DRIVERS OF LAND COVER CHANGES AND IMPACTS ON CONSERVATION OF PROTECTED AREA BUFFER ZONES, TANZANIA

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ACRONYMS

B –Billion

CBC-Community Based Conservation

CMPA-Collaborative Management of Protected Areas

DEM-Digital Elevation Model

Ha-Hectares

GIS –Geographical Information System

LULC-Land use and land cover change

Km -Kilometres

M-million

M-metres

MNRT-Ministry of Natural Resources and Tourism

NTFPs-Non Timber Forest Products

PFM-Participatory Forest Management

TNBS-The Tanzania National Bureau of Statistics

TMA- Tanzania Meteorological Agency

SAGA-System for Automated Geoscientific Analyses

SRTM-Shuttle Radar Topographic Mission

SCP-Selous Conservation Programme

SGR-Selous Game Reserve

UTM –Universe Transverse Mercator

URT-United republic of Tanzania

WMA-Wildlife Management Areas

WHC-World Heritage Conventions
Drivers of land use and land cover (LULC) changes are complex and interrelated. With more than 83% of rural residents in areas rich of natural resources in Kisarawe district - Tanzania, spatial assessment of land cover becomes necessary to identify the main drivers of LULC changes. The study aimed at examining LULC changes using satellite-derived data from 1995 to 2015 in rural wards of Kisarawe district. Two wards that were spatially analysed are Vikumbulu, which is close to Selous game reserve and Masaki, which is close to Dar-es-salaam. A variety of demographic and socio-economic data from Kisarawe district and Tanzania National Bureau of Statistics (TNBS) were linked to spatially analysed data for interpretation and discussion. It also compared the status of LULC in the two wards in relation to their distance from Dar-es-salaam and the likely impacts on Selous game reserve buffer zones. Three cloud-free landsat image dates of 1998, 2011 and 2015 were classified and statistically analysed using SAGA GIS. Four categories of land covers were used (forest, wooded grassland, riverine and bare land/settlements/cultivation). Bare land, settlements and cultivation were combined to avoid spectral confusion. Statistical analysed data was imported to Ms Excel and pivot table for graphs and interpretations.

The findings show a decreasing trend of forest and wooded grassland cover in Masaki and Vikumbulu wards between 1998 and 2015. Rapid conversion of forest cover to bare land, grassland, settlements and cultivation occurred between 1998 and 2011 in Masaki ward and then followed by Vikumbulu ward from 2011 to 2015. Small cropped-land in both wards (5% in Masaki and 0.15% in Vikumbulu) suggests charcoal burning, shifting cultivation and logging are likely drivers of land cover changes in these wards. However, the rapid population increase in Masaki ward might also be the cause of land cover changes, due to increased cultivated area and energy needs. Depletion of natural resources and the rapid land cover changes in these wards threatens protected area buffer zones, Selous game reserve and the rural livelihood strategies in general. Since most of the rural population depend on natural resources, policy planning should focus on community livelihood strategies and development of entrepreneurship skills on sustainable and wise utilization of natural resources.

Key words: Land use and land cover changes, agriculture, poverty, charcoal, population in Vikumbulu and Masaki wards and SGR buffer zones
CHAPTER 1-INTRODUCTION AND RESEARCH CONTEXT

1.0 DEFINITION OF SOME KEY WORDS

Land use and land cover (LULC) change is the modification and conversion of land by humans to meet social, economic and other anthropogenic needs (Meyer & Turner 1994). Drivers of LULC are natural and human induced factors causing changes in ecosystems directly or indirectly (Kalaba 2014). Direct factors are the biological, chemical or physical factors influencing the condition of ecosystems that can be measured by parameters such as change in LCLU, species removal, harvest or direct consumption and population pressure (Kalaba 2014). Indirect drivers of ecosystem changes include factors like policy, market, socio-economic and socio-political influence that cannot be measured directly, however, they stimulate ecosystem changes (Meyer & Turner 1992; Kalaba 2014). Policy can influence land management that ultimately affects natural resources. The natural resources market also has been identified as an indirect driver of LULC changes due to people’s perceptions of the market with little value of sustainable conservation of natural resources (Kalaba 2014). Land cover includes biotic and abiotic components occurring naturally on the earth’s surface and subsurface (Lambin et al. 2003). Land cover involves all attributes of the earth on the surface, such as flora and fauna, soil, topographic factors, ground water and human infrastructure such as settlements. Land use broadly refers to the reasons for land cover change or activities of humans to meet their social-economic needs (Lambin et al. 2003). Forest is a type of land cover dominated by standing trees, and forest land cover change might be a result of complete conversion of land by cutting trees due to agriculture, mining or other associated socio-economic activities (Meyer & Turner 1992; Turnel 1993, as cited in Lambin et al. 2000). For this study LULC changes will concentrate on the removal of vegetation cover particularly forest and woodland, and the conversion of it to bareland, settlements or cultivation.

1.1 INTRODUCTION

Global research on biodiversity has noted an increase in the magnitude and spatial changes in LULC of global biophysical resources due, to increasing demands from humans (Meyer & Turner 1994). Continuous pressure and unsustainable utilization of biophysical resources to acquire life-sustaining needs has resulted in escalating and considerable impact on the Earth’s ecosystem functions (Lambin et al. 2001). The rising demand of social economic activities has facilitated competing LULC changes (Ramankutty & Foley 1999). It is estimated that
about 40% of a global land once covered by natural vegetation has been transformed into agricultural cropland (Prasanth 2012). In the developing world, population growth, high demand for food, charcoal, timber and poles in urban areas are driving forces contributing greatly to natural resources degradation in rural areas (Kangalawe & Lyimo 2010; MacKenzie & Hartter 2013). Expansion and development of urban and peri-urban areas and associated socio-economic activities, to a large extent have resulted in vegetation changes in rural areas (Asselen & Verburg 2013). Altogether, population growth and its associated socio-economic activities have resulted in unsustainable extraction of natural resources and transformation of land surface (Turner et al. 1994; Hartemink et al. 2008).

However, drivers of LULC vary across the local, regional and global scale (Ramankutty & Foley 1999) but the ultimate implication for these rapid LULC changes have significant impact across all three scales. For example the consequences of LULC changes includes global climate change (World Bank 2008a), natural resources depletion, species loss, habitat encroachment around protected areas buffer zones (Kintz et al. 2006), soil erosion and loss of fertility and water polution (Asselen & Verburg 2013). It is estimated that the world loses about 13 million ha of forest and between 14,000 and 40,000 of forest species from tropical forests each year (Kremen et al. 2000). Moreover, tropical forest clearing is responsible for 20 to 30% of carbon emissions. For example, each year 5.6 to 8.6 Gt of carbon is emitted (Kremen et al. 2000) and most forests are threatened in regions of poverty (Sunderlin et al. 2005). Despite the shift of the conservation paradigm from protectionists to participatory management, many protected areas continue to be degraded and unprotected forests are being changed into other land uses in developing countries (Kramer et al. 1997; Treue et al. 2014).

Human sprawl is now considered to be of great concern in affecting protected areas buffer zones in developing countries in Africa (Vanderpost 2006; Robinson et al. 2013b). Currently protected areas are under threat due to increasing LULC changes that are associated with degradation of natural resources around buffer zones (Kintz et al. 2006). Therefore, understanding the relationship between socio-economic activities and LULC is very important in biodiversity conservation (Bamford et al. 2014). In a country like Tanzania, high demand for food and energy in urban areas has accelerated loss of forest cover to an estimated rate of 91,276 ha annually (MNRT 2002 as cited in World Bank 2008b). Land cover changes occurring around protected areas buffer zones, have significant impacts on the species inside the protected areas and its ecosystems (Diego 2001; Kintz et al. 2006). This is evident in
Selous Game Reserve (SGR) in Tanzania, which is a protected area vulnerable to degradation and loss of biological diversity, due to land use changes that occurs along wildlife corridors and surrounding buffer zones (Baldus et al. 2003; Bamford et al. 2014). Thus, an understanding of the drivers of LULC changes at the local scale are fundamental for the development of policies and measures that aims to alter the current trends in a more sustainable and environmentally friendly manner (Hoııınuma et al. 2012; Bamford et al. 2014). This study explores the drivers of LULC changes with the associated activities in Kisarawe district wards bordering SGR buffer zones from 1998 to August 2015.

1.2 BACKGROUND OF LULC AROUND SGR

SGR is located in southeast Tanzania and occupies an area of about 55,000 square kilometres, which represents 5% of Tanzania’s land mass (Caro et al. 2009). The Game reserve was first gazetted in 1922 and then expanded during 1940s and 1960s by evicting people in the part of south-eastern, eastern and northern boundaries of the reserve due to the prevalence of sleeping sickness (Matzke 1976 as cited in Gallingham & Lee 2003). Ecologically, the game reserve forms a continuous ecosystem by connecting Niassa protected area (42,000 km$^2$) in Mozambique, Mikumi, Udzungwa mountains National parks and community managed conserved areas with an estimated area of more than 154,000 km$^2$ (Baldus et al. 2003; WHC 2015).

The SGR is dominated by miombo woodlands which vary in their density depending on soil, topographic characteristics and other associated human activities (Caro et al. 2009). The northern part of the reserve is wooded grassland (savanna) dominated by *Terminalia spinosa* and *Hyphaene thebaica* and *Borassus aethiopium* along the rivers. The southern part of the SGR is dominated by deciduous miombo woodland with *Brachystegia spiciformis* and *B. boehmii*, which occur as dense forest in the centre of the reserve. The eastern part is dominated by scattered tree grassland (Caro et al. 2009). The west buffer zone of the game reserve is bordered by wetlands (Kilombero Ramsar site and Game Controlled Areas which are part of the Ramsar site) and dominated by wooded grassland and miombo woodland with some sparsely distributed, evergreen multilayered forest (Haule et al. 2002; Rannestad et al. 2015). The SGR is surrounded and bordered by more than 10 districts (Figure 1) inhabited by people with variety of socio-economic activities such as agriculture, pastoralism and forestry.
Between 1970s and 1980 the SGR experienced intensive commercial poaching and a rapid decline of animal population (Gallingham & Lee 2003; Haller et al. 2008). Elephants declined by 70% due to heavy commercial poaching and rhinos declined from 2500 to 200 animals in 1980s. To curb the loss of wildlife, the Tanzanian and German governments entered a bilaterial agreement and established the Selous Conservation Programme (SCP) in 1988 (Gallingham & Lee 2003). The project aimed at maintaining the ecological integrity of the SGR and to improve the relationship between the SGR management and surrounding human population by implementing sustainable wildlife management at village level (Gallingham & Lee 2003; Haller et al. 2008). The SCP in collaboration with rural communities established buffer zones around the protected area in five districts (Liwale, Rufiji, Morogoro rural, Tunduru and Songea districts) bordering the SGR (Gallingham & Lee 2003; Bamford et al. 2014).

In 1990 the government of Tanzania undergone major policy reforms by shifting from centralization to decentralization of resources management (Hartmann 2008). By recognizing the importance of buffer zones around protected areas, the Ministry of Natural Resources and Tourism (MNRT) introduced changes in 1998 in wildlife and forestry policies to
accommodate Community Based Conservation programme (CBC) (Haller et al. 2008). This encourages establishment of Wildlife Management Areas (WMAs) and Participatory Forest Management (PFM) around protected areas buffer zones (Funder et al. 2013; Robinson et al. 2013a). Administratively, most of these areas forming buffer zones are under the village authority (Sunseri 2014). The main objectives of introducing CBC areas in village lands is to protect core areas by reducing encroachment, reducing forest degradation and conserving biodiversity by encouraging sustainable utilization to benefit rural communities (Songorwa 1999).

It is argued that the use and socio-economic benefits associated with CBC in buffer zones does not always meet rural needs and attitudes (Songorwa 1999; Sunseri 2014). This new approach to conservation is perceived as a strategy of the government to extend its jurisdiction far beyond protected areas by imposing restriction and access of the land (Neumann 1997). In some villages, there is little management of these resources surrounding protected areas buffer zones (Baldus et al. 2003). Bamford et al. (2014) found that in arable land, land uses such as pastoral and agriculture practices are threatening the protected area buffer zones of Selous game reserve. While in low fertile soils, other land uses like fuel extraction or timber have been the main drivers of land cover changes in buffer zones (Bamford et al. 2014).

1.3 PROBLEM STATEMENT AND JUSTIFICATION

Of the 30 to 40 million ha of Tanzania’s forest and woodlands, about 37% is forest reserve and 6% is under national parks protected by laws and rules, while the remaining 57% is under village management or general land with limited protection (Luoga et al. 2005; Bongers & Tennigkeit 2010; Havnevik & Isinika 2010). Most of these community’s forests occur as buffer zone in rural villages around the protected areas (Songorwa 1999; CHAPOSA 2002). Lack of effective and sustainable measures to utilize forest resources in villages and general land has resulted in deforestation and degradation (Bongers & Tennigkeit 2010). These resources are being degraded due to unsustainable agriculture practices, pastoralism (Bamford et al. 2014) timber extraction and charcoal consumption to supply the rising demands in urban areas (Mwampamba 2007). Currently, there is a great effort to establish CBC area such as WMAs and PFM around the protected areas and in villages rich in forest resources (Neumann 1997; Treue et al. 2014). Nevertheless, land cover changes and degradation is still a challenge facing natural resources management in Tanzania (Sunseri 2005; Treue et al. 2014).
Many studies have provided descriptive statistics on LULC but few try to understand the complex drivers behind these changes at local level (Lambin et al. 2003; Hartemink et al. 2008). To fill this gap the study conducts a spatial analysis of rural land cover change to assess the drivers of LULC changes in rural wards, Tanzania. The study hypothesizes that the closer the rural community to the main city, the greater the loss of natural forest cover, due to unsustainable practices and destructive harvesting of natural resources to meet the growing demands in urban centre. This in turn can have consequences in the management of biodiversity in buffer zones and inside protected areas. The focuses is on land cover changes in two wards of difference distance to urban center, to assess if the proximity to the country’s main business center (Dar-es-salaam) makes SGR buffer zones more vulnerable to land cover changes. The findings will help in better policy recommendations and measures to improve rural livelihoods and sustainable natural resources utilization in rural wards.

1.4 RESEARCH AIM

Detailed spatial analysis of land cover changes in rural wards surrounding SGR from 1995 to 2015 along with demographic and socio-economic factors that impact on the SGR buffer zone in Tanzania.

1.4.1 Objectives

The study focuses on four specific objectives which are:-

a) Spatial assessment and quantitative analysis of land cover in wards bordering the SGR,
b) To link spatial data with socio-economic and demographic data
c) To identify and to discuss drivers for land cover changes in wards and likely impact on SGR buffer zones in relation to city proximity
d) To make policy recommendations for the future, on natural resource management and livelihoods in relation to LULC change.
CHAPTER TWO - LITERATURE REVIEW

2.1 INTRODUCTION TO DRIVERS OF LULC

Drivers of LULC changes are complex and are the result of multiple factors which vary in spatial and temporal extent (Singh et al. 2010; Kilaba 2014). In developed countries, cultivators and loggers who cleared trees and converted the land to meet the demands for food and fibre caused forest decline (Rudel et al. 2005). However, with industrial revolution and agriculture intensification some abandoned farms regenerated into forest (Rudel et al. 2005). In these days, the main drivers of LULC changes are complex and involve an interaction among factors at different spatial and temporal scales (Lambin et al. 2003). Some of the factors associated with LULC changes are population growth, agriculture development, pastures and infrastructure developments (Turner et al. 1994; Lambin et al. 2003). Thus the drivers for vegetation clearance in the tropical regions of the developing countries are happening for same purposes as in the temperate regions including agriculture, tree plantations, settlements, pasture or feedstock and infrastructure developments (Hartemink et al. 2008). For example, in Tanzania the forest loss is estimated to range from 130,000 to 500,000 ha annually, because of charcoal production, forest fires, clearing for agriculture including tobacco farming, illegal logging and pressure from other forms of land uses (FAO 1997 as cited in Petersen & Sandhovel 2001). The recent increasing population and associated socio-economic activities in villages around buffer zones bordering SGR threatens the land cover and conservation prospects of biodiversity in the protected area (Baldus et al. 2003; Gillingham & Lee 2003; Vanderpost 2006; Bamford et al. 2014).

Therefore, assessment of land cover for a specified period of time is very crucial in monitoring, conservation management, understanding the status of LULC and the main drivers for changes of natural resources (Turner et al. 1994; Fisher 2011). Studies on LULC are critical for improving our understanding on how human interact with environments and provide a scientific foundation for sustainability, vulnerability and resilience of land systems and their benefit to humans (Wang 2010). Below is a review of drivers of LULC changes from a global, regional, national and local context with a specific focus on the Kisarawe district, Tanzania.
2.2 MAIN DRIVERS OF LAND USE AND LAND COVER (LULC) CHANGES

2.2.1 Agriculture

Agriculture activities are considered to be among the major drivers of forest destruction around the world (Ramankutty & Foley 1999). Global research on LULC changes has shown a 50% increase of the cropped land area from 1200 m ha in 1900 to 1800 m ha in 1990 (Ramankutty et al. 2002). Great expansion of cropland occurred in eastern Europe, northern-south America and the former Soviet Union. Eastern Europe is an extensively cultivated region in the world, though the Soviet Union seems to have the largest cropland area. In south and southeastern Asia, about 11% and 18% of the total land was cleared for agriculture during the 20th century (Ramankutty et al. 2002 as cited in Hartemink et al. 2008). In Africa, cropland intensification remained almost the same and few new areas for cultivation were found between 1700s and 1992. This indicates persistence of subsistence farming in Africa (Ramankutty et al. 2002).

Nevertheless, the estimated global forest cover of about 7-11 m km² has been lost in the last 300 years (World Bank 2008b). Studies suggest that the success in world grain yield (in excess of 2 billion tonnes a year (168%) for the last 4 decades was attributed to 12 percent increase in world cropland area (Lambin et al. 2003; World Bank 2008a). Despite global rise in food production, this economic growth has not been sufficient to provide alternative means of employment to rural communities. For example, between 2000 and 2002, about 13% of poor communities suffered acute malnutrition and were unable to purchase food (Lambin et al. 2003; World Bank 2008a). As in any other Sub-Saharan country, about 80% of Tanzanian’s population lives in rural areas conducting cultivation as their main source of income to sustain their livelihoods (Allen et al. 2014). Lack of agricultural inputs, infertile soil and the reliance of seasonal rain fed agriculture makes agricultural production unreliable and uncertain to support rural livelihood (Kangalawe & Lyimo 2012). The use of artificial fertilizers is expensive and cannot be afforded by many rural societies. Thus, to increase crop yield and income, taking advantage of large available open access land, traditional shifting cultivation have been the best option for rural community (Hartemink et al. 2008; Deininger et al. 2011). This has contributed to increasing LULC changes in rural landscape (Deininger et al. 2011).
2.2.2 Population growth
The world’s population has tripled from 1.5 billion in 1900 to 5.2 billion in 1990. Currently, the world population is about 6 billion and it increases at the rate of 1.3% per year and is projected to reach 8.9 billion by the year 2050 (Ramankutty et al. 2002). Urban population growth, settlements sprawl, rural livelihood strategies and environmental degradation are closely linked (Kangalawe & Lyimo 2010; Asselen & Verburg 2013). This is due to extension or intensification of socio-economic activities in urban to rural areas (Asselen & Verburg 2013). A study on global population and cropland during the 20th century, by Ramankutty et al. (2002) showed a positive correlation between an increasing population growth and cropland in regions with higher population growth.

In the coming 40 years, Sub-Saharan Africa population growth is projected to reach 1.7 billion (Kangalawe & Lyimo 2010). However, rapid urban population growth in developing countries triggers raising demands for food and biomass energy from rural areas (Whiteman et al. 2009; Forkuor & Cofie 2011; De Castro et al. 2012). Since the population growth in rural areas is happening in the context of poverty and food insecurity (Kangalawe & Lyimo 2010), this makes population another driver of LULC changes in rural areas (Lambin et al. 2003). Higher population which lives in poverty and without alternative economic opportunities result into overdependence and unsustainable extraction of natural resources and hence rapid declining of forest cover in rural communities (Lambin et al. 2001; Kangalawe & Lyimo 2010). For example, a study in assessing sustainability of PFM in Tanzania has shown increasing degradation of village and central government forests in spite of being jointly managed (Sunseri 2005; Treue et al. 2014). Increasing population in Dar-es-salaam city has contributed to LULC changes in Kisarawe wards, due to biomass fuel and timber harvest to meet growing demand in the city as explored in this study (Ahrends et al. 2010; Treue et al. 2014). In addition, more than 86% of Kisarawe household lives in rural depending on cultivation for income (TNBS 2012). Since shifting cultivation is widely practiced, increasing population in rural area and Dar-es-salaam means more land clearance for crop cultivation and hence natural resources degradation (Treue et al. 2014).

2.2.3 Biomass for fuel energy
It is obvious that every human needs food in everyday life that require source of energy to be process in any form (Feldmann & Marlis 2011). In developing countries biomass such as firewood, charcoal, agriculture residues and animal dung are major source of fuel for domestic
uses (Feldmann & Marlis 2011). Nonetheless, the use of biomass as a source of fuel is among the drivers of LULC changes in developing countries (Chaturvedi 2004). It is estimated that about 29,760 km$^2$ is deforested in Africa and 80% of this is charcoal-based deforestation (Neufeldt et al. 2015). In sub-Saharan Africa, biomass accounts for about 80-90% of the primary energy consumption in the households (Feldmann & Marlis 2011). For example, charcoal consumption in eastern and western Africa has dramatically increased from 4.3 million tons (1982) to more than 12 million tons (2012) (Figure 2).

![Charcoal production in Africa](image)

Figure 2. Charcoal production in Africa (FAOSTAT 2014 as cited in Neufeldt et al 2015)

As in other developing countries, about 90% total household energy consumption in Tanzania is derived from fuel wood in rural areas. Studies show that the use of biomass fuel as a source of energy accounts for more than 70% of forest cover loss in Tanzania (Luoga et al. 2000; Msuya et al. 2010). This has made charcoal burning to be the main causes of forest degradation in Tanzania (Msuya et al. 2010). Currently, Dar es Salaam city is known to consume more than 70% of charcoal produced in Tanzania (Mwampamba 2007; Msuya et al. 2010) which is approximately more than half of the Tanzania’s annual consumption (Felix & Gheewala 2011). Usually charcoal harvest is dominant within a distance of 20 to 100 Km from the urban energy markets (Ahrends et al. 2010). Although some wood charcoal might be harvested legally from forest reserves under the license from the government, a large percentage is harvested illegally from unreserved forest areas under village land or from a farmland being cleared for agriculture (Luoga et al. 2000; Kilahama 2008; Sander et al. 2013).
Most charcoal is supplied to Dar-es-salaam from coastal region (Kisarawe, Bagamoyo and Mkuranga and Rufiji districts), Morogoro rural district and Tanga region (Handeni and Kilindi) (Msuya et al. 2010). In 2009, the average charcoal consumption in Dar es Salaam was estimated to be 1904 tons/day (Msuya et al. 2010) and demands are increasing due to relatively high cost of electricity and petroleum based fuels in both urban and rural areas (Luoga et al. 2000). In addition, more than 75% of construction materials have been known to come directly from forests (Havnevik & Isinika 2010). Thus there is a total forest loss of about 91,000 ha every year, mainly due to charcoal burning, timber and firewood demands in the countryside (Hussein 2010).

Charcoal provides alternative income to the rural people (through their role in production, transporting to the main road, and contract labourers in loading) that supplements to farm income and enables them to purchase grain and other household commodities during the offseason (Mwampamba 2007; Neufeldt et al. 2015). Large numbers of people are attracted to charcoal business because of stable demand, easy access to forest resources and low investment (Arnold et al. 2006 as cited in Neufeldt et al. 2015). For example, studies suggests that charcoal creates 200-350 job days per Terajoule consumed, compared to 80-110 of electricity, 10-20 for LPG and 10 for kerosene (Neufeldt et al. 2015). Generally, higher demand and availability of markets for charcoal and timber in urban areas has stimulated financial incentive for tree falling in rural areas (Kalaba 2014). The estimation from the International Energy Agency (IEA), the number of people using biomass energy is going to rise rather than decrease (Feldmann & Marlis 2011). Charcoal consumption is expected to rise in the coming future due to increasing population, continue urbanization and if the price of other alternative sources of energy such as electricity and gas will continue to rise (Msuya et al. 2010; Sander et al. 2013). Such a rise in charcoal demand will have enormous impacts on natural resources in the buffer zones.

2.2.4 Poverty

Poverty is yet another indirect driver which facilitates LULC changes in developing countries, particularly in communities surrounding conservation areas such as SGR (Haller et al. 2008). In spite of rapid economic growth for the last decades in sub Saharan Africa, the national poverty rates have remained unchanged in developing countries like Tanzania and Mozambique (Pauw &Thurlow 2011). Statistics have shown 4.4% growth in agriculture production from 1998-2007 (Pauw &Thurlow 2011). However this growth seems to be
enjoyed by large-scale industries of the country that invest in cash crops. Pauw & Thurlow (2011) found a little change for poor people whose livelihood depends upon agriculture. Furthermore, the economic growth does not reflect the actual situation of poverty and households nutrition status, which suggest lack of link between the components (Pauw & Thurlow 2011). Poverty is widespread among rural communities due to scarcity of fertile land, inadequate government support and lack of market for the agriculture outputs (Habib-Mintz 2010).

On top of that, climate changes have huge implication on Tanzania rural poverty due to reliance on rain fed agriculture for their economy (Ahmed et al. 2011). The recent impact of climate variability on Africa agriculture (Arndt et al. 2012) has resulted in reduced crop yield and it is expected to intensify in the coming decades (Ahmed et al. 2011; Rowhani et al. 2011). Poverty and reliance on rain-fed agriculture makes rural people unable to cope, adapt and respond to negative impacts of climate changes (Ojoyi et al. 2015). This makes African people’s livelihoods and economies vulnerable (Paavola 2008; Ojoyi et al. 2015). For example, the reduction of rainfall for about 200 mm in Kiarawe district has led to drying of perennial rivers and decreases in crop production in the district (Kashaigili et al. 2014). Low crop yields and the shortage of offfarm employment to rural community have resulted in considerable pressure on natural resources (Petersen & Sandhovel 2001; World Bank 2008b; Mdemu et al. 2010; Kashaigili et al. 2014). Poverty and the reliance on natural resources as an alternative source of income to sustain rural livelihoods greatly contributes to environmental degradation and loss of vegetation cover in the countryside (Kangalawe & Lyimo 2010).

2.3 LINKING SPATIAL ANALYSIS AND SOCIAL-ECONOMIC DATA

The use of remote sensing and geographic information system (GIS) are vital for mapping, identifying and monitoring the spatial extent and temporal pattern of LULC (Ned 2010). Remote sensing has facilitated the assessment of LULC in local, regional and global scale (Newton et al. 2009). It provides a powerful set of analytical tools to understand how humans interact with the landscape (Lambin et al. 2003; Jiang 2003; Turner 2003 as cited in Tomich 2005). Therefore spatial satellite derived data on LULC has been accepted as baseline information in assessing the condition of tropical forest cover change (Fuller & Chowdhury 2006 as cited in Fisher 2011). This data can also be used in estimating carbon density and stocks, which are required for carbon trade (Kashaigili et al. 2013). The data can be used as a
tool to predict the potential biodiversity loss and vulnerability and the consequences of policy implementation (Newton et al. 2009).

Despite the usefulness of satellite-derived data, alone they cannot answer the question on why and how changes are occurring (Fisher 2011). To make spatial science more descriptive it is important to incorporate socio-economic and demographic data for meaningful analysis and interpretation of the satellite assessments (Van de Bergh et al. 2004) particularly when it involves evaluation of LULC at a local scale (Turner et al. 1994). This will lead to better understanding of the main drivers of LULC changes at a national scale. This study uses spatial sciences, socio-economic and demographic data to assess the main drivers of LULC changes in rural Tanzania from 1995 to 2015.
CHAPTER THREE- METHODS

3.1 STUDY AREAS DESCRIPTION
From the constitution of the united republic of Tanzania (1977), the administrative unit in Tanzania begins from region. Region is the largest unit consisting of many districts, followed by the district which contains different divisions that are made of wards, then ward consists of various villages not less than 5 and the latter is made up of hamlets or households not less than 250 (Figure 3).

![Diagram showing administrative units from region to village level in the United Republic of Tanzania](image)

The study was conducted in Kisarawe district at Masaki and Vikumbulu wards that are facing challenges in natural resources conservation because of their proximity and easy access to the main city. Available socio-economic and demographic data and literature review were linked to the spatially analysed data in two wards. Natural vegetation in Vikumbulu and Masaki wards is an extension of protected areas and buffer zones surrounding SGR and other reserve in the coastal region. The reason for selecting Kisarawe district is because it is close to the main business centre (Dar-es-Salaam), at a distance of about 30 kilometres and it is bordering
SGR (Figure 4). Moreover, the district is associated with social-economic activities that might have huge impacts on the conservation of buffer zones around the protected area. Study area selection also focused within the administrative boundaries of ward, its location near the protected area and the distance from urban centre.

Other criteria used were available cloud free satellite image, the current vegetation cover status and land cover change status. The study intended to collect data between twenty years interval (1995 to 2015), however, due to clouds in the study area of some satellite images, only image dates between 1998 and 2011 and 2015 were used in this study. Masaki and Vikumbulu wards that are 45 km and 98 km from the country’s main commercial city (Dar-es-salaam) were selected for spatial analysis of land cover changes. The percentage land cover changes were then compared in the two wards.

Figure 4. Study location (a) Map of Tanzania showing location of Selous Game Reserve, Kisarawe district with respect to Dar es Salaam city (b) Kisarawe district boundaries (c) Vikumbulu ward (d) Masaki ward.
3.1.1 Kisarawe district

Kisarawe district covers an area of about 5,028.48 km² with 4 divisions, 14 wards and 76 villages (Pwani 2015). It is among the six districts found in Coastal Region of Tanzania. The district urban centre is 30 kilometres from the major centre business district that is Dar-es-Salaam (Habib-Mintz 2010). It is bordered by Dar es Salaam city in north east, Kibaha district in north, Rufiji district (including SGR) in south, Morogoro region in the west and Mkuranga district in east (Lupala et al. 2014). According to the Tanzania National Bureau of Statistics (TNBS) (2012), the population of Kisarawe district was 99,635 with a density of 20.2 inhabitants per km².

The district areas have bimodal rainfall pattern twice a year with the mean annual rainfall of 1236 mm (Mdemu et al. 2010; Lupala et al. 2014). October to December is short rainfall period and March to June is the period of long rain season, while June to October is the dry season. The district temperature ranges from 24°C -31°C in which June to November is characterised by drop in temperature and from December to April the temperature rises (Mdemu et al. 2010; Lupala et al. 2014). However, the rainfall record pattern is not consistence and has shown a general trend of declining since 1981(Kashaigili et al. 2014).

The district is characterized by wet coastal plain vegetation, the remnant of Zanzibar inhambene regional mosaic (Bongers & Tennigkeit 2010). The area is predominated by wet miombo woodlands that extend from the sea level to 1600 m above the sea level. It also contains some of the valuable timber wood species such as *Afzelia quanzensis* (pod mahogany), *Pterocarpus angolensis* and *Dalbergia melanoxylon* (African Blackwood) (Bongers & Tennigkeit 2010).

The main economic activities in Kisarawe district are subsistence small-scale agriculture, fishing and charcoal production (TNBS 2012). According to the agriculture census of 2007/2008 in Pwani region, more than 89% of the Kisarawe residents depend on crop farming as the source of income to earn their living (TNBS 2012) (Figure 5). Kisarawe district is considered to be the most poorest with the least off farm income among the coastal regions and the per capital income of $ 150 per year. The district household cropland cultivation ranges between 0.5 ha and 1 ha (Mandari 2010) with the national average family size of 4.6 members (Habib-Mintz 2010). Both forestry and agriculture products are used for domestic consumption and as a source of household income (TNBS 2012). Firewood is the main source of energy in Kisarawe district and is harvested from within village land. Data have shown that
of the total 23,356 household, about 22,549 which is equivalent to 96.5%, use firewood as their main source of energy for cooking and other domestic uses (TNBS 2012).

Figure 5. Source of household income in Kisarawe district (Source TNBS 2012)

3.1.2 Masaki ward
Masaki ward has the population density of 59.1 inhabitants per km$^2$ with an area of about 121 km$^2$ (TNBS 2012). DEM shows a large proportion of ward to be flat and swampy particularly in the western part, while streams and a valley are apparent in north eastern end corner and western side of the ward (Figure 6a). The elevation of the ward ranges between 158 m in the valley and 339 m on the higher ridges to the south east (Figure 6b).

Figure 6. Masaki ward (a) 3D Satellite image (b) DEM to highlight topographical features
3.1.3 Vikumbulu ward

Vikumbulu ward occupies an area of 1,002.6 km$^2$ with a population density of 3.2 inhabitants per km$^2$ (TNBS 2012). The ward consists of very few ridges and hills in the northeastern corner with elevation ranging between 285 m to 436 m above the sea level (Figure 7). However, large proportion of ward is at low elevation, particularly the western, centre and southeastern corner, with elevation ranging between 62 m to 248.5 m (Figure 7b).

![Vikumbulu ward 3D Satellite image and DEM](image.png)

Figure 7. Vikumbulu ward (a) 3D Satellite image (b) DEM to highlight topographical features

3.2 DATA

For this study demographic, socio-economic and spatial data in vector and raster form were used.

3.2.1 Demographic and social-economic data.

These included data for population growth, agriculture yields and area under cultivation in Vikumbulu and Masaki wards for the period of 20 years (1995 to 2015). These data were obtained from Kisarawe district council in table format (Table 5). Other data from TNBS and published journals were used to link the spatial analysis component of the study.

3.2.2 Vector data

The vector data included administrative boundaries of the country, Kisarawe district, Vikumbulu and Masaki wards in form of polygon shape files. The shape files were obtained from the TNBS. The roads shape files were extracted from Landsat 8 imagery. This was achieved manually by tracing the road as seen on the landsat 8 images as vector shape file. Landsat 8 band 8 was used because of its spatial resolution of 15 m from which roads can be clearly identified.
3.2.3 Raster data
These included satellite images and elevation data

Satellite imagery

Landsat is a multispectral sensor with moderate resolution acquiring images in several spectral bands at spatial resolution of 28 metres and temporal resolution of 16 days (Khorram et al. 2012). Moderate resolution data are suitable for mapping and classifying large homogenous habitats and are appropriate for mapping the presence or absence of vegetation cover (Ned 2010). In addition, the spatial, spectral and temporal resolutions suits the level of details and extent of the study area. In this study, the minimum spatial size of a feature is tree canopy or any land use greater than 30 m. Free landsat satellite images were obtained from glovis (http://glovis.usgs.gov/), earth explorer website (http://earthexplorer.usgs.gov/) and libra (https://libra.developmentseed.org/) from path 166 and row 65. Dry season imagery from May to December was chosen to distinguish different land use pattern and vegetation types such as forest cover from grasses and other land cover types. In dry season most annual grass dries out and deciduous plants shed leaves and thus make it easy to distinguish woodland and forest cover from other land use patterns. This study investigated land cover changes for 20 years between 1995 and 2015. Three landsat image dates in 1998, 2011 and 2015 were free from cloud cover and suitable for this study as shown in Table 1.

Table 1. Landsat satellite image selection criteria of Kisarawe district for land cover classification and analysis

<table>
<thead>
<tr>
<th></th>
<th>Image</th>
<th>Acquisition date</th>
<th>Cloud cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Landsat8</td>
<td>03 AUG 2015</td>
<td>09%</td>
</tr>
<tr>
<td>2</td>
<td>Landsat5</td>
<td>07 July 2011</td>
<td>04%</td>
</tr>
<tr>
<td>3</td>
<td>Landsat5</td>
<td>16 May 1998</td>
<td>&lt;10%</td>
</tr>
</tbody>
</table>

Digital Elevation Model (DEM)

Shuttle Radar Topographic Mission (SRTM) used synthetic aperture radar (SAR) technology to produce globally consistence elevation data (Farr et al. 2007). SAR in a platform consists of dual radar antennae, which can collect elevation using three-dimensional measurements at every point of the Earth (Farr et al. 2007). National Aeronautics and Space Administration (NASA) (Rabus et al. 2002) first launched the SRTM in February 2000. The SRTM data
covers about 80% of the Earth surfaces between 60°-north latitude and 56° south latitude and has 90 m resolution (Foni & Seal 2004). For this study, a GeoTiff file was downloaded from SRTM Tile Grabber (http://dwtkns.com/srtm/) over study region. This data was used to characterise the terrain and describe how it may have influenced land cover and land cover changes. The SRTM files were clipped to the extent of study area to produce descriptive elevation and terrain maps.

3.3 IMAGE PROCESSING

Satellite image analysis was conducted using System for Automated Geoscientific Analyses (SAGA) GIS version 2.1.4. SAGA GIS is free remote sensing and raster analysis software (http://sourceforge.net/projects/saga-gis/files/). Visible, NIR and thermal bands were used in the analysis as shown in Table 2. Bands from landsat 5 and 8 (Table 2) were used in detection and mapping of land cover types in the study area, based on Khorram et al. 2012.

Table 2. Landsat satellite bands used during identification of major land covers in Kisarawe district (Source Khorram et al.2012)

<table>
<thead>
<tr>
<th>Band</th>
<th>Color</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band1 (LT5-4) and Band2(LT8)</td>
<td>Blue</td>
<td>Penetrate water bodies, analysis of vegetation and land use</td>
</tr>
<tr>
<td>Band 2 (LT5-4) and Band 3(LT8)</td>
<td>Green</td>
<td>Green reflectance of health vegetation</td>
</tr>
<tr>
<td>Band 3 (LT5-4) and Band 4 (LT8)</td>
<td>Red</td>
<td>Vegetation delianation, discriminating soil and geological boundaries</td>
</tr>
<tr>
<td>Band 4 (LT5-4) and Band5(LT8)</td>
<td>Near infrared(NIR)</td>
<td>Crop identification, soil crop and land water contrasts</td>
</tr>
<tr>
<td>Band 5(LT5-4) and Band6(LT8)</td>
<td>Mid infrared (MIR)</td>
<td>Drought studies, discriminating between clouds, snow and ice</td>
</tr>
<tr>
<td>Band 6 (LT5-4) and Band7 (LT8)</td>
<td>Thermal infrared (TIR)</td>
<td>Locating geothermal activity, vegetation stress, soil moisture and detecting urban heat islands</td>
</tr>
<tr>
<td>Band 7(LT5-4) and Band 8(LT8)</td>
<td>Mid infrared</td>
<td>Discrimination of geological rock formation</td>
</tr>
</tbody>
</table>

3.3.1 Pre-processing data

Vikumbulu and Masaki shape files were reprojected to UTM zones 37S. Images were then clipped to the administrative boundaries of study areas using the administration shape file.
3.3.2 Classification

Object Based Image Analysis (OBIA) classification was performed to obtain land cover maps of the study areas (Figure 8) for each image date. Object based classification uses a segmentation process that group pixel of similar spectral characteristics together into multiple polygons. Unlike pixel-based classification, OBIA reduces a complex mosaic of pixels and gives clear border separation between classes which are easy to classify (Khorram et al. 2012). Vikumbulu and Masaki raster data were classified using OBIA in SAGA GIS. Twelve polygons classes were created and polygons of similar spectral properties were grouped together using prior knowledge of the study areas, remote sensing knowledge of spectral properties and Google Earth. Classification was conducted for each image date (1998, 2011 and 2015) and polygons were merged into four land-cover class map. The image dates class maps were then compared to assess the land cover changes over time.

Figure 8. Classification of Vikumbulu and Masaki ward grids by using Object Based Image Segmentation

3.3.3 Land cover classes

The classes below were chosen because they offer the clearest distinction of land cover from the Landsat images. In the absence of forest and woodland, the land cover was classified as settlements, bare ground or cultivation as it was impossible to make further distinction.
• Forest cover (FC) is a landscape characterised by high tree density. The forest cover in this study refers to both closed and open forest. The open forest is distinguished from wooded grassland by lack of grasses and close tree intervals.

• Wooded grassland (WG) in this study is a landscape with sparsely distributed trees dominated by grasses or thickets of shrubs.

• Riverine/riparian vegetation/water (RV) was characterised by vegetation growing and found along the river or valley. Because the images were taken in the dry season there were no clear water bodies, but swampy vegetation such as marshes and other swampy thickets could be identified.

• Settlements/cultivation, grassland and bare ground (BL) were treated as one class due to their similar spectral properties which bring difficulties in distinguishing them. Grassland in this category includes cropped, cleared or harvested land and can not always be distinguished from bareland.

3.3.4 Accuracy assessment
The accuracy assessment was conducted using an error matrix method to determine the correlation between classified images of 2015 and the ground truth, as described by Khorram et al. (2012). A point grid was produced using SAGA GIS with points outside the administrative boundaries of the study area manually deleted. A total of 120 points at spacing of 1.05 km in Masaki and a total of 149 points at spacing of 2.4 km in Vikumbulu wards were used. These points were then intersected with the classified image and attributed with the classified land cover value. The point files were converted into KML and imported into Google Earth. In Google Earth and each point was visually assessed and given a land cover class from the Google Earth imagery. These two point data sets were then exported to Microsoft Exel and pivot tables were used to obtain an error matrix (Figure 9). Points from Google Earth maps were scored against the corresponding pixel value on the classified image and percentage accuracy calculated.
Figure 9. Accuracy assessment by comparing Google and classified maps of Masaki and Vikumbulu wards

3.3.5 Spatial and statistical analysis

This involved calculating the area of land cover classes over the analysis period and the percentage forest cover as a function of distance from main roads.

Land cover

Land cover of the study areas for each of the image date were calculated in SAGA and then exported to Microsoft Excel 2010. In the Ms Excel, the percentage land cover and changes of study area were calculated using polygon properties and graphed to enable comparison between 1998, 2011 and 2015 image dates. The comparison was conducted by assessing the percentage increase or decrease in land cover between image dates (Figure 10).

Distance from the road

The percentage of forest cover as a function of distance from roads was analysed to track the trend and status of encroachment based on access to forest. This was achieved by creating a new road shape files from landsat image in both wards and then clipping into wards grids. Next, through SAGA GIS, buffer zones were created in either sides of the road at a distance of 0.5 km to 3.5 km and followed by calculating the area occupied by forest away from the road in three images dates using zonal statistics (Figure 10).
Figure 10. Steps in statistical analysis of Vikumbulu and Masaki classified grids
CHAPTER FOUR-RESULTS

4.1 LAND COVER CHANGES IN MASAKI (1998-2015)

Analysis showed a substantial change of land cover in Masaki ward, of which forest and wooded grassland seems to undergo a rapid change in the ward. From satellite image analysis, almost half of Masaki land was a forest cover in the year 1998 (Figure 11). Spatial analysis of land cover showed a rapid decrease in forest cover between 1998, 2011 and 2015. However, the decrease in forest cover was associated with increase in wooded grassland and thicket and increase in bareland, settlements and cultivation from 1998-2011. With further increasing bareland, cultivation and settlements between 2011 and 2015, wooded grassland and thicket begun to decrease.

![Figure 11. The Masaki LULC classification maps showing distribution of land cover from 1998, 2011 and 2015 images.](image)

4.1.3 Percentage LULC

Analysis of 1998 satellite image shows that, of the total 12,000 ha, about 64% of Masaki ward was occupied by forest while wooded grassland covered an area of about 11% of the ward. By 2011 the forest cover decreased from 64% in 1998 to 33% in 2011 whereby the wooded grassland increased from 11% in 1988 to 33% in 2011. However, in 2015 the forest and wooded grassland cover seems to occupy about 27% and 24% and greater percentage of Masaki ward was dominated by bareland, grassland or cultivation (Figure 12).
4.1.4 Percentage change of land cover to other LULC in Masaki ward

In the year 1998 about 64% of Masaki ward was forest cover (Figure 12). However, about 31% of this forest cover was converted into bareland, settlements or cultivation, while 22% of it was turned into wooded grassland and thicket between 1998 and 2011. It is only about 2% of wooded grassland was converted into bareland, settlements and cultivation between 1998 and 2011 (Figure 13).

Figure 12. Percentage of LULC in Masaki ward between 1998 and 2015

Figure 13. Percentage change of LULC between 1998 and 2011 in Masaki ward
The LULC analysis of Masaki ward shows that by 2011 about 33% of the ward was a forest cover and 33% was a wooded grassland (Figure 12). By the end of 2015, about 43% of this forest cover was converted into bareland, settlements or cultivations while about 12% was turned into wooded grassland and thicket. More than 38% of the wooded grassland that remained in 2011 was transformed into bareland, settlements and cultivation and only 17.3% of this wooded grassland regenerated into forest cover by 2015 (Figure 14).

![Figure 14. Percentage change of LULC between 2011 and 2015 in Masaki ward](image)

**4.1.5 Percentage of forest cover in relation to distance from the road in Masaki ward**

In 1998 the forest cover was higher (~55-73%) between a distance of 0.5 km and 3.5 km away from the road. By 2011 the forest cover dropped between 20% and 35% (Figure 15). Interestingly in 2015, the forest cover increased between 30% and 45%. In the year 1998 and 2015 the forest cover showed an increase from the road and then a dip around a distance of 2500 m before increasing again. But in 2011 the dip was not evident and forest cover was low (~18-20%) and increased from ~20-35% at a distance of 2500 m.
4.2 LAND COVER CHANGES IN VIKUMBULU (1998-2015)

The forest cover in the eastern part of the ward became more fragmented and changed into wooded grassland cover by 2011. However, a large land cover change seems to occur between 2011 and 2015 from which more than half of the forest was lost. A considerable proportional of a land which was covered by wooded grassland turned into bare land or grassland, settlements and cultivation as it can be seen in 2015 land cover image (Figure 16). Thus, there was a rapid increase in wooded grassland and thicket with a decrease in forest cover between 1998 and 2011. While from 2011 to 2015, there was a decrease in wooded grassland and thicket with a sharp increase in bare land, cultivation and settlements.

Figure 16. Vikumbulu LULC classification maps showing distribution of land cover from 1998, 2011 and 2015 images
4.2.3 Percentage LULC

Analysis of 1998 Vikumbulu ward satellite image (99, 660 Ha) (Figure 16) showed 54% and 38% of the land was dominated by forest cover and wooded grassland and thicket respectively. Whereby the 2011 satellite image showed wooded grassland and thicket was the dominant land cover, occupying about 62% of the ward. In contrast, analysis of 2015 satellite image have shown wooded grassland and thicket to be the dominant land cover occupying 46% of the ward. Whereby bareland, settlements and cultivation occupies 39% of the ward area and forest is the lowest land cover which occupies 15% of the ward area by 2015 (Figure 17).

![Vikumbulu 1998, 2011 & 2015](image)

Figure 17. The percentage land covers of Vikumbulu ward for 1998, 2011 and 2015

4.2.4 Percentage change of land cover to other LULC in Vikumbulu ward

From the image analysis about 54% of Vikumbulu ward was dominated by forest cover in 1998 (Figure 17). Albeit, about 8% of this forest cover was converted into bareland, settlements and cultivation and 43% of it changed into wooded grassland and thicket between 1998 and 2011. On other hand of the 38% wooded grassland and thicket that remained in 1998 (Figure 17), about 5% of it was transformed into bare land, settlements and cultivation. Only 8% of wooded grassland and thicket regenerated into forest cover between 1998 and 2011 (Figure 18).
Figure 18. Percentage LULC change between 1998 and 2011 in Vikumbulu ward

Of the total 30% of forest cover that remained in 2011, 25% of it was converted into bareland, settlements and cultivation while 40% of this forest cover was transformed into wooded grassland and thicket between 2011 and 2015. On top of that, of the remained 62% of wooded grassland and thicket in 2011, about 44% of it was transformed into bareland, settlements and cultivation between 2011 and 2015. It is only 7% of the wooded grassland and thicket recovered into the forest by 2015 (Figure 19).

Figure 19. Percentage LULC change between 1998 and 2011 in Vikumbulu ward
4.2.5 Percentage changes of forest cover in relation to distance from the road in Vikumbulu ward

The percentage change in forest cover from the road was between ~65-85% between 0 and 2500 m in Vikumbulu ward in 1998. However, the forest cover dropped to ~40-60% between a distance of 0 and 2500 m by 2011. Image analysis of the 2015 Vikumbulu have shown a further decreases in forest cover to about ~5-10%, between the distance of 0 and 2500 m as you move away from Vikumbulu main road (Figure 20).

Figure 20. Percentage forests cover change with distance from the road (1998, 2011 and 2015)

4.3 ACCURACY ASSESSMENT

Overall accuracy obtained were 76.7% for Masaki and 74% for Vikumbulu ward which was calculated by summing up all the correct points and dividing by total points assessed (Table 3 and 4). These accuracy assessments are satisfactory to carry analysis of data in the study areas.

Table 3. Accuracy assessment of Masaki image 2015 showing number of points correctly matched between classified map and Google Earth (BL is ‘settlements/cultivation, grassland and bare ground’, FC is ‘forest cover’, RV is ‘riverine/riparian vegetation/water’ and WG is the wooded grassland and thicket).

<table>
<thead>
<tr>
<th>LULC Classes</th>
<th>BL</th>
<th>FC</th>
<th>RV</th>
<th>WG</th>
<th>Grand Total (No of points)</th>
<th>Accuracy for each class (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL</td>
<td>40</td>
<td>8</td>
<td>4</td>
<td></td>
<td>52</td>
<td>76.9</td>
</tr>
<tr>
<td>FC</td>
<td>21</td>
<td></td>
<td>1</td>
<td></td>
<td>22</td>
<td>95.5</td>
</tr>
<tr>
<td>RV</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td>3</td>
<td>100.0</td>
</tr>
<tr>
<td>WG</td>
<td>11</td>
<td>4</td>
<td></td>
<td>28</td>
<td>43</td>
<td>65.1</td>
</tr>
<tr>
<td>Grand Total</td>
<td>51</td>
<td>33</td>
<td>3</td>
<td>33</td>
<td>120</td>
<td>76.7 (Overall accuracy)</td>
</tr>
</tbody>
</table>
Table 4. Accuracy assessment of Vikumbulu image 2015 showing number of points correctly matched between classified map and Google Earth (BL is ‘settlements/cultivation, grassland and bare ground’, FC is ‘forest cover’ and WG is ‘wooded grassland and thicket).

<table>
<thead>
<tr>
<th>LULC classes</th>
<th>BL</th>
<th>FC</th>
<th>WG</th>
<th>Grand Total (no of points)</th>
<th>Accuracy of each class (%)</th>
</tr>
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<td>7</td>
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<tr>
<td>FC</td>
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<td>90</td>
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</tr>
<tr>
<td>Grand Total</td>
<td>54</td>
<td>20</td>
<td>75</td>
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4.4 TRENDS IN DEMOGRAPHIC DATA AND CROPPING ACTIVITIES IN MASAKI AND VIKUMBULU WARD

The population in Masaki and Vikumbulu wards is increasing, but the former has higher rate of growth than the latter. However, in Masaki ward the population increased from the year 2000 to 2005 while in Vikumbulu ward the population decreased. This was followed by population increases in both wards from the year 2005 to 2015 (Figure 21). The area under crops has almost doubled for Masaki ward from 1995 to 2015 at the same time the area under crops (although much smaller) has almost tripped in Vikumbulu ward. Increase in crop area was slightly higher between 2005 to 2015 in both wards and by 2015 the total area under cultivation was 633 ha in Masaki ward and 150 ha in Vikumbulu ward (Figure 21).
Figure 21. Population growth and area under cultivation (ha) in Masaki and Vikumbulu wards (Data supplied by Kisarawe district council 2015). Area under cultivation is the combination of cassava, maizes and legumes.

The area under cultivation increases while the productivity (tons/year) decreases in both wards for all crops except cassava in Vikumbulu ward (Table 5).

Table 5. Area under cultivation and crop production in Vikumbulu and Masaki wards

<table>
<thead>
<tr>
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<td><strong>Masaki</strong></td>
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<td></td>
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<tr>
<td>Population</td>
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<td>4804</td>
<td>5989</td>
<td>6607</td>
<td>7225</td>
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<tr>
<td>Cassava (ha)</td>
<td>206</td>
<td>228</td>
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<td>272</td>
<td>294</td>
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<tr>
<td>Cassava-Tons/year</td>
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<td>2052</td>
<td>2040</td>
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<tr>
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<td>55</td>
<td>100</td>
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<tr>
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<td>132</td>
<td>189.5</td>
<td>287</td>
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<tr>
<td>Legumes (ha)</td>
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<td>30</td>
<td>33</td>
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<tr>
<td>Legumes-Tons/year</td>
<td>29.7</td>
<td>30</td>
<td>27</td>
<td>23.4</td>
<td>19</td>
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<tr>
<td><strong>Vikumbulu ward</strong></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
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<td>2700</td>
<td>2997</td>
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</tr>
<tr>
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<td>13</td>
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<td>38</td>
<td>50</td>
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<tr>
<td>Cassava-Tons/year</td>
<td>90</td>
<td>104</td>
<td>150</td>
<td>247</td>
<td>350</td>
</tr>
<tr>
<td>Maize (ha)</td>
<td>30</td>
<td>45</td>
<td>50</td>
<td>75</td>
<td>90</td>
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<td>Maize-Tons/year</td>
<td>258</td>
<td>306</td>
<td>250</td>
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<td>Legumes (ha)</td>
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<td>10.5</td>
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<td>27.2</td>
<td>21</td>
<td>21</td>
<td>15</td>
<td>10</td>
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</table>
4.5.0 OVERALL RESULTS

Because forest and wooded grassland experience the most changes, the discussion will emphasize on the conversion of forest and wooded grassland cover into other LULC. In total more than 70% of Vikumbulu and Masaki wards were covered by forest and wooded grassland by 1998. At that time other LULC were very minimal and occupied less than 30% of the ward.

4.5.1 Forest cover change

Analysis have shown more than 50% of Vikumbulu and Masaki wards were covered by forest in 1998. A substantial loss of forest cover occurred from 1998 to 2015 in these wards. At this time Masaki ward was dominated by conversion of forest cover to bareland, settlements and cultivation, while in Vikumbulu ward the conversion of forest cover to wooded grassland was dominant. This is an indication of increasing socio-economic activities that involves tree clearing such as agriculture and charcoal burning in wards. For example, between 1998 and 2011 about 31% of forest cover was cleared to bareland, settlements or cultivation in Masaki ward while about 43% of forest cover turned into wooded grassland and thicket in Vikumbulu ward (Figure 13 & 18). Until 2011 the remaining forest cover was 33% in Masaki and 30% in Vikumbulu ward (Figure 12 & 17). By 2015 a greater proportion of these forest covers were converted to wooded grassland and thicket (40%) for Vikumbulu ward, and bareland, grassland, cultivation and settlements (43%) for Masaki ward. Thus, until August 2015, only 27% and 15% of forest cover remained in Masaki and Vikumbulu wards, making the latter ward to have a greater loss of forest cover within the last 4 years (2011-2015)(Figure 12 & 17). This means that the difference in land cover and percentage change in two wards distinguishes the type of socio-economic activities and their rate of occurrence.

4.5.2 Wooded grassland and thicket

In the year 1998 Vikumbulu ward had a larger proportion of wooded grassland than Masaki (Figure 12 & 17). However, by 2011 the proportion of wooded grassland and thicket increased in both wards. For example, Vikumbulu ward had about 62% wooded grassland and thicket, while Masaki ward had 32%. Interestingly, the transformation of wooded grassland to bareland, grassland, settlements and cultivation was slow between 1998 and 2011 in both wards (Figure 13 & 18). Unlike Masaki ward, the decreasing forest cover and increasing wooded grassland and thicket between 1998 and 2011 was associated with constant bareland, cultivation and settlements at Vikumbulu (Figure 12 & 17). This implies limited socio-
economic activities which involved land clearance such as shifting agriculture occurred at that time, perhaps associated with a very low population. The conversion of wooded grassland to bareland (grassland), settlements and cultivation appears to increase at a greater pace between 2011 and 2015. For example, by 2015, about 38% of Masaki and 44% of Vikumbulu wooded grassland and thicket that remained by 2011 was turned into bareland (grassland)/settlements or cultivation. This suggests increasing population, socio-economic activities and increasing demands of forest-related products in the two wards.

Generally, the percentage recovery of cleared land into wooded grassland was higher in Vikumbulu ward and lower in the Masaki (Figure 13, 14, 18 & 19). This implies few options and a depletion of natural resources in Masaki, while it suggests available options in Vikumbulu ward. This suggests recovery of wooded grassland. During this time, the percentage of cleared land returning to forest cover was low in both wards.

4.6 FOREST COVER CHANGES ALONG THE ROAD

Most of forest clearance were evident along the road in which many settlements reside (Figure 15 and 20) and among the reason for this is road construction. This was easily detectable in satellite imagery as a straight strip of bare land. In the year 1998, settlements seemed to follow the road and so road patterns defined households socio-economic activities associated with forest clearance like access to biomass fuel. There was a progressive increases in forest cover away from road between 1998 and 2011 in both wards (Figure 15 & 20). The big decrease in forest cover in Masaki ward is likely due to significant clearance that happened between 1998 and 2011. Between 2011 and 2015, there was a recovery of forest cover to about ~20-45% in Masaki ward. This is probably due the nature of land clearance for shifting agriculture which usually last for 3-4 years before moving to a new area and allowing the vegetation to recover or increased enforcement in the Kola forest reserve. The nature of charcoal clearance might also allow recovery of vegetation.

Also a steady increase in forest cover as a function of distance from the road was observed in Vikumburu ward. While between 1998 and 2011 there were approximately 20% increases in forest cover away from the road, in 2015 there was only ~5% increase in forest cover away from the road (Figure 20). This perhaps is because of persistence harvest in the same area with no recovery period for multiple years.
4.7 LAND COVER CHANGES IN RELATION TO CITY PROXIMITY

Though it was hard to quantify the whole district spatially due to low processing capacity of the software, but it shows that forest and woodland cover degradation is the function of distance from the main city of Dar-es-salaam. Spatial analysis have shown that, between 1998 and 2011 forest conversion to bareland, settlements and cultivation was rapid at Masaki ward (Figure 13) which is at about 45 km from the main city, whereby it was low at Vikumbulu ward which is at about 100 km from Dar-es-salaam city. However, there was a rapid increase in bareland, settlements and cultivation in both wards between 2011 and 2015. Also there was rapid population increases in Masaki ward from 4357 in 1995 to 7225 in 2012 while it was very low in Vikumbulu ward (Table 5). Therefore this indicates on how the difference in distances from the main city has influenced changes in LULC in these wards.
CHAPTER FIVE—DISCUSSION

5.1 DRIVERS OF LAND COVER CHANGES IN VIKUMBULU AND MASAKI WARDS

Increasing wooded grassland and thicket together with increasing bareland, settlements and cultivation in Masaki (Figure 11 & 12) and Vikumbulu (Figure 16 and 17), indicates presence of tree clearance activities. Previous studies have shown that crop cultivation, charcoal production and timber harvest are the main sources of income in Kisarawe district (Mandari 2010). According to TNBS (2012), more than 89% of the households in Kisarawe district engage in agricultural activities as their main source of income. Further, more than 50% of household income of the rural population near Dar-es-salaam, is obtained from charcoal burning and firewood collection, while 70% of the periurban income is derived from charcoal trade (CHAPOSA 2002). Ahrends et al. (2010) found an increasing trend in charcoal production as a function of distance from Dar-es-salaam, in their study on forest and biodiversity degradation between 1991-2005. Ahrends et. al (2010) further suggested that as nearby forest is depleted, charcoal and timber prices increase which makes production at longer distance attractive to businessman. Therefore, the rapid conversion of Masaki land cover between 1998 and 2011, followed by Vikumbulu between 2011 and 2015, is likely to be attributed to short distances from Dar-es-salaam. Hence, there it is likely that the increasing LULC change in Masaki and Vikumbulu is the outcome of combination of drivers including charcoal harvesting, population increase, poverty and shifting agriculture.

5.1.1 Agriculture

Subsistence farming is widely practiced in many rural areas rich in forestry. In most cases fertile areas which are cleared for charcoal production are used for crop production for 3-6 years and then left fallow for about 4 years (Luoga et al. 2000). Studies have shown this to be too short a time for tree recovery. Clearing of trees and then moving to other areas to farm, requires big areas of land, hence making subsistence farming another driver of LULC in rural communities (Luoga et al. 2000). According to Kisarawe district natural resources officer, agricultural practices like cassava and maize has increased in recent years in the Masaki ward (A Kavishe 2015, pers. comm., 13 November). This has contributed to vegetation clearing and prevents regeneration of woodland and forest. The residents in Masaki ward have been selling
their farms to people from Dar-es-salaam for cultivation and settlements (A Kavishe 2015, pers. comm., 13 November). Currently, the main cash crop is cassava, followed by maize.

Data obtained from Kisarawe district council shows an increasing cropland from 268 ha in 1995 to 633 ha in 2015 in Masaki ward. This is an increment of about 365 ha in cultivated area. Thus the current area under cultivation occupies about 5% of the total ward area when divided by total area (Figure 21). According to the Tanzanian national and regional agriculture census of 2007/2008 (TNBS (2012), the estimated utilizable cropland nationwide has remained constant at about 2 ha per household and Kisarawe household cropland cultivation ranges from 0.5 ha to 1 ha per household. The total number of agricultural households in Kisarawe is estimated to be 23,356 which is 13.4% of the Pwani region in Tanzania. With a total population of 7,202 and average household of 3.8 (TNBS 2012), the number of households at Masaki is estimated at about 1,895. This means, with the estimated cropland of 0.5 -1 ha per household in Kisarawe district (TNBS 2012), the total size of area under agriculture would range from 947.5 to 1895 ha which is about ~7.8-15.7% of the (12,100 ha) total land cover in Masaki ward. The range might shift as not all households derive their income from agriculture. By taking into account all agriculture data, the total size under crop cultivation covers a small area of Masaki ward. Linking spatial analysis (Figure 12, 13 & 14) to this simple statistical analysis of area under agriculture, it shows that the variation in LULC changes in Masaki may well be driven by shifting cultivation which involves clearing trees and then moving to other area.

Unlike Masaki, the Vikumbulu ward total area under cultivation by 2015 was 150 ha (Table 5), which is about 0.15% of the total ward area (Figure 7). The population at Vikumbulu ward is estimated to be 3,248 according to 2012 census results (TNBS 2012). From the overall district household size of 3.8 (TNBS 2012), the estimated number of household in Vikumbulu ward is 854. To obtain an estimate of land under crop cultivation, the number of households can be multiplied by the district household’s cropland (0.5 ha – 1 ha) (TNBS 2012). The estimated area under cultivation would range between 427 ha - 855 ha in Vikumbulu. This is about ~4-9% of the total land (99,660 ha) of Vikumbulu ward (Figure 7), which is more than the current cropland from the data provided in Table 5. Therefore the increase in agricultural area from 1995 to 2015 is very small in Vikumbulu ward when compared to Masaki ward (Figure 21).
From spatial data, the slow transformation of forest cover and wooded grassland into bareland (grassland), cultivation or settlements between 1998 and 2011 in the Vikumbulu ward (Figure 18), indicates low associated levels of natural-resource based socio-economic activities like charcoal burning and shifting cultivation at that time. However, the spatial data of 2011-2015 showed an increase in bareland (grassland), cultivation or settlements with decreasing wooded grassland and forest cover in Vikumbulu ward (Figure 19). Until 2015 more than one third (39%) of the ward was occupied by bareland (grassland), settlements and cultivation (Figure 17). This means that under the given current population, the current area under crop cultivation (0.15%) is very small when compared to forest and woodland degradation as shown in satellite data (Figure 18 & 19). Thus, if agriculture is the driver of LULC changes, then it implies shifting cultivation will be responsible for land cover changes in Vikumbulu ward.

5.1.2 Poverty

Basic needs are defined as absolute minimum resources necessary for long-term physical well being in terms of food consumption (TNBS 2012). Poverty line is the amount of income (36,482 Tanzanian shillings per adult per month) required to satisfy the minimum amount of food required for long-term physical well being, and a food poverty line or extreme poverty is the level at which the household total spending in all items is less than (26,085 Tanzania shilling per adults per month) they need to spend to meet their need for food (TNBS 2012). Studies showed that more than 84% of the poor people in Tanzania live in rural areas (TNBS 2012). In developing countries most rural poor maintain diversified livelihood strategies to reduce risks because they can not obtain sufficient income from a single source. This is the reason for subsistence farmers including forest products among their source of income (Sunderlin et al. 2005; Paul et al. 2007).

Poverty has been shown to be a driving force causing degradation of natural resources in rural areas (Luoga et al. 2000). If agriculture is the main source of income, then low agricultural returns and poverty can be correlated in Vikumbulu and Masaki wards (Figure 21). Ahmed et al. (2011) explained that for communities whose economies rely on agricultural products, reduction in crop production has severe implication for poverty. The contribution of charcoal production to poor rural economy in southeastern Tanzania is well documented by van Beukering et al. (2007). Trade in charcoal is not only the source of employment and income to rural poor, but also for the urban dwellers. In the cities, there is a higher proportion of
charcoal consumption due to the inability to use and pay bills for electric or gas stoves (CHAPOSA 2002).

Kisarawe district is considered to be the poorest district with an estimated household income of $150 per year (Mandari 2010). Rainfall variability for the past 30 years (1985-2015) with reduction of short and long rainfall for about 200 mm in Kisarawe districts makes agriculture unproductive and unreliable (Kashaigili et al. 2014). Less crop returns has accelerated rising food prices and poverty in the community as they have lost the main sources of income (Ahmed et al. 2011; Kashaigili et al. 2014). Data about trends in population and total area of cropland have shown uncertainty in crop harvest (Figure 21). There is a decreasing trend in crop yield from 1995 to 2015 with an increasing area under cultivation in Masaki and Vikumbulu ward (Table 5). For example, in 1995, 30 ha of land in Vikumbulu yielded 258 tons of maize while in Masaki 35 ha of land yielded 101 tons of maize. In 2000, 45 ha of land in Vikumbulu yielded 306 tons of maize where by 55 ha of land in Masaki yielded 132 tons of maize (Table 5). Nonetheless, Vikumbulu seems to have better crop production and yield per ha than Masaki. Thus, over the past 20 years, there is decreasing crop production particularly of the main foodstuffs like maize and legumes coupled with increasing population in Masaki ward. For instance, at the population size of 4,357 in 1995, cassava production was 2018 tons. Interestingly, at population size of 7,225 in 2015 cassava production was 1764 tons lower than at the low population size in Masaki ward (Table 5). Thus a farmer has to cultivate a large area to obtain sufficient yield.

Again if agriculture was the main economic activity, vegetation clearance should match with increasing area under cultivation as seen from data provided (Figure 21). Decreasing wooded grassland and increasing bareland in Masaki and Vikumbulu wards between 1998 to 2015 (Figure 11 and 16), are the likely outcomes of poverty due to lack of an alternative income source. For instance, studies showed more than 50% of the households income was derived from sales of forest products such as charcoal production, honey, wild fruits and firewood in villages close to Dar-es-salaam, while more than 70% of the households income in peri urban area is derived from woodlands charcoal production (CHAPOSA 2002). The study by Kashaigili et al. (2014) and van Beukering et al. (2007) have found decreasing crop yield (maize) and increasing charcoal trade and production in Masaki ward. In connection to this, poverty is highlighted to be among the main drivers of resources depletion in rural poor (Luoga et al. 2000). With an increasing population trend and poverty resulting from low agriculture
returns in Vikumbulu and Masaki wards (Table 5), more pressure will be placed on surrounding natural resources.

5.1.3 Population growth

The changes in African ecosytems are the outcomes of land-use practices that have been caused by increasing human sprawl in rural Africa (Vanderpost 2006), again an example of how these multiple drivers are interrelated. CHAPOSA (2002) found that charcoal demand is directly linked to urban population growth in developing countries (CHAPOSA 2002). More than 80% of Sub-Saharan populations, with the exception of Southern Africa, depend on wood biomass as a sources of energy for cooking. It is predicted that, as the population of African urban grows, more supply of charcoal will be required to meet the growing demands (CHAPOSA 2002). CHAPOSA (2002) found that for each 1% increases in urbanization, a 14% increase in charcoal consumption results. A study by Chirwa et al. (2008) as cited in Kalaba (2014) noted that the conversion of miombo woodedland to agriculture land is the outcome of increasing human population in miombo woodlands. In Tanzania, urbanization is considered to grow at 5% in most cities. Although a large percent (>50%) of the forest is reserved, illegal harvest is expected to increase due to poor protection (Mwampamba 2007).

According to TNBS (2012) census, Kisarawe population was 78,290 in 1988 and 95,323 in 2002. Among them about 80,817 lived in the rural region while 14,506 lived in Kisarawe urban area in 2002. The national population census of 2012 shows that, Kisarawe district population was at 99,635, of which 82,848 lived in rural areas and 16,787 lived in Kisarawe urban area (TNBS 2012). This large proportion of rural population in Kisarawe has implications for LULC changes and natural resources use. The current population in Masaki ward stands at about 7,202 according to data obtained from TNBS (2012). Since the last census of 2002, the population in Masaki ward increased by 22% at 2012 (from 5,899 in 2002 to 7,202 in 2012), while that of Vikumbulu ward decreased by 5.7% (from 3446 in 2002 to 3248 in 2012) (TNBS 2012). The reason behind the population increase in Masaki might be due to its closeness to Dar-es-salaam city and Kisarawe urban (A Kavishe 2015, pers. comm., 13 November). A Kavishe (2015, pers. comm., 13 November) said, there are increasing immigrants from Dar-es-salaam city. Therefore the decreasing forest and wooded grassland cover in Masaki shown by spatial analysis (Figure 11 & 12) could likely be related to this population increase (Table 5).
Increasing human population in miombo woodlands leads to shifting cultivation and increasing energy needs and hence more pressure on woodlands (Chirwa et al. 2008b as cited in Kalaba 2014). However, there are other factors influencing loss of natural resources apart from population increases. For example, the population growth and density is very low (3.2 inhabitants/km²) in Vukumbulu ward when compared to Masaki ward (59.1 inhabitants/km²) (Table 5), however, a significant loss of forest and wooded grassland cover occured in Vikumbulu ward between 1998 and 2015 (Figure 16 & 17). Spatial analysis showed that about 25% and 44% of forest cover and wooded grassland were converted into grassland, cultivation and settlements (Figure 18 & 19). In this case, the increasing depletion of natural resources, shown by spatial data does not reflect its population growth. Land cover changes which are happening are not because of increasing settlements or agriculture growth due to population, but is rather the outcome of other drivers of LULC like firewood collection, timber cutting and charcoal burning. In connection to this, Mwampamba (2007) found that increasing population and fuel demand in Dar-es-salaam city coupled with increasing rural poverty are factors causing resources depletion in coastal areas. Thus as a struggle to escape from poverty, population growth in Dar-es-salaam city might have indirectly influenced forest and woodland degradation in Vikumbulu and Masaki ward due to rising demand for charcoal and timber.

5.1.4 Charcoal demands
Charcoal production in Tanzania is primarily conducted in state forests and public or village owned forest (Sander et al. 2013). The impacts of charcoal production is widely documented (Mwampamba 2007). In southern Mozambique for example, 70% of the cash income is from charcoal business (CHAPOSA 2002). With the collapse of agricultural market in Zambia, charcoal has been the main sources of income in Zambia’s rural communities (CHAPOSA 2002). Studies suggest that in Africa almost 90% of wood removal is used for fuel (Kees & Feldmann 2011). In spite of agriculture being the main economic activity in rural Africa, trade in charcoal is widely practiced by rural farmers (CHAPOSA 2002). These trends provide evidence on how charcoal business has escalated in African rural and city centres.

About 75% of farmers in investigated study areas in Tanzania conducted charcoal business as an important source of income (CHAPOSA 2002). Dar es salaam is considered to be the main consumer (about 70%) of the charcoal produced in Tanzania, leaving areas nearby widely affected due to resources degradation (Ahrends et al. 2010). Charcoal production was
positively related to its price and demand in Dar–es-Salaam (Luoga et al. 2000). Among major reasons for growth of charcoal consumption in this city is the availability of cheap and affordable charcoal stoves in the market compared to electric and gas stoves (Luoga et al. 2000). Demand for charcoal is predicted to increase in major cities of developing countries as a result of increasing population and unaffordable sources of energy (Mwampamba 2007).

Figure 22: Area set for community forest in Masaki ward showing all tree have been cleared due to charcoal burning (Source: Kavishe, A Natural resources officer 2015)

This study shows a decrease in forest cover and an increase in wooded grassland between 1998-2011, which then followed by decreasing trend of the latter between 2011 and 2015 (Figure 12 & 17). Given the small area under crop cultivation in these wards (Table 5), this indicates that clearing for charcoal burning is widespread in Masaki and Vikumbulu wards as shown in Figure 22 & 23. The study about Charcoal potential in Southern Africa from 1998 to 2002 showed charcoal production to be a dominant activity in the woodlands managed by district council through village governments (CHAPOSA 2002). As a results of poor management, these woodlands have been depleted or turned into isolated bare ground pockets (Mwampamba 2007). Charcoal consumption is estimated to range between 3.12 sacks per person/ per year for low consumption and 4.62 sacks per person per year for the medium consumption (Mwampamba 2007). The estimated households charcoal consumption in Dar-es-salaam is 1000 tons of charcoal per day which is equivalent ot 18,800 bags each at 53 kg. By considering all consumers, the total charcoal consumption in Dar-es-salaam is estimated to about 24,000 bags of charcoal per day (CHAPOSA 2002; Mwampamba 2007).
Forexample, about 102 and 123 households at Maguruwe and Kisanga villages in Masaki wards involved in charcoal production with an estimated production of 9,514 and 32,657 bags/year (each bag weighing 30 kg). The charcoal production per household was estimated at 0.85 bags/day for farmers and 1.22 bags/day for charcoal specialists (van Beukering et al. 2007). This might have resulted in escalating land cover changes between 1998-2015 at Masaki ward in Kisarawe district (Figure 11).

Kavishe 2015, suggested biomass fuel to be the reason for rapid resources depletion in Masaki and Vikumbulu wards to supply the higher demand in Dar-es-salaam city (per com. Kavishe 2015). The use of motorcycles has facilitated transportation and hence depletion of natural resources in Masaki ward. It is cheap, easy and it takes only a few hours to carry a large quantity of charcoal from a charcoal kiln to the road for the wholesaler to load (A Kavishe 2015, pers. comm., 13 November). All the community forest cover is gone as a result of charcoal burning at Kisanga village in Masaki ward (Figure 22). Sometimes the residents are felling mango and coconut palm trees for charcoal burning for domestic and income generation (A Kavishe 2015, pers. comm., 13 November). Charcoal production and timber trade have been a dominant activity within Dar-es-salaam proximity (Ahrends et al. 2010). With exhaustion of biodiversity in the nearby areas, there is increased price of charcoal and
timber which makes biodiversity and forest at longer distance attractive to businessmen (Ahrends et al. 2010).

Figure 24. Charcoal burning in Vikumbulu ward (Source: Nyanda 2013)

Thus, the higher loss of forest cover in Masaki ward between 1998 and 2011 might be a result of its closeness and easy access to Dar-es-salaam city. But with depletion of forest cover in other nearby wards and improved road access, the forest and wooded grassland cover in Vikumbulu ward were later exposed to higher risks of LULC changes due to charcoal harvest and other socio-economic activities like agriculture. The rapid LULC changes in Kisarawe rural region is a threat to the protected areas buffer zones in SGR which is bordered by villages close to Dar-es-salaam. Shanley (2002) argued that the impact of charcoal burning and timber logging will not only deplete trees upon which the community relies but also they will suffer socio-cultural and substantial associated damage which affect the future harvest of forest products.

5.2 LAND COVER CHANGES, ITS IMPLICATION ON PROTECTED AREA BUFFER ZONES AND RURAL LIVELIHOODS

As discussed in the previous section, there is a dramatic decrease in vegetation cover, particularly wooded grassland and forest cover in Masaki and Vikumbulu ward for the past 18 years. This study showed that forest cover decreased by more than half, from about 54% in
1998 to 14.7% in 2015 in Vikumbulu ward (Figure 17). Interestingly, a decrease in forest and wooded grassland covers in Vikumbulu ward is associated with low population when compared to Masaki (Figure 17 & 21). Most of forest cover is converted into wooded grassland. Although the wooded grassland has shown a decreasing trend between 2011 and 2015 as it is being transformed into grassland or bareland and cultivation (Figure 17). Decreasing trend in wooded grassland signals the disappearance of forest cover and increasing charcoal or timber trade in Vikumbulu ward. This has serious impacts in the nearby protected areas and rural community livelihood strategies. Although charcoal in Dar-es-salaam is supplied from different nearby regions like Morogoro, Tanga, Lindi and other coastal districts, but Kisarawe district is prone to charcoal exploitation from wholesalers. This is because of the comparatively short distance from Dar-es-salam city, cheap labour and hence less cost. As examined by Ahrends et al. (2010) that, with exhaustion of forest and woodlands in the nearby ward areas, there is an increased price of charcoal and timber which makes biodiversity and forest at longer distance attractive to businessman. In connection to this, the depletion of forest resources in wards which are close to city like Masaki, makes businessman to look for more forest and woodland cover at Vikumbulu ward and finally into SGR buffer zones.

Depletion of buffer zones not only affect the survival of wild animals and plants, but also threaten to rural people livelihoods strategies for the future (Merinda & LaPalme 1997; Diego 2010). Most poor rural populations live in marginal land rich in forest and wildlife resources and many have no alternative source of energy than wood fuel (Merinda & LaPalme 1997). These marginal areas are regarded as buffer zones, are open access and have little protection on wise extraction of natural resources. With 10% of urban homes electrified in Tanzania, the inspiration to affordable use of electricity will take many years in both rural and urban areas (Mwampamba 2007). In Kisarawe district, more than 97% of the rural community depends and uses fuelwood as their main sources of energy for various activities (TNBS 2012). Increasing demands of charcoal in both city (Dar-es-salaam) and rural villages coupled with shifting cultivation will leads to buffer zones degradation and consequently pose considerable pressure in Selous protected area.

Under different scenerio, Mwampamba (2007) predicted a complete loss of public forest by 2028, due to their unrestricted access and perception that these are areas for charcoal production. This does depend on the time interval given for the forest to recover after harvest
(Mwampamba 2007). Increasing population and depletion of public or marginal forests will encourage forest use and exploitation in conserved and protected areas (Merinda & LaPalme 1997; Mwampamba 2007). Degradation of natural resources rises the prices and add another additional burden to household budgets and particularly for women and children as they have to spend more time on searching and collecting firewood (Kees & Feldmann 2011). For example, it has been reported people stoped cooking food that needs more simmering, such as beans due to inadequate and shortage of firewood in Malawi (Kees & Feldmann 2011). The decreasing trend in forest and wooded grassland cover in Vikumbulu ward could impact not only on SGR buffer zones but also on people’s food security and livelihood strategies.
CHAPTER SIX

6.0 RECOMMENDATION AND CONCLUSION

The declining forest cover and wooded land in Masaki and Vikumbulu signify increasing socio-economic activities in the two selected wards. Though agriculture is described as the main economic activity in the district, the area under crops cultivation appears to be very small compared to rapid degradation of forest and woodland cover in these wards. This implies reliance of rural communities on natural resources as a significant source of income. Also small agriculture area and low population in Vikumbulu ward suggests that these are not driving force towards the escalating degradation of natural resources. Taking into account that agriculture is the main economic activity, poverty and agriculture can be related with land cover changes in Vikumbulu and Masaki wards. Poor agriculture returns increases reliance on natural resources as an alternative source of income. Moreover, to maximize crop yields the communities have to cultivate large area or practice shifting cultivation and hence increased clearance of forest and woodlands in these wards. The pattern of land clearance seems to begin along the road towards the interior. This study has shown a rapid drop in forest cover from 85% in 1998 to 10% in 2015 within a distance of 0 km-3.5 km in Vikumbulu ward, while there was a sharp drop from ~55-73% in 1998 to ~20-35% in 2011 in Masaki ward. With exhaustion of resources in nearby areas we expect a further degradation of the resources in buffer zones bordering SGR protected area. The rapid degradation of resources between 1998 and 2011 in Masaki ward, which is at 45 km from the city, and then followed by Vikumbulu ward between 2011 and 2015, at about 100 km from the city, suggest the impacts of city proximity to rural LULC as stated in the hypothesis.

Many approaches have been suggested for effective and sustainable conservation around protected area buffer zones. For example, Brandon, (1997) suggested two approaches which are Integrated Conservation-Development Projects (ICDPs) and locally managed reserves approaches. ICDPs links biodiversity conservation in parks with rural socio-economic development. It aims at achieving conservation by promoting socio-economic developments and providing local people with alternative source of income without threatening natural resources, such an example include buffer zone projects (Well & Brandon 1992 as cited in Kramer et al. 1997). Locally managed reserves areas emphasize on maintaining livelihoods and biodiversity conservation is a secondary objective. In most local managed reserves human
(consumption) objective comes first (Brandon 1997). But based on experienced problems and tensions between conservation objectives and local people’s livelihoods, several studies have reported ICDPs do not provide sufficient income to alter the negative attitudes towards conservation (Barrow & Fabricius 2002 as cited in Vanderpost 2006). So in order to balance between biodiversity management and improvement of local people’s livelihoods we have to first resolve the conflict between the two, otherwise the long-term prospects for both may be undermined (Vanderpost 2006). Kothari et al. 2013, suggested Collaborative Management of Protected Areas (CMPA) that lead to governance and equity in conservation and ultimately decision making power, responsibility and accountability are shared for the betterment of rural livelihood.

Currently there are more than seven WMAs which have been established around SGR buffer zones. This WMAs are jointly managed by villages each contributing a piece of land. Unfortunately, villages bordering SGR in the Kisarawe district have not established WMA and they lack regulations in sustainable utilization. Analyses have shown significant land cover degradation at Vikumbulu ward bordering SGR in Kisarawe district of which, without appropriate regulations and action the woodland and forest cover will be depleted in the future. Therefore participatory CBC should be of immediate concern to halt the ongoing land cover changes, otherwise this will impacts on people’s livelihood and SGR buffer zones.

As in most wards surrounding SGR, household income is a main problem in Vikumbulu and Masaki ward in Kisarawe district (TNBS 2012). To boost household income, establishment of WMAs or PFM should be associated with developing and promoting alternative sources of income generation to poor communities. Taking advantages of the organic and green agricultural markets in cities and tourism industry around protected area, capacity building in intensive agriculture practices and agribusiness skills such as horticulture will increase yields per hectare and hence increase income to rural poor. Emphasis in education and training should be given to qualified rural community to create conducive environment for them to be absorbed in employment opportunities. CMPA and prioritising to rural community members to work in protected areas particularly those bordering protected areas create a sense of responsibility in taking care of forest resources and provide livelihood opportunities. Because biomass energy is the main cause of forest and woodland degradation, the government should invest in solar cooker both in rural regions and urban to utilize the available sunlight and hence reduce forest use.
To reduce LULC changes around buffer zones, the project should be compatible with land use in protected area (Diego 2001). For example, Shanley 2002; Marshall et al. (2003); Belcher & Schreckenberg (2007); Persha & Blomley (2009); Ahenkan & Emmanuel (2011) emphasized that, the inclusion of NTFPs like honey, beewax, mushroom and wildfruits would increase income and reduce biodiversity degradation in poor rural communities. Merinda & LaPalme (1997) insisted on income generating project which enhance the use of forest products as a way to vest locals in sustainable utilization and conservation of forest resources around them. For communities whose natural resources have been depleted, the destruction and degradation of fragile ecological relation and biodiversity of protected areas is in process (Merinda & LaPalme 1997). Thus for the success of these protected areas, the government or authority should decide on how to devolve responsibility to the adjacent rural communities. This is by providing them with alternative livelihood strategies or sufficient opportunities to earn income (Merinda & LaPalme 1997).

LULC changes are a results of multiple drivers which needs multisectoral collaboration and broad ranges of stakeholders involvements in policy implementation. Institutions like ministry of energy, water and environment are neccessary part for a better policy. For instance the need for a national energy policy to subside energy and promoting alternative income generating projects to rural people like NTFPs. Wirtenberg (2008) emphasised that for sustainable conservation, there is great potential of other sectors to recognize the significant contribution of natural resources to the successes of their own sectors. Shackleton & Pandey (2014) said a policy is ineffective and unsustainable when it pays little attention to promote sustainable conservation of the sources (catchments forests or water sources) from which it depends for its products. Integration and harmonization of different policies will save the lives of rural and urban people whose lives are going to be threaten in the near future due to rapid exploitation of natural resources (Luoga et al. 2000). Conclusively, to promote sustainable utilization and conservation in Vikumbulu and Masaki ward, first, there should be local participation in decision making about their livelihood as well as for conservation goals. Next is developing mutual use of natural resources by applying equitable allocation to every individuals and lastly plant harvest should consider the nature and tolerance of plant above which there should be a gap to allow plant recovery or regeneration.
Future work

Although the study gives a picture of the relationship between city proximity and land cover changes, the future study should try to quantify the land cover changes of the whole district from the city to SGR buffer zones. This would provide a better understanding of the trends in LULC changes across the whole district to SGR buffer zones. Further investigation of pastoralisms and fire as the drivers of LULC in Vikumbulu ward and the field quantitative analysis of socio-economic, demographic factors coupled with spatial data to understand the pattern and response of natural resources to human interaction will enhance the value of this study.

Limitations of the spatial analysis

An image with higher percentage of clouds might obscure the study areas and makes it difficult to distinguish different features or LULC underneath. Therefore, for heterogeneous landcover it is necessary to conduct ground truth to locate and name the features or land cover hidden by clouds for easy classification of the study area. Another challenge is spectral mixing between bare land, grassland, settlements and cultivation makes it difficult in distinguishing between them, especially for detecting settlements that were roofed with thatched grasses.

Absence of critical data

Challenging in quantifying charcoal and timber as the drivers of land cover in both wards, due to lack of charcoal harvest data in respective wards despite the fact that charcoal business is prevalence in Vikumbulu and Masaki.
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