IMPLICATION OF CLIMATE CHANGE ON LAND USES OF SELOUS-NIASSA TRANSFRONTIER CONSERVATION AREA, TANZANIA AND MOZAMBIQUE

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2019

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Open University of Tanzania thesis entitled; ñ**Implication of Climate Change on Land Uses of Selous-Niassa Transfrontier Conservation Area, Tanzania and Mozambique**ò in fulfillment for the requirements for the degree of Doctor of Philosophy of the Open university of Tanzania.

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DECLARATION

I, Adili Yohana Zella, do hereby declare that this thesis is my own original work and that it has not been submitted and will not be submitted to any other University for a similar or any other degree award.

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Signature

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Date

DEDICATION

This work is dedicated to my son and daughters Kelvin, Mercy, Agnes and Mariamu.

God bless you all.

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ABSTRACT

Climate is changing and that the changes are largely due to increased levels of carbon emissions into the atmosphere caused by changes of land uses as a result of anthropogenic activities. Considering the impacts of climate change insisted the need for new conservation areas to fill connectivity gap between protected areas (PAs) or transfrontier conservation areas (TFCAs) through habitat corridors so as to enable species migration with their climatic niche. The study aimed at analysing the implication of climate change on land uses of Selous-Niassa TFCA . Specifically, the study intended to; determine spatial and temporal changes in land uses, forecast changes in land uses, determine wood balance of the study area dwellers, determine amount of carbon released to the atmosphere, and identify consequences of climate change and variability in managing TFCAs. Survey, PRA (Participatory Rural Appraisal), remote sensing and GIS (Geographical Information System) techniques were employed to get the intended results. The study results revealed that, land use conversion from woodlands and grassland were mostly transformed into built up area and cultivated land. This evidenced by 50.8% of woodlands lost equivalent to 529 million trees (average of 27 million trees per year) from 1986 to 2016 with only 28.7% population increase. This imply unsustainable wood supply, however the wood supply for the years 2016 and 2035 was at least 25 and 20 times the average demand per year per capita respectively. Carbons released to the atmosphere from 1986-2016 and 2015-2035 are 7205306.34 tons and 804343.11 tons respectively, equivalent to US$ 1415070.96 and US$ 3217372.44 of carbon trade in respective periods. Moreover, carbons stocks for the years 2016 and 2035 are 13114780.2 tons and 8789814.9 tons equivalent to US$ 52459120.8 and US$ 46918043.68 respectively. The study concludes that, the management of the study area is unsustainable. The study recommends the inclusion of the area into connected PAs ecosystem of the Selous-Niassa TFCA or formulation of sustainable participatory management strategies of the area.

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LIST OF ABBREVIATIONS AND ACRONYMS

AGB	Above Ground Biomass
BGB	Below Ground Biomass
BLT	Built up Area
BS	Bush Land
CA	Cellular Automata
CBC	Community Based Conservation
CBD	Convention of Biological Diversity
CBNRM	Community Based Natural Resources Management
CITES	Convention on International Trade of Endangered Species of Fauna and Flora
CL	Cultivated Land
CNPPA	Commission on National Parks and Protected Areas
CWD	Closed Woodland
Dbh	Diameter at Breast Height
DW	Dead Wood
FZS	Frankfurt Zoological Society
GL	Grassland
GLOVIS	Global Visualization Viewer
GMP	General Management Plan
GPS	Global Positioning System
GR	Game Reserve
HWC	Human Wildlife Conflict
LULC	Land Use and Land Cover

MA	Millennium Ecosystem Assessment
MAS	Multi-Criteria Agent System
MCE	Multi-criteria Evaluation
MLC	Maximum Likelihood Classifier
MLHS	Ministry of Land, Housing and Settlement
MNRT	Ministry of Natural Resources and Tourism
MWMA	MAGINGO Wildlife Management Area
NAFORMA	National Forest Resources Monitoring and Assessment
NBS	National Bureau of Statistics
NCCARF	Nation Climate Change Adaptation Research Facility
NRMMA	Natural Resource Management Ministerial Council
OWD	Open Woodland
PAs	Protected Areas
PFM	Participatory Forest Management
REDD	Reduce Emissions from Deforestation and Forest Degradation
SADC	Southern African Development Countries
SCBD	Secretariat of the Convention on Biological Diversity
SCP	Semi-automatic Plug-in
SNWC	Selous-Niassa Wildlife Corridor
TFCA	Transfrontier Conservation Area
URT	United Republic of Tanzania
USAID	United States Agency for International Development
USGS	United States Geological Survey
WCA	Wildlife Conservation Act

WEO	Ward Executive Officer
WMA	Wildlife Management Area
WTR	Water
WWF	World Wide Fund for Nature
%	Percentage

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Climate is changing and that the changes are largely due to increased levels of carbon emissions into the atmosphere caused by changes of land uses as a result of anthropogenic activities (IPCC, 2013; UNFCCC, 2010 and 2009). Land use changes can affect global carbon budgets significantly by changing the level of carbon storage in the vegetation and soil of terrestrial ecosystems (Jaiarree *et al.*, 2011). Global carbon emissions caused by land use change accounted for 20% and 12.5% of total carbon emissions from the 1980s to 1990 and from 2000 to 2009, respectively (Friedlingstein, 2010).

Climate change already affected all species worldwide (Vale *et al*., 2018). Redistribution of speciesô range in response to climate change already experienced and future prediction of widespread range shifts and contraction is uncertain (Chen *et al*., 2011; Lenoir and Svenning, 2015; Pecl *et al*., 2017; Vale *et al*., 2018). The establishment of protected areas (PAs) remains a key strategy in biodiversity conservation (Crouzeilles *et al*., 2013a; Vale *et al*., 2018); currently representing nearly 13% of the global land surface (Jenkins and Joppa, 2009; Vale *et al*., 2018). However, speciesô redistribution due to continuous climate change predicted to affect speciesô representativeness and persistence in current PAs networks (Araujo *et al*., 2011; Loyola *et al*., 2013; Lemes *et al*., 2014; Vale *et al*., 2018).

Considering the impacts of climate change insisted the need for new conservation areas to fill connectivity gap between protected areas (PAs) or transfrontier conservation areas (TFCAs) through habitat/wildlife corridors so as to enable species migration with their climatic niche (Loyola *et al*., 2013; Vale *et al*., 2018). But, depending on conservation criterion sometimes these corridors reside with dwellers and depend on corridor resources for their livelihood. These livelihood practices change land uses of the corridor and hamper biodiversity and ecosystem services; and sometimes contribute to climate change on one way and restrict wildlife adaptation to climate change on the other way.

Nonetheless, it is widely recognized that the decisions for allocation of land to protected areas (PAs) are based on three categories of reasons: *pragmatic, ecological and socioeconomic*. The pragmatic reasons for the establishment of PAs are based on factors such as low productivity and availability. The ecological reasons are based on naturalness, uniqueness, ecosystem diversity, integrity, and size while the socioeconomic reasons are based on social and economic principles (Mpanduji, 2004; Kundilwa *et al.,* 2016; and Bailey *et al*., 2016). Thus, establishment of many PAs including wildlife corridors in Eastern and Southern Africa followed pragmatic and economic criteria (Sarunday and Ruzika, 2000 cited by Mpanduji 2004; Kundilwa *et al.,* 2016; and Malimbwi *et al*., 2016). Hence, responding to the ecological and socioeconomic benefits of connected ecosystems, a wide range of TFCAs have been established (SADC, 2012; Kundilwa *et al*., 2016; Malimbwi *et al*., 2016). Selous-Niassa TFCA is among eighteen established SADC TFCAs.

Selous-Niassa TFCA is the largest TFCA in Africa covering a total area of approximately 15,400,000 ha. Two thirds of the area is protected by the Selous Game Reserve (4,800,000 ha) in the United Republic of Tanzania, and Niassa

National Reserve (4,200,000 ha) is Mozambiqueǿs largest conservation area. The two protected areas are linked by a corridor ï the Selous-Niassa Wildlife Corridor (SNWC), which extends for a total length of approximately 160 to 180 km following the Ruvuma River. SNWC has multiple land uses consists of three land tenure structure; state (Game Reserves, Forest Reserves and Wetlands), communal (Wildlife Management areas and Village Forests) and individual ownership (land owned legally or public land (always forested areas).

Improving landscape connectivity of Selous ï Niassa TFCA claimed to be high on Tanzania and Mozambique political agenda, evidenced by signed of the Memorandum of Understanding (MoU) on March 2007 and its reaffirmation on protection of Ruvuma landscape on May, 2015 for protection of the TFCA with governmentsô instigation. However, establishment of co-management of the TFCA, General Management Plan (GMP) and a strategy to restore and manage ecological connectivity of the TFCA is still silence. The situation accelerates deterioration of the TFCA ecosystem.

1.2 Statement of Research Problem

Establishment of Transfrontier conservation areas (TFCAs) is a new strategy for climate change (CC) adaptation and mitigation in terrestrial ecosystems. The strategy is fulfilling goals 13 (climate action) and 15 (life on land) of sustainable development goals (SDGs) and aspiration 1(10, 16 and 17) of agenda 2063 (The Africa We Want) by the year 2030 and 2063 respectively. Adaptation occurs as wild animals abandoned core protected areas (PAs) and reside to new areas or use them to migrate with their climatic niche to other PAs within TFCAs. Mitigation is the response of governments, PAs managers, and the public on initiating inclusion of new identified conservation areas in PAs network and recategorisation of abandoned areas within core PAs in TFCAs.

TFCAs are still a relatively new phenomenon in Africa (SADC, 2012; Kundilwa *et al*., 2016; Malimbwi *et al*., 2016). Changes of land uses associated with fragmentation of habitat into small patches is a major threat for terrestrial biodiversity in connected areas outside core PAs of TFCAs ecosystem (NCCARF, 2015; Virkkala *et al*., 2013; WWF, 2014; and Bailey *et al*., 2016). Land use changes are always driven by economic and social factors (Dewan *et al*. 2012; Du *et al*., 2014; and Song *et al*., 2014). Selous-Niassa TFCA is not exempted from this scenario as the corridor connecting the two PAs resides with dwellers whose livelihood relies on it. Livelihood practices resulting to changes of corridor land uses and restrict wildlife mobility with their climatic niche in PAs network of the TFCA ecosystem.

Previous studies of the implication of climate change and variability on land uses have been carried out by many scholars (for examples, Chuai *et al*., 2013, 2014 and 2015; Houghton *et al*., 2015; Marlier *et al*., 2012; Plevin *et al*., 2015; and Zhong *et al*., 2006); but none of these studies conducted in TFCAs linked their PAs with corridors. Thus, this study intended to fill these gaps using Selous ï Niassa TFCA as a case study. Before enaction of Tanzania Wildlife Conservation Act No. 5 of 2009, there were no legal ways of protecting corridors. Additionally, guidelines and management scenarios of the corridor in the face of climate change and variability is uncertain. This calls urgency for research on implication of climate and variability on land uses of Selous-Niassa TFCA; specifically, determining and forecasting land use and land cover changes, wood balance, biomass and carbon stocks, and identifying consequences of climate change and variability in managing Selous-Niassa TFCA so as to attain sustainability.

1.3 Research Objectives

1.3.1 General Objective

The main objective of this study was to analyse the implication of climate change on land uses of Selous-Niassa transfrontier conservation area.

1.3.2 Specific Objectives

Specifically the study intended to:

i. Determine spatial and temporal changes in land uses of the study area
ii. Forecast changes in land uses of the study area
iii. Determine wood balance of the study area dwellers resulted from changes in land uses of the study area
iv. Determine amount of carbon released to the atmosphere as a result of changes in land uses of the study area
v. Identify consequences of climate change and variability in managing TFCAs

1.4 Research Questions

This study was guided by the following questions:

i. What are the temporal changes in land use and land cover (LULC) of the study area?
ii. What are expected future changes in land use and land cover in the study area?
iii. What is the current and predicted future wood balance of the study area

dwellers resulted from changes in land uses of the study area?

iv. What is the current and predicted future amount of carbon released to the atmosphere as a result of changes in land use and cover in the study area?

v. What are there consequences of climate change and variability in managing TFCAs?

1.5 Justification of the Study

1.5.1 Significance of Study Findings

The findings of this study will serve as environmental management tool for:

Raising awareness among general public, policy and decision makers regarding trends of land uses and their impact to the management of TFCAs in the face of climate change and variability; Provide necessary information that can directly inform PAs managers within Selous-Niassa TFCA the importance of including the study area into core PA network or formulating management strategies that can ensure sustainability.

1.5.2 Why Study Transfrontier Conservation Areas

Political boundaries that demarcate country borders were historically drawn for reasons based on national security and strategic interests, colonial land claims, geological and other riches, and convenience, never with conscious thought of maintaining ecological integrity. And so today a political map of the world shows continents carved into a jig-saw puzzle of countries, each with its own pattern of land use, political priorities, and management styles. Even so, historical coincidence has often left conservation areas in different countries adjoining each other, separated by fences or varying ideologies, resulting in fragmented ecosystems or disrupted ecosystem processes.

We know enough by now to realize that such fragmented systems lead to a loss of ecological resilience and a steady attrition of species over time. By taking a broader view, a regional view, and jointly managing these natural assets for regional benefit we can overcome many of the disadvantages caused by the sometimes almost arbitrary political lines drawn for historical reasons. Ecological benefits; Socio-economic and cultural benefits; collaboration and partnerships; and regional peace, harmony and stability are some of these benefits which flow from collaborating across boundaries and adopting a regional approach in natural resource management.

1.5.3 Why Study Selous – Niassa

The study was done in Selous-Niassa TFCA due to the following reason: (i) scanty information of study area interests which is eastern part of the corridor also known as Selous ï Masasi compared to western part; (ii) huge area coverage in Africa as the largest trans-boundary natural dry forest eco-regions covering approximately 154,000 km^2 with a critical gap between these protected areas that stretches for about 160 ï 180 km and extending across southern Tanzania and the Mozambique border.

Through a network of protected areas of various categories of protection, an area of 110,000 km^2 of this ecosystem is presently under conservation (Baldus and Hahn, 2009); (iii) wildlife migration and richness as it constitutes one of the largest elephant ranges in the world and contains half of the world remaining wild dog population, supports a large number of other globally significant, threatened and CITES listed fauna and flora species (Baldus *et al.*, 2003); (iv) there was no legal protection of wildlife corridors before enaction of wildlife Act of 2009; (v) there was no signed memorandum of understanding between Tanzania and Mozambique concerned protection of the ecosystem before March 2007 and reaffirmation on protection of Ruvuma landscape in May 2015; and (vi) established wildlife management areas (WMAs) which act as a buffer zone to core protected areas to help conservation of wildlife corridor by involving local communities. WMAs established are bordering Selous, Msanjesi and Lukwika-Lumesule game reserves (MAGINGO WMA, NDONDA and MCHIMALU proposed WMAs respectively) within Liwale, Nachingwea/Masasi and Nanyumbu districts respectively in Tanzania whereas people are living inside Niassa national reserve in Mozambique (Pesambili, 2003).

CHAPTER TWO

LITERATURE REVIEW

This chapter covers review of relevant documents related to the study objectives and their measurable variables or indicators. It includes main concepts of the study, literature on determining land use and land cover changes; forecasting changes in land uses; determining and forecasting wood balance; determining amount of biomass and carbon; and consequences of climate and variability in managing transfrontier conservation areas (TFCAs).

2.1 Main Concepts in Natural Resources Management

2.1.1 Climate Change and Variability

2.1.1.1 Weather and Climate

Climate is what you expect and weather is what you get.

Weather is the day-to-day state of the atmosphere and its short-term (from hours to a few weeks) variations such as temperature, humidity, precipitation, cloudiness, visibility or wind; and **Climate** are statistical information, a synthesis of weather variation focusing on a specific area for a specified interval. Climate is usually based on the weather in one locality averaged for at least 30 years (IPCC, 2013).

2.1.1.2 Climate Variability and Climate Change

Climate change refers to any change in climate over time, whether due to natural variability or anthropogenic forces; and **Climate variability** refers to variations in the mean state and other climate statistics (standard deviations, the occurrence of extremes, etc.) on all temporal and spatial scales beyond those of individual weather events. Variability may result from natural internal processes within the climate system (internal variability) or from variations in natural or anthropogenic external forces (external variability) (UNFCCC, 2009).

Climate change is already occurring and its impacts are being felt in ecosystems and communities around the world. The effects of climate change interact with and exacerbate existing human-caused stresses to natural systems, such as habitat loss due to land use change, over-allocation of water and other natural resources, spread of invasive species, altered disturbance regimes, landscape fragmentation, and declines in air and water quality (Mote *et al.,* 2005). Because of the many complexes, interrelated changes associated with climate change, 21^{st} wildlife managers will need to adapt their management techniques and strategies. They will need to learn to cope better with uncertainty, incomplete information, and a rapidly changing environment, and they will need to find better ways to tap into existing information on climate change and its impacts. Failure to do so will lead to the permanent loss of species and ecosystems, disruptions to ecosystem services such as clean air and water and flood control, and significant declines in resource-dependent industries such as fisheries, timber, agriculture, and tourism and recreation (Lawler, 2008).

2.1.1.3 Enhanced Greenhouse Effect

Greenhouse gases include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and ozone (O3)are a natural part of the atmosphere that, through a natural process called the **greenhouse effect**, trap the sun's warmth and maintain the earth's surface temperature at the level necessary to support life (approximately 15ºC). The earth's climate has been alternating between hot and cold periods for at least the past million years. Records from polar ice cores show oscillating periods of glacial (ice ages) and interglacial (warm) periods (UNFCC, 2009 and 2010).

The earth is currently in an interglacial period. However, the observed warming since the 1970s cannot be explained by natural causes alone. During the past 200 years, human activities such as fossil fuel burning and land clearing have caused an increase in greenhouse gases in the atmosphere ï called the enhanced greenhouse effect ï trapping more heat and raising the earth's surface temperature (UNFCC, 2009 and 2010). The increase in surface temperature in the northern hemisphere during the twentieth century is considered greater than for any century in the last 1000 years. Statistics show the global mean surface temperature increased by 0.6±0.2°C, the number of hot days in a year increased in many places and the number of cold days decreased in nearly all land areas (IPCC, 2001).

Carbon dioxide concentrations, globally averaged surface temperature and sea level are projected to rise in the future. Climate model projections show that the average surface temperature would increase with a range of 1.4 to 5.8°C between 1990 and 2100. This is about two to ten times larger than the observed warming during the twentieth century. Similarly, the average global precipitation is projected to increase during the twenty-first century but at regional levels, there will be both increases and decreases ranging from 5 percent to 20 percent (UNFCC, 2009 and 2010).

2.1.1.4 Climate Change and Variability on Ecosystem

Climate change affect ecosystem processes within a context of pre-existing human-caused stresses. Land-use change, landscape fragmentation, habitat destruction, pollution and other threats to water quality and quantity, introduction of invasive species, and other anthropogenic processes have already endangered many species and driven some to extinction. For species and systems already at risk, climate change may prove to be one stress too many (Leggett and Folger, 2007).

Dealing with existing stressors on ecosystem processes may be among the most valuable and least risky strategies available for climate change adaptation, in part because we have more knowledge about causes, effects, and solutions (*ibid*). Managing ecosystems to maintain and restore these key processes will help to keep future management options open and greatly increase our capacity to deal with uncertainty and change. Existing policy and planning frameworks that acknowledge and address the importance of ecosystem processes can provide a useful starting point for addressing climate adaptation needs.

2.1.2 Transfrontier Conservation Areas (TFCA)

Transfrontier Conservation Areas (TFCA) can be defined as fairly large areas, on both sides of frontiers between two or more countries and cover large-scale natural systems encompassing one or more protected areas (Osofsky *et al.,* 2005; Ara_Ujo, 2009 and 2011; and Kundilwa *et al.*, 2016). TFCAs involve a unique level of international co-operation between the participating countries, particularly issues related to the opening of international boundaries and within each region. The history of transfrontier conservation areas (TFCAs) can be traced back to 1932 with the first one established between Canada and the USA (NCCARF, 2005; Ara_Ujo, 2011). Since then a steady trickle of these collaborative conservation initiatives has emerged in almost all continents, but Africa TFCAs starts in 1990s (SADC, 2012a&b).

Africa has its own perspectives on TFCAs, seeing them in most cases not just as good vehicles for biodiversity conservation, but also as drivers for socio-economic upliftment (Suter *et al.*, 2008; The Nature Conservancy, 2009; and Barber *et al*., 2016). Few continents can rival Africa in wildlife-based tourism, but these tourism opportunities often remain underutilized. Africa has recognized TFCAs as worthy ventures with multiple potential benefits, but it will take political will to make this potential become reality (Laurance and Laurance, 1999; Caro and Davenport, 2015). Many TFCAs in Africa are connected by wildlife corridors which extended in various ranges depending on conserved species (Mpanduji, 2004, Caroll *et al*., 2010; Bright and Rose, 2014; and Chase *et al*., 2016).

The major effects of habitat fragmentation may be additional to those that occur from habitat loss, including increased external influences (such as invasion or predation), altered microclimate (e.g. associated with evapo-transpiration, wind and hydrological cycles) and increased isolation from other areas of similar habitat (Andren, 1994; Heller and Zavaleta, 2009; Ryan *et al*., 2011; and Kundilwa *et al*., 2016). Longrun destruction, reduction or fragmentation of the sizes of corridors around the protected areas threatens the persistence and viability of many protected species due to reduction in mobility (Mpanduji, 2004; Mascia and Pailler, 2011; and Chase *et al*., 2016).

Besides, damages or fragmentation and blockage of migratory corridors expose the large bodied migratory species such as elephants, which require large home range to extinction. Thus, appropriate management of wildlife corridors provides various ecological benefits to the wildlife. The benefits include returning the landscape to its natural connected state, allow species to migrate between core areas of biological significance, increase gene flow and reduce rates of inbreeding. All these benefits improve species fitness and survival (Schmitt and Seitz, 2002; Suter *et al.*, 2008; Kharouba and Kerr, 2010; and Chase *et al*., 2016). Corridors in particular despite allowing greater mobility (Andreassen *et al*., 1996; Suter *et al.*, 2008; and Caro and Davenport, 2015), are potential for species to escape predation and respond to stochastic events such as fire. Additionally, corridors allow species to respond more easily to long term climatic changes (McEuen, 1993; Suter *et al.*, 2008; and Malimbwi *et al.*, 2016).

2.1.2.1 SADC Transfrontier Conservation Areas

There are eighteen SADC Transfrontier Conservation Areas (TFCAs) established based on instruments such as the Declaration and Treaty of the Southern African Development Community (1992); the SADC Regional Indicative Strategic Development Plan ï RISDP (2004); the SADC Wildlife Policy and Development Strategy (1997); the SADC Forestry Strategy (2010); the Biodiversity Strategy (2007) and the SADC Policy and Strategy for Environment and Sustainable Development (1996).

Additionally, there are agreements through which the Member States commit themselves to collaborate in attaining regional integration and sustainable social and economic development such as the Protocol on the Development of Tourism (1998); the revised Protocol on Shared Water Courses (2000); and the Protocol on Forestry

(2002). In the Protocol on Wildlife Conservation and Law Enforcement (1999) the Member States have made a commitment ñ*to promote the conservation of shared wildlife resources through the establishment of Transfrontier Conservation Areas (TFCAs)*ò.

At the international level TFCAs complement the goals and objectives of a number of conservation conventions to which many SADC Member States are signatory or party such as the African Convention on Nature and Natural Resources (1968); UNESCOôs Man and Biosphere Programme (1971); the Ramsar Convention on Wetlands Conservation (1971); World Heritage Convention (1972); Convention on International Trade in Endangered Species of Flora and Fauna (1973); Convention on Migratory Species (1979); Convention on Biological Diversity (1992); the United Nations Framework Convention on Climate Change (1992); and the United Nations Convention to Combat Desertification (1994). These Conventions urge the signatories and the parties to collaborate in the sustainable utilization of shared natural resources and encourage them to actively involve local communities in the management of the natural environment and in the equitable sharing of benefits derived from the resources therein.

SADC TFCAs (Table 2.1) are not necessarily between SADC Member States only but may also involve partnerships with countries that border SADC Member States. Three broad categories based on the legal status and levels of development of the TFCAs exist:

i. Category A ï Established TFCAs: These are TFCAs established through a Treaty or any other form of legal agreement between the participating countries;

ii. Category B ï Emerging TFCAs: These are TFCAs established on the basis of a Memorandum of Understanding (MOU). The MOUs serve as instruments that facilitate negotiations of Treaties to formally establish the respective TFCAs for eventual formalization to Category A;

iii. Category C ï Conceptual TFCAs: These are TFCAs without an official mandate from the participating countries but have been proposed by SADC Member States as potential TFCAs.

Table 2.1: SADC Transfrontier Conservation Areas (TFCAs)

Established TFCAs Treaty Signed	**Emerging TFCAs MOU signed**	**Conceptual TFCAs**
1. /Ai/Ais - Richtersveld TP *(Namibia/South Africa)*	8. Chimanimani TFCA *(Mozambique/Zimbabwe)*	13. Kagera TFCA (Rwanda/Tanzania/Uganda)
2. Great Limpopo TP and TFCA *(Mozambique/South Africa/Zimbabwe)*	9. Greater Mapungubwe TFCA *(Botswana/South Africa/Zimbabwe)*	14. Liuwa Plains-Mussuma TFCA (Angola/Zambia)
3. Kavango Zambezi TFCA *(Angola/Botswana/Namibia/ Zambia/Zimbabwe)*	10. Iona-Skeleton Coast TFCA *(Angola/Namibia)*	15. Lower Zambezi-Mana Pools TFCA (Zambia/Zimbabwe)
4. Kgalagadi TP *(Botswana/South Africa)*	11. Mayombe Forest TPA *(Angola/Congo/DRC/Gabon)*	16. Mnazi Bay-Quirimbas TFCMA (Mozambique/Tanzania)
5. Lubombo TFCA (Mozambique/South Africa/Swaziland)	12. Selus-Niassa TFCA *(Tanzania/Mozambique)*	17. Western Indian Ocean TMP (Comoros/Kenya/Reunion (France)/Madagascar/Mauritius/ Mozambique/ Seychelles/ Somalia/South Africa/Tanzania)
6. Malawi-Zambia TFCA *(Malawi-Zambia)*		18. ZIMOZA TFCA (Mozambique/Zambia/Zimbabwe)
7. Maloti-Drakensberg TFCA* *(Lesotho/South Africa)*		

2.1.3 Wildlife Corridors

In general terms, terrestrial wildlife corridors refer to two types of area; (i) an area used by animals to pass from one ñhabitat patchò to another; or (ii) an area that connects two patches of suitable habitats by passing through a matrix of unsuitable habitat. In Tanzania, wildlife corridors are often identified through their use by large charismatic mammals ï so-called ñlandscape-speciesò, such as elephant (*Loxodonta africana*) or wild dog (*Lycaon pictus*). However, many smaller animals such as duikers, small carnivores, bats, birds and amphibians will also use these corridors. Thus corridors may be important both for maintenance of populations in protected areas linked by corridors, and for populations moving through or living in corridors (Jones *et al.*, 2009).

The ability of wildlife populations to respond to climate and land use change depends upon connectivity and migration corridors. Estimating the amount of connectivity among populations at a broad spatial scale is very challenging. Traditional radio tracking and Global Positioning System (GPS) data from captured animals are applicable at the scale of wildlife management units (10 - 100 miles) and statewide or regional scales (100 - 1000 miles) (Mpanduji, 2004). Host genetics can be used to infer movement patterns at broad spatial scales, but the long generation times of many host species means that recent changes due to land - use change, roads, and climatic factors are undetectable.

Wildlife corridor as an unprotected area (defined as an area with no legally protected status, or an Open area, or a Game controlled area (GCA) between two or more PAs (defined as National parks (NPs), Game reserves (GRs), Forest reserves (FRs), Nature reserves (NRs) or the Ngorongoro conservation area (NCA)) (i) either through which animals area known to move or are believed to move, (ii) that are connected by (or can potentially be reconnected by) natural vegetation such as forest or grassland, or (iii) both (i) and (ii) together (Jones *et al*., 2009).

2.1.3.1 Importance of Wildlife Corridors

According to Jones *et al*., (2009), wildlife corridors are important due to the following reasons:

i. If an animal or plant population declines to low levels or become extinct in one area or habitat patch, individuals from another patch can immigrate and rescue that population from local extinction.

ii. If a small population is isolated, it will lose genetic variation over the long term and suffer from in breeding. A corridor allows immigrants to import new genetic variation into isolated populations.

iii. A corridor increases the area and diversity of habitats over and above the area of the two habitat patches that it connects.

iv. If the habitat of one area becomes unsuitable (e.g. because of climate change), organisms (both plants and animals) can move along corridors to reach more suitable habitat, and thus be órescuedô

v. Some protected areas do not encompass the range of ecosystem requirements needed by certain flora and fauna. Migrating species, for example, especially large mammalian herbivores and associated carnivores, move outside and/or between protected areas. They may also use corridors as dispersal areas.

2.1.3.2 Types of Wildlife Corridors in Tanzania

There are 31 wildlife corridors in Tanzania which fall within five categories includes uncontrolled corridors, uncultivated lands between PAs without documentation on animal movement, continuous or semi-continuous non-agricultural land between PAs with anecdotal information on animal movements, known animalsô movement routes between two PAs, and potential connectivity of important habitats (Jones *et al.* 2009):

2.1.3.2.1 Uncontrolled Corridors (A)

Uncontrolled corridors (A) are most poorly documented type of corridor. They consists two sub-categories (i) known historical migration routes of particular species, usually elephants, where is unclear if these routes are still in use or (ii) the shortest distance between two PAs across which animals could travel. Current land use is not taken into account.

2.1.3.2.2 Uncultivated Lands Between Protected Areas (PAs) Without Documentation on Animal Movement (B)

Uncultivated lands between PAs without documentation on animal movement (B) are usually patches of natural vegetation that lie between two PAs, or sometimes a string of FRs or WMAs between larger PAs. For almost all such corridors, it is known whether any populations use them to move between the PAs. Furthermore, habitat suitability and the population sizes of species living in these corridors are unknown. Such corridors may be needed in the future if habitat in one of the protected area becomes modified and unsuitable, for example through climate change, oil exploration or mining. These areas may also be very important for wildlife already, forest dwelling birds that will not cross open spaces, but still is not documented yet.

2.1.3.2.3 Continuous or Semi-Continuous Non-Agricultural Land Between Protected Areas (PAs) with Anecdotal Information on Animal Movements (C)

Continuous or semi-continuous non-agricultural land between PAs with anecdotal information on animal movements (C) consists patches or network of one or two FRs that lie between two larger PAs and additionally across which one or more species are known to move (or assumed to move). These type of corridors often focuses on elephant movements.

2.1.3.2.4 Known Animals' Movement Routes Between two Protected Areas (PAs) (D)

Known animalsô movement routes between two PAs (D) are documented movements of large animals, usually elephants, across a habitat that connect two PAs, for example by radio telemetry, satellite tracking or transect studies. The habitat may be legally protected, or agricultural land, or both.

2.1.3.2.5 Potential Connectivity of Important Habitats (E)

Potential connectivity of important habitats (E) are proposed or potential corridor areas linking fragmented or threatened habitat patches that contain endangered or other species. These are usually highland forests. Instigation of such corridors may involve forest restoration projects and/or compensation scheme for local people. The above types makes 31 wildlife corridors in Tanzania (Table 2.2) to be grouped into three groups namely extreme (denotes probably less than two years remains for extinction: A-2 and D-3), critical (less than five years remaining: A-1, B-1, C-3, D-5 and E-8) and moderate (less than 20 years remaining: A-2, C-1 and D-5).

Table 2.2: List of Wildlife Corridors in Tanzania

Number	Name	Type
1.	Bujingijila (Mt Rungwe-Livingstone)	E
2.	Burigi-Akagera (Rwanda)	B
3.	Burigi-Moyowosi/Kigosi	C
4.	Gombe-Kwitanga	E
5.	Gombe-Mukungu-Rukamabasi	E
6.	Greater Gombe Ecosystem-Masito-Ugalla	A
7.	Igando-Igawa	D
8.	Katavi-Mahale	D
9.	Katavi-Rungwa	C
10.	Kilimanjaro-Amboseli (Kenya) (Kitendeni)	D
11.	Loazi-Kalambo	E
12.	Loazi-Lwafi	D
13.	Manyara Ranch-Lake Natron	D
14.	Manyara-Ngorongoro (Upper Kitete/Selela)	D
15.	Muhezi-Swaga Swaga	C
16.	Selous-Niassa (Mozambique)	D
17.	Tarangire-Makuyuni (Makuyuni)	D
18.	Tarangire-Mkungunero/Kimotorok	D
19.	Tarangire-Simanjiro Plains	D
20.	Tarangire-Manyara (Kwakuchinja)	D
21.	Udzungwa-Mikumi	C
22.	Udzungwa-Ruaha	D
23.	Udzungwa-Selous	D
24.	Uzungwa Scarp-Kilombero NR (Mngeta)	E
25.	Uluguru North-South	E
26.	Usambaras, East (Derema)	E
27.	Usambaras, West	E
28.	Wami Mbiki-Handeni/ Southern Masai Steppe	A
29.	Wami Mbiki-Jukumu/Gonabis/Northern Selous	A
30.	Wami Mbiki-Mikumi	A
31.	Wami Mbiki-Saadani	A

Source: adapted from Jones *et al.*, (2009)

2.1.4 Selous – Niassa Wildlife Corridor

Selous ï Niassa TFCA is linked the two protected areas (PAs) by a corridor, Selous ï Niassa wildlife corridor (SNWC) (URT, 2005). Aim of the corridor is to connect fragmented patches of habitat within TFCA ecosystem to support species dispersal, persistence, and adapt to climate change (CBD, 2007; Bright and Rose, 2014; Caro and Davenport, 2015; Jewitt *et al.*, 2015; and Malimbwi *et al.*, 2016).

SNWC comprises of two parts, western part (administratively passes in Namtumbo and Tunduru Districts of Ruvuma regions in southern Tanzania) and eastern part (administratively passes in Liwale, Nachingwea, Masasi, and Nanyumbu Districts). This study concentrated in eastern part. In eastern SNWC, migration of elephants, buffalos and zebras has been observed (Pesambili, 2003; Ntongani, *et al.*, 2007).

Two migratory routes have been identified as follows:

(i) From Selous through Nahimba, Nakalonji, Mbondo, Kilimarondo, Matekwe and Kipindimbi proposed game reserve (GR) in Nachingwea District and then via Msanjesi, Mkumbalu, Sengenya, Nangomba and Nanyumbu in Nanyumbu District to Lukwika-Lumesule GR and then crosses Ruvuma River to the Niassa GR.

(ii) From Selous to Kiegei, Namatumu, Kilimarondo in Nachingwea then along Mbangala and Lumesule rivers to Mchenjeuka and Mitanga in the Lukwika-Lumesule GR, from where they cross the Ruvuma River to the Niassa Reserve.

These routes forms SNWC called Selous-Masasi corridor includes the Msanjesi (2,125 ha) and the Lukwika-Lumesule (44,420 ha) GRs in Masasi and Nanyumbu

Districts respectively and areas of Liwale, Nachingwea, Masasi and Tunduru Districts. However, human resides in the corridor and practices various socioeconomic activities for their livelihoods. These socio-economic activities degrade corridor habitats and contribute to climate change and variability. Some of these activities include uncontrolled wildfires; agricultural expansion due to high human population growth; mining and logging; and increased human ï wildlife conflicts due to blockage of corridor resulted from ribbon strip developments along the major roads within the corridor (Baldus and Hann, 2009; Kulindwa *et al.*, 2016; and Malimbwi *et al.*, 2016).

Encroachments of the corridor disturb the wildlife movements and lead to a dramatic reduction of wildlife populations and local extinction of some species. Baldus and Hann (2009) and Baldus *et al*. (2003, 2006 and 2009) reported poaching to be extensive in Selous-Niassa TFCA. This scenario necessitates the need of effective climate change mitigation and adaptation strategies in managing Selous-Niassa TFCA so as to gain conservation profit from carbon trade.

2.1.5 The Link between Climate Change, Ecosystem and Wildlife Corridors

Effectively managing wildlife and habitats in the context of climate change requires an ambitious approach that includes both core conservation areas, which are managed primarily for conservation values, and areas that are managed for multiple values while providing habitat for wildlife species. Core conservation areas include both public lands and private lands managed by land trusts, conservation organizations, or individuals for conservation purposes. However, other private landowners often manage lands for production as well as conservation values.

Incentive programs and other mechanisms can help encourage these landowners to create buffer zones around core areas or provide enough habitat connectivity for wildlife to move among core areas.

Climate change makes the need for strategic conservation efforts on both public and private lands ever more pressing. Past conservation decisions did not always take into account the need for habitat connectivity, which will prove to be especially important under changing climate conditions (Watts *et al.*, 2010). Mobile species can move to more suitable habitat, but they do so in unpredictable and chaotic ways, and narrowly defined ñwildlife corridorsò is not sufficient. Managers should avoid creating any new barriers to dispersal, and some existing barriers will need to be removed.

Habitat connectivity at the scale needed for climate change adaptation requires land management agencies, land conservation groups, and incentive programs to plan their conservation interventions strategically, collaboratively define priority lands and strategy, invest in these priorities first (Noss and Cooperrider, 1994; Boitani *et al.,* 2007). Although the habitats and species found in a given area may change over time, managing lands to sustain ecological processes helps make the larger surrounding landscapes more resilient to the effects of climate change (Austin, *et al.,* 2004). Careful management can help ensure that these places continue to provide needed ecosystem services support healthy populations of plants and animals.

Maintaining functional landscape connectivity as development continues to fragment habitat is an important conservation goal. However, past accomplishments in conserving wildlife and their habitats are important and will help provide the foundations for this network by modeling corridors using generic focal species or multiple focal species that are likely to serve as a collective umbrella for many native species and ecological processes (Watts *et al.*, 2010; Beier *et al.*, 2008). Conversely, a lack of coordination among diverse stakeholders has made it difficult to act strategically. Decisions about what land needs to be managed primarily or partially for conservation purposes should be coordinated at least at the state level.

2.1.6 Climate Change Adaptation and Mitigation Strategies Using Ecosystem Based Approaches

Impacts of climate change on biodiversity have already been observed and an increasing number of ecosystems, including areas of high biodiversity, are likely to be further disrupted by a temperature rise of 2°C or more above preindustrial levels. Societies need to be aware of the adverse impacts of climate change response measures on biodiversity and the provision of key ecosystem services (UNEP, 2010).

Ecosystem-based approaches that integrate biodiversity conservation and sustainable use; and the provision of ecosystem services into overall climate change adaptation and mitigation strategies can be cost-effective, can generate social, economic and cultural co-benefits and can help to maintain resilient ecosystems (SCBD, 2009 cited by UNEP, 2010). Such approaches include, but are not limited to, the protection of natural forest and peatland (wetland) carbon stocks, the sustainable management of forests, the use of native assemblages of forest species in reforestation activities, sustainable wetland management, restoration of degraded wetlands and sustainable agricultural practices. These approaches have potential benefits for indigenous peoples and local communities. Many ecosystem-based approaches to mitigation and adaptation can be designed and implemented to enhance the conservation and management of biodiversity and the relatively long-term provision of key ecosystem services (UNEP, 2010).

Protected areas have important role in conserving biodiversity and thereby increasing ecosystem resilience. Protected areas should constitute an explicitly recognized component of an ecosystem-based adaptation strategy (*ibid*). Protected areas can serve as important elements of climate change adaptation in several ways: first, by providing unbroken blocks of intact habitat; second, by providing places to which species and ecosystems can shift their ranges; third, by increasing ecosystem resilience and recovery by providing intact structures and natural processes; fourth, by providing protection against the physical impacts of climate change such as rising sea levels, rising temperatures and extreme weather events (Mulongoy and Gidda, 2008); and, fifth, by sustaining water supplies and increasing water security under changing hydrological conditions. Additionally, corridors between protected areas will become increasingly important to dealing with climate change as they will allow species to migrate along temperature or precipitation gradients in response to changing conditions. Protected areas are also subject to the impacts of climate change, and the risks posed by that fact need to be better understood and anticipated.

2.2 Land Use and Land Cover Change (LULCC)

Land Use and Land Cover Change (LULCC) calls for special attention since humans have been modifying land to obtain food and other essentials for thousands of years, but current rates, extents and intensities of LULC changes are far greater than ever in history (Ruddiman, 2003), driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales. LULCC can occur through the direct and indirect consequences of anthropogenic activities to secure their economic and social needs. Burning of areas to develop the availability of wild game as well as cultivated land, resulting in extensive clearing such as deforestation and earthôs terrestrial surface management that takes place today (Ellis and Pontius, 2006).

LULCC is a complex process which influenced by the jointly interactions between environmental and other social factors at different spatial and temporal scales (Valbuena, *et al*., 2008; Rindfuss *et al.,* 2004). More recently, industrial activities and developments, the so-called industrialization, has encouraged the concentration of population within urban areas. This is called urbanization, which includes depopulation of rural regions along with intensive farming in the most productive lands and the abandonment of marginal lands (Ellis and Pontius 2006). These conversions and their consequences are obvious around the world and it has been becoming a disaster around the metropolitan areas in developing countries. These changes encompass the greatest environmental concerns of human populations today (Foley *et al.,* 2005), including climate change, biodiversity loss and the pollution of water, soils and air. Monitoring and mediating the negative consequences of LULCC while sustaining the production of essential resources has therefore become a major priority of researchers and policymakers around the world.

2.2.1 Impacts of Land Use and Land Cover Change on Ecosystem Services

Households living in all terrestrial wildlife ecosystems like corridors depend heavily on services provided by those ecosystems for their livelihoods. LULCC can greatly alter the provision of ecosystem services. Land Conversion to human utilization introduces the risk of undermining human wellbeing and long term sustainability (Rockstrom *et al*, 2009). Particularly, it is considered to be one of the drivers of global environmental change (Shao *et al.,* 2005).

Transformation of ecosystems into other land use categories, primarily the conversion of various vegetation covers to agricultural land and urban areas, impacts water flows and the biogeochemical cycle, and is closely linked to climate change (Milad, *et al*., 2011; Schulp, *et al*., 2008). The joint effects of land use and climate change are perceived as the most important driver of biodiversity loss (Sala *et al.,* 2000). Because biodiversity is known to represent a key prerequisite for the functioning of an ecosystem and delivery of bundles of ecosystem services (MA, 2005; De Groot *et al.,* 2010), land use change may undermine regulatory capacities of the ecosystems, e.g. In terms of the ability to avoid and minimize hazards (Rockstrom *et al.,* 2009; Preston *et al.,* 2011). A number of risks initiated by land use change or its consequences originate in diminished land productivity, land degradation, disruption of water regime, water contamination, or extra losses of biodiversity (Shao *et al.,* 2005).

Biodiversity has been diminishing considerably by land change. While lands change from a primary forested land to a farming type, the loss of forest species within deforested areas is immediate and huge (Ellis and Pontius 2006). According to Ellis and Pontius (2006), the habitat suitability of forests and other ecosystems surrounding those under intensive use are also impacted by the fragmenting of existing habitat into smaller pieces, which exposes forest edges to external influences and decreases core habitat area.

The conversion of tropical forest to grassland disrupts the herbivores food chain of different sizes according to their dependent feeding structure and altering of many wildlife species; for example disappearances of ñecotonesò (area which separate grassland and wooded grass land) which is the living habitat of some antelopes (Kashaigili *et al*., 2003).

LULCC, particularly natural forest alteration makes soils vulnerable to a massive increase in windy and water soil erosion forms, particularly on steep topography. When accompanied by fire, also pollutants to the atmosphere are released. Soil fertility degradation within time is not the only negative impact; it does not only cause damage to the land suitability for future farming, but also releases a huge amount of phosphorus, nitrogen, and sediments to aquatic ecosystems, causing multiple harmful impacts of sedimentation and eutrophication.

2.2.2 Application of Remote Sensing on Land Use and Land Cover Detection

Remote sensing is an essential tool for land-change science because it facilitates observations across larger extents of earthôs surface than is possible by ground-based observations. Many studies have been done by various natural resources experts, Slayback (2003) studied land cover change in the Takamanda forest reserve in Cameroon. The study revealed that most of the areas of forest conversion into other land uses were located on the periphery of existing villages and areas of pre-existing secondary forest and the rates of forest clearing increased as the expanding patterns of forest conversion indicated. Mulongo (1993) used remote sensing to assess the rate of natural resources exploitation and the implication of existing land policy in the reserved lands of Mboele- Muyonzi in Zambia.

Shreier *et al.* (1994) used remotely sensed data and historic land use/land cover dynamics to study resources status in the Himalaya, Nepal watershed using geographical information system. In this study forest, cropping system and socio-economic factors were investigated. Observations showed that between 1947 and 1990, forest, shrubs and agriculture were the only land uses. Deforestation was significant from years 1972 to 1990 and was more critical in the middle mountains of Nepal. It was reported that geographical information systems when integrated with remotely sensed data could be useful in identifying impact of deforestation due to increased agricultural activities and grazing.

Remote sensing has also been used in several studies done in Tanzania. Luoga *et al.,* (2005) used remote sensing to investigate the potentials of local communities to sustainably manage miombo woodland resources. Results revealed that woodlands of Kitulanghalo Forest Reserve and surrounding public land covered 82.3% in 1964. However, woodland declined by 50% representing a decline of an overall mean of 1.6% per year for the period between 1964 and 1996.

Rugenga (2002) used remote sensing to study land use changes due to traditional irrigation activities for the periods 1955 to 1999 in Ruaha River, Tanzania. The study identified seven main land use classes including riverside vegetation, forest woodland, scrub, settlements and abandoned fields. The land use change was mainly observed along the Great Ruaha River and its distributaries. It was found that overpopulation, grazing and charcoal making were among socio-economic factors leading to land use/land cover changes.

2.2.3 Predicting Future Land Use Change

Forecasting and evaluating future land change is a complex set of tasks and, hence, it has to be performed after a deep scientific knowledge of the extent individuals, characters, as well as consequences of land transformation have been gathered (Meyer and Turner, 1994). A typical land use planning process requires the landscape planners to realise, classify, and investigate the current circumstances in order to project future probable development patterns, and propose plans based on available information (Brail and Klosterman, 2001).

According to Brail and Klosterman (2001), planners usually approach this task in two ways, a predominant or traditional approach and an analytical approach. The traditional approach foresees a future land use outcome and then prioritises present-day policies required to achieve that outcome. The analytical approach simulates alternate current strategies and compares their consequences. A recent pervasive approach to consider and simulate human decisions in LULCC is the use of multi-agent systems (MAS) (Parker *et al*. 2003; Matthews 2006; Robinson et al. 2007; Valbuena *et al*. 2008). MAS are defined as modeling tools that allow entities to make decisions according to the predefined agents, and the environment also has a spatial explicit pattern. In fact, agents in the system might represent groups of people or individuals, etc. (Valbuena *et al.,* 2008; Sawyer, 2003; Bonabeau, 2002; Crawford *et al.* 2005).

2.2.4 Land Use and Land Cover Prediction Models

Several methods have been developed for forecasting land use change, with varying degrees of sensitivity to the influence of transportation networks. The simplest types of models for forecasting land use change are Markovian models (such as Markov chain models) and Cellular and agent based models (Brown, 2000; Levinson, 2005; Weng, 2002).

2.2.4.1 Markov Model

The Markov model is a theory based on the process of the formation of Markov random process systems for the prediction and optimal control theory method (Jiang *et al.,* 2009). It tends to treat land use change as a stochastic process by assuming that rates of change between land use types are more or less constant from one period to the next. The Markov model not only explains the quantification of conversion states between the land use types, but can also reveal the transfer rate among different land use types (Hou *et al*, 2004). The model projects land use transitions forward to any given future date, eventually reaching an equilibrium distribution of land uses. These models tend to have a limited ability to incorporate transportation networks and other spatial features, except as states (e.g., land use types) in the model (Yang *et al.,* 2007). It is commonly used in the prediction of geographical characteristics with no after effect event which has now become an important predicting method in geographic research (Jiang *et al.*, 2009).

Based on the conditional probability, the prediction of land use changes is calculated by the following equation (1)

$S(t+1) = S(t) \times P_{ij}$é (1)

Where;

S (t); is the system status when there is no change at the time (t)

S (t+1); is the system status when there is a change at time (t+1)

Pij; is the transition probability matrix in a state which is calculated as follows

$$P_{ij} = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1N} \\ P_{21} & P_{22} & \cdots & P_{2N} \\ \cdots & \cdots & \cdots & \cdots \\ P_{N1} & P_{N2} & \cdots & P_{NN} \end{bmatrix}$$

$$\left(0 \le P_{ij} < 1 \text{ and } \sum_{j=1}^{N} P_{ij} = 1, \ (i, j = 1, 2, \ldots, n)\right)$$ é é é é é é é é é é (2)

2.2.4.2 Cellular Automata Model

The behaviour of Cellular Automata (CA) models is affected by uncertainties arising from the interaction between model elements, structures, and the quality of data sources used as the model input (Batty *et al*., 1999; Peterson *et al.,* 2009). It focuses mainly on the local interactions of cells with distinct temporal and spatial coupling features and the powerful computing capability of space, which is especially suitable for dynamic simulation and display with self-organizing feature systems. Advances in computational power and data storage have facilitated the development of models that disaggregate urban space to a greater degree and can operate with individuals or land parcels as the units of analysis, rather than zones. These include micro-simulation models of urban development (Waddell *et al.,* 2003) as well as models based on a cellular automata framework (Jants 2004; Yeh, 2002).

CA models emphasize neighbour effects and dynamic interactions between agents (with land use cells as agents), while micro-simulation models treat individual households and firms as agents and attempt to simulate their behaviour in terms of location and travel choices. The use of geographic CA for land use change simulations not only takes into account comprehensive consideration on soil conditions, climatic conditions, topography and other natural factors, but also considers a comprehensive policy, economy, technology and other human factors, and takes into account the historical trends of land use with strong applicability.

The CA model can be expressed as follows, equation (3)

S (t, t+1) = ä(S (t), N)é (3)

Where; S is states of discrete cellular, t is the time instant, t +1 is the coming future time instant respectively, N is the cellular field and f is the transition rule of cellular states in local space.

2.2.4.3 CA Markov Model

Cellular Automata ï Markov (CAï Markov) model is a combined Cellular Automata/Markov Chain/Multi-Criteria/Multi- Objective Land Allocation (MOLA) land cover prediction method that adds an element of spatial contiguity as well as knowledge of the likely spatial distribution of transitions to Markov chain analysis.

The Markov model focuses on the quantity in predictions for land use changes. For this model, the spatial parameters are weak and do not know the various types of land use changes in the spatial extents (Arnold, *et al.,* 2009). The CA model has a strong space conception, which is a strong capability of space-time dynamic evolution with complex space systems. The CAï Markov model, which incorporates the theories of Markov and CA, is about the time series and space for the advantages of forecasting. It can achieve better simulation for temporal and spatial patterns of land use changes in quantity and space (Ji *et al.,* 2009). The CAï Markov module in IDRISI32 integrates the functions of cellular automaton filter and Markov processes, using conversion tables and conditional probability of the conversion map to predict the states of land use changes, and it may be better to carry out land use change simulations.

2.3 Estimation and Prediction of Carbon Released to the Atmosphere as a Result of Land Use Change

2.3.1 Land Use in Tanzania

The most dominant land uses in Tanzania are; Agriculture (23%), Production forest (22%) and Wildlife areas (21%). The three land uses account for more than 60% of total land area. One third of the country land area is protected wild life reserves and protection forest and 48% of total volume is in these areas (Figure 2.1) (URT, 2015).

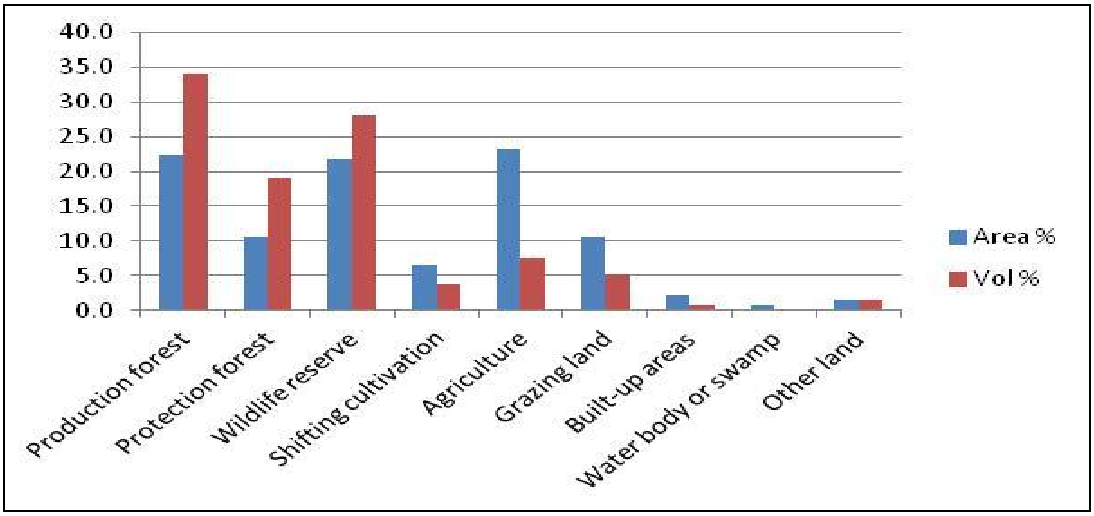

Figure 2.1: Area and Volume Distribution by Land Use (URT, 2015)

All land in Tanzania is considered public land, which the President holds as trustee for the people. The Tanzania Land Policy (1995), the Land Act and Village Land Act (1999), set out the fundamental principles guiding land rights and management.

The Land Act classifies land in three categories: (1) reserved land; (2) village land; and (3) general land. The reserved land is land under the central and local governments. Village land constitutes about 36% of the total land area. Other dominant land owners are central government and private land. The local governments and general land have minor shares (Figure 2.2).

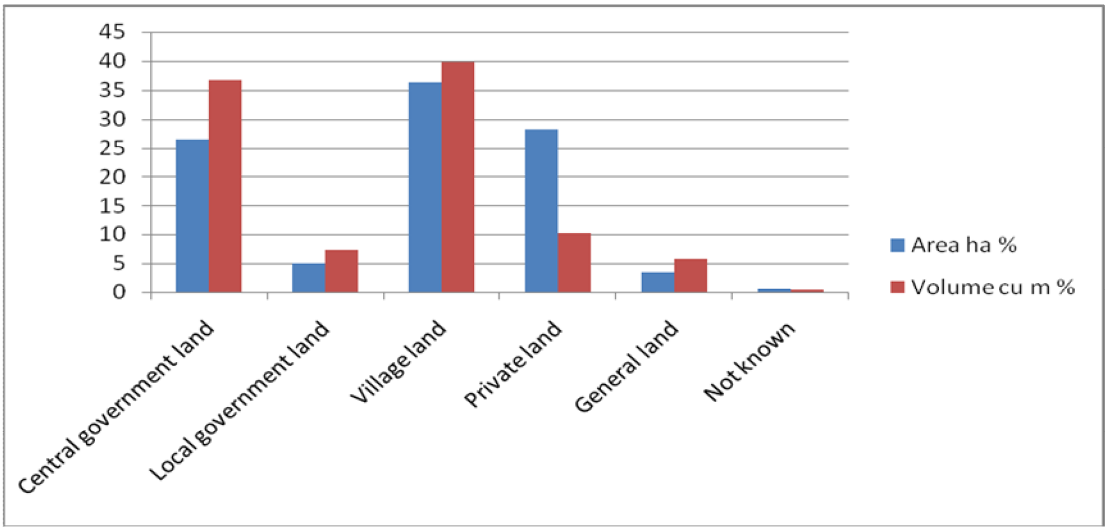

Figure 2.2: Area and Volume Distribution by Ownership (URT, 2015)

Forest Policy of 1998, the area of non-reserved land (general land) was 19,038,000 ha. Since then the major part of General land has shifted into village land and the remaining area now stands at 2,732,575 ha according to the NAFORMA findings. This is the result of implementing Property and Business Formalization Program (PBFP) popularly known as *MKURABITA* established in 2004. The goal of the program was to facilitate formalization of property and business assets in the extralegal sector, into legally held and formally operated entities in the formal sector of the economy. About 22% of the land use area in Tanzania is production forests and village land constitutes 36% of the total land area. Calculations show that 66% of the volume in production forest is in village land (URT, 2015).

2.3.2 Forests in Tanzania

Tanzania Government has assessed all forests in the country in terms of plots, size and cover trends popularly known as NAFORMA (URT, 2015). Before NAFORMA, the state and trends of the forestry resources in the country were largely unknown as the information that existed was fragmented and outdated. NAFORMA produces forests data that can be used as a tool necessary to be used for national policy and international reporting addressing REDD and climate change as a whole.

The total land area of Tanzania is 88,334,300 ha while the total growing stock is 3,322 million m^3. NAFORMA biophysical results show that total forest area is estimated to be 48.1 million ha which accounts 54.4% of the total land area. The results are highly precise and as an example, the error estimate for forests and woodlands is below ten percent at 95% probability level indicated highly reliable volume estimates (URT, 2015). The high number of sample plots by vegetation type has contributed to the high precision and accuracy of the baseline information on above ground biomass and its Carbon content (Table 2.3).

Table 2.3: Sampling Errors and Precision Estimates by Primary Vegetation Type (URT, 2015)

Primary vegetation type	Number of sample plots	Mean volume (m3/ha)	Error Est (m3/ha)	Precision (%)
Forest	1,594	111.84	8.09	6.87
Woodland	15,640	55.11	1.13	2.02
Bushland	2,671	21.85	1.76	8.91
Grassland	2,742	5.70	0.62	10.10
Cultivated land	6,067	11.76	1.14	10.13
Open land	85	5.72	2.73	45.14
Water	405	9.19	4.22	42.95
Other areas	656	16.79	4.17	22.96

About 55% of the land area is forest and woodland. Woodlands alone cover 51 % of the total land area. FAO/FRA (2010) defined forests (both the forest and classes are classified as forest) as a minimum area of 0.5 ha, the trees must be at least 5 m in height or capable of reaching that height on the site and canopy cover must be 10% or more. There are four forest classes in the detailed vegetation classification: The humid montane forest, lowland forest, mangrove forest and plantations. The woodland is the most extensive vegetation type in the country, and most activities are carried out in the woodlands (Table 2.4).

Table 2.4: Major Land Uses Carried Out in the Woodland

Land use	Area (ha)	Percent in the woodlands (%)
Wild life	31,535,345	70
Production forest	35,589,890	79
Grazing	23,876,761	53
Protection forest	31,084,840	69
Shifting cultivation	14,866,663	33

Source: (URT, 2015)

Forests (Table 2.5) shows that the plantation area has increased from 250,000 ha (FAO 2010) to more than 500,000 ha as revealed by NAFORMA (URT, 2015). This is a result of response from communities to establish woodlots and most of these efforts are in the Southern Highlands.

Table 2.5: Area Distribution of the 'Forest'

Forest	Area (ha)
Humid Montane	991, 737
Lowland	1, 650, 656
Mangrove	157, 570
Plantation	552, 576
Total	**3, 352, 538**

Source: (URT, 2015)

Table 2.6 summarizes distribution of forest and woody vegetation resources by regions. Morogoro, Lindi, Ruvuma, Mbeya, Tabora and Katavi regions have the largest wood volumes. The average number of trees per ha is 876 varying from less than 200 in Simiyu to about 1,700 stems in Mtwara region. The large number of trees is due to the methodology used by NAFORMA of measuring all trees with Dbh of one cm and above. When the number of trees in one ha exceeds 1,000, it may demonstrate that most of the trees are small.

Table 2.6: Distribution of Forests and Woody Vegetation Resources by Regions

Zone	Region	Total area ha	Mean volume m^3/ha	Total volume Million m^3	Number of trees/ha	Forest + wood-land, %	Forest + wood-land, m^3/ha
Eastern	Dar es Salaam	150,809	24.9	3.7	704	32.5	53.4
	Morogoro	6,886,883	54.8	376.2	1,268	63.6	76.7
	Pwani	3,196,403	37.4	118.9	1,508	58.7	54.5
Southern	Lindi	6,785,532	55.2	372.8	1,622	77.2	64.1
	Mtwara	1,794,853	43.4	77.5	1,685	41.4	81.1
	Ruvuma	6,338,030	52.6	332.0	968	74.6	64.9
Southern Highlands	Rukwa	2,167,494	29.7	64.1	454	41.2	57.0
	Njombe	2,194,407	26.5	58.0	641	37.0	52.2
	Iringa	3,453,694	37.2	127.8	762	52.1	57.3
	Mbeya	6,106,391	52.3	318.2	786	70.6	69.7
Central	Manyara	4,469,962	19.9	88.4	588	45.5	32.8
	Dodoma	4,183,192	28.3	117.8	685	32.8	45.3
	Singida	4,856,938	25.8	124.7	930	45.7	40.1
Lake	Mara	2,189,924	9.4	20.4	289	15.7	34.5
	Simiyu	2,345,074	8.5	19.9	186	18.0	30.8
	Mwanza	1,092,257	13.3	14.5	284	14.3	61.3
	Kagera	2,527,312	25.1	63.3	763	54.3	39.1
	Geita	2,098,555	34.5	72.1	674	48.1	60.8
Western	Tabora	7,595,994	39.8	301.3	689	61.2	58.9
	Shinyanga	1,853,931	11.5	21.3	425	17.1	48.2
	Kigoma	3,819,825	42.4	161.4	534	60.4	61.0
	Katavi	4,342,814	59.4	256.9	730	82.7	69.2
Northern	Kilimanjaro	1,250,496	38.5	47.9	579	48.6	66.2
	Arusha	3,822,918	15.3	58.3	693	43.5	28.9
	Tanga	2,810,612	41.1	115.2	1576	47.9	67.6
Total /average		**88,334,300**	**37.9**	**3,332.7**	**876**	**54.6**	**59.4**

Source: (URT, 2015)

In forest plantations, this may be young stands while in natural forests, it indicates good regeneration. Katavi, Lindi, Ruvuma and Mbeya regions are the most forested. More than 70% of the land of these regions is covered by forests and woodlands (URT, 2015).

At district level, only seven districts have more than 60 m^3/ha average stocking. These are Chunya, Mpanda, Nanyumbu, Kibondo, Ulanga, Namtumbo and Kilombero. The highest stocking of 67.7 m^3/ha was recorded in Ulanga district. Shinyanga, Simiyu, Mara, Mwanza and Geita regions which are largely livestock keeping, have the least forest areas as well as smallest growing stock. These regions are also dominated by grassland and/or bushland. Moreover, Shinyanga, Kwimba, Kishapu, Busega, Monduli, Serengeti and Mkalama districts have forest stocking of less than 10 m^3/ha (URT, 2015).

2.3.3 Estimation of Carbon Released to the Atmosphere as a Result of Land Use Change

2.3.3.1 Living Biomass Stocks

Forest Carbon can be estimated in three pools namely AGB (above ground biomass), BGB (below ground biomass) and DW (dead wood) (URT, 2015). BGB was estimated as a fraction of AGB. AGB and BGB were estimated as follows:

i. AGB (tonnes/ha) = Tree stem volume (m^3/ha) * wood density/1000; and
ii. BGB (tonnes/ha) = AGB * 0.25 (as default), or root to shoot ratios.

The following conversion factors were programmed into the NAFORMA analysis system by tree species or species groups:

Table 2.7: Wood Density

Type of wood	Density
Pines	390 kg/m^3
Dalbergia melanoxylon (Mpingo)	1060 kg/m^3
Humid montane forest	580 kg/m^3
Other woody vegetation	500 kg/m^3

Biomass Expansion Factor (BEF): not used, only bole volume calculated!

Default carbon conversion factor: 0.47

Table 2.8: Root Conversion Ratios: Default 0.25

Vegetation type	Root/shoot conversion ratios
Lowland forests	0.37
Humid montane	0.27
Bushland	0.40
Open woodland, scattered cropland	0.37
Grassland	0.37
CL: herbaceous crops, CL:grain crops	0.37
Wooded grassland	0.37
OL: Coastal bare land, bare rock	0.37
Wa: Ocean, Inland water built-up areas	0.37
Mangroves, closed WL, WL:AF systems, wooded crops	0.28
Plantations	0.20

URT (2015) through NAFORMA reveals that, Tanzania has a total Carbon in the living trees of 1,060.8 million tons (Table 2.9). The major carbon sink is the woodland with 73.5% of the Tanzania mainland Carbon.

Table 2.9: Living tree Stem Wood Biomass and Carbon by Primary Vegetation Type

Primary Vegetation Type	Volume m^3/ha	Aboveground Stem Biomass, t/ha	Belowground Biomass, t/ha	Carbon t/ha	Carbon t	Share %
Forest	111.8	59.5	18.2	36.5	122,340,057	11.5%
Woodland	55.1	27.7	9.5	17.5	779,607,827	73.5%
Bushland	21.8	11.0	4.4	7.2	46,388,588	4.4%
Grassland	5.7	2.9	1.1	1.8	15,115,401	1.4%
Cultivated land	11.8	5.9	2.1	3.8	83,293,969	7.9%
Open land	5.7	2.9	1.1	1.9	466,006	0.0%
Water	9.2	4.6	1.7	3.0	3,429,530	0.3%
Other areas	16.8	8.4	3.1	5.4	10,192,480	1.0%
TOTAL CARBON, MAINLAND TANZANIA					**1,060,833,858**	100.0%

Source: (URT, 2015)

2.3.3.2 Deadwood Biomass

Dead wood (DW) biomass is estimated from the volume computed using Smalian formula multiplied by wood density of 619 kg/m^3 (Chidumayo, 2012 cited by URT, 2015). URT (2015) through NAFORMA reveals the dead wood Biomass tons of Tanzania (Table 2.10) is relatively low since most dead wood in accessible areas is collected as fuelwood. As woodlands are generally more accessible than forests, collection of deadwood for fuelwood from these areas is easier. The relatively high volume of dead wood in water is assumed to be because dead trees lying in areas with water / wetlands are difficult to access and decay slowly and because they are wet and therefore unattractive for fuelwood.

Table 2.10: Dead Wood Biomass and Carbon of Tanzania Mainland

Primary Veg. Type	**Biomass t/ha**	**Carbon t/ha**	**Total DW Carbon, t**	DW **carbon %**
Forest	4.87	2.39	7,997,394	12.7
Woodland	1.82	0.89	39,664,224	63.0
Bushland	0.73	0.36	2,284,911	3.6
Grassland	0.35	0.17	1,397,907	2.2
Cultivated land	0.91	0.45	9,929,475	15.8
Open land	0.22	0.11	27,480	0.0
Water	1.31	0.64	741,566	1.2
Other areas	0.99	0.48	914,657	1.5
TOTAL DEADWOOD (t)			**62,957,614**	**100**

Source: (URT, 2015)

2.3.3.3 Carbon

According to URT (2015), carbon can be computed as follows:

Carbon (tonnes/ha) = Biomass * 0.47

Total carbon calculation includes Living tree stem wood carbon (above ground and below ground carbon)and dead wood carbon stocks derived from biomass (as computed in sections 2.3.3.1 and 2.3.3.2).

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter covers relevant methodologies used in the study includes description of the study area, data types and sources, data collection and analysis methods as follows:

3.1 Description of the Study Area

3.1.1 Location

The study was carried out in eastern Selous-Niassa TFCA with an area of 1, 462, 560 hectares called Selous-Niassa wildlife corridor (SNWC) which extends across southern Tanzania into northern Mozambique between 10^0S to 11^0 40ôS with north-south length of 160 to 180 km (Figure 3.1). The study area comprise wildlife management areas (WMAs) bordering Selous, Msanjesi and Lukwika-Lumesule game reserves (MAGINGO WMA, NDONDA and MCHIMALU proposed WMAs respectively) which are within Liwale, Nachingwea/Masasi and Nanyumbu Districts respectively. In this study three villages namely Mpigamiti, Kilimarondo and Mpombe within MAGINGO WMA and NDONDA and MCHIMALU proposed WMA were purposely selected for ground of the study.

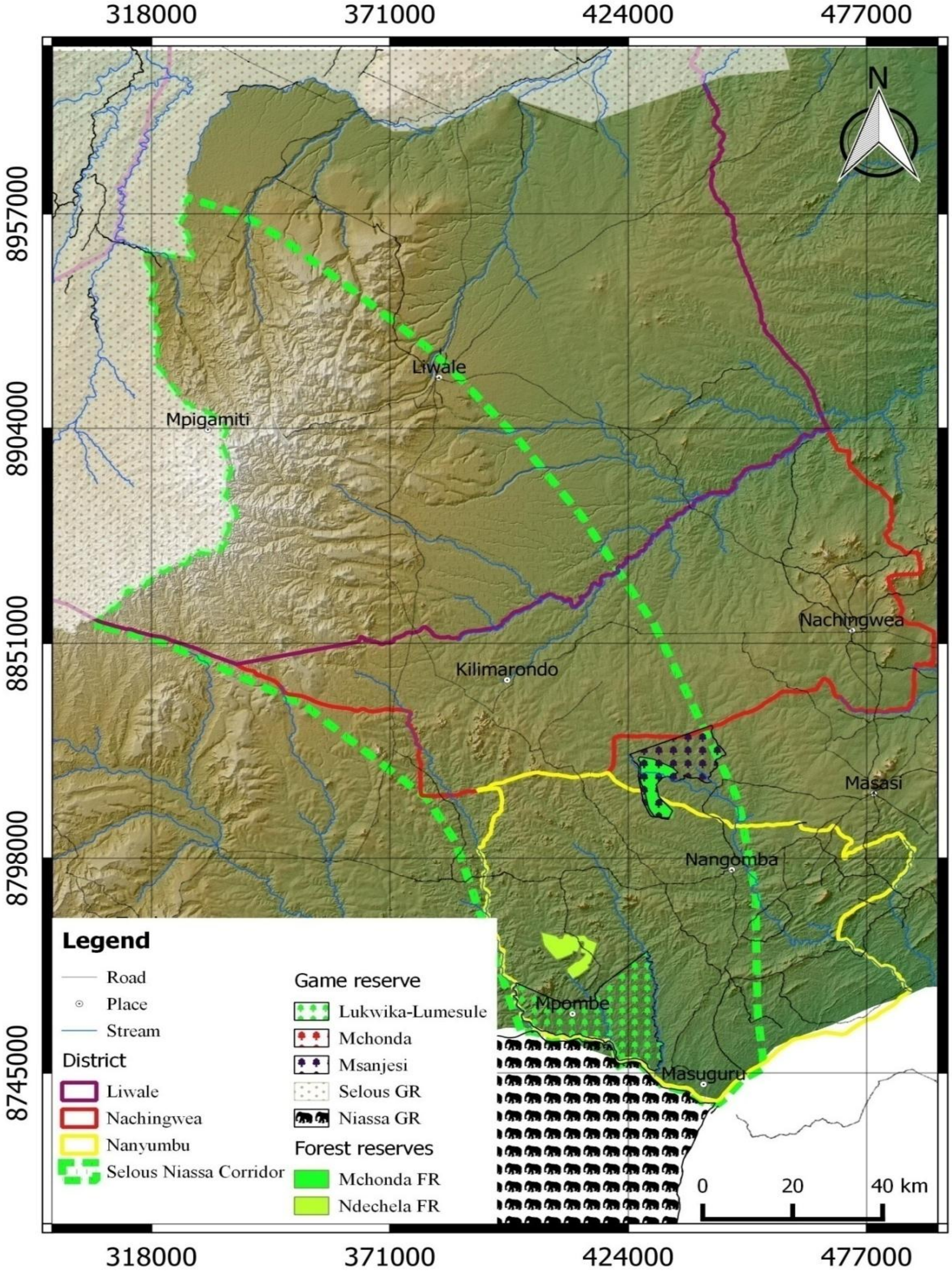

Figure 3.1: The Map of the Study Area

3.1.2 Geology

In general the northern part is hilly while the area towards the Ruvuma River is slightly undulated to flat with isolated hills, some of them having prominent rock outcrops (inselbergs). Mtungwe Mountain (1284m a.s.l.) in the centre of the corridor is the highest elevation. From the North the plateau slightly slopes to the Ruvuma River which reaches its lowest level of about 460m a.s.l. in the southeastern corner of the Corridor. The soils are generally very sandy and washed-out. Two drainage basins exist in the SNWC. North of the watershed, located along the Lake Niassa ï Indian Ocean Highway, the rivers drain into the Rufiji River while the area south of the watershed is part of the Ruvuma drainage basin. Some of the major tributaries like Mbarangandu, Lukimwa, Luchulukuru, Luego or Msanjesi are usually permanent watercourses.

3.1.3 Climate

The corridor has the typical unimodal rainfall system of the Miombo woodland ecosystem. The southeast monsoons, bearing moisture from the Indian Ocean, are responsible for the rainy season chiefly occurring from mid-November to mid-May. The rainfall generally decreases from the northern part with about 1200-1300 mm rainfall per year towards the south having a mean annual rainfall of about 800 mm along the Ruvuma River. The mean annual temperature is about 21°C.

3.1.4 Vegetation

The wide variety of its wildlife habitats ï Miombo woodland dominated by *Brachystegia spp, Julbernardia spp. and Isoberlinia spp.,* wooded grasslands, open savannahs, granite inselbergs, seasonal and permanent wetlands and riverine forests along numerous perennial and seasonal streams - account for globally significant biodiversity. Although vegetation studies are still in progress about 500 plant species including one tree species (*Xylopia sp. nov.*), which has been never described before, have been identified. A number of these plant species are either CITES listed or are of the IUCN category for threatened species and endemic to Tanzania (Baldus, *et al.*, 2009).

3.1.5 Wildlife

Several dry season aerial censes were carried out simultaneously in both countries at intervals of three years - the latest in 2012 (TAWIRI, 2012). Accordingly the total elephant population of the entire Selous ó Niassa ecosystem seems to be less than 70,000 as reported in 2006, with the majority in Tanzania. Globally significant populations of Lichtensteinõs hartebeest *(Alcelaphalus buselaphus lichtensteinii)*, African buffalo *(Syncerus caff er)*, Niassa wildebeest *(Connochaetes taurinus cooksoni)*, Eland *(Taurotragus oryx)*, Greater kudu *(Tragelaphus strepsiceros)*, Common waterbuck *(Kobus ellipsiprymnus)*, Bushbuck *(Tragelaphus scriptus)*, Common Reedbuck *(Redunca arundinum)*, Zebra *(Equus burchelli)*, Impala *(Aepyceros melampus)* and Klippspringer *(Oreotragus oreotragus)* are linked by the corridor. Their distribution and occurrence varies substantially depending on the rainy or dry season and their location in the corridor.

Large numbers of Rooseveltõs sable antelope *(Hippotragus niger roosevelti)* are widespread throughout the corridor. Beside these species both reserves and the corridor are home of a variety of large carnivores including African wild dog *(Lyacon pictus)*, Lion *(Panthera leo)* and Leopard *(Panthera pardus)* and Spotted hyaena *(Crocuta crocuta)*. Other wildlife includes Crocodile *(Crocodilus niloticus)* and Hippopotamus *(Hippopotamus amphibius)*. The highly endangered Black rhino (*Diceros bicornis)* is still found in both reserves and the corridor, but numbers are low. The ecosystem has also a rich diversity of bird life. Migratory birds use the Ruvuma River area as a nesting or resting place on the fly way route from Northern Europe to South Africa.

3.1.6 Socio-Economic Activities

The economy of the corridor communities in Liwale and Nanyumbu Districts is based on subsistence agriculture (95%). Staple crops grown are maize and cassava, cash crops predominantly cashewnut, sesame, sunflower, rice and groundnuts. Livestock is mostly restricted to goats, sheep and chicken. Cattle are rare due to the presence of Tsetse in the region (Schuerholz and Bossen, 2005). Currently, high immigration of livestock and livestock keepers are experienced in the area.

Dependency on natural resources by corridor dwellers is rated as ñvery highò. Natural products collected regularly include poles for house construction, grass for thatching, reeds, firewood, wild fruits, mushrooms, traditional medicines and (legally or illegally) fish and bush meat. Firewood is the main source of domestic energy for cooking for over 96 percent of all households with no affordable energy alternatives in the foreseeable future (Smith, 2005).

3.1.7 Ethnicity

Ngindo, Yao, Mwera, Makua and Matambwe tribes are common in eastern part of the corridor. Ngindo are commonly found in Liwale District, Mwera in Nachingwea

District, Makua, Yao and Matambwe in Masasi and Nanyumbu Districts. Historically these tribes were hunters and gatherers. Thus, living adjacent or within wildlife protected areas for this ethnicity is inexorable (Schuerholz and Bossen, 2005).

3.2 Research Design

A cross sectional survey design was employed. This type of research design utilizes different groups of people who differ in the variable of interest, but share other characteristics such as socioeconomic status, educational background, and ethnicity (Kothari, 2004). Cross sectional survey design has various merits including (i) it takes place at a single point in time, (ii) does not involve manipulating variables, (iii) allows researchers to look at numerous things at once (age, income, gender) and (iv) often used to look at the prevalence of something in a given population.

3.3 Sampling Procedure and Sample Size Determination

3.3.1 Sampling Procedure

Mpigamiti, Kilimarondo and Mpombe villages in Liwale, Nachingwea and Nanyumbu districts respectively were purposively selected as those found within eastern wildlife corridor of Selous-Niassa TFCA. The study villages selected because (i) all are within the corridor, (ii) all are members of wildlife management areas (WMAs) (Mpigamiti ï MAGINGO WMA, Kilimarondo ï NDONDA proposed WMA and Mpombe-MCHIMALU proposed WMA) and (iii) Mpigamiti is within the beginning of the corridor, Kilimarondo at the middle of the corridor while Mpombe is within the destination of the corridor in Tanzania.

A list of all households from the updated village register book in the study villages was the sampling frame. Sampling unit for this study was a household. Household was defined as a group of people living together and identifying the authority of one person the household head, who is the decision maker for the household (Katani, 1999). Simple random sampling was used to identify the sample units. In this method every household has an equal chance of being selected. Where a candidate happened to come from the same household, one was dropped (Bouma, 2000; Henn *et al*., 2006; Veal, 1997; and Kaswamila, 2009).

3.3.2 Sample Size Determination

The sample size for each study village was 30 households whereby 10 households were drawn from each income group (low, medium and high) as described in villageôs fact sheet. Sample size determination of this study obeyed central limit theory which states that ñsampling distribution of the sample means approaches a normal distribution as the sample size gets larger ï no matter what the shape of the population distribution; and this holds true for the sample sizes of at least 30ò.

Additionally, sample size in socio-economic studies can be decided by the researcher depending on the nature of study but should be at least 30 units as supported by many scholars (Bailey, 1994, Boyd *et al.*, 1981; Kajembe and Luoga, 1996; Mbwambo, 2000; and Kaswamila, 2009). Judgmental/purposive sampling technique was used to obtain 17 key informants. The distributions of sample size are shown in Table 3.1.

Table 3.1: Respondent Sample Composition

Category of respondent	District	Villages			
		Mpigamiti	Kilimarondo	Mpombe	Total
Households		30	30	30	90
Village Executive officers (VEOs)		1	1	1	3
Village Natural Resources Officers(VNROs)		1	1	1	3
Project Manager of LLM (PLLM)	1				1
District Game officers (DGOs)	3				3
Sector warden of SGR (SWS)	1				1
Village Development Officers (VDOs)		1	1	1	3
WMA Chairpersons (WCs)	3				3
Total	**8**	**33**	**33**	**33**	**107**

Source: researcher, 2019

3.3.3 Pilot Study

Prior to actual data collection, pilot study was conducted so as to provide a general picture of the study area and testing of the questionnaire in order to verify if the questions could be understood by the respondents. Questionnaire pilot-testing was done in Majonanga village which is within Selous-Niassa wildlife corridor in NDONDA proposed WMA in Nachingwea District and is adjacent to Msanjesi GR aimed to test questionnaire wording, sequencing and layout; and to estimate response rates and time.

3.4 Data Collection Methods

In order to attain the overall aim and objectives of this study, a combination of methods and techniques were employed. Different scholars stress the need to use a combination of methods and develop a more ñrigorous methodologyò as they are useful to corroborate and ensure validity, not providing proof but improving consistency across methods in a process of triangulation (Kaswamila, 2009). This study consisted two phases of data collection whereby primary and secondary data were collected.

3.4.1 Secondary Data

Secondary data was collected using Remote Sensing and Geographical Information Systems (GIS) and literature surveys. Both quantitative and qualitative data were acquired.

3.4.1.1 Remote Sensing and Geographical Information Systems (GIS)

Spatial data includes satellite images and digital elevation model (DEM) downloaded from USGS ï GLOVIS

3.4.1.2 Literature Surveys

Published and unpublished archive information obtained from SGR, LLM, Village, and or Districts offices, libraries and internet. Data accessed were in the form of reports, manuscripts, books, journal papers and other documents found in office files and other collections. Documented information related to land uses of Selous-Niassa TFCA; and impact of climate change and variability in managing Selous ï Niassa TFCA were accessed. Similar information was also sought from districts and villages experts (agriculture, wildlife and community development). This information was used to supplement data collected from interviewed households and downloaded spatial data.

3.4.2 Primary Data

Primary data for this study were collected using survey (household questionnaire survey and key informants interview); participatory rural appraisal (focus group discussion and direct observation). Both quantitative and qualitative data were acquired.

3.4.2.1 Household Questionnaire Survey

Semi-structured questionnaires were administered to the sampled households (see appendix 1). This type of questionnaires can be used with informants who are illiterate, blind, bedridden or very old and when a respondent does not understand the question the researcher can translate and elaborate to bring the right meaning as explained much by Gillham (2005); Miler & Wilson (1983); and Kaswamila (2009).

The household questionnaire survey were useful in acquisition of quantitative information for statistical analysis, acquiring much social economic information quickly, current land uses within Selous-Niassa TFCA, and consequences of climate change and variability in managing Selous-Niassa TFCA. Both pre-testing and pilot-testing of questionnaires were exercised. During questionnaires preparation, pre-testing was done to OUT staffs and students. Pre-testing was used to assess whether the questions are clear, specific, answerable, interconnected and substantially relevant (Kaswamila, 2009).

Before administering the questionnaires one task was accomplished, this is training of three local research assistants including questionnaire pilot-testing as part of training. The use of local research assistants aiming at reducing researcher or experimental bias effect (Miller & Wilson, 1983; Kaswamila, 2009), to exploit local peopleös willingness to provide information to a person they know. During research assistants training, questionnaire pilot-testing was done in Majonanga village which is within Selous-Niassa TFCA in Ndonda proposed WMA in Nachingwea District. The instrument was self-administered to 10 respondents following procedures described by White (2002) and Mauch *et al.* (2003).

3.4.2.2 Key Informants Interview

Checklist of questions (Appendix 2) was used to guide interview with 17 key informants as shown in Table 3.1 above. Type of data collected was involved current land uses within Selous-Niassa TFCA, and consequences of climate change and variability in managing Selous-Niassa TFCA, and related studies done in the area and also recommendations on how management strategies can be improved so as achieving sustainability. At that time researcher recorded the relevant information which relate with the study.

3.4.2.3 Focus Group Discussions

Two focus group discussions in each study village with villagers were organised. Each discussion group comprised 6-12 people (Mikkelsen, 1995; Charmaz, 2005; and Lusambo, 2009). A checklist of questions (Appendix 3) were used to cover discussion themes, which hinged on current land uses within Selous-Niassa TFCA, and consequences of climate change and variability in managing Selous-Niassa TFCA. In the discussions, the researcher acted as a facilitator, tape recording and ensures that everyone have a say. The age group of discussants were at least 18 years of age as they are familiar with the study area and issues concerning management of the TFCA.

3.4.2.4 Direct Observation

As the data collection being carried out, direct field observation method was used to supplement data collected from social surveys and focus group discussion. A researcher and assistants together with some villagers and key informants were randomly site observing land uses that destruct wildlife habitat within Selous-Niassa TFCA as identified during focus group discussion. The assistants undergo training on the critical issues of the study to be captured. The obtained information enabled the researcher to discuss with respondents (households, key informants and focus groups) for triangulation purposes. Again, this tool was used for generation of first hand data which is not interfered by other factors standing between researcher and respondent. This covered the gaps left by other data collection instruments for example cross checking whether what was claimed to be facts and actual facts. A checklist contained issues for cross checked was used in recording the observed data. Also, digital camera was used to take photographs relevant to the study.

3.5 Data Analysis

3.5.1 Analysis of Spatial and Temporal Changes in Land Use and Land Cover in the Study Area

3.5.1.1 Analysis of Spatial and Temporal Changes in Land Use and Land Cover in the Study Area from 1986 - 2016

The land cover change detection analysis was conducted based on the following steps:

i. Satellite image selection and acquisition

Appropriate satellite imagery acquisition was done with highly consideration of cloud cover, the seasonality and phonological effects (Kashaigili, 2006). Clouds free satellite images with the interval not less than five years from 1986 to 2016 (Table 3.2) were used in assessing temporal and spatial variation of land use/cover change in the study area.

Table 3.2: Satellite Imagery Data

Year	Satellite	Sensor	Path/Row	Acquisition date	Cloud cover (%)
1986	Landsat 5	TM (SAM)	166/67	19/8/1986	0
	Landsat 5	TM (SAM)	166/68	30/9/1984	0
	Landsat 5	TM (SAM)	167/67	21/8/1990	5
1997	Landsat 5	TM (SAM)	166/67	14/6/1997	7
	Landsat 5	TM (SAM)	166/68	20/8/1998	8
	Landsat 5	TM (SAM)	167/67	27/12/1996	7
2005	Landsat 5	TM (BUMPER)	166/67	10/10/2005	10
	Landsat 5	TM (BUMPER)	166/68	23/6/2006	1
	Landsat 5	TM (BUMPER)	167/67	30/8/20058	8
2016	Landsat 8	OLI-TIRS	166/67	8/10/2006	0.28
	Landsat 8	OLI-TIRS	166/68	8/10/2016	0
	Landsat 8	OLI-TIRS	167/67	13/9/2006	0.8

ii. Image Pre-processing

To ensure accurate identification of temporal changes and geometric compatibility with other sources of information, images were pre-processed whereby geo-correction was conducted to rectify precisely matching of images. Band stacking and Images enhancement was performed using different color composite band combination and its contrast was stretched from minimum to maximum to reinforce the visual interpretability of images. Images were registered to the UTM map coordinate system, Zone 36 South, Datum Arc 1960.

iii. Preliminary Image Classification and Ground Truthing

Supervised image classification using Maximum Likelihood Classifier (MLC) was conducted to create base map. Data from ground truth were used to formulate and confirm different cover classes existing in the study area. Training sites were identified by inspecting an enhanced color composite imagery. Areas with similar spectral characteristics were trained and classified.

Supervised classification by using Semi-automatic Classification Plug-in (SCP) available in QGIS 2.12.1 was conducted. The process involved selection of regions of interest (ROI) on the image, which represent specific land classes to be mapped. During Supervised Classification, maximum of seven distinct land cover classes were identified (Table 3.4) which are; Closed woodland (CWD), Open woodland (OWD), Bushland (BS), Grassland (GL), Water (WTR), Built up area (BLT) and Cultivated land (CL).

iv. Final Image Classification and Accuracy Assessment

Kappa coefficient statistics was used to assess the accuracy of final image classification.

Where N is the total number of sites in the matrix, r is the number of rows in the matrix,

$$K = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})} \quad \text{é é é .é é é é é é é é é é é é é .(1)}$$

x_{ii} is the number in row i and column i, x_{+I} is the total for row i, and $xi+$ is the total for column.

The classified maps show good agreement with the real world as indicated in Table 3.3.

Table 3.3: Accuracy Assessment

Year	1986	1997	2005	2016
Overall accuracy (%)	98%	82%	89%	92%
Kappa statistic	0.97	0.79	0.92	0.91

Table 3.4: Land Use/Cover Classification Scheme

Land cover class	Description
Closed woodland	Area of land covered low density trees forming open habitat with plenty of sunlight and limited shade
Open woodland	Area of land covered with low density and scattered trees with crop cultivation activities
Bushland	Area dominated with bushes and shrubs
Grassland	Land area dominated by grasses
Water	Area within body of land, of variable size, filled with water, localized in a basin, which rivers flow into or out of them (Lake/Dam)
Built up area	Man made infrastructure (roads and buildings) and settlement
Cultivated land	Farm with crops and harvested cropland
Unclassified	Area with no input data or insufficient information which has been missed due to several reason including clouds, clouds shadow, darkness, and sensor dysfunctioning

v. Land use and Land Covers Change Detection

Post classification comparison was used to quantify the extent of land cover changes over the period 1986 ï 2016. Post classification comparison sidesteps the difficulties associated with the analysis of the images that are acquired at different times of the year, or by different sensors and results in high change detection accuracy (Li *et al.*, 2007). The estimation for the rate of change for the different land covers was computed based on the following formulas (Kashaigili and Majaliwa, 2013).

$$\% \text{ cover change} = \frac{Area_{i\ year\ x} - Area_{i\ year\ x+1}}{\sum_{i=1}^{n} Area_{i\ year\ x}} \times 100 \quad \text{é é é é é é é é é} \quad (2)$$

$$\textit{Annual rate of change} = \frac{Area_{i\ year\ x} - Area_{i\ year\ x+1}}{t_{years}} \quad \text{é é é é é é é é é} \quad (3)$$

$$\textit{\% Annual rate of change} = \frac{Area_{i\ year\ x} - Area_{i\ year\ x+1}}{Area_{i\ year\ x} \times t_{years}} \times 100 \quad \text{é é é é} \quad (4)$$

Area $_{i\ year\ x}$ is the area of cover i at the first date,

Area $_{i\ year\ x+1}$ is the area of cover i at the second date,

$\sum_{i=1}^{n}$**Area** $_{i\ year\ x}$ is the total cover area at the first date

t $_{years}$ is the period in years between the first and second scene acquisition dates

3.5.1.2 Prediction of the Future Changes in Land Use/Cover of the Study Area

The study utilized Markov Chain Analysis and Cellular Automata Analysis, jointly called CAï Markov, to predict and simulate the future change of land use and land cover of the study area by the year 2035.

3.5.1.2.1 CA – Markov Chain Analysis

Markov chain is a statistical tool that describes the probability of land use to change from one time period to another by developing a transitional probability matrix between first period and second period based on the neighborhood effects (Araya and Kabral, 2010; Al-Bakri *et al.,* 2013; Wang *et al.,* 2014; and Chilagane, 2016). This model was based on using and evaluating land use layers of previous years to predicting the spatial distribution of land uses in the future (Wu *et al,* 2010). For the better simulation for temporal and spatial patterns of land use changes in quantity and space, the combination of Cellular automata and Markov chain (CA-Markov) were developed.

The simulated model was developed by using IDRISI Selva 17.0 software and it involved two main stages which are calculating conversion probability (conversion probability matrix, conversion area matrix and layers of conditional probability) done by using Markov chain analysis, and the second stage was spatial specification of land use coverage simulated based on CA spatial operator and multi criteria evaluation (MCE). In the developing CA Markov model, the classified land use map of 1990 which represent past, and 2015 which represent present time were converted into IDRISI data format (Figure 3.2 and Figure 3.3) and selected to be input data into the model, to calculate matrices of conversion probabilities and conversion areas (Transition area matrix and transition probability matrix).

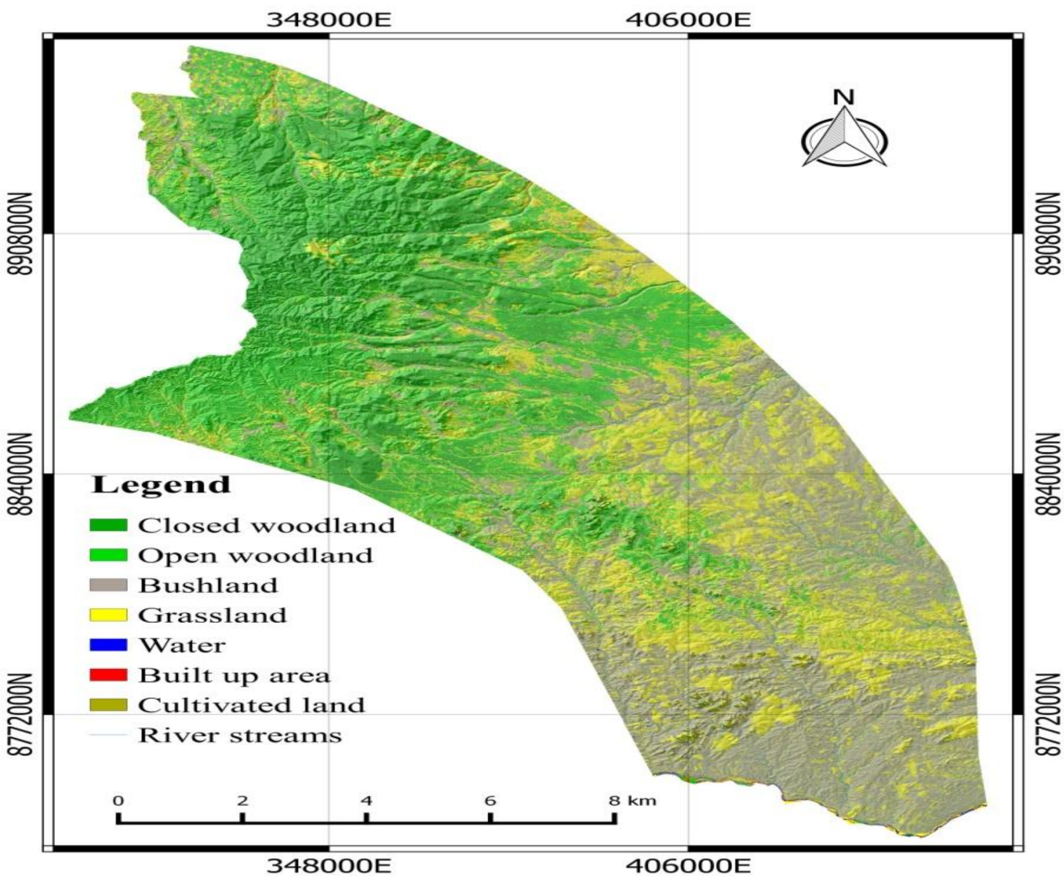

Figure 3.2: Land Use/Cover of 1990 used in Developing CA Markov Model

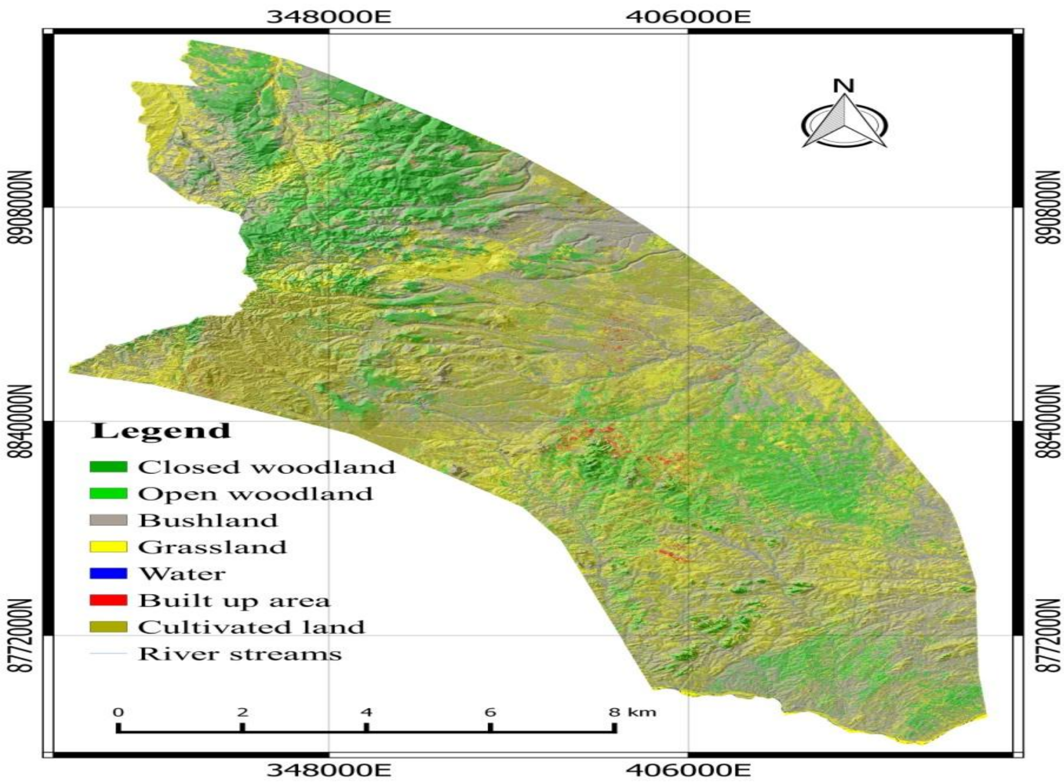

Figure 3.3: Land Use/Cover of 2015 used in Developing CA Markov Model

The transition probability matrix (Table 3.5) expresses the likelihood that a pixel of a given class that will change to any other class (or stay the same) in the next time period. This could be derived from transition areas matrix by knowing the total cells of each class.

Table 3.5: Transitional Probability Matrix for Land Use/Cover to Change Between 1990/2015

Given	Probability of a cell to change (transition) to						
	CWD	OWD	BS	GL	WTR	BLT	CL
CWD	0.1716	0.2419	0.2578	0.176	0.0001	0.0027	0.15
OWD	0.0559	0.1564	0.2821	0.2483	0.0001	0.0062	0.251
BS	0.031	0.1497	0.3597	0.3105	0.0001	0.0042	0.1448
GL	0.0199	0.0975	0.3813	0.2879	0.0006	0.0092	0.2035
WTR	0	0	0	0.6609	0.3391	0	0
BLT	0.0487	0.0779	0.2366	0.4436	0.0006	0.0376	0.1549
CL	0.0265	0.0891	0.3432	0.3521	0	0.0202	0.1688

CWD = Closed woodland, OWD = Open woodland, BS = Bushland, GL = Grassland, WTR = Water, BLT = Built Up area, and CL = Cultivated land

The transition areas matrix (Table 3.6) expresses the total area (in cells) expected to change from the year 2015 to the year of 2035 according to those changes happened from 1990 to 2015.

Table 3.6: Transitional Area Matrix for Land Use/Cover Change between 1990/2015

Given	**Area in cells expected to change**						
	CWD	OWD	BS	L	WTR	BLT	CL
CWD	171422	241691	257582	175840	59	2659	149838
OWD	136846	382630	690221	607619	141	15062	614201
BS	165394	799051	1919142	1656696	635	22290	772811
GL	87004	427493	1671288	1261817	2750	40443	891863
WTR	0	0	0	4742	2433	0	0
BLT	4794	7658	23269	43624	58	3698	15235
CL	78901	265483	1022734	1049308	79	60339	502909

CWD = Closed woodland, OWD = Open woodland, BS = Bushland, GL = Grassland, WTR = Water, BLT = Built Up area, and CL = Cultivated land

In the final step of predicting and simulation the future change of land use and land cover, the land use map of 2015 was used as a base map, together with conditional probabilities data and matrix conversion probabilities were integrated using the CA spatial operator based on Markov chain analysis and MCE.

3.5.1.2.2 CA – Markov Model Validation

For model validation the simulated land use/cover map for 2015 was compared with the actual satellite derived land use/cover map based on the Kappa statistics. Then, standard Kappa index is used to check whether the model is valid or not (usually the Kappa Index for a valid model should be >70%) (Wen, 2008). If the model has the Kappa Index less than 70% then the suitability map for the land covers and filter used should be repeated based on several considerations. Using VALADATE tool, IDRISI gave the standard Kappa of 0.83, Kappa for no information of 0.89, Kappa for grid-cell level location of 0.86 and Kappa for stratum-level location of 0.864 which are all more than 0.7.

3.5.2 Assessment of Wood Balance of the Study Area Dwellers

3.5.2.1 Analysis of Current Wood Balance of Study Area Dwellers

Current human population of corridor dwellers was estimated based on NBS (2012) census and computing average demand for wood compared with supply from the corridor ecosystem. The study employed NAFORMA (URT, 2015) baseline information that estimates Tanzaniaõs average demand for wood is 1.39 m^3/year/capita while the annual allowable cut (the sustainable supply) was estimated at 0.95 m^3/year/capita.

The study area belongs to southern zone as classified by URT (2015). The number of trees and volume per hectare of the distribution of forest and woody vegetation resources have been classified by employing methodology used by NAFORMA (URT, 2015) of measuring all trees with Dbh of one cm and above as shown in Table 3.7.

Table 3.7: Distribution of Forests and Woody Vegetation Resources of the Study Area

Districts	Average mean volume m^3/ha	Average number of trees/ha
Liwale, Nachingwea & Nanyumbu	49.3	1,654

3.5.2.2 Prediction of Future Wood Balance of Study Area Dwellers

Projected human population of study are dwellers in 2035 was estimated based on National Bureau of Statistics (2012) census and computing average demand for wood compared with supply from the corridor ecosystem. Projected LULC in 2035 was used to estimate number of trees and volume by using baseline information from URT (2015) as indicated in table 3.7.

3.5.3 Analysis of Amount of Carbon Released to the Atmosphere as a Result of Changes in Land Uses of the Study Area

3.5.3.1 Estimation of Amount of Carbon Released to the Atmosphere as a Result of Changes in Land Uses of the Study Area from 1986 to 2016

According to URT (2015), carbon in terrestrial ecosystems of Tanzania can be computed as follows:

Carbon (tonnes/ha) = Biomass * 0.47

3.5.3.1.1 Biomass Stocks

(a) Living Biomass Stocks

Tanzania forest Carbon can be estimated in three pools namely AGB (above ground biomass), BGB (below ground biomass) and DW (dead wood) (URT, 2015). BGB was estimated as a fraction of AGB. AGB and BGB were estimated as follows:

(i) AGB (tonnes/ha) = Tree stem volume (m^3/ha) * wood density/1000; and

(ii) BGB (tonnes/ha) = AGB * 0.25 (as default), or root to shoot ratios.

URT (2015) uses conversion factors into programmed NAFORMA analysis system by tree species or species groups to provide standards in each terrestrial ecosystem of Tanzania as shown in Table 3.8.

Table 3.8: Living tree Stemwood Biomass by Primary Vegetation Type

Primary Vegetation Type	CWD	OWD	BS	GL	WTR	CL	BLT
Aboveground Biomass (t/ha)	59.5	27.7	11.0	2.9	4.6	5.9	2.9
Belowground Biomass (t/ha)	18.2	9.5	4.4	1.1	1.7	2.1	1.1

CWD = Closed woodland, **OWD** = Open woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **CL** = Cultivated land and **BLT** = Built Up area

(b) Deadwood Biomass Stocks

Dead wood (DW) biomass is estimated from the volume computed using Smalian formula multiplied by wood density of 619 kg/m^3 (Chidumayo, 2012 cited by URT, 2015). URT (2015) through NAFORMA reveals the dead wood Biomass of Tanzania (Table 3.9) is relatively low since most dead wood in accessible areas is collected as fuelwood. As woodlands are generally more accessible than forests, collection of deadwood for fuelwood from these areas is easier. The relatively high volume of dead wood in water is assumed to be because dead trees lying in areas with water / wetlands are difficult to access and decay slowly and because they are wet and therefore unattractive for fuelwood.

Table 3.9: Dead Wood Biomass by Primary Vegetation Type

Primary Vegetation Type	CWD	OWD	BS	GL	WTR	CL	BLT
Biomass (t/ha)	4.87	1.82	0.73	0.35	1.31	0.91	0.22

CWD = Closed woodland, **OWD** = Open woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **CL** = Cultivated land and **BLT** = Built Up area

3.5.3.1.2 Carbon Stocks

Living tree stemwood and dead wood carbon (t/ha) by primary vegetation type as adapted from URT (2015) are illustrated in Table 3.10 and 3.11.

Table 3.10: Living Tree Stemwood Carbon (Aboveground + Belowground) by Primary Vegetation Type

Primary Vegetation Type	CWD	OWD	BS	GL	WTR	CL	BLT
Carbon (t/ha)	36.5	17.5	7.2	1.8	3.0	3.8	1.9

CWD = Closed woodland, **OWD** = Open woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **CL** = Cultivated land and **BLT** = Built Up area

Table 3.11: Dead Wood Carbon by Primary Vegetation Type

Primary Vegetation Type	CWD	OWD	BS	GL	WTR	CL	BLT
Carbon (t/ha)	2.39	0.89	0.36	0.17	0.64	0.45	0.11

CWD = Closed woodland, **OWD** = Open woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **CL** = Cultivated land and **BLT** = Built Up area

3.5.3.2 Prediction of Amount of Carbon Released to the Atmosphere as a Result of Changes in Land Uses of the Study Area from 2015 to 2035

Predicted changes in LULC from 2015 to 2035 was used to predict amount of carbon to be released to the atmosphere following procedures described in section 3.5.1.2 above.

3.5.4 Estimation of Current and Predicted Carbon Stocks of the Study Area

Distribution of LULC of 2016 and 2035 were used to estimate current and predicted carbon stocks of the study area by following procedures described in section 3.5.1.2. Consequently, conservation profit estimated based on carbon trade of US$ 4 per ton if REDD+ is implemented as emphasized by Jenkins (2014), and Lobora *et al.* (2017). The mentioned price was used to estimate study area conservation profit disposed as a result of changes in LULC from 1986 to 2016; existing amount of conservation profit in 2016; predicted conservation profit that will be disposed as a result of LULC from 2015 to 2035; and future predicted conservation profit in 2035.

3.5.5 Examination of Consequences of Climate Change and Variability in Managing Selous-Niassa TFCA

Quantitative data from questionnaire was analysed statistically. Qualitative data from focus group discussions (FGDs) and key informants were analysed through content analysis. Content analysis is useful in analyzing details of the components of verbal discussions held with key informants and FGDs (Kajembe, 1996 cited by Kijazi, 2006).

3.5.5.1 Statistical Analysis

The Statistical Package for Social Sciences (SPSS) version 20 and Microsoft Excel version 2010 were employed. Two types of statistical analysis namely, descriptive and inferential statistical analyses were carried out.

3.5.5.1.1 Descriptive Statistical Analysis

Analysis of quantitative data by descriptive statistics was involved frequencies, percentages, means, and standard deviations of variables such as age, marital status, sex, education level, household size and income. Also examining relationship between two variables by the use of cross tabulation method was employed.

3.5.5.1.2 Inferential Statistical Analysis

Inferential statistical analysis was involved application of multiple regression model used to determine the existence of correlation between socio-economic factors influencing encroachment of wildlife corridor. Multiple regression model has been successfully employed in social sciences, biostatistics and demographic issues (Pallant, 2005).Multivariate regression analysis was run to assess the influence of independent variables on dependent variable. Giliba *et al.* (2011) argued that, applications of multivariate regression analysis depend on the nature of the dependent variable of the particular study inquiry. Significant value should be less than 0.05 (Pallant, 2005 and Akankali and Chindah, 2011). The model was expressed as follows:

$$Y_i = \beta_0 + \sum_{i=1}^{i=j} \beta_i X_i + e_i$$

Where:

Y_i= encroachment of TFCA (presence of socio-economic activities that have adverse effect on ecosystem)

β's = coefficients to be estimated

B_0 = constant coefficient (intercept of the equation)

X_i= independent variables

i=1,2, 3… … j

$e_{i=}$ error term

The hypotheses tested were:

H_o: $\beta_i = 0$ that is regression coefficients are equal to zero implying that socio-economic factors (independent variables) have no significant influence on encroaching Selous – Niassa TFCA ($p<0.05$)

H_a: $\beta_i \neq 0$ that is regression coefficients are not equal to zero meaning that socio-economic factors have significant influence on encroaching Selous – Niassa TFCA ($p<0.05$)

From the above, the variables included in the regression model were:

X_1= Age

It was hypothesized that age of respondents influence encroachment of Selous – Niassa TFCA. Young respondents (≤ 35 years), middle-aged (36–45 years) and respondents over 60 years old (commensurate with Tanzania's mandatory retirement age of60) differed in the level of encroachment in the TFCA. Young people depended more on natural resources extraction for their survival compared to older people who were more likely to have income from wages, salaries or pensions, and less income from natural resources. Therefore, age has negative regression coefficient (-).

X_2= Sex

This could have positive coefficient (+) in the sense that sex influence encroachment in Selous ï Niassa TFCA as male are more destructive compared to women as almost most poachers arrested in the TFCA are male.

X_3= Education level

This could have a negative coefficient (-). It was hypothesized that respondents with higher education has low influence on encroachment of Selous ï Niassa TFCA compared to respondents with low education. The reason behind is that, respondents with higher education can be employed in various private and government sectors operating in Districts where Selous ï Niassa TFCA lies.

X_4= House hold size

The regression coefficient for household size was expected to be positive (+). The reason behind is that large household size have many mouths to feed resulting in increasing food production and other necessities. This scenario accelerates encroachment of Selous ï Niassa TFCA as ethnicity of the area encourages polygamy.

X_5= Household income

Household income could have positive coefficient (+) as higher income families mostly employed or business oriented respondents compared to low income families who engage in illegal extracting natural resources to supplement necessities. Furthermore low income families are easier to corrode with outsiders of Selous ï Niassa TFCA to encroach valuable natural resources.

CHAPTER FOUR

FINDINGS AND DISCUSSIONS

4.1 General Information of Respondents in the Study Villages of Selous-Niassa TFCA

The study villages were found to have large household sizes. Results in Table 4.1 shows that 53.3% have 1-5 persons per household and 46.7% have more than 5 persons. This is due to the culture of marrying many wives (polygamy) which results into a lot of dependents to feed and take care of. Education background of the surveyed population was at most primary education (85.0%), very few had at least secondary education (3.3%). This is due to shortages of schools especially primary schools resulting into children walking long distances to school.

There was no nearby secondary school in Mpigamiti or Mpombe villages. This implies that, low education level provides low payment employment opportunities to tourism industry within Selous-Niassa TFCA. The study villages found to have low income per month resulted mostly from small-scale farming compared to standard living cost needed in the study area. Results show that 71.1% have income less than TZS 90,000, and 28.9% above TZS 90,000, whereas 45.6% below TZS 60,000 which means below TZS 2,000 per day (Table 2). This shows that those employed villagers have high income compared to non-employed (Table 4.1) as 54.6% of employed villagers have income of above TZS 150,000 per month compared to unemployed villagers 82.3% with income below TZS 90,000 per month. Moreover, the chi-square test indicated statistical insignificance on all socio-demographic characteristics of respondents in study villages implies that, there is no direct relationship between those characteristics in study villages.

Table 4.1: Socio-Demographic Characteristics of Respondents

Information	Study villages				Pearson's chi-square	
	Mpigamiti n=30	**Mpombe n=30**	**Kilimarondo n=30**	**Overall N=90**	**Exact Significance: (2-sided)**	**(1-sided)**
Age class:						
18-24 Years	6(20.0)[1]	5(16.7)	4(13.3)	15(16.7)		
25-35 Years	8(26.7)	11(36.7)	10(36.7)	29(32.2)	0.420	0.225
36-44 Years	9(30.0)	8(26.7)	8(26.7)	25(27.8)		
45-65 Years	5(16.7)	3(10.0)	5(16.7)	13(14.4)		
> 65 Years	2(6.7)	3(10.0)	3(10.0)	8(8.9)		
Sex:						
Male	16(53.3)	13(43.3)	15(50.0)	44(48.9)		
Female	14(46.7)	17(56.7)	15(50.0)	46(51.1)	0.606	0.303
Education background:						
Informal education	6(20.0)	11(36.7)	8(26.7)	25(27.8)		
Basic adult education	6(20.3)	5(16.7)	4(13.3)	15(16.7)	0.491	0.068
Primary	12(40.0)	11(36.7)	12(40.0)	35(38.9)		
Secondary	4(13.3)	3(10.0)	4(13.3)	11(12.2)		
> secondary	2(6.7)	0(0.0)	2(6.7)	4(4.4)		
Household size:						
1-5Persons	14(46.7)	18(60.0)	14(46.7)	46(51.1)		
6-10Persons	13(43.3)	9(30.0)	12(40.0)	34(37.8)		
11-15Persons	3(10.0)	2(6.7)	4(13.3)	9(10.0)	0.572	0.368
> 15Persons	0(0.0)	1(3.3)	0(0.0)	1(1.1)		
Income per month:						
Below TZS 30 000	3(10.0)	4(13.3)	5(16.7)	12(13.3)		
TZS 30 000-59 000	11(36.7)	9(30.0)	9(30.0)	29(32.2)		
TZS 60 000-89 000	6(20.0)	8(26.7)	9(30.0)	23(25.6)	1.000	0.206
TZS 90 000-119 000	4(13.3)	3(10.0)	3(10.0)	10(11.1)		
TZS 120 000-149 000	2(6.7)	3(10.0)	3(10.0)	8(8.9)		
TZS 150 000-179 000	3(10.0)	1(3.3)	1(3.3)	5(5.6)		
TZS 180 000-209 000	1(3.3)	1(3.3)	0(0.0)	2(2.2)		
>TZS209000	0(0.0)	1(3.3)	0(0.0)	1(1.1)		

[1] Figures outside and inside the parentheses are frequencies and percentages respectively.

Also the results show that the study population has 12.2% of employed villagers while 87.8% are unemployed. Mostly those villagers who are employed work in Tourism industry and those who are not employed are likely to engage themselves in other socio-economic activities including encroachment of wildlife and forest resources. Those unemployed people are the one who are poor compared to employed villagers.

Table 1.2: Income Level of Respondent per Month

Income per month:	Employed n=11	Unemployed n=79	Overall N=90
Below TZS 30 000	0(0.0)[1]	13(16.5)	13(14.5)
TZS 30 000-59,000	0(0.0)	27(34.2)	27(30.0)
TZS 60 000-89 000	0(0.0)	25(31.6)	25(27.8)
TZS 90 000-119,000	0(0.0)	9(11.4)	9(10.0)
TZS 120 000-149,000	5(45.6)	5(6.3)	10(11.1)
TZS 150 000-179,000	3(27.2)	0(0.0)	3(3.3)
TZS180 000-209,000	2(18.1)	0(0.0)	2(2.2)
>TZS 209 000	1(9.1)	0(0.0)	1(1.1)

χ^2 = 45.445, P<0.001 *(Statistically significant at 0.001 level of significance)*
[1] Figures outside and inside the parentheses are frequencies and percentages respectively.

The study villages observed to have large household size with low income of her people as a result concentrates on utilizing protected wildlife and forest resources. Alternatively, those employments in tourism industry has its consequences, for instance foreigners are paid much compared to locals and this is common in many tourism companies includes Tanganyika Wildlife Safaris (TAWISA), Bushman Hunting Safaris and Tanganyika Wildlife company Ltd (TAWICO) which have invested in Selous-Niassa TFCA. Furthermore, the chi-square test indicated statistical significance (P< 0.001, i.e χ^2 = 45.445) on monthly income of employed and unemployed households (Table 4.2). This implies that, affirmative action policies may need to be adopted to improve payments of the excluded and to enhance equitable access to job opportunities.

4.2 Spatial and Temporal Changes in Land Use and Land Cover of the Study Area

4.2.1 Land Use and Land Cover Assessment

The land use land cover maps for the year 1986, 1997, 2005 and 2016 are presented in Figures 4.1, 4.2, 4.3 and 4.4. Generally, the maps show variations in cover coverage between the three periods under consideration. Table 4.3 represents the spatial distribution of land use/cover coverage for the period between 1986 and 2016.

Table 4.3: Land Use/Cover Area Distribution between 1986 and 2016 (US-GLOVIS, 2017)

LULC	1986		1997		2005		2016	
	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)
Closed woodland	227731	15.57	244348	16.71	103198	7.06	89923	6.15
Open woodland	402201	27.50	411211	28.12	288176	19.70	220217	15.06
Bush land	433706	29.65	333399	22.80	256911	17.57	480269	32.84
Grassland	394960	27.00	437621	29.92	515143	35.22	394461	26.97
Water	1431	0.10	790	0.05	906	0.06	646	0.04
Built up area	2532	0.17	3391	0.23	7623	0.52	8851	0.61
Cultivated land	0	0.00	31799	2.17	290602	19.87	268193	18.34
TOTAL	**1462560**	**100**	**1462560**	**100**	**1462560**	**100**	**1462560**	**100**

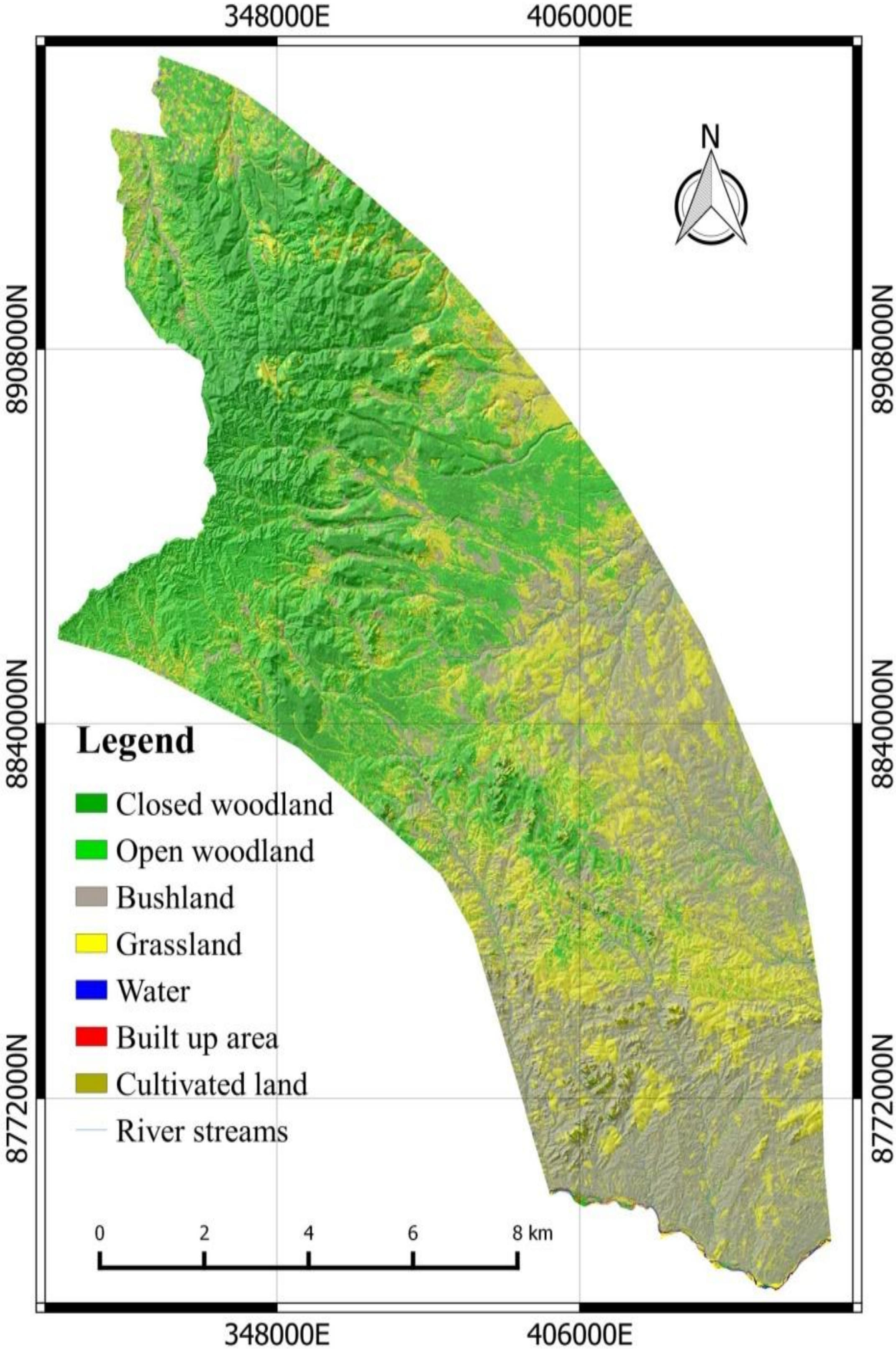

Figure 4.1: Land Use/Cover Map for Eastern Selous – Niassa TFCA 1986
Source: US-GLOVIS (2017)

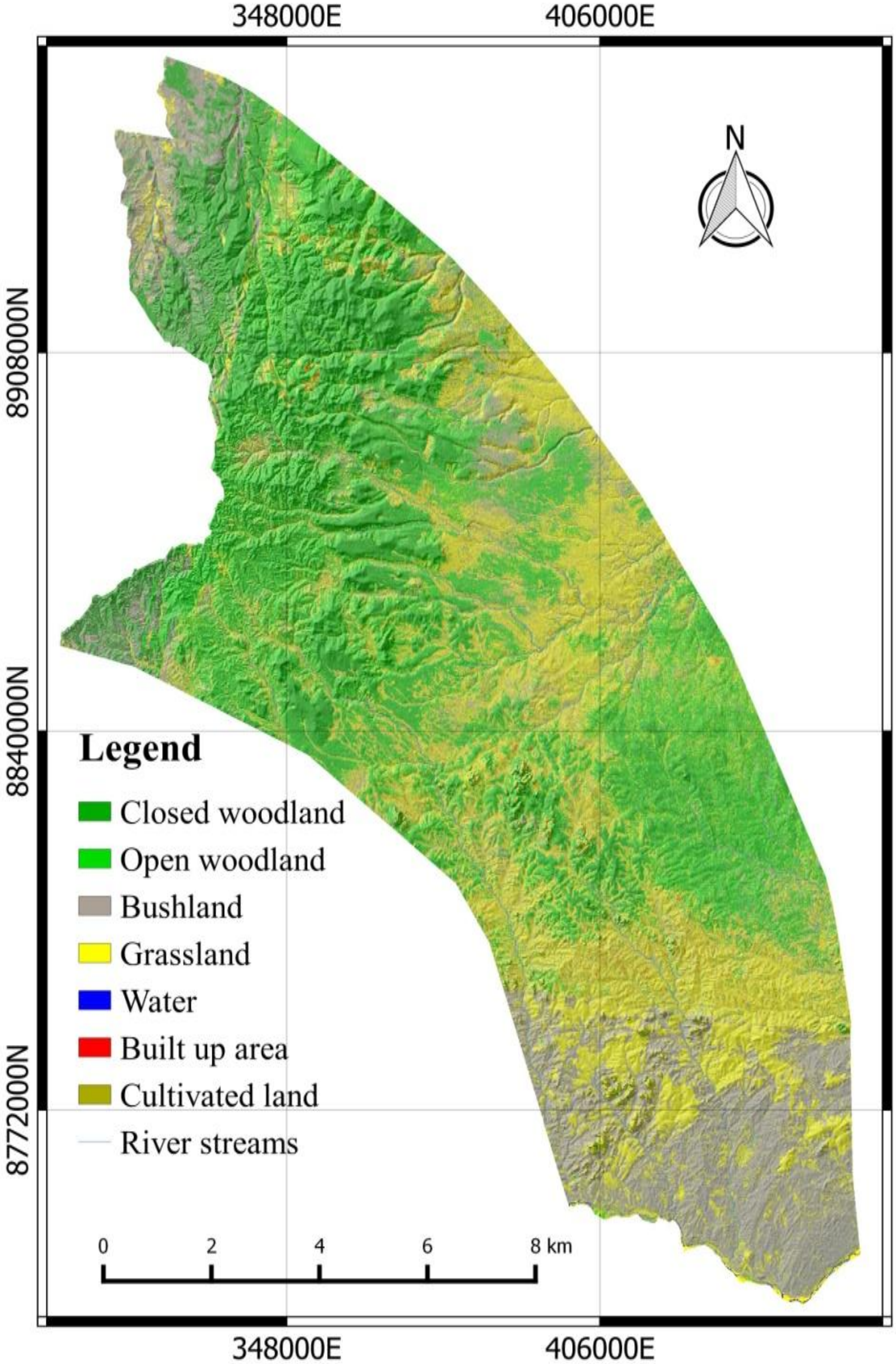

Figure 4.2: Land Use/Cover Map for Eastern Selous – Niassa TFCA 1997

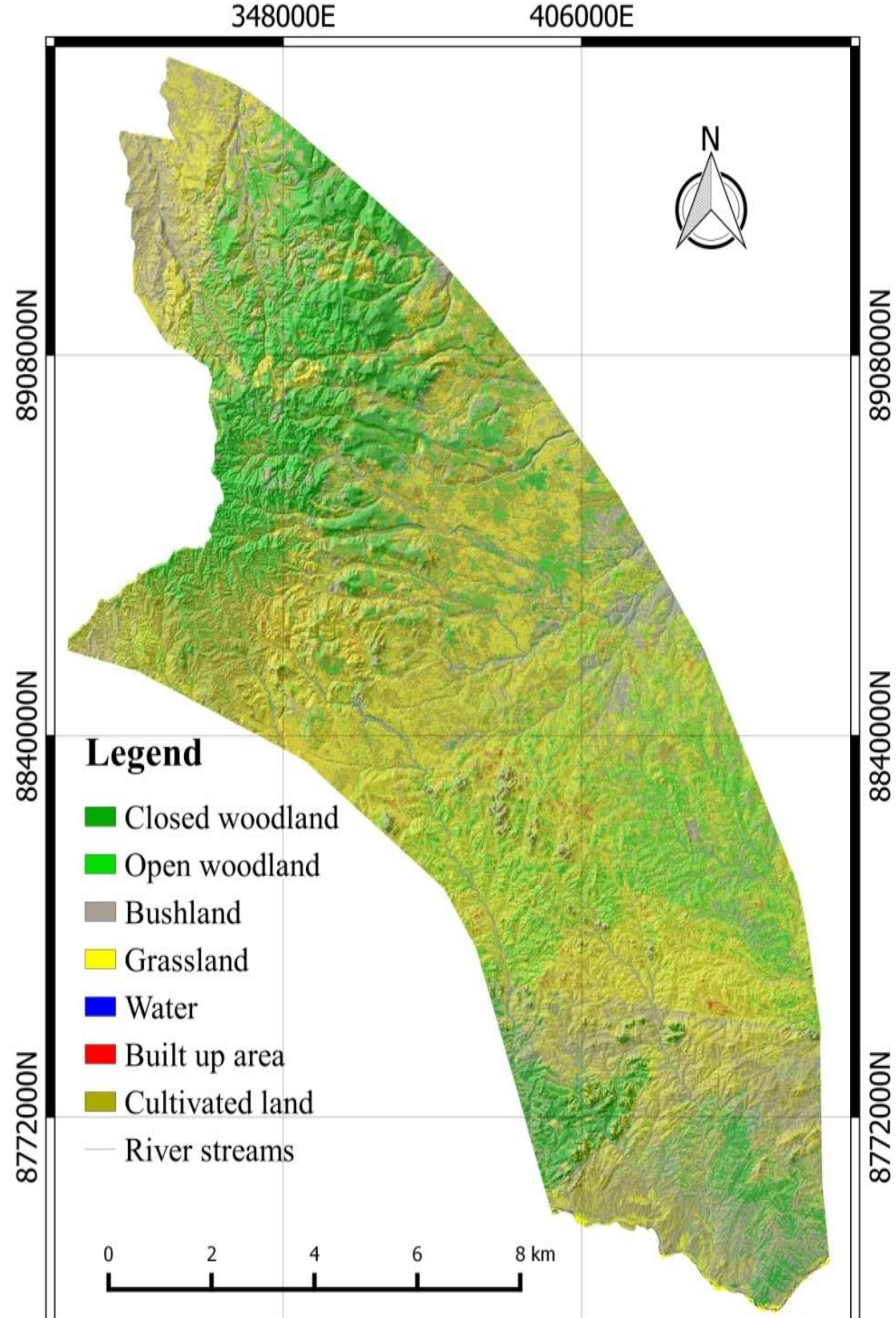

Figure 4.3: Land Use/Cover Map for Eastern Selous – Niassa TFCA 2005

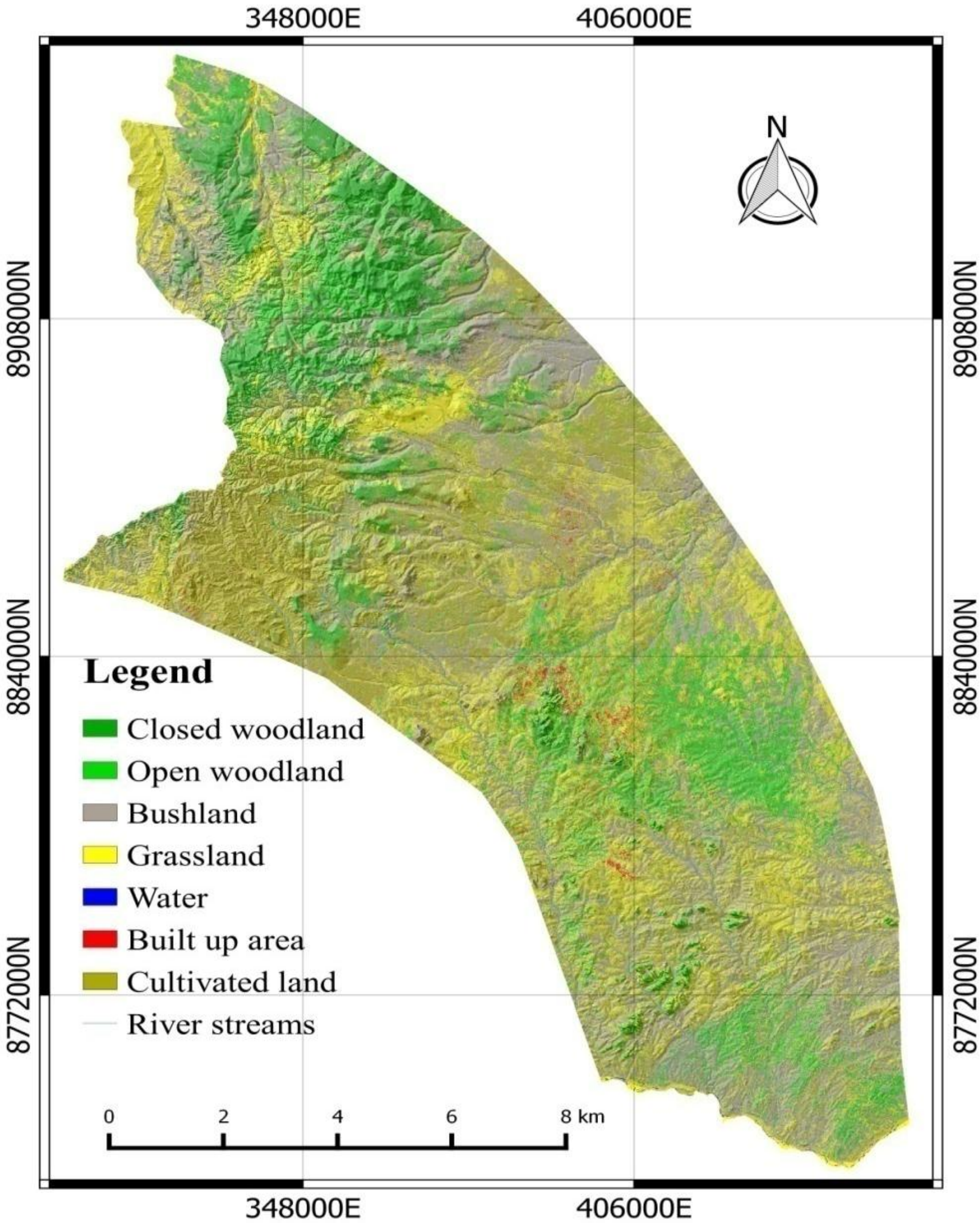

Figure 4.4: Land Use/Cover Map for Eastern Selous – Niassa TFCA 2016

4.2.2 Land Use/Cover Changes between 1986 and 2016

The extent of land use land cover change including area, percentage area change and percentage annual rate of change are summarised on Table 4.4. The increased and decreased amount is represented by positive signs (-) and (+) respectively.

Table 4.4: Land Use/Cover Change between 1986 and 2016

LULC	1986 – 1997			1997 – 2005			2005 – 2016		
	Area change (Ha)	**Percentage change (%)**	**Annual Rate of Change (Ha/year)**	**Area change (Ha)**	**Percentage change (%)**	**Annual Rate of Change (Ha/year)**	**Area change (Ha)**	**Percentage change (%)**	**Annual Rate of Change (Ha/year)**
CWD	-16617	-1.14	-1511	141150	9.65	11762	13275	0.91	1207
OWD	-9010	-0.62	-819	123035	8.41	10253	67959	4.65	6178
BS	100306	6.86	9119	76488	5.23	6374	-223357	-15.27	-20305
GL	-42661	-2.92	-3878	-77522	-5.30	-6460	120682	8.25	10971
WTR	641	0.04	58	-116	-0.01	-10	260	0.02	24
BLT	-860	-0.06	-78	-4232	-0.29	-353	-1228	-0.08	-112
CL	-31799	-2.17	-2891	-258803	-17.70	-21567	22409	1.53	2037

CWD = Closed woodland, **OWD** = Open woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **BLT**= Built Up area, and **CL** = Cultivated land

The results (Table 4.4), indicate that for the period between 1986 and 1997 the area under closed woodland, open woodland, grassland, built up area, and cultivated land increases by 1.14%, 0.62%, 2.92%, 0.06%, and 2.17% respectively. Likewise, bushland and water decreased by 6.86 and 0.04 respectively. For the period between 1997 and 2005, the closed woodland, open woodland, and bushland declined by 9.65%, 8.41%, and 5.23% respectively. For the same period of time, grassland, water, built up area, and cultivated land increased by 5.3%, 0.01%, 0.29%, and 17.7% respectively. Moreover, for the period between 2005 and 2016, the closed woodland, open woodland, grassland, water, and cultivated area declined by 0.91%, 4.65%, 8.25%, 0.02% and 1.53% respectively. For the same period of time, bushland and built up area increased by 15.27% and 0.08% respectively.

As revealed in Table 4.4, the decrease of closed woodland, open woodland, and bushland from 1997 to 2016 might be due human encroachments for timber, firewood and medicine, noticeable felling of trees for expansion of agricultural farms; whereas during 1986 to 1997 the increase of the closed and open woodlands happened as a result of famous operation ñUhaiò done national wide to curb antipoaching and illegal harvesting of forest and wildlife resources. Also, the cashew nuts cultivated land was included in woodlands and thickets because the land cover is uncertain for this.

Also, the results supported by group discussants during focus group discussions emphasized that:

> *"wildfire, cutting trees; drying up trees are serious problems in recent years due to expansion of simsim farming, livestock immigrants, and commercial logging and timbering".*

4.2.3 Change Detection of Different Land Use/Cover

The net change of each land use/cover category is presented in Figure 4.5, and the change detection matrix for the period between 1986 and 2016 is presented in Tables 4.5 to 4.7, clearly reflecting on the land use transformation in the study area.

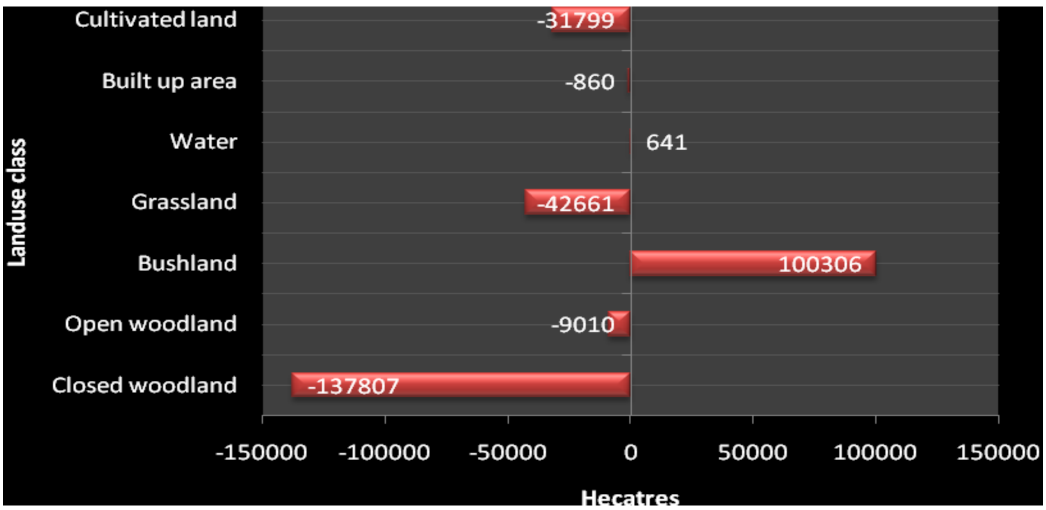

Figure 4.5: Gain and Looses by Each Land Use Category between 1986 and 2016

Table 4.5: Change Detection Matrix for the Period of 1997 to 2005

Cover in 1986	Cover in 1997 (Ha)							
	CWD	OWD	BS	GL	WTR	BL T	CL	TOTAL
CWD	113076	65719	15637	17197	0	225	1526	**213379**
OWD	81872	165795	68741	84577	31	772	5194	**406982**
BS	20562	91588	169619	146223	9	514	7452	**435967**
GL	28746	87920	78420	187456	131	1826	17493	**401992**
WTR	42	25	255	616	489	3	1	**1431**
BLT	35	141	707	1529	104	153	31	**2701**
CL	1	0	1	6	0	0	100	**107**
TOTAL	**244334**	**411188**	**333381**	**437604**	**763**	**3492**	**31798**	**1462560**

CWD = Closed woodland, **OWD** = Open woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **BLT** = Built Up area, and **CL** = Cultivated land

Table 4.6: Change Detection Matrix for the Period of 1997 to 2005

Cover in 1997	Cover in 2005 (Ha)							
	CWD	OWD	BS	GL	WTR	BLT	CL	TOTAL
CWD	35521	71673	33529	62757	0	479	40457	**244416**
OWD	21869	115440	43831	127066	1	1970	101009	**411188**
BS	32885	39815	102169	104523	6	1063	52920	**333381**
GL	12481	57906	74047	200868	450	3376	88469	**437596**
WTR	0	0	0	343	447	0	0	**790**
BLT	80	229	292	1830	2	167	791	**3391**
CL	356	3178	3029	17727	0	568	6939	**31797**
TOTAL	**103193**	**288242**	**56897**	**515114**	**906**	**7623**	**290586**	**1462560**

Table 4.7: Change Detection Matrix for the Period of 2005 to 2016 (Ha)

Cover in 2005	Cover in 2016							
	CWD	OWD	BS	GL	WTR	BLT	CL	TOTAL
CWD	30929	20520	24539	16728	9	135	10415	**103275**
OWD	23689	73670	83706	62077	8	835	44175	**288160**
BS	9899	33202	113970	70239	31	538	29019	**256897**
GL	14772	64418	168122	170195	269	3999	93340	**515114**
WTR	0	0	0	587	320	0	0	**906**
BLT	148	452	1740	2809	1	410	2062	**7623**
CL	10482	28025	88165	71805	8	2933	89167	**290586**
TOTAL	**89918**	**220287**	**480242**	**394439**	**646**	**8850**	**268178**	**1462560**

4.3 Future Changes in Land Use and Land Cover of the Study Area

The land use land cover map for the next 20 years is presented in Fig.4.6 below.

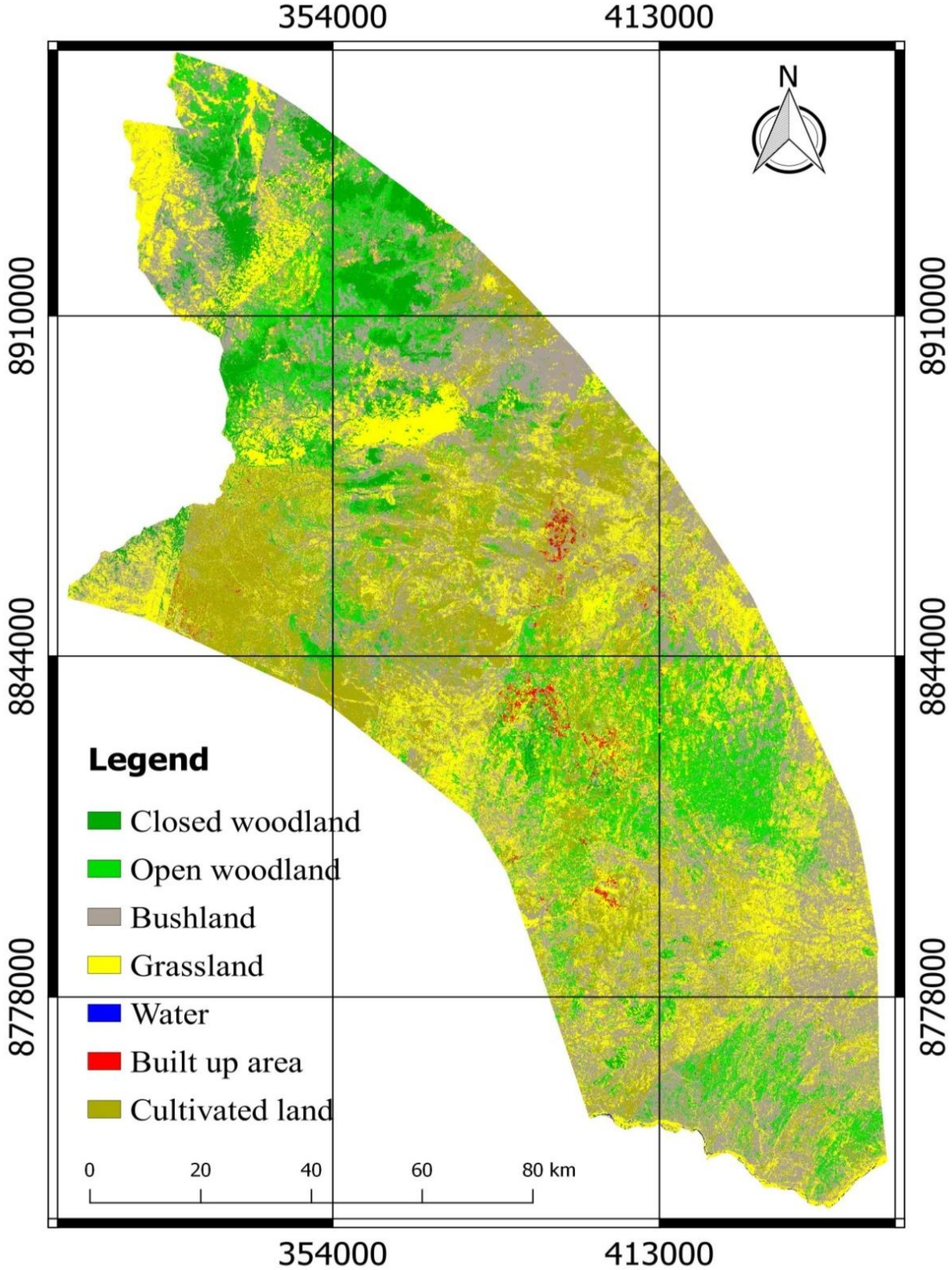

Figure 4.6: Projected Land Use/Cover Map for Eastern Selous-Niassa TFCA for 2035

The statistical analysis of land use land cover for the predicted year 2035 illustrated in Table 4.8. An overall change in land use and land cover in all the twenty years of prediction revealed that, the bushland and grassland will dominate by occupying 56.29% which is equivalent to 823 222 ha of the corridor followed by cultivated land which is expected to cover 22.75% equivalent to 332 676 ha. Natural forest (closed and open woodlands) coverage will decrease from 310 140 ha (21.21%) existing in 2015 to 293 671 ha (20.08%) in 2035, built up area will increase from 8851 ha (0.61%) existing in 2015 to 12 749 ha (0.87%); and water surface will decrease from 646 ha (0.04) in 2015 to 242 ha (0.02) in 2035. As explained by Lobora, *et al.*, (2017) that, decrease in natural forest cover impact water resource, this has been revealed in this study due to projected decrease in water bodies and wetland.

Table 4.8: Land Use/Cover Area Distribution in 2035

LULC	**2015**		**2035**	
	(Ha)	**(%)**	**(Ha)**	**(%)**
Closed woodland	89923	6.15	81981	5.61
Open woodland	220217	15.06	211690	14.47
Bushland	480269	32.84	411950	28.17
Grassland	394461	26.97	411272	28.12
Water	646	0.04	242	0.02
Built up area	8851	0.61	12749	0.87
Cultivated land	268193	18.34	332676	22.75
TOTAL	**1462560**	**100**	**1462560**	**100**

source: researcher data, 2019

4.4 Wood Balance of the Study Area Dwellers

4.4.1 Current Wood Balance of the Study Area Dwellers

Existing amount of trees from 1986 to 2016 (Table 4.9) used to estimate wood balance by using estimated population of the study area in these periods.

Table 4.9: Existing amount of Trees from 1986 to 2016

Year	Total woodland area (ha)	Total volume Million m^3	Number of trees (in millions)	Estimated human population	Wood balance (trees/capita/year)	Wood balance (m3/year/ capita)
1986	629, 932	31.1	1041.9	312, 081	3339	99.7
1997	655, 559	32.3	1084.3	351, 866	3082	91.8
2005	391, 374	19.3	647.3	381, 229	1698	50.6
2016	310, 140	15.3	513	437, 921	1172	34.9

source: researcher data, 2019

The results reveled in Table 4.9 shows that, wood supply in the study area for the year 2016 is at least 25 times the average demand per year per capita. This implies that the area is still virgin interms of wood balance that means wildlife habitat is still intact. However, the trend of wood supply from 1986 to 2016 shows dramatic deforestation of the area which implies tragedy of common and is the public property where there is no control policies or rules. The emergence of reviewing management and conservation strategies is unexceptional if we need sustainability of Selous-Niassa TFCA.

Moreover, Table 4.10 shows amount of trees loss in eastern Selous- Niassa TFCA from 1986 to 2016. The results show that, there are intercernal changes of tree loss/gain from 1986 to 2016. The results revealed gain of trees regenerated in the study area during the period 1986 ï 1997 with an average of 3.5 million trees per year. The reason behind the results might be due to low population of the area, inaccessible roads, low markets of valuable forests and wildlife resources from the study area, lack of policies for conservation and protection of forest and wildlife resources, and national wide operation ñUhaiò which was done in this period. Moreover, there was rampant conversion of woodland in the study area during the period 1997 ï 2016 with average loss of 27 million trees per year.

Table 4.10: Amount of Trees Loss from 1986 to 2016

Years	**Total area converted (ha)**	**Total volume Million m^3**	**Number of trees loss/gain (in millions)**
1986 ï 1997	- 25, 627	- 1.3	- 42
1997 ï 2005	+ 264, 184	+ 13.1	+ 437
2005 ï 2016	+ 81, 234	+ 4.0	+ 134
Total	**+ 319, 791**	**+ 15.8**	**+ 529**

This implies that, the loss was due to other socio-economic activities which are environmental harmful but economic rewarding like commercial farming of simsim, cashewnuts, sesame, logging and timbering, artisanal mining, and livestock keeping/gathering. These activities involves clearance of woodlands by using fire and drying of standing trees to remove leaves so as to allow sunlight for crops farming and livestock gathering, and reducing tsetse infections.

4.4.2 Future Wood Balance of the Study Area Dwellers

Forecasted amount of trees in 2035 (Table 4.11) used to estimate wood balance by using estimated population of the study area in 2035.

Table 4.11: Forecasted Amount of Trees in 2035

Year	Total woodland area (ha)	Total volume Million m^3	Number of trees (in millions)	Estimated human population	Wood balance (trees/capita/ year)	Wood balance (m3/year/ capita)
2035	293, 671	14.5	486	535, 446	908	27.1

source: researcher data, 2019

The results reveled in Table 4.11 shows that, wood supply in the study area for the year 2035 will be 20 times the average demand per year per capita. This implies that the area will still be partially degraded if and only if no immigrants will invade the area and encroaching existing resources. The emergence of reviewing management and conservation strategies is of urgency for the time being so as to plan for sustenance of Selous-Niassa TFCA.

Furthermore, Table 4.12 shows expected amount of trees to be loss in eastern Selous- Niassa TFCA for 20 years from 2015 to 2035 as 28 million trees. The results revealed average trees loss of 1.4 million trees per year. This implies that, the loss will be due to conversion of the area to other socio-economic activities which are environmental destructive but economic rewarding.

Table 4.12: Forecasted Amount of Trees Loss from 2015 to 2035

Year	Total area converted (ha)	Total volume Million m^3	Number of trees loss/gain (in millions)
2015 ï 2035	+ 16469	+ 0.8	+ 28

source: researcher data, 2019

4.5 Amount of Carbon Released to the Atmosphere as a Result of Changes in Land Uses of the Study Area

4.5.1 Amount of Carbon Released to the Atmosphere as a Result of Changes in LULC for a Period of 1986 – 2016

4.5.1.1 Amount of Biomass Loss from 1986 to 2016

The results in Table 4.13 and Table 4.14 revealed that, nearly 93% of closed woodland (forests) degraded compared to other vegetation type; followed by open woodland (45.74%). This implies that, average amount of 128344.25 tons and 79708.99 tons of biomass (above ground + below ground + deadwood) from closed and open woodlands respectively loss annually from 1986 to 2016. This degradation rate impacts negatively to ecosystem services offered to wildlife residing or using the area for migration or adapting to climatic change. The degraded area converted to bushland, cultivated land and built up area due to increase of human population, livestock, and dependence of corridor dwellers on existing natural resources in the ecosystem for their livelihoods. Thereof, the average total annual loss of 163732.8 tons of biomass (above ground + below ground + deadwood) in all vegetation type from 1986 to 2016 experienced in eastern Selous ï Niassa TCA.

These results necessitated the inclusion of the area in core PA or formulating sustainable management strategy which will assure the survival of wildlife without compromising livelihoods of corridor dwellers. The existing formulation of wildlife management areas (WMAs) of Liwale (MAGINGO), Nachingwea (NDONDA) and Nanyumbu (MCHIMALU) districts relies only adjacently to core PAs of Selous, Msanjesi and Lukwika-Lumesule game reserves, and forgetting other areas which are crucial to wildlife as their living habitat and migration trails.

Table 4.13: Amount of Living Tree Stem Wood Biomass (Aboveground + Belowground) Loss of Eastern Selous-Niassa TFCA From 1986 To 2016

Primary Vegetation Type	Total area converted (ha)	Above ground biomass loss (t/ha)	Below ground biomass loss (t/ha)	Total Biomass loss (t)	Biomass loss (%)
Closed woodland	137807	4.87	18.2	3179207.49	92.68
Open woodland	181984	1.82	9.5	2060058.88	45.74
Bushland	-46563	0.73	4.4	-238868.19	-4.69
Grassland	499	0.35	1.1	723.55	0.03
Water	786	1.31	1.7	2365.86	0.14
Cultivated land	-268193	0.91	2.1	-807260.93	-33.71
Built up area	-6319	0.22	1.1	-8341.08	-0.19
Total				**4187885.58**	**100.00**

source: researcher data, 2019

Table 4.14: Amount of Dead Wood Biomass Loss of Eastern Selous-Niassa TFCA from 1986 to 2016

Primary Vegetation Type	Total area converted (ha)	Biomass loss (t/ha)	Total Biomass loss (t)	Biomass loss (%)
Closed woodland	137807	4.87	671120.1	92.68
Open woodland	181984	1.82	331210.9	45.74
Bushland	-46563	0.73	-33991	-4.69
Grassland	499	0.35	174.65	0.03
Water	786	1.31	1029.66	0.14
Cultivated land	-268193	0.91	-244056	-33.71
Built up area	-6319	0.22	-1390.18	-0.19
Total			**724098.5**	**100.00**

source: researcher data, 2019

4.5.1. 2 Amount of Carbon Released to the Atmosphere as a Result of Changes in LULC from 1986 to 2016

The results in Table 4.15 and Table 4.16 revealed that, nearly 74.38% of closed woodland (forests) released more Carbon to the atmosphere compared to other vegetation type; followed by open woodland (46.45%). This implies that, average amount of 178643.81 tons and 111556.19 tons of Carbon (above ground + below ground + deadwood) from closed and open woodlands respectively loss annually from 1986 to 2016. These scenarios need urgent action so as to reverse the situation.

Reversing releasing of Carbon to the atmosphere is a mitigation measure, but reacting now is adapting with mitigation measures which their results will be appreciated over thousands years to come. Thus, the need for sustainable utilization and management of natural resources in the area is vital. Conversely, the average total annual loss of 240176.88 tons of Carbon (above ground + below ground + deadwood) from 1986 to 2016 experienced in eastern Selous ï Niassa TCA. Since, climate change is a result of increasing greenhouse gases in the atmosphere, there are must be strategies to reverse the situation. If, the government decides to include the area into core PAs network, it must incur cost that the corridor dwellers have to accept to release the area for protection.

In order to officiate the process of including the area into core PAs network, communities should be willingly accept the compensated cost that will be given to them or area similar to the previous one if and only if they actively participated and ensures that the benefits of protecting the area should be large compared to the cost. For Tanzania scenario, we must agree that those areas abandoned by wildlife which previously used as PAs should be recategorise by considering all species used to live in those areas have proper management plan which considered their climatic niche.

Table 4.15: Amount of Living Tree Stemwood Carbon (Aboveground + Belowground) Released To the Atmosphere As A Result Of Habitat Conversion Of Eastern Selous-Niassa TFCA From 1986 To 2016

Primary Vegetation Type	Total area converted (ha)	Carbon loss (t/ha)	Total Carbon loss (t)	Share (%)
Closed woodland	137807	36.5	5029955.5	73.4
Open woodland	181984	17.5	3184720	46.48
Bushland	-46563	7.2	-335253.6	-4.89
Grassland	499	1.8	898.2	0.03
Water	786	3.0	2358	0.04
Cultivated land	-268193	3.8	-1019133.4	-14.88
Built up area	-6319	1.9	-12006.1	-0.18
Total			**6851538.6**	**100**

source: researcher data, 2019

Table 4.16: Amount of Dead wood Carbon Loss of Eastern Selous-Niassa TFCA from 1986 to 2016

Primary Vegetation Type	Total area converted (ha)	Carbon loss (t/ha)	Total Carbon loss (t)	Share (%)
Closed woodland	137807	2.39	329358.73	93.11
Open woodland	181984	0.89	161965.76	45.78
Bushland	-46563	0.36	-16762.68	-4.74
Grassland	499	0.17	84.83	0.03
Water	786	0.64	503.04	0.14
Cultivated land	-268193	0.45	-120686.85	-34.12
Built up area	-6319	0.11	-695.09	-0.2
Total			**353767.74**	**100**

source: researcher data, 2019

4.5.2 Future Amount of Carbon to be Released to the Atmosphere as a Result of Changes in LULC

4.5.2.1 Amount of Biomass that will be Loss in Eastern Selous-Niassa TFCA from 2015 to 2035

The results in Table 4.17 and Table 4.18 revealed that, 124.5% of biomass will be lost in woodland, bushland and water; while, 24.5% of biomass will be stored by other vegetation type as a result of habitat conversion of eastern Selous-Niassa TFCA. Bushland alone will loss 67.7% of biomass, followed by woodlands (56.7%). This implies that, average amount of 36801.95 tons of biomass (above ground + below ground + deadwood) from woodlands; bushland; and water will be loss annually from 2015 to 2035. Moreover, average amount of 7242.19 tons of biomass (above ground + below ground + deadwood) from other vegetation type will be stored annually from 2015 to 2035.

The results shows that, the natural vegetation will be degraded and new tree species will take (under succession) place. The degradation will impacts negatively ecosystem services offered to wildlife residing or using the area for migration or adapting to climatic change. The degraded area will be converted to bushland, cultivated land and built up area due to increase of human population, livestock, and dependence of corridor dwellers on existing natural resources in the ecosystem for their livelihoods. Therefore, the average total annual loss will be 29559.76 tons of biomass (above ground + below ground + deadwood) in all vegetation type from 2015 to 2035. These results necessitated the emergence of new management strategies of the area which will assure the survival of wildlife without compromising livelihoods of TFCA dwellers. The existing formulation of wildlife management areas (WMAs) of Liwale (MAGINGO), Nachingwea (NDONDA) and Nanyumbu (MCHIMALU) districts relies only adjacently to core PAs of Selous, Msanjesi and Lukwika-Lumesule game reserves, and forgetting other areas which are crucial to wildlife, using their living habitat and migration trails.

Table 4.17: Amount of Living Tree Stemwood Biomass (Above Ground + Below Ground) Loss of Eastern Selous-Niassa TFCA from 2015 to 2035

Primary Vegetation Type	Total area converted (ha)	Above ground biomass loss (t/ha)	Below ground biomass loss (t/ha)	Total Biomass loss (t)	Biomass loss (%)
Closed woodland	7942	4.87	18.2	183221.9	35.91
Open woodland	8527	1.82	9.5	96525.64	18.92
Bushland	68319	0.73	4.4	350476.5	68.69
Grassland	-16811	0.35	1.1	-24376	-4.78
Water	404	1.31	1.7	1216.04	0.24
Cultivated land	-3898	0.91	2.1	-11733	-2.3
Built up area	-64483	0.22	1.1	-85117.6	-16.68
Total				**510213.6**	**100.00**

source: researcher data, 2019

Table 4.18: Amount of Dead Wood Biomass Loss of Eastern Selous-Niassa TFCA from 2015 To 2035

Primary Vegetation Type	Total area converted (ha)	Biomass loss (t/ha)	Total Biomass loss (t)	Biomass loss (%)
Closed woodland	7942	4.87	38677.54	47.76
Open woodland	8527	1.82	15519.14	19.16
Bushland	68319	0.73	49872.87	61.59
Grassland	-16811	0.35	-5883.85	-7.27
Water	404	1.31	529.24	0.65
Cultivated land	-3898	0.91	-3547.18	-4.38
Built up area	-64483	0.22	-14186.3	-17.52
Total			**80981.5**	**100.00**

source: researcher data, 2019

4.5.2.2 Amount of Carbon Released to the Atmosphere as a Result of Habitat Conversion of Eastern Selous-Niassa TFCA from 2015 to 2035

The results in Table 4.19 and Table 4.20 revealed that, 122.29% of carbon will released to the atmosphere from in woodland, bushland and water; while, 22.9% of carbon will be stored by other vegetation type as a result of habitat conversion of eastern Selous-Niassa TFCA. Bushland alone will loss 64.1% (516491.6 tons) of carbon, followed by woodlands 57.89% (465675.9 tons). This implies that, average amount of 49181.91tons of carbon (above ground + below ground + deadwood) from woodlands; bushland; and water will be loss annually from 2015 to 2035.

Moreover, average amount of 8964.75 tons of carbons (above ground + below ground + deadwood) from other vegetation type will be stored annually from 2015 to 2035. This is something that we can never stay quiet; and the need to act urgently is unquestionable. Thus, the need for sustainable utilization and management of natural resources in the area is vital. Nevertheless, the average total annual loss will be 40217.16 tons of Carbon (above ground + below ground + deadwood) from 2015 to 2035. Since, climate change is a result of increasing greenhouse gases in the atmosphere, there are must be strategies to reverse the situation.

If, we decide to include the area into core PA network, we must revise the current participatory management strategies which insist on formulation of Wildlife Management Areas (WMAs) but forgetting that those WMAs are only adjacent to core PAs which in other scenarios doesnôt fit. Thus, the need to formulate other management strategies that will include all areas in the corridor which has wildlife climatic niche; economical and ecological importance for corridor dwellers is unavoidable.

Table 4.19: Amount of Living Tree Stemwood Carbon (Aboveground + Belowground) That Will be Released to the Atmosphere as A Result of Habitat Conversion of Eastern Selous-Niassa TFCA From 2015 To 2035

Primary Vegetation Type	Total area converted (ha)	Carbon loss (t/ha)	Total Carbon loss (t)	Share (%)
Closed woodland	7942	36.5	289883	37.91
Open woodland	8527	17.5	149222.5	19.52
Bushland	68319	7.2	491896.8	64.33
Grassland	-16811	1.8	-30259.8	-3.96
Water	404	3.0	1212	0.16
Cultivated land	-3898	3.8	-14812.4	-1.94
Built up area	-64483	1.9	-122518	-16.02
Total			**764624.4**	**100**

source: researcher data, 2019

Table 4.20: Amount of Dead wood Carbon that will be loss in Eastern Selous-Niassa TFCA from 2015 to 2035

Primary Vegetation Type	Total area converted (ha)	Carbon loss (t/ha)	Total Carbon loss (t)	Share (%)
Closed woodland	7942	2.39	18981.38	47.79
Open woodland	8527	0.89	7589.03	19.11
Bushland	68319	0.36	24594.84	61.92
Grassland	-16811	0.17	-2857.87	-7.19
Water	404	0.64	258.56	0.65
Cultivated land	-3898	0.45	-1754.1	-4.42
Built up area	-64483	0.11	-7093.13	-17.86
Total			**39718.71**	**100**

source: researcher data, 2019

4.5.3 Current Amount of Carbon Stock in the Study Area

4.5.3.1 Amount of Biomass Stock of the Study Area

The results in Table 4.21 and Table 4.22 revealed that, nearly 84.38% of biomass stock found in closed woodland (forests), open woodland and bushland. This implies that, amount of 12873004tons of biomass (above ground + below ground + deadwood) existing in closed woodland (forests), open woodland and bushland of eastern Selous ï Niassa TFCA in 2016. Degradation of the area will impact negatively ecosystem services offered to wildlife residing or using the area for migration or adapting to climatic change.

The degraded area converted to bushland, cultivated land and built up area due to increase of human population, livestock, and dependence of corridor dwellers on existing natural resources in the ecosystem for their livelihoods. These results necessitated formulation of sustainable management strategy which will assure the survival of wildlife without compromising livelihoods of corridor dwellers. The existing formulation of wildlife management areas (WMAs) of Liwale (MAGINGO), Nachingwea (NDONDA) and Nanyumbu (MCHIMALU) districts relies only adjacently to core PAs of Selous, Msanjesi, and Lukwika-Lumesule game reserves, and forgetting other areas which are crucial to wildlife as their living habitat and migration trails.

Table 4.21: Amount of Living Tree Stemwood Biomass (Aboveground + Belowground) Stock of Eastern Selous-Niassa TFCA

Primary Vegetation Type	Total area (ha)	Above ground biomass stock (t/ha)	Below ground biomass stock (t/ha)	Total Biomass stock (t)	Biomass stock (%)
Closed woodland	89923	4.87	18.2	2074524	24.63
Open woodland	220217	1.82	9.5	2492856	29.59
Bushland	480269	0.73	4.4	2463780	29.25
Grassland	394461	0.35	1.1	571968.5	6.79
Water	646	1.31	1.7	1944.46	0.02
Cultivated land	268193	0.91	2.1	807260.9	9.58
Built up area	8851	0.22	1.1	11683.32	0.14
Total				**8424017**	**100.00**

source: researcher data, 2019

Table 4.22: Amount of Dead Wood Biomass Stock of Eastern Selous-Niassa TFCA

Primary Vegetation Type	Total area (ha)	Biomass stock (t/ha)	Total Biomass stock(t)	Biomass stock (%)
Closed woodland	89923	4.87	1636599	23.89
Open woodland	220217	1.82	2092062	30.54
Bushland	480269	0.73	2113184	30.85
Grassland	394461	0.35	433907.1	6.34
Water	646	1.31	1098.2	0.02
Cultivated land	268193	0.91	563205.3	8.22
Built up area	8851	0.22	9736.1	0.14
Total			**6849790**	**100.00**

source: researcher data, 2019

4.5.3.2 Amount of Carbon Stock of the Study Area

The results in Table 4.23 and Table 4.24 revealed that, nearly 80.68% Carbon stored in closed woodland (forests), open woodland and bushland. This implies that, 11177730 tons of Carbon (above ground + below ground + deadwood) from closed woodland (forests), open woodland and bushland for the year 2016. This is something that we can never stay quiet; and the need to act urgently is unquestionable. Conserving these vegetation is a climate change mitigation measure, but reacting now is adapting with mitigation measures for wildlife using the corridor as a migratory route or adapted area for their climatic niche. Thus, the need for sustainable utilization and management of natural resources in the area is vital.

The need to include the area into core PA network is paramount; however there is a cost (in terms of money or other areas suitable for their livelihoods) that the corridor dwellers have to accept as a compensation for releasing the area for protection. This cost can be regarded as an opportunity cost for corridor dwellers which the government must incur to officiate the process. For Tanzania scenario, we must agree that those areas abandoned by wildlife which previously used as PAs should be recategorise by considering all species ecology analysis in the face of climate change and have proper management plan.

Table 4.23: Amount of Living Tree Stemwood Carbon (Aboveground + Belowground) Stock of Eastern Selous-Niassa TFCA

Primary Vegetation Type	Total area (ha)	Carbon stock (t/ha)	Total Carbon stock(t)	Share (%)
Closed woodland	89923	36.5	3282190	26.59
Open woodland	220217	17.5	3853798	31.22
Bushland	480269	7.2	3457937	28.02
Grassland	394461	1.8	710029.8	5.75
Water	646	3.0	1938	0.02
Cultivated land	268193	3.8	1019133	8.26
Built up area	8851	1.9	16816.9	0.14
Total			**12341842**	**100**

Table 4.24: Amount of Dead Wood Carbon stock of Eastern Selous-Niassa TFCA

Primary Vegetation Type	Total area (ha)	Carbon stock (t/ha)	Total Carbon stock(t)	Share (%)
Closed woodland	89923	2.39	214916	27.81
Open woodland	220217	0.89	195993.1	25.36
Bushland	480269	0.36	172896.8	22.36
Grassland	394461	0.17	67058.37	8.68
Water	646	0.64	413.44	0.05
Cultivated land	268193	0.45	120686.9	15.61
Built up area	8851	0.11	973.61	0.13
Total			**772938.2**	**100**

source: researcher data, 2019

4.5.4 Future amount of Carbon Stock of the Study Area

4.5.4.1 Future Amount of Biomass of the Study Area

The results in Table 4.25 and Table 4.26 revealed that, nearly 8789814.9 tons of biomass (above ground + below ground + deadwood) stock found to be stored in the study area in 2035. Degradation of the area will change natural habitat and negatively impact ecosystem services offered to wildlife residing or using the area for migration or adapting to climatic change. There is a need to formulate sustainable management strategy which will assure the survival of wildlife without compromising livelihoods of corridor dwellers.

Table 4.25: Amount of Living Tree Stemwood Biomass (Aboveground + Belowground) stock of eastern Selous-Niassa TFCA

Primary Vegetation Type	Total area (ha)	Above ground biomass stock (t/ha)	Below ground biomass stock (t/ha)	Total Biomass stock (t)	Biomass stock (%)
Closed woodland	81981	4.87	18.2	1891301.67	25.29
Open woodland	211690	1.82	9.5	2396330.8	32.06
Bushland	411950	0.73	4.4	2113303.5	28.27
Grassland	411272	0.35	1.1	596344.4	7.98
Water	242	1.31	1.7	728.42	0.02
Cultivated land	12749	0.91	2.1	38374.49	0.51
Built up area	332676	0.22	1.1	439132.32	5.87
Total				**7475515.6**	**100.00**

source: researcher data, 2019

Table 4.26: Amount of Dead Wood Biomass Stock of Eastern Selous-Niassa TFCA

Primary Vegetation Type	Total area (ha)	Biomass stock (t/ha)	Total Biomass stock(t)	Biomass stock (%)
Closed woodland	81981	4.87	399247.5	30.37
Open woodland	211690	1.82	385275.8	29.32
Bushland	411950	0.73	300723.5	22.88
Grassland	411272	0.35	143945.2	10.95
Water	242	1.31	317.02	0.03
Cultivated land	12749	0.91	11601.59	0.88
Built up area	332676	0.22	73188.72	5.57
Total			**1314299**	**100.00**

source: researcher data, 2019

4.5.4.2 Future Amount of Carbon Stock of the Study Area

The results in Table 4.27 and Table 4.28 revealed that, nearly 87.17% of Carbon will be stored in closed woodland (forests), open woodland and bushland. This implies that, 11729510.92 tons of Carbon (above ground + below ground + deadwood) will be stored in the year 2035. Conserving these vegetation is crucial for wildlife using the corridor as a migratory route or adapted area for their climatic niche.

Table 4.27: Future Amount of Living Tree Stemwood Carbon (Aboveground + Belowground) stock of Eastern Selous-Niassa TFCA

Primary Vegetation Type	Total area (ha)	Carbon stock (t/ha)	Total Carbon stock(t)	Share (%)
Closed woodland	81981	36.5	2992306.5	26.99
Open woodland	211690	17.5	3704575	33.42
Bushland	411950	7.2	2966040	26.76
Grassland	411272	1.8	740289.6	6.68
Water	242	3.0	726	0.01
Cultivated land	12749	3.8	48446.2	0.44
Built up area	332676	1.9	632084.4	5.7
Total			**11084467.7**	**100**

source: researcher data, 2019

Table 4.28: Future Amount of Dead Wood Carbon stock of eastern corridor of Selous-Niassa TFCA

Primary Vegetation Type	Total area (ha)	Carbon stock (t/ha)	Total Carbon stock(t)	Share (%)
Closed woodland	81981	2.39	195934.59	30.38
Open woodland	211690	0.89	188404.1	29.21
Bushland	411950	0.36	148302	22.99
Grassland	411272	0.17	69916.24	10.84
Water	242	0.64	154.88	0.02
Cultivated land	12749	0.45	5737.05	0.89
Built up area	332676	0.11	36594.36	5.67
Total			**645043.22**	**100**

source: researcher data, 2019

4.5.5 Amount of Conservation Profit of the Study Area

4.5.5.1 Amount of Conservation Profit Disposed Resulted from Changes in LULC from 1986 to 2016

Results in Table 4.29 revealed that, the study area loss an average amount of US$ 47169.03 of carbon trade annually from 1986 to 2016 due to degradation of the area.

Closed woodland and open woodlands pioneered degradation on which they loss an annual average of 65509.93 tons of Carbon from 1986 to 2016. It seems that open and closed woodlands have potential hard wood species which are regarded as commercial rewarding but environmental destructive by corridor dwellers.

Also, the Government earmarked those commercial rewarding tree species with their prices; but administering their utilization and their market chain are questionable. Thus, we need community centered decision making which is integrated but different from PFM (Participatory Forest Management), JFM (Joint Forest Management) and WMA (Wildlife Management Areas) because they really not fully integrate targeted population and they cannot benefit individual entity in the community. Also, all these scenarios do not consider that those individuals in the community are changing in time, thus, scientific revised community members monitoring strategy and recording system is unavoidable; and emphasis of integrative participatory approach as advocated by Pimbert and Prety (1995).

Table 4.29: Amount of Conservation Profit Disposed as a Result of Habitat Conversion of Eastern Selous-Niassa TFCA from 1986 to 2016

Primary Vegetation Type	Total Carbon loss (t)	Amount of money loss (US$)	Share (%)
Closed woodland	329358.73	1317434.92	93.11
Open woodland	161965.76	647863.04	45.75
Bushland	-16762.68	-67050.72	-4.73
Grassland	84.83	339.32	0.04
Water	503.04	2012.16	0.15
Cultivated land	-120686.85	-482747.4	-34.11
Built up area	-695.09	-2780.36	-0.21
Total	**353767.74**	**1415070.96**	**100**

source: researcher data, 2019

4.5.5.2 Future Amount of Conservation Profit to be Disposed as a Result of Changes in LULC

Results in Table 4.30 revealed that, eastern Selous ï Niassa TFCA will loss an average amount of US$ 160868.6 of carbon trade annually from 2015 to 2035 due to habitat conversion of the area. Woodlands, bushland and water pioneered degradation on which they will loss an annual average of US$ 196727.6 from 2015 to 2035. It seems that the area have potential hard wood species which are regarded as commercial rewarding but environmental destructive by corridor dwellers. Sustainable utilization of natural resources in the area is of important priority. Thus, the government need to integrate community in management of the area by combined PFM (Participatory Forest Management), JFM (Joint Forest Management) and WMA (Wildlife Management Areas) and having one entity which will be integral and community-centered in decision making on corridor management.

Table 4.30: Amount of Conservation Profit Disposed As A Result Of Habitat Conversion of Eastern Selous-Niassa TFCA from 2015 to 2035

Primary Vegetation Type	Total Carbon loss (t)	Amount of money loss (US$)	Share (%)
Closed woodland	308864.4	1235458	38.4
Open woodland	156811.5	627246.1	19.5
Bushland	516491.6	2065967	64.21
Grassland	-33117.7	-132471	-4.12
Water	1470.56	5882.24	0.18
Cultivated land	-16566.5	-66266	-2.06
Built up area	-129611	-518443	-16.11
Total	**804343.1**	**3217372**	**100**

source: researcher data, 2019

4.5.5.3 Current Amount of Conservation Profit

Results in Table 4.31 revealed that, the study area have Carbon stock equivalent to US$ 52459124 for the year 2016 if adopted REDD+ strategy. Estimated population of corridor dwellers of 2016 (using data of NBS, 2012) implies that, each individual was expected to gain nearly US$ 119.79 as a conservation profit in 2016. Consequently, closed woodland, open woodland, and bushland pioneered 85.22% of the conservation profit which could be gained from carbon sell. It seems that open and closed woodlands have potential hard wood species which are regarded as commercial rewarding but environmental destructive by corridor dwellers. This scenario necessitated the need to have sustainable management of the area so that to give room for wildlife to migrate in PAs present in the study area and those use the area for adaptation of climate change and variability from core PAs.

Table 4.31: Amount of Conservation Profit of Eastern Corridor of Selous-Niassa TFCA

Primary Vegetation Type	Total Carbon stock (t)	Amount of money (US$)	Share (%)
Closed woodland	3497106	13988424	26.66
Open woodland	4049791	16199164	30.87
Bushland	3630834	14523335	27.69
Grassland	777088.2	3108353	5.93
Water	2351.44	9405.76	0.02
Cultivated land	1139820	4559280	8.69
Built up area	17790.51	71162.04	0.14
Total	**13114781**	**52459124**	**100**

source: researcher data, 2019

4.5.5.4 Future Amount of Conservation Profit

Results in Table 4.32 revealed that, the study area will have Carbon stock equivalent to US$ 46918043.68 for the year 2035 if REDD+ strategy will be adopted. Predicted population of corridor dwellers of 2035 (using data of NBS, 2012) implies that, each individual was expected to gain nearly US$ 87.62 as a conservation profit in 2035. Consequently, closed woodland, open woodland, and bushland will pioneer 86.92% of the conservation profit which could be gained from carbon trade. This implies that, open and closed woodlands have potential hard wood species which will continue to be degraded if sustainable management strategies of the area canôt be implemented.

Table 4.32: Predicted Future Amount of Conservation Profit of Eastern Corridor of Selous-Niassa TFCA

Primary Vegetation Type	Total Carbon stock (t)	Amount of money (US$)	Share (%)
Closed woodland	3188241.09	12752964.36	27.18
Open woodland	3892979.1	15571916.4	33.19
Bushland	3114342	12457368	26.55
Grassland	810205.84	3240823.36	6.91
Water	880.88	3523.52	0.01
Cultivated land	54183.25	216733	0.46
Built up area	668678.76	2674715.04	5.7
Total	**11729510.92**	**46918043.68**	**100**

source: researcher data, 2019

4.6 Consequences of Climate Change and Variability in Managing Selous–Niassa TFCA

4.6.1 Access to Land and Land Tenure in the Study Area

The land tenure system in the study area is given in Table 4.33. The dominant land ownership system is individual land obtained through inheritance (83.3%). This is followed by rent land (16.7%) where the majorities are females who were either divorced or widowed because the traditional rules for accessing land did not favor them. The minimum farm size owned by an individual farmer was one hectare, while the maximum farm land was 15hectares. Average farm land per farmer was 1.2 ha. Regarding land area, 80% of the respondents have land parcels between 1-3hectares and 20% had more than three hectares. However, 86.7% of the respondents claimed that land was not enough.

For possibilities to get more land for cultivation, 78.3% claimed that it was possible either through formal application to the village government (81.7%), buying from those with big farms (10.0%) and renting on temporary basis (8.3%) (Table5). Even though, the majority of respondents (85%) indicated the possibility of getting additional piece of land (Table 4). During the focus group discussions it was found that there is a problem of fertile land for rice farming in Mpigamiti village resulted to land use conflicts.

The conflict arose in 2010 after MAGINGO WMA getting user right for the area while immigrants invaded the area and cultivated protected land and uses water from the source of Liwale River (Mpigamiti spring) without prior consultation and permission from the village, MAGINGO leaders and District authority as the river is only source of water to Liwale District. This is due to divisions of former village of Mpigamiti into three villages (Mpigamiti, Namakololo and Mitawa) while during formation of the WMA it was one village. Thereof, distribution of income from WMA goes to only one village (Mpigamiti) and other two remaining villages get nothing contrary to sharing their land to WMA.

Table 4.33: Land Ownership in Study Villages

Information	**Villages**			
	Mpigamiti	Kilimarondo	Mpombe	Overall
(a)Land ownership:	n=30	n=30	n=30	N=90
Individual	27(90.0)[1]	25(83.3)	23(76.9)	75(83.3)
Rent	3(10.0)	5(16.7)	7(23.3)	15(16.7)
(b)Size of land owned hectares:				
1 - 3 ha	24(80.0)	21(70.0)	27(90.0)	72(80.0)
4 ï 6 ha	4(13.4)	5(16.7)	2(6.7)	11(12.3)
7 - 10 ha	1(3.3)	2(6.7)	1(3.3)	4(4.4)
11-15 ha	1(3.3)	1(3.3)	0(0.0)	2(2.2)
> 15 ha	0(0.0)	1(3.3)	0(0.0)	1(1.1)
(c)Land available:				
Enough	2(6.7)	4(13.4)	6(20.0)	12(13.3)
Not enough	28(93.3)	26(86.6)	24(80.0)	78(86.7)
(d) Possibility to get more land:				
Yes	23(76.7)	25(83.3)	28(93.3)	76(84.4)
No	6(23.3)	5(16.7)	2(6.7%)	14(15.6)
(d)Location of owned land:				
Within migratory routes	2(6.7)	2(6.7)	1(3.3)	5(5.5)
Five km from core PA	2(6.7)	2(6.7)	1(3.3)	5(5.5)
Within the WMA	0(0.0)	5(16.7)	10(33.3)	15(16.7)
In the planned area	23(76.7)	20(76.7)	18(60.0)	61(67.9)
In wetland area	3(10.0)	1(10.0)	0(0.0)	4(4.4)

[1] Figures outside and inside the parentheses are frequencies and percentages respectively.

Table 4.34: T-Test for Possibility to Get More Land for Cultivation by Households in Study Villages

T	Df	Sig. (2-tailed)	Mean Difference	95% CI of the Difference: Lower	Upper
-1.067E3	89	.000	-58.767	-58.88	-58.66

CI=confidence interval

t-test in Table 4.34 indicated statistical significance (p=0.05) on possibility to get more land for cultivation by households in study villages through various means includes application to the village government, buying or rent.

Findings from the analysis of variance (ANOVA) in Table 4.35 shows that there was a significant variation (p<0.05) of means to acquire land for cultivation by households in study villages.

Table 4.35: One-Way ANOVA for Means to Acquire Land for Cultivation by Households in Study Villages

Source of variations	Sum of Squares	Df	Mean Square	F	Sig. Level
Between villages	1.067	1	1.067	2.994	< 0.05
Within villages (error)	20.667	88	.356		
Total	**21.733**	**89**			

*Statistically significant at 0.05 level of significance

Furthermore, information obtained from MAGINGO and MCHIMALU WMAs offices and DLOs shows that, study villages bordering Selous, Msanjesi and Lukwika-Lumesule GRs have land use plans made by Tanzania Land Use Plan Commission (TLUPC) in collaboration with Ministry of Land, Housing and Settlement (MLHS); and Liwale, Nachingwea and Namyumbu District Councils in 2008, 2010 and 2012 respectively. The planning process was funded by WWF however excluded SGR, MGR and LGR which in one way or another is among of the cause of border conflict between adjacent villages and PAs. It was explored that, study villages land use plans maps don't have "buffer zones" as suggested by Wildlife Conservation Act No. 12 of 1974 and its successor No.5 of 2009.

Therefore, this shows that, all professionals were only listening to villagers without considering other laws and policies like Wildlife, Environmental, Forest and others. For instance, during 2015 boundary conflict resolution between MAGINGO WMA and SGR done by the committee made by then Minister of MNRT which involved professionals from TLUPC, LDC, MLHS, MNRT and SGR also Village elders of nine villages forming WMA includes Mpigamiti, Ndapata, Barikiwa, Chimbuko, Kikulyungu, Kimambi, Mirui and Naujombo (MWMA and SGR office reports, 2016). At the end of resolution, all villages except Kikulyungu agreed with the Government Notice No. 275 of 1974 which declares the boundaries of SGR. The zoned land area for WMA in Kikulyungu village is no more favourable for wildlife conservation as it was converted to agriculture activities.

4.6.2 Socio-Economic Activities Resulted from Climate Change and Variability in the Study Area

4.6.2.1 Agriculture

Agriculture is a major economic activity and source of income in Selous-Niassa TFCA. Many villagers in Liwale, Nachingwea and Nanyumbu Districts practice shifting cultivation associated with destroying Miombo forests which are also habitat for wild animals thereafter causing human-wildlife or wildlife-crops interactions/ conflicts as the animals moving in their ecological trails and searching their climatic niche. Specifically, this behavior depends on population of the Districts; for instance 2012 census show Liwale District to have a population of 91 380 people with average of one person per 6.7 hectares suitable for agriculture and outside protected areas; while Nanyumbu District have 150 857 people with average of one person per 2.3 hectares. This shows that, Nanyumbu District will extend to protected land for agriculture activities if shifting cultivation is not reversed.

Table 4.36: Food and Cash Crops Areas

Information:	**Area (in hectares)**		
(a)Food crops:	**Liwale District**	**Nachingwea District**	**Nanyumbu District**
Cassava	12 809	8 247	27 558
Maize	14 464	6 211	16 450
Rice	5 998	11 99	2 154
Sorghum	11 741	48 04	10 280
Total	**33 492**	**20 461**	**56 442**
(b)Cash crops:			
Cashew nuts	13943	11 397	105 820
Sesame	6 800	3 445	5 400
Cowpea	1 400	-	3500
Pigeon	1 220	3 341	14 000
Gram	4 340	-	9 811
Groundnuts	870	3 206	15 120
Total	**28 573**	**11 389**	**153 651**

Source: Liwale, Nachingwea and Nanyumbu District Councils Reports, 2017

Cultivated crops in the study area can be categorized into three main groups namely annual, semi perennial and perennial crops. Major annual cultivated crops include maize (*Zea mays*); rice (*Oryza sativa*) and sorghum (*Sorghum vulgare*). Semi perennial cultivated plant species are cassava (*Manihot esculenta*), sugar cane

(*Saccharum officinarum*), simsim (*Sesamum sp*), and banana (*Musa esente*, *Musa cavendishii*, and *Musa sp*). Perennial cultivated plant species are cashewnut (*Anacardium ocidentale*) and coconut (*Cocos nucifera*).

Other minor cultivated plant species are groundnuts (*Arachis hypogea*), melon (*Cucurbita mero*) and Pigeon beans (*Cajanus cajan*). Fruits plant species cultivated in study area include mango (*Mangifera indica*), orange (*Citrus sp*) and pawpaw (*Carica papaya*). However, perennial and semi perennial crops are grown on small scale level but all crops are grown for subsistence and trade, but cashew nuts remains the principal cash crop and sesame emerged as short term cash crop involve highly forests destructions. Production trend varies in different years depending on input and equipments supplied. Figures 4.7 4.8 and 4.9 show some of the existing production for Liwale, Nachingwea and Nanyumbu Districts in years:

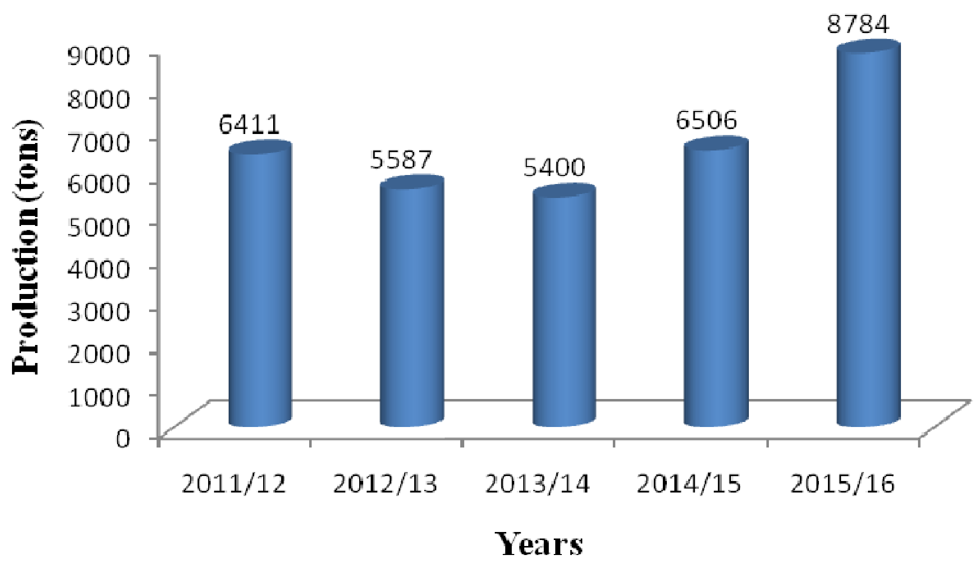

Figure 4.7: Liwale Cashewnut Production (Tons) for the years 2011/12 up to 2015/16
Source: Liwale District Council report, 2017

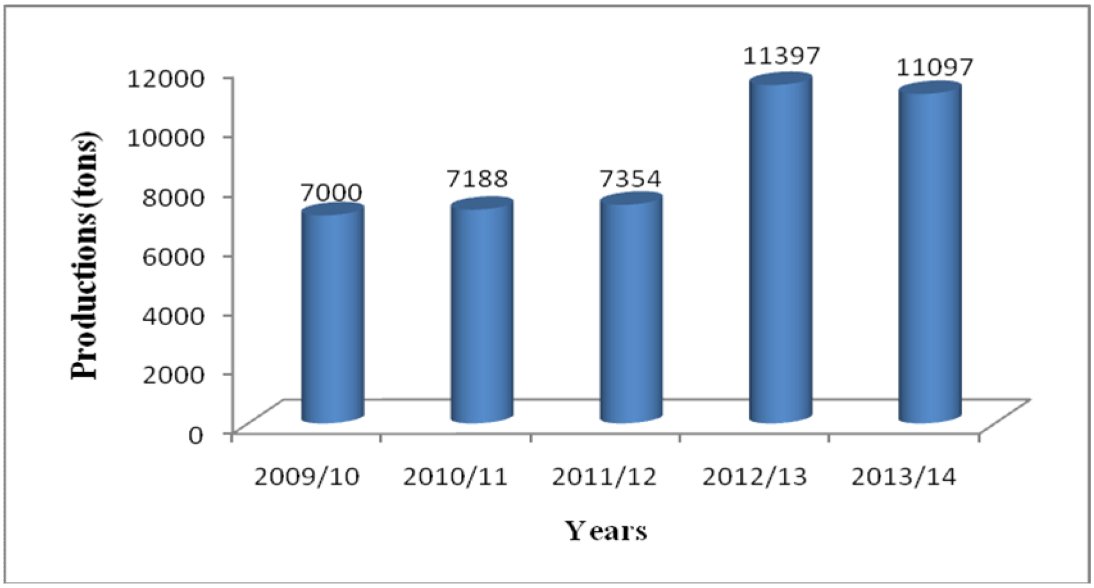

Figure 4.8: Nachingwea Cashewnut Production (Tons) for the Years 2009/10 up to 2013/14

Source: Nachigwea District Council report, 2017

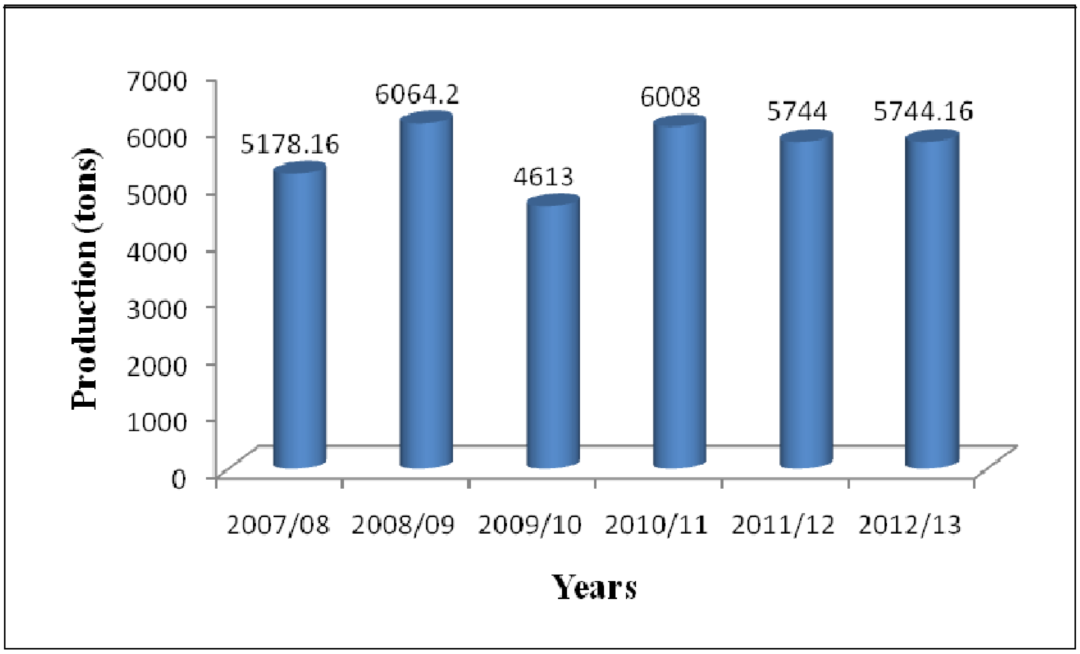

Figure 1.9: Nanyumbu Cashewnut Production (Tons) for the years 2007/08 up to 2012/13

Source: Nanyumbu District Council report, 2017

During in-depth interview with Districts agriculture officers, it was seems that the productions trend are not actual due to the presence of illegal buyers (Chomachoma) where quantity bought are unknown and increase loss of Districts income. Therefore, out of other factors, production variation in years depends on strength of District security on exit routes of that particular year.

The emerged of highly production of simsim (Sesamum sp) seems to overtake cashewnut and becomes the leading source of Districts revenues and householdsô income. For instance, simsim production in Liwale District for the year 2015/16 was 7 925 157 kg compared to 7 483 874 kg of cashewnut amounted TZS15 850 314 000 and TZS 8 980 648 800 respectively. This shows that, simsim production in terms of revenues accrued almost double cashewnut production. However, most of cashewnut are at least fifty years of age and are owned through inheritance, thus accelerates conservation efforts compared to simsim production which is environmental destructive but short time income rewarding activity. There is no actual figure for the land size used for simsim production as most of producers invade and clear public Miombo forests for establishment of farms. This statement evidenced by a large number of ñMakondeò from Newala, Tandahimba and Mahuta claimed during focus group discussions to invade the study area .

Also these food and cash crops attract wild animals which are the source of conflict of interests between conservation and agriculture. The study villages show that 88.6% of respondents suffered from wildlife related problems while only 11.4% had not experienced the problem (Table 4.37).

Table 4.372: Problem Animals Destroying Crops and Human Life

Information:	**Villages**			
	Mpigamiti		Mpombe	Overall
	Kilimarondo		n=30	N=90
(a)Availability of problem animals:	n=30	n=30		
Yes			26(86.7)	78(86.7)
No	28(93.3.7)[1]	24(80.0)	4(13.3)	12(13.3)
(b)Common problem animals:	2(6.7)	6(20.0)		
Elephant *(Loxodonta africana)*	26(86.7)	4(13.3)	4(13.3)	30(50.0)
Bushpig *(Potamochoerus porcus)*	20(66.7)	11(36.7)	11(36.7)	31(51.7)
Vervet monkeys *(Chlorocebus aethiops)*	9(30.0)	17(56.7)	15(50.0)	41(45.6)
Hippos (*Hippopotamus amphibius*)	6(20.0)	5(16.7)	3(10.0)	14(15.6)
Olive baboon *(Papio anubis anubis)*	15(50.0)	8(26.7)	12(40.0)	35(38.8)

For (b) Multiple responses answers were obtained
[1] Figures outside and inside the parentheses are frequencies and percentages respectively.

The study found the animals that damage crops in the field are shown in (Table 4.37). Elephants seem to damage mostly in Mpigamiti village (86.7%) compared to Kilimarondo and Mpombe were vervet monkey take chances by 56.7% and 50% respectively. This indicates that elephant poaching is at alarming rate in Kilimarondo and Mpombe villages compared to Mpigamiti village within the Selous-Niassa TFCA. Furthermore, rats were reported by many respondents that they cause great damage on stored cereal crops at home compared to fieldsô crops. During field observation and focus group discussions it was found that, damage to crops varied from one village to another and from one plot to another within the study area. The most preferred crops by animals were maize, cassava, sugarcane, melon and cashew nuts.

During focus group discussions, community categorized the wild animals that damage crops into three main groups:

(a) All wild animalsô species which damage crops during the day. These include

Vervet monkey (*Cercopithecus aethiops arenarius*), Rufiji blue monkey (*Cercopithecus mitis monoldes*) and yellow baboon (*Papio cynocephalus*).

(b) All wild animalsô species which damage crops at night. These include African elephant *(Loxodonta africana*), bushpig (*Potamochoerus porcus*), buffalo (Cy*ncerus caffer*) and hippopotamus (*Hippopotamus amphibius*).

(c) All animalsô species that cause minor damage of crops at night. These include warthog (*Phacochoerus aethiopicus*), eland (*Taurotragus oryx*), greater kudu (*Strepsiceros strepsiceros*), bushbuck (*Tragelaphus scriptus*), impala (*Aepyceros melampus*), black backed jackal (*Canis mesomelas*), Reed buck (*Redunca redunca*), porcupine (*Hytrix africae astralis*) and cane rat (*Thyronomys swinderianus*).

Elephants, bush pigs and baboons are animals that cause greater damage to maize farm plots both in wet and dry season. Baboons start to destroy maize seedling immediately after germination. They jab germinated maize seedlings and continue to damage crops in the growing season until they are harvested. Elephant start to feed on maize seedlings between 3 - 4 weeks after germination and continue to damage the crops until they are harvested. The relative ranking of damage caused by elephant varies in the study area. Elephants were found to enter crops most in both wet and dry season depending on the location of the field from the feeding or migratory routes to or from core protected areas. Bushpigs were reported to use stems of maize and sorghum at early stage.

The measures taken by farmers to control include non lethal deterrents applied by farmers include oil chilled ropes and chilled elephant dung blocks. The farmers who applied oil chilled ropes and chilled dungs around their farm plots in the study area had less crops loss or raided by animals especially elephants. These measures experienced in Mpigamiti village were peasants who applied the deterrents of elephants in their farm plots yielded much and had large farms plots compared to those who do not apply (See Figure 4.1 - 4.12). Therefore, as suggested by Kagaruki (2004) crop production in the study villages would be increased if more efforts toward preventing crop damage will be focused on the control of weeds, crop diseases, and smaller species such as bush pigs, baboons, rodents or birds because elephants in many areas within the corridor are deteriorating.

Figure 4.10: Chill-Elephant Dung Bricks

Figure 4.11: Oil Chilled Ropes Around Farm plot.

Figure 4.12: Harvested Chilies Used in HWC

However, wildlife not only represent problems for people living around them but there is also an overall great deal of respect, affection and positive culture associate with the populations of wild animals. Wild animals are part of peopleös lives, their identity and attachment to the land. There might be a considerable faith in the managerös capability to alleviate problems around communities while protecting natural resources. Nevertheless, major threat hinder sustainable conservation of wildlife is a limited range of opportunities and alternatives in a situation characterized by wide spread poverty and increased population pressure within the wildlife corridors. Therefore, the need to facilitate community mobilization seems to be the pre-requisite for sustainable wildlife management (Pinter-Wollman, 2012).

Population growth of people and ghastly land uses in study villages brings pressure on resources available as results of habitat destruction and environmental degradation. During field observation, it was seen that, many farms are within the wildlife corridor and out of planned areas which implies that, people are not only interested with growing crops only but their eyes are on wild animals. The existence of conflicts within the corridor is based on the differing term-utilization attached to the available resources. The objectives behind the conservation scheme is to conserve natural resources for long-term benefits, while the concern of the inhabitants of the corridor is the need to have a means of livelihood for survival. The different functional interpretations given to the corridor have generated the varying degrees of conflicts experienced.

4.6.2.2 Encroachment for Fuelwood, Logging and Mining

Encroachment for fuel wood, logging and mining is increasing daily in the study area as alternative source of income for their livelihoods. During direct field observation and focus groups discussions in study area, mining tunnels observed and most of mining practiced within rivers (Liwale, Lumesule, Mbwemkuru, Lukwika and Ruvuma rivers) inside wildlife and forest protected areas found in Selous-Niassa TFCA. Focus groups discussants claimed that, minerals found in the study area are such as white sapphire, green sapphire, blue sapphire, green tourmaline and gold. During in-depth interview with DGOs and passing through District revenues collections records for five years 2011 to 2016, the quantity of mines and revenues accrued by Districts authorities are still a myth.

Illegal logging increased in study area especially in forest reserves, WMAs, and SGR, LLM GRs as these are the only areas in Liwale, Nachingwea and Nanyumbu districts concentrated with valuable trees for logging and timbering. For year 2011 to 2016, LLM arrested 1953 timbers from TFCA in Nachingwea and Nanyumbu Districts while SGR arrested 2217 in Liwale District (LLM and SGR annual reports of 2011 to 2016). Encroachments of forests for valuable trees increased due to emerged application of chainsaws in illegal and legal harvesting contrary to Forest Act of 2002. For instance, the year 2014, twenty six (26) people and more than 4000 timbers which were illegally harvested were arrested inside MAGINGO WMA, Nyera/Kipele forest reserve and open areas by Tanzania forest service (TFS) in collaboration with SGR. The growing number of people, farms and wildlife in the study area are leading to increased conflict between the needs of conservation and development as explained much by World Bank (2008), Nelson (2009 and 2010) and Wilfred (2010).

Tree planting help to reduce shortage of fuelwood and logging which are important for householdsô consumption. The study villages found to have high concentration of people who do not adopt trees planting strategy contrary to the national agenda (Liwale DGO, 2017). Most households in study villages depend on natural regeneration of trees to tackle fuelwood shortage and few infrequent practiced private tree planting, agro-forest and communal tree planting (personal observation). This scenario implies more encroachment in Selous ï Niassa TFCA.

4.6.2.3 Wildfires

Control of wildfires is one among the strategies for conservation of biodiversity and other wildlife. During focus group discussion in study villages, it was found to have very few people adopt strategies/practices to control loss of wildlife resources. The area is the migratory route for migrating elephants and other animals. Wildfires occur frequently in the area. The major causes of these fires are honey mongering, charcoal production, clearance for cultivation and local beliefs. Wildfires have overwhelming effects on the biodiversity and ecology of the Selous-Niassa TFCA ecosystem thereof calls for efficiency and effective management especially when occurred at the wrong season.

In Nanyumbu and Liwale districts more than eight wildfires reported each year in different villages within Selous-Niassa TFCA. Figure 4.10 and 4.11 shows reported incidences of wildfires from 2010-2015. The extent of damage to Selous-Niassa TFCA is immeasurable but core PAs of Selous GR, Msanjesi GR, Lukwika-Lumsule GR, and some of forest reserves have natural firebreaks which are rivers(Matandu, Liwale, Mbwemkulu, Lumesule, Lukwika, Ruvuma etc) and man-made breaks includes roads. Availability of by-laws for preventing wildfires were aware to many villagers but traditional ways of starting the fire is unavoidable as mostly done at night hours.

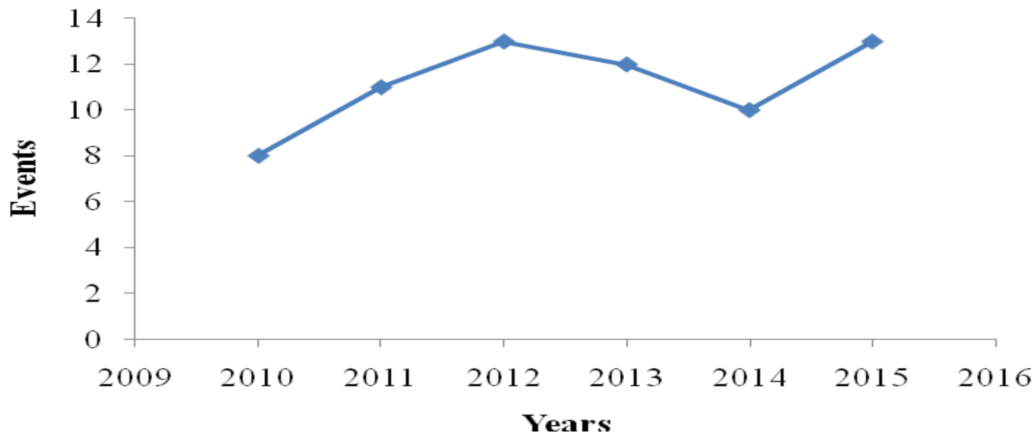

Figure 4.13: Incidence of Wildfires in Liwale District from the Year 2010 to 2015
Source: Liwale District Council office (2017)

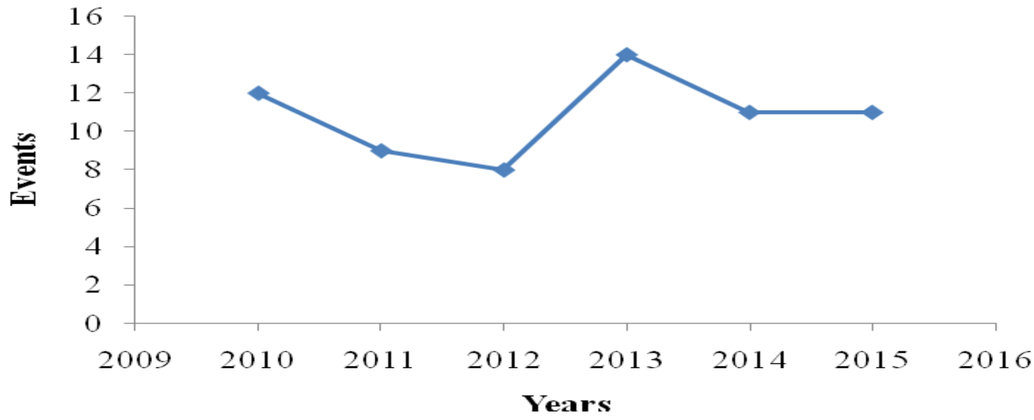

Figure 4.14: Incidence of Wildfires from the Year 2010 to 2015
Source: Nanyumbu District Council office (2017)

4.6.2.4 Settlements in Migratory Routes

Settlements are amongst the wildlife-human interaction which causes stress on natural resources in Selous-Niassa TFCA ecosystem. In the study villages (Table 4.47), the respondents donợt see these as great sources of stress on wildlife resources because their effects are seen in a long term basis, instead they rank interaction of wildlife and human/livestock is Very high (56.7%). The villages forgetting that, when make settlement in migratory routes automatically interaction with wildlife will be great and the ecosystem will be disturbed as a result affect wildlife range area, genes distribution and migration of wild animals.

Whatsoever, agriculture ranked High (65%) and Settlement ranked Medium (63.3%). Furthermore, statistical tests shows that, settlement has a significant mean as a source of stress in Selous-Niassa TFCA compared to other sources as indicated in Table 4.48. This shows that the wildlife population is at risk. Therefore, unless strategies to alleviate the situation are in place, environmental degradation including loss of wildlife habitat will not continue. This negative interaction between human and wildlife is also caused by other sources of stresses on natural resources in PAs as stipulated much by Hackel (1999); URT (2002); Johansen (2002); UNDP (2003) and Kideghesho (2005).

Table 4.38: Sources of Stress on Natural Resources in Selous-Niassa TFCA

Sources of stress	**Strength of stress**					**Mean±Sd**
	Very high	High	Medium	Low	Overall	
(a)Poverty/Low income	34(56.7)[1]	26(43.3)	0(0.0)	0(0.0)	60(100)	1.65± 1.02
(b)Ignorance	2(3.3)	35(58.3)	12(20.0)	11(18.3)	60(100)	2.75± 0.88
(c)Income generation from natural products	12(20.0)	34(56.7)	14(23.3)	0(0.0)	60(100)	1.55± 1.00
(d)Population increase	1(1.7)	37(61.7)	21(35.0)	1(1.7)	60(100)	1.50± 0.91
(e)Sabotage	0(0.0)	10(16.7)	21(35.0)	29(48.3)	60(100)	2.58± 1.20
(f)Uncontrolled burning	3(5.0)	23(38.3)	20(33.3)	14(23.3)	60(100)	1.25± 0.82
(g)Interaction between	34(56.7)	22(36.6)	3(5.0)	1(1.7)	60(100)	2.52± 1.31
wildlife and human/	5(8.3)	35(58.3)	13(21.7)	7(11.7)	60(100)	1.58± 1.94
livestock						
(h)Drought/Floods						
(i)Agriculture	18(30.0)	39(65.0)	3(5.0)	0(0.0)	60(100)	1.58± 1.00
(j)Settlements	6(10.0)	13(21.7)	38(63.3)	3(5.0)	60(100)	3.03± 1.21
(k)Banditry	0(0.0)	37(61.7)	11(18.3)	12(20.0)	60(100)	2.13± 0.85
(l)Lack of land use plans	2(3.3)	0(0.0)	18(30.0)	40(66.7)	60(100)	2.97± 1.25

[1] Figures outside and inside the parentheses are frequencies and percentages respectively.

4.6.2.5 Socio-Economic Factors Influencing People Encroaching Selous-Niassa TFCA

In this study, socio-economic factors influencing people encroaching of Selous-Niassa TFCA were strived to reveal their significance statistically. Towards revealing the statistically significance of socio-economic factors influencing encroachment of Selous-Niassa TFCA, a multiple regression model was employed. The socio-economic factors revealed in the study area were entered sequentially in the multiple regression model, checked and the insignificant factors were removed from the prediction model. The explanatory variables that were accommodated in multiple linear regression model were; age, sex, education level, household size, household income, years lived in a village and land size owned by a household. The model was purposely employed to assess the significant socio-economic factors influencing encroachment of natural resources in the study area.

4.6.2.5.1 Results of the Multiple Regression Model

The multiple regression model was used to determine the effects of explanatory variables (socio-economic factors) on encroachment of natural resources in the study area. The model summary in Table 4.38 shows that the independent variables fit well in the regression model in that R square was 0.537.This means that the fit explains 53.7% of the total socio-economic factors influencing people encroaching wildlife corridor were explained by the tested factors. The R and adjusted R^2 of 0.773 and 0.475 respectively show that there is correlation between encroachment and explanatory variables.

Table 4.39: Model Summary for Socio-Economic Factors Influencing Encroachment of Selous-Niassa TFCA

Model	R	R Square	Adjusted R^2	SE
	0.773	0.537	0.475	0.226

The model reveled ANOVA results as follows, with F value of 8.621 estimated at 11 and 78 degrees of freedom and a standard error of 0.226,gave a p value of 0.000 (Table 4.40).This imply that at a significance level of 5% the explanatory variables are statistically significant in explaining the involvement in encroachment of TFCA.

Table 4.40: ANOVA for Socio-Economic Factors Influencing Encroachment of Selous-Niassa TFCA

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	3.080	11	.440	8.621	.000
Residual	2.654	78	.051		
Total	**5.733**	**89**			

Table 4.41 summaries the socio-economic factors influencing encroachment of Selous-Niassa TFCA. The result shows that, some explanatory variables influences encroachment of the Selous-Niassa TFCA significantly. Of the seven independent variables used in the model only three variables are significant at 5% significance level (Ŭ).

Table 4.41: Multiple Regression Results for Socio-Economic Factors Influencing Encroachment of Selous-Niassa TFCA

Model	B	Std. Error	Beta	T	Sig
(Constant)	.827	.254		3.251	.002
Age	-.010	.028	-.038	-.359	.721NS
Sex	.153	.068	.247	2.250	.029*
Education level	-.026	.031	-.095	-.863	.392NS
Household size	.061	.043	.140	1.409	.165NS
Household income	.000	.021	.002	.017	.986NS
Years lived in a village	.161	.059	.275	2.719	.009*
Size of land owned	.484	.070	.706	6.894	.000*

* = *Statistically significant at* $\alpha = 0.05$*;* NS = *statistically not significant at* $\alpha = 0.05$

4.6..2.5.1.1 Sex

The results in Table 4.40 suggest that sex of household head influence encroachment of Selous-Niassa TFCA positively and significantly (b=0.153, p<0.05). This implies that males are exponentially engaged with encroachment activities like commercial poaching, logging, mining, charcoal making, extensive crop faming, livestock keeping and others compared to females who concentrates with subsistence farming, fuelwood collection. The results concur with Ntongan *et al*. (2007) and Noe (2003).

4.6.2.5.1.2 Years lived in a village

Respondentsô years lived in a study village influence encroachment of Selous-Niassa TFCA positively and significantly (b=0.161, p<0.05) (Table 4.40). This implies that, those respondentsô stays longer in a village equipped with indigenous technical knowledge and experience in wildlife migrations seasons, routes used, species involved and different valued Miombo trees species location and concentrations. The situations accelerates sabotage of the respondents with poachers and businessmen comes outside the district for illegal harvesting of natural resources within Selous-Niassa TFCA as explained much by Pimbert, and Pretty (1995), Mbwambo (2000), and Pesambili (2003).

4.6.2.5.1.3 Size of Land Owned

Findings also revealed that size of land owned by a household influence encroachment of Selous-Niassa TFCA positively and significantly (b=0.484, p<0.05) (Table 4.40). This implies that as household size increases also size of land owned by a household need to be increased so as to supplement the need of increased members as a result of encroaching Selous-Niassa TFCA. An explanation behind the observed relationship is that the encroaching land within Selous-Niassa TFCA for livelihood is violating village land use plan and extended area for food production, building materials, settlement area and other socio-economic activities which hamper biodiversity conservation and ecosystem services of fauna and flora as supported much by Pinter-Wollman (2012).

4.6.3 Property Damage and Human Life Caused by Wild Animals

Protected areas in Tanzania are not fenced thus wildlife freedom of movement is almost boundless. However, climate change and variability accelerate the movements due to animalsô searching for their climatic niche. District Councils have a duty to combat dangerous animals and assist farmers in crop protection. Many Districts are understaffed and not adequately equipped to perform this duty (Kideghesho, 2006). People who share the immediate boundaries with protected areas incur costs inflicted by wildlife conservation. Such costs include; loss of access to legitimate and traditional rights, damage to crops and other properties, livestock depredation, and risk posed to peopleϕs lives through disease transmission and attacks by wild animals.

Out of the strategy used to minimize property damage and loss of life is the use of game scouts. Liwale District has seventy six (76) villages, Nachingwea District have 127 villages and Nanyumbu District have 93 villages. Over 50% of these villages experience human wildlife conflict (HWC). This is due to the fact that there are few game scouts distributed whereby only seven game scouts are in Liwale and distributed in seven villages include Lilombe, Mkutano, Liwale Mjini, Mirui, Mpigamiti, Nangano and Mlembwe (Liwale District Council report, 2017) while

Nanyumbu have only one game scout (Nanyumbu District Council reports, 2017).

During interview with Liwale DGO; it was found that, low knowledge of district game scouts on non-lethal deterrents needed to be used for controlling problematic animals accelerate shooting of animals. These game scouts undergo short courses in wildlife management before they resume their duties. However these courses are inadequate. For years 2008 - 2015, eastern Selous-Niassa TFCA experienced fourteen (14) problem animals killed and other one hundred thirty four (134) injured. Most of the injured died and increase the mortality of wild animals (Table 4.42). Also, sixty seven (67) people were injured and forty two (42) people killed and mostly by elephant and crocodile; a total of 322.5 acres of different crops were destroyed as shown in Tables 4.43, 4.44, and 4.45, respectively. Furthermore, a total of 63 livestock killed by wild animals in Selous-Niassa TFCA from 2011 ï 2014 (Table 4.45).

Table 4.42: Problem Animals Killed or Injured by Game Scouts in Eastern Selous –Niassa TFCA 2008 - 2015

S/N	Type of Animal	Killed	Injured
1.	Elephant (*Loxodonta Africana*)	12	129
2.	Hippo (*Hippopotamus amphibius*)	2	5
Total		**14**	**134**

Source: LDC, NDC & LLM office (2017)

Table 4.43: People Injured by Dangerous Animals in Eastern Selous –Niassa TFCA 2008 - 2015

Year	2008	2009	2010	2011	2012	2013	2014	2015	Total
Number of injured people	2	14	29	11	2	3	3	3	**67**

Source: LDC, NDC & LLM office (2017)

Table 4.44: People Killed by Dangerous Animals in Eastern Selous –Niassa TFCA 2008 - 2015

Year	2008	2009	2010	2011	2012	2013	2014	2015	Total
Number of killed people	2	9	14	7	3	1	4	2	**42**

Source: LDC, NDC & LLM offices (2017)

Table 4.45: Extent of Crops Damaged by Wild Animals in Eastern Selous – Niassa TFCA 2008 - 2015

S/N	Type of Crop	Type of Animal	Acreage
1.	Cashewnuts (*Anacardium ocidentale)*	Elephant	48
2.	Maize (*Zea mays)*	Elephant	75.5
3.	Sorghum (*Sorghum vulgare)*	Elephant	70
4.	Rice (*Oryza sativa*)	Elephant and Hippo	34
5.	Cassava (*Manihot esculenta*)	Elephant	49
6.	Sesame	Elephant	18
7.	Banana (*Musa sp*)	Elephant	20
8.	Sugarcane	Elephant	2
9.	Sweet potatoes	Elephant	5
Total			**322.5**

Source: LDC & NDC offices (2017)

Table 4.46: Livestock Killed by wild Animals in Eastern Selous-Niassa TFCA 2011 - 2014

S/N	Type of Livestock	Quantity	Type Of Animal
1.	Cattle	1	Lion
2.	Goat	53	Lion and Hyena
3.	Pig	9	Lion
Total		**63**	

Source: LDC , NDC & LLM offices (2017)

The wildlife policy of 2007 statement unlike the previous one (of 1998) has failed even to give short-term and long-term strategies to address the human-wildlife conflict and instead the government is now trying to assign the responsibility to CBC institutions (Kaswamila, 2009). Tanzanian government has introduced a compensation scheme for crop damage not exceeding five acres and consolation for human injured/killed by wildlife whereby the consolation does not exceed one million Tanzania shillings. The Government will devolve progressively the responsibility for Problem Animal Control (PAC) to operating Community Based Conservation (CBC) programmes and continue to give assistance where village communities have not developed this capacit*y* (WPT, 2007).

The government shifts wildlife management from Decentralisation (according to WPT, 1998) to Recentralisation (according to WPT, 2007). Liwale, Nachingwea and Nanyumbu Districts are not distinguished from this scenario as it has eight (8) villages out of seventy six (76); nine (9) out of one hundred and twenty seven (127) and nine (9) out of ninety three (93) in Liwale, Nachingwea and Nanyumbu Districts respectively forming CBC (WMAs). Therefore this approach is likely to exacerbate the problem for two reasons. First, there are few CBCs in areas where humans live with wildlife countrywide and where these institutions exist they are still in futile and/or ineffective. Second, the institutions lack both human and finance capacity to deal with this sensitive and long-standing problem (*ibid*).

Furthermore, Sections 71 of Wildlife Conservation Act No. 5 of 2009 gives power to the Minister of MNRT make regulations specifying the amount of money to be paid as consolation to a person or groups of persons who have suffered loss of life, livestock, crops or injury caused by dangerous animals as stipulated much in Wildlife Conservation of Tanzania (Dangerous Animals Damage Consolation) Regulations (2011). Likewise, the Act considered only dangerous animals such as lion, buffalo, elephant and other animals categorized in fourth schedule for consolation of life, crops or injury while problems animals are not considered for this while contribute to crops destruction, injury or loss of life (URT, 2009).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study demonstrated that implication of climate change on land uses of Selous-Niassa TFCA was prejudiced by analysing changes in land uses that affect wildlife resources, wood balance, carbon stock and carbon released to the atmosphere as a result of changes in land uses, conservation profit resulted from carbon trade, and consequences of climate change and variability in managing Selous-Niassa TFCA as follows:

The study area has undergone notable changes in terms of land use and land cover. Local knowledge revealed various factors associated to land use and cover change that includes fire, cultivation, and deforestation. The main factors mentioned as contributing to fire were beekeeping, hunting activities, and local beliefs, while for deforestation include commercial logging and timbering, charcoals production, population growth, expansion of commercial farming and food crops production. The change in land uses has a significant impact to the management of biodiversity and maintenance of ecosystem services of the TFCA.

The greater increase of land use conversion alters wildlife movements, gene flow and stochastic events like fire and climate change. Also, modification of the land use and cover resulted in behavioral changes of some wild animals due to changes of their habitats. However, the changes in land uses resulted to high number of trees loss and wood balance of the study area dwellers shows unsustainable supply.

The study estimated amount of carbon stock and carbon released to the atmosphere as a result of habitat conversion of the study. The findings have revealed that, the study area has undergone notable biomass loss due to socio-economic activities performed by study area dwellers. Also amount of carbon released to the atmosphere can contribute much to climate change and climate variability. The amount of conservation profit of the area seems to offset amount of benefit received by corridor dwellers from their destructive activities if adopted REDD+ strategies. The foreseeable future necessitate inclusion of the area into core PAs network; however, adopting this scenario imply cost which the government must occur in order to safeguard the adaptation of wildlife suffered from climate change and variability in core PAs. Nevertheless, formulation of sustainable participatory management strategies to safeguard the study area for connectivity purposes without compromising livelihoods of study area dwellers is another scenario.

Furthermore, there are consequences of climate change and variability that affect management of Selous-Niassa TFCA, includes; access to land in study area which is possible and unreserved land is fairly not enough compared to population available. However, gender inequality experienced especially to women who are continued to be discriminated and denied direct access to land and insecure. Though, the land in the study villages under go land use plan, then land legally accessed by the community is mainly the one that planned for agriculture. Shifting cultivation is still practiced in the study area and need to be reversed so as communities adopt best agriculture practices that will use small farm plots which will be well mechanized in terms of pesticides, insecticides and fertilizers application.

The study area suffered from wild animals that destroy crops but adoption of application of non-lethal deterrents has become the best control measure. Poaching, encroachment for fuel wood and wildfires cause wildlife habitat destruction and decrease of wildlife population as a result those direct and indirect benefits of wildlife resources in the ecosystem destroyed. Generally, benefit-based approaches is a fundamentally inconsistent due to the fact that, their design and implementation can hardly enhance the value of the wildlife to local people but cannot ensure equity access and cannot guarantee sustainability of the benefits to local communities. Therefore, the current benefits are less effective in inspiring sustainable conservation behaviors. This, however, does not mean that the PAs in Selous-Niassa TFCA should abandon the benefit-based approaches and return to the ófences and finesô approach.

5.2 Recommendations

5.2.1 Changes of Land Uses of Selous – Niassa TFCA

The government in collaboration with other stakeholders should

i. formulate user friendly guidelines for protection of wildlife corridors as stipulated in Tanzania Wildlife Conservation Act No. 5 of 2009;

ii. formulate new and enhancing existing wildlife management areas (WMAs), participatory forests managements (PFMs) and joint forests managements (JFMs) so as accrued benefits should be higher than protection costs of the existing resources;

iii. formulate land use plans of the corridors so as to protect wildlife routes within the corridors;

5.2.2 Wood Balance of Selous – Niassa TFCA

The government in collaboration with other stakeholders should initiate and encourage usage of alternatives cost effective wood resources so as to offset the supply deficit and attain sustainability. The study area is within Ruvuma landscape circuit which has natural gas in Mtwara Region and can be used as alternative source of energy for cooking and lighting with affordable price. Also, usage of alternative furniture and building materials will safeguard the natural capital of woodlands.

5.2.3 Carbon Stock of Selous – Niassa TFCA

The government in collaboration with other stakeholders should initiate and include the study area into local and international carbon market like REDD+ scheme so as to increase household income of corridor dwellers. If the benefit accrued will offset cost incurred by community on maintain the fauna and flora with their climatic niche in the corridor; then conservation of TFCA ecosystem will be attained.

5.2.4 Consequences of Climate Change and Variability in Managing TFCAs

The government in collaboration with other stakeholders should:

i. formulate sustainable management strategies that will emphasis on species adaptability in the corridor ecosystem in regard to their climatic niche without compromising livelihoods of corridor dwellers;

ii. land tenure system should be gendered accessed by both groups including divorced or widowed who customary laws does not favored them. Invaded reserved land for MAGINGO, NDONDA and MCHIMALU WMAs should be taken into account by making sure the present land use plans are followed.

iii. encourage cultivation on permanent farm plots which are well mechanized in terms of pesticides, herbicides and fertilizers application is vital.

iv. improving working facilities, number of staffs, and new antipoaching techniques training to reverse rampant poaching activities. Participation of other stakeholders such as Tanzania Revenue Authority (TRA), Tanzania Ports Authority (TPA), Tanzania forces (Police, Military and Migration) and communities are vital for sustainable management of the study area.

v. encourage communities to fling those unimportant beliefs for increasing wildfires in order to assure their future life which impact ecosystem services of Selous-Niassa TFCA;

vi. ensure 25% of the income accrued from hunting blocks residing in Liwale, Nachingwea and Nanyumbu Districts to be known to communities. Also hunting companies invested in these blocks should help the adjacent communities according to Tourist hunting regulations of 2010. Also, Ministry of Natural Resources and Tourism (MNRT) should effectively implement compensation/consolation scheme to people injured/killed and crops damaged/destroyed by problem animals.

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APPENDICES

Appendix 1: Questionnaire for Households

This is the questionnaire of a student of Open University of Tanzania pursuing Degree of Philosophy (PhD) in Environmental Studies undertaking research on the topic ñImpact of Climate Change and Variably in managing Selous-Niassa TFCA, Tanzania and Mozambiqueò.

The goal of this survey is to gather information that will enable researcher to examine consequences of climate change and variability in managing Selous-Niassa TFCA. The answers are strictly for academic use and therefore, the confidentiality of your answers is highly guaranteed. Thanks for your understanding and cooperation.

Dateé é é é é .Questionnaire number é é .Villageé é é é é Hamleté é é ..é

A: Household particulars

A1. Name (not necessary)é é é é é é é é é é é é é é

A2. Age (years) i)18-24é ..ii)25-35é é iii) 36-44é é é iv)45-65é ..v)Above 65

A3. Sex: Maleé é é é é Femaleé é é é é é é é é é .

A4.What highest level of education has you attained? (Tick required)
i) No education (informal)é é é é ..ii) Basic adult educationé é é é é é .
iii) Primary educationé é é é é é iv) Secondary educationé é é é é ..
v) Above secondary educationé é é é é é é é é é é é é .

A5.What is marital status of household head? (tick required)
i) Marriedé é é é é é é é .ii) Unmarriedé é é é ..
iii) Widow/widoweré é é ..iv) Separatedé é é é é .
v) Divorcedé é é é é é é

A6. What is your household size? (tick required)

(i) 1-5Personsé é é é é é é é (ii) 6-10Personsé é é é é é é ..

(iii) 11-15Personsé é é é é é é (iv) Above 16Personsé é é é é .

A7. What is your household income per month? (tick required):

(i) Below TZS30,000 é é é é

(ii) TZS30,000-59,000 é é é ...

(iii) TZS60,000-89,000 é é é ..

(iv) TZS90,000-119,000 é é é .

(v) TZS120,000-149,000 .é é .

(vi) TZS150,000-179,000 é é .

(vii) TZS180,000-209,000 é ..é

(viii) Above TZS209,000é é é

A8. What is your Occupation? (tick required):

(i) Employed é é é é é é é é é é é

(ii) Unemployedé é é é é é é é é .

A9. What is number of meals per day? (tick required):

(i) One (ii) Two (iii) Three

A10. For how long have you lived here? (tick required):

(i) 0 ï 5yrsé é é é é é é é é é ..

(ii) 6 ï 12 yrsé é é é é é é é é é

(iii) more than 12 yrsé é é é é é é

A11. Where did you come from? (tick required):

(i) Born hereé é é é é é é é ..

(ii) Outside the wardé é é é é ..

(iii) Outside the divisioné é é é é .

(iv) Outside the Districté é é é é ..

If the answer is outside the District ï then which District did you come from? é é .

A12. What type of land ownership? (tick required):

(i) Individual é é é .

(ii) Rent......................

If the answer is individual,

S/n	How many parcels	Size	Location	Remarks

If the answer is rent,

S/n	How many parcels	Size	Location	Remarks

A13. Do you consider your land adequate? (tick required):

(i) Yes é é é .

(ii) No é é é ..

If the answer is No, how much would be adequate and why?

é é

é é

A14. Which crops do you cultivate and how big is the area?

S/n	**Type of crop**	**Farm size (acres)**

Production per Acre

S/n	**Type of crop**	**Production(tins/bags)**

B: Existing Strategies for natural resources management

B1. Is there any community based organizations which deals with natural resources conservation in your area? (Put ã where appropriate) Yes------------- No---------------

B2. Is there any community Capacity Building Programmes in preserving natural resources in your area? (Put ã where appropriate) Yes------------------- No-------------

B3. If yes what are those programmes?

i.--

ii.---

iii.--

B4. Are there any by-laws against loss of natural resources in your area? (Put ã where appropriate)

Yes-------- No--------

B5. If yes what are they?

i.--

ii.---

iii.--.

iv.--

B6. Does this by-laws efficiency and effective? (Put ã where appropriate)

Yes----- No---

B7. If yes how are they efficiency and effective?

i.---

ii.--

iii --

B8. If No, why are they not efficiency and effective?

i.---

ii. --

iii. --

B9.What do you think are causes of Wildlife-Human interaction which make stress on natural resources in the Selous-Niassa wildlife corridor? (Put ã where appropriate)

i. Agriculture
ii. Banditry
iii. Drought/Floods
iv. Ignorance
v. Income generation from natural products
vi. Interaction between wildlife and livestock
vii. Lack of Land use Plans
viii. Population increase
ix. Poverty/low income
x. Sabotage
xi. Settlements
xii. Uncontrolled burning

B10. Rank the following as Sources of stress on natural resources in SNWC (Put ã where appropriate and comments)

Sources of Stress	**Very High**	**High**	**Medium**	**Low**	**Comments**
Poverty/low income					
Ignorance					
Income generation from natural products					
Population increase					
Sabotage					
Uncontrolled burning					
Interaction between wildlife and livestock					
Drought/Floods					
Agriculture					
Settlements					
Banditry					
Lack of Land use Plans					

B11. Do you use any kind of strategies or practices to control loss of natural resources? (Put ã where appropriate) Yesé é é é Noé é é é é

B12. If yes which of the following strategies do you practices? (Put ã where appropriate)

Practices	Frequency of use		
	Often	infrequency	Not used at all
Minimization of Wildfire			
Use of alternative Source of Energy			
Stay away from Protected area			
Change agricultural practices			
Destocking			
Active Participation in SNWC Management			
Wind breakers			
Land use planning			

B13. For your own opinion suggest measures to be undertaken in order to overcome problem of loss of natural resources in SNWC?

i.---

ii. ---

iii. --

B14. Is there any wild animals damage/destroy your crops or your life? (tick appropriate)

(i) Yesé é ., (ii) Noé é é .

B15. If yes, mentions the wild animals that always damage/destroy you crops and life:

i. é ...

ii. é

iii. é ..é ......

iv. é ..é é

v. é ..é .....

vi. é ..é ....

B16. Are you getting any Compensation from Life and Crops damaged from Government? (tick appropriate), (i)Yesé é , (ii)Noé é

B17. If yes. How much for:

(i)Cropsé é é é é é é é é é ., (ii) Lifeé é é é é é é

B18. Do you think the money compensated is correlating with the loss caused by wild animal? (tick appropriate) , (i)Yesé é é é , (ii)Noé é é é é é é .

B19. If No, what do you think is the proper way for solving the problem?

....

B20. Is there any other social economic activities undertaken in the study area? Yes..........,No..............

B21. If yes which of the following socio-economic activities do you undertake?

Practices	**Frequency of use**		
	Often	**infrequent**	**Not used at all**
Agriculture(AG)			
Livestock(LS)			
Charcoal making(CM)			
Fire wood collection (FW)			
Businesses(BS)			
Lumbering/Timbering(LM)			
Honey mongering(HM)			
Hunting(HT)			
Others(specify)			

B22. Do you use fire during honey mongering? Yesé é é .. Noé é é é ..

B23. Is there any timber business in your area? Yesé é é . Noé é é é é

B24. Where do you get building materials?

ié é é é é é é é é é é é é é ....

iié é é é é é é é é é é é é é ....

iii..é é é é é é é é é é é é é é .....

B25. Do these economic activities raise the household income?

Yesé é ..Noé é é é .

B26. If yes how much per month? ....

B27. Do you grow trees on your farms? Yesé é é . Noé é é é é é é ..

B28. If yes, for what purpose do you grow trees?

i. Fuel woodé é é é é é é é é é é é é ....

ii. Building materialé é é é é é é é é é ....

iii. Soil fertility maintenanceé é é é é é ....

iv. Wind breakersé é é é é é é é é é é ....

v. Shadesé é é é é é é é é é é é é ....

vi. Others (specify)é é é é é é é é é ....

B29. Which of the following measures are you taking to deal with fuel wood shortage in your area?

Practices	Frequency of use		
	Often	infrequent	Not use at all
Agro forest			
Private tree planting			
Communal tree planting			
Natural regeneration			

B30. What is the main source of water? (Put ã where appropriate)

i) Pipe water

ii) Borehole

iii) River

iv) Shallow wells

v) Spring water

vi) Rain harvesting

vii) Others (Please specify)

é é é é é é é é é é é é é é é é é é é é

B31. Where is the location of water sources? (Tick those located in Protected Area)

i) Pipe water

ii) Borehole

iii) River

iv) Shallow wells

v) Spring water

vi) Rain harvesting

vii) Others (Please specify)

é é é é é é é é é é é é é é é é é é é é

B32. Do you use any kind of practices to maintain or enrich soil fertility of your farming land? (Put ã where appropriate) Yes................ No ....

B33. If yes which of the following practices do you use?

Practices	Frequency of use		
	Often	Infrequency	Not used at all
Use of fertilizers			
Use of farm yard manure			
Inter cropping			
Agro forest			
Mulching			
Alley farming			
Green manure			
Composite manure			
A forestation			

Appendix 2: Guiding Questions for Focus Group Discussion

Name of the villageé é é é é é ..

Dateé é é é é é é é é é

1. What is the historical profile of your village?
2. Is the village have land use plan? If yes, is the land use plan followed?, and if not followed what are the causes?
3. What are major socio-economic activities performed within the corridor?
4. Is there any factors influencing people encroaching the corridor?, if yes, what are they?
5. Is there any bureaucracy access to ritual sites in the corridor? If Yes or No what can be done to improve the current situation?
6. What is the performance of Selous-Niassa TFCA hunting companies in natural resource management and relationship with local community? Suggest ways to be followed so as to improve the relationship situation
7. What are indigenous technical knowledge for natural resource management in this area?
8. Is there any conflict existing between the people and wild animals in your village? If yes, what are the causes?
9. What kind of intervention mechanisms have you been using to improve management of natural resources?
10. What weaknesses do you think the conflict intervention mechanisms had and need some modification?
11. What do you think should be done as intervention measures for management strategies of Selous-Niassa TFCA?

Appendix 3: Checklist for Key Informants

1.1 Background Information

Dateé é é é é é é é é

Respondent No. ---------------

Full Name---

Age-------------

Sex------------ (1, Male 2, Female)

Education level---

Designation---

1.2 Official Information

1. What are the major consequences of climate change and variability in managing Selous-Niassa TFCA?

i. é
ii. é
iii. é
iv. é ....
v. é ....
vi. é ....
vii. é

2. What are strategies used in mobilizing the community to undertake sustainable natural resources Management in Selous-Niassa TFCA in the face of climate change and variability?

No.	Strategies used

3. How many people killed by wild animals since 2007?

Year	Number of people killed
2007	
2008	
2009	
2010	
2011	
2012	
2013	
2014	
2015	
2016	
2017	

6. What is the total amount of money (Tsh) were compensated since 2007?

Year	Total Amount(TZS)
2007	
2008	
2009	
2010	
2011	
2012	
2013	
2014	
2015	
2016	
2017	

7. What is the trend of income from Tourism since 2007?

Year	Total Amount(USD)
2007	
2008	
2009	
2010	
2011	
2012	
2013	
2014	
2015	
2016	
2017	

8. Rank the following threats to natural resources and their sources (Use: Very High, High, Medium and Low)

	POACHING		FIRE		DISEASES		ENCROACHMENT		Overall ranking for target
	Rank		Rank		Rank		Rank		
Source of Stress	Sources contribution rank	Stress sources rank	Sources contribution rank	Stress sources rank	Sources contribution rank	Stress sources rank	Source of Stress	Stress Source Rank	
Population pressure									
Poverty									
Wildlife / livestock interaction									
Agriculture									
Banditry									
Lack of Land Use Plans									
Low level of awareness (About environmental conservation)									