauline, N.M., Kuguru, B. 2015. Review of Literature for a Climate Vulnerability Assessment in the RUMAKI Seascape, Tanzania. WWF Tanzania Country Office, Dar es Salaam, Tanzania. x+87pp.

Design and layout:

M. M. Mangora

Cover photos:

M. M. Mangora

LIST OF ACRONYMS

ANOVA	Analysis of Variance
BMU	Beach Management Unit
CEAI	Coastal East Africa Initiative
CFMA	Collaborative Fisheries Management Area
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COSTECH	Tanzania Commission for Science and Technology
DoE	Division of Environment
EU	European Union
IPCC	Intergovernmental Panel for Climate Change
IUCN	International Union for Conservation of Nature
MACEMP	Marine and Coastal Environment Management Project
MIMP	Mafia Island Marine Park
MW	Mega Watts
NAPA	National Adaptation Plan of Action
NEM	North East Monsoon
NGO	Non Gobvernamental Organization
REMP	Rufiji Environmental Management Programme
RUMAKI	Rufiji-Mafia-Kilwa Seascape
SEM	South East Monsoon
SST	Sea Surface Temperature
TAFICO	Tanzania Fishing Company
TAFIRI	Tanzania Fisheries Research Institute
TCMP	Tanzania Coastal Management Programme
TCO	Tanzania Country Office
ToR	Terms of Reference
URT	United Republic of Tanzania
VPO	Vice President's Office
WWF	World Wildlife Fund

EXECUTIVE SUMMARY

This report provides a synthesis of the scientific literature on communicating background information for a climate vulnerability assessment in the Rufiji-Mafia-Kilwa (RUMAKI) Seascape, Tanzania. The objective of this assignment was to prepare a review document summarising available information, data and references relevant to assessing climate vulnerability in the RUMAKI seascape. The report is divided in five major sections:

- Trends in the status of ecosystems, natural resources and natural resource-based livelihoods
- Major development issues affecting the above
- Climate trends and projections for the area
- Vulnerability and resilience of ecosystems and livelihoods to climate change
- Extent to which climate change adaptation is addressed in relevant (natural resources) management policies and strategies

Ecosystems, natural resources and natural resources based livelihoods

The RUMAKI seascape is characterised by a wide diversity of biotopes and species that are predominantly utilized by surrounding local communities. The fact that different habitats support different species, there is disproportionate distribution of natural resources as well as economic activities. Artisanal fisheries is concentrated in productive areas which include estuaries, mangrove forests, coral reefs flats, sandy beaches, cliffs, sea grass-beds and muddy tidal flats. Agricultural activities are concentrated in the floodplains.

Coastal forests are a source of valuable timber and non-timber forest products, which are vital to the livelihoods of local communities. They provide timber for boat building, fuel wood for dry processing of fish, charcoal, building poles and woodcarvings. The value of non-marketed forest products is immense. Non-timber forest products from coastal forests, which are traded by local communities, include bee products, food, fruits, medicines, and natural dyes and fibres, among others. Due to their low cost and wide availability, plant-based traditional medicines are more popular in Rufiji, Mafia and Kilwa districts. However, overexploitation and clearing for other uses has led to a reduction of these important forests. In many areas forests have been cleared for agriculture, firewood and charcoal. Clearing of coastal forests poses a threat to mangroves because local communities shift from the use of coastal forest to mangroves for fuel wood, timber and charcoal making. Cutting of mangrove poles is a major activity in the delta. A mangrove management plan has been put in place to control the harvest of mangrove products, but effective enforcement of this plan has been far from reach. Because of the capital required for permits, most permits are in the hands of traders from large centres outside the Rufiji Delta. These external traders employ local people to do the cutting. Nonetheless, most harvesting is reported to be illegal, unselective and unsustainable. The future trends of this trade are likely to be influenced by demographic changes in the delta as well as its growing external demand.

Agriculture is one of important economic activities in the RUMAKI area despite the fact that marine resources are taken as the core livelihood activity. Major crops grown in the three districts of Rufiji,

Mafia and Kilwa are rice, maize and cashew nut. Agriculture in these districts like in most of rest of the country is whether dependent and therefore trends in agricultural production varies between years and seasons, where good years are related good whether (timely and enough rainfall) and increased crop productions. Bad years are mainly associated with extreme whether events (droughts and floods) where crop production is jeopardized. In the past agricultural production in most villages produced beyond self-sufficiency to create surplus for export outside their local boundaries. Currently, the old crop production trend has significantly changed. The present agricultural production in Rufiji is not even enough for subsistence. Despite the declining trends in agriculture, various studies indicate that it is still the main livelihood occupation of many households in the lower Rufiji.

Major development affecting ecosystems and natural resources in the RUMAKI seascape

Tanzania has recently made natural gas discoveries in coastal regions, and is expected to be one of the largest gas producers in Eastern Africa. Songo Songo off the eastern coast, and Mnazi Bay in southeast Tanzania - are in production with an estimated gas potential ranging from 2 to 3 trillion cubic feet. Although the discovery of gas in the coast region is very potential for the economy of the country, activities associated with exploration, extraction, transport poses threats to ecosystems and livelihoods. In general the nature of mining sector in the RUMAKI area is very limited and small compared to large inland mining operations. Lime mining for cement production is done in Kilwa. Illegal coral mining is done mainly in Mafia district.

The proposed future impoundment of the Rufiji River at Stiegler's Gorge was planned during the late 1970s. The Stiegler's Gorge project is envisaged as a multipurpose project with several expected long-term benefits, of which two are considered to be the most important: 1) its high hydropower potential (2100 MW) would facilitate the pursuit of Tanzania's policy for industrialization and further electrification and 2) flood control. A number of studies have shown that the implications of implementing the proposed project will not be realized without some environmental impacts, the major one being the degradation of the river bed and river main channel, leading to disruption of the natural flooding pattern of the river and sedimentation pattern. All these will in turn lead to disruption of livelihoods and ecosystems depending on the Rufiji Delta and its floodplain.

Climate trends and projections in the RUMAKI seascape

A number of studies projecting the impact of climate change on water resources in Tanzania have been undertaken, using multiple General Circulation Models have generally concluded that while future rainfall patterns were uncertain, the RUMAKI area may receive more rainfall under various climate change scenarios. Some of these studies have suggested that there would be a seasonal shift in rains, with less rainfall early in the season and stronger rains later in the season. In terms of temperature (air and sea surface) increases, all studies concluded that these would be in the range of 1.5°C - 2°C for the first half of this century and around 2°C - 4°C for the second half. These findings from local studies are within the range predicted for East Africa by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

In terms of the impact of climate change on water flows in the Rufiji River Basin, studies predict increased flows in the Rufiji Basin; as it is predicted in the Great Ruaha Basin. A country-wide projections indicate a rise in perennial drainage to a total of 136% in central Tanzania and 125% in northwest Tanzania by the end of this century. There are also suggestions that by mid-century, national basis stream flows will be between 80-100% of 1961-1990 flows and only 80-90% of the base period flows by 2100. Historical trends and projections on sea level rise indicate increases in sea-level rise. However, these results are blanketed with large uncertainty due to lack of gauged long-term sea-level rise data. Same trends have also been observed in wind speed and direction, as well as in ocean salinity and pH.

Vulnerability and resilience of ecosystems and livelihoods in the RUMAKI seascape

The concept of vulnerability and resilience address the degree to which at a given point in a time a society is adapted to the hazards of its environment. However, it should be noted that the relationship between vulnerability and resilience is not linear but rather dialectical such that lowering vulnerability may not necessarily increase resilience but it may also create other forms of vulnerability. In Tanzania, there have been efforts in analysing the vulnerabilities of sectors to the impacts of climate change; however, there has been a bias towards the agricultural sector and semi-arid lands. For the RUMAKI seascape, there is no a comprehensive analysis of climate observations, impacts and response options, but rather some few insights of the vulnerability and resilience of ecosystems to climate change impacts. Moreover, a number of studies have been carried out at a smaller scale across coastal regions.

Coastal areas are already affected by extreme events. Both ecosystems and livelihoods are exposed to the future impacts of climate change. Sea level rise and the associated shoreline change are uncertain, however, increased floods and environmental degradation will exacerbate erosion and sedimentation. Coastal ecosystems such as coral reefs, sea turtles, sea grasses are extremely vulnerable because they have already been significantly altered by human activities. The Rufiji Delta and floodplain is expected to suffer further losses of productivity and services that they provide. Manmade components such as the proposed Stigler's Gorge dam are also vulnerable to climate change due to the projected increase in precipitation, which might lead to changes in dam operations. Therefore, as the climate continues to change, repeated disruptions of lives, infrastructures and economic activities will pose challenges to the RUMAKI ecosystems and livelihoods. Further, it is anticipated that after the construction of the dam, the frequency of low flow discharges will be significantly reduced.

TABLE OF CONTENTS

LIST OF ACRONYMS i
EXECUTIVE SUMMARY ii
TABLE OF CONTENTS v
LIST OF FIGURES viii
LIST OF TABLES x
1. INTRODUCTION 1
1.1 Background Information 1
1.2 Objectives and Scope 2
1.3 Methodology 3
1.3.1 Review of literature and other relevant documents 4
1.3.2 Field visit to the study area 4
1.4 Output 5
2. ECOSYSTEMS, NATURAL RESOURCES AND NATURAL RESOURCE BASED LIVELIHOODS 6
2.1 Agricultural land, crops and livestock 6
2.1.1 Agriculture in Rufiji District 8
2.1.2 Agriculture in Kilwa District 10
2.1.3 Agriculture in Mafia District 11
2.2 Livestock 12
2.2.1 Rufiji District 12
2.2.2 Kilwa District 12
2.2.3 Mafia District 12
2.3 Fisheries and aquaculture 13
2.3.1 Artisanal fishery 13
2.3.2 Trends in Fishing Vessels 15
2.3.3 Delta and brakishwater fishery 17
2.3.4 Coral reef fishery 18
2.3.5 Octopus fishery in Mafia and Kilwa 19
2.3.6 Small pelagic fisheries in Mafia Channel & Kilwa 20
2.3.7 The semi-industrial shrimp trawl fishery 21
2.3.8 Prawn aquaculture in Mafia 25
2.3.9 Seawead culture 25
2.3.10 Large pelagic fish fishery 25
2.3.11 Crab fishery 26
2.4 Terrestrial Coastal Forests 26
2.5 Mangroves 27
2.6 Shallow Marine Habitats 29
2.6.1 Seagrasses 29
2.6.2 Coral reefs 30
2.7 High profile species 31
2.7.1 Marine turtles 31
2.7.2 Dolphins and Whale Sharks 32
2.7.3 Dugongs 32

2.7.4 Important bird areas 34
2.8 Fresh water Resources 34
2.8.1 Rainfall: seasonality and distribution 34
2.8.2 River flows 35
2.8.3 Lakes 37
2.8.4 Wetlands and floodplains 39
2.8.5 Groundwater 40
3. DEVELOPMENT TRENDS AND PRESSURES 41
3.1 Population growth and 30 year projection for the RUMAKI area 41
3.2 Land use and land cover changes in the Rufiji Delta 41
3.3 Increasing cutting for timber, poles and fuel wood 43
3.4 Agriculture 44
3.4.1 Investment Opportunities in Crop Production in Rufiji District 44
3.4.2 Irrigation potential and prospects in the Rufiji District 44
3.5 Infrastructures in the RUMAKI 45
3.6 Coastal tourism 46
3.7 Oil and Gas Extraction 48
3.8 Mining activities 49
4. CLIMATE TRENDS, PROJECTIONS, AND IMPACTS 50
4.1 Surface air temperature 50
4.1.1 Surface air temperature trends 50
4.1.2 Surface air Temperature Projections 51
4.1.3 Impacts of surface air temperature on selected coastal ecosystems 52
4.2 Sea surface temperature 53
4.2.1 Sea surface temperature trends 53
4.2.2 Sea Surface Temperature Projections 54
4.3 Rainfall trends and variability 55
4.3.1 Historical rainfall trends in RUMAKI 55
4.3.2 Rainfall projections 56
4.3.3 Trends in Extreme Weather Events 57
4.4 Trends in other water Resources 59
4.5 Historical River flow data 60
4.5.1 Projections in river flows/ Runoff 61
4.5.2 Relationship between rainfall and river flows 63
4.6 Impacts of projected rainfall trends on ecosystems on selected ecosystems 63
4.6.1 Impacts of projected rainfall trends on Mangroves 63
4.6.2 Impacts of rainfall trends on Prawns and other estuarine fish and fisheries 64
4.6.3 Impacts of rainfall trends on Patterns of Sediment deposition in the Rufiji delta 64
4.7 Sea level rise 64
4.7.1 Trends in sea level 64
4.7.2 Sea level rise projections 65
4.7.3 Impacts of sea level rise on selected coastal ecosystems and communities 66
4.8 Wind pattern and frequency 66
4.8.1 Trends in wind patterns and frequency 66
4.8.2 Projections in wind pattern and frequency 68

4.8.3 Impacts of changes in wind pattern and frequency....68
4.9 Salinity and Ocean acidification....68
5. VULNERABILITY AND RESILIENCE TO CLIMATE VARIABILITY AND CHANGE....70
5.1 Fisheries and aquaculture based livelihoods....70
5.2 Agriculture and livestock based livelihoods....71
5.3 Vulnerability and resilience of coral reefs and mangrove ecosystems....72
5.3.1 Coral reefs....72
5.3.2 Mangroves....73
5.4 Freshwater....73
6. POLICY AND STRATEGIES....75
6.1 National Adaptation Plan of Action (NAPA)....76
6.2 National Climate Change strategy (2012)....76
6.3 On-going climate change adaptation projects....77
7. CONCLUSIONS....79
8. BIBLIOGRAPHY....81

LIST OF FIGURES

Figure 1.1: WWF CEAI priority landscapes and seascapes in coastal East Africa 3
Figure 2.1: Map of Tanzania showing Rufiji Basin. 7
Figure 2.2: The Rufiji-Mafia-Kilwa Seascape on the central-southern coast of Tanzania 8
Figure 2.3: Map of approximate production areas for major fishery types 14
Figure 2.4: Estimates of total weight of fish caught in 000's tones by month (January-October 2007) for the three pilot Districts of Tanzania mainland. 15
Figure 2.5: Catch rates per boat per day for the three Districts. 15
Figure 2.6: Catch per gear from the three districts during the survey 16
Figure 2.7: Percentage mean catch rates (Kg/vessel) from the three districts 17
Figure 2.8: Estimated mean percent fish family contribution to the total production for the Rufiji District in 2007 18
Figure 2.9: Octopus Production in Kilwa and Mafia 20
Figure 2.10: Estimated mean percent fish family contribution to the total production for the Mafia District in 2007 22
Figure 2.11: Estimated mean percent fish family contribution to the total production for the Kilwa District in 2007 22
Figure 2.12: Standardized monthly CPUE of *Peneus indicus* made by commercial shallow water prawn trawler in three fishing zones along the coastal water of Tanzania. Zone I = Bagamoyo, zone II = Rufiji, Zone III = Kilwa/ jaja 23
Figure 2.13: Annual Fishing effort and catch trend of the commercial prawn trawler fishery 24
Figure 2.14: Catch rates (kghr-1) of penaeid prawns in the three fishing zones i.e., Zone I (Bagamoyo), Zone II (Rufiji) and Zone III (Kilwa) in Tanzania in 2009 and 2011. 24
Figure 2.15: Record based on local knowledge of sightings of dugongs during the period of 1950 – 2004 in the RUMAKI seascape [red blocks] as compared to other sites along the coast of Tanzania. Source: WWF (2004) 33
Figure 2.16: Average monthly discharge for the Little Ruaha River (1ka31), GR River (1ka59) and Kisigo (1ka42) 37
Figure 2.17: Map of Lower Rufiji with the Flood Plain adjacent lakes. 38
Figure 3.1: Historical population census and 30 year growth projections in RUMAKI area 42
Figure 4.1: Monthly climatology of minimum and maximum temperature (^{0}C) for Dar es Salaam 51
Figure 4.2: Long term variability in surface air temperature (^{0}C) 1951-2010 51
Figure 4.3: Downscaled maximum temperature anomalies (l temperature on average period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response. 52
Figure 4.4: Patterns in SST for local monitoring sites in Mafia. Source RUMAKI Temperature Monitoring data 54
Figure 4.5. SST time series from 1981 – 2010 for the coast of Tanzania (A) and 1871 to 1991 for Zanzibar (B). 54
Figure 4.6: Monthly and annual rainfall standard anomalies for the Dar es Salaam International Airport (DIA). 55
Figure 4.7: Change in monthly total rainfall for Dar Es Salaam station under SRES A2 (left) and SRES B1 (right) emission scenario. 58

Figure 4.8: Change in monthly mean dry spell duration for Dar Es Salaam station under SRES A2 (left) and SRES B1 (right) emission scenario.....58
Figure 4.9: Annual and dry season flows in the Great Ruaha River at the Msembe Ferry.....60
Figure 4.10: Daily discharge at Stiegler's Gorge in m3/s (1957–1984). 61
Figure 4.11: Flow duration curve plotted with normal scale (top) and logarithmic scale (below) indicating the historical and near future stream flows for sub-basin 1ka59. Red continuous line is historical stream flow for the period (1976-2005). 62
Figure 4.12: Observed monthly sea level - Zanzibar 65
Figure 4.13: The seasonal mean wind speeds recorded at 0900 hrs local time (GMT +3). The vertical axis presents the wind speed (m/s).....67
Figure 4.14: Loes smooth curves of the monthly mean wind speeds recorded at 1200 hrs local time. The dotted bold line represents the combined linear regression trend for all the stations. 68

LIST OF TABLES

Table 2.1: Agro-ecological zones in the Rufiji. 9
Table 2.2: District contribution on food production for the selected food crops and cash crops in Rufiji District 1999-2010. 10
Table 2.3: Area cultivated and production of various crops. 11
Table 2.4: Food Production on Mafia Island. 12
Table 2.5: Record of mangrove cover change in the RUMAKI seascape. 28
Table 2.6: Percentage changes in coral cover following 1997/98 bleaching event in selected coral reefs of RUMAKI seascape. 31
Table 2.7: Various threats to marine turtles as recorded from the main nesting sites in RUMAKI seascape. 32
Table 2.8: Sub-basins within the Rufiji River basin and their contributions to annual runoff. 36
Table 3.1: Population of coastal wards in the RUMAKI seascape. 42
Table 3.2: Land and mangrove cover changes in the Northern Rufiji Delta between 1989 and 2010 (brackets indicate loss). 43
Table 3.3: Investment in paddy production. 44
Table 3.4: Number of visitors within MIMP. 47
Table 3.5: Environmental and social issues related to oil and gas activities. 48
Table 4.1: Review of food shortages recorded in the Rufiji valley over the past 100 years. 59
Table 4.2: Summary descriptive trends in mangrove ecosystems of RUMAKI, according to field observations and local knowledge. 67
Table 5.1: Summary predictions on vulnerability of mangroves in RUMAKI to various pressures and recommended adaptive strategies/management responses. 74
Table 6.1: Climate change adaptation strategies for the marine and coastal environments. 77

1. INTRODUCTION

1.1 Background Information

WWF's Coastal East Africa Initiative (CEAI) is an umbrella programme that provides regional strategic support to the work of WWF country offices in Kenya, Tanzania and Mozambique. The CEAI was launched in 2010 and has a technical team based in Dar es Salaam. Priority areas of work include:

- Natural resources governance in nine priorities landscapes & seascapes (see Fig.1.1 below)
- Governance of Western Indian Ocean tuna fisheries
- Fisheries certification, especially shrimp fisheries in Mozambique
- Africa-China natural resources trade, especially timber
- Climate change adaptation

Within the CEAI, the climate change adaptation programme was initiated early in 2011 and aims to ensure that WWF's conservation programme in coastal Eastern Africa recognizes and addresses the impacts of global climate change on priority ecosystems, and on communities that depend on them. In particular, during the period 2012 – 2015 the CEAI is supporting five priority landscapes to undertake climate change vulnerability assessments and to develop and implement climate change adaptation strategies, where possible integrated into existing or new natural resources management strategies and plans.

The Rufiji-Mafia-Kilwa (RUMAKI) Seascape lies on the central-southern coast of Tanzania on the Indian Ocean coastal belt. The seascape experiences hot weather throughout the year with a bi-modal rainfall pattern typical of coastal areas: short rains in November-December and long rains in March-April. Average annual precipitation is 1000-1500 mm. The extensive Rufiji Delta, Mafia Island, Mafia Chanel and the Songo Songo Archipelago dominate the seascape. Marine habitats within the seascape harbour the equal highest levels of coral and fish biodiversity in the region, alongside southern Tanzania and NW Madagascar. Highly important prawn, finfish and invertebrate fisheries are sustained by the delta and extensive coral reef habitats. The area also has important turtle nesting sites and it is one of the few remaining dugong refuge areas in Tanzania. Apart from its biodiversity significance, the RUMAKI Seascape supports a human population of some 150,000 coastal residents and is one of the centres of coastal Swahili culture in mainland Tanzania. Rice farming in the Rufiji Delta, and elsewhere, mixed subsistence agriculture, together with coconuts, underpins livelihoods in the seascape. Alongside that, artisanal fishing is a key economic activity. Typically coastal households are 35-40% dependent on fishing for their livelihoods, but dependence can be as high as 80% of household income particularly in the smaller islands of

Bwejuu, Jibondo, Chole, Juani, Songo Songo, Pombwe and Jaja. Fishing, boat/vessel building and repair, fish transport, fish sale, fish processing and food vending are widespread.

The WWF RUMAKI Seascape Programme is a marine resource management and coastal livelihoods programme, launched in July 2005 by the WWF Tanzania Country Office (WWF TCO) and partners. The programme works in association with three district councils, communities in Rufiji, Mafia and Kilwa and the Ministry of Livestock & Fisheries Development. The overall aim of the programme is to improve the socio-economic well-being of coastal communities in the three districts by facilitating sustainable management of fisheries and other marine and coastal resources. There is a particular focus on developing effective fisheries co-management systems through building capacity of beach management units (BMUs) to manage collaborative fisheries management areas (CFMAs) as provided for under the National Fisheries Sector Policy and Fisheries Act, 2003.

The present review of information and data will inform and guide the planning for climate adaptation process for ecosystems, and dependent communities in the RUMAKI seascape. This synthesis of literature illustrates important information for climate vulnerability assessment of socio-ecological communities in the RUMAKI seascape.

1.2 Objectives and Scope

The overall objective of this work, was to prepare a review document summarising available information, data and references relevant to assessing climate vulnerability in the RUMAKI seascape and communicating the collected information to stakeholders during a climate adaptation planning process. To accomplish this objective, the terms of reference required undertaking of the following activities:

- Review of trends in status of ecosystems, natural resources and natural resource-based livelihoods
- Review of major development issues affecting the above
- Review of climate trends and projections for the RUMAKI seascape
- Review of vulnerability and resilience of ecosystems and livelihoods to climate change
- Review of extent to which climate change adaptation is addressed in relevant (natural resources) management policies and strategies

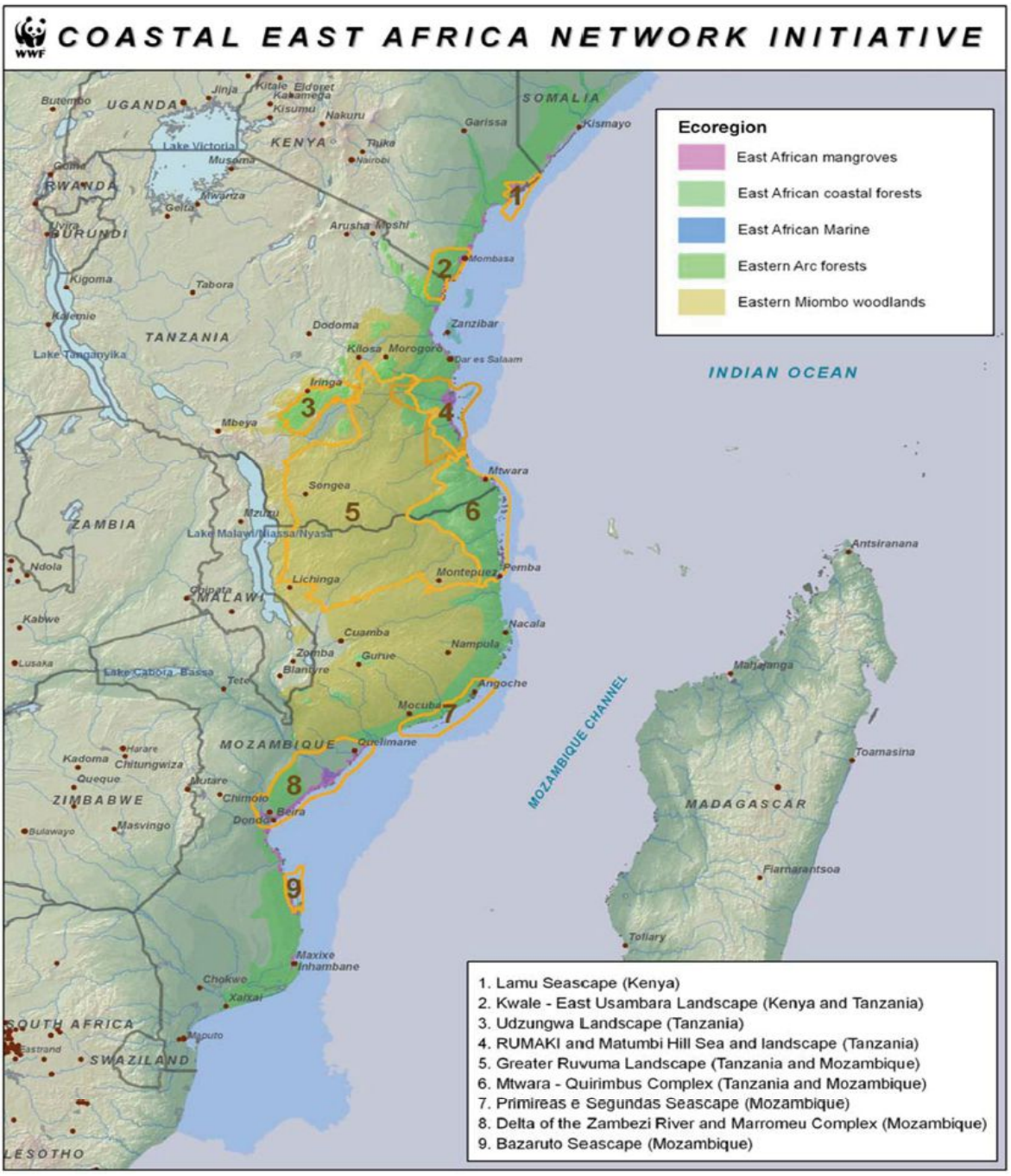


Figure 1.1: WWF CEAI priority landscapes and seascapes in coastal East Africa

1.3 Methodology

The assignment was largely desk-based, most materials were extracted from existing documents and data. However, some out-of-office activity to track down relevant source material at other institutions and offices was done. This assignment did not involve new data collection and/or analysis. Six major activities were defined consistent with the outline of the assignment as described in the ToR:

i) Review of literature and other relevant documents
    a. Online literature search
    b. Ground based literature search
ii) Synthesis of collected information for each objective/expected output
iii) Writing and production of first draft
    a. Sharing the draft report with relevant stakeholders for comments
    b. Incorporate stakeholders comments
iv) Submission of final report
v) Submission of power point presentations for each theme
vi) Participation and presentation of the review findings in stakeholders workshops

1.3.1 Review of literature and other relevant documents

A detailed and comprehensive literature review was undertaken to investigate: i) trends in status of ecosystems, natural resources and natural resource-based livelihoods ii) major development issues affecting ecosystems natural resources and livelihoods iii) climate trends and projections for the area iv) vulnerability and resilience of ecosystems and livelihoods to climate change v) extent to which climate change adaptation is addressed in relevant (natural resources) management policies and strategies. The collection of literatures was guided by section 4 and 5 of the supplied Terms of Reference (ToR).

1.3.2 Field visit to the study area

A rapid field visit was done in Rufiji and Kilwa districts to verification of information on, but not limited to:

- Population in the areas (per district, division, ward and village);
- Social services available (education, health, communication and transport etc.);
- Extension services available (agriculture, public health, community development, infrastructure and markets etc.);
- Division of labour based on age and gender;
- Ownership of major resources i.e. who owns what among members of the communities;
- Decision making powers among the communities i.e. who decides on what etc.;
- Social activities and timing e.g. traditional practices, where and when are they normally done etc.;
- Economic activities (major and minor ones) and production relations in the areas;
- Economic utilization of natural resources e.g. mining, hunting, farming etc.;
- Marketing of the economic products;
- Economic projects in the areas: how they operate and their effects;

The following institutions and officers were met to provide information relevant information as specified in the ToR:

- At district level: District Land Officers, Community Development Officers, Agricultural Officer, Natural Resources Officers (wildlife, forestry and environment officers), Cooperatives Officer, Health and Education Officers etc.;
- At community level: Ward/Village government leaders and/or committees, Women groups, youth groups, Cooperative or Economic groups/activities etc.;
- Management teams of the economic and environmental management projects;
- Mpingo conservation program
- Rufiji Basin Development Authority

1.4 Output

The output for this review covers information in the following areas, with respect to the RUMAKI seascape:

- ❖ Trends in status of ecosystems, natural resources and natural resource-based livelihoods
- ❖ Major development issues affecting the above
- ❖ Climate trends and projections for the area
- ❖ Vulnerability and resilience of ecosystems and livelihoods to climate change
- ❖ Extent to which climate change adaptation is addressed in relevant (natural resources) management policies and strategies

2. ECOSYSTEMS, NATURAL RESOURCES AND NATURAL RESOURCE BASED LIVELIHOODS

RUMAKI seascape is a unique complex of ecotypes/ecoregions. The Rufiji River and its vast floodplain and delta is the major feature that shape the complex interactions in the seascape, with its basin draining about 20% of the mainland Tanzania through three major tributaries, the Great Ruaha, the Kilombero and the Luwegu (Figure 2.1; Duvail and Hamerlynck, 2007). This contiguous landscape-seascape system is structured by the river floodplain surrounded by coastal bushlands, woodlands and forests, and deltaic and fringing mangrove forests descending towards the Mafia channel that host rich seagrass meadows and coral reefs particularly around Mafia Island and the Songo Songo archipelago (Figure 2.2). The delta, representing the main ecological feature of RUMAKI is in particular made by nine main channels and intersected with several smaller ones which are dynamic depending on the annual flooding patterns, hence the landscape changes continuously. These ecosystems are rich in terrestrial, coastal and marine wildlife and plant resources, which form an important part of livelihoods of the population in and around (Turpie, 2000). The following sub-sections present brief reviews of the literature on the status and trends of the important ecosystems and related livelihood dependence associated with RUMAKI seascape.

2.1 Agricultural land, crops and livestock

This section covers economic activities that support livelihoods in the RUMAKI area. These include agricultural activities such as farming, livestock keeping and fishing. It is important to note that most of the agricultural information presented in the next section covers most of the Rufiji district and the Rufiji delta in particular. This is not driven by the fact that most researches have been conducted in this district or the delta in particular, but due to its potentials in terms of agriculture and fishing activities. There is little information in farming and livestock keeping in Mafia and Kilwa. For this reason, agricultural activities in the three districts will be presented separately.

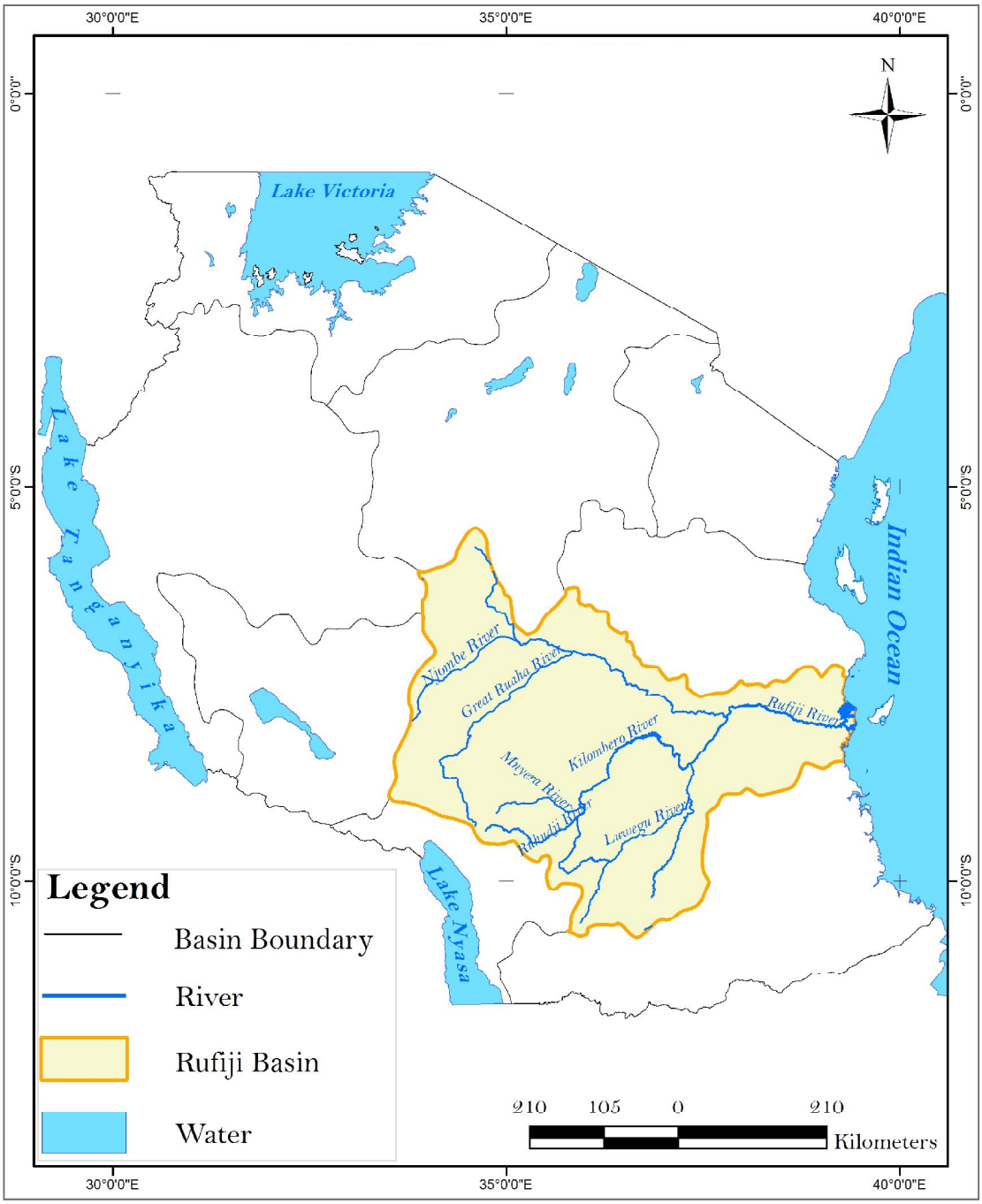


Figure 2.1: Map of Tanzania showing Rufiji Basin.



Figure 2.2: The Rufiji-Mafia-Kilwa Seascape on the central-southern coast of Tanzania

2.1.1 Agriculture in Rufiji District

The economy of Rufiji district is predominantly based on subsistence agriculture and fishing. The lower Rufiji (delta) has been considered to be an area of great agricultural potential (Cook, 1974; Ngana, 1980; Kajia, 2000; Turpie, 2000; Ochieng, 2002; Arthurton et al., 2008). It is estimated that 95% of the inhabitants are farmers and fishers. Agricultural cultivation in the district is dominated by the flood plain agriculture (Ndesanjo, 2009; Rufiji District Council, 2010). Another agricultural system, which is of less importance in the district, is the hill agriculture.

Most agricultural activities are practiced in the flood plain. There are three main sub-zones in the floodplain along the Rufiji River. The three zones also falls on the Rufiji agro ecological zones (Table 2.1). These include the western floodplain (situated south of the river), the central floodplain (situated north of the river) and the eastern floodplain (between Ndundu Bridge and the delta). The frequently flooded and easily accessible lands are generally north of the river (Hamerlynk *et al.*, 2010). The eastern floodplain, which is of interest to this study, is characterised by heavy clay soils. It is a prime area for rice growing and recession agriculture (*Mlao*) the floodplains in years of heavy or prolonged flooding. The southern part of the river is higher and complex, with sandy ridges. The traditional *Mlao* system is well adapted to the local conditions. Farmers understand well the interplay between short rain crops, long rain crops, floods and recession agriculture (Hamerlynk *et al.*, 2010). According to Hamerlynk *et al.* (2010), excessive floods causing extensive floods damage to long rains crops has proved a cyclic occurrence once in seven years.

Table 2.1: Agro-ecological zones in the Rufiji.

S/N	ZONE	SOIL TYPE	SUITABLE CROPS
1	Floodplain	Sandy loam, sandy clay loam and loam. Found at Mwaseni, Ngorongo, Mkongo, Utete, Ikwiriri, Mgomba, Umwe, Mtunda and Chumbi wards. Potential for irrigated agriculture	Maize, rice, pumpkins, leguminous species, cashew nut, cotton, sesame and Cotton.
2	Plateau (Hill/Highland) zone	Sandy and sandy clay loam. Found at Bungu, Kibiti, Mahege, Ruaruke and Mbwara wards	Cassava, maize, beans, sorghum, rice, vegetables and fruits, cashew nuts, sesame, coconut and cotton
3	Delta and Coastal Zone	Sandy, sand clay, sandy silt loam.	Rice, cashew nuts, and coconut

Source: Rufiji District Council, 2010

The agriculture system in the Rufiji Delta has been changing gradually over time. The primary influencing factors being the interplay between natural, ecological and anthropogenic factors (Cook, 1974). The natural factors include: rainfall, floods, and droughts. Ecological factors include invasive locusts; pests and weeds. Others include demographic changes, political decisions (e.g. villagization policy), and lifestyle. The changing nature of flood regime and the ecological characteristics of the delta have greatly controlled subsequent evolution of the *Mlao* cultivation on the delta islands. It is reported that in 1978 the river created a new inlet to the delta and brought more fresh water to some areas of the mangrove forest. Consequently the cultivation of rice in the mangroves increased, and resulted to movement of rice farms from South delta to North delta mangroves. Shifting cultivation is a common practice in the delta agriculture. The mangrove farm fields are usually abandoned after few years (3-5 years) because of colonization by weeds and then re-farmed. It should be noted that farms can be abandoned completely only when the farms are above the highest tide levels which makes it impossible for agricultural processes to be implemented. Since the regeneration of mangroves in those

areas does not take place spontaneously, this type of cultivation is therefore considered to be a threat to the conservation of biodiversity (Ochieng, 2002; Arthurton *et al.*, 2008).

Only 800 km^2 of the total arable land of 4,824.38 km^2 is cultivated. Major food crops are maize, paddy, cassava, sorghum, different types of fruits and vegetables. In 2010, cassava, paddy and maize occupied 16,845.5 ha, 16,213.4 ha; 15,526 ha respectively. Production has however, been dominated by cassava contributing to at least 75% of annual production over the last 10 years (Table 2.2). The main cash crops are cashew nut occupying 4150 ha and sesame 3088.5 ha (Rufiji District Council, 2010). Main cash crops are cashew nuts, cotton and sesame.

Table 2.2: District contribution on food production for the selected food crops and cash crops in Rufiji District 1999-2010.

YEAR	FOOD CROPS (Tons)			CASH CROPS (Tons)		
	Maize	Cassava	Paddy	Cashew nuts	Fruits	Simsim
1999	10,852.0	100,100.0	24,934.0	748.7	6345.0	491.0
2000	14,634.0	126,952.0	4,610.0	1,000.2	7800.0	218.0
2001	30,566.0	148,653.0	27,576.0	1,311.0	12,614.0	394.0
2002	4,461.0	146,635.0	5,883.0	2,487.8	15,612.0	546.7
2003	33,921.7	88,925.0	37,823.0	2,022.72	16,289.9	462.8
2004	20,353.0	177,991.0	26,476.0	2,261.8	33,240.4	305
2005	3514.0	176,368.0	18,542.0	3,170.0	55,069.0	387.0
2006	15,568.0	154,264.9	44,873.8	2500.0	57,380.0	3792.0
2007	2,431.0	141,687.0	8,407.9	2710.0	87,949.0	4352.0
2008	23,182.0	230,960.0	30,435.7	3950.0	168,128.0	579.9
2009	16,836.9	183,415.0	41,070.4	2882.7	156,425.0	470.4
2010	27,946.94	168,455.0	29,184.1	3330.0	142,954.0	1482.5

Source: Rufiji District Council, 2010

2.1.2 Agriculture in Kilwa District

Agriculture is the main economic activity in Kilwa district engaging 81% of the total labor force. Major cash crops grown are coconuts, cashew nuts and sesame. Main food crops grown include sorghum, cassava, maize, paddy, sweet potatoes and cowpeas (Table 2.3). Other crops grown include pulses, mangoes, citrus and vegetables. Intercropping is widespread and often results in complicated cropping patterns. Yields for most crops are generally low compared to the land potential and climate (Kilwa District Council, 2013). The area with potential for irrigation is estimated to be 4332 ha, however only 80 ha (1.8%) is currently irrigated. Matandu valley (3,552 ha) is one of the best agricultural areas in Kilwa. With an exception of Makangaga, no reasonable attempts have been made to exploit the agricultural potential of the valley (Kilwa District Council, 2013).

Table 2.3: Area cultivated (acres), production (kg) and average yield (kg/area) of various crops.

Crop	2003/2004			2004/2005			2005/2006		
	Area	Product	Yield	Area	Product	Yield	Area	Product	Yield
Sorghum	12,060	310,621	26	11,309	284,966	25	10,608	219,114	21
Cassava	12,046	240,794	20	13,397	66,534	5	3,839	166,350	43
Rice	1,122	45,699	41	1,225	49,118	40	883	49,115	56
Maize	3,245	317,492	98	2,728	251,000	92	2,335	108,950	46
Cashew	24,500	4,996,422	20	147,991	12,348,860	83	272,610	302,445	1.1
Sesame	3,003	260,160	87	4,082	209,698	51	4,124	315,684	77
Coconut	8,264	177,000	21	7,472	114,700	15	7,470	92,800	12
Cowpeas	711	17,600	25	445	13,200	30	618	26,160	42

Source: Kilwa District Council, 2013.

2.1.3 Agriculture in Mafia District

The main subsistence crops in Mafia Island are rice (both dry and wet paddy), cassava and sweet potatoes. Mafia has not been self-sufficient in food crops since at least German times, because much of the land is planted with cash crops mainly coconut. The district face recurrent food deficits and in some years there are severe food shortages (Caplan, 2002). The annual deficits range from one-third to three-quarters of requirements (Table 2.4). The level of rainfall primarily determines the size of the harvest, although insect pests such as edible grasshoppers (*nyavule*) may also be significant factors. Most food crop cultivation is done in the north of the island than the south, since there are large amounts of bush land cultivated on a shifting pattern, but even here most households cannot feed themselves and need to buy food. In years when the rains are insufficient or when insects or other animal pests such as wild pigs or monkeys consume part of the harvest, there will be greater dependence upon shop-bought food. Similarly food will need to be bought in households where there is insufficient labour to clear land, plant, weed, guard and harvest the crop. There is less labour available for cultivation, since many able-bodied men spend much of their time fishing (Caplan, 2002).

The main cash crop in Mafia is coconut and has been so since German times, when every man was required to plant at least one hundred trees (Caplan, 2002). In the 1960s, the major use for coconuts was for copra, and it was sold though government-backed cooperative societies. By the 1970s, the cooperatives were scarcely functioning and people had to ship their coconuts direct to Dar es Salaam. This continued into the 1980s when the economy began to be liberalized and cooking oil to be imported, leading to a decline in demand from city-dwellers for coconuts (Caplan, 2002). By 2002, the profits on the shipping of nuts to Kariakoo market in Dar es Salaam had shrunk and the production decreased significantly. The second cash crop is cashew nuts, which grow more profusely in the south than the north of the island. In 2002, the market for cashew nuts started to improve a little

better. The district council planned to spray the trees in Kilindoni with sulphur powder to prevent fungal disease and thus improve the productivity of the crop.

Table 2.4: Food Production on Mafia Island.

Year	Annual production (tons)	Deficit
1995-96	6542 (64.5%)	3,585 (35.4%)
1996-97	2763 (25%)	8208 (75%)
1997-98	4258 (38%)	7019 (62%)
1998-99	8113.3 (68%)	3849.3 (32%)
1999-2000	7180.5 (58%)	5138.5 (42%)
2000-2001	8397.75 (67%)	4106.25 (33%)
2001-2002	645.9 (67.5%)	4165.1 (32.5%)

Source: Caplan (2002).

2.2 Livestock

2.2.1 Rufiji District

Livestock keeping is currently a fast growing economic activity in Rufiji. All major types of livestock are kept in the district. According to the District Socio-economic Profile of 2010, the district had about 143,874 cattle (22%), 28,453 goats (5%), 13,765 sheep (2%) and 450,548 poultry (71%). The inflow of livestock from Ihefu Mbeya has contributed to the high concentration of livestock in some divisions. Livestock production is ranked as the third important way of sustaining the livelihood of the people in the flood plain. Production levels and the prices offered are important in stimulating production of livestock for sale, particularly chicken.

2.2.2 Kilwa District

Kilwa District inhabitants are traditionally non-livestock keepers, except for small stock of goats and poultry kept mainly for household consumption. In 1996, Kilwa District had 1,436 cattle, 4,879 goats and 5000 sheep. In the past two years pastoralist and agro-pastoralist have migrated to Kilwa from the southern highlands, northern and western circuits of the country, bringing with them large herds of cattle. In 2006 alone Kilwa district received 11,902 cattle, 313 goats and 143 sheep from Ihefu Mbeya region. This has brought the number of livestock kept in Kilwa today to be 12,336 cattle, 5,192 goats and 5,143 sheep. It predicted that 5,000 more cattle are on the way coming (Kilwa District Council, 2013).

2.2.3 Mafia District

Livestock keeping Mafia is not prominent. According to Caplan (2002) there were some 12,000 cattle and 600 goats on the island by 2002. There is no record of recent livestock

census that could be reached for any updated statistics. Five per cent of these were found in the Kanga village, which has more suitable land for both subsistence agriculture and livestock keeping. The majority of these animals are African zebu cattle. Only two owners have the larger, 'improved' breed of cattle and therefore the milk production is very low.

2.3 Fisheries and aquaculture

Fisheries in Rufiji Mafia and Kilwa districts can be grouped into two main categories: Artisnal fisheries and semi industrial fisheries. These fisheries have been managed with more or less similar strategies, of limiting the entries with licensing systems. Licences are, however, obtained from two different authorities: Those for vessels below 11m are sought from district councils, while the ones above 11m are applied for from the Fisheries Division, (Ministry of Livestock and Fisheries Development). Otherwise, the rest of management strategies are the same for both sizes of vessels.

2.3.1 Artisanal fishery

Artisanal fisheries in RUMAKI can be described to contain four important fishery types: Delta and brakish water fishery targetting prawns, clupeids and catchfish; Coral reef fishery, targetting demasal finfish; and Octopus fisheries. The status and trends in artisinal fishery are based on a detailed study on artisinal fish catch in the RUMAKI (MLFD, 2007). The results from this study indicated that there are about 32 fish families in the RUMAKI, however, there is variation in dominance of fish families among the studied areas but also variations in months.

The result of the total catch trends in the three districts for the months of January to October 2007 is shown in Figure 2.4 (MLFD, 2007)

The total estimates of fish caught in the three Districts Rufiji, Mafia and Kilwa were 928.2, 2,221.63 and 1,661.51 tonnes respectively for the months of January to November 2007. The highest catch was observed in Mafia (2,221.62 tones) and the lowest catch was observed in Rufiji (928.2 tones) (one way ANOVA, $F_{(2,30)} = 7.71$, $P < 0.002$, MLFD 2007). The highest mean annual total estimates of fish caught at Mafia compared to Kilwa and Rufiji could in part be contributed with higher catches of pelagic species. Ecological conditions in particular nutrients may have been the reason for the observed higher catches of pelagic species (sardinella, and scombridae (*Rastrelliger kanagurta*) in Mafia. The other reason could be the geographical position of Mafia and higher numbers of motorized boat, which makes accessibility to fishing throughout the year. During South East (SE) monsoon, the northern part of the Island is accessible to fishing while during North East (NE) monsoon the Southern part of the Island is accessible to fishing.

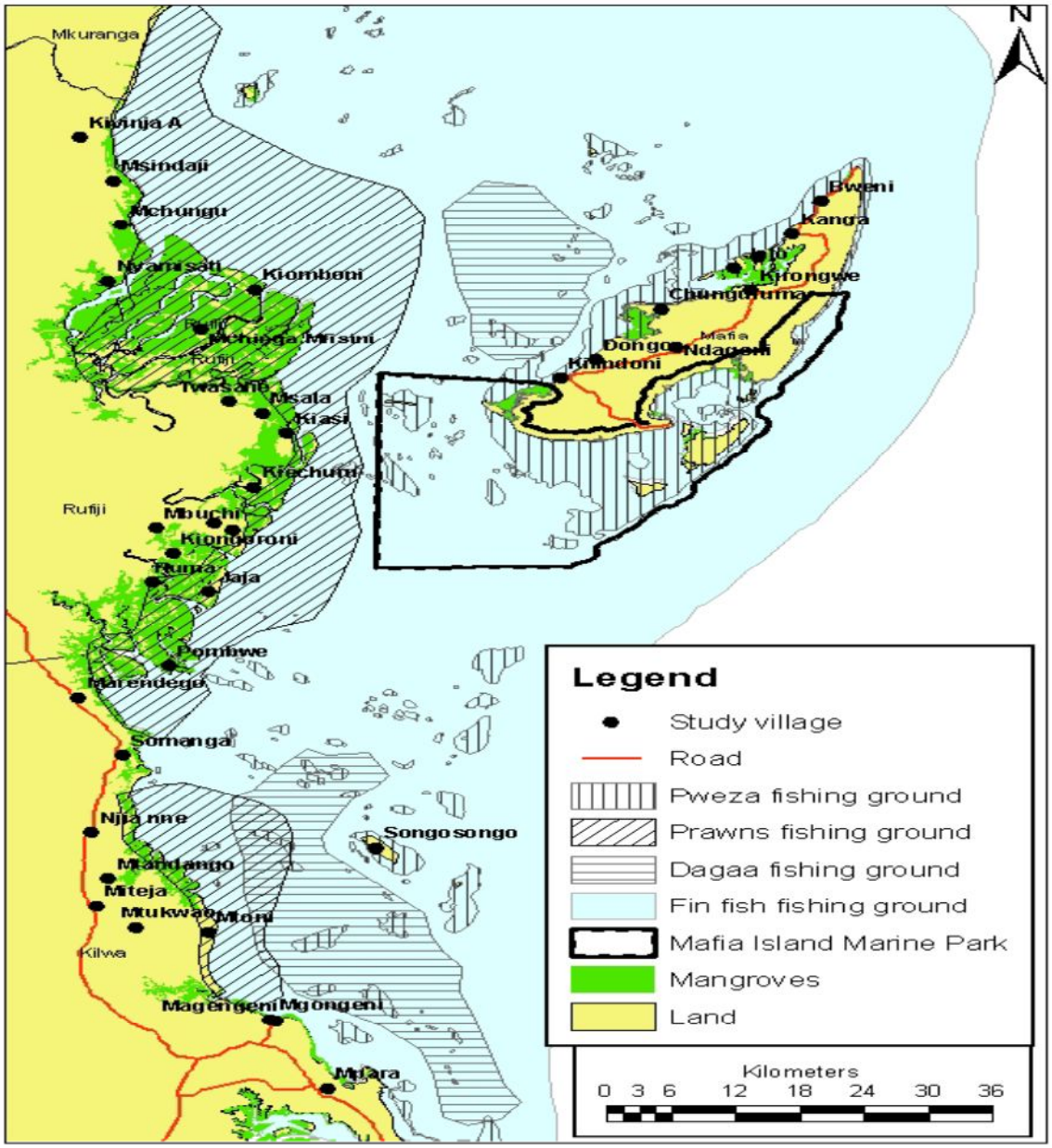


Figure 2.3: Map of approximate production areas for major fishery types.

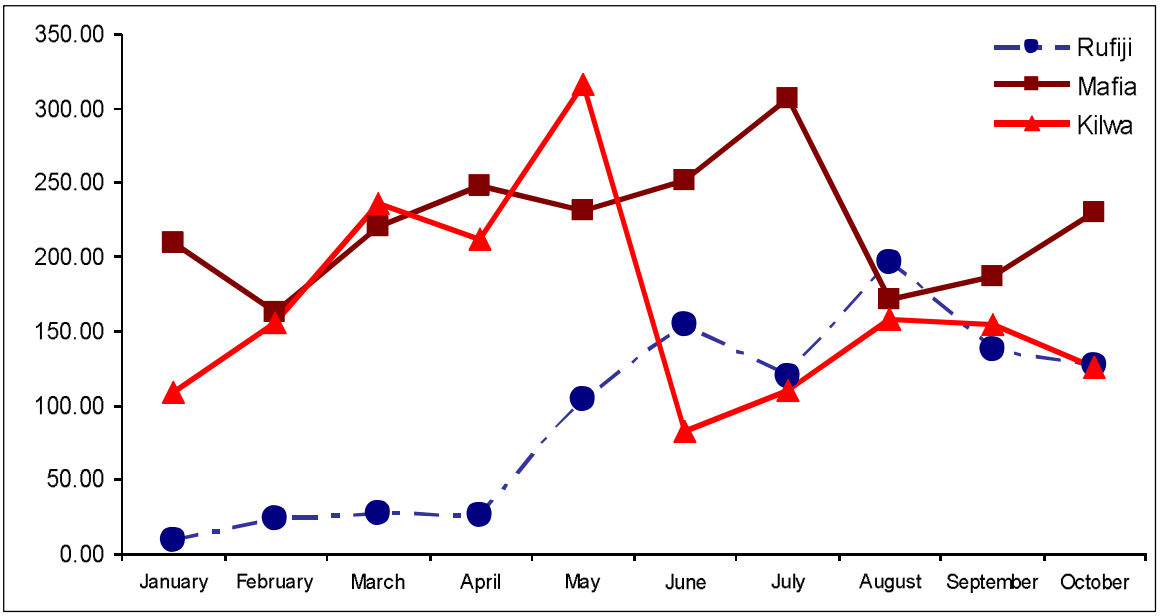


Figure 2.4: Estimates of total weight of fish caught in 000's tones by month (January-October 2007) for the three pilot Districts of Tanzania mainland.

2.3.2 Trends in Fishing Vessels

A review of literature on fisheries and information presented in section 2.2 shows there is an increased trend in fishing activities, which leads to increased number of fishing vessels. Figure 3.2 shows catch rates per boat per day (kg/boat/day) from the RUMAKI districts. There is a significant difference in the estimated catch rate among the surveyed districts (one way ANOVA, $F_{(2, 30)} = 13.71$, $p < 0.0001$). Kilwa District had statically highest catch rates (kg/boat/day) followed by Mafia while Rufiji had the lowest catch rates (SNK: $p < 0.001$).

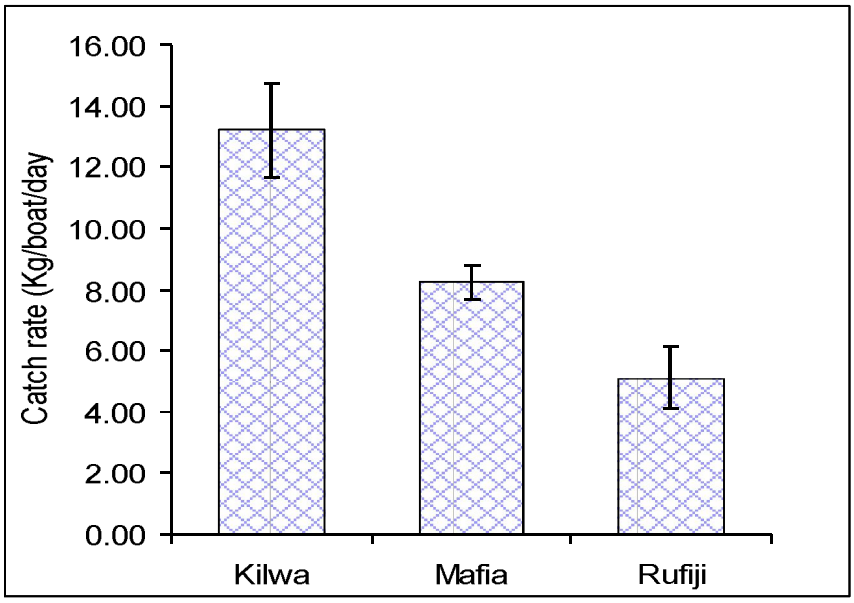


Figure 2.5: Catch rates per boat per day for the three Districts.

Figure 2.5 shows catch rate per gear (kg/gear) from the three districts. The result of catch rate per gear (kg/gear) showed there was a significant different in catch per gear among the three CAS surveyed Districts (one way ANOVA, $F_{(2, 30)} = 85.49$, $p < 0.0001$). However, Kilwa and Mafia Districts had statically equal catch rate (kg/gear) while Rufiji had the lowest catch rates (SNK: $p < 0.001$).

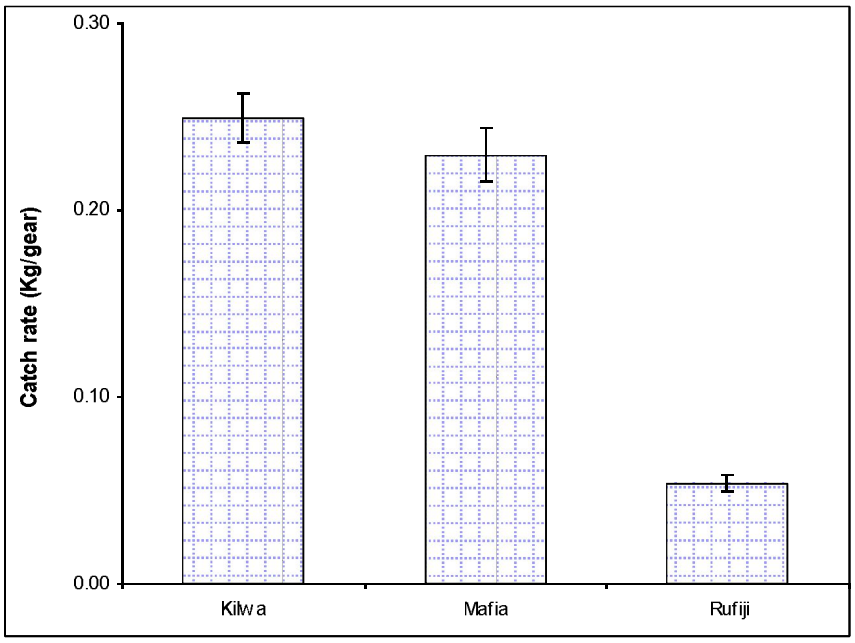


Figure 2.6: Catch per gear from the three districts during the survey.

The results on catch rate per vessel (kg/vessel) based on six different types of vessel among the three Districts showed that there was a significant different in catch rate values (Fig 2.6). Mafia had highest catch rate from boats while Rufiji had higher catch rate from dugout canoes and Kilwa recorded significant higher catch rate from dhows. Catch rates from Mashua, Ngalawa and Foot fishers were equal among the Districts (Figure 2.7). The fishery in Kilwa and Mafia Districts were dominated by dhows and bigger boats which enabled fishers to target offshore large fishes and this may have contributed to the observed high catch rates. On the other hand the fishery of Rufiji district composed of many small dugout canoes targeting near shore species. Fishers of Rufiji were engaged in shrimp fishing activities using dugout canoes in the delta channels, which contributed a greater percentage of their catch (71 Kg/vessel). The fisheries of prawns were directly dependent on the mangrove ecosystems, which are their nursery grounds. Foot fishers for shrimps in Rufiji delta are more traditional usually use small beach seines and *mtando*, which normally records low catch.

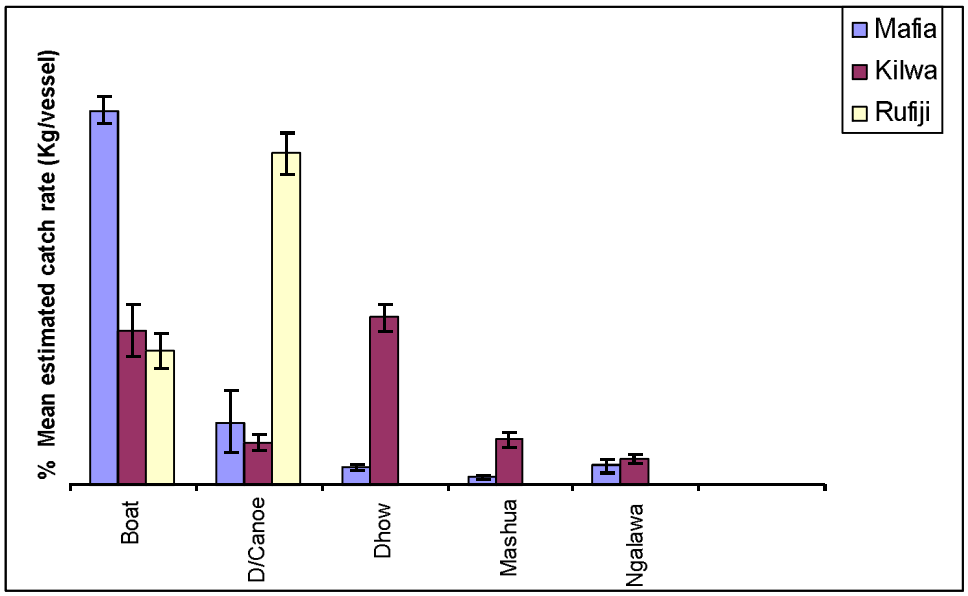


Figure 2.7: Percentage mean catch rates (Kg/vessel) from the three districts.

The boats are commonly used in Mafia due to the targeted fish; the large pelagics, which are obtained offshore and therefore, need to have motorized vessels. In Kilwa, the catch rates obtained from dhows were significantly higher than other fishing vessels in other districts. The fishers have the option of using engine or sail because most of the fishing grounds were outside the fringing reef or around the reefs. About 95% of the total marine catches is from this type of fishery using traditional vessels and gear (Jiddawi and Marcus 2002). In addition, the outrigger canoes mainly target for near shore species such as snappers, emperors, rabbit fish, and groupers whereas the dhows and bigger boats catch the offshore larger fish such as marlin, kingfish, sailfish, and tuna. In this survey, few of the boats were fitted with outboard or inboard engines. The vessels included *ngalawa* (outrigger dug-out boat), *mtumbwi* (dug-out canoe), *dau* and *mashua* (planked boats). Most of these vessels lack cooling and freezing facilities so fishing is limited by both time and distance. The gears include *dema* (basket fish-trap), *uzio* (stakes tidal fish-trap), *mshipi* (hand-line), *nyavu* or *jarife* (gillnet), and *juya* (seine net) (Bryceson 1985).

2.3.3 Delta and brakishwater fishery

This fishery is mostly done in Rufiji delta and immediate coastal brakishwater up to 10m depth, employing small canoes with mainly gillnets or long lines. According to artisanal fisheries monitoring done by BMUs in Rufiji, villages, the most important species supporting fisheries in Rufiji are Prawns and Clupeids; followed by Serranidae (Groupers) and Arridae (catfish). According to MLFD, 2007, Caches for groupers peaked in July and dropped in February; Ariidae peaked in September and dropped in January (Figure 2.8). The family Penaeidae peaked in April and October.

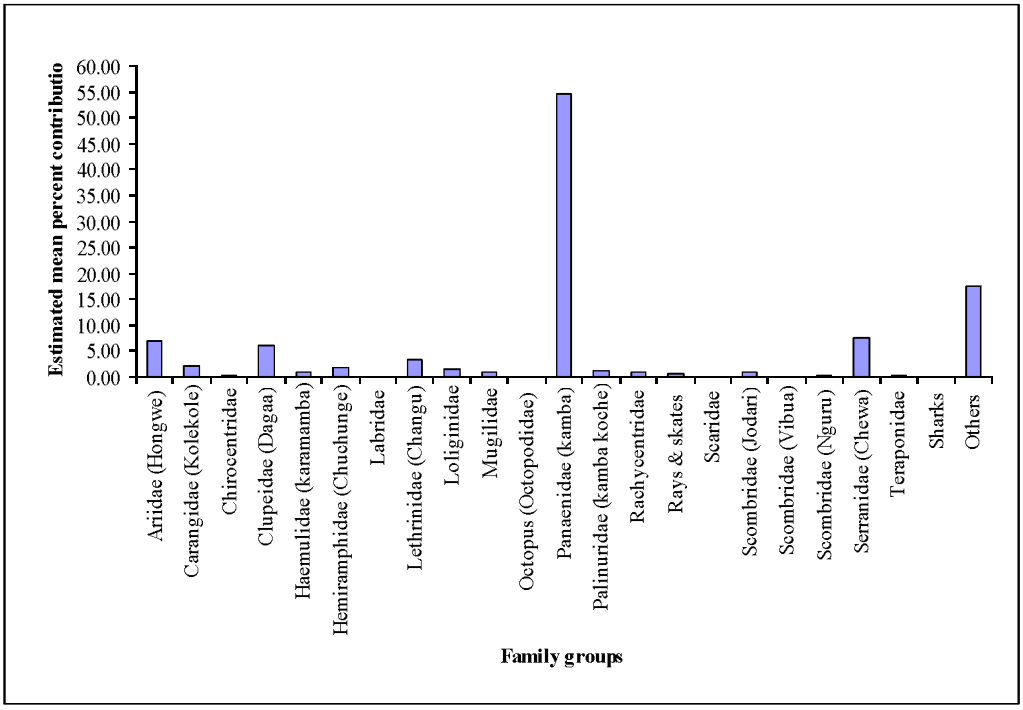


Figure 2.8: Estimated mean percent fish family contribution to the total production for the Rufiji District in 2007.

The observed variation in dominance is associated with the onset of long and short rainy season respectively. Spawning migration of prawn has been shown to be associated with short rains, which start in October. The peak in February coincides with the onset of the new recruits of the juveniles to the fishery (Nhwani *et al.*, 1993). These results are in agreement with findings from previous studies (Nhwani *et al.*, 1993; Bwathondi *et al.*, 2002), which also observed high prawn catches in the Rufiji area.

2.3.4 Coral reef fishery

Coral reef fishery is well developed in Rufiji Mafia and Kilwa districts. This fishery is done by various gears and vessels types. Gears used are such as beach seines, dema traps, uzio, hand lines and "mitando" nets. Important species for this fishery depend on particular gear, but in general context, emperors (lethrinidae), snappers (lutjanidae) Rabitfish (Siganidae) and Parotfish (Scaridae) are the leading families. Dominance of a particular species is generally dictated by the dominant gear, except where mitando nets are involved, then schooling fish like kolelole (carangidae), vibua (scombridae) and mbono (Sesionidae) can dominate.

2.3.5 Octopus fishery in Mafia and Kilwa

Studies on octopus fisheries shows that, three octopus species of commercial importance are found in Tanzania; Octopus vulgaris, O. macropus and O. cyaneaa. (Bianchi 1985). O. Cyanea is the most common species, attaining 99.5% of all individuals fished from the coastal villages in Mafia, Mtwara, Tanga and Zanzibar. Traditionally, harvesting of octopus was done by women in the intertidal areas, while fishing using stick (a gear which is locally known as Mtapo or utapo) for four to five days in each spring tide. In 1980s, in Kilwa district for example, octopus population was high and distributed all over Kilwa Kivinje and Masoko. In those days, octopus were only used for local consumption.

By 1990s, improved processing, marketing and the rising prices for octopus made octopus fishing lucrative business thus attracting men who started to venture into more effective techniques of fisihng subtidal areas by free diving. In 1995, Octopus became more valuable due to the introduction of EU market demand. This increase in the octopus demand in the EU market was accompanied by increase in fish processing plants and a number of fish processing plants got into the business, increasing further fishing pressure. By 2005, octopus had changed its regime from fishing 10 days per month of spring tides only in Mafia Island Marine Park to fishing 20 days per month and in some places through out the month. Consequently, octopus production went down as indicated by Kilwa data from Sea Product Ltd, Mafia production data from Tanpesca, and Catch per fisher from MIMP (Figure 2.9). Recent data from BMUs indicate slight recovery of catches.

Octopus are managed along with other fish, in terms of licensing. The number of octopus fishers have always been counted as a component of broader group of footfishers; despite the fact that a good number of these fishers use boats to access patch reefs; therefore, the actual number is not known. Access to fisheries is easier than other fisheries as one need only a stick and be able to identify the animal in the hole. This makes management of thte fisheries difficult. Management measures for octopus fishing has so far been limited to:

1. Regulation of minimum size, set at 500g; however this may only be applicable for octopus sold to fish processors, and not for local consumption, as it has been oberved that such small octopus are being sold in the local markets.
2. Regulating fishing days in a month, to 20 days; 10 from each fortnight, as calculated from the onset of spring tide (around 11th day and 27th day of lunar month). This measurer is practiced in Mafia Island Marine Park, however its enforcement is not strict.

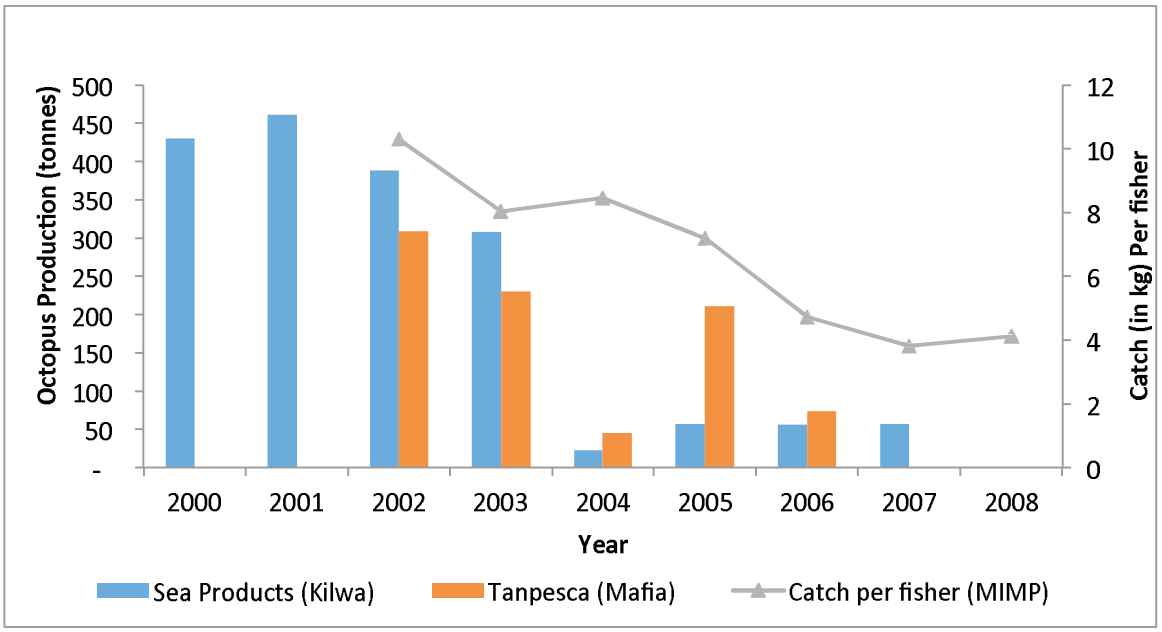


Figure 2.9: Octopus Production in Kilwa* and Mafia+. Sources: *MLDF & +MIMP Fisheries Catch Database.

In 2012 the Government of Tanzania prepared Octopus management Plan for Mainland Tanzania, with the main goal is to ensure biological, ecological and economic sustainable development of the octopus resource. Specific objectives include, among others:

- Improved data acquisition, analysis and information flow system on octopus resources
- Effective enforcement of management regime
- Rationalize octopus catch according to scientifically determined limits
- Enhance stakeholders' participation in the management of the octopus fishery
- Enhance research and dissemination of information on the octopus fishery to stakeholders
- Enhance livelihoods of coastal communities

The Plan was developed in consultative manner, and thus recognises all important stakeholders, namely: fishers, village agents (boat owners, etc); company agents. Octopus traders, Fish Processors, Government agencies, NGOs and Regional and International community. Implementation of this managemetn plan however, has not been tried out.

2.3.6 Small pelagic fisheries in Mafia Channel & Kilwa

Small pelagics in Tanzania composed of mackerels and Sardines. Mackerel is a common name applied to a number of different species of fish, mostly, from the family Scombridae. The commercial important species of small pelagic Mackerel in Tanzania are Rastrelliger

spp. and Sardinella spp; Anchovies. They are found in different habitats which include; bays, harbors, and deep lagoons in turbid plankton-rich waters, usually form large schools, making them proper target for ring nets.

According to catch assessment survey (MLFD, 2007), in Mafia and Kilwa the dominant families were Scombridae (vibua), Lethrinidae and Clupeidae (dagaa) with the exception of Sphyraenidae, which appeared in Mafia only (Figure 2.10 and Figure 2.11). In both sites, fish families showed different peaks within months. The observed differences in the families above could be due to habitat variations, because in Rufiji fishers concentrates in river channels while those in Mafia and Kilwa fishing is normally done in corals and open water habitats. The South East monsoons played a significant role with regard to Scombridae and Clupeidae catches in both Mafia and Kilwa. In Mafia these families were caught during the South East Monsoon in May and August respectively, while in Kilwa both Scombridae and Clupidae were caught in February and January respectively (North East monsoon).

The observed reduced catches in Scombridae and Lethrinidae , during the months of June to August in both Mafia and Kilwa could be explained by bad weather conditions (wind and currents) which led to reduced number of fishers (*pers comm).*

2.3.7 The semi-industrial shrimp trawl fishery

Prawns and shrimps constitute a large group of crustaceans with nearly 2,500 species known worldwide. Different studies in Tanzania shows that only eight penaeid prawn species comprise substantial annual landings of the shrimp catches in Tanzania. Species of Penaeidae family forming the most significant artisanal and commercial prawn fishery industry include *Fenneropenaeus indicus* (formally known as *Penaeus indicus*), *Penaeus monodon, P. semisulcatus, P. latisulcatus, P. japonicus, P. canaliculatus, Metapenaeus monoceros and M. Stebbingi* (Bwathondi *et al.*, 2002; Jiddawi and Ohman, 2002). These eight species are widely distributed, occurring in shallow (to 20 m) marine and brackish waters adjacent to the estuaries of the Wami, Ruvu, Rufiji and Matandu (Kilwa) rivers . Peneus indicus and P. Monoceros are the dominant prawn species in Rufiji and Kilwa fishing grounds. A desk study assessing the dynamic of prawn fishery and in particular *P. Indicus* (Kuguru et al., *in preparation*) using data collected from a total of 1070 trawls recorded over the 19-year (1988-2007) period between March and November. At commercial level prawn are graded at 7 to 8 classess based on weight either Tiger (T00-T7 = P. Monodon) of Banana/white (B1-B7), Study by Kuguru et al (in preparation) focused on the most dominant class found in all fizing zones and throughout the fishing period B2 which composed on P. indicus. The study found that most productive prawn fishing ground was Rufiji (= zone II, Figure 2.12). Other studies which found the same results are from Bwathondi *et al.* (2002) and Taikwa and Mgaya (2003).

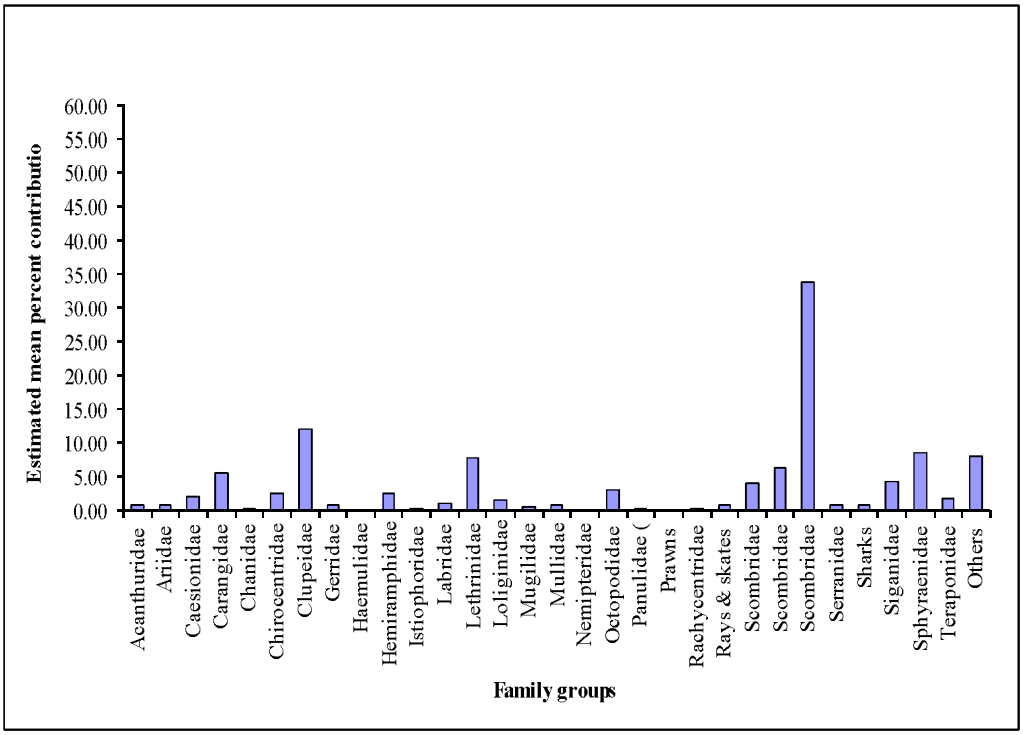


Figure 2.10: Estimated mean percent fish family contribution to the total production for the Mafia District in 2007.

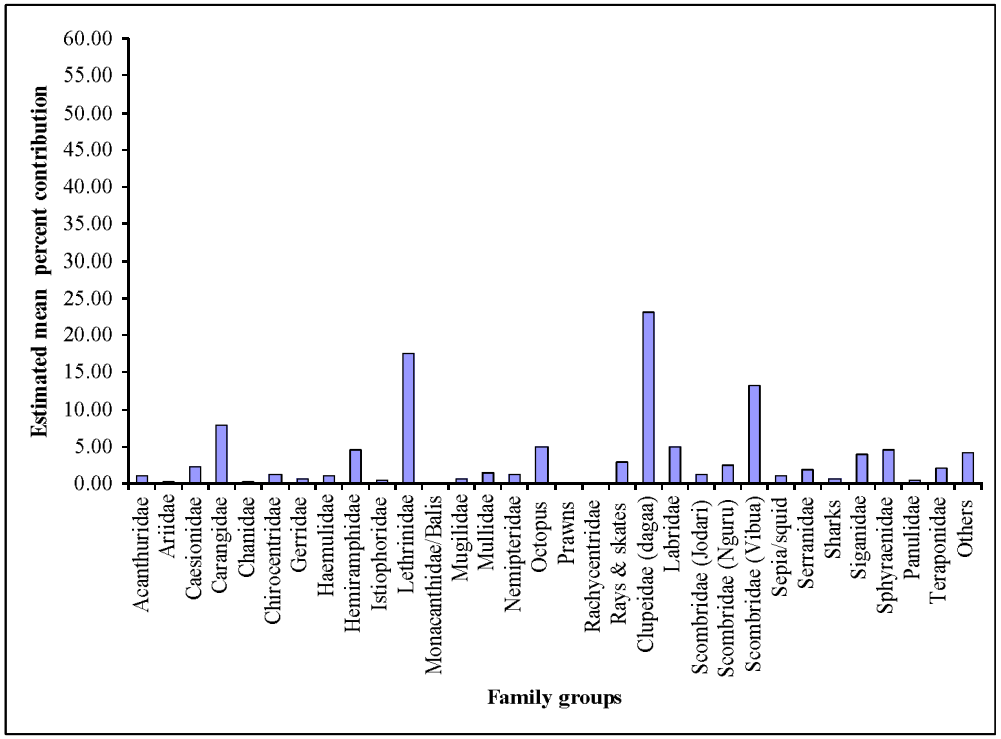


Figure 2.11: Estimated mean percent fish family contribution to the total production for the Kilwa District in 2007.

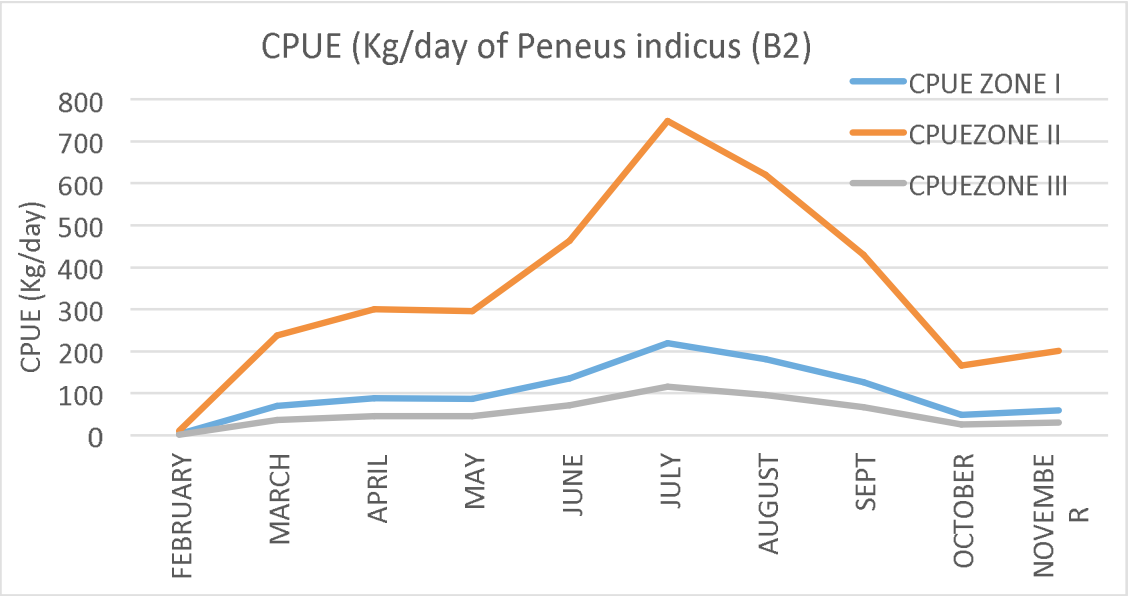


Figure 2.12: Standardized monthly CPUE of *Peneus indicus* made by commercial shallow water prawn trawler in three fishing zones along the coastal water of Tanzania. Zone I = Bagamoyo, zone II = Rufiji, Zone III = Kilwa/ jaja.

Prawn fishery has always been artisanal until the 1970s and in the late 1980's when industrial exploitation statrted to be operated by Tanzania Fishing company (TAFICO) in Tanzania. However, industrial exploitation has proved to be unsustainable due to among others a decline in prawn catches. Observation from catch data indicates a downward trend in the landings (Fig. 2.13). Trend in catches has raised concerns on the ineffectiveness of the management systems for sustaining the fishery. When the government of Tanzania realized that prawn stocks were getting smaller and smaller and almost collapsing, a moratorium (reduction of fishing effort) was imposed on industrial fishing of this fishery. This moratorium became effective as from 2007. Preliminary data collected after 2 years indicate that the moratorium provided a unique recovery of some stocks along gradient of management regimes. Forexample a significant recovery of prawn was observed in Bagamoyo (Fig 2.14) because BMUs were supported by the Tanzania Coastal Management programme (TCMP), some fishing grounds areas were closed from fishing (District Fisheries officer Bagamoyo, pers comm). On the contrally there was a slightly recovery of Prawn in Kisiju compared to Bagamoyo. At Kisiju there was no fund from NGO/government allocated for controlling campaign of programme for fishereis resources (Mwakosya *et al.*, 2010). In view of this situation, the government had no other option but to revisit existing management regime on prawn fishery beginning with development of this General Prawn Fishery Management Plan. The aim of this plan was to highlight issues and point out management strategies related to sustainable management of the prawn fishery. In principle, the plan maintains the moratorium measure imposed in 2007 and provide management framework for the artisanal sub-sector.

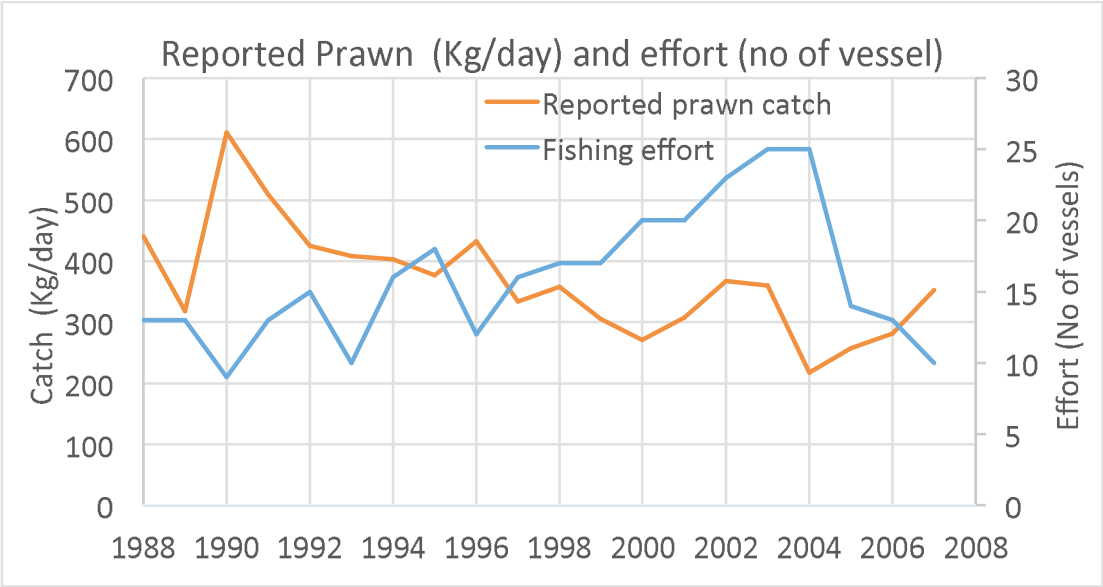


Figure 2.13: Annual Fishing effort and catch trend of the commercial prawn trawler fishery.

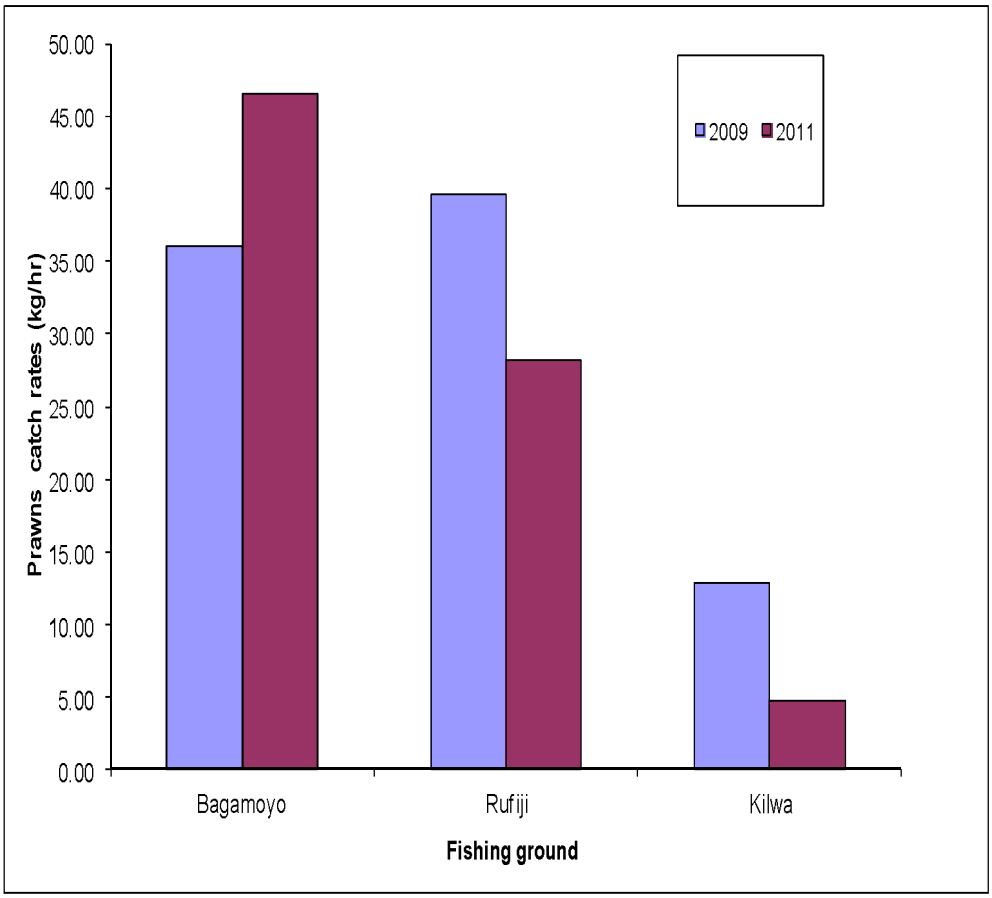


Figure 2.14: Catch rates (kghr-1) of penaeid prawns in the three fishing zones i.e., Zone I (Bagamoyo), Zone II (Rufiji) and Zone III (Kilwa) in Tanzania in 2009 and 2011.

2.3.8 Prawn aquaculture in Mafia

There have been attempts to set prawn farms in Tanzania for past 4 dacades . In 1997, there was a plan to set up a large shrimp farm in the Rufiji Delta, however it was contested by local people and environmental activists to an extent that considerable controversy around the proposal both nationally and internationally was generated and led to cancellation of the project by the investor (mafia-islandtanzania. gold.ac.uk/economy). Alphakrust Ltd., a subsidiary of Alpha Africa (based in Kenya) was established in Dar es Salaam in 2002 to develop an integrated shrimp farm in Mafia. This project has taken off with a vertical integration approach, starting with broodstock collection to hatchery production of postlarvae, shrimp ongrowing in earthen ponds, processing and finally export (www.zoomtanzania.com/Alphakrust-Aquaculture).

2.3.9 Seawead culture

Seaweed farming in Tanzania was initiated through research by the University of Dar es Salaam (UDSM) in the 1970s and early 1980's. This was followed by commercial cultivation, which was started by private entrepreneurs in 1989. By 1996 seaweed was being farmed all along the coast of Tanzania. Production in 2008 was 6000–7000 tonnes annually, with *Eucheum adenticulatum* and *Kappaphycus alvarezii* as the main cultivated species. Tanzanian seaweed is exported mainly to the USA, France, Denm ark, and Spain. Within RUMAKI project area, sea weed farming have been extensively paracticed in Jibondo, Chole, Songosongo and Bweejuu. In most cases women form majority of participants in this activity.

2.3.10 Large pelagic fish fishery

Artisanal fishers deal with almost all tuna and tuna-like species but the most common caught species are Spanish mackerel, commonly referred to as Wahoo (Nguru-maskati), Kawakawa (Sehewa), Tuna (Jodari) and Skipjack tuna (TAFIRI, 2013). The main fishing gears used in the tuna and tuna like fishery are drifting gillnets, troll lines and purse seine nets commonly known as 'Hiari', 'Mishipi ya kurambaza' and ring nets respectively. Fishing of tuna and tuna-like species is carried out between 5 and 20 kilometres away from the shoreline. Total catch of tuna and tuna-like species from 2010-2011 (Annual Fisheries statistics reports) indicated that Tuna, King Fish and Indian Mackerel landing data from all coastal districts had almost the same quantity of fish caught between the two years but with different trends among the districts (TAFIRI, 2013). Data on fish landings from three dominant tuna and tuna like species from the year (2007 to 2010) indicate a fluctuating trend for tuna, but constant trends for King Fish and Indian Mackerel respectively. For instance, in 2007 total landings for tuna was about 4000 tonnes, this decreased to less than

1000 tonnes in 2008 and increased again to over 7000 tonnes in 2009 before falling again to about 2000 tonnes in 2010. Similar trend was also evident from Mafia district from 2009 to 2012. The catch trends for Indian Mackerel and King Fish were between 4000 to 4500 and 1000 to 2000 tonnes respectively over the same period . Another study conducted by TAFIRI (2012) revealed that coastal tuna were at high risk of depletion. The study suggested that Coastal tuna need immediate management interventions as its vulnerability score was approaching high risk level. In other words any small change in increased susceptibility to fishing (fishing effort, anthropogenic activities, or productivity (abiotic and biotic factors) due natural catastrophes such as climate change may put the coastal tuna fishery into a high risk of depletion.

2.3.11 Crab fishery

The mud crabs (*Scylla* spp) represent a valuable component of small scale coastal fisheries in tropical and subtropical countries. There are about four species of the genus *Sylla* that occur in the Indo-Pacific region, but the most common and widely distributed species is *Scylla serrata*. The current mud crab stocks in RUMAKI was based on estimates from the number of holes in the field.It was estimated that there is a 28% chance of finding a mud crab in holes. Based on this estimate and total mangroves area per particular village surveyed and number of holes per square meters it was found that, the number of crabs where 2458,1904,1410 and 610 crabs in Ngusimba, Mwasende, Msala and Mbwera repectively.

On average there were 5 crabs per 200 m^2 at Msala; 1, 5 and 3 crabs/200 m^2 at Mbwera, Mwasende and Ngusimba respectively. This finding is based on a total area of the mangroves that are within a radius of 4km measured from the centre of a fishermen's village. It was also found that more than 70% of the total catch in all locations were juvenile crabs with carapace length (CL) of less than 12 cm indicating a possible recruitment overfishing. Therefore RUMAKI was categorised as a potential nursery ground of the mud crabs.

2.4 Terrestrial Coastal Forests

The terrestrial coastal forests of Tanzania are part of the regional biodiversity hotspot that stretches along the coast including the islands of Pemba, Zanzibar and Mafia. Most of these coastal forests are state forest reserves (Burgess *et al.,* 2000; Malimbwi, 2001; MNRT, 2001). They are unique and fragile ecosystems that provide various useful products such as firewood, charcoal, poles, timber, fruits, honey and traditional medicine (Karengi, 2012). In terms of coverage, Burgess *et al.* (2000) had estimated that there were about 70,000 ha coastal forests in Tanzania, but Burgess *et al.* (2003) revised it to 69,200 ha. A most recent estimate covering the entire Zanzibar-Inhambane bio-geographical region indicated that in year 2000 there were some 456,500 ha of coastal forest habitat in Tanzania with a loss of

about 37,200 ha in the span of 10 years between 1990 and 2000, representing an annual rate of loss of 0.8% (Tabor *et al.*, 2010). Woodland areas in the RUMAKI area and surrounding areas have relatively high productivity with recorded standing volume of about 70m^3 ha^{-1}, and a mean annual increment (MAI) or sustainable yield of 2m^3 ha^{-1}.

Of the coastal forests in Tanzania, RUMAKI area hosts the most important two centres of endemism in the south of the Rufiji River: Lindi and Matumbi-Kichi centres (Burgess, 2000). These forests are characteristic for their high biological richness among plants, birds, mammals and reptiles (Ornis Consult, 2000) with a reported plant species richness of more than 4,500 plant species, of which over 1000 are endemic (Clarke *et al.*, 2000). Burgess (2000) reported that these coastal forests supports a large number of forest obligate species that have narrow geographic ranges, often endemic to a single forest site. In Mafia Island, a recent survey by Swai *et al.* (2011) indicated that the island is rich in flora and fauna biodiversity, where they identified 75 plant species and 92 animal species with diversity indices above 3 of the Shannon Wiener diversity index scale.

According to Ornis Consult (2002), the terrestrial coastal vegetation on the high ground in Kilwa for example, shows a typical transition from coastal Brachystegia forest through mixed scrub forest towards the sea margin. On the seaside of the plateaux, smaller pockets of coastal forest occurs, such as the Kitope Hill in the extreme north-east corner of the district where small forest patches still occur. However, most of the forest is cleared, burnt and converted with only small patches of forest remaining in the deep valleys along streams. Another important site of coastal forests in the RUMAKI area is Matumbi Hills situated in the northern part of Kilwa. The coastal forest of Mitumbi Hill is almost continuous with Kichi Hill just south of Rufiji River. Subsistence cultivation is characteristic on most of the hills, which comprises a series of forested ridges and steep sided, narrow valleys.

2.5 Mangroves

Rufiji Delta hosts the largest single mangrove forest in Tanzania and the East Africa region, occupying about 53,250 ha (nearly 50% of the country's total; Semesi, 1992). The extent of mangrove cover in the delta has however been changing over time (Table 2.5). For example, Sørensen (1998) reported that the total mangrove area in the Rufiji Delta in 1947 was only 40,000 ha largely attributing the increase to the record floods of 1960s, which diverted the main distributary of Rufiji River from a south-easterly direction to a north-easterly direction. Wagner and Sallema-Mtui (2010) later reported that the diversion created favourable substrate for rapid mangrove expansion. However, a decline in mangrove area from 49,799 ha in 1990 to 49,032 ha in 2000 was recorded and attributed to among other factors, annual floods of the Rufiji River that lower the degree of salinity in the channels resulting in changes in mangrove area at the upper end of the river mouths and near the landward edge of the mangroves (Wang *et al.*, 2003).

Table 2.5: Record of mangrove cover change in the RUMAKI seascape.

Year	Rufiji	Mafia	Kilwa	Source
1950	40000			Sørensen 1998
1980	40470	405	13995	Semesi 1992
1990	53255	3473	22439	Semesi 1992
2000	48030		21755	Wang et al 2003
2010	45471			Nindi et al 2014

Several tidal channels and creeks dissect the mangrove swamps through which tidal controlled water flows between mangrove swamps and the Indian Ocean. The tidal range in the delta at spring tides is about 4m, and its influence extends about 40km upstream which allows further expansion of the mangrove limits landward. There are eight species occurring in the Rufiji Delta, which often occur in pure stands, or in mosaics of several species. *Rizophora mucronata* is the most dominant. Other mangrove species in the Rufji are *Avicennia marina*, *Sonneratia alba*, *Ceripos tagal*, *Heritiera littoralis*, *Bruguiera gymnorrhiza, Xylocarpus granatum* and *Lumnitzera racemosa*.

Another important mangrove area in the RUMAKI seascape is that of Kilwa, south of the delta covering 22,439 ha, where mangroves form more or less continuous belt joining those of the Rufiji Delta and facing extensive shallow water with several islands, surrounded by corals, seagrass beds, and seaweeds. Extensive mangrove areas fringes Somanga, Miteja, Kilwa Kivinje, where as in Kilwa Kisiwani, Songo Mnara, Rushingi, they form estuarine stands.

On Mafia Island, mangrove cover a total are of 3,934 ha, and the largest and most dense stands of mangroves are found on the western and southern parts of the island, at Ras Mkumbi, on the northern tip of the island, Kanga–Kirongwe, Ras Mbisi-Ngesa, and between Kilindoni and north of Kisiwani. There are also considerable portions of mangrove stands on the northern shore of Chole Bay and the islands of Jina, Juani and Chole (Semesi, 1991). Species composition of mangroves, include all species that occur in Rufiji delta, with additional of two other species: *Xylocarpus mollucensis* and *Pemphis acidula*, which seems to be characteristic in isolated habitats in the islands.

Studies on the structural characterization of the mangroves in the RUMAKI seascape indicate that, despite the observed and looming degradation through heavy harvesting pressure, most mangrove stands are still viable and in good health with minimal net loss of taxa and/or reduction of abundance (Whitney *et al.*, 2003). For example, Wagner and Sallema-Mtui (2010) reported mean stand densities of 1100 stems ha^{-1} in the northern delta and 2400 stems ha^{-1} in the southern delta with corresponding basal areas of 18 m^2 ha^{-1} and 7 m^2 ha^{-1}. This indicated that small densely populated individuals characterize standing stock in the southern block. Regeneration niche also indicated potential of natural recovery from

both human and natural disturbance to be generally well, although Erftemeijer and Hamerlynck (2005) specifically reported that excessive flooding due to the 1997/98 *El-Nino* event had a significant negative impact on the regeneration of the mangrove *H. littoralis* in the delta following massive dieback of mature trees. In addition, local communities took advantage of the dieback to turn the areas into rice farms, further halting natural recovery.

Mangroves in the RUMAKI seascape are a significant source of local materials for construction (e.g. house building, boat and furniture making (Semesi, 1992). Mangrove poles are a common product shipped to as far as Zanzibar where they are supplied into local markets for house construction (Mangora, pers observation). In addition, mangroves in the area are harvested for wood fuel (charcoal and firewood). Leaves, fruits, backs and roots of some mangroves species are used as herbal medicines to treat different ailments. For example, local communities report that *R. mucronata* leaves are used to treat hernias while fruits of *X. granatum* are used to treat stomach discomfort and *A. marina* leaves are used as fodder for goats (Semesi, 1992). Bee-keeping that produce valuable honey is also a common activity in the mangroves of Rufiji and Kilwa (Karengi, 2012). The Rufiji Delta mangroves are a prominent habitat as far as prawn fishery is concerned (Masalu, 2003).

Threats to mangrove forests in the RUMAKI seascape are mainly associated with use including uncontrolled harvesting for both domestic and commercial use and illicit conversion to rice farms (Kajia, 2000; Nindi *et al.*, 2014). Extensive stretches of the delta mangroves have been cleared and converted to rice farms (Kajia, 2000; FAO, 2005; Nindi *et al.*, 2014). The natural phenomena of climate change such as sea level rise, flooding and increased sedimentation are also implicated in transforming and compounding mangrove degradation in RUMAKI seascape, especially in the delta (Erftemeijer and Hamerlynck, 2005; Punwong *et al.*, 2012).

2.6 Shallow Marine Habitats

2.6.1 Seagrasses

Comprehensive seagrass distribution maps and/or area estimates have not yet been done for Tanzania mainly because of complications in eliminating water column errors inherent in common satellite sensors (Muhando and Rumisha, 2008). Nonetheless, the Tanzania mainland coast (and offshore islands), which is characterized by a shallow and relatively narrow coastal shelf of less than 100 m deep and 10 km wide (Frazier, 1975; Richmond, 1997), appears to have extensive seagrass pastures which occur from the high intertidal to shallow sub-tidal areas off the coasts including those of Rufiji, Kilwa and west of Mafia Island (Richmond, 1997; Muhando, 1999; UNEP, 2001; Ochieng and Erftemeijer, 2002; Wells *et al.*, 2004). Seagrass beds are known to be breeding, nursery, and feeding areas for many invertebrate and vertebrate species including commercially important species of finfish and

shellfish; and shelter and refuge for resident and transient adult animals such as Dugong, and green and hawksbill turtles (Muhando and Rumisha, 2008). Twelve species of seagrasses have been identified in Tanzania including the genera preferred by dugongs such as Halophila, Halodule, Cymodocea and Syringodium (Ochieng and Erftemeijer, 2002; Whitney *et al.*, 2003). The extensive seaagrass beds off the southern Rufiji Delta (Kichinja Mbuzi and Toshi) including Mohoro Bay (Fungu ya Kasa) are reported by local residents to be important feeding grounds for green turtles (Muir, 2005) and dugongs (Muir *et al.*, 2003).

Nonetheless, seagrass beds in the RUMAKI seascape are not excluded from the human induced threats to their survival and sustenance. Major threats to seagrass beds come from excessive sedimentation of coastal waters resulting from the different upland human activities; from increased turbidity, which tends to cut down the light penetration; and from inshore prawn trawling and seine nets, which destroy seagrass beds (Muhando and Rumisha, 2008).

2.6.2 Coral reefs

Coral reefs occur almost along the entire coastline of Tanzania covering about 3580 km^2 (Spalding *et al.*, 2001). In the RUMAKI seascape, extensive, abundant and luxurious fringing and patchy reef areas are found around Mafia Island and Songo Songo Archipelago from which they extend to meet the mainland south of Kilwa Masoko (Wells *et al.*, 2004; Muhando, 2006). The coastal waters facing Rufiji Delta and adjacent areas have limited coral reefs and where they occur are highly stressed because of freshwater dilution and sediment inputs. Most reefs of socio-economical and ecological importance around Mafia Island are within Mafia Island Marine Park (MIMP), which is considered the most productive reef community in Tanzania (Muhando, 2006). The coral reef ecosystems play important ecological roles as a habitat, nursery, feeding and spawning ground for many commercial and non-commercial fish species. Coral reefs and adjacent areas support important artisanal fisheries and thus they constitute the basis of food security and incomes for many coastal people in the country. The high biological diversity and the beauty of coral reefs also support coastal tourism (Muthiga *et al.*, 2008). Snorkelling and diving are a profound tourism attraction around Mafia Island and the Songo Songo Archipelago. Unfortunately, destructive practices (e.g., beach seining, use of small mesh seine nets, etc.), overexploitation of some fished stocks (e.g., octopus) and coral mining remain to be the major threats and have not been adequately controlled and/or addressed. Compounding to these human threats, coral reefs not only in the RUMAKI seascape but all along the country's coastline faces various natural disasters such as floods and associated terregenous sedimentation (Muhando, 2003), coral predators (crown-of-thorns-starfish, reef bioeroders and biological competition (Muhando *et al.*, 2002). One significant climate change related natural effect on coral reefs around Mafia and other areas in Tanzania was the 1998 coral-bleaching event, which caused widespread coral mortality (Mohammed *et al.*, 2002).

Following the 1998 massive bleaching event of coral reefs, MIMP and the Institute of Marine Sciences (IMS) started a monitoring programme in 1999 to track the condition of benthic coral reef habitats within the park boundaries. Change detection is done through monitoring of indicator parameters of reef benthos, reef fishes and non-coral macro-invertebrates. This monitoring has so far indicated that coral reefs within MIMP were amongst the severely degraded reefs (Muhando, 1999; Mohammed *et al.*, 2000, 2002; Obura *et al.*, 2002). However, Muhando (2006) and Obura (2008) revealed a general recovery albeit with slow growth rate of about 2% year^{-1} (Table 2.6) This slow recovery rate constitutes a management challenge to MIMP which calls for enhanced options like coral transplantation (Muhando, 2003).

Table 2.6: Percentage changes in coral cover following 1997/98 bleaching event in selected coral reefs of RUMAKI seascape.

Site	1997/98	1999	2001/02	2007	2009
Mafia Island	73.3	19.4	24.0	30.0	33.0
Songo Songo Archipelago	35.0	37.5		38.0	40.0
Country overall	52.0	27.1	26.1		

Source: Obura *et al.* (2002), Obura (2008).

2.7 High profile species

2.7.1 Marine turtles

All of the five species of marine turtles that occur in Tanzania's waters: green, hawksbill, loggerhead, olive ridley and leatherback are categorised by IUCN as endangered or critically endangered and are also listed on Appendix I of CITES (Muir, 2005). Although there are reports indicating that marine turtle population in Tanzania are declining as a result of a number of drivers such as habitat destruction and alteration, overexploitation for meat and eggs, and incidental capture in gillnets and trawlers (Table 2.7), their conservation status remains largely unknown. Lack of adequate protection and enforcement, limited awareness and land-based development and pollution are also compounding threats to marine turtle population in Tanzania.

In the RUMAKI area, the most concentrated numbers of recorded marine turtle nests are reported to be on the offshore islands of Mafia and Songo Songo Archipelago (Wells *et al.*, 2004; Muir, 2005). About 231 nests were recorded in Mafia of which the majority belonged to the green turtle (*Chelonia mydas)* and only 9 nests belonged to Hawkbills (*Eretmochelys imbricata)*. Other turtle species like the Loggerheads (*Caretta carreta*), Olive Ridley (*Lepidochelys olivacea*) and Leatherback (*Dermachelys cariaca*) have been sighted but do not nest in the area (Wells *et al.*, 2004). The relevance of conservation concerns on marine turtle is attached to their increasing recognition for their passive use values including

intrinsic, ethical, existence and bequest values rather than direct and consumptive use values. Troeng and Drews (2004) revealed that non-consumptive use, such as turtle tourism, generates proportionally more revenue and provides more economic and social benefits than consumptive use.

2.7.2 Dolphins and Whale Sharks

The occurrence and abundance of marine mammal species in Tanzanian waters is still poorly described. Few studies that have been conducted report on sightings, strandings and museum specimen. Dolphins are commonly reported in the waters surrounding Zanzibar Island, especially Menai Bay where there is a significant population of about 150 resident bottlenose and 75 humpback dolphins (Muhando and Rumisha, 2008). In the RUMAKI seascape, dolphins have occasionally been reported as aggregating in groups of 5-20 off the west coast of Mafia Island and rarely in the Rufiji Delta and Kilwa (Muhando and Rumisha, 2008). Humpback whales (*Megaptera novaeangliae*) are also known to migrate along the coast of Zanzibar Island and are most frequently sighted during July to October (de Boer *et al.*, 2002). Whale sharks are largest living fish. As apex predators, their life history characteristics are typified by slow growth, late maturity and low rates of reproduction. These traits make these animals particularly vulnerable to both natural and human induced shocks like exploitation. They are characteristically fished for their liver oil for waterproofing and their fins and meat for food as a delicacy in the growing tourist hotel industry (Muhando and Rumisha, 2008).

Table 2.7: Various threats to marine turtles as recorded from the main nesting sites in RUMAKI seascape.

Site	Disturbance	Cause
Nyororo/Shungi mbili (Mafia)	Heavily disturbed	Permanent and makeshift camp fishing
Other areas of Mafia	Slightly disturbed	Local residents
Simaya Islnad (Rufiji)	Heavily disturbed	Camp fishing
Songo Songo Archipelago (Kilwa)	Significantly disturbed	Camp fishing

Source: Muir (2005).

2.7.3 Dugongs

The number of dugong in the waters of Tanzania is reported to have dramatically declined over the past 25-30 years. To a large extent there is only anecdotal evidence of the presence of dugong population in Tanzania. Reports from local knowledge of the dugong sightings are now rare and the species is considered critically endangered in Tanzania (Muir *et al.*, 2003; WWF, 2004; BG Group, 2013). According to IUCN (2000), the dugong (Dugong dugon - Müller, 1776) is listed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and classified by IUCN as vulnerable to extinction. Records of local knowledge in Tanzania (Muir and Abdallah, 2002; Muir *et al.*, 2003) is consistent with

early report by Ray (1968) and Bryceson (1981) that resident breeding populations of dugongs are by far still existing in the RUMAKI area (between Jaja in Rufiji and south of Somanga in Kilwa) as compared to other sites (Figure 2.15), although there are indications of some movement between dugong populations in Mozambique and the Rufiji Delta, via Mtwara, along areas with extensive seagrass beds (Sea Sense, 2011).

Muir *et al.*, (2003) reported that most sightings correspond to the incidental gillnet capture at the Rufiji-Kilwa site with high frequency during the south east monsoon (SEM, May-August) when sea temperatures are lower and dugongs dwell closer to the shores. Perception of local fishers is that dugongs move to deeper waters during the northeast monsoon (NEM) escaping the high sea temperatures. Muir *et al.* (2003) recommended the need for further studies to determine the sizes of dugong populations and movements, as well as the condition of their seagrass habitats in Tanzania.

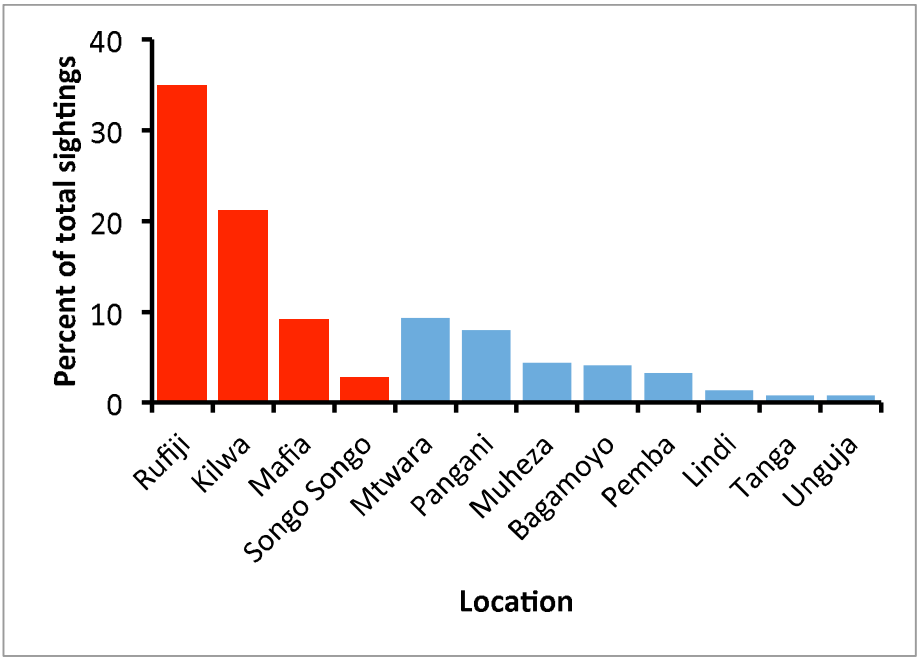


Figure 2.15: Record based on local knowledge of sightings of dugongs during the period of 1950 – 2004 in the RUMAKI seascape [red blocks] as compared to other sites along the coast of Tanzania. Source: WWF (2004).

The main threat to dugongs in the past was deliberate hunting for meat and oil. Dugongs are also in danger of incidental capture in gillnets, habitat degradation pollution and dynamite fishing (Korrubel and Cockcroft, 1997; Marsh *et al.*, 2001). Today, with the mammals having become so rare, accidental entanglement in both set and drift gillnets with a mesh size of >6' is the main cause of mortality in Tanzania. Disturbance, both to dugongs directly and to critical seagrass feeding habitats, from commercial prawn trawling and destructive fishing practices such as dynamite fishing, is likely also to have contributed to the population decline.

2.7.4 Important bird areas

Wells et al (2004) provide a comprehensive review of the importance of RUMAKI seascape as an important bird area. Rufiji Delta mangroves and adjacent coastal forests are important roosting sites and feeding grounds for tens of thousands of migratory water birds. The Rufiji-Mafia complex is known as a prime habitat for feeding and nesting site for shorebirds. This seascape complex is recognized locally and internationally as an important wintering ground for migrant birds such as lesser black-backed gull, herring gull, *Larus argentatus* and Caspian Terns and *Lamprotornis corruscus* (Semesi, 1991, 1992). Especially, Mafia Island and its various islets are important bird areas known to hold at least 154/160 species of birds and share several bird species with Zanzibar Archipelago (Baker and Baker, 2002). The island is a staging ground for various Palearctic migrant species. The Mafia channel forms a rich feeding ground for true seabirds such as terns, gannets, brown noddies and boobies. The island race of the Eastern Bearded Scrub Robin, *Cercotrichas quadrivirgata greenwayi*, is endemic to Mafia Island and Zanzibar (Baker and Baker, 2002). In Kilwa important bird areas are at Nyarama north, Nyamara south and Pindiro. Common reported breeding species are *Cercococcyx montanus, Tauraco livingstonii* and *Musophaga porphyreolopha* (Eriksen *et al.*, 1994; Baker and Baker, 2002).

2.8 Fresh water Resources

Surface water refers to water from lakes (manmade and natural), rivers (seasonal and perennial) and wetlands, which are normally replenished by rainfall. The surface freshwater resources of the RUMAKI seascape are not distributed equally among the three districts of Rufiji, Kilwa and Mafia. Water resources in the Rufiji district and the delta in particular are discussed in relation to the Rufiji basin. Freshwater resources in Kilwa district consist of three perennial rivers, which are Matandu, Mavuji and Mbwemkuru. In addition, there are other seasonal rivers, which are not well documented. On the other hand, the Mafia Island has no definitive freshwater resources. There are only couple of shallow freshwater ponds and few seasonal streams, which form up during storm events and dry up afterwards.

2.8.1 Rainfall: seasonality and distribution

Rainfall is the major input into the hydrological circle of the RUMAKI seascape. Some fresh water bodies for example Umwe Lake are replenished by groundwater. However, run off from rainfall is still the main source of water. Rainfall for the RUMAKI seascape is discussed separately for the districts of Mafia and Kilwa. Rainfall characteristics for Rufiji district are discussed as part of the Rufiji basin since the Rufiji Delta is located at the Lower Rufiji sub-basin.

Seasonal variations for the Great Ruaha River basin indicate the dominance of a uni-modal rainfall regime, relating to a single rainy season between November–May, with a general rainfall peak occurring between January–April depending on region. For the high rainfall areas, the peak occurs around March–April, with the rainfall peak within low rainfall areas occurring around January–February. Mean monthly rainfall varies from less than 100 mm per month in the low rainfall areas to more than 300 mm in high rainfall areas. The seasonal variations further indicate the relatively dry period from June to September, with monthly rainfall amounts predominantly below 50 mm and August being the driest month.

Kilombero sub-basin rainfall is divided in three zones: the northern part, the southern part and the central part. The northern part experiences bimodal rainfall with short rains between the months of October and December and long rains from March to May. The southern part has unimodal rainfall, which falls from October to May while the central zone experiences a transition between unimodal and bimodal rainfall.

Lower Rufiji receives a unimodal rainfall lasting from October/ November to May, with a peak around March/April (Arthurton *et al.*, 2008). However, Rufiji district is along the coast and receives a bimodal rainfall with recorded annual average rainfall of 1200 mm along the coast decreasing to 600 mm on the western floodplain (CEEST, 2004). The long rain season lasts from March to May and the short rain season is from mid-November to January (CEEST, 2004; Mongi *et al.*, 2010).

Rainfall in Kilwa can be categorized into two separate zones; the area north of Kilwa Masoko with annual rainfall ranging between 1000 mm and 1400 mm and south of Kilwa Masoko with rainfall between 800 mm and 1400 mm (URT, 2013). The rain season is unimodal starting form late October to end of May. Mafia receives an annual average rainfall of 2000 mm falling in two seasons. The short rains lasts between November and December while the long rains is from March to May.

2.8.2 River flows

2.8.2.1 Rufiji basin

The Rufiji River Basin, with total area of 177,429 km^2; comprises four sub-basins: 1) the Great Ruaha; 2) Kilombero; 3) Luwegu and 4) Lower Rufiji. The drainage areas and their contributions to annual runoff are listed in Table 2.7 sourced from Duvail and Hamerlynck (2007) and Arthurton et al. (2008).

Table 2.8: Sub-basins within the Rufiji River basin and their contributions to annual runoff.

Sub-basin		Size		Contribution to annual runoff (%)
		Area (km^2)	Proportion of Total (%)	
1	Great Ruaha	83 979	47	15
2	Kilombero	39 990	23	62
3	Luwegu	26 300	15	18
4	Lower Rufiji	27 160	15	5
	Total	177 429		

The Rufiji River is the largest river in Tanzania. The river originates from the Southern highlands and has an annual discharge at Stiegler's Gorge ranging from 800 m^3/s to 1133 m^3/s (Kapetsky, 1981). Seasonal discharges vary from 200 m^3/s during the dry season to 2000 m^3/s in April, which is the peak of rainfall season (Temple and Sundborg, 1972; Tesaker, 1979; Duvail and Hamerlynck, 2007). Discharges of up to 9800 m^3/s have been observed during storm events (Temple and Sundborg, 1972). The average daily discharge for Rufiji river are highest in April (approximately 20% of the total annual discharge) and lowest in September to November.

The Great Ruaha River (approximately 480 km long) (Kapetsky, 1981) is the biggest in terms of catchment area, covering 83,970 km^2. The annual average flow is estimated at 140 m^3/s. The runoff patterns in the basin correspond closely to the uni-modal rainfall patterns prevailing in the whole basin. However, the seasonal variations of the runoff (flow regime) vary quite considerably for the three main rivers flowing into Mtera Dam in the basin (Figure 2.16).

The Kilombero headwaters are situated in the Njombe district and its main tributary, the Ruhuji, flows through a step and narrow valley before reaching the Kilombero plains. Kilombero River is approximately 85 km long, flowing mainly within the Selous Game Reserve (Kapetsky, 1981). The reported discharge ranges from 482.8 m^3/s to 520 m^3/s (Kapetsky, 1981, Yawson *et al.*, 2005). The tributaries of Kilombero River are Luhembero, Kihansi, Mpanga, Mnyera, Ruhuji, Pita and Furua.

The Luwegu River has a catchment area of 26,300 km^2. The Luwegu River drains the southern part of the Rufiji Basin. The Mbarangandu draining about the same size of catchment joins it. This is partly a hilly region and the river gradient is steeper than on the Great Ruaha and the Kilombero rivers (FAO, 1961). The main tributaries of Luwegu are Mbarangandu and Luwegu. Very little is known about rainfall and runoff in the whole of the Luwegu catchment.

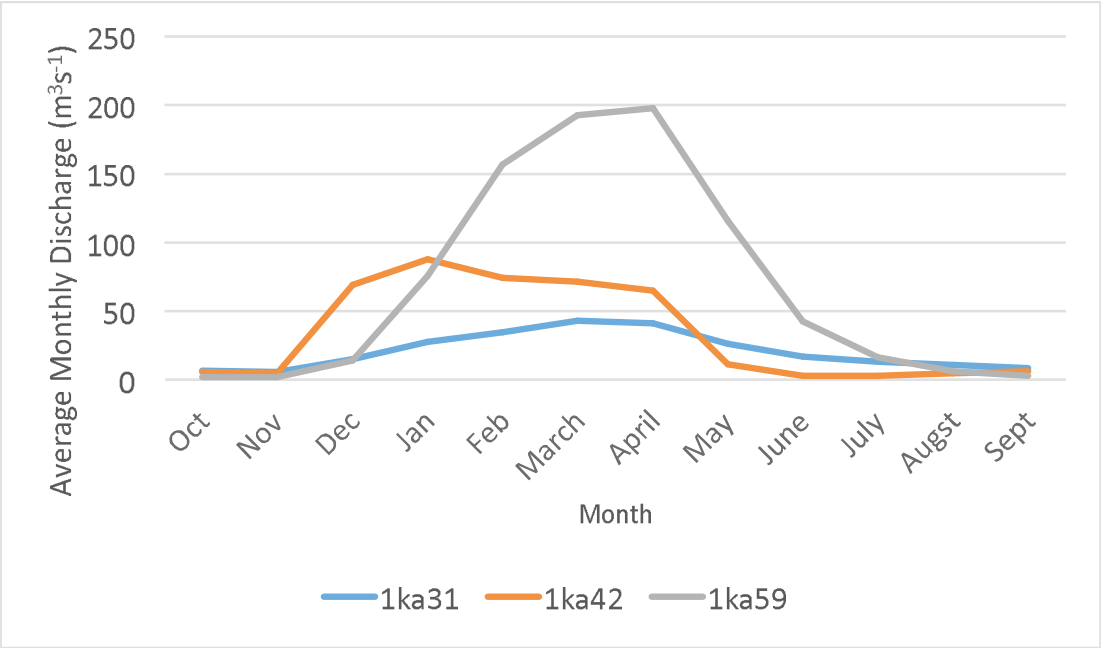


Figure 2.16: Average monthly discharge for the Little Ruaha River (1ka31), GR River (1ka59) and Kisigo (1ka42) (Source: Tumbo, 2014).

2.8.2.2 Kilwa and Mafia District River flows

The riverine water resources of Kilwa district consists of three major rivers (Matandu, Mavuji and Mbwemkuru) and ten seasonal rivers (URT, 2003a). The tributaries of Matandu River are Murembwi, Nakikona, Liwale, Nganga and Narangombe. All the rivers in Kilwa flow in the South-eastern direction towards the Indian Ocean but their contribution into the sea is less significant. There is no enough literature on the characteristics of these rivers.

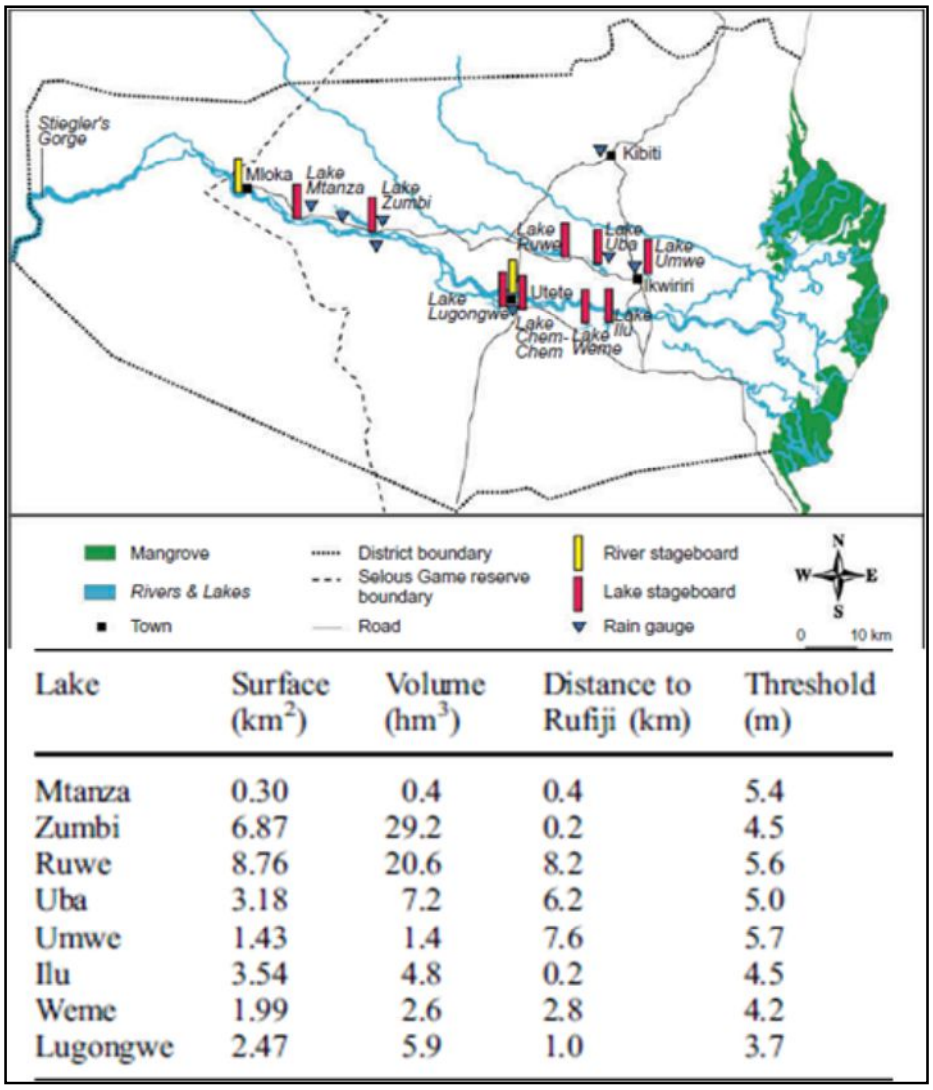
2.8.3 Lakes

Based on the reviewed literature, lakes in the Rufiji basin are well documented. The lakes may be categorized into natural lakes and man-made lakes or dams.

2.8.3.1 Natural Lakes

The lakes Mtanza, Zumbi, Lugongwe, Ruwe, Uba, Weme, Ilu, Umwe, Chemchem, Tangalala are located adjacent to the Rufiji floodplain. The lakes are characteristically shallow with depths less than 8 meters and are formed from tributaries, which carry water into the Rufiji River. During high floods, the lakes are joined to the river to form one water body and they reappear as the floods recede. The small floodplain lakes are individually connected to the river when water in the river raises to certain threshold levels (Figure 2.17). This connection is important as it enables exchange of water, fish and nutrients between the lakes and the river. Also it is the source of water for lakes with no tributaries such as Uba and Umwe.

These lakes are very important to people around them as they are used for fishing and as a source for domestic uses.



Lake	Surface (km^2)	Volume (hm^3)	Distance to Rufiji (km)	Threshold (m)
Mtanza	0.30	0.4	0.4	5.4
Zumbi	6.87	29.2	0.2	4.5
Ruwe	8.76	20.6	8.2	5.6
Uba	3.18	7.2	6.2	5.0
Umwe	1.43	1.4	7.6	5.7
Ilu	3.54	4.8	0.2	4.5
Weme	1.99	2.6	2.8	4.2
Lugongwe	2.47	5.9	1.0	3.7

Figure 2.17: Map of Lower Rufiji with the Flood Plain adjacent lakes.

2.8.3.2 Manmade Lakes and Dams

There are several man-made lakes/dams in the Rufiji basin. Mtera and Kidatu dams are located on Great Ruaha River, controlling about 20 percent of the flow (Duvail and Hamerlynck, 2007). The two dams are very important sources of hydroelectric power production in Tanzania. Prior to 1988, hydropower was only generated at Kidatu. In 1988, an additional turbine was installed at Mtera to increase the generating capacity of the reservoir system. The Kidatu Dam is located approximately 170 km downstream of the Mtera Dam. Although, Kidatu is a much smaller reservoir, its function is largely to maintain sufficient head for power generation. Hence, power is mainly generated at Kidatu and water is mainly stored at Mtera.

Mtera Dam/Reservoir was constructed in Mid-1980. The Mtera Reservoir has a surface area of 620 km^2 at its full capacity. It is 8.5 m deep ranging from 690.0 m to 698.5 m above mean sea level. The storage capacity of Mtera Reservoir is 125 M m^3. The installed capacity at Mtera is 80 MW of power and there are two turbines.

The proposed Stiegler's Gorge dam which is to be built upstream of the Lower Rufiji plain was originally designed by Norplan and Hafslund since 1980s. The dam has a design flood of 2500 m^3/s and storage capacity of 34,000 Mm^3. The estimated residence time of water in the dam is 1.35 years. The dam will control about 95% of the flow in the Rufiji River (Duvail and Hamerlynck, 2007). A study done by Mwalyosi (1988) indicated that the construction of Stiegler's Gorge will alter the flow regime causing less flow during flood period and increased flow in the dry period. The modified flow regime will result into decreased variation in salt intrusion over the year and therefore affect the downstream ecology; with decreased fish catch (Bernacsek, 1980, Mwalyosi, 1988). Over a long period, the dam will result into less sediment supply to the delta which together with coastal erosion along the Mafia channel will lead to deepening of tidal channels (Duvail and Hamerlynck, 2007). Further, the reduced sediment supply to the delta will lead to increased growth of coral reefs, but reduced prawn habitats (Duvail and Hamerlynck, 2007).

2.8.4 Wetlands and floodplains

The most documented wetlands and floodplains in RUMAKI seascape are in the Rufiji basin. The basin has three wetlands with extensive floodplains, which are famous for rice farming namely Usangu (also known as Bohoro), Kilombero and lower Rufiji.

The Usangu wetlands are located in the Usangu floodplain, close to the headwaters of Great Ruaha River (GRR). The floodplain covers an area of 4 480 km^2 (Kashaigili *et al.*, 2006; WWF, 2010) with the permanent Utengule swamp covering 518 km^2. The floodplain is located at the Upper Great Ruaha, receiving water from the GRR and Ndembera rivers. A flow analysis of the GRR by Kashaigili *et al.* (2006) shows that a dry season inflow of 7 m^3/s into the wetland is required to sustain a dry season outflow of 0.6 m^3/s necessary for ecological activities. The inflow into the river has decreased by 70% for the period between 1958 and 2004 due to withdrawal for irrigation. The total dry season flow in the rivers between 1998 and 2003 was measured as 112.6 Mm^3 but only 56.3 Mm^3 flowed into the wetland. The floodplain has large fish varieties and has 2,100 km^2 of potential irrigation area (Kapetsky, 1981; WWF, 2010), however, the irrigated area up to 2002 was only 440 km^2 (SMUWC, 2001).

Kilombero wetland is termed as the largest freshwater wetland at low altitudes of less than 300 m.a.s.l. Kilombero floodplain covers an area of 6736 km^2 and contains the permanent Kibasira swamp, which was estimated at 89 km^2 in 1962 (Kapetsky, 1981). This is a seasonal

wetland formed when water overflows into the Kilombero River, usually between late November or early December and May or June. Major economic activities in the floodplain are fishing and agriculture. The estimated potential irrigable area is 3335 km^2 (FAO, 1961). The flooding results into nutrients flow into the wetland, enabling flourishing of various fish species. The Kilombero wetland is also rich in wildlife including birds and Nile crocodiles. Wetlands inside the Selous game reserve provide habitats for a wide range of wild animals.

Rufiji floodplain, which is 150 km long, covers an area of 1450 km^2. The floodplain consists of 13 permanent lakes (Duvail and Hamerlynck, 2007), river channels, levees and shallow depressions with sparse shrub, cultivated area, scattered tree crops or tall grasslands, palm trees and acacia woodlands (Ochieng, 2002). The floodplain is usually flooded from January to May, enabling nutrients and water exchange between river water and floodplain lakes, hence the flooding is important for the economic activities of the floodplain. The Rufiji floodplain has 80,000 ha of potential areas for agriculture but only 20,000 are under cultivation.

2.8.5 Groundwater

Potential areas for groundwater extraction are mostly located within the floodplain with static water levels ranging between 5 and 15 meters below ground level and yields of 5 to 15 m^3/h (CEEST, 2004). Majority of groundwater sources in the Rufiji are saline with salinity increasing during the dry season (CEEST, 2004). Most of the ground water in Kilwa and Mafia districts is too saline for human consumption and irrigation (URT, 2003a).

3. DEVELOPMENT TRENDS AND PRESSURES

This chapter presents development trends and pressures in the RUMAKI area. Population and land use trends are major drivers, which shape the patterns in socio-economic activities and land cover changes over time.

3.1 Population growth and 30 year projection for the RUMAKI area

According to the national population census there is a linear increase of population in Rufiji, Mafia and Kilwa districts (Figure 3.1). According to the reports of the National Population and Housing Census by the National Bureau of Statistics, a trend in 1988, 2002 and 2012 census, indicate that population in Rufiji district increased from 153,938, 202,001 and 217,274 respectively. In Mafia district the population increased from 33,079, 40,557 and 46,438 respectively, whilst, in Kilwa district it increased from 150,419, 171,057 and 190,744 respectively. The proportion of coastal bound population in Rifiji and Kilwa districts are estimated at 40 and 60% respectively (Table 3.1). The current population growth rate for the Pwani region which includes Rufiji and Mafia districts is 2.2, whilst that of the Lindi region, which includes the Kilwa district is 0.9 (NBS, 2012). This decadal linear increase in population is a potential cause of pressure on the arable land, thus leading to opening of rice farms in the Rufiji delta by clearing mangroves (details of land use/cover will be provided in the next section). The 30 year population projection for the RUMAKI area indicates a tremendous increase in population for the year 2042 basing on the current population growth rate. According to census data projections, the population for Rufiji, Mafia and Kilwa districts is projected to be 263,093, 64,081 and 249,805 respectively (Figure 3.1). The current trend and the projected increase in population will cause even higher pressure to the natural resources base and further expansion of agricultural land, and increased demand on forest and fishery resources.

3.2 Land use and land cover changes in the Rufiji Delta

Agriculture, particularly rice farming has increased significantly (Table 3.1) in the Rufiji Delta compared to the past two decades (Ndesanjo, 2009; Nindi *et al.*, 2014). Some land uses/cover types have registered highest gain between 1989 and 2010. As discussed in section 2.5 above, for example, rice farms in the north Rufiji Delta have doubled within two decades at the cost of other vegetation types of mangroves in the delta, particularly Heritiera and Bruguiera. In an attempt to explain the observed dieback of the mangrove *H. littoralis* in Rufiji Delta following excessive rainfall and subsequent flooding during the 1997/98 El Nino, Erftemeijer and Hamerlynck (2005) noted that the process of natural regeneration in degraded areas was hampered in some parts of the affected areas by encroaching rice farmers who had cut down the remaining trees and burnt the undergrowth

(including mangrove seedlings) to establish paddy fields, which are usually abandoned at about 5 years of cultivation. The system of shifting cultivation for rice farming in the mangroves of Rufiji Delta has proven to be highly unsustainable (Kajia, 2000; Nindi *et al.*, 2014). Land covers dominated by Heritiera, Sonneratia, Ceriops, Avicennia, bare saline flats and Rhizophora, all showed decreased trends (Table 3.2). Non-mangrove area showed an increased cover whereas areas dominated by sparse Avicennia and Ceriops increased tremendously (Wang *et al.*, 2003; Nindi *et al.*, 2014). According to Ndesanjo (2009), most of the traditional crops grown in the delta in the past decades have disappeared except rice, which shows to be expanding. Changes in vegetation and land cover in the south delta is also attributed to the changes in the water regime, when the river flows progressively changed its direction to north delta in the 1960s and 1970s. Consequently rice farming that was well established in the south delta is now replaced by thin mangrove forest, and in some cases vast open saline flats.

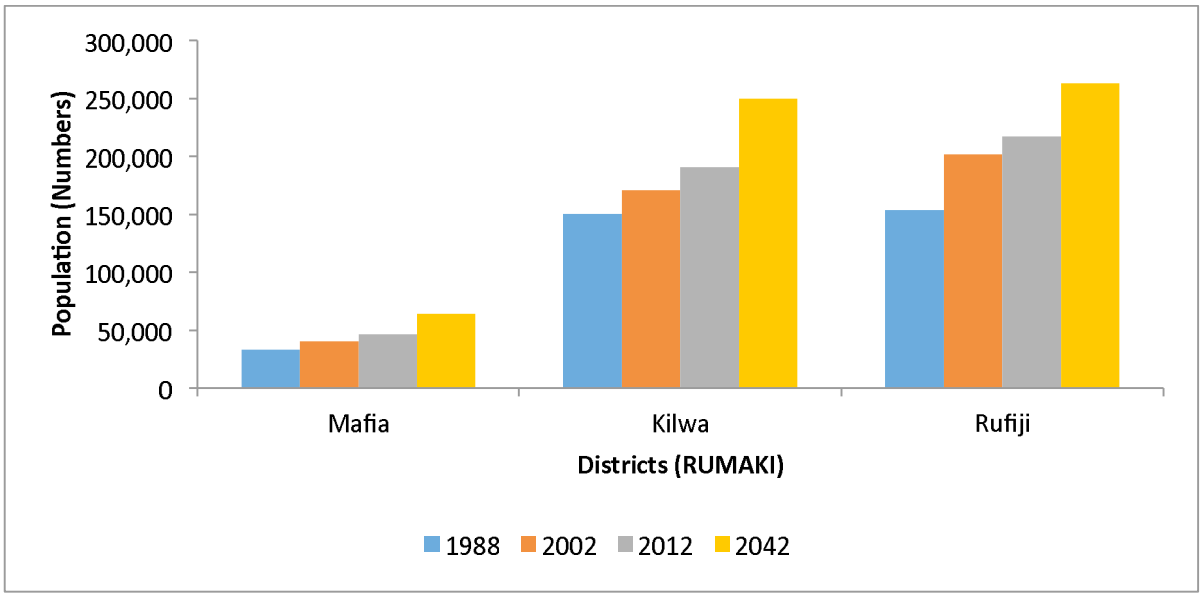


Figure 3.1: Historical population census and 30 year growth projections in RUMAKI area.

Table 3.1: Population of coastal wards in the RUMAKI seascape.

	Total Population	Coastal Wards	Percent of Coastal Population
Kilwa	190,744	118,290	62.0%
Mafia	46,438	46,438	100.0%
Rufiji	217,274	85,889	39.5%
Grand Total	454,456	250,617	55.1%

Source: National Population and Housing Census 2012 (NBS, 2012).

Table 3.2: Land and mangrove cover changes in the Northern Rufiji Delta between 1989 and 2010 (brackets indicate loss).

Change Category	Mangroves/land use type	1989	2010	Change in ha	% Change
Land cover	Avicennia dominant	3,693	2,912	(781)	(21)
	Ceriops dominant	4,948	3,629	(1,319)	(27)
	Rice farms and Heritiera	379		(379)	(100)
	Heritiera dominant	2,367	558	(1,809)	(76)
	Rhizophora dominant	13,672	13,212	(460)	(3)
	Rice farms	2,111	5,948	4,140	229
	Sonneratia dominant	426	279	(147)	(35)
	Mixed Avicennia/Ceriops	206	1,857	1,651	801
Mangrove cover	Total mangrove area (ha)	25,312	22,447	2,865	(11.3)
	Dominant mangrove (ha)	25,106	20,590	4.516	(18.0)

Source: Nindi *et al.* (2014).

3.3 Increasing cutting for timber, poles and fuel wood

Commercial logging from both coastal forests and mangroves is largely an illegal business in the delta and adjacent coastal forests because of the requirement to obtain and pay for cutting licences. For this reason, people are generally reluctant to reveal the full extent of pole cutting beyond their domestic consumption, which is therefore generally overlooked as it is considered of insignificant impact to the forests. A comprehensive survey of resource use patterns in the Rufiji Delta and associated floodplain by Turpie (2000) estimated that over 1.3 million poles, including withies, are harvested from the woodlands. This represented by far an underestimate of wood removal because it reflected only an estimated amount required annually in local building/construction. For timber, the most valuable coastal forest species, *Pterocarpus angolensis* (mninga) is already scarce due to overexploitation, and the highest demand has shifted to its substitute, *Afzelia quanzensis* (mkongo). Reports from local people indicate that about 12,000 trees are cut annually from the coastal forests around Rufiji Delta.

Commercial charcoal making in the Rufiji-Kilwa forests complex is also rampant. Local communities hardly report it as an occupational livelihood activity. For example, only 3.7% and 3.5% of households in floodplain and transition zone acknowledged making charcoal. But field observations by Turpie (2000) indicated that almost any type and size of wood is used for charcoal making in the delta and adjacent woodlands and forests. Preferred coastal forests species for charcoal include *mtondo, mkolwa, mpingo*, and *mkongo*. However, it is argued that the use of mkongo (a valuable timber species), for charcoal, makes no economic sense, but it is unfortunate that charcoal makers are seldom timber cutters (and *vice versa*). Such cases are then a matter of competition for the same resources, the practice that compounds the cutting pressure from different user groups.

In the delta and Kilwa specifically, cutting of mangrove poles is a major commercial activity, majority of which again is carried out illegally without licencing. The commercial demand for mangrove poles is mostly for the middle-sized *boriti*, which are used in construction almost all over the coast region (particularly Tanga, and Zanzibar). A survey by Turpie (2000) estimated that mangrove involve an annual harvest of 126,000 scores of poles. The most commercially preferred mangrove species are those of the family Rhizophoraceae: *R. mucronata, C. tagal and* and *B. gymnorrhiza*. Recently, preference for *Xylocarpus granatum* for timber has exerted significant pressure on this species (Mangora pers. observation)

3.4 Agriculture

3.4.1 Investment Opportunities in Crop Production in Rufiji District

The main investment opportunities earmarked by the district include paddy (Table 3.3), fruit and vegetable production and processing. The government of Tanzania in collaboration with some donors like Japan is supporting Nyamweke irrigation scheme in Utete. Communities potentially identified a total of 320 hectares for this type of irrigation. About 120 hectares was in Ngorongo while 140 ha were in Nyakitope Utete-ward and 60 in Segeni Mkongo ward. Area under irrigation in Rufiji district increased from 176 ha in 2004/05 to 230 ha and about 80,000 ha along Rufiji is suitable for irrigation. Only 230 ha are under irrigation particularly in vegetable crops. Total of 640 ha are in plan for improved irrigation while 79,360 needs to be utilized for irrigation activities.

Table 3.3: Investment in paddy production.

Products	Rice for human consumption and sales of surplus. The district produces 1.5 Ton/year/ha and it performs well in area of flood plain. Irrigated rice can be grown throughout the year.
Potential target areas	40,000 hectares along the floodplain and some other parts of the district are available and suitable for irrigation.
The market situation	The market is available within the district, neighbouring regions such as Dar es Salaam. There is a large number of individuals, traders and institutions and also for export.
Future expectations	Developed irrigated agriculture both small and large scale with improvement in varieties and irrigation skims
Quality demands	Improved varieties with high market demand within and outside the district.
Type of investors	Both large and small scale farmers in paddy production are encouraged.

Source: Rufiji District Council, 2010

3.4.2 Irrigation potential and prospects in the Rufiji District

The potential of irrigated agriculture in the Rufiji can be divided into three periods: pre-World War II (1895-1945), post-World War II (1945-1985) and post-structural adjustment (1985–present) (Hamarlynck *et al.*, 2010). The description and overview of the irrigation potential of the Rufiji Delta is detailed in historical analysis by Hoag (2003) and Harmerlynk

et al. (2010) and will not be repeated in this section. Based on the available literatures and the close link that exist between the ecology, flooding and farming activities, it is fairly clear that, implementation of large scale irrigation activities the Rufiji Delta will not be an easy task. The planning for irrigation should be based on the proper understanding of the social and ecological regime of the Rufiji floodplain and delta. Despite challenges highlighted in various reports (Hoag, 2003; Hamarlynck *et al.*, 2010), the high irrigation potential of the Lower Rufiji floodplain is still being supported by FAO, Rufiji Basin Development Authority (RuBaDa), the official Rufiji District development plans and in the National Irrigation Master Plan, Kilimo Kwanza, SAGCOT and big results now (BRN) plans and strategies. A thorough analysis of the ecological, social and economic aspects would be required before implementation of these initiatives. A bottom-up development approach to small-scale irrigation supported by a microcredit scheme and targeting the driest western floodplain where food insecurity is highest is likely to be a more realistic option (Hoag, 2003; Hamerlynck *et al.*, 2010)

3.5 Infrastructures in the RUMAKI

The RUMAKI seascape complex has been one of the economically poor regions in the country with little development in terms of infrastructure and socio-economic incentives. It is until recent that the on-going road construction and improvement to link the business capital Dar es Salaam and the southern regions, including the completion of the Mkapa Bridge has opened up opportunities for socio-economic development. The completion of the Mkapa Bridge across the Rufiji River was heralded as not just a major engineering success for the African subcontinent but also a great step for national development (Milledge and Kaale, 2003). Kilwa is accessible through the same main road which is all tarmac, and its district headquarter is located about 320km form Dar es Salaam.

Kilwa and Mafia are accessible by Cessna flights. Mafia has scheduled 13-seaters flights, which occasionally goes to Kilwa (on request). Both districts have air strips but the Mafia one is newly built at tarmac level, while that of Kilwa is still having earth runways. As often air transport is expensive, local passengers and goods to Mafia are transported by roads in the mainland and by dhows from the harbours of Nyamisati and Kisiju, which are closest to Mafia.

Apart from this main road, all feeder roads within Rufiji, Kilwa and North of Mafia are earth surfaced, seasonal and passable only by four wheel drive vehicle during the rainy season. In Rufiji, the deltaic environment necessitates more bridges, which are in most cases made up of wood. These bridges are tracked back to the DANIDA Village Travel and Transport Project (VTTP - 1999-2004), a five years endeavour that placed a number of wooden bridges to facilitate easy travel within Rufiji. However all bridges except but few in main feeder roads have been destroyed. Mafia district has two main roads, one from Kilindoni north to Ras

Mkumbi (with side roads to the villages in the north) and the second from Kilindoni to Utende, the centre of the tourism area on Chole Bay. A third arterial road connects the south-east of the island, centred on Kitoni. There are no tarmac roads in the district and the recent improved road to southern Mafia is to bitumen standard. Transport to mafia from Kilwa and Rufiji is by means of dhows and small boats.

The impact of opening of the southern corridor is evident to both terrestrial and marine resources. Human disturbance to the natural habitats in the RUMAKI area increased rapidly because of the improved road infrastructure, notably the improved access to previously remote and inaccessible areas (Milledge *et al.*, 2007). In particular, the opening Mkapa Bridge increased access for lorries to carry timber (including illegal timber). The looming ecological danger of the forest loss in particular is that those species confined to forest habitats, including the majority of the endemic species (Burgess *et al.*, 1998; Burgess and Clarke, 2000), will decline in range and population over time. Degradation of the coastal forests in this Rufiji-Kilwa region has left only small patches of less than 500 ha and in some locations, the remaining tracts are as little as 5% of the original forest habitat (Tabor *et al.*, 2010). This high degradation exposes the natural habitats to environmental shock, especially those related to climate change drivers. From conservation point of view forest dependent species are of particular interest since they will disappear when the forest is modified to any great extent. Forest dependent species that are also endemic to the coastal forests are of even higher conservation importance as they may go extinct if the forest area(s) where they occur is disturbed (Ornis Consult, 2000).

Access to Dar-es-salaam also opened fish business in the coastal villages of Rufiji, Mafia and Kilwa. Fish that were to take up to 48 hours to reach Dar es Salaam from Kilwa are now taking just 6 hour, hence more fishing pressure is directed to these areas.

The proposed construction of a large hydropower dam at Stiegler's Gorge is of high environmental concern for the Rufiji Delta because the delta and floodplain could face major hydrological impacts as already highlighted in the previous sections above. It is predicted that the flood hydrograph of the Rufiji River will be strongly modified, affecting downstream ecosystems including the mangroves (Mwalyosi, 1988) and adjoining seagrass beds and coral reefs (Muhando and Rumisha, 2008).

3.6 Coastal tourism

Coastal tourism has grown over the years and so is its contribution to the Tanzania's economy (TCMP, 2001). The presence of attractive coastal habitats and resources, such as coral reefs, mangroves and seagrass beds, and historical buildings, ruins and monuments has boosted investments in tourism industry as evidenced in the number, variety and diversity of accommodation facilities that have been constructed or are planned along the

coast. Mafia Island is in particular rapidly expanding in tourism industry (TCMP, 2001). Tourism development in the Mafia Island started way back in the 1950s in the form of Game Fishing Club at Utende. A Government-owned hotel called Mafia Island Lodge was constructed in 1971. Five more hotels have been constructed between 1995 and 2011. The current number of beds stands at 152. Tourists in Mafia Island engage in a number of activities including SCUBA diving & snorkeling, Whale shark swimming, sport fishing, sailing, windsurfing and visits to cultural sites and Mlola Forest. Trends indicate that the occupancy rates of tourists have remained within an average of 30% from 1997 to 2007. This is below the average National rate that is between 40-50%. The main obstacle appears to be a lack of economic regular transport (URT, 2011). The trend of tourists visiting the Mafia Island Marine Park (MIMP) has been varying between Tanzanians and non-Tanzanians since the year 2000. The trend indicates that the number of both Tanzanians and non-Tanzanians is increasing but still foreign tourists are increasing substantially (Table 3.4).

Table 3.4: Number of visitors within MIMP.

Year	Tanzanian	Non- Tanzanian		Comments
2000	393	484		Data reversed based on MIMP gate records
2001	79	1091		Data reversed based on MIMP gate records
2002	98	1353		Data reversed based on MIMP gate records
2003	90	1380		
2004		190	2212	
2005		132	2593	
2006		112	3007	

Tourism activities in the Rufiji district is confined to the area in and around the Selous Game Reserve and the main foci are wildlife photography and hunting pursuits. The potential for tourism to contribute more to the economy of the district and the country is high. Existing campsites and tourist accommodations are mostly clustered in Selous. These include Rufiji River Camp, Mbuyu camp, Selous Safari camp, Behobeho, Sand Rivers, Nomad Kibambawe camp, Impala camp, Stiegler's Gorge camp. There are four tourist camps bordering the Selous in Mloka area: Mbega, Hidden paradise camp, Patrick and Kenneth camp, Msigara. There are no tourist camps or hotels in the rest of the plains or delta, though Mtanza and Msona sub villages are piloting campsites (Rufiji District Council, 2010).

Kilwa district has a high potential for eco-tourism and game viewing tourism. The attractions under the legal authority of the Antiquities Department include all ruins and monuments found on Kilwa Kisiwani, Songo Mnara, and Sanje ya Kati, Kilwa Kivinje and other various areas found in the vicinity. In addition, the caves found at Kipatimu are also included as protected areas under the Antiquities Act. Other natural attractions, such as the "hippo pool" at River Nyange and the extensive mangrove forests throughout the area, are under different management regime. Marine resources including mangroves forests, coral reefs and sand beaches have attracted a number of tourist investments in Kilwa. Tourism

development is both labour and capital intensive. Provision of services by the local communities is through casual labour. High investment cost in the tourism sector makes it impossible for local communities to invest in this sector. These at present are constraining development of the industry in the district (Kilwa District Council, 2013). In 2002-2003, only 400 visitors were recorded in Kilwa – an extraordinarily low number for a World Heritage Site; this is an average of roughly one person per day. Conservation and protection of the site over subsequent years appears to have led to some improvement, but figures are still very low. For example, between 2005-2006 and 2006-2007, there were 1,160 and 1,616 visitors respectively.

Unplanned development of tourist-related facilities and infrastructure has adversely affected the coastal ecosystems. Investments in coastal areas involve mangroves clearing, and the degradation of estuaries and reefs. The most definite threat to biodiversity posed by tourism is land clearance and degradation resulting from tourism development. Other impacts are related to land and water pollution due to poor wastewater treatment, solid waste disposal. Poor management of solid water during construction and operation phase may lead sediment concentrations and nitrification in fresh waterways, seagrass beds, and eventually on coral reefs.

3.7 Oil and Gas Extraction

RUMAKI complex is developing as a center for the booming oil and gas exploartion and extraction in Tanzania. Already natural gas extraction is ongoing at Songo Songo Archipelago and recently discovered at Nyuni Island north of Songo Songo. While the oil and gas industry is viewed as the driver for economic growth and poverty alleviation, these ongoing exploration and extraction if not well managed, the industry may present a major threat to biodiversity and therefore livelihoods of the coastal communities in the region that are dependent on natural resources (Table 3.4; Muhando and Rumisha, 2008).

Table 3.5: Environmental and social issues related to oil and gas activities.

Oil Gas activity	Environmental issues	Social issues
Offshore exploration	-Oil spills, accidents Deforestation	-Restriction of fishing zones -Opportunities for employment
Oil and gas transport	- Oil spills, accidents -Soil and water contamination	-Risk of accident -Improvement of transportation network
Refinery	-Oil spill and accidents -Air pollution -Water and soil contamination	-Opportunities for employment -Opportunities for new services(e.g health, education
Biofuel development	-Soil degradation -Biodiversity loss	-Competition for land -Opportunities for new services

3.8 Mining activities

Mining activities in the Rufiji Mafia and Kilwa are concentrated on cement, coral and lime. The nature of mining sector in the Rufiji Mafia and Kilwa, is very limited and small in relation to large inland mining operations and is mostly limestone mining for cement manufacturing. However, there is a potential for more investments in limestone mining due its availability. Currently there is only one cement factory in Kilwa. Although coral mining is illegal and is mainly done in Mafia, it provides revenue for local communities and low cost building materials for the construction of their homes.

4. CLIMATE TRENDS, PROJECTIONS, AND IMPACTS

Although there are some uncertainties surrounding the understanding of earth's complex systems, there is strong evidence in current literature and climatic measurements to demonstrate that, as a result of increasing greenhouse gas emissions, atmospheric, land and sea surface temperatures are rising (IPCC, 2001). Temperature increase is likely to combine with other forms of climate change to bring about pressures to the environment and ecosystems. With climate change both coastal ecosystems and livelihoods are exposed to environmental risks. Climate change may alter rainfall patterns which, in turn, change local environment, for example salinity pattern of the brackish water in the delta, or soil water content, which organisms in the ecosystem interacts with.

4.1 Surface air temperature

4.1.1 Surface air temperature trends

The climate along the Tanzanian coast, including the Rufiji Mafia and Kilwa districts is typically tropical with relatively high humidity. The average temperature, which is moderated by the sea breeze, ranges between 27°C and 29°C. Seasonal variations in temperature are small with small differences between minimum and maximum temperatures, as is expected for a coastal location in the tropics (Figure 4.1). Increasing temperature trends are detectable in a number of temperature indices with the most significant (at the 90% confidence level) for increasing monthly maximums of both minimum and maximum daily temperatures (Figure 4.2). Generally negative trends are found in the maximum temperature and the number of days exceeding 32°C with the largest trends occurring during the peak of the two rain season. A positive trend is found in minimum temperature throughout the year but is strongest during the first half when minimum temperatures are higher. Impacts and implications of the changes and/or shifts in temperature are discussed in section 4.1.3 below.

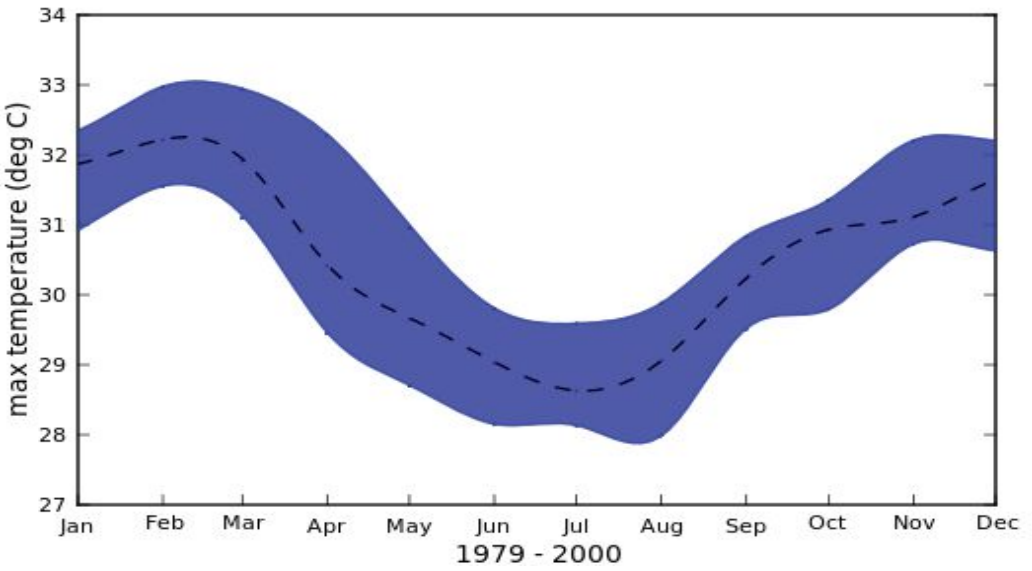


Figure 4.1: Monthly climatology of minimum and maximum temperature (^{0}C) for Dar es Salaam. (Source: Jack 2010).

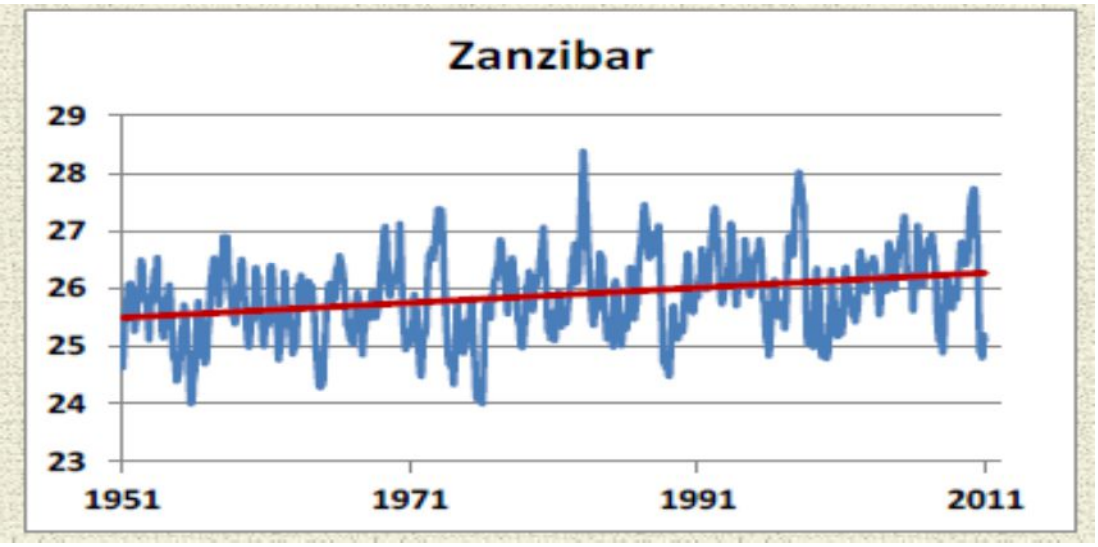


Figure 4.2: Long term variability in surface air temperature (^{0}C) 1951-2010. (Source: Mahongo, 2009).

4.1.2 Surface air Temperature Projections

The average global surface temperature has warmed by 0.8°C in the past century and 0.6°C in the past three decades (IPCC, 2001; Hansen et al., 2006). Future projected temperature trends for the Rufiji, Mafia and Kilwa area are based on the Dar es Salaam station (Mwandosya et al., 1998; Jack, 2010, Watkiss *et al.*, 2011), where all studies suggest temperature increase. The climate models project significant increases in average temperature with increases in maximum monthly temperature of 1.5 to 2°C by the 2050s (2045-2065) and 2 to 4°C by the 2090s (2081-2100), with a fairly similar increase across the

months of the year (Jack, 2010). The number of days on which the temperature exceeds 32° C is projected to increase significantly with the largest change projected to occur during October which might be linked to the delay in the onset of the short rains. These results are based on Climate System Analysis Group (CSAG) and they are similar to an ensemble of 13 CORDEX regional climate model (RCM) predictions for the future period (2031-2060), where a 2-3 degree temperature increase has been observed across all RCM models (Tumbo *et al.*, 2013). Similar trends have been observed by previous studies such as US Country Studies Programme assessment of vulnerability and adaptation response options for Tanzania in 1997. The study used the Global Climate Change Scenarios, projected a rise in the mean daily temperature, on average, by 3°C - 5°C throughout the country, and a rise in the mean annual temperature on average by 2°C - 4°C.

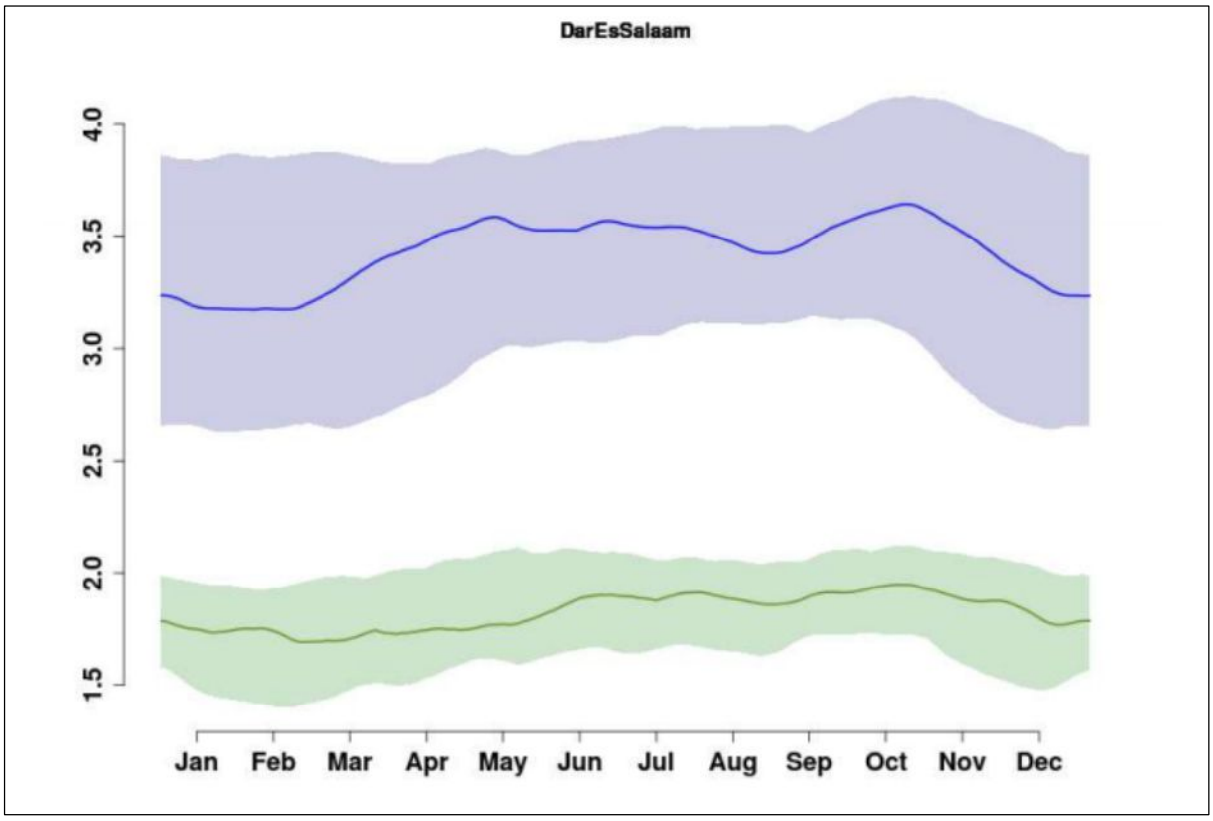


Figure 4.3: Downscaled maximum temperature anomalies (l temperature on average period (green) and 2081-2100 period (blue). Shading indicates the spread of results for the various models and solid lines the median model response.

4.1.3 Impacts of surface air temperature on selected coastal ecosystems

In terms of the increases in temperature and CO_2, there are virtually no documented accounts of how increasing air temperature and CO_2 affect the mangroves and associated life forms in the Rufiji-Mafia-Kilwa system. However, it is known that two fundamental plant physiological processes that determine productivity i.e. photosynthetic carbon gain and respiration are sensitive to temperature and CO_2. Studies on mangroves from other areas

indicate that low temperatures limit mangrove reproduction and distributions (Duke *et al.*, 1998). In many plant species elevated CO_2, enhances photosynthesis and growth. For example, in the Australian mangroves Ball *et al.* (1997) found that elevated CO_2 conditions at a rate of double ambient, exerted little effect on growth rates when salinity was a compounding stress, but increased growth by up to 40% when humidity was a compounding stress. Such findings imply that mangrove species with fast growth rates, but less tolerant to salt are more sensitive to CO_2, suggesting that productivity and expansion of mangroves into freshwater habitats could occur at an accelerating pace.

4.2 Sea surface temperature

4.2.1 Sea surface temperature trends

The average Sea Surface Temperature (SST) in Tanzanian offshore waters is around 27^{o}C and the typical range is from 22 to 30°C (Francis *et al.*, 2001). The SSTs are generally higher during the North East monsoon as compared to the South East monsoon. The SSTs are also highest in early March and lowest in either August or September. However, higher SSTs of up to 32.5^{o}C occur in shallow coastal areas. Local SST from WWF monitoring sites in Mafia, while agrees with overall averages and seasonal patterns with previous studies, the months of lowest and highest temperatures tended to occur in April and August respectively (Figure 4.4).

Sea surface temperature SST is a well suited parameter for monitoring climate change due to the oceans large thermal inertia compared with that of atmosphere and land (Deser *et al.*, 2010). However, accurate estimations of long-term SST trends is hampered by poor spatial and temporal sampling and errors associated with measuring instruments (Deser *et al.*, 2010). The increases in sea surface temperature are particularly important for coastal ecosystems and livelihoods and are thus a key concern for the RUMAKI sea scape. For example: Coral reefs are said to be sensitive to small anomalies in sea temperature change such as that which occur during El-Niño events. Smaller change in temperature interferes with coral growth, reproduction and recruitment while slightly more temperature rise leads to bleaching and eventually death. In 1998, large portion of the Tanzania's (including Mafia) coral reefs experienced bleaching with reported death ranging between 50 and 80 percent (Muhando, 1999; Obura, 2002; Obura, 2008.)

Sea surface temperatues in the Indian Ocean have generally increased at a rate of as high as 0.2°C/decade in the last decade. Figure 4.5 shows a steady increase in sea surface temperatures throughout the 30 year period. Mahongo (2009) also depicted in the local monitoring data. For the east African region, the SST has been has been warmest during the last two decades within the past 140 years Figure (4.4).

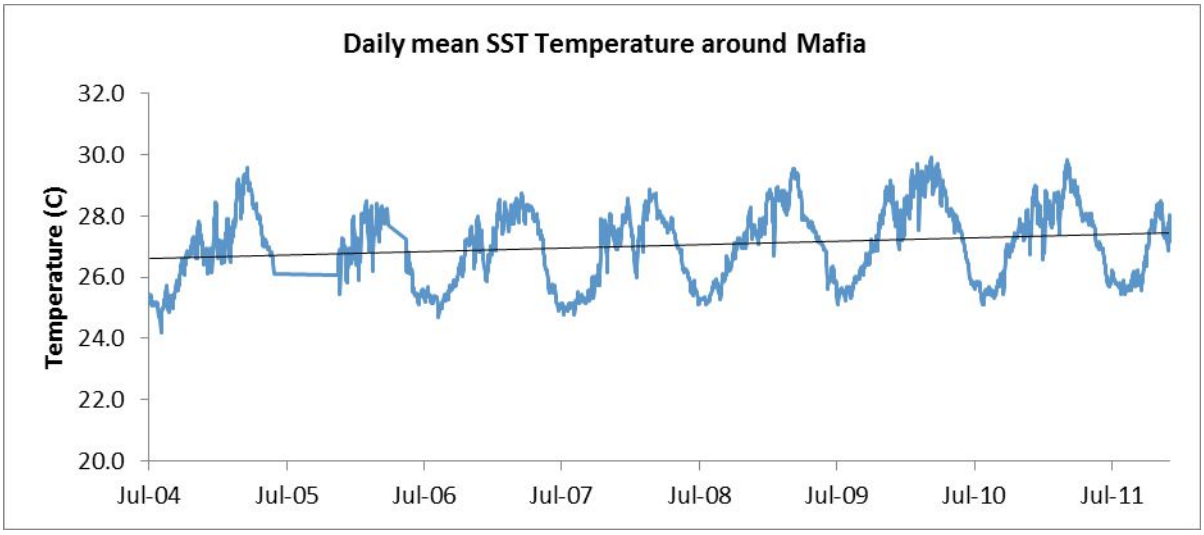


Figure 4.4: Patterns in SST for local monitoring sites in Mafia. Source RUMAKI Temperature Monitoring data.

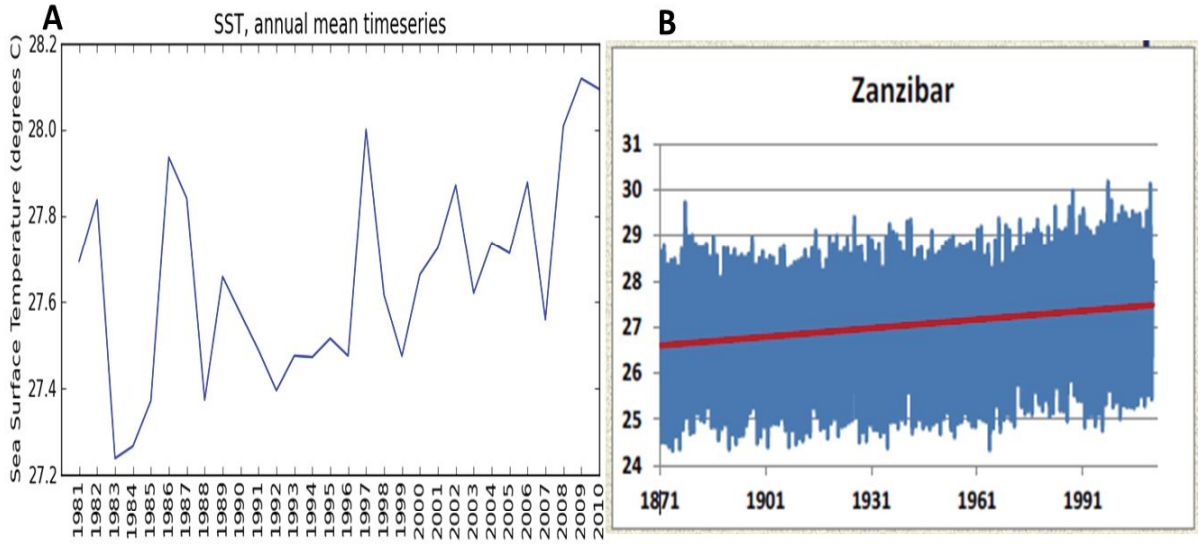


Figure 4.5. SST time series from 1981 – 2010 for the coast of Tanzania (A) and 1871 to 1991 for Zanzibar (B).

4.2.2 Sea Surface Temperature Projections

Data on projected ocean SST is currently unavailable for the RUMAKI area as well as Tanzania in general. However, the observed trends in SST shows an increasing trends of which we don't not know for how long the ocean SST will continue to heat. The unavailability of SST projections is due to the difficulties in simulating the complex water balance of the planet, which includes important components such as land and sea ice.

4.3 Rainfall trends and variability

Observed rainfall information for the RUMAKI area is based on the Dar es Salaam and Mtwara stations. The former station represents characteristic patterns of Mafia and Rufiji rains, and later for Kilwa situation. Dar es Salaam features a tropical climate, which is modulated by its location on the coast. It experiences bimodal rains with the long rains occurring from March – May and the short rains from November – December. Dry spells between rain events is generally short since light rain occurs throughout the year, but heavy and extreme rainfall are restricted to the two peak rain seasons. The rainfall trends are complex, but do suggest that the frequency and intensity of rainfall is generally decreasing, while the tails of the rainy seasons are getting wetter (Figure 4.6).

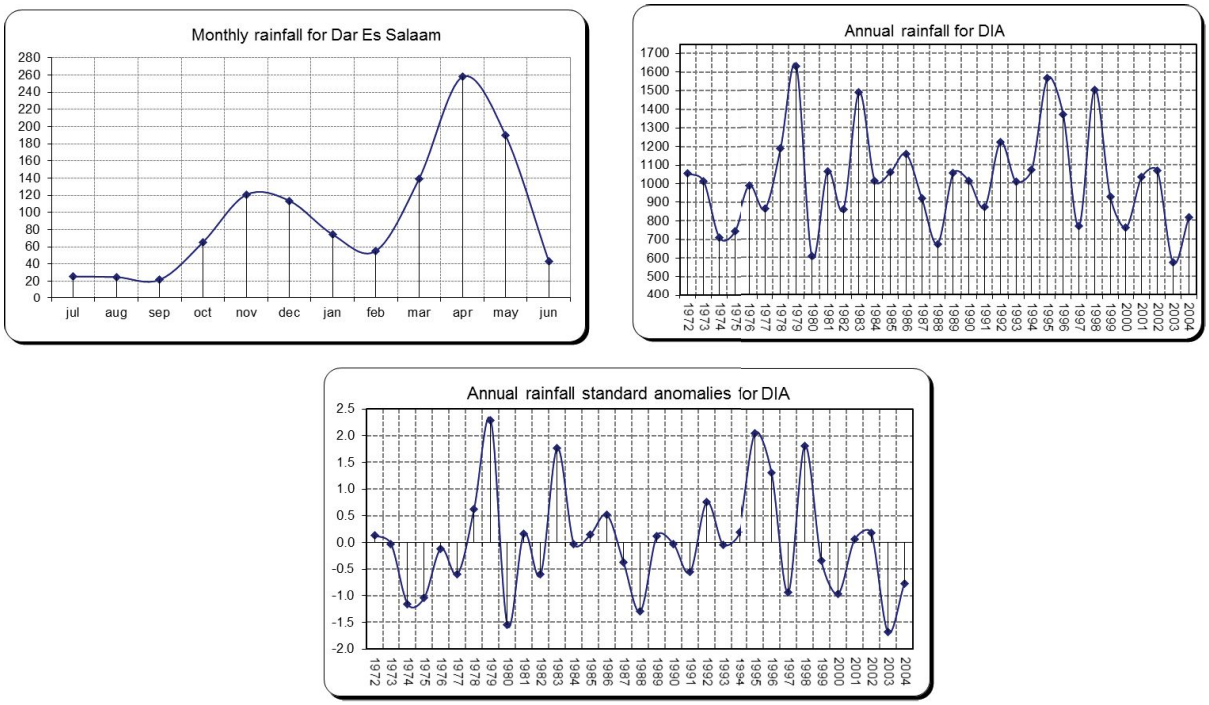


Figure 4.6: Monthly and annual rainfall standard anomalies for the Dar es Salaam International Airport (DIA).

4.3.1 Historical rainfall trends in RUMAKI

Studies in climate trends over the Southern African region (Hulme, 1992; Fauchereau *et al.*, 2003; Valimba *et al.*, 2006) indicates that there are no any trends in seasonal rainfall but increased variability in inter-annual rainfall with intense and widespread droughts. For the East African region, rainfall patterns have shown a somewhat stable regime during the 20th century with evidence of long-term wetting (Hulme, 1996; Hulme *et al.*, 2001).

In the Great Ruaha Rriver basin the average of annual rainfall records from 1960 to 2009 in the Usangu catchment shows insignificant decline trend. SMUWC (2001) selected 100 rainfall gauges to examine the long term trends in rainfall for the 44 year period 1955-98

using arithmetic averaging technique and no significant decline trend found based on linear-regression method. There is large uncertainty associated with trend analysis results in the GRR basin, this limits the use of this information. Discrepancy exists in some years, which implies uncertainty of the rainfall records. The spatial averaging methods of annual rainfall, selection of representative rainfall gauges, time series coverage and also the time series trend analysis methods are the main sources of uncertainty.

For the Kilombero basin, a decrease occurred in annual rainfall for the period between 1964 and 1993. Analysis of the short rains season shows an increasing trend while the dry season indicated a mixed trend of increase and decrease. However, Arthurton *et al.* (2008) reported a constant trend at Kilombero station for the period between 1962 and 2002. Based on these results, there is no a clear conclusion on to whether rainfall increase or decrease. Trend analyses are influenced by the quality of data use, data quality check procedure used and record length. Hence, In this regard, data scarcity is a large stumbling block for regions like the Rufiji basin. The decline of hydro-meteorological observation networks causes regional hydrologic predictions to be highly uncertain (Koutsouris *et al.*, 2010). Data scarcity limits the understanding of coupled water resources – climate systems (Washington et al., 2004) and may also lead to strong errors when interpolations are made across space and time using only a few observation stations or periods (Jung *et al.*, 2012).

Decreasing rainfall trends are reported for the Lower Rufiji basin (Duvail and Hamerlynck, 2007; Arthurton *et al.*, 2008). Trends show a decrease in rainfall from an average annual rainfall of 900 mm between 1923 and 1998 to an average annual rainfall of 662.1 mm between 1999 and 2012. Five of the ten driest years in Lower Rufiji are reported to occur since 2003 while the historical long-term annual average rainfall of 900 mm has been exceeded only once for the period between 1999 and 2012 (Duvail and Hamerlynck, 2007). The decrease in annual rainfall is explained by a decrease in rainfall during the short rains season and shortening of the long rains season. However, other studies on the Rufiji basin reported an undefined trend with increased trend at Stiegler's Gorge (1955-1990), increased trend at Kingupira (1962-2002) and constant trend at Utete (1921-2002) (Arthurton *et al.*, 2008).

4.3.2 Rainfall projections

Changes in rainfall patterns for Africa are still uncertain (Joubert and Hewitson, 1997; Jack, 2010) due to inability of the models to replicate and project the behaviour of the ENSO (El-Nino Southern Oscillations), which have a great influence on the seasonal rainfall in parts of Africa (Hulme *et al.*, 2001). In East Africa, a maximum annual increase of 25% is expected for rainfall with the greatest increase in (September, October, November (SON) although some areas will experience drying of up to 3% with the greatest decrease appearing in (June, July, August) JJA. From the MAGICC/SCENGEN, analysis of annual precipitation over the whole of

Tanzania is projected to increase by 10% by 2100, although seasonal declines of 6% are projected for June-August (JJA) seasons, and increasers of 16.7% for December- February (DJF) seasons (Hulme *et al.,* 2001). Although predictions from different models give somewhat varying predictions, a general trend show that the Rufiji basin will experience highest rainfall increases of up to 30% along the coast (Lower Rufiji) and south eastern part of the basin (Mwandosya *et al.*, 1998). Increased rainfall will be experienced from January to November with highest increment of 1.4 mm in December and lowest increment of 0.7 mm in May (Mwandosya *et al.*, 1998; Mgaya, 2004).

The future projected climate change for the RUMAKI based on downscaled Dar es Salaam station suggest a decrease in rainfall during the main dry season (June – October) and an increase during the rest of the year (Figure 4.7). Rain day frequency shows the same general tendency and is associated with an increase in dry spell duration during the dry season (Figure 4.8).

4.3.3 Trends in Extreme Weather Events

Tanzania has experienced increased frequencies of extreme weather events (floods, droughts and tropical storms) with six major droughts occurring over the past 30 years (GIZ, 2012). Studies by Bantje (1979) and Ochieng (2002) in the lower Rufiji shows that, the frequency of floods has increased since 1935. Prior to 1935, serious floods with major crop damage occurred only once in every 12 – 15 years (recorded in 1875, 1890, 1905, 1917 and 1930). After 1935, serious floods with damaging effects to crops occurred at a much higher frequency (1936, 1940, 1942, 1944, 1945, 1956, 1958, 1959, 1962, 1963, 1964, 1968, 1972, 1974, 1979 etc.). Further concluded that these floods were not linked to climate as there was no corresponding rainfall increase but rather it was a result of land use change.

Rainfall and flooding are the two dominant environmental factors in Lower Rufiji catchment that control agriculture and the livelihood of people. In good years, they both complement each other so as to create favourable conditions (especially for rice cultivation). In bad years, their interaction may result in either drought or disastrous flooding. According to Bantje (1979), good or poor harvest is determined by the quantity, timing and duration of both rainfall and flooding, and these conditions vary from year to year. A failure of short rains may cause food shortage unless rainfall and flooding in the flooding season are favourable. Thus, if the failure of short rains is followed by no floods (i.e. prolonged draught), poor harvest of both maize and rice will result, leading to serious famine (Table 4.1). However, if the failure of short rains is followed by adequate floods, good *mlau* harvest would result with poor maize harvest, leading to less serious famine. The other scenario of a good short rain season followed by poor flood season would lead to a more serious famine than the scenario of poor short rain season followed by good flood season. Several studies in the area recognize that the exceptional potential of Lower Rufiji lies in the floodplain

(rather than the upland areas), which has its fertility regenerated yearly by the river flood (e.g. Cook, 1974; Kajia, 2000; Ochieng, 2002).

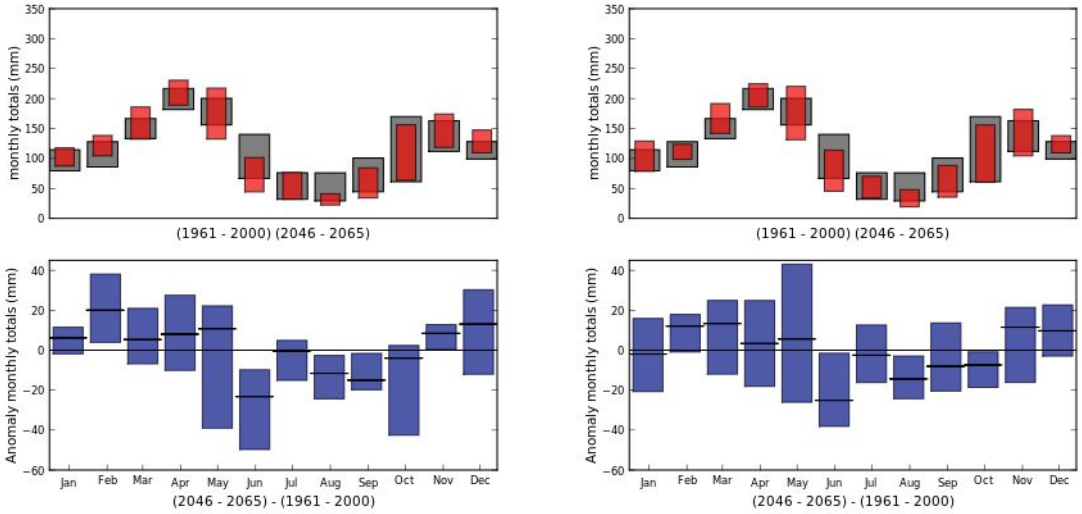


Figure 4.7: Change in monthly total rainfall for Dar Es Salaam station under SRES A2 (left) and SRES B1 (right) emission scenario.

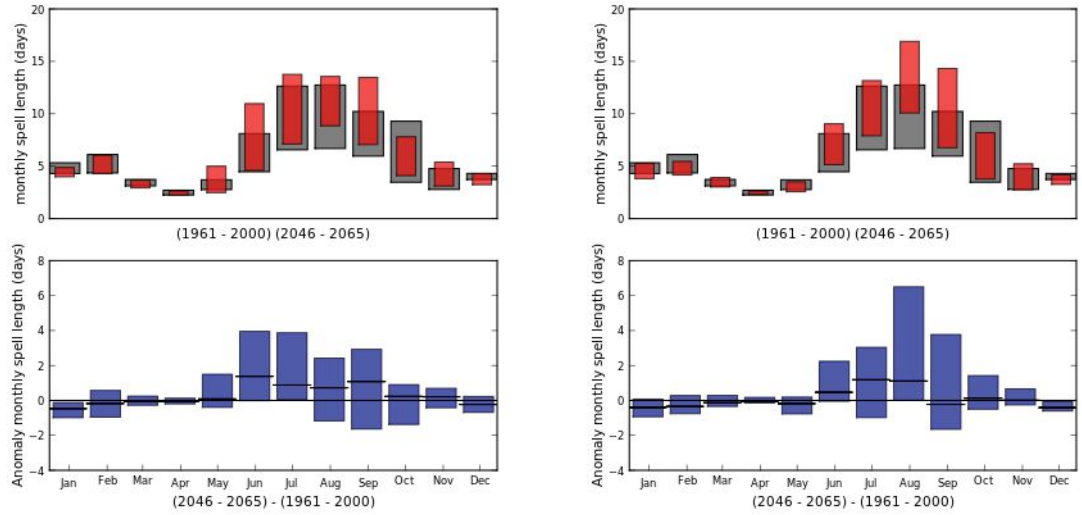


Figure 4.8: Change in monthly mean dry spell duration for Dar Es Salaam station under SRES A2 (left) and SRES B1 (right) emission scenario.

Table 4.1: Review of food shortages recorded in the Rufiji valley over the past 100 years.

Year	Remarks
1880/81	Famine caused by prolonged drought
1884	General famine caused by drought
1893/95	General famine caused by drought, locust invasions, and Ngoni raids
1898/1900	General famine caused by failure of three successive rain seasons
1906/07	Famine caused by the disruptions and destruction caused by the Maji Maji war, aggravated by the serious flood of 1905
1917	Famine caused by depletion of man-power by war and the highest flood in history
1924/25	Famine caused by drought and failure of the flood in two successive years
1929/30	Crop failure and famine caused by drought in April/May 1929, high flood and Locusts invasion.
1934	Local famine in Mohoro village caused by Locust plague
1936	Famine caused by a heavy flood
1940	Famine caused by high flood which destroyed early crops, and drought
1941	Main rains failed
1943/44	Poor rice and maize harvests caused by failure of short rains and heavy flooding
1945	75% of rice destroyed by very long and severe flood
1946	Food shortage caused by failure of short rains
1948	Local food shortage caused little rain and little flooding
1949	Famine caused by drought (no *Mlao* crop)
1950	Famine continues at the beginning of the year
1952	Crops destroyed by drought and flood
1953	Poor crop harvests caused by the continued drought and failed flood
1956	Famine caused by heavy flood and drought, with failure of short and long rains
1958	Poor crops harvest caused by drought and high flood
1962	Famine caused by heavy flooding
1963/64	Seasonal food shortage due to crop damage caused by early and heavy rains
1965/66	Seasonal food shortage due to drought with little flood
1967	Food shortage caused by high flooding (very wet year)
1968	Complete loss of crops caused by the biggest flood ever
1971/72	Famine caused by drought
1973/74	Famine caused by drought
1974	Famine caused by loss of crops due to flood disaster
1976-1978	Food shortage in the upstream villages
1978/79	Extensive crop damage resulted in the loss of almost all rice and maize. Caused by the 1979 flood

Source: Bantje, 1980

4.4 Trends in other water Resources

There are three existing dams in the Rufiji River (Mtera, Kidatu and Kihansi) and one proposed dam at Stiegler's gorge. All these dams were constructed for hydropower production although there are proposals to use them for irrigation and other uses (Havnevik, 1993). The three dams have so far not brought any significant impact on the flow regime (Yawson *et al.*, 2005).

Trends in lakes is related to the connection between the flood plain lakes and the Lower Rufiji River which is mostly influenced by rainfall and flows from the upstream part of the Rufiji basin (Arthurton *et al.*, 2008). However, his connection does not occur every year. Frequencies of no connection were observed for Mtanza (2003-2005), Zumbi (2001 and 2005) and Umwe. In some years the lakes connected for only few hours e.g. Mtanza (2006 and 2007) and Zumbi (2003 and 2006). In 2008, Mtanzalake connected for only one week. The Uba Lake connected only in 2002 and the water level has declined by 6 m since then resulting into increased salinity. Although Lake Umwe connected in 2002 only, the water level has so far remained stable indicating possibility of groundwater recharge.

4.5 Historical River flow data

There are mixed trends of changed and fluctuating trends reported for the Rufiji basin. For annual average flow, increased flow is reported for Little Ruaha (from 1977/78 peaking at around 1980/81 then dropped) while Great Ruaha annual average discharge decreased from the 1990s. However, Kashaigili *et al.* (2006) reported no significant trend for average annual flow at Msembe Ferry station for the period between 1958 and 2004, but the dry season flow has decreased significantly (Figure 4.9). The Upper Kilombero sub-basin shows a declining trend in river flow.

Rivers in the Ruvuma and Southern coast basin of which Kilwa is part of shows a fluctuating trend for both annual average discharge and annual maximum and minimum discharges. The highest flows were recorded in 1961/62, 1967/68, 1970/71 and 1978/79 while lowest flows are recorded in early 1970s (Figure 4.10).

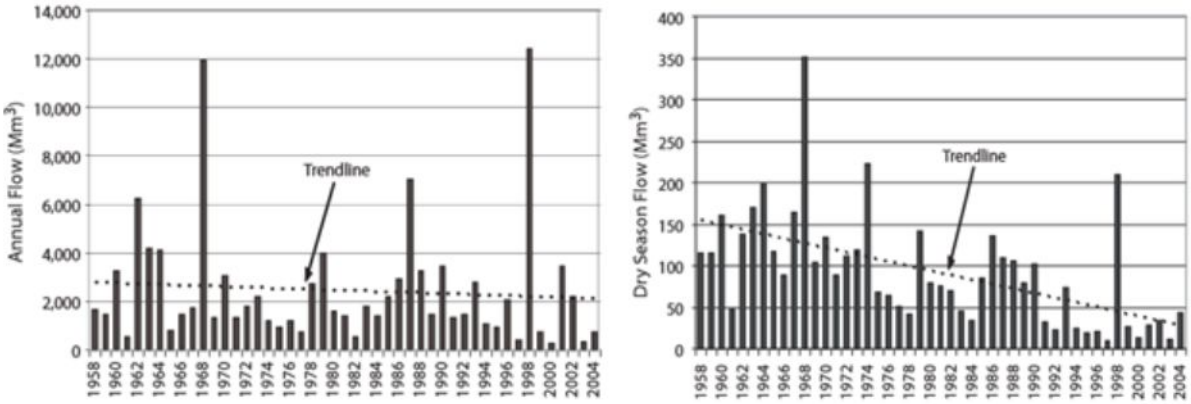


Figure 4.9: Annual and dry season flows in the Great Ruaha River at the Msembe Ferry (Kashaigili *et al.*, 2006).

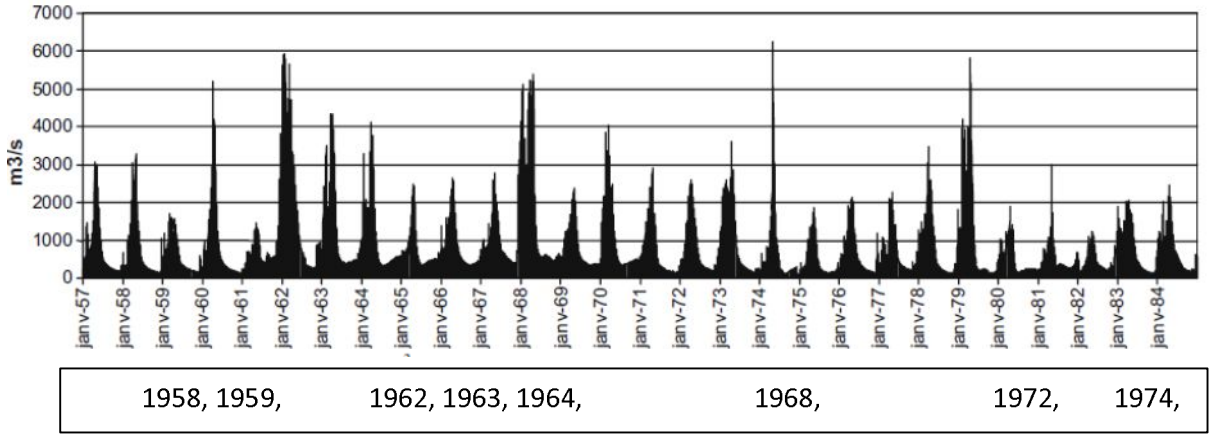


Figure 4.10: Daily discharge at Stiegler's Gorge in m3/s (1957–1984) (Duvail and Hamerlynck, 2007).

4.5.1 Projections in river flows/ Runoff

A number of studies carried out in the Rufiji basin projects an increase in stream flows (Mwandosya *et al.*, 1998; Tumbo, 2014). Rufiji River is projected to have increased flow with maximum peak discharge for the rainy season twice the present peak discharge. Mtera and Kidatu are also projected to have increased flows of 5 percent and 11 percent respectively. Increase in average, maximum and minimum flow is predicted for Upper Great Ruaha, Little Ruaha, Kilombero while the Kisigo sub basin will not experience any changes. Preliminary results based on three GCM-RCM combinations (NCC_RCA4, MPI-ESM_CRCM5 and MIROC5_RCA4) on the GRR sub-basin downstream of the Usangu wetlands clearly indicate a shift in mean discharge (Figure 4.11). There are notable changes in both high and low flows. In all three GCM-RCM combinations, low flows are lower than the historical flow conditions, while high flows are higher than historical flow conditions (Tumbo, 2014). The high flows correspond to the projected increase in precipitation where results indicate a clear tendency across the RCM to increased precipitation in the wet season and decreased precipitation in the dry season with an overall annual increase in precipitation (Tumbo, 2014). Potential evapotranspiration tends to increase due to a consistent 2-3 degree temperature increase across all RCM's. The decrease in low flows is largely a result of the increased evapotranspiration and, therefore, decreased soil moisture storage (Tumbo, 2014). While this effect could lead to increased irrigation demands, these were not included as part of the initial climate change assessment (Tumbo, 2014).

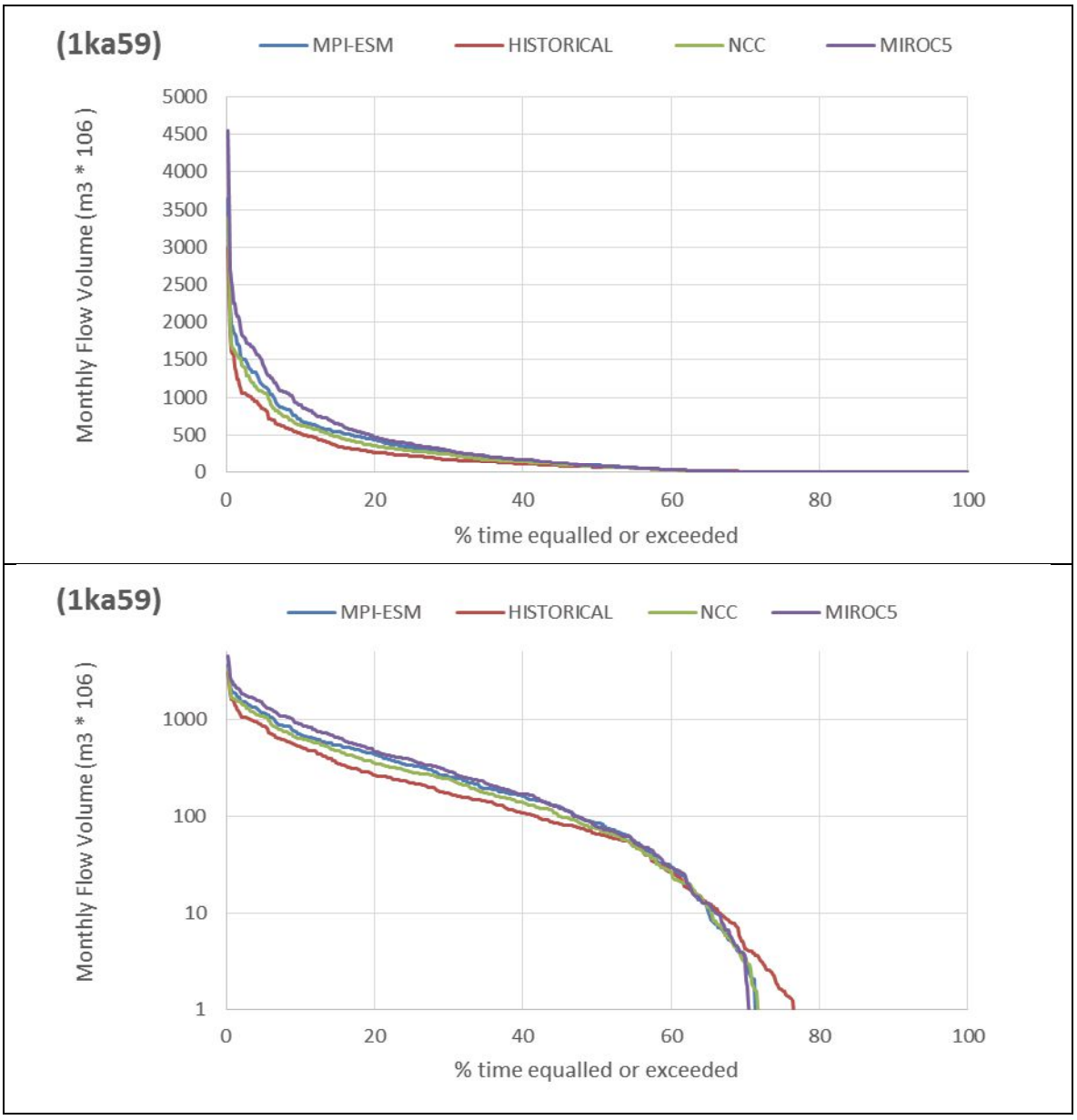


Figure 4.11: Flow duration curve plotted with normal scale (top) and logarithmic scale (below) indicating the historical and near future stream flows for sub-basin 1ka59. Red continuous line is historical stream flow for the period (1976-2005) (Source: Tumbo, 2014).

Rivers in Kilwa district are also expected to have increased flow. Mavuji River will have the highest increase in average flow while the Matandu and Mbemkuru Rivers will not have any change in minimum flow and lowest increase in the maximum flow is reported for Matandu River.

4.5.2 Relationship between rainfall and river flows

Although rainfall is the major source of water for runoff, these two parameters are not always correlated (Duvail and Hamerlynck, 2007 Arthurton *et al.*, 2008). This may be due to the complex nature of the rainfall-runoff transformation process. Together with the rainfall characteristics, runoff is a function of watershed and channel characteristics such as size of watershed, soil type and land use in the catchment. The amount of runoff generated from rainfall is very sensitive to slight changes in the rainfall (SMUWC, 2001). A small change in rainfall (-15%) can cause a large change in recharge (-45%) and hence base flow decrease. For most southern African regions observations shows an insignificant relationship between rainfall and inter-annualflows while seasonal flows showed similar trends to rainfall. According to Arthurton *et al.* (2008), a short record length could explain this; a longer record length will produce a significant relationship.

4.6 Impacts of projected rainfall trends on ecosystems on selected ecosystems

Evidence is mounting regarding existing trends in and projections for increases in precipitation in some coastal areas in Tanzania (Mwandosya *et al.*, 1998). Climate change involves many changes to the physical environment that affect coastal systems. Changes in precipitation patterns include seasonal and annual amounts, intensity (millimeters/hour), frequency, storm duration, severity and duration of droughts, variability, locations of storm tracks, and the occurrence of major storms. Changes in precipitation patterns in turn can affect runoff, flooding, erosion, sedimentation, water quality, vegetation, navigation, and many other processes and factors important to the sustainability of coastal ecosystems and human health.

4.6.1 Impacts of projected rainfall trends on Mangroves

Mangroves survive in sheltered shores of tropics, between mean sea level and high water spring tide. Delta mangroves are unique, as they exist in a highly saline fluctuating environment. Estuarine mangroves are highly susceptible to change since they depend on nutrient supply from rivers, which constantly migrate resulting into fluctuation in nutrients supply. The annual floods of the Rufiji River force fresh water into the delta, lowering the degree of salinity in the channels. For this reason, 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 delta is therefore a landscape with its own dynamics and it's surface changes constantly (Wagner and Sallema-Mtui, 2010). Increased incidence of flooding has already given an indication of its impacts on mangroves. The 1997-98 El-Nino is exemplary on the effect of excessive and prolonged flooding to mangroves and adjoined ecosystems. In the Rufiji Delta, Erftemeijer and Hamerlynck (2005) clearly shows how the El-Nino flooding and how human induced

pressures impacted mangroves by encroaching rice farmers compounded to limit the response in regeneration and/or shifting range of the ecosystems. Although the impact was more or less localized, a record 2% mortality was significant in altering the ecosystem processes as a result of poor drainage caused by clogging of tidal channels with excessive sediment, creating an area of a longer hydroperiod.

4.6.2 Impacts of rainfall trends on Prawns and other estuarine fish and fisheries

The amount of fish, crustaceans and molluscs catch in estuarine and coastal is directly related to the fluctuations in river flows (Grimes, 2001; Erzini, 2005). Climate change impacts might lead to change in ecological characteristics, population dynamics, changed habitats, destruction of breeding sites, occurrence and spread of some diseases and pests, changed chemical and physical characteristics of coastal waters (Yanda, 2013). It is already established from the community reports that there is tendency of prawns moving in and out of rufiji delta areas as a result of respective reduction and increase of rain freshwater in the river channel. This observation was also reported by Laizer *et al.*, 2013, when citing the case effect of 1998 El-Nino.

4.6.3 Impacts of rainfall trends on Patterns of Sediment deposition in the Rufiji delta

Sediments and the nutrients, which are carried within it, are important for productivity of plankton and seaweed. Also, they are a source of nutrients to mangroves growing in the delta. The projected increase in rainfall may lead to high sediment loads to be deposited at the delta. Increased sediment deposition has negative impacts on coral reefs and sea grass beds. Moreover, fisher deposition is reducing the depth of fishing grounds in the vicinity of delta mangroves, as it is reported in areas in front of Kiomboni village.

4.7 Sea level rise

4.7.1 Trends in sea level

On a global perspective, Sea level rises are associated with temperature increase, resulting to ocean expansion and ice melt, (IPCC, 2001). However, establishing sea level rise at local scale is more complex due to the influence of ocean currents, influencing local scale sea-levels and shifts in regional circulation patterns (Mahongo, 2009). This leads to large uncertainties in establishing trends in sea level rise. Generally, sea level rise can be established from shoreline gauges, ocean bottom pressure gauges and satellite based sensors (Mahongo, 2009). Tide gauge records in the region are not long enough to give any conclusive evidence on sea level rise. Long records of at least 50 years are needed for sea level trend analysis because of the influence of natural variability in the climate system.

There are no specific gauges for the RUMAKI seascape project area, however, information on sea level rise can be extracted from Zanzibar station since it's the only station with long record. A study on mean sea levels in trends Tanzania indicates falling sea level in Tanga (between 1962 and 1966), Dar es Salaam (between 1986 and 1990) and Zanzibar (between 1984 and 2004) (Mahongo, 2009). Figure 4.12 below shows the long-term trend on sea-level rise for Zanzibar where the observed data shows high variability and there in an increase in sea level.

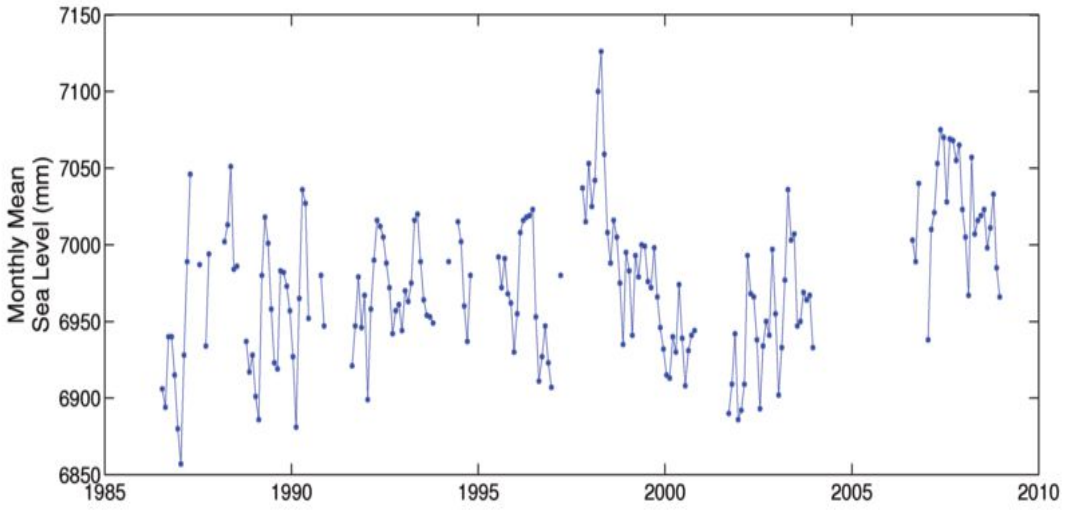


Figure 4.12: Observed monthly sea level - Zanzibar (source www.pmsl.org).

4.7.2 Sea level rise projections

Sea-level rise is expected to continue through the end of the next century and beyond, which will significantly impact coastal resources and ecosystems. Past trends provide valuable evidence in preparing for future environmental change but are insufficient by themselves for assessing the risks associated with an uncertain future. The available global assessments on impacts of sea-level rise on deltas, wetland areas and port cities identify that Africa is highly vulnerable to sea-level rise and its consequences. Based on the most recent scientific assessments sea level rises of up to one meter are likely to happen. The IPCC projects a global average increases of between 0.2metre and 0.6 metres of sea level rise over the next century, however, regional trends in SST are more complex due to shifts in ocean circulation as well as coastal effects such as upwelling. Moreover, the projected rate of sea-level rise was reported (from 1980-1999 to 2090-2099) as 0.18 m to 0.59 metres across the range of SRES scenarios (Meehl *et al.*, 2007). The trend for sea level shows an increase of between 4-6mm/year from 1992-2010.The study on sea level rise data for the Tanzanian coast show an overall rising trend from 0.4 to 2.0 mm/year (Mahongo, 2009). The same study also indicated that the sea level rise trends for the Western Indian Ocean are expected to rise from -0.4 to 2.4 mm/year (Mahongo, 2009). A contour map of the regional

model reconstruction of sea-level using a combination of in-situ gauge data and satellite altimetry for the period (1955-2005) shows a rising sea level trend in the north (1.2 mm/year) and south (2.0 mm/year). Based on these results it is clear that there is inconsistence in projected trends and it is not easy to draw an overall conclusion on sea level rise.

4.7.3 Impacts of sea level rise on selected coastal ecosystems and communities

Sea level rise is not a new phenomenon in the Rufiji Delta. Punwong *et al.*, (2012) reconstructed the Holocene mangrove dynamics and response to sea level rise and found an indication that around 4640 cal. year B.P. mangroves in the Rufiji Delta shifted landward suggesting a phase of sea level rise and later after 1170 cal. year B.P. mangrove taxa decreased, suggesting drier conditions and less inundation frequency, likely due to a receding sea level. Presence of paddy fields in place of mangroves reflects increase of human settlement in the delta, a trend that continues to date. Punwong *et al.* (2012) further noted the decrease of some mangrove species like *R. mucronata*, an observation that suggest less inundation by saline water and therefore a lower sea level albeit human pressures over the last millennium. Table 4.2 below drawn from Wagner and Sallema-Mtui (2010) show that mangroves in RUMAKI seascape have only low vulnerability to sea level rise alone, but with other pressures like wave action and extreme events such as storm surges, high water events and flooding, puts mangroves to high vulnerability. On the landward edges, however, although mangroves may be able to migrate upwards to match sea level rise under natural conditions, human interference through agriculture, settlements and infrastructure development is likely to block landward migration, thus making them more vulnerable.

4.8 Wind pattern and frequency

4.8.1 Trends in wind patterns and frequency

Observed trends in wind patterns and frequency for the Rufiji Mafia and Kilwa area are based on data spanning 28 years (1977-2004) from four meteorological stations (Tanga, Zanzibar, Dar es Salaam and Mtwara) since these are the nearest stations to the RUMAKI Seascape area but also share some physical characteristics i.e. all are coastal regions. Based on Figure 4.13 and 4.14 it is clear that the wind speeds and the frequency and intensity of tropical storms had generally been increasing during the past three decades. Similar trends have been observed in Zanzibar (Shaghude and Dubi, 2008; Mahongo and Francis, 2010) and Dar es Salaam (Shaghude, *et al.*, 2012). For Dar es Salaam the total number of days with wind speeds exceeding 10 knots (5.14 m/s) are significantly higher during the decade spanning from 1995 to 2004 than those in the previous decades (Shaghude *et al.*, 2012).

Table 4.2: Summary descriptive trends in mangrove ecosystems of RUMAKI, according to field observations and local knowledge.

Site	Locations/zones	Trends
Rufiji	Seaward edges	Annual shifts in accretion, sedimentation and erosion resulting in either loss or gain of mangrove areas.
	Landward edges	Loss of large areas of mangroves like that of 1998 El-Nino flooding Rice farming makes it difficult to determine what the natural trend would have been, either: • Sea level rise cause intrusion of mangroves landward, or • Higher sedimentation rates than sea level rise cause mangroves retreat towards the sea
Kilwa	Seaward edges	Sedimentation due to coastal run-off; generally more accretion than erosion; formation of new stands of mangroves, particularly *Sonneratia*
	Landward edges	Human pressures hinder mangroves from migrating landward
Mafia	Seaward edges	Coastal erosion due to strong wave action Mangrove loss, particularly *Sonneratia*
	Landward edges	Slope hinders mangroves from migrating landward

Source: Wagner and Sallema-Mtui (2010).

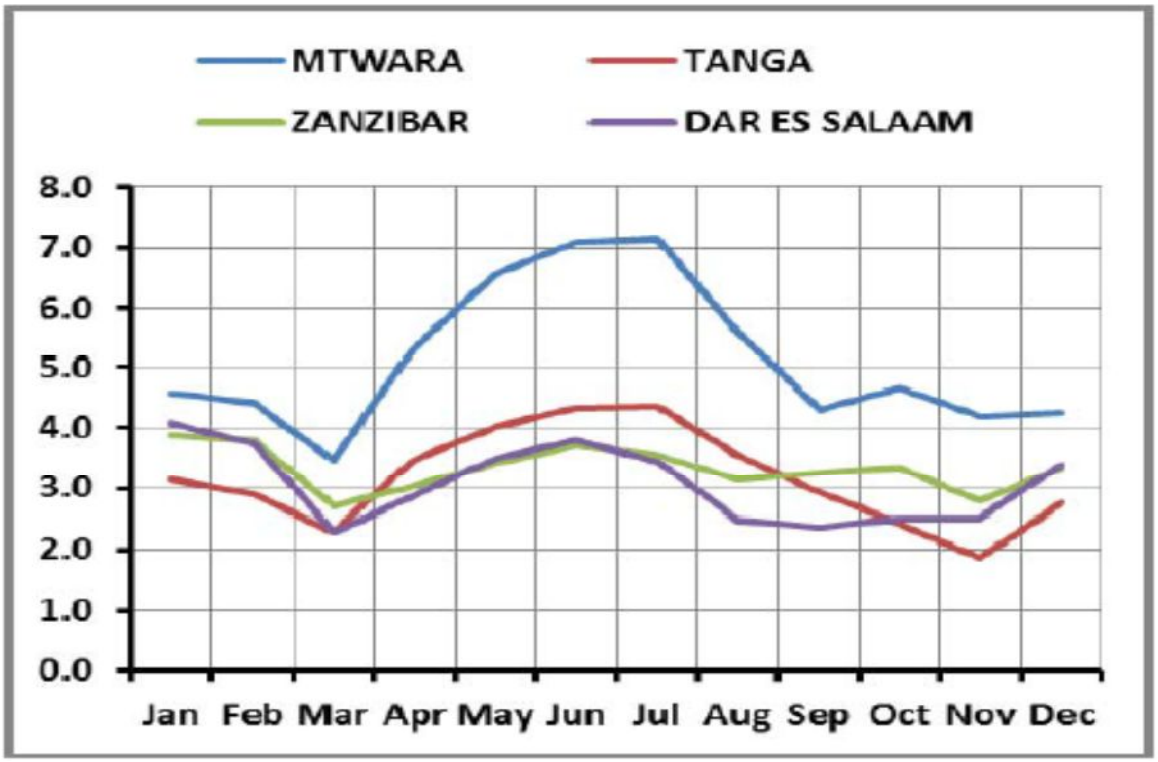


Figure 4.13: The seasonal mean wind speeds recorded at 0900 hrs local time (GMT +3). The vertical axis presents the wind speed (m/s).

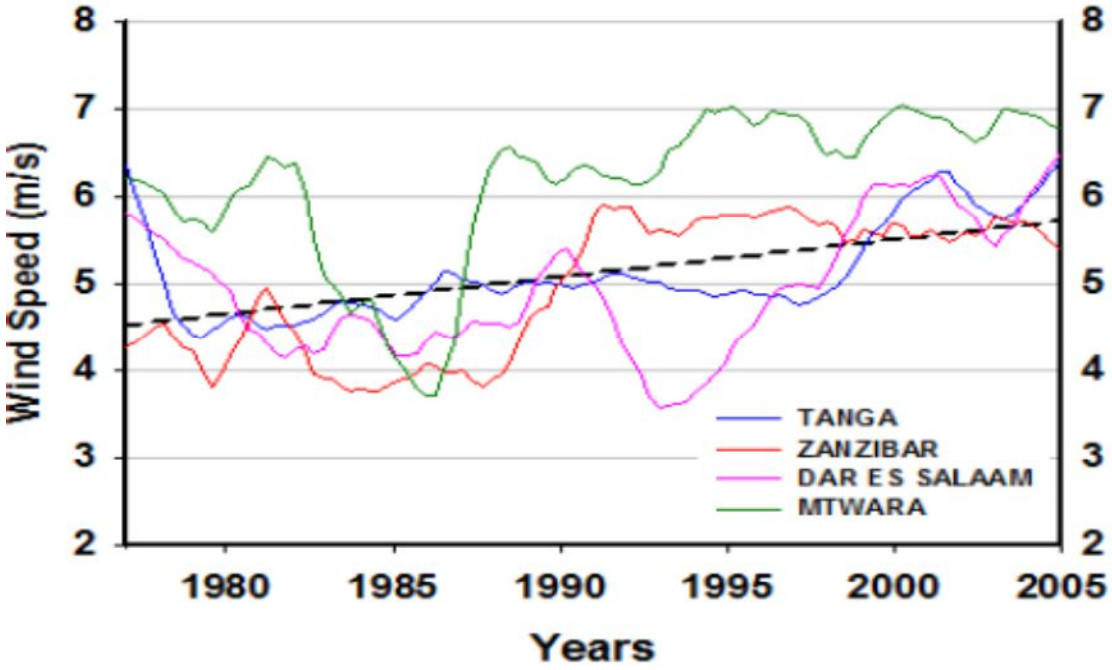


Figure 4.14: Loes smooth curves of the monthly mean wind speeds recorded at 1200 hrs local time. The dotted bold line represents the combined linear regression trend for all the stations.

4.8.2 Projections in wind pattern and frequency

Wind speeds increase from the south during March-May, whereas they decrease and become more southerly during December-February. This represents a strengthening of the southeast monsoon during March-May and a weakening of the northwest monsoon during December-February. Changes during June-November are weaker with the suggestion of weak northerly and offshore anomalies during September—November.

4.8.3 Impacts of changes in wind pattern and frequency

The protective role of mangroves to the coasts from storms is appreciated from mainly the Southeast Asia region (Dahdouh-Guebas *et al.*, 2005; Danielsen *et al.*, 2005). For the RUMAKI area, there is an on-going PhD study that deals with severe weather and its impacts on rainfall and land cover changes along the coastal Tanzania looking at the impacts of warmed tropical cyclones and storms on spatial land cover changes and vegetation productivity. This work will reveal potential impacts of cyclones on rainfall and land cover changes that a current poorly understood.

4.9 Salinity and Ocean acidification

Ocean CO_2 levels and acidification arises as a result of increase in atmospheric CO_2 levels, which leads to a decrease in sea water pH as more atmospheric CO_2 is absorbed by water as atmospheric CO_2 levels increase, more is absorbed by surface waters, decreasing. Result

from the IPCC 4th Assessment report shows a general increase in dissolved CO_2 concentrations and a decrease in pH levels across the major ocean basins over the past 15 years. There are no studies and/or data on pH and salinity trends for the RUMAKI area. In the Mafia Channel, observed salinity ranges between 34.7 and 34.95 PSU while in the Rufiji delta, salinity range 12-14 PSU inside the estuary and 20-25 PSU at the mouth of the delta.

5. VULNERABILITY AND RESILIENCE TO CLIMATE VARIABILITY AND CHANGE

This section discusses the vulnerability and resilience of ecosystems, species, livelihoods and infrastructure to climate variability and change. The vulnerability and resilience of ecosystems depends on sensitivity (a combination of resistance and tolerance. Resistance is the ability to experience exposure without impacts whereas tolerance is the ability to survive after impact. Recovery potential is the likelihood of the ecosystem to be replaced after impacts. Therefore, recovery potential and sensitivity determine the resilience of ecosystems and livelihoods to climate change. It is now widely acknowledged that coastal and marine environments are experiencing enhanced changes as a result of natural and anthropogenic induced causes (Tobey *et al.*, 2011; IPCC, 2012). The coastal and marine resources and livelihoods are vulnerable to climate variability and change due to the projected changes in sea-surface temperatures, sea level rise, changes in wind speed and direction, changes in rain seasons (Tobey *et al.*, 2011). This vulnerability is exacerbated by other factors such as coastal erosion, deforestation of mangrove forests, unsustainable utilization of coastal and marine resources, uncontrolled investments along the cost etc. Further, the overexploitation of offshore fisheries is linked to the impacts on the food security of coastal populations. Other key concern is related to the modification of river flows to the coast by damming and irrigation, and pollution from land, marine and atmospheric sources (Crossland *et al.*, 2005). Population increase and migration to coastal areas are putting resources under increasing pressure, and people are resorting to practices to cater for their needs, which are increasingly environmentally damaging (Francis and Torell, 2004).

Projected climate change impacts on coastal and marine environments includes:

- Degradation and destruction of coastal ecosystems, such as mangroves and coral reefs, that function as buffers to increased storm activity leading to coastal erosion, and as important habitats for fish and other marine species providing an important food source for coastal populations;
- Coastal erosion (due to sea level rise and increased storm activity) leading to destruction of coastal infrastructure, floods and droughts affecting coastal agriculture; mangroves and saline water intrusions into coastal aquifers.

5.1 Fisheries and aquaculture based livelihoods

Based on projected changes on climate parameters the vulnerability of fishery-based livelihoods may substantially increase. Increasing temperatures, altered precipitation

patterns, sea-level rise, ocean acidification, and changes in dissolved oxygen concentration all affect the structure and productivity of marine and coastal ecosystems and fish populations. Exposure, sensitivity, and adaptive capacity influence the vulnerability of fishery-based livelihoods in different ways. However, it should be noted that communities that are most exposed are not necessarily the most sensitive or least able to adapt. Therefore, the climatic stresses and shocks have unequal impacts in different fishery-dependent communities. Having the least adaptive capacity does not necessarily make a household or a community most vulnerable because of its lower sensitivity and/or exposure. But within a fishing community, where households are similarly exposed, higher sensitivity and lower adaptive capacity combine to create higher vulnerability.

RUMAKI seascape has been affected by excessive rainfall and flooding, storm events and drought. Extreme weather events such as cyclones and floods may further intensify these impacts by disrupting fishing operations and land-based infrastructure (IPCC, 2013). The land-based assets can also be deteriorated by sea-level rise, coastal erosion, and variations in temperature and rainfall. These impacts may result in vulnerability of fishery-dependent livelihoods in the RUMAKI seascape. Further, small-scale fishing communities are considered especially vulnerable to the negative impacts of climate variability and change.

5.2 Agriculture and livestock based livelihoods

Understanding where vulnerabilities to climate lie is crucial to knowing where to focus efforts in mitigating future risks. In the past the RUMAKI sea-scape area have been affected by excessive rainfall and flooding, storm events and drought (Ndensanjo, 2009; Hamerlynck *et al.*, 2011; Laizer *et al.*, 2013). The Rufiji Mafia and Kilwa districts just like other coastal regions of Tanzania, is very sensitive to changes in temperature and precipitation which in turn impacts food production as well as availability of pasture and water for livestock (UNEP, 2009). According to Laizer *et al.* (2013), food security in the three districts of Rufiji, Mafia and Kilwa is mainly determined by rainfall availability because the majority of Rufiji-Mafia-Kilwa people are directly dependent on rain-fed agriculture for their food and/or livelihoods. This is supplemented across many villages by fishing, with fishing becoming the primary livelihood for food and cash in those villages close to shore or with little access to land, particularly in Mafia and Kilwa. The major climate-related hazards associated with climate change are droughts and extreme flooding events. Other climate-related phenomena, such as strong winds, storms and beach erosion also pose a serious threat to local livelihoods, though they occur less frequently (Laizer *et al.*, 2013). All these changes increase the vulnerability of livestock and agriculture to climate change impacts.

In the Lower Rufiji, the past decade has been characterized by an unprecedented series of dry years with 2003, 2004, 2006 and 2007 totalling less than 600 mm rainfall in Utete (all four are among the 10 driest years since 1923), and 2000, 2001, 2002 and 2005 all totalling

less than 730 mm, well below the long-term average of 860 mm (1923–2008) (Hamerlynck *et al.*, 2011; Yanda, 2013). This local drought was accompanied by a series of low flood peaks, which led to severe food insecurity in the Rufiji District, requiring the distribution of some 500 t of food aid in 2003 and 2006 (A.B. Mwakalinga, unpublished data). The western floodplain was especially hard hit, partly because the 1997–1998 El Niño related floods (Erftemeijer and Hamerlynck, 2005) deposited vast quantities of sand in the lowest-lying and normally fertile areas around the main river bed, and also because a man-eating lion (Baldus, 2004) caused people to abandon their farms south of the river. These became overgrown and have only recently been re-opened to cultivation.

5.3 Vulnerability and resilience of coral reefs and mangrove ecosystems

5.3.1 Coral reefs

Rising of sea surface temperatures is one of the major threats to coral communities. High SST leads to severe bleaching of coral reefs (Obura, 2008). The amount of damage from bleaching depends not only on the rate at and extent of climate change, but also the ability of reefs to cope with change. Currently, coral reefs are under pressure from human activities such as unsustainable fishing, coastal developments, deforestation of coastal forests etc. The current pressures on corals combined with climate change reduce the resilience of systems and its ability to cope with climate change impacts. The study of vulnerability and resilience of coral reefs of RUMAKI was done based on benthic cover coral size class and distribution, coral condition including bleaching, diseases, fish herbivory functional groups and resilience indicators. All these factors are well explained in Obura (2008) and will not be repeated here. Results from Obura (2008), indicates that the large delta and flow regime of the Rufiji River is clearly the defining feature of coral reef ecosystems of Mafia and Kilwa including Songo Songo Archipelago. For example, recovery of coral reefs since the 1998 bleaching event has been variable with sites that are protected by turbidity and that suffered low mortality (< 50%) generally appearing near their apparent pre-bleaching coral cover while those that suffered higher levels of mortality and with little influence of turbidity are still at < 50% levels of recovery. The delta in particular offers protection with respect to climate change and increasing seawater temperatures. Mangrove systems trap sediment, preventing delivery to the sea, while at the same time releasing large amounts of organic material into the water column which contribute to high turbidity of waters within the Songosongo and inner Mafia waters, preventing bleaching and mortality. Maintaining the Rufiji delta intact may be of critical importance in protecting the reefs of the Mafia-Songosongo system, particularly now with increasing seawater temperatures due to climate change

5.3.2 Mangroves

According to the survey by Wagner and Sallema-Mtui (2010) and Ellison (2012) vulnerability and resilience of mangroves in RUMAKI complex are partly defined by the dynamics of erosion and accretion which are particularly pronounced in the Rufiji Delta than Kilwa and Mafia, generally overriding impacts of sea level rise where human pressures (land use change and infrastructure development) would not be a constraint to landward transgression. In Mafia, mangroves are subject to considerable reduction or complete loss in area coverage because of the characteristic steep slopes above the high water mark. Anthropogenic pressures increase the vulnerability of the mangroves to climate change impacts, if they continue unchecked. Table 5.1 below presents a brief description of the predictions on mangrove vulnerability in RUMAKI as summarized from adapted from Wagner and Sallema-Mtui (2010).

5.4 Freshwater

Studies on the impacts of climate change on water resources in the Rufiji basin, predicts increased flows. Mwandosya *et al.* (1998) predicts increased flows of 5-11% in the Rufiji basin by 2075 based on the 2XCO2 scenario, while the de Wit and Stankiewicz study project a rise in perennial drainage to a total of 136% in central Tanzania and 125% in northwest Tanzania, based on a 10% rise in rainfall by the end of this century. In GRR sub-basin flows are also expected to increase (Tumbo, 2014). Both sets of data thus project increased flows in parts of Tanzania, though they vary on the total percentage of the increase. In interpretation of the results above, it must be noted that other drivers of climate and water resources were either not considered or inadequately incorporated in the GCM/RCM. For example, land use change was not sufficiently addressed in GCMs (Hulme *et al.*, 2001), though there are ongoing efforts to quantify the interaction between land use change and regional climate change (Olson et al., 2008). Land use change also has a major impact on runoff and thus is potentially a strong influence on downstream water availability, both in terms of quantity and quality. The impact of ENSO is also an issue in GCMs, with the response of ENSO events to global warming poorly understood (Hulme *et al.*, 2001), which affects climate change projections and also may impact on future estimates of water resources. In summary, one of the major vulnerability of water resources in the RUMAKI area is the high degree of uncertainty of future projected changes in river flows. In addition to the biophysical uncertainties, projections of socio-economic factors – especially population growth and the rate of urbanization – are also unsure and may further increase the vulnerability of the water resources in the RUMAKI.

Table 5.1: Summary predictions on vulnerability of mangroves in RUMAKI to various pressures and recommended adaptive strategies/management responses.

Site	Pressures	Zone/location	Vulnerability	Adaptive strategies/ management responses
Rufiji	Sea level rise	Seaward edges	Shoreline, river banks erosion and seawater intrusion	Little can be done
		Landward edges	Landward mangrove migration where there would be no human interference	• Creation of buffer zones along upper edges • Ban rice farming rice farming in the buffer zone especially northern block • Planting suitable mangrove species along upper edges and in abandoned rice farms
	Extreme events: storms, flooding	Landward edges	Mangrove mortality and habitat loss likely be species specific	Mangrove replanting with original or other appropriate species
	Overexploitation	Primarily inner areas	Loss of mangrove habitat, diversity and biomass	• Awareness and sensitization • Enforcement • Replanting mangrove cut species
	Conversion to rice farming	Landward edges	Loss of mangrove habitat, diversity and biomass	
Kilwa	Sea level rise	Seaward edges	Sediment accretion from coastal runoff Mangrove migration	Natural colonization and seaward shift
		Upper edges	Landward migration where no human interference	Create buffer zone with no agriculture, settlement and infrastructure development
Mafia	Sea level rise and storm surges	Seaward edges	Coastal erosion, mangroves habitat loss, low sediment input	Natural dynamics
		Landward edges	Steep slope hinder mangrove migration landward	
		Saline areas within forest	Mangrove migration into saline areas	Natural shift of mangroves into saline areas keep pace with sea level rise Planting of appropriate species
		Flat lowland coastal areas	Gradual mangroves shift/colonization of lowland areas landward	• Create buffer zone • Plant selected mangrove species

Source: Wagner and Sallema-Mtui (2010).

6. POLICY AND STRATEGIES

Implementation of climate change issues in Tanzania falls within the National Environmental Policy, 1997 and the Environmental Management Act 2004 and other related policies and legislations. At national level, the Vice-Presidents office Division of Environment (DoE) is responsible for all climate related activities. The DoE is both the NCCFP and Designated National Authority (DNA) for clean development mechanism under the Kyoto Protocol.

The Fisheries Policy of 1998, National Water Policy 2002 and the Fisheries Act of 2003 are the main national guiding the management of freshwater and marine fisheries. Other legislation relevant for the management of the RUMAKI sea scape includes the Environment Management Act 2004, the Wildlife Act 2009 the Forest Act (2000), the Land and Village Land Acts (2001), Irrigation policy 2009, and Irrigation Act 2013, National Integrated Coastal Management Policy 2003, National Wildlife Policy, Marine Parks and Reserves Act 1994, National Water Policy 2002, National Water Management Act, 2009. The management and conservation of coastal and marine environments have been strengthened through the development of the National Integrated Coastal Environment Management Strategy in 2002 (URT, 2003b). The strategy provides a framework to overcome the previously dominated, fragmentation inherent in single-sector approach to coastal and marine resource management (URT, 2003b).

The national environmental management act provides for measures on climate change where ministries and independent government departments to put in place strategies and action plans to deal with climate change and to advise schools and higher learning institutions to include matters relating to climate change in their curriculum. Furthermore, EMA provides for the establishment of various committees at both national and local levels. At national level, there is an established NCCSC chaired by Permanent Secretary of the VPO. This committee provides policy guidance to the NCCFP ensure coordinated actions and participation within various sectors and institutions. There is also NCCTC chaired by the Director of Environment, which is geared to provide technical advice to the NCCFP, stimulate more coordinated actions of actors and broaden the participation of various actors in addressing climate change.

Climate change issues are not included in Fisheries Policy and Act and most policies related to natural resources management, including marine and coastal environments the reason being that, most policies and acts were developed prior to National Environmental Management Act and the National Adaptation Plan of Action.

6.1 National Adaptation Plan of Action (NAPA)

Enhancing national adaptive capacity has been the most important area in addressing climate change in Tanzania. Responses to climate change have been commonly categorised as either aimed at reducing the rate at which climate is changing to levels that occur naturally (and especially reducing the atmospheric concentrations of GHGs, so-called "mitigation") or responding to the adverse effects of climate change ("adaptation"). NAPA is the framework, which guides climate change adaptation priorities in Tanzania. The overall aim is to identify immediate and urgent adaptation action that is robust enough to lead to long-term sustainable development in a changing climate (URT, 2007). Within NAPA as well as other relevant literatures climate change has been recognised as one of the potential threats to marine and coastal environments, and livelihoods. Climate induced threats are related to sea level rise and increase in both sea-surface temperature and air temperatures (Yanda, 2013). The focus of the current Tanzania NAPA work has been on adaptation needs in the agriculture, water, energy, health and forestry sectors (URT, 2007).

Coastal and marine resources ranked 9th out of 11 priority sectors identified in NAPA (URT, 2007). The ranking of marine and coastal resource has received very little attention in terms of government priorities, however, it should be noted that every sector will be impacted differently by climate change impacts and adaptation measures will be developed and implemented differently depending on the need of a specific environment and/or community. Moreover, the selection of priority sectors was done in a subjective way, given the fact that the overall approach for the development of NAPA relied upon stakeholder's perceptions and literature reviews, which makes the identified to be highly uncertainty. Future climate trends are uncertain and the uncertainty rises steeply over the longer-term. Therefore, any planning for adaptation must therefore be able to adjust to changing circumstances and timeframes. For this reason, the implementation of the Tanzania NAPA needs to plan flexibly for a wide range of possible responses over the medium- to long-term. There is also a need for monitoring and evaluation systems to update our knowledge of how rapidly and where the change is occurring and the effectiveness of adaptation responses.

6.2 National Climate Change strategy (2012)

An effective Tanzania climate change response requires economic, social and environmental interventions that integrate mitigation and adaptation elements within a developmental framework. Furthermore, an effective climate change response also requires the management of any response measures generated by our action as well as being able to respond to activities that have negative consequences on the environment and livelihoods. The Tanzania Climate Change Strategy (2012) provides details for the strategic adaptation, mitigation and cross- cutting interventions in key economic sectors. There exist environmental planning in the context of the Environmental Management Act, 2004,

however a clear institutional arrangements is still required to address all aspects of climate change mitigation and adaptation in each sector. To address this, the government has undertaken several efforts including undertaking a *Quick Scan on the Impacts of Climate Change in 2009*; preparation of the *National Adaptation Programme of Action in 2007*, *CDM Guide for Investors in 2004* and *the Initial National Communication to the UNFCCC in 2003*. The national climate change strategy builds on the already existing information to enhance the technical, institutional and individual capacity of the country to address the impacts of climate change (URT, 2011). It is expected that the implementation of the strategy will enable the country to put in place measures to adapt to climate change and mitigate GHG emissions in order to achieve sustainable national development through climate resilient pathways (URT, 2011). Table below shows strategies on climate change adaptation for the marine and coastal environments.

Table 6.1: Climate change adaptation strategies for the marine and coastal environments.

Strategic statement	Goal	Strategic Objective	Strategic Intervention
Coastal and marine environment, harbours enormous ecosystem goods and services that are vital for life.	To sustain availability of coastal and marine ecosystem goods and services.	a) To promote sustainable management of coastal and marine environment	a) Establishing mechanisms for coastal erosion control
		b) To strengthen coastal and beach erosion control systems	b) Promoting alternative sources and technologies to enhance water availability
		c) To promote sustainable management of coastal and marine environment	c) Promoting sustainable coastal land use planning
		d) To strengthen coastal and beach erosion control systems	d) Enhancing protection and conservation of coastal and marine ecosystems
		e) To promote livelihood diversification for coastal communities	e) Enhancing decentralization of coastal systems management.
			f) Supporting alternative livelihood initiatives for coastal communities

6.3 On-going climate change adaptation projects

The Vice president's Office division of environment is implementing the project "Implementation of Concrete Adaptation Measures to Reduce Vulnerability of Livelihoods and Economy of Coastal Communities of Tanzania" funded by the Adaptation Fund Board. The objective of the project is to reduce vulnerability of ecosystems, infrastructure and economy in Tanzania through implementation of concrete and urgent adaptation measures.

Expected outputs from the project includes:

- Adverse impacts of Sea Level Rise (SLR) and floods on coastal infrastructures and settlements are reduced.
- Coastal ecosystems are rehabilitated and Integrated Coastal Area Management is implemented.
- Knowledge of climate impacts and adaptation is increased.

The Vice-Presidents office is also implementing the project ''Shifting of Shallow Water Wells Affected by Inundation on Coastal Regions of Tanzania Mainland and Zanzibar''. The overall aim of this project aims at constructing new water wells to enable people get reliable access to safe and clean drinking water and for other development processes. The projected is planned to run for three years with a budget of US$ 3,300,000, in the five coastal regions of Tanzania.

7. CONCLUSIONS

The RUMAKI seascape is endowed with a wide range of ecosystems and natural resources, which supports livelihoods and investment activities. Both development and livelihood activities will continue to have, a distinct impact on the socioeconomic and environmental status of the coastal RUMAKI seascape. There are many challenges facing almost all natural resources and most of them are related to exploitation of natural resources. Both over-exploitation of natural resources and infrastructure have had a widespread impact on livelihoods and ecosystems. There are also strengths and opportunities, such as potential alternative income generating activities e.g. beekeeping, provision of microfinance opportunities for business and investment and opportunities related to future investments in the area e.g cement industries and gas exploration. However, environmental degradation also remains a threat. The destruction of marine habitats, forest depletion, pollution and the potential for over-exploitation all highlight the environmental challenges confronting RUMAKI seascape and hence, increase the vulnerability to climate change impacts. While the government and NGO's has promoted sustainable development practices through a number of projects e.g the world bank funded project (MACEMP) , there are still bottlenecks towards achieving expected conservation goals. Lack of capacity has made it difficult moving forward.

Based on climate change studies in the RUMAKI seascape, it is clear that there is a great deal of uncertainty about potential impacts. In terms of rainfall, studies predict increases in some areas though there is not always agreement as to which areas will experience which type of change; most studies also predict greater intra-seasonal variability. There is some agreement on the range of possible temperature and sea-surface increases, with research suggesting it will be on the order of 1.5°C - 2°C by 2050 and around 2°C - 4°C by the end of the century. As with rainfall, the effect of climate change on river flows is uncertain, with some studies projecting increased flows in some basins while a national level analysis suggests stream flows will be only 80-90% of the 1961-1990 flows by 2100. In addition to the biophysical uncertainties, projections of socioeconomic factors – especially population growth, deforestation and the rate of urbanization – are also uncertain and may further impact of the water resources in Tanzania. However, uncertainty about the range and severity of climate change impacts does not mean responsible authorities should delay implementing adaptation measures. There is no question that human alterations of coastal ecosystems have accentuated vulnerability to climate change impacts. Environmental degradation caused multiple factors, which increases natural exposure of coastal ecosystems to climate change impacts. Coastal erosion has been exacerbated by clear cutting of mangroves has further added to environmental degradation. Addressing the root causes of that will help in reducing the exploitation and efficiency in management of coastal

resources and ecosystems. Moreover, adaptation and resilience to climate change must be undertaken at local level.

8. BIBLIOGRAPHY

Arthurton, R., Le Tissier, M., Snoussi, M., Kitheka, J., Shaghude, Y., Kane, A., Flöser, G. and H. Kremer. (2008). AfriCat: LOICZ - Global Change Assessment and Synthesis of River Catchment - Coastal Sea Interactions and Human Dimensions in Africa, LOICZ Reports & Studies No. 30, LOICZ IPO, Geesthacht, Germany.

Baker, N.E. and Baker, E.M. (2002). Important Bird Areas in Tanzania: A first inventory. Wildlife Conservation Society of Tanzania, Dar es Salaam, Tanzania. 303pp.

Baldus, R.D. (2004). Lion conservation in Tanzania leads to serious human–lion conflicts, with a case study of a man-eating lion killing 35 people. Wildlife Discussion Paper 41. GTZ Wildlife Programme in Tanzania, Wildlife Division, Dar es Salaam, Tanzania.

Ball, M.C., Cocharane, M.J. and Rawson, H.M. (1997). Growth and water use of the mangroves *Rhizophora apiculata* and *R. stylosa* in response to salinity and humidity under ambient and elevated concentrations of atmospheric CO_2. Plant Cell and Environment 20:1158-1166.

Bantje, H. (1979). The Rufiji agricultural system: impact of rainfall, flood and settlement. BRALUP Research Paper No. 62.

Bantje, H. (1980). Floods and Famines: A study of Food Shortages in Rufiji District. Bureau of Resource Assessment and Land Use Planning, Research Paper No 63. University of Dar es Salaam, Tanzania.

Bernacsek G.M. (1980). The Stiegler's Gorge hydroelectric scheme. Predicted effects on fish yields from the Rufiji River basin, Tanzania. In Report. Fisheries Division of the Ministry of Natural Resources and Tourism and the Rufiji Basin Development Authority.

BG Group (2013). Tanzania LNG project site selection: Environmental and social baseline study report

Bryceson, I. (1981). A review of some problems of tropical marine conservation with particular reference to the Tanzania coast. Biological Conservation. 20:163-171.

Burgess N., Butynski T., Gordon I., Luke Q., Sumbi P., Watkin, J. (2003). Ecosystem profile Eastern Arc Mountains and coastal forests of Tanzania and Kenya. Critical Ecosystem Partnership Fund.

Burgess, N.D. (2000). Global importance and patterns in the distribution of Coastal Forest species. In N.D. Burgess & G.P. Clarke (eds.), *Coastal Forests of Eastern Africa*. IUCN Forest Conservation Programme, Gland and Cambridge. pp 235–248.

Burgess, N.D. and Clarke, G.P. (Eds.) (2000). *Coastal Forests of Eastern Africa.* IUCN. xiii+443pp.

Burgess, N.D., Matthews, P., Evers, Y. and Woodcock, K. (2000). Human and forest interactions; non-timber uses, threats and local attitudes. In N.D. Burgess & G.P. Clarke (eds.), *Coastal Forests of Eastern Africa*. IUCN Forest Conservation Programme, Gland and Cambridge. pp 281–301.

Bwathondi, P.O.J., Chande, A.I., Bayona, J.D.R., Mhitu, H.A., Mwakosya, C.A., Shayo, D. and Kulekana, J. (2002). Investigation of prawn abundance and distribution in Bagamoyo and Rufiji areas. Report submitted to the Ministry of Natural resources and Tourism, Dar es Salaam, Tanzania. 56pp.

Caplan, P. (2002). Local Understandings of Modernity: Food and Food Security on Mafia Island, Tanzania. Tanzania Commission for Science and Technology (COSTECH). Dar es Salaam, Tanzania.

CEEST (2004). Analysis of Technical and Policy Options for Adaptation to Consequences of Climate Change for Tanzania. Rufiji Background Report.

Clarke, G.P. (2000). Defining the eastern African Coastal Forests. In Burgess, N.D. and Clarke, G.P. (Eds.) *Coastal Forests of Eastern Africa.* IUCN. pp. 9-27.

Cook, A. (1974). Land-Use Recommendations for Rufiji District. BRALUP Research Report No. 11, UDSM.

Crossland, C.J., Kremer, H.H., Lindeboom, H.J., Marshall Crossland, J.I. and Le Tissier, M.D.A. (eds.) (2005). *Coastal Fluxes in the Anthropocene –The Land-Ocean Interactions in the Coastal Zone Project of theInternational Geosphere-Biosphere Programme.* Global Change – the International Geosphere-Biosphere Program Series. Springer, Berlin.

Dahdouh-Guebas, F., L.P. Jayatissa, D. Di Nitto, J.O. Bosire, D. Lo Seen and N. Koedam. (2005). How effective were mangroves as a defence against the recent tsunami? Current Biology 15: 443-447.

Danielsen,F., Sørensen, M.K., Olwig, M.F., Selvam, V., Parish, F., Burgess, N.D., Hiraishi, T., Karunagaran, V.M., Rasmussen, M.S., Hansen, L.B., Quarto, A. and Suryadiputra, N. (2005). The Asian Tsunami, A Protective Role for Coastal Vegetation. Science 310: 643.

de Boer, M.N., Baldwin, R., Burton, C.L.K., Eyre, E.L., Jenner, K.C.S., Jenner, M-N.M., Keith, S.G., McCabe, K.A., Parsons, E.C.M., Peddemors, V.M., Rosenbaum, H.C., Rudolph, P. and Simmonds, M. P. (2002). Cetaceans in the Indian Ocean Sanctuary: A Review. Science report. Whale and Dolphin Conservation Society (WDCS).

Deser, C., A. S. Phillips, and M. A. Alexander (2010). Twentieth century tropical sea surface temperature trends revisited, *Geophys. Res. Lett.*, 37, L10701, doi:10.1029/2010GL043321.

Duke, N.C., Ball, M.C. and Ellison, J.C. (1998). Factors influencing biodiversity and distributional gradients in mangroves. Global Ecology and Biogeography Letters 7: 27-47.

Duvail S. and Hamerlynck O. (2007). The Rufiji River flood: plague or blessing? Int J Biometeorol 52: 33–42.

Ellison, J.C. (2012). Climate Change Vulnerability Assessment and Adaptation Planning for Mangrove Systems. Washington, DC: World Wildlife Fund (WWF).

Erftemeijer, P.L.A. & Hamerlynck, O. (2005). Die-Back of the Mangrove *Heritiera Littoralis* Dryand, in the Rufiji Delta (Tanzania) Following El Niño Floods. Journal of Coastal Research 42: 106-113.

Eriksen, T., Halberg, K, Lehmberg, T., Petersen, F.S. (1994). A survey of bird life in five Coastal Forests of southeastern Tanzania. 1993. BirdLife Denmark, Zoological Institute, University of Copenhagen, Copenhagen.

Erzini, K. (2005). Trends in NE Atlantic landings (southern Portugal): Identifying the relative importance of fisheries and environmental variables. Fish Oceanogr. 14: 195–209.

FAO (1961). The Rufiji Basin, Tanganyika. Report to the Government of Tanganyika. Rome.

FAO (1995). Forest resources assessment 1990. Global Synthesis. FAO, Rome.

Fauchereau N, N., Trzaska, S., Rouault, M.and Richard, Y. (2003). Rainfall Variability and Changes in Southern Africa during the 20th Century in the Global Warming Context. Natural Hazards 29: 139–154. Kluwer Academic Publishers. Netherlands.

Francis, J. and Torell, E. (2004). Human dimensions of coastal management in the Western Indian Ocean region. *Ocean and Coastal Management* 47 (7-8): 299-307.

Francis, J., Mahongo, S. and Semesi, A. (2001). The coastal environment. In: Eastern Africa atlas of coastal resources of Tanzania. UNEP. Nairobi, Kenya.

Frazier, J. (1975). Marine turtles in Tanzania. Report to the Ministry of Natural Resources, Tanzania

GIZ (2012). Support to the Water Sector Reform. Climate Change Stakeholder Survey. Stakeholders and Activities in the Water and Neighbouring Sectors in Tanzania. Final Draft.

Grimes, C. B. (2001). Fishery production and the Mississippi River discharge. Fish 26: 17–26.

Hamerlynck, O. *et al.* (2010). The large-scale irrigation potential of the Lower Rufiji floodplain, Tanzania: reality or persistent myth? In: B. Calas and C.A. Mumma Martinon, ed. Shared water, shared opportunities. Hydropolitics in East Africa. Nairobi, Kenya: IFRA and Hekima College, 219–234.

Havnevik, K. J. (1983). Analysis of Rural Production and Incomes, Rufiji District Tanzania. Institute of Resource Assessment (IRA) paper no. 3. DERAP Publications Bergen.

Hoag, H.J. (2003). Designing the Delta: A History of Water and Development in the Lower Rufiji River Basin, Tanzania, 1945-1985. PhD thesis. Boston University, USA.

Hulme M (1996). Climatic change within the period of meteorological records. In: Adams WM, Goudie AS, Orme AR (eds) The physical geography of Africa. Oxford University Press, Oxford, pp 88–102.

Hulme, M. (1992). Rainfall changes in Africa: 1931-60 to 1961-90 Int. J. Climatol. 12: 685-699.

Hulme, M., Doherty, R., Ngara, T., New, M. and Lister, D. (2001). African climate change: 1900–2100. Climate Research 17: 145–168.

IPCC (2001). *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, J.J.McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, Eds., Cambridge University Press, Cambridge, 1032 pp.

IPCC (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582pp.

IPCC (2013). Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IUCN (2000). The 2000 Red List of Threatened Species. The World Conservation Union, Gland, Switzerland.

Jack, C. (2010). Climate Projections for United Republic of Tanzania. Climate Systems Analysis Group, University of Cape Town.

Jiddawi, N.S. and Ohman, M.C. (2002). Marine Fisheries in Tanzania. Ambio 31:518-275.

Joubert A. M. and Hewitson B.C. (1997) Simulating present and future climates of southern Africa using general circulation models. ProgPhysGeogr 21:51–78.

Jung, G., Wagner, S., and Kunstmann, H. (2012). Joint climate-hydrology modeling: an impact study for the data-sparse environment of the Volta Basin in West Africa. *Hydrology Research.* 43(3): 231-248.

Kajia Y.S. (2000). Assessment of the effects of rice farming in the mangrove forests of the Rufiji Delta (mainland Tanzania). MSc thesis, Virje Univrrsiteit Brussels, Brussels. 82pp.

Kapetsky, J.M. (ed.), (1981). Seminar on river basin management and development. Blantyre, Malawi, 8–10 December 1980. Papers presented. CIFA Tech. Paper (8). 302p.

Karengi, S. (2012). The productivity og honey bees and floristic characteristics in Rufiji District. MSc thesis, Open University of Tanzania, Dar es Salaam.

Kashaigili, J. J., McCartney, M. P., Mahoo, H. F., Lankford, B. A., Mbilinyi, B. P.; Yawson, D. K., and Tumbo, S. D. (2006). Use of a hydrological model for environmental management of the Usangu wetlands, Tanzania. Colombo, Sri Lanka: International Water Management Institute. IWMI Research Report 104. 48p.

Kilwa District Council (2013). Kilwa District Socio-economic Profile.

Korrubel J and Cockcroft,V. 1997. Dire days for dugongs. Africa – Environment & Wildlife. Vol 5. No 1: 28-33.

Koutsouris, A.J., Jarsjö, J., Destouni, G., and Lyon, S.W., (2010). Hydro-climatic trends and water resource management implications based on multi-scale data in the Lake Victoria region, Kenya, *ERL*, 5.

Laizer, J., Harrison, P.J., Machano H., Samoilys, M.A. and Maina, G. W. (2013). Understanding Community Climate Change Issues in the Rufiji- Mafia-Kilwa Context: An assessment of Community Climate Vulnerability and Adaptive Capacity in the Rufiji-Mafia-Kilwa Seascape, Tanzania.

Mahongo, S.B, (2009). The Changing Global Climate and its Implication on Sea Level Trends in Tanzania and the Western Indian Ocean Region. Tanzania Fisheries Research Institute (TAFIRI).

Mahongo, S.B and J. Francis, (2010). Monthly variations of sea level at the Island of Zanzibar. Western Indian Ocean J. Mar. Sci. 9: 1-14.

Malimbwi, R.E. (2001). *Interim Reports of Forest Management in Tanzania.* Tanzania Forest Conservation and Management. Ministry of Natural Resources and Tourism, Forest and Beekeeping Division, Dar es Salaam. 30pp.

Marsh, H., Penrose, H., Eros, C. and Hughes, J. (2001). Dugong Status Report and Action Plans for Countries & Territories. UNEP/IUCN.

Masalu D.C.P. (2003). Challenges of coastal area management in coastal developing countries—lessons from the proposed Rufiji delta prawn farming project, Tanzania. Ocean & Coastal Management 46: 175–188

Meehl G.A., Stocker TF, Collins W.D., Friedlingstein P., Gaye A.T., Gregory J.M., Kitoh A., Knutti R., Murphy J.M., Noda A., Raper S.C.B., Watterson I.G., Weaver A.J., Zhao Z.C. (2007). Global climate projections. In: Solomon S, Qin D, Manning M et al., (eds) Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, pp 433-497.

Mgaya, Y.D. (2004). The vulnerability of mangrove and adjacent coral reefs to climate change in Rufiji delta. Literature review submitted to WWF Tanzania (The Eastern African Marine Ecoregion), January 2004.

Milledge, S.A.H., Gelvas, I.K. and Ahrends, A. (2007). *Forestry, Governance and National Development: Lessons learned from a Logging Boom in Southern Tanzania.* TRAFFIC East/ southern Africa/ Tanzania development partners Group/ ministry of Natural Resources and Tourism, Dar es salaam, Tanzania. 252pp.

Milledge, S.A.H. and Kaale, B.K. (2003). *Bridging the Gap: Linking Timber Trade with Infrastructure Development and Poverty Eradication Efforts in Southern Tanzania*. Dar es Salaam: TRAFFIC East/Southern Africa.

MLFD (2007). Report on marine catch assessment survey conducted in Rufiji, Mafia and Kilwa.

MNRT (2001). *National Forest Programme in Tanzania 2001-2010.* Ministry of Natural Resources and Tourism, Dar es Salaam, Tanzania. 134pp.

Mohammed SM, Muhando C.A. and Machano H. (2002). Coral Reef Degradation in Tanzania: Results of Monitoring 1999-2002. In: O Linden, D Souter, D Wilhelmsson and D Obura (eds). Coral Reef Degradation in the Indian Ocean, Status Report 2002. CORDIO, Kalmar, Sweden: 21-30.

Mohammed, M.S., Muhando, C.A. and Machano, H. (2000). Assessment of coral reef degradation in Tanzania: Results of coral monitoring in 1999. In: Souter, D., Obura, D., and Linden, O. (eds.) 2000. Coral Reef Degradation in the Indian Ocean: Status Report 2000. CORDIO. 35-42 pp.

Mongi, H., Majule, A.E and Lyimo, J.G. (2010). Vulnerability and adaptation of rain fed agriculture to climate change and variability in semi-arid Tanzania. African Journal of Environmental Science and Technology 4(6): 371-381.

Muhando C.A. (1999). Assessment of the extent of damage, socioeconomic effects, mitigation and recovery in Tanzania. In: Linden, O. and Sporrong, N. (eds). Coral reef degradation in the Indian Ocean. Status Reports and Project Presentations 1999. CORDIO, SAREC Marine Science Programme, Stockholm. pp. 43-47.

Muhando C.A. and Rumisha C.K. (2008). Distribution and status of coastal habitats and resources in Tanzania. Report submitted to WWF Tanzania Country Office– Dar es Salaam.

Muhando, C.A. (2003). Trends in Reef Benthos After the 1998 Coral Bleaching Event in Mafia Island Marine Park, Tanzania. Institute of Marine Sciences, Zanzibar.

Muhando, C.A. (2006). Trends in Reef Benthos in Mafia Island Marine Park, Tanzania: 1999-2005 coral reef monitoring results. Institute of Marine Science, University of Dar es Salaam.

Muir C. (2005). The Status of Marine Turtles in the United Republic of Tanzania, East Africa. Sea Sense (Tanzania Turtle & Dugong Conservation Programme), Dar es Salaam.

Muir, C. E. and Abdallah, O. (2002). A survey to assess the status of dugongs in Mafia Island and Rufiji, Tanzania.

Muir, C.E., Sallema, A., Abdallah, O., De Luca, D.W. & Davenport, T.R.B. (2003). The dugong (Dugong dugon) in Tanzania: A national assessment of status, distribution and threat. Wildlife Conservation Society. 31pp.

Muthiga, N.A., Costa, A., Motta, H., Humando, C.A., Mwaipopo, R., and Schleyer, M. (2008). Status of Coral Reefs in East Africa: Kenya, Tanzania, Mozambique and South Africa. Global Coral Reef Monitoring Network. Status of Coral Reefs of the World.

Mwakosya, C. A., Kuguru, B., Senkondo, E., Kulekana J.J., Ulotu E., Sululu, J. Mhitu, H., Matola H., Budeba Y. L., Ngatunga, B. P. Kangwe S.J., Mahongo, S.B. Mgeleka S., and Kuboja B. (2010). Report on the Assessment of the effectiveness of closure of commercial prawn trawling in Tanzania coastal waters. Tanzania Fisheries Research Institute (TAFIRI). 89pp.

Mwalyosi, R.B.B. (1988). Environmental impacts of the proposed Stiegler's Gorge hydropower project, Tanzania. Environmental Conservation 15(3): 250-254.

Mwandosya, M.J., Nyenzi, B.S. and Luhanga, M.L. 1998. The assessment of vulnerability and adaptation to climate change impacts in Tanzania. The Center for Energy, Environment, Science and Technology (CEEST), Tanzania.

NBS (2012). National Population and Housing Census of 2012. National Bureau of Statistics, Dar es Salaam.

Ndesanjo, R. (2009). Climate Change Impacts and Adaptive strategies in the Rufiji Delta. MSc. Dissertation, University of Dar es Salaam.

Ngana, J.O., (1980) Hydraulic Studies of the Proposed Stiegler' s Gorge Dam. BRALUP Research Report No. 35.

Nhwani, L.B, Mwaiko, S.P., Chande, A.I., Mwamsojo G.U.J. and Mhitu, H.A. (1993). Crustacean resource assessment in Rufiji and by-catch studies of prawn trawlers. 35pp.

Nindi S J, Machano H and Rubens J. (2014). Remote sensing study of mangrove vegetation change in rufiji delta, Tanzania from 1990 to 2010. WWF Tanzania Country Office, Dar es Salaam. 48pp.

Obura D. (2008). Baseline assessment of the coral reef ecosystems of Mafia and Songo Songo-Kilwa for vulnerability to climate change. WWF US/GEF Coastal Resilience to Climate Change Project, WWF TCO, Dar es Salaam.

Obura et al. (2002). Status of coral reefs in eastern Africa: Kenya, Tanzania, Mozambique and South Africa. Status of the Coral Reefs of the World 2002.

Obura, D. (2002). "Status of coral reefs in East Africa," in: Linden, 0., Souter, D., Wilhelmsson, D., and Obura, D. (Editors). Coral Reef Degradation in the Indian Ocean. Status Report 2002, CORDIO, Kalmar, Sweden, pp 15-20.

Ochieng, C A and Erftemeijer, P L A. (2002). The status of seagrass ecosystems in Kenya and Tanzania. University of Dar es Salaam. 39pp.

Ochieng, C.A. (2002). Research Master Plan for the Rufiji Floodplain and Delta 2003 – 2013. REMP Technical Paper No. 22.

Olson, J.M., Alagarswamy, G., Andresen, J.A., Campbell, D.J., Davis, A.Y., Ge, J., Huebner, M., Lofgren, B.M., Lusch, D.P., Moore, N.J., Pijanowski, B.C., Qi, J., Thornton, P.K., Torbick, N.M. and Wang, J., (2008). Integrating diverse methods to understand climate–land interactions in East Africa. Geoforum 39: 898–911.

Ornis Consult (2002). UTUMI Biodiversity surveys. Ministry of Foreign Affairs and DANIDA, Dar es Salaam, Tanzania.

Punwong P., Marchant R. and Selby K. (2012). Holocene mangrove dynamics and environmental change in the Rufiji Delta, Tanzania. Vegetation History and Archeobotany DOI 10.1007/s00334-012-0383-x.

Ray, C. (1968). Marine Parks for Tanzania, results of a survey of the coast of Tanzania. The Conservation Foundation, New York Zoological Society.

Richmond, M.D. (ed.). (1997). A guide to the Sea Shores of Eastern Africa and the Western Indian Ocean Islands. Sida Department for Research Cooperation, SAREC, 448pp.

Rufiji District Council (2010). Rufiji District Socio-economic Profile.

Rufiji Environment Management Project (2002). Environmental Management and Biodiversity Conservation of Forests, Woodlands, and Wetlands of the Rufiji Delta and Floodplain. A Socio-Economic Profile of the Rufiji Floodplain and Delta. Technical report No. 6, Volume 1 (of 3).

Sea Sense, (2011). Community based endangered marine species conservation in Tanzania. Sea Sense Annual Report, 58p.

Semesi A.K. (1991). Management Plan for the Mangrove Ecosystem of Mainland Tanzania. Vol 11. Ministry of Tourism, Natural Resources and Environment, Forest and Beekeeping Division, Catchment Forest Project, Dar es Salaam.

Semesi A.K. (1992). Developing management plans for the mangrove forest reserves of mainland Tanzania. Hydrobiologia 247: 1-10.

Shaghude Y.W and A. M. Dubi, (2008). Survey of beach erosion problems at Lagemma Dell Est Beach Hotel, Nungwi, Zanzibar, Report submitted to Lagemma Dell Est Beach Hotel. 26pp.

Shaghude Y.W, J. W. Mburu, J. Uku, J. Ochiewo, N.Nyandwi, H. Onganda, C. Magori, I. Sanga and R. S. Arthurton (2012). Beach sand supply and transport at Kunduchi, Tanzania and Bamburi, Kenya, Western Indian Ocean J. Mar. Sci., in review (2012).

SMUWC (2001). (Sustainable Management of Usangu Wetlands and its Catchment) 2001a. Baseline 2001. Available online at: http://www.usangu.org/ (viewed 20/08/2002).

Spalding MD, Ravilious C, Green EP (2001). World Atlas of Coral Reefs. Berkeley (California, USA): The University of California Press. 436 pp.

Swai, G., Shirima, D.D., Makero, J, Emanuel, J., Yahaya, A and Olrik, B. (2011). Identification of flora and fauna and their conservation status: A case study of Mafia Island 'Coastal Forest Mosaic'. Report submitted to Rufford Small Grants Foundation (RSG).

Tabor K., Burgess, N. D., Mbilinyi, B. P., Kashaigili, J. J., Steininger, M. K. (2010). Forest and woodland cover and change in coastal Tanzania and Kenya, 1990 to 2000. *Journal of East African Natural History* 99(1): 19–45.

TAFIRI (2013). Report of the baseline study on Socio-economic benefits of artisanal tuna and tuna-like fishery in the United Republic of Tanzania.

TCMP (2001). Tanzania Coastal Tourism Situation Analysis. Tanzania Coastal Management Programme Prepared by the National Environmental Management Council, the University of Rhode Island Coastal Resources Centre and the United States Agency for International Development. www.crc.uri.edu/comm/download/CT_Sit_%20Anal.pdf.

Temple, P. H. and Sundborg, A. (1972). The Rufiji River, Tanzania. Hydrology and Sediment Transport. GeofrafiskaAnnaler 54 (A) 3-4, 345-368.

Tesaker, E. (1979). Rufiji Basin Multipurpose Development Stiegler's Gorge Power and Flood Control Development Report on Hydraulic Studies in Lower River, Vol 1&2 NORAD/VHL &Rufiji Basin Development Authority. Project No. 602273, 136 pp.

Tobey J., Meena, H., Lugenja, M., Mahenge, J., Mkama, W., Y Robadue D. (2011). Village Vulnerability Assessment and Adaptation Planning: Mlingotini and Kitonga, Bagamoyo District, Tanzania, Coastal Resources Center, University of Rhode Island, Narragansett. 20 pp.

Troeng, S. and Drews, C. (2004). Money talks: economic aspects of marine turtle use and conservation. WWF-International, Gland, Switzerland.

Tumbo, M. (2014). Uncertainties in Modelling Gauged and Un-gauged Catchments. PhD Thesis, Rhodes University, South Africa.

Tumbo, M., Stisen, S., Hughes, D., Stindel, M. and Joel, N. (2013). An ensemble approach in assessing climate change impacts on the hydrology of Great Ruaha River basin in Tanzania. Paper presented during the International Conference on Regional Climate, CORDEX, 4th to 8th November 2013, Brussels, Belgium.

Turpie J. K. (2000). The Use and Value of Natural Resources of the Rufiji Floodplain and Delta, Tanzania Technical report No. 17, IUCN East Africa, Dar es Salaam, Tanzania.

UNEP (2001). Eastern Africa Atlas of Coastal Resources: Tanzania. Nairobi, Kenya.

URT (2007). National adaptation program of action. Dar es Salaam: Vice President's Office.

URT (2011). The National Climate Change Strategy and Action Plan. Vice President's Office, Division of Environment.

URT 2003a. Initial National Communication under the UNFCCC. Dar es Salaam: Division of Environment, Vice President's Office.

URT 2003b. National integrated coastal environment management strategy. Dar es Salaam: Vice President's Office.

Valimba, P., et al. (2006). Influences of ENSO and SST variations on the interannual variability of rainfall amounts in southern Africa. *AHS-AISH Publication* 308: 362-368.

Wagner G.M. and Sallema-Mtui R. 2010. Change analysis of Rufiji-Mafia-Kilwa mangroves, Tanzania in relation to climate change factors and anthropogenic pressures. WWF US/GEF Coastal Resilience to Climate Change Project. WWF Tanzania Country Office, Dar es Salaam.

Wang, Y.Q., Ngusaru, A., Tobey, J., Bonynge, G., Nugranad, J., Makota V. and Traber, M. (2003). Remote sensing of mangrove change along the Tanzania coast. *Marine Geodesy* 26: 35-48.

Watkiss, P. Downing, T., Dyszynski, J., Pye, S. et al. (2011). The Economics of Climate Change in the United Republic of Tanzania. Report to Development Partners Group and the UK Department for International Development. Published January 2011. www.economics-of-cc-in-tanzania.org.

Wells S., Juma S., Muhando C., Makota V. and Agardy T. (2004). Study on the Ecological Basis for Establishing a System of MPAs and Marine Management Areas in the United Republic of Tanzania. Final Report submitted to the World Bank.

Whitney A, Bayer T, Daffa J, Mahika C, Tobey J. (2003). Tanzania State of the Cost Report, 2003. The National ICM Strategy and Prospects for Poverty Reduction. TCMP Coastal Management Report No. 2002. 78pp.

WWF (2010). Environmental Flow Assessment. The Great Ruaha River and Ihefu Wetlands, Tanzania, and options for the restoration of dry season flows. 274pp.

WWF (2004). Towards a Western Indian Ocean Dugong Conservation Strategy: the status of Dugongs in the Western Indian Ocean Region and priority conservation actions. WWF Eastern Africa Marine Ecoregion. Dar es Salaam, Tanzania. 68pp.

Yanda, P.Z. (2013). Coastal and Marine Ecosystems in A Changing Climate: The Case Of Tanzania. Climate Change Adaptation Series: Document 1. The Coastal Resources Center, University of Rhode Island.

Yawson, D. K., Kongo ,V. M. and Kachroo, R. K. (2005). Application of linear and nonlinear techniques in river flow forecasting in the Kilombero River basin. Hydrological Sciences–Journal–des Sciences Hydrologiques, 50(5) October 2005. IAHS Press 783, Tanzania.