MASAI GIRAFFE (*Giraffa camelopardalis tippelskirchi*) POPULATION AND LANDUSE TRENDS IN THE TSAVO LANDSCAPE, KENYA

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DECLARATION

I declare that this thesis is my original work and has not been presented for the award of a degree in any other University. Where other people's work has been used, this has been properly acknowledged and referenced in accordance with the requirements of University of Nairobi.

Signature .... **Date**.... **8th December 2021** ....

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This thesis has been submitted for examination with our approval as the university supervisors.

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Signature .... **Date**.................................... December 8, 2021

Dr. Philip Muruthi

African Wildlife Foundation

DEDICATION

I dedicate this work to my dear parents and sisters; Mr. and Mrs. Peter Njueini Kabue, Gathoni Njueini and Wanja Njueini, for their support and endurance during my long period of absence when working on this project.

Secondly, I dedicate this work to all conservation biologists who endeavor to secure and preserve natural ecosystems in an increasingly modern Africa.

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ABSTRACT

This study analyzed giraffe (*Giraffa camelopardalis tippelskirchi*) population and land use trends in the Tsavo landscape. The main objectives of the study were: to assess the past and current distribution of giraffe; to analyze how land use and land cover has changed in the Tsavo landscape from the 1985 to 2020; and to determine how Land Use Land Cover (LULC) change and other factors influence giraffe distribution within the Tsavo landscape.

Tsavo landscape was divided in to five regions, Tsavo West National Park (TWNP), Tsavo East National Park (TENP), South Kitui National Reserve (SKNR), Taita Ranches and Rombo Group Ranch. Current giraffe population, density, age structure and sex structure were established using road transect counts in the different regions. Data were also collected on the status and distribution of water sources during the road transect surveys. Past giraffe population was determined through review of secondary data from past large mammal censuses in the study area. Landsat satellite images for the years 1985,1999,2010 and 2020 were classified into various land and vegetation classes and later analyzed to establish LULC change.

Giraffe density differed significantly among all the regions (H = 12.99, df = 4, P<0.05) in the Tsavo landscape; Rombo Group Ranch had the highest density followed by TWNP. Taita Ranches came in third followed by TENP, there were no giraffe sightings in SKNR. There was a significantly higher number of female giraffe than male giraffe in the Tsavo landscape (χ^2= 36.94, df = 1, P<0.05), the male: female sex ratio was 1:1.63. Giraffe age distribution varied significantly within the different regions (χ^2 = 38.34, df = 18, P<0.05), TENP had the highest proportion of adults followed by Rombo Group Ranch, TWNP came in third but Taita Ranches had the least proportions of adults. Total giraffe population showed a significantly declining trend since the 1970's (R = -0.77, P<0.05). The number of giraffe sightings decreased significantly with increase in distance to permanent rivers (R = -0.88, P<0.05) and wet artificial waterpoints (R= - 0.93, P<0.05). Giraffe sightings decreased though not significantly with increasing distance to seasonal rivers (R = -0.69, P>0.05) and dry artificial water points (R= -0.48, P>0.05).

Chi-squared tests showed that there was a significant difference in the area covered by forest (χ^2 = 286.91, df = 3, P < 0.05), bushland and *Commiphora* thicket (χ^2 = 355.21, df = 3, P < 0.05), *Acacia* woodland (χ^2 = 4820.30, df = 3, P <0.05) and woodland (χ^2 = 411.97, df = 3, P < 0.05). There was a significant increase in the area covered by grassland (χ^2 = 2678.32, df = 3, P <0.05), bareland (χ^2 = 3413.81, df = 3, P < 0.05), agriculture (χ^2 = 1626.22, df = 3, P <0.05) and settlement (χ^2 = 448.97, df = 3, P < 0.05). There was no significant change in the area covered by water (χ^2 = 3.42, df = 3, P < 0.05). The study also conducted a finer scale LULC change analysis on Rombo Group Ranch between 1985 and 2020. Chi-squared tests revealed that there was significant increase in the area covered by agriculture (χ^2 = 62.62, df = 3, P <0.05) and bareland (χ^2 = 19.45, df = 3, P < 0.05). The area covered by *Acacia* woodland decreased significantly (χ^2 = 18.12, df = 3, P < 0.05). There was no significant change on the area under woodland (χ^2 = 6.99, df = 3, P > 0.05), grassland (χ^2 = 4.55, df = 3, P > 0.05) and settlement (χ^2 = 0.83, df = 3, P > 0.05).

The study observed that the overall Masai giraffe population was decreasing over the years in the Tsavo landscape, while LULC types that compromise giraffe conservation were observed to be increasing. The study proposed formation of conservancies and formulation of land use plans in community and private ranches to curb the development of LULC regimes that conflict with giraffe conservation in the Tsavo landscape.

CHAPTER ONE: INTRODUCTION

1.1 Background

Over the past decade, the giraffe population across Africa has been declining as a result of habitat loss due to fragmentation and encroachment, severe poaching (especially for bush meat) and increasing human population (Fennessy, 2009). Between 1985 and 2005 global giraffe population declined from 150,000 to 98,000 individuals representing a 40% decrease (Muller, 2018). Giraffe no longer exist in some countries such as Mali, Eritrea, Guinea, Burkina Faso, Nigeria, and Senegal. Even in countries where giraffe currently exist their habitat range is diminishing (Shorrocks, 2016).

Land cover change and other anthropogenic activities greatly compromise the integrity of species habitats (Syombua, 2013). Degraded habitats have direct impact on the reproductive fitness, foraging behavior and ultimate survival of organisms (Vogel *et al*.,2017). Tsavo ecosystem has experienced huge fluctuations of giraffe populations over the past years. This has largely been attributed to habitat loss due to Land Use Land Cover (LULC) change (KWS 2018 a). Giraffe movements within the Tsavo landscape have also been affected by fragmented habitats and diminishing wildlife corridors due to changing land use practices (KWS, 2017).

Kenya ranks highly in terms of wildlife richness in Africa. With 390 mammal species and 22 of these being endemic, Kenya is home to a third of all African mammals (Musila *et al*., 2019). Some of the iconic large mammal species found in Kenya include the African savanna elephant (*Loxodonta africana*), Giraffe (*Giraffa camelopardalis***)**, Buffalo (*Syncerus caffer*), Lion (*Panthera leo*) and the Leopard (*Panthera pardus*). Some of the most notable endemic mammal include; Mount Kenya Duiker (*Cephalophus hooki*), Mountain Bongo (*Tragelaphus eurycerus isaaci*), Hirola **(***Beatragus hunteri*), Tana River Mangabey **(***Cercocebus galeritus*) and the Tana River Red Colobus **(***Procolobus rufomitratus*).

It is estimated that wildlife numbers in Kenya dropped by more than 68% between 1977 and 2016 (Ogutu *et al*., 2016). The decline was attributed to habitat degradation and fragmentation due to LULC change, climate change and variability, poaching and increased human population (Ogutu *et al*., 2016). Some of the most affected mammal species include the African wild dog (*Lycaon pictus*), Black Rhinoceros (*Diceros bicornis*), the Grevy's Zebra (*Equus grevyi*), the African Elephant

(*Loxodonta africana*), the Masai Giraffe (*G.c.tippleskirchi*) and the Reticulated giraffe (*G.c.reticulata)*.

The giraffe inhabits arid and semiarid savannahs south of the Sahara in Africa. The population of mature giraffe was estimated at 68,293 individuals in 2015 signifying a huge drop from a previous survey in 1985 which estimated about 114,416 individuals (Muller *et al*., 2018). The overall species trend reflects general decline of the giraffe population and giraffe habitat range across Africa (O'connor *et al*., 2019). Some giraffe subspecies are increasing such as, *G. c. angolensis* which occurs on the border between Botswana and Namibia, *G. c. giraffa* which occurs in southern Africa, *G. c. peralta* which is also known as the West African Giraffe and *G. c. rothschildi* which is found in Uganda and Kenya (Muller *et al*., 2018). Giraffe subspecies that are decreasing include; Kordofan giraffe (*G. c. antiquorum*) which resides in the central Africa region and the East African Nubian giraffe *(G. c. camelopardalis)*, Masai giraffe and Reticulated giraffe. The subspecies occupying Luangwa Valley in Zambia, *G. c. thornicrofti* is stable (Muller *et al*., 2018). The International Union for Conservation of Nature (IUCN) Red list of threatened species categorizes two giraffe subspecies as Critically Endangered, the Nubian giraffe, and the Kordofan giraffe, (Fennessy and Marais, 2018; Wube *et.al*., 2018). Four giraffe subspecies occupy the Eastern part of Africa, three of which are found in Kenya. The Reticulated giraffe occupies northern Kenya and parts of Somalia and Ethiopia, the Rothschild giraffe is found in Kenya and Uganda. Tanzania and Southern Kenya is inhabited by the Masai giraffe (Figure 1.1).

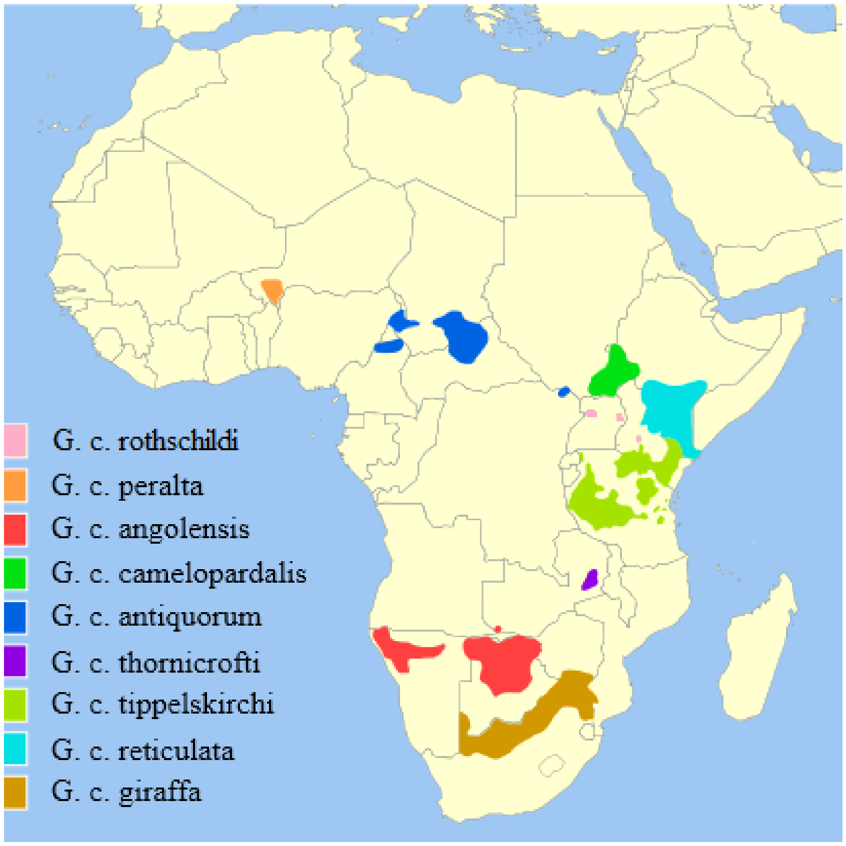

Figure 1: Giraffe subspecies distribution across Africa

Source: IUCN Red List of Threatened Species (2010)

Giraffe are under the continuous threat of extinction due to the unprecedented depletion and degradation of natural habitats (Fennessy *et al*., 2004). Like other large herbivores, they are most affected by habitat loss because of their characteristic slow reproductive rates, large food requirements and vast ranging patterns (Dagg, 2019). In East Africa, the Masai giraffe population has decreased from an estimated 63,292 in the 1980's to 35,000 individuals in 2015. Reticulated giraffe population has dropped from a population of 36,000 in the 1980's to 15,985 individuals in 2015. Unlike the Reticulated and the Masai giraffe, the Rothschild giraffe has increased from 1,331 in the 1960's to 1,671 individuals in 2015 (Muller *et al*., 2018). In Kenya, the most abundant subspecies is the Reticulated giraffe with a population estimate of 15,801 followed by the Masai giraffe at a population 12,700 individuals. The Rothschild giraffes which are only limited to protected areas, conservancies and private ranches in Kenya are the least abundant at a population estimate of 609 individuals (KWS, 2018 a).

The Tsavo landscape in southern Kenya is one of the key Masai giraffe ranges in the country (KWS, 2018 a). It is a huge conservation area that encompasses parks, reserves, conservancies, ranches and community pastoral lands. It also includes farms and human settlements. The Tsavo landscape is home to one the highest free ranging Masai giraffe populations in the country with a population estimate of 4,323 individuals (KWS, 2018 b). Within the expansive landscape, the interphase between South Kitui National reserve (SKNR) and northern Tsavo East National Park (TENP) forms a potential transition between Masai giraffe and reticulated giraffe, which occupy northern and southern parts of Kenya as their natural range, respectively (KWS, 2018 a, KWS, 2018 b).

In parts of the Tsavo landscape Masai giraffe population have been seen to decrease immensely over the years. In SKNR for example, the population of giraffe dipped sharply from 187 individuals sighted in a 2014 aerial census survey to only 4 individuals in 2017 (Ngene *et al.,* 2017). This fluctuation has been linked to many factors such as displacement by people and livestock, poaching and interspecies competition but the main reason is habitat loss. Charcoal burning activities have been largely hypothesized to be the major contributor to habitat loss (KWS, 2018 a). Previous aerial censuses by the Kenya Wildlife Service (KWS) and other stakeholders in 2011, 2014 and 2017 within the Tsavo-Mkomazi ecosystem have established information gaps on distribution and population dynamics (including age structure) of giraffe within the Tsavo landscape.

The distribution of different age classes defines the age structure of a population (Obari, 2009), most organisms have three age classes; juveniles, sub adult and adults (Marjamäki *et al*., 2013). Giraffe populations can be structured using the three age classes, juveniles are individuals that are less than 1 year old, sub adults are individuals between 1-5 years while individuals above 5 years are adults (Foster, 1966; Hall-Martin and Janson, 1975; Dagg and Foster, 1982; Fennessy, 2004; Obari, 2014). Organisms that reproduce sexually have a near equal allocation of male to female sex ratios as an evolutionary stable strategy (Fisher, 1930; Edwards, 1998; Benvenuti *et al*., 2018). Foster, (1966) and Fenessy, (2004) while working in Nairobi National Park and on the desert dwelling giraffe of Namibia respectively, established that giraffe populations exhibit 1:1 male to female sex ratios. However, sex ratios may vary in some wild populations due to skewed juvenile, sub adult and adult mortality (Marealle *et al*., 2010; Kappeler, 2017).

Water is a key limiting factor in wildlife distribution in Africa's arid and semi-arid habitats (Western, 1975; Redfern *et al*., 2008; Obari, 2014). During droughts, animals converge close to the limited watering points as opposed to the wet seasons when animals disperse widely due to the presence of numerous ephemeral water sources (Chammaille-James *et al*., 2007; Redfern *et al*., 2008). Water availability is a major factor that influences the distribution of giraffe within a habitat (Berry, 1978; Pellew, 1984; Brand 2007; Obari, 2014).

Though the giraffe is one of the iconic terrestrial African mammals, there is deficient information on the ecology and behavior as compared to other large mammals, accurate population counts are scarce, incomplete and often confined to technical documents and local wildlife department census reports which are not widely available or accessible to researchers and scientists (Muller *et al*., 2018). This study was prompted by the need to fill gaps revealed by previous studies on the population and distribution of giraffe and the compounding effect of increasingly changing landscapes due to anthropogenic factors. The study will contribute to the National Recovery and Action Plan for Giraffe (*Giraffa camelopardalis*) in Kenya (2018-2022).

1.2 Problem statement and Justification

There has been limited studies in the Tsavo landscape that have focused on giraffe population and LULC change. A study by Obari (2014) analyzed Masai giraffe population ecology in southern Kenya and linked it to climate variability. The study recommended for more research on the impact of LULC change on the Masai giraffe populations. Most of other giraffe population ecology work in the Tsavo landscape has been based on large mammal aerial censuses within the Tsavo Mkomazi Conservation Area (Ngene *et al*., 2011, 2014 and 2017). A study by Western, Russell and Cuthill (2009) analyzed the status of wildlife in all protected and unprotected areas. Obari (2009) analyzed factors affecting habitat use by Masai giraffe in the Athi-Kapiti Plains, Kenya. Other studies that have been carried out mainly focused on giraffe ecology and behavior within the Tsavo landscape are (Leuthold and Leuthold, 1972, 1978 a, 1978 b; Leuthold, 1979).

This study is motivated by the need to establish giraffe population and distribution trends in the light of an increasingly changing Tsavo landscape. Understanding the dynamics surrounding giraffe population trends and corresponding changes in habitat will help determine the future of giraffes in the Tsavo landscape. Findings of this study will not only fill data and information gaps, but will also provide crucial information that will guide the conservation of the endangered Masai giraffe in the Tsavo landscape and other endangered giraffe subspecies across Africa such as the Kordofan and Nubian giraffe.

This study also contributes to the National Wildlife Strategy which highlights the need to conduct comprehensive analysis on the status and conservation priorities of species and ecosystems while supporting the development of frameworks for integrated planning and effective coordination of species protection in the country (Ministry of Wildlife and Tourism ,2018).

1.3 Research Objectives

1.3.1 Main Objective

The main aim of this study was to determine the population, distribution and LULC trends of giraffe in the Tsavo landscape.

1.3.2 Specific Objectives

i. To assess the past and current Masai giraffe distribution in the Tsavo landscape.
ii. To analyze LULC change from 1985 to 2020 in the Tsavo landscape.
iii. To determine how LULC changes and other factors influence the distribution of Masai giraffe in the Tsavo landscape.

1.4 Research Hypotheses

i). The population and distribution of giraffe in the Tsavo landscape has not changed significantly from the 1970's to 2020.
ii). LULC has not changed in the Tsavo landscape from 1985 to 2020.
iii). Giraffe population and distribution within the Tsavo landscape is not influenced by LULC change.

1.5 Research Questions

i). How do past and current giraffe numbers and distribution compare between different regions in the Tsavo landscape?
ii). How has LULC changed in the Tsavo landscape from 1985 to 2020?
iii). How are giraffes' population and distribution affected by LULC change in the Tsavo landscape?

If this study establishes that there has been LULC change in the Tsavo landscape and that LULC change has directly affected giraffe population and distribution, the study will have provided a basis for curbing LULC practices that are incompatible with Masai giraffe conservation in the Tsavo landscape.

CHAPTER TWO: LITERATURE REVIEW

2.1 Giraffe ecology

The giraffe belongs to the *Giraffidae* family which is a group of ruminant mammals. The family consists of only two genera the *Giraffa* and the *Okapi*. They are both found in Africa, the *Giraffa* in the savannahs, and the *Okapi* in the dense rain forests of Congo. The two close relatives are very different in appearance, but at a closer look they share numerous common characteristics such as skin covered knobs called ossicones, lobed canine teeth and a prehensile tongue (Mitchel *et al*., 2003).

The giraffe has very long legs and a very long neck making it the tallest and one of the heaviest land mammals. Adults can reach heights of up to 5.5 meters and weigh up to 1,900kgs. They also have beautiful color patterns on their body that range from chest nut, pale tan to black. Though no two individuals have similar coat patterns, the patterns vary geographically and are used in classifying the different giraffe subspecies (Barnosky, 2009). They have good vision which is attributed to their good color vision which helps them detect predators, food and other giraffes from far. Giraffe are able to communicate over large distances through infrasonic sounds that are below the human hearing range (Barnosky, 2009). Recent research however disputes the infrasonic communication by giraffe and calls for more research (Baotic, Sicks and Stoeger, 2015). Their hind legs and fore legs are very strong and are often used for defense purposes, a well-placed kick on a predator can kill instantly. The main giraffe predators are lions and hyenas which are mostly a threat to juveniles and sub-adults (Hayward and Kerley, 2005; Strauss and Packer, 2012). Giraffe are mainly generalist's feeders, this considerably reduces the time and energy they spend in foraging (Obari, 2014). Based on their feeding behavior, they provide crucial ecosystem services such as opening up closed habitats, seed dispersal, pollination and stimulate regeneration of new forage (Muller *et al*., 2018).

Peterson and Ammann (2013), defined giraffe as gregarious but not territorial. They form very loose social bonds and have inconsistent patterns of relationships with the exception of mothers and their off springs (Leuthold, 1979). Studies have shown that they exhibit fission -fusion social systems where herds are usually small temporary units of association which are determined by the sex of individuals and kinship (Bercovitch and Berry, 2012; Carter *et al*., 2013). The more consistent social groups are nurseries that consist of calves and their mothers and peer groups which constitutes sub-adults and young adults. The peer groups have much stronger social bonds than giraffe of all other age classes (Leuthold, 1979). Giraffe disperse widely during the wet season and aggregate at the riverine areas during the dry seasons (Obari, 2014).

Ungulates usually move in response to changes in seasons resulting to migrations that are influenced by water, forage quality and quantity (Western, 1973). Seasonal changes in forage quality causes seasonal selection of forage, hence triggering animal movements (Western, 1973). Giraffe distribution and movement is determined by both external and internal factors. External factors being precipitation, human disturbance, habitat disturbance and competition for resources while internal factors are largely the density dependent processes (Obari, 2014).

Forage availability and quality greatly influences the movement and distribution of giraffe in a habitat (Brand, 2007). During the dry seasons they move beyond protected areas in search of forage and water using specific corridors (Okello *et al.,* 2015). Their distribution during such times is highly influenced by their movements. (Obari,2014). In other habitats they are also seen to move to riverine areas during the dry season where there is better quality foliage at the time (Leuthold, 1978; Obari, 2014). Within the Athi Kapiti ecosystem in Kenya, it has been observed that giraffe numbers increased during the wet seasons of the short and long rains of October-November and March-May respectively. This fluctuation of numbers between different seasons is mainly attributed to differences in forage abundance, vegetation productivity and the rate of plant compensatory growth (Leuthold, 1978; Obari, 2009).

Unlike most ungulates giraffe can go for days without water (Western 1975; Fennesy 2004), they however switch to more regular drinkers with increased water availability (Brand, 2007). During dry seasons when there’s water scarcity, they depend on perennial water source and thus move long distances in search for water (Obari, 2014). In the wet season’s giraffe depend on the readily available watering points both natural and man-made. Their movement in search of water during the wet season is thus greatly limited (Obari, 2014). Water availability is a key determinant of giraffe distribution within a habitat (Brand, 2007).

2.2 Giraffe Population and LULC change

Population trends and dynamics in species is fundamentally influenced by natality, mortality migration and emigration (Turkalo, Wrege and Wittemyer, 2018). Dynamics and trends in populations of free ranging giraffe populations can also be influenced by other factors which include but are not limited to poaching, habitat fragmentation, predation and forage (Obari, 2009). Giraffe population dynamics can be studied through tracking of known individuals or herds, ground counts and aerial surveys (Leuthold 1979; Caro, 1999).

The alteration of the earth's biophysical attributes is referred to as land cover change while land use is a direct result of the human exploitation of the earth through various processes to produce desired results (Lambin *et al*., 1999). LULC changes when aggregated together, have tremendous impact on ecosystem processes and functions at both a local and global scale (Lambin *et al*., 2001). LULC changes have been observed to greatly affect biodiversity all over the world (Sala *et al*., 2000). Bulging human population across Africa has led to subsequent increase in agricultural activities which result in the acute fragmentation and depletion of wildlife habitats (Ezeh *et al*.,2012). Though encroachment of wildlife habitats might seem understandable to meet the prevailing social, political and economic needs, habitat loss is pushing species to extinction (Koh and Sodhi, 2010).

Kenya faces the continuous problem of declining wildlife species; this includes giraffe which have declined substantially in both protected and unprotected areas. The decline has been caused by recurrent droughts, growing human population and settlement, extensive agriculture and other LULC changes (Ogutu *et al*., 2011). LULC change especially for agricultural purposes and infrastructure development has led to the shrinking of giraffe habitats in Kenya, this has further resulted to high competition for space, food and water. Other human activities such as charcoal burning, over grazing and trade in giraffe meat and parts are posing a huge threat to giraffe populations. LULC change coupled with climate change and other factors are compromising the ecological viability of giraffe's historical habitats (Obari, 2014; KWS 2018 a).

Continuous trends of wildlife declines have been observed in areas faced by major LULC changes such as in Masai Mara, Athi-Kapiti plains (Ottichilo, 2000) and Amboseli (Western and Maitumo, 2004). In these areas, wildlife decline has been attributed to growing human population, habitat loss and habitat fragmentation. The Masai giraffe inhabits the southern parts of Kenya. The subspecies occupies the savannah ecosystems of Amboseli National Park, Tsavo National Parks, Naivasha, Magadi and Maasai Mara National Reserve, as well as many community areas surrounding these conservation areas. The savannah ecosystem in southern Kenya strides across the Kenya/Tanzania border thus forming transboundary giraffe ranges (Obari, 2014; O'connor *et al*., 2019).

An aerial census undertaken in February of 2017 in the larger expansive Tsavo-Mkomazi ecosystem estimated giraffe numbers at 4,323, which was a considerable increase from 2,891 giraffe counted in a similar aerial census in February of 2014. The fluctuation in population was attributed to the difference in the area covered by the two censuses. The census in the in 2014 did not cover part of the Taita ranches. The highest number of giraffes in 2017 was counted in Tsavo West National Park (TWNP) as compared to 2014 whereby the highest number was outside protected areas.

2.3 Conservation Status

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) highlights that unprecedented LULC degradation of terrestrial landscapes has had a huge impact on biodiversity and further affected long-term sustainable development (Scholes *et al.* 2018) The uncontrolled conversion of African rangelands, forests, wetlands and other natural areas for urban development and food production is on the rise. Such conversions result to habitat degradation, loss and fragmentation resulting to loss of biodiversity and livelihoods. (Scholes *et al.* 2018)

There has been decline of giraffe populations and their habitat ranges across Africa (Muller, 2018; O'connor *et al*., 2019). The enormous decrease resulted in the giraffe species being categorized as Vulnerable in 2016 by the (IUCN) Red List on Threatened Species (Muller *et al*.,2018). In August of 2019, the Conference of Parties (CoP) to the Convention on International Trade in Endangered Species (CITES) passed a resolution to place the giraffe in Appendix II (species that are not threatened with extinction but their trade has been controlled to avoid over utilization that would threaten their survival) (www.cites.org, 2019). Two giraffe sub-species which currently exist in small fragmented populations in the northern part of Africa, Kordofan giraffe (Fennessy and Marais, 2018) and the Nubian giraffe (Wube *et al*., 2018) are categorized as critically endangered by the IUCN red list on threatened species. Two giraffe sub-species which are present in Kenya, Masai giraffe and Reticulated giraffe have been reviewed recently by the IUCN Red List on threatened species and their conservation status have been lifted from vulnerable to endangered (Muneza *et al*., 2018; Bolger *et al*., 2019).

This study mainly focused on the endangered Masai giraffe found in southern Kenya. Its range has reduced by 4.7% between 2016 and 2019, with only 59% of the population occupying protected areas (O'connor *et al*., 2019). Protected areas are critical giraffe habitats but cannot independently support viable giraffe populations. These areas are not adequate in size and number for giraffe which have huge ranging patterns. Community areas and ranches adjacent to protected areas support 41% of the total Masai giraffe population (O'connor *et al*., 2019). These areas are currently under intense anthropogenic activity, intensive grazing, mining charcoal burning, farming, infrastructure development and land subdivision. These activities have greatly compromised the viability of non-protected areas as viable habitats, corridors and dispersal areas (Ogutu *et al*., 2011). The above-mentioned anthropogenic factors coupled with poaching activities pose a major threat to the already struggling endangered Masai giraffe population.

The Tsavo landscape is one of the few remaining expansive landscapes in the world that harbor free ranging endangered Masai giraffe populations (KWS 2018b). This study seeks to establish the impact of human induced LULC changes on the population and distribution of Masai giraffe in the Tsavo landscape.

CHAPTER THREE: STUDY AREA, MATERIALS AND METHODS

3.1 Study Area

Early explorers described the Tsavo landscape as vast desolate thicket baking in sweltering heat and with lurking danger at every turn (Hobley, 1895). Ravaging rivers, lone buffalos, hostile elephants, man eating lions, scorpions and poisonous snakes added to its long list of dreaded hostilities. Presently, the Tsavo landscape is the largest conservation complex in Kenya covering more than 43,000km^2 representing about 4% of the total Kenyan land mass (Hobley, 1895; Njogu, 2004; KWS, 2008a; Kamau and Sluyter, 2018).

This region has rich and well documented history which dates back to centuries. In the late pre-colonial era, there was increased demand of ivory in the Kenyan coast by Arab merchants, which converted the area into a popular ivory trade route with a wide network of traders, hunters and porters (Hobley, 1985; Steinhart, 2000; KWS, 2008; Kamau and Sluyter, 2018). The trade routes later paved way for the railway construction and subsequent colonization of Kenya (KWS, 2008; Kamau and Sluyter, 2018). The Tsavo landscape still serves as a major African trade corridor, it harbors the Northern transport corridor that links the port of Mombasa to Uganda, Burundi, Rwanda, DRC and Ethiopia (Northern Corridor Transit & Transport Coordination Authority, 2018). It is occupied by five communities who after displacement formed a ring around the TENP and TWNP. They include; Maasai, Taita, Taveta, Kamba, Oromo and Watta. The communities in the landscape have diverse socio-economic practices which range from hunting, pastoralism, farming and mixed agriculture. (Kamau and Sluyter, 2018). Tsavo landscape lies in four counties namely Kitui, Tana River, Taita Taveta and Kajiado. South wards it extends to the Kenya Tanzania border (KWS, 2008; Kamau and Sluyter, 2018). The landscape encompasses National parks, National reserves, farms, ranches, conservancies and community areas that provide interesting LULC interphases in wildlife conservation between protected and unprotected areas (Njogu ,2004; KWS, 2008). The study focused on several study sites that were representative of the entire study area.

3.2 Study Sites

The study was conducted in TWNP, SKNR, TENP and in the ranches, conservancies and community areas (Figure 3.2). TENP and TWNP are Kenya's largest Parks, TENP is about 12,000 km^2 and TWNP covers an area of 9,000Km ^{2}, they were both established in 1948 (KWS, 2008). SKNR is found in Kitui County, it was established in 1979 and has an area of about 1,833km^2, it borders

TENP to the south and Tana River County to the east (KWS, 2018b). Taita ranches constitute numerous private and community ranches on the southeastern side of the Tsavo landscape. The study only sampled giraffe in 5 ranches (Maungu Ranch, Kasigau Ranch, Taita Ranch, Rukinga ranch and Lumo Community Wildlife Conservancy). Rombo Group Ranch which borders TWNP on the southern western side, was also included in the study.

The Tsavo landscape is characterized by vast plains that are occasionally punctuated by hills and inselbergs. This explains the huge elevation range of between 400 meters and 2,000 meters above sea level in the area. The difference in elevation accounts for the difference in precipitation and vegetation throughout the entire landscape (Leuthold, 1978; KWS, 2008; Mukeka, 2010). The vast plains change from woodlands and semi-arid *Acacia* scrub to savannah bush land and grasslands. *Acacia -Commiphora* account for the highest percentage of the woody plants' species found in the landscape. The density of *Acacia-Commiphora* shrubs and trees vary seasonally and spatially throughout the landscape (Leuthold, 1978; KWS, 2008).

The landscape has a bimodal rainfall pattern with the short rains occurring between November and December and the long rains occurring between April and June (Mukeka, 2010). TWNP, Taita Ranches and Rombo Group Ranch have an annual rainfall of about 100-1200 mm. This part of the landscape has much denser vegetation as compared to TENP and SKNR which has an annual rainfall of about 200-500mm. Galana and Tsavo are the two permanent rivers in the area amidst many seasonal rivers, water pans and boreholes. Riverine forests across the landscape are among the most vegetated areas forming closed canopy forests all year round (Leuthold, 1978; Wijngaarden,1985; Mukeka, 2010; KWS, 2018b). Soils in the Tsavo landscape show a wide range physical and chemical properties. The soils are rich in ferruginous gravel and quartz, with finer sand cemented by a red lateritic crust. Gravel and sand of the alluvial soils are cross-bedded together along the river loops of the Galana (Ngene *et al*., 2013).

Tsavo landscape has the highest diversity of fauna in Kenya, and also harbors the largest population of free ranging elephants (Blanc *et al*., 2007; Omondi *et al*., 2008). Other notable large mammals include; black rhino, buffalo, leopard, hippo (*Hippopotamus amphibius)*, giraffe and lion (Cobb 1976; Wijngaarden, 1985; Mukeka 2010). TENP and TWNP jointly receive an average of 200,000 visitors per year making the Tsavo ecosystem the second most popular wildlife tourist destination after the Masai Mara (KWS 2008; KWS 2017).

3.3 Study Design

Topographical maps for the Tsavo landscape were obtained from the AWF GIS LAB and the specific study area was delineated. The study area was divided into 5 study regions; Rombo Group Ranch, SKNR, TENP, TWNP, and the Taita ranches.

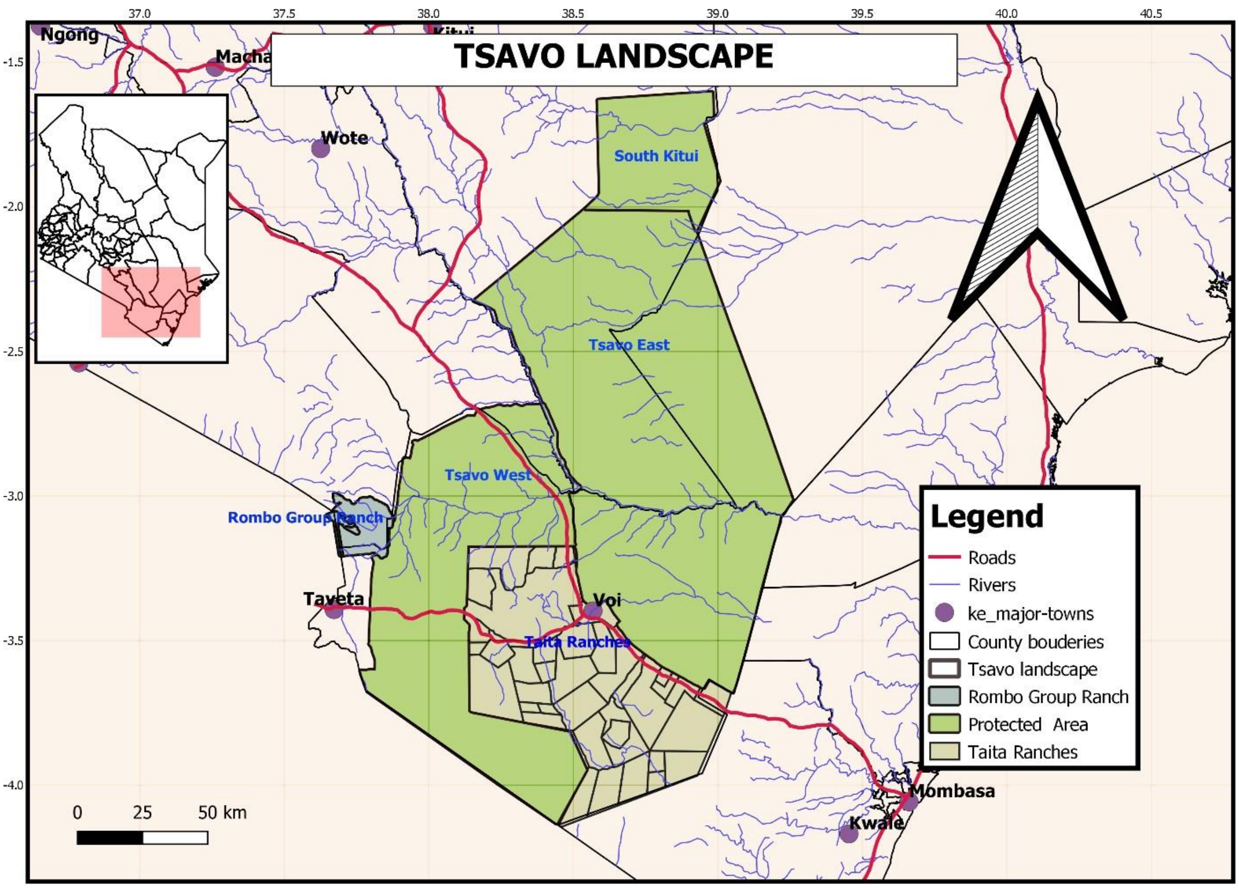

Figure 1: Map of the Tsavo landscape

Source: AWF GIS Lab

To determine the current Masai giraffe demography and distribution, each of the five regions were surveyed three times. Two surveys covered the dry season of Jan-March 2020/2021 and July-September 2020, while one survey covered the wet season November-December 2020.

To establish past Masai giraffe population trends, past aerial count data were obtained from KWS and Department of Resource Survey and Remote Sensing (DRSRS) who have been conducting large mammal aerial censuses every three years since 1980's. The methods adopted for these aerial surveys are as described by (Eltringham and Norton-Griffiths, 1977; Ngene *et al*., 2013, 2017).

An aircraft flies within a one-kilometer width transect and large mammals including Masai giraffe are sampled 500m on each side of the aircraft. The aircraft flies at a speed of 80-90 knots and at a consistent height of between 300 and 350 ft. Depending on wind direction and terrain condition, the transects are flown from north-south or west-east directions. The surveys are carried out by trained and experienced pilots and observers

GIS, Satellite remote sensing and statistical analysis are lucid, cost-effective tools that can be used to establish spatial temporal dynamics in LULC changes (Jat, Garg and Khare, 2008; Serra, Pons and Saurí, 2008; Dewan and Yamaguchi, 2009). In order to establish LULC change in the Tsavo landscape, six landsat satellite images which covered the extent of the study area and had less than 20% cloud cover, were downloaded from the United States Geological Survey (USGS) GloVis website (www.glovis.usgs.gov,2020). The images were for the years 2020,2010,1999 and 1985.They covered the period between January – March which represents the dry season in the study area (Appendix 4). Landsat images lay in paths 167 and 166, and rows 61,62 and 63. Using the Semi-Automatic Classification (SCP) plugin (Conged, 2020) in QGIS Version 3.8.3 software (QGIS Development Team 2019), the 6 downloaded Landsat images for each of the years were projected to Universal Transverse Mercator (UTM) zone 37s. They were then mosaicked (joined) and the study area clipped. Areas in the clipped image that had high cloud cover were masked. The images were then analyzed to establish LULC change in the Tsavo landscape over time.

3.4 Data Collection

3.4.1 Masai giraffe population in the Tsavo landscape

Masai giraffe data were obtained through road transects counts on 51 roads that covered a total distance of 1,574 kms throughout the landscape (Figure 3.3). Each of the road transects were divided into 10 km long strips that represented the basic Masai giraffe sampling units. Road transects are based on the principle that a vehicle is driven along already established road system that is representative of the study area and the researcher collects data on sighted animals within a predetermined distance from the vehicle (Eltringham and Norton- Griffiths, 1977). During the field surveys, the vehicle was driven at average speed of 30km/hr. and giraffe were actively searched and tracked along the road transects. All Masai giraffe sighted within 1000 meters from the transect were recorded, Masai giraffe are relatively tall and could be spotted at that distance.

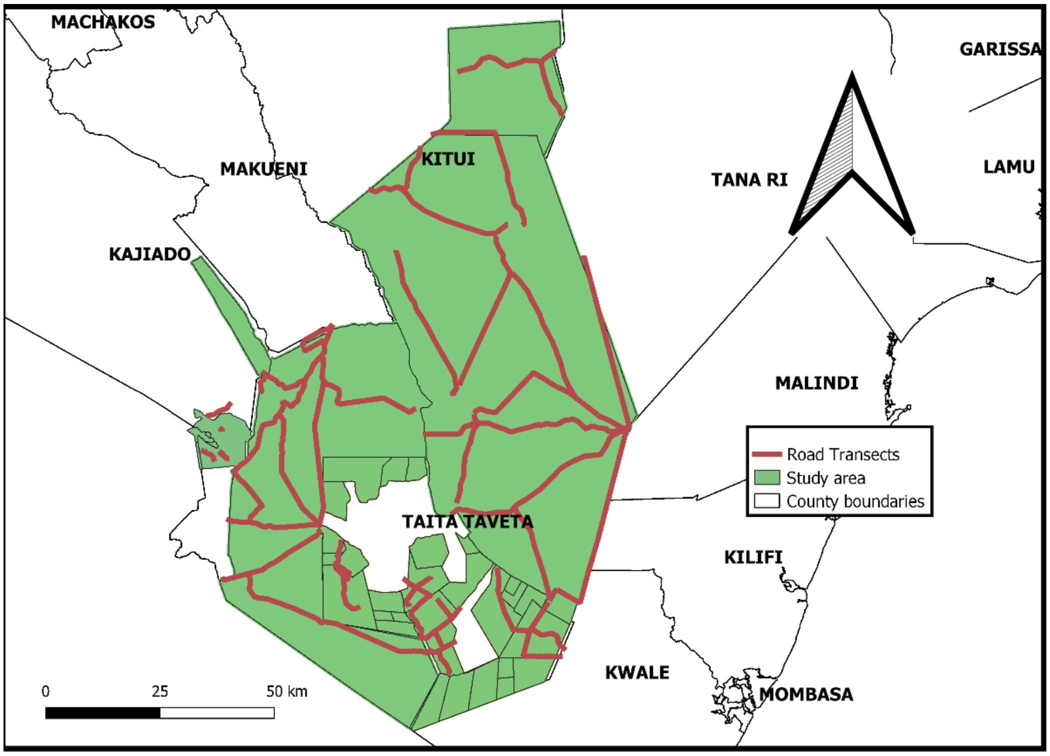

Figure 2: Road transects in the Tsavo landscape

Three surveys were carried out in each of the 5 regions (SKNR, TENP, TWNP, Taita Ranches and Rombo Group Ranch). Two surveys covered the dry season of Jan-March 2020/2021 and July-September 2020, while one survey covered the wet season October-December 2020. Each survey started in the early morning and was conducted between 6:00am and 10:00am. Individual Individuals and herds were located visually and using a pair of binoculars. Upon sighting the animal G.P.S coordinates, distance and angle from the vehicle were recorded. The number, sex and age of Masai giraffes seen were recorded in the field using cyber tracker mobile application (Ansell and Koenig, 2011). Counts were used to estimate population and density using Distance 7.3 software (Thomas *et al.*, 2010), which introduces a detection function that models the decrease in animal detectability with increasing distance from the observer (Buckland *et al.*, 2001). Using the obtained samples total animal population and density were estimated.

$$\hat{D} = n/2wL\hat{P}_a$$

D is the estimator of wildlife density; n is the total number of counted wildlife from a line of L length within w distance from the line. For this case , L was the road transect length while w was the distance from the observer to the sighted animal. P is the probability of detection for an object within an area a. Pa can be expressed as below:

$$P_a = \frac{\int_0^w g(x)dx}{w}$$

g(x) is detection function in relation to x length which is the distance between the line and the object. Distance sampling assumes that; there are no errors in measuring distance, probability of detecting animals along a transect is 1 and animals do not move (Iijima, 2020).

To determine past Masai giraffe population trends, a review of secondary data on past large mammal counts from censuses conducted in the Tsavo landscape since the 1970‘s to 2020 was conducted. Secondary data was obtained from KWS (Ngene *et al*., 2013, 2017) and Department of Resource Survey and Remote Sensing (DRSRS) (Grunblatt *et al.*, 1996; DRSRS, 2003).

3.4.2 Land use Land Cover Change Assessment

LULC change assessment was conducted on the entire Tsavo landscape and also in Rombo Group Ranch within the Tsavo landscape. The study took a particular interest in Rombo Group Ranch because at the time of the study, Rombo Group Ranch was observed to be a Masai giraffe hotspot. The transboundary nature of Rombo Group Ranch in the Kenya-Tanzania border also provided an interesting dynamic to role of the ranch in wildlife conservation.

Supervised Image classification was conducted on the processed downloaded images using the SCP plugin (Congedo Luca, 2020) in the QGIS Version 3.8.3 software (QGIS Development Team 2019). Classification used false color composite bands for land cover interpretation and analysis. Homogenous pixels were clustered into the predetermined LULC classes. Maximum Likelihood distance classifier (Maktav and Berberoglu, 2018) was used to classify the images for the years 1985,1999,2010 and 2020. Nine land use and land cover types were identified and classified according to Lambin *et al*., (2001) guidelines as forests, woodland, *Acacia* woodland, closed bushland /*Comiphora* thicket, bareland with scattered trees, grassland/perennial shrubs, settlement, agriculture and water (Table 3.1). Classification was based on the dominant LULC types in the Tsavo landscape as described by KWS (2018a), Mukeka (2010), Leuthold (1978), and Wijngaarden, (W.1985).

Table 1: Land Use Land Cover types in the Tsavo landscape

LULC Type	**Description**
Forest	Evergreen closed canopy trees that mostly occur along sections of permanent rivers and on top of Taita, Ngulia , Sagala and Kasigau hills .Vegetation also occurs on the Chyulu ranges.
Woodland	Semi-ever green trees that occur at high elevations areas next to forests. They also form a major part of the riverine vegetation.
Acacia Woodland	Mainly comprise open woodlands interspersed with grassland or bare ground. It occurs most parts of the Tsavo landscape with *Acacia tortilis* being the dominant tree species
Grassland	Characterized by sections of pure grasslands and perennial shrubs. In some sections of the landscape, the grasslands are dotted with *Acacia* trees
Bareland	Degraded areas with exposed soil and scattered trees, it includes areas along river banks.
Agriculture	Sisal plantations, Irrigated agriculture and rain fed agriculture
Settlement and Built-up	Areas with human settlements.
Water	Water bodies including rivers and lakes

Closed Bush/*Commiphora* thicket	Mainly comprised of *Commiphora* tree species that are closed and impenetrable. The common *Commiphora* species are, *Commiphora campestris*, *Commiphora baluensis,Commiphora schimperi* and *Commiphora africana* .

A total of 4,764 training and validation points were collected in the Tsavo landscape (Figure 3.4). They were used to train the model for LULC change analysis and accuracy assessment. LULC training points are used to train, validate and assess the accuracy of a classification (Wahap and Shafri, 2020). The points were randomly selected through manual interpretation of high-resolution images from google earth engine as described by Phan, Kuch and Lehnert, (2020), Wahap and Shafri (2020) and Bwangoy *et al*., (2010). Overall accuracy, producer accuracy and user accuracy were calculated using 30 % of the training points while 70% of the points were used to train the model.

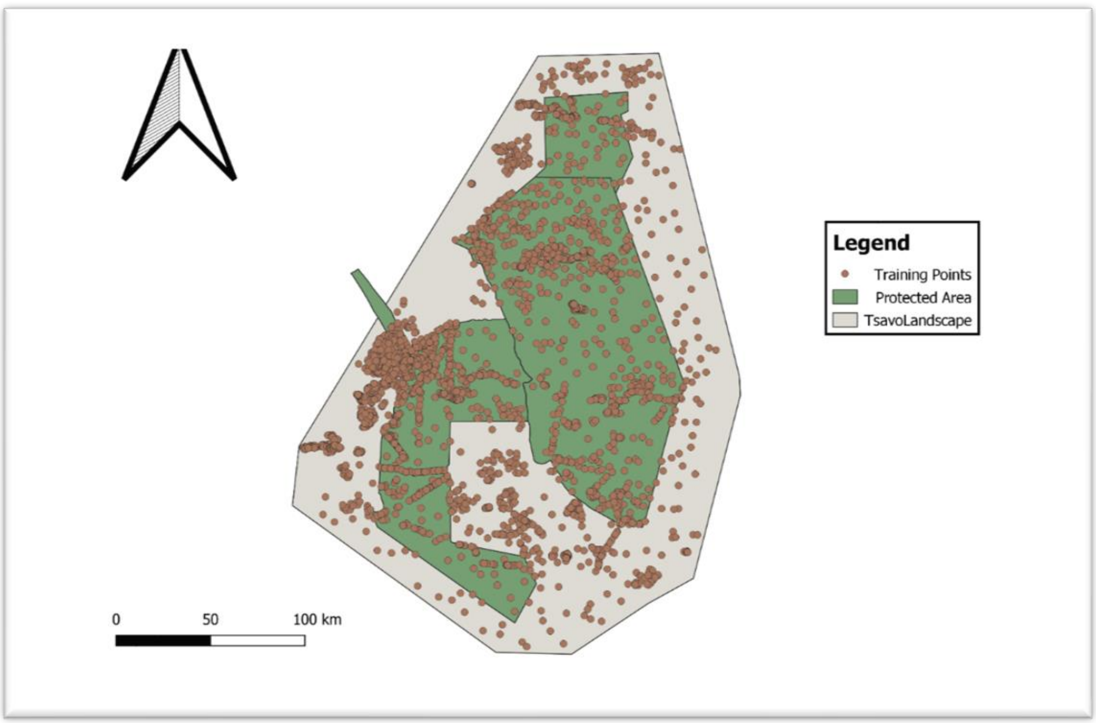

Figure 3: Tsavo landscape training points

3.5 Statistical Analysis

Collected data were sorted in Ms. Excel (Microsoft Corporation, 2018), all statistical analyses were conducted in R Version 4.0.3 (R Core Team 2020) using R Studio version 1.3 (RStudio Team 2020). Kruskal- Wallis test, was used to analyze the difference in Masai giraffe density and population among the five regions. Masai giraffe sex-age structure, seasonal distribution and LULC change were tested using Chi-squared goodness of fit test as described by Glover and Mitchell, (2016). Nonparametric statistical tools (Kruskal-wallis and Chi- squared tests) were preferred to their parametric equivalents in cases where data were not normally distributed and data transformation could not correct non-normality. Trends in Masai giraffe populations over time as well as the impact of water availability on Masai giraffe distribution were tested using regression analysis. For all statistical tests, $\alpha \leq 0.05$ was considered significant for all calculations.

CHAPTER FOUR: RESULTS

4.1 Masai giraffe Population and Distribution

4.1.1 Masai giraffe Population

Masai giraffes were sighted in all regions within the Tsavo landscape except in SKNR. Population differed significantly among the different regions ($H(4) = 11.60$, $P < 0.05$*), this was attributed to size differences between the regions, TWNP had the highest population at (1,329.67± 187.90) followed by TENP at (757.67± 345.03). Rombo Group Ranch had (263.67± 149.67) while Taita ranches had (174.33± 46.15), (Figure 4.5 and Appendix 2).

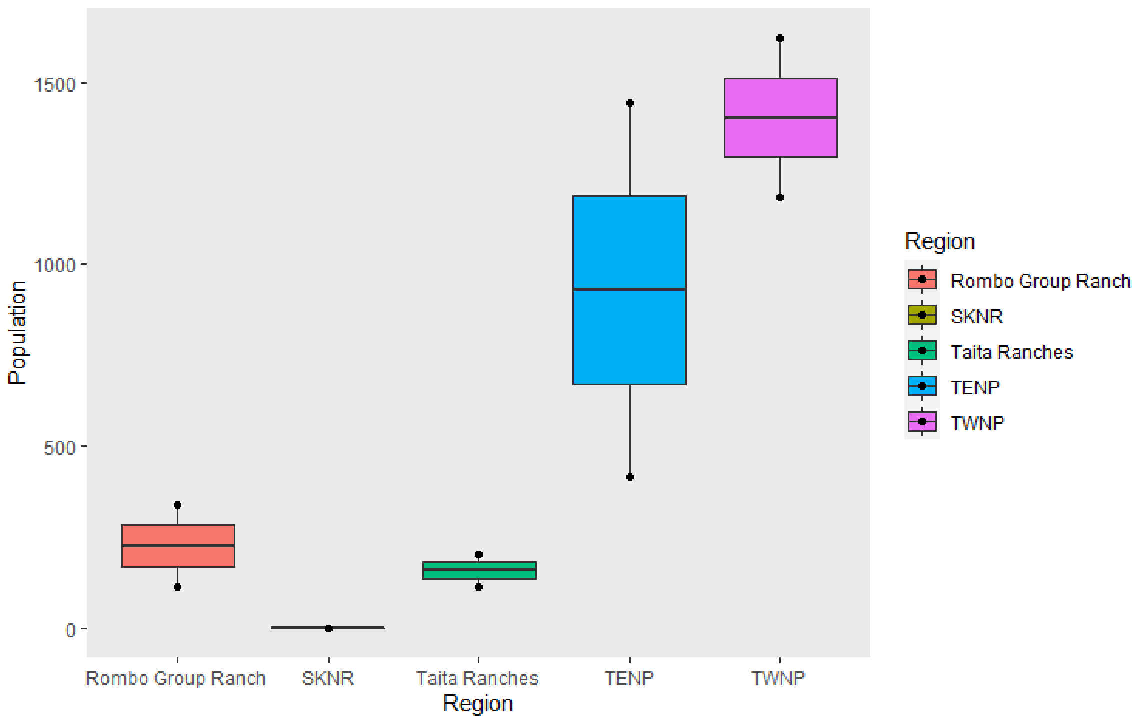

Figure 4: Masai giraffe Population in the Tsavo landscape

4.1.2 Masai giraffe Density

Population density was calculated by dividing Masai giraffe population in each region by its respective area (Wilson *et al*., 1996). The study found out that Masai giraffe population density varied significantly between different regions within the Tsavo landscape ($H(4) = 13.00$, $P < 0.05$*).

Rombo Group Ranch had the highest density of Masai giraffe at (0.65± 0.33) followed by TWNP at a density of (0.19± 0.03). Taita Ranches and TENP had (0.09± 0.02) and (0.05± 0.03) respectively. There were no Masai giraffe sightings at SKNR (Figure 4.6 and Appendix 2).

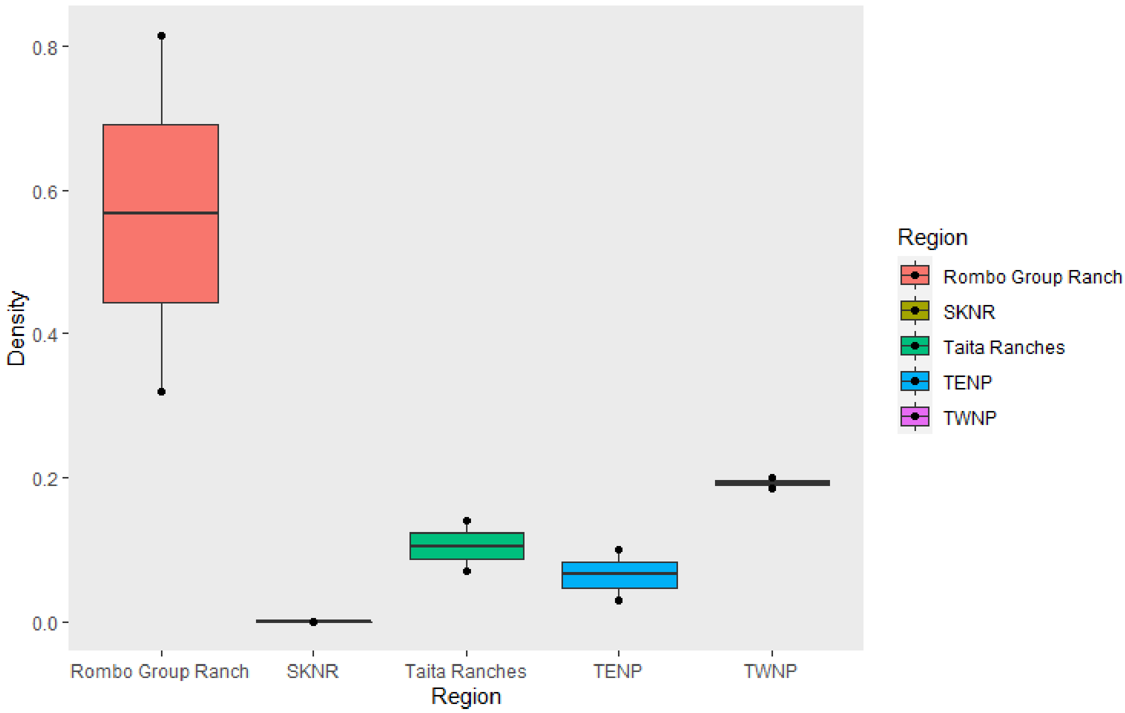

Figure 5: Masai giraffe Density in the Tsavo landscape

4.1.3 Masai giraffe sex and age structure

A total of 851 Masai giraffes were sighted during the entire sampling period. Females constituted 44.18% and males constituted 24.91% of the sighted Masai giraffe in the study area. Male to female sex ratio was 1.00: 1.63. Among the observed individuals, 85.55% were adults, 7.76% subadults, and only 6.70% were juveniles. The ratio of subadults to adults was 1.00: 11.02 and juveniles to others was 1.00: 13.92 (Figure 4.7). TENP had the highest proportion of adults followed by Rombo Group Ranch, TWNP and Taita Ranches had the least proportions of adults respectively. There was significant difference in the distribution of Masai giraffe age classes within the different regions in the Tsavo landscape (χ^2 = 38.34, df = 18, P < 0.01**).

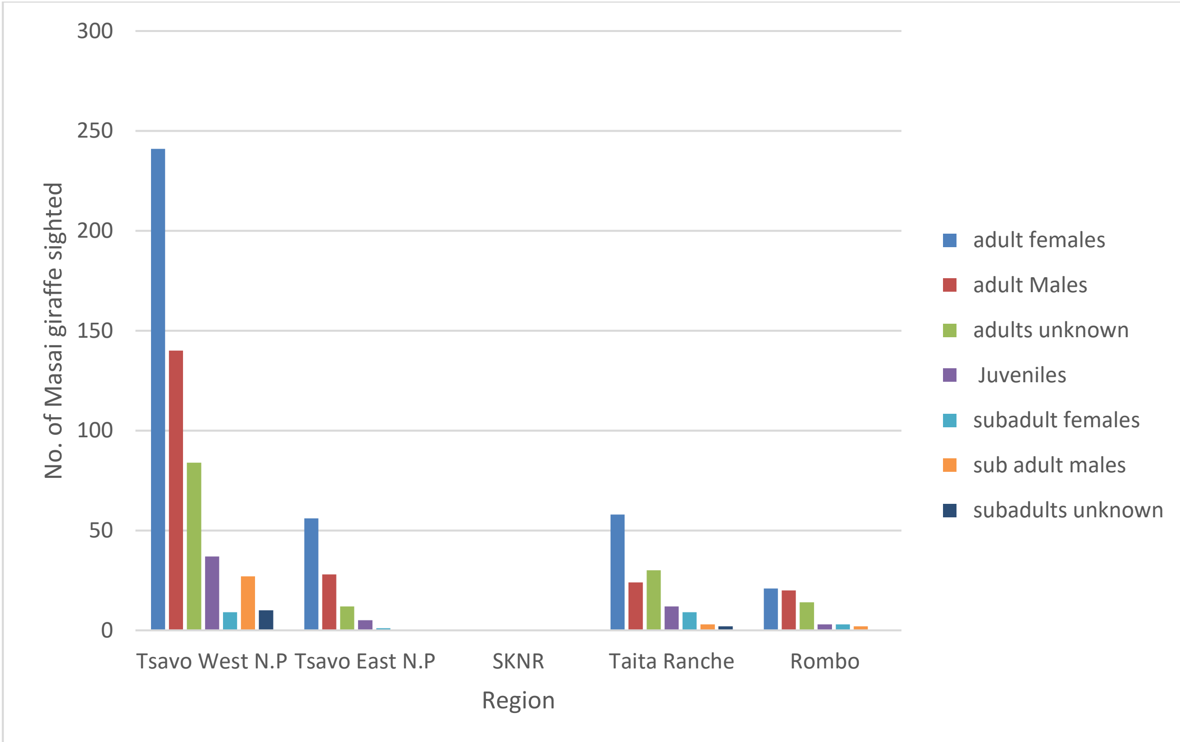

Figure 6:Masai giraffe age structure in the Tsavo landscape

The overall male to female sex ratios in the Tsavo landscape were 1:1.63 (244 males to 398 females), this departed significantly from the 1:1 male to female sex ratio ($\chi^2 = 36.941$, df = 1, $P < 0.01$**) (Figure 4.8).

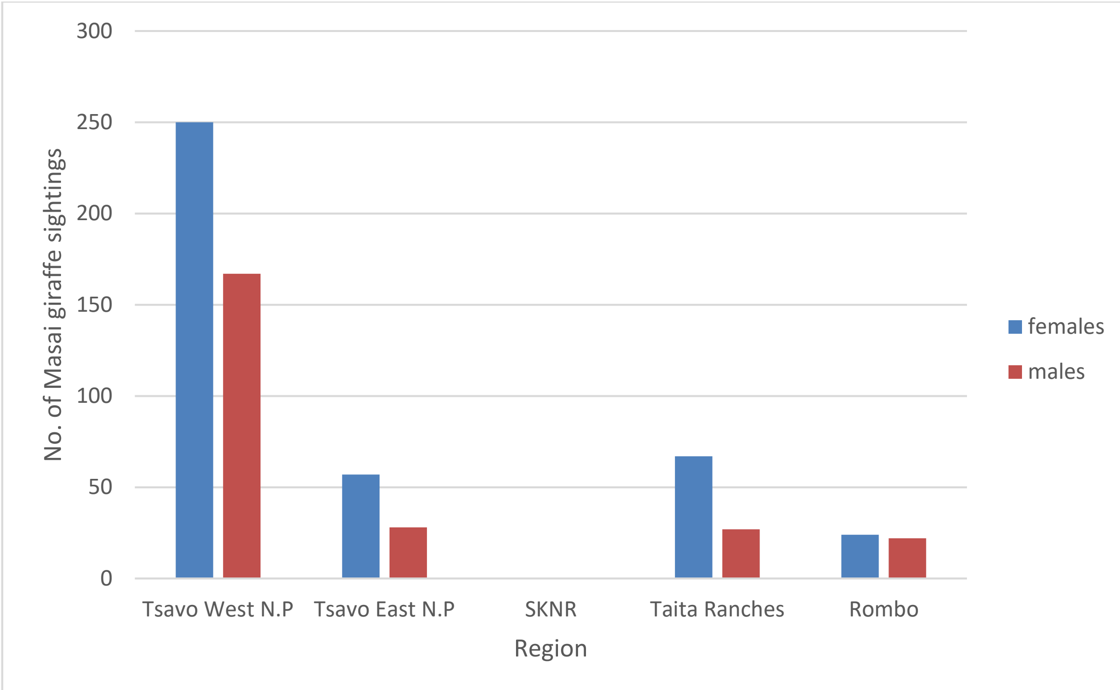

Figure 7:Masai giraffe male to female sex ratio

4.1.4 Masai giraffe population trends

Masai giraffe population has been decreasing in the Tsavo landscape since the 1970's (Figure 9). The sharpest decrease was between 1990's and 2005 where the population dropped from 5,744 to 1,258 individuals. There has however been a drastic increase in population between 2014 and 2017, during this time the population increased by 98% from 869 individuals to 1724 individuals (Figure 4.9). Masai giraffe population was negatively correlated to change in time, ($F_{1,6} = 8.66$, $R = -0.77$, $P < 0.05$*)

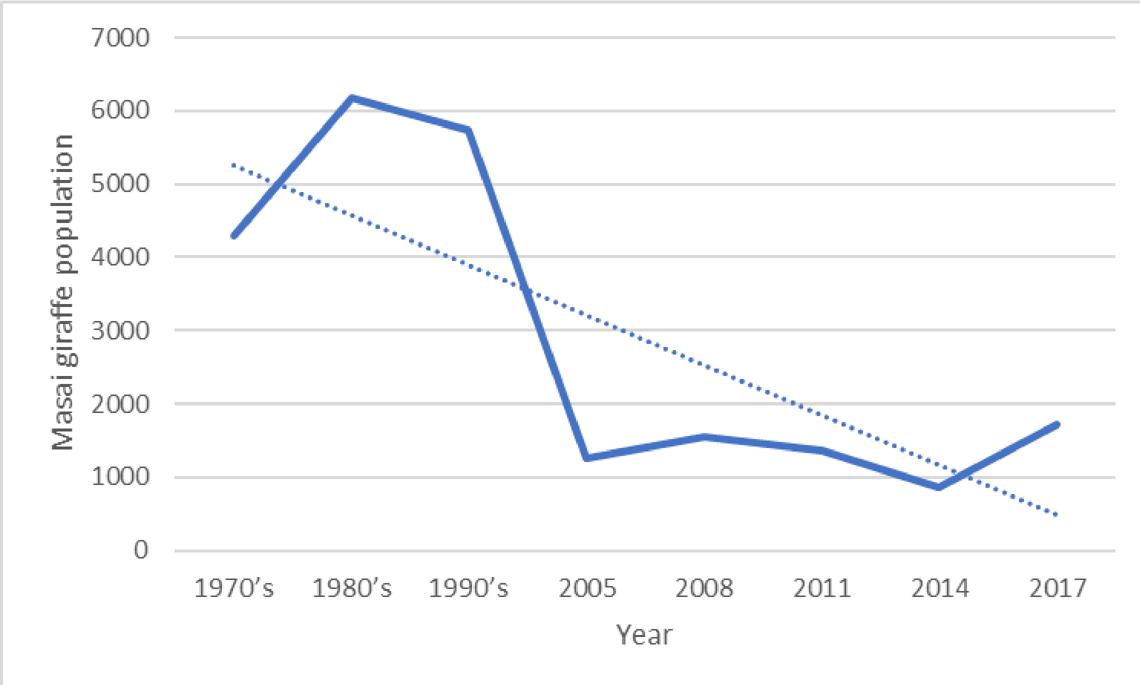

Figure 8: Masai giraffe population trends in the Tsavo landscape

4.2 Impact of water availability on the distribution of Masai giraffe in Tsavo landscape.

The study observed that rivers and artificial watering points impact on the distribution of Masai giraffe throughout the Tsavo Landscape. Masai giraffe sightings decreased significantly with increasing distance from water sources. Permanent rivers and wet artificial water points had a significant influence on their population and distribution ($F_{1,11} = 35.88$, $R = -0.88$, $P < 0.01$**) and ($F_{1,11} = 69$, $R = -0.93$, $P < 0.01$**) respectively. On the other hand, dry artificial water points and seasonal rivers had insignificant impact on Masai giraffe distribution at ($F_{1,11} = 3.36$, $R = -0.48$, $P > 0.05$ NS) and ($F_{1,6} = 5.29$, $R = -0.69$, $P > 0.05$ NS) respectively (Figure 4.10, Figure 4.11, Figure 4.12, Figure 4.13 and Figure 4.14).

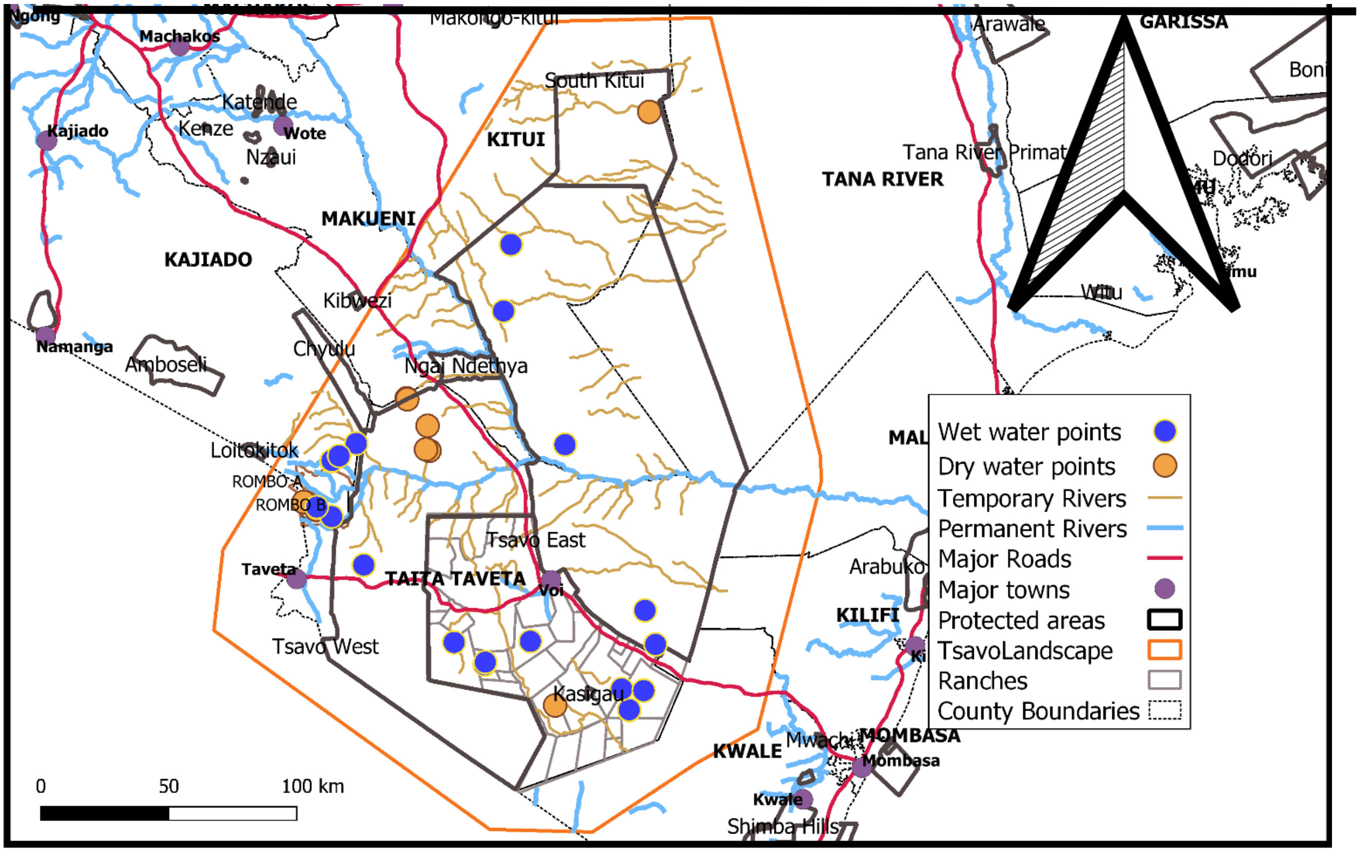

Figure 9: Waterpoint distribution in the Tsavo landscape

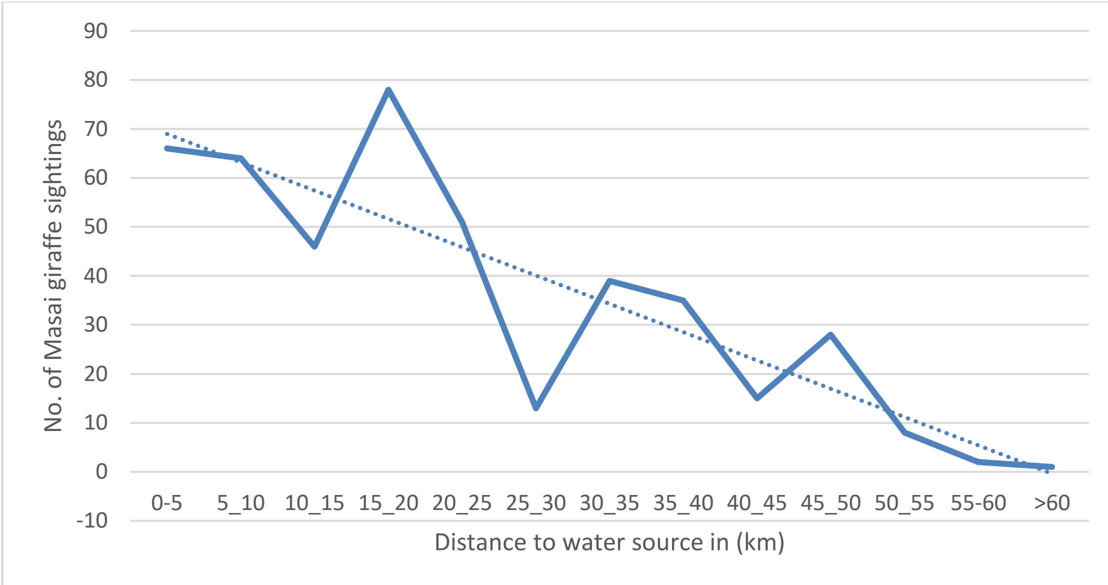

Figure 10: Masai giraffe distance to permanent rivers

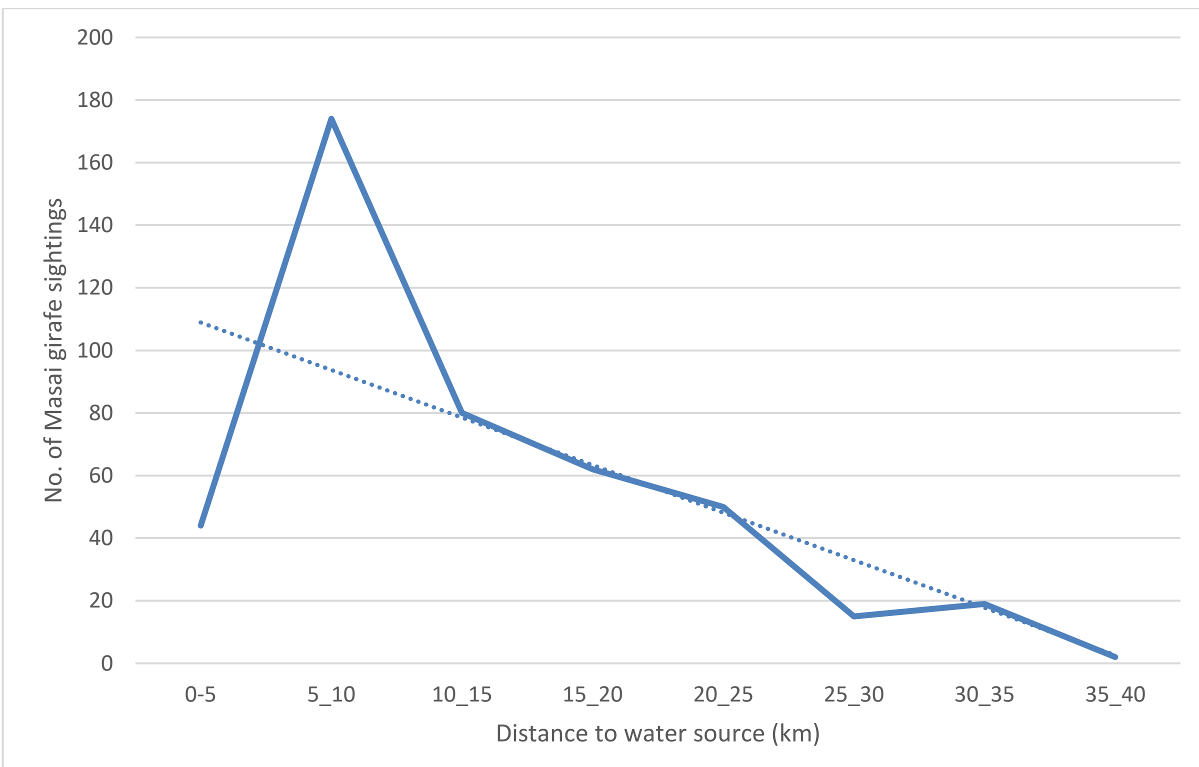

Figure 11: Masai giraffe distance to seasonal rivers

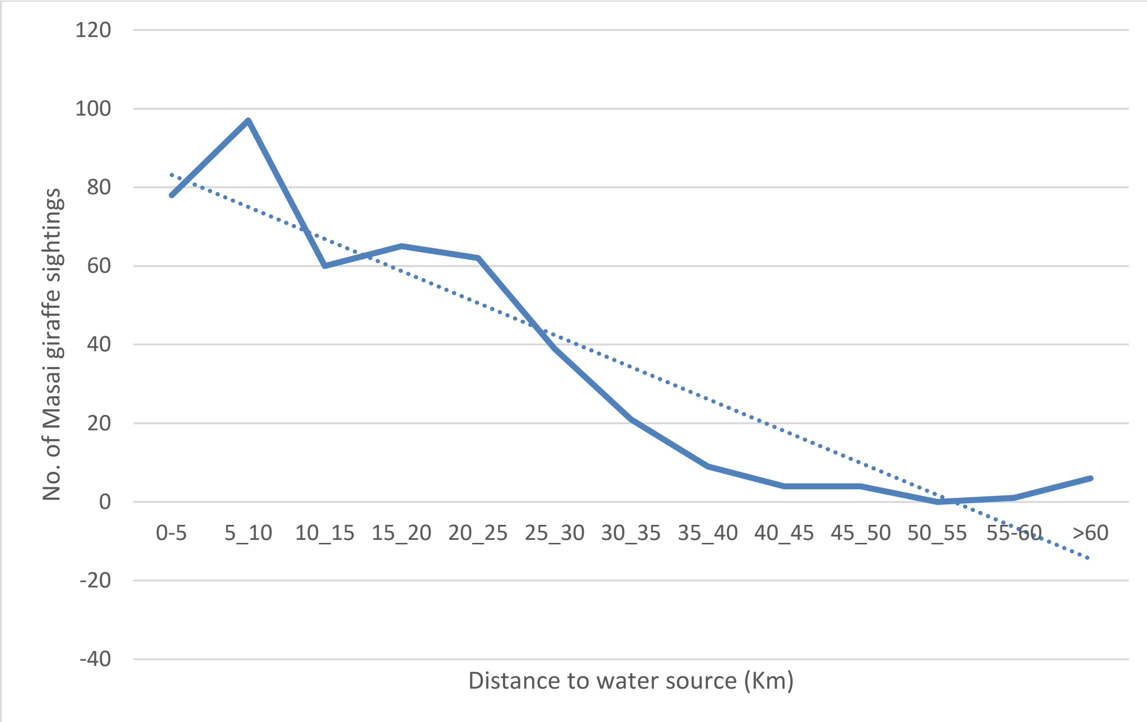

Figure 12: Masai giraffe distance to wet artificial water points

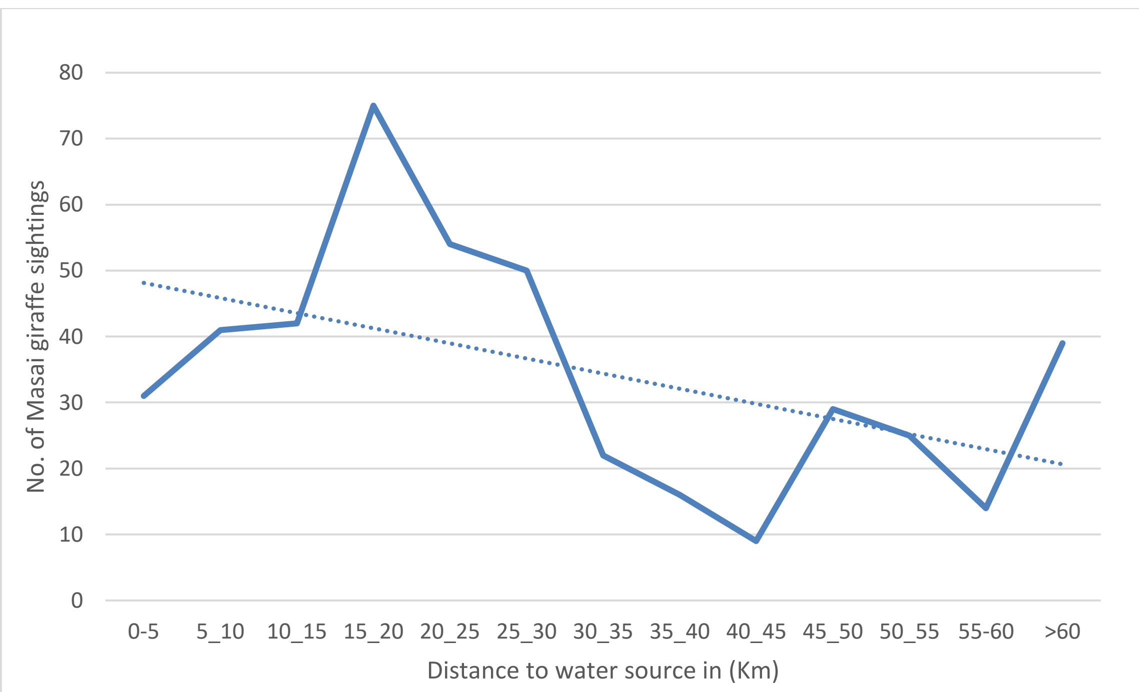

Figure 13: Masai giraffe distance to dry artificial water points

4.3 Impact of seasons on Masai giraffe distribution

Distribution of Masai giraffe differed significantly among seasons in all regions of the Tsavo landscape. TWNP (χ^2 = 68.71, df = 1, P< 0.01**), (TENP χ^2 = 571.79, df = 1, P < 0.01**), Taita ranches (χ^2 = 25.96, df = 1, P < 0.01**) and Rombo Group Ranch (χ^2 = 111.75, df = 1, P > 0.01**), SKNR had no Masai giraffe sightings. TWNP and TENP had high Masai giraffe numbers during the wet season 1622 and 1445 respectively as compared to the dry season where they had 1183 and 414 respectively. On the contrary, Taita Ranches and Rombo Group Ranch had higher numbers during the dry season and much lower numbers during the wet season. Taita ranch had an average of 114 Masai giraffe in the wet season and 205 Masai giraffes in the dry season. Rombo Group Ranch had 114 Masai giraffes in the wet season and 339 Masai giraffes in the dry season (Figure 4.15).

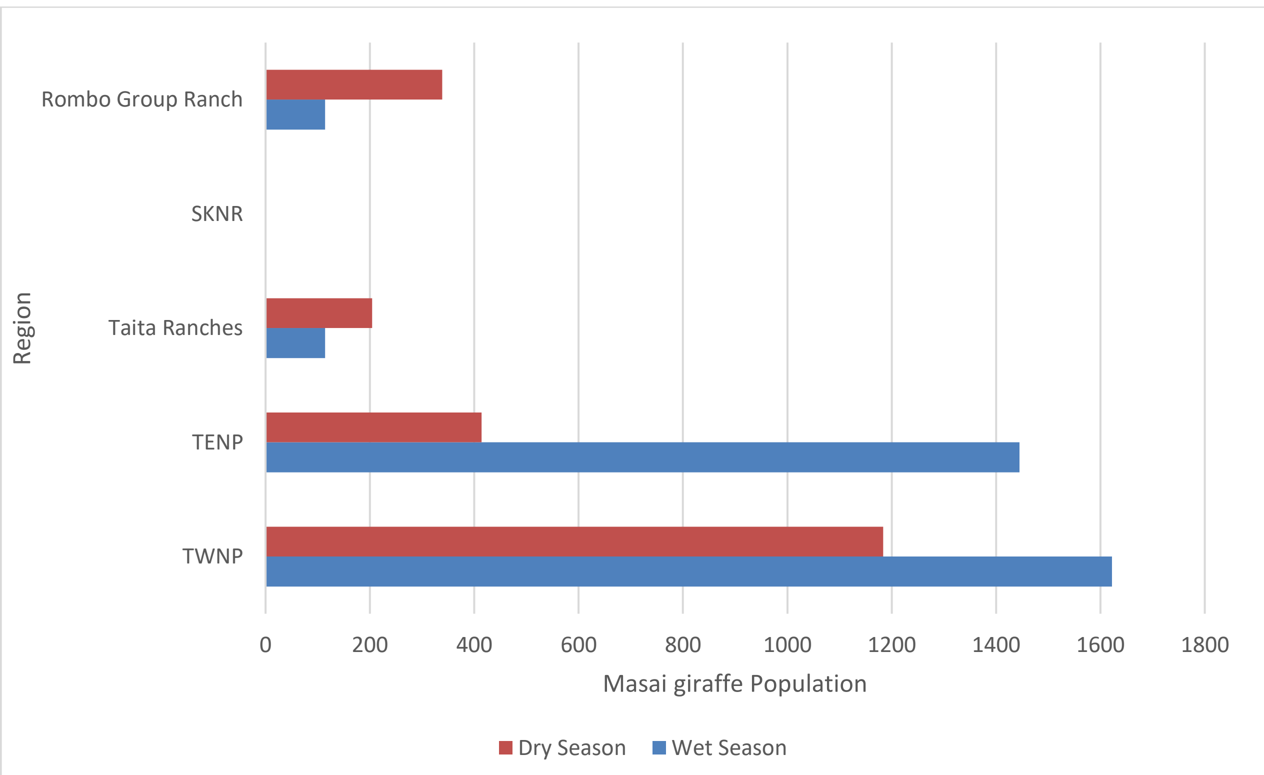

Figure 14: Masai giraffe population during different seasons

4.4 Land Use land Cover change analysis

4.4.1 LULC change in the Tsavo landscape

The area covered by the various LULC classes varied significantly between 1985 and 2020 in the Tsavo landscape. The average overall accuracy for the classification 52% (Appendix 5). Forest (χ^2 = 286.91, df = 3, P < 0.01**), woodland (χ^2 = 411.97, df = 3, P < 0.01**), *Acacia* woodland (χ^2 = 4820.30, df = 3, P < 0.01**), bushland and *Commiphora* thicket (χ^2 = 355.20, df = 3, P < 0.01**), grassland (χ^2 = 2678.30, df = 3, P < 0.01**), bareland (χ^2 = 3413.80, df = 3, P < 0.01**), agriculture (χ^2 = 1626.20, df = 3, P < 0.01**) and settlement (χ^2= 448.97, df = 3, P < 0.01**). Though the area covered by water decreased, the decrease was not significant (χ^2 = 3.42, df = 3, P > 0.05 NS).

Area covered by *Acacia* woodland had the highest decrease in land cover at an overall average of 44% with the highest decrease occurring between 1999 and 2010 at 85%. Forests had an average decrease in area of 25%, the highest decrease was 34%, it occurred between 1999 and 2010. Overall decrease in area covered by woodlands was 23%, the highest decrease in woodland occurred between the years 1999 and 2010 at 32%. Closed bush land had an average decrease in area of 6% with the highest decrease occurring between 1985 and 1999.

Settlement had the highest increase in land cover at 55.60%, the highest increase occurred between 1985 and 1999 at 68.80%. Bareland increased by 43.20%, highest bareland increase happened between the years 1985 and 1999. Average increase in land covered by agriculture was 35% with the highest increase in size of land under cultivation occurring between 1985 and 1999 at 50.30%. Grassland increased by 11.60% with the highest increasing between 1985 and 1995 (Figure 4.16, Figure 4.17, Figure 4.18 and Figure 4.19).

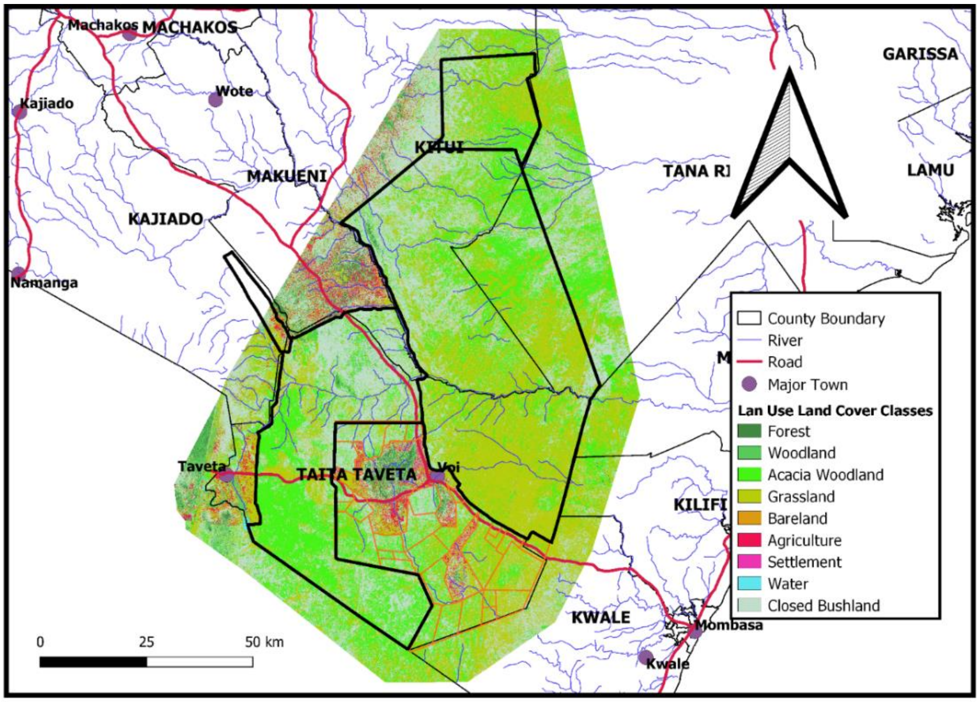

Figure 15: Tsavo landscape 1985 LULC map

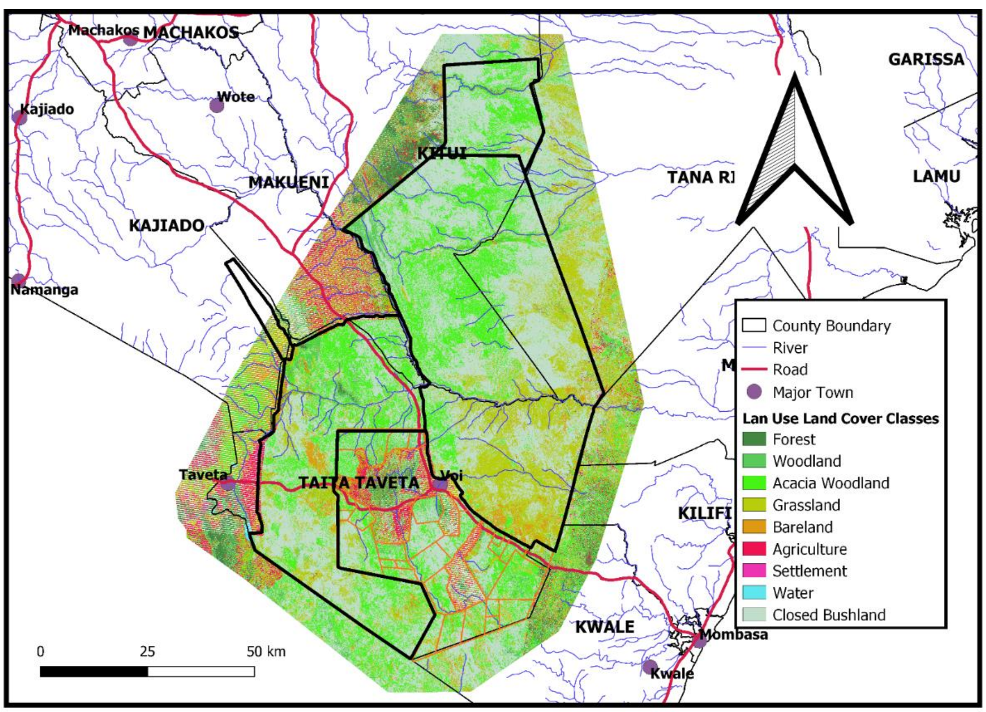

Figure 16*:* Tsavo landscape 1999 LULC map

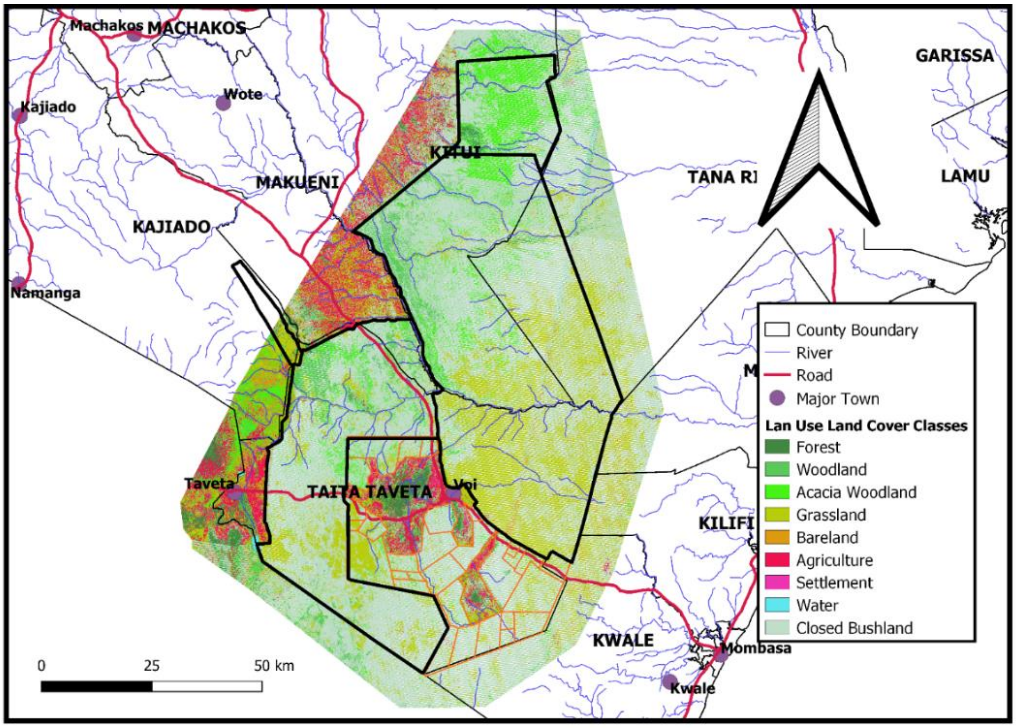

Figure 17: Tsavo landscape 2010 LULC map

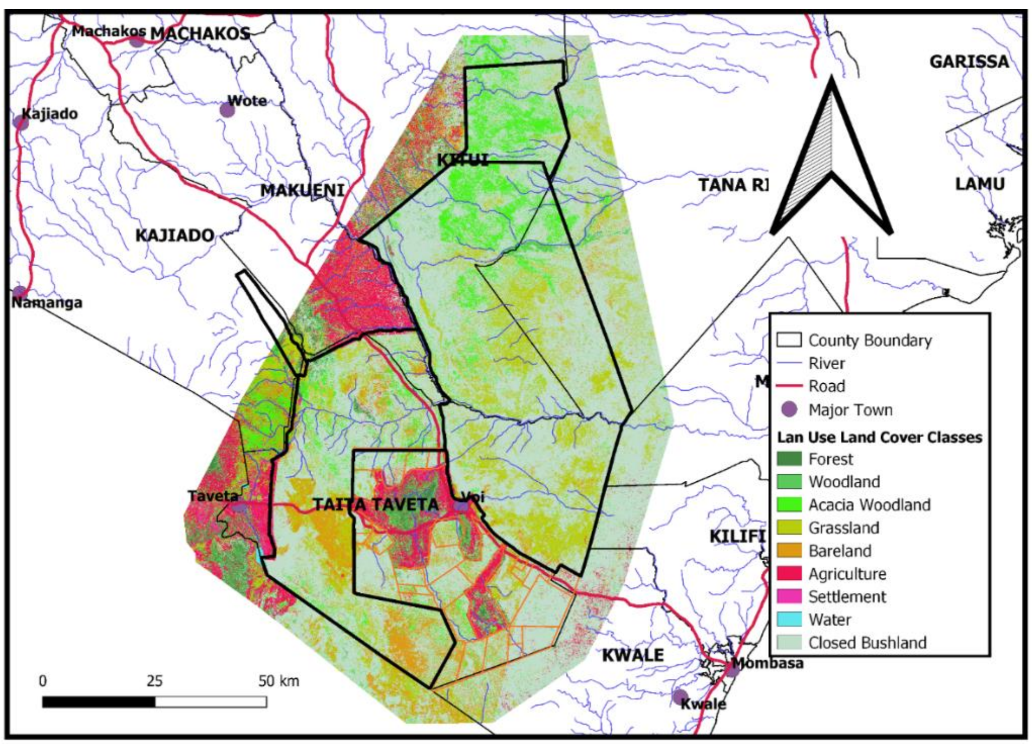

Figure 18: Tsavo landscape 2020 LULC map

Average area covered by each LULC type was calculated for the years 1985,1999,2010 and 2020. Closed bushland/*Commiphora* thicket was the most dominant vegetation type with an average area totaling to 46% in the whole landscape. This was followed by *Acacia* woodland and grassland at 16.9% and 16% respectively. Area covered by bareland land represented an average of 8% while agriculture comprised of 5.20%. Woodland covered an average area of 4.20% while forest covered an average area of 2.60%. Settlement covered an average area of 0.90%, water had the least coverage at 0.20%.

4.4.2 LULC change in Rombo Group Ranch

The study zeroed in on Rombo Group Ranch that is within the Tsavo landscape because it is a Masai giraffe hotspot. The average overall accuracy for the classification 74% (Appendix 5). Chi-squared tests revealed that there was significant change in the area covered by agriculture (χ^2 = 62.62, df = 3, P < 0.01**), bareland (χ^2 = 19.45, df = 3, P < 0.01**) and *Acacia* woodland (χ^2 = 18.13, df = 3, P < 0.01**). There was no significant change on the area under woodland (χ^2 = 6.99, df = 3, P > 0.05NS), grassland (χ^2 = 4.55, df = 3, P > 0.05NS) and settlement (χ^2 = 0.83, df = 3, P > 0.05 NS).

The overall average decrease in area covered by woodlands was 71.50% while area under *Acacia* woodland decreased by 10%. The highest decrease in area covered by woodlands occurred between 2010 - 2020 at 117.80%. Bareland had the greatest increase at 71.10% while agriculture increased by 32.80%. Grassland and settlement increased by 17% and 57% respectively. (Figure 20, Figure 21, Figure 22 and Figure 23).

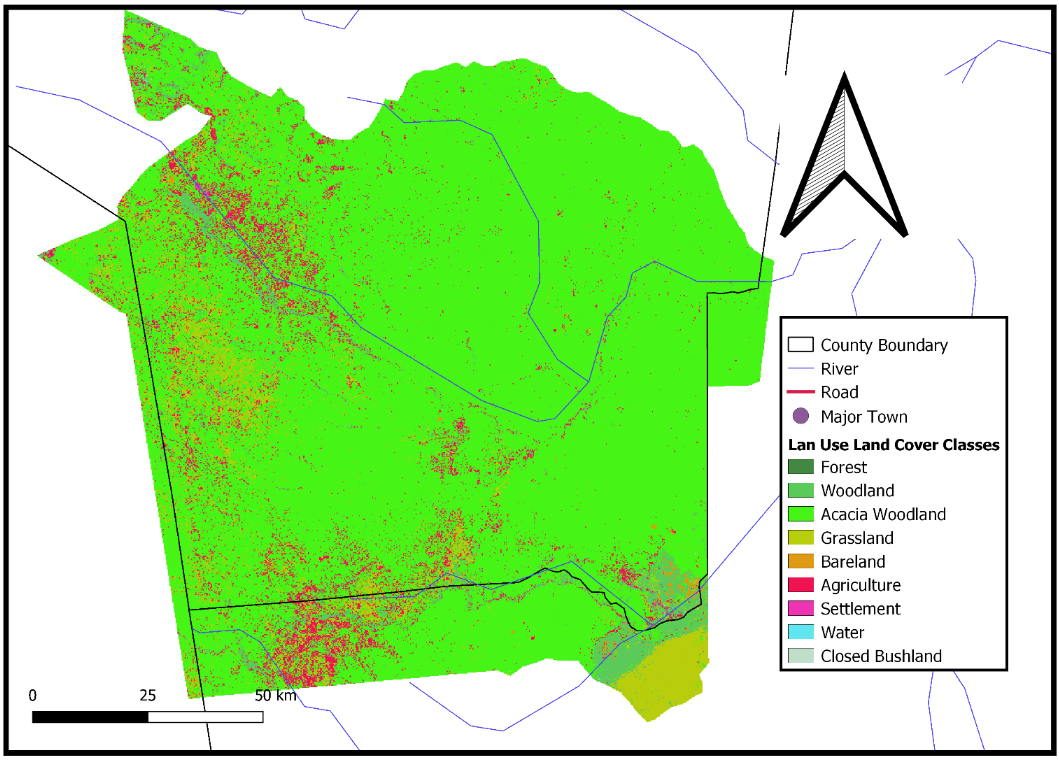

Figure 19: Rombo Group Ranch 1985 LULC map

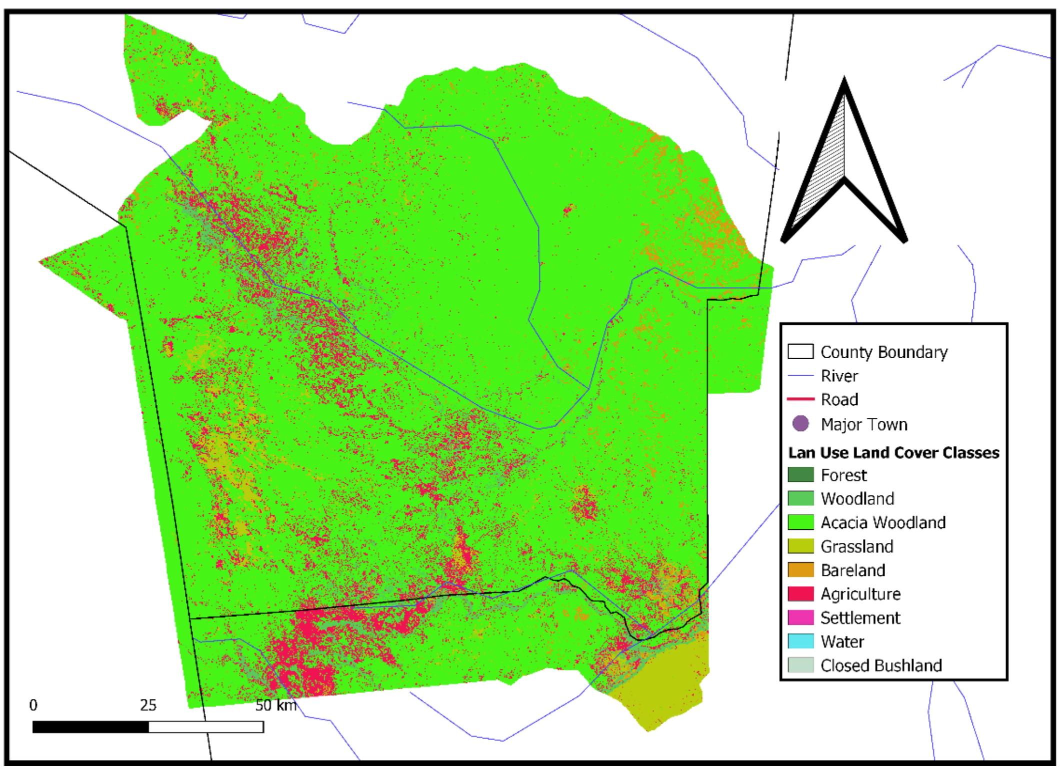

Figure 20: Rombo Group Ranch 1999 LULC map

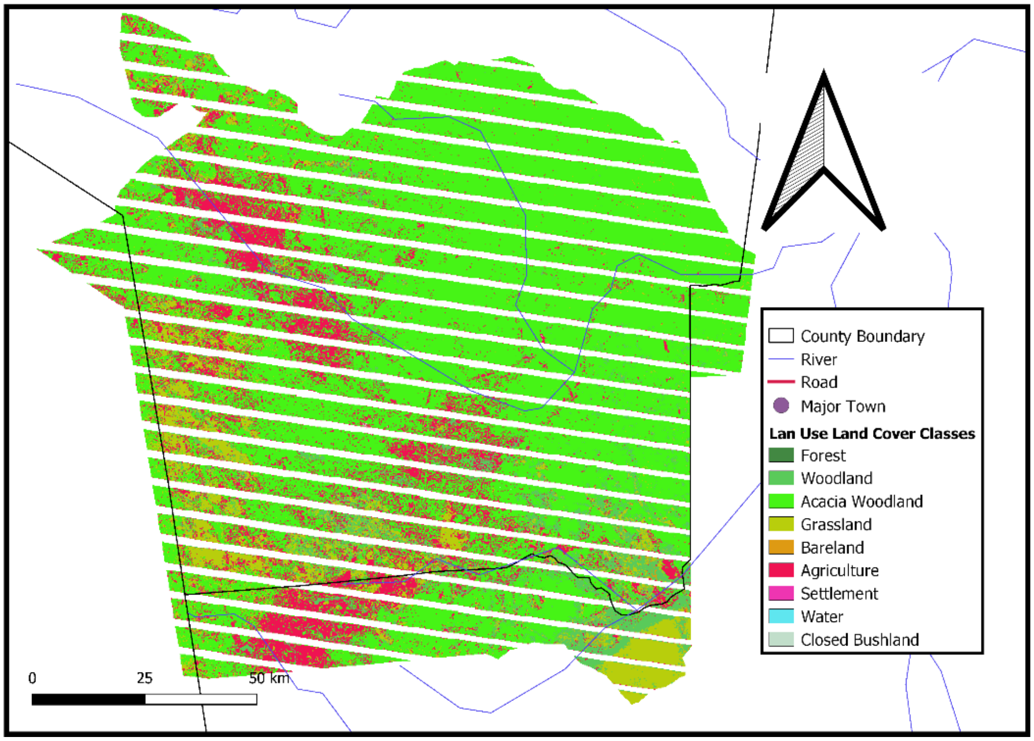

Figure 21:Rombo Group Ranch 2010 LULC map

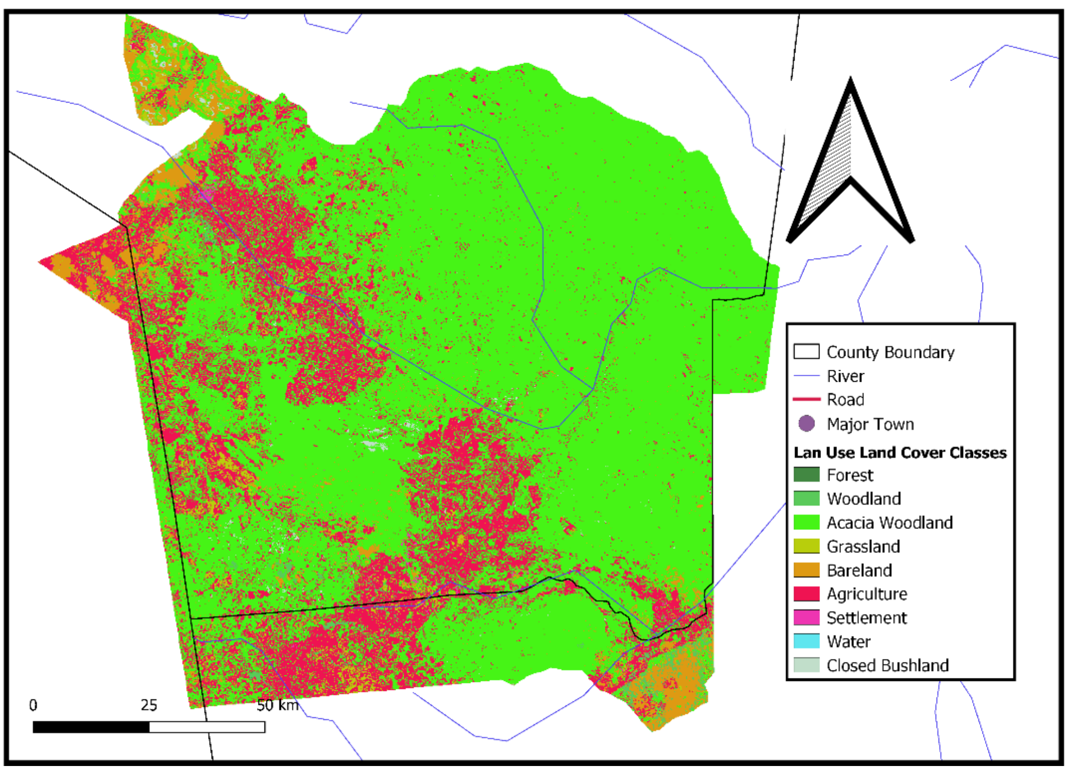

Figure 22: Rombo Group Ranch 2020 LULC map

Acacia woodland had the highest average landcover area at 75.80%, this was followed by agriculture at 14%. Grasslands covered an average area of 5.70%, woodland and bareland had an average area of 2.30% and 2.20% respectively. Settlement, forest, woodland, water and closed bush/*Commiphora* thicket all had less than 1% cover in the Rombo Group Ranch.

CHAPTER FIVE: DISCUSSION AND RECOMMENDATIONS

5.1 Discussion

5.1.1 Masai giraffe population and distribution

Protected areas provide numerous ecosystem services that are necessary in maintaining healthy and sustainable ecosystems (Utami *et al*., 2020). Most protected areas are also core wildlife habitats and are crucial in building and maintaining wildlife populations (Okello *et al*., 2015). A study by Thapa *et al*., (2017), within the transboundary Terai region of India and Nepal revealed that source populations for wild tigers were majorly confined to protected areas. This study observed that, Masai giraffe population was highest in the protected areas. There were no sightings in SKNR, lack of lack of Masai giraffe in SKNR was attributed to destruction of food sources through charcoal burning and overgrazing in the reserve. The findings of this study are consistent with a previous study on Masai giraffe population in southern Kenya where numbers were higher inside protected areas as compared to outside protected areas (Obari, 2014). Low numbers outside protected areas have been attributed to increased cases of habitat degradation and poaching (Obari, 2014).

Forage and water availability are the major factors that drive wildlife density, distribution and productivity in arid and semi-arid habitats (Groom and Western, 2013; Rich *et al*., 2019). The high Masai giraffe densities in Rombo Group Ranch and TWNP was attributed to high abundance of *Acacia* tree vegetation and watering points in the two areas as compared to other regions in the Tsavo landscape. These findings agree with the findings of Deacon and Smit (2017), where giraffe movements were observed to be primarily influenced by forage availability, rainfall and seasons in the Kalahari region of South Africa. Habitats that are water and forage abundant are highly preferred by most large mammals such as elephants (Purdon *et al*., 2018), buffaloes (Megaze, Belay and Balakrishnan, 2012) and giraffes (Leuthold and leuthold, 1972; Obari., 2014).

Past research in the mid Kenya-Tanzania borderland revealed Masai giraffe were more abundant in protected areas during the wet season, as compared to the dry season when they were more abundant outside protected areas (Okello *et al*., 2015). Similar to the findings of Okello *et al*., (2015), this study established that seasons greatly affected the distribution of Masai giraffe inside and outside protected areas. TWNP and TENP had higher numbers during the wet season as compared to the dry season. Rombo Group Ranch and Taita ranches had more Masai giraffe numbers during the dry season and fewer numbers during the wet season. Higher numbers in the protected areas during the wet season was attributed to presence of pasture and seasonal watering points. On the other hand, higher numbers outside protected areas were attributed to the migration of giraffe in search of water and pasture.

Previous large mammal censuses by KWS, DRSRS and other stakeholders, reveal an overall decrease in Masai giraffe population in the Tsavo landscape since the 1970's. Persistent decline of wild populations can easily lead to extinction (Valeix *et al.*, 2008). Drastic fluctuation of Masai giraffe population between different years in the Tsavo landscape pointed to the instability of the population. Populations with huge potentials for growth (r) are likely to show fluctuations and therefore have increased possibility of extinction at low population sizes (Eiswerth and Van Kooten, 2009).

Masai giraffe population in the Tsavo landscape was female skewed with a 1:1.63 male to female sex ratio. This ratio differed significantly from the expected 1:1 sex ratio, a skewed sex ratio in a population is either a result of skewed sex allocation at birth or skewed adult and subadult mortality (Marealle *et al.*, 2010; Kappeler, 2017). A study by Jones *et al.*, (2018), revealed that targeted poaching of male African savannah elephants greatly distorted their population structures and sex ratios in different protected areas in Tanzania. Though disproportional sex ratios are not desirerable, female skewed sex ratios may increase the viability and reproductive fitness of a population (D'haen *et al.*, 2019; Folt *et al.*, 2021). In line with the findings of D'haen *et al.*, (2019) and Marealle *et a*l., (2010) on giraffe populations in Garamba National Park and the Serengeti ecosystem respectively, this study attributed female skewed sex ratio to poaching incidences that mostly target male giraffe within the Tsavo landscape.

Most viable wildlife populations maintain age structures with high juvenile survival rates whereas unviable populations have low juvenile survival rates and therefore lower recruitment to breeding adults (Ludwig *et al.*, 2018; Folt *et al.*, 2021). Despite having the second highest Masai giraffe population, TENP had the least juvenile and sub adult population compared to all the other regions in the Tsavo landscape. This finding raised serious questions on the viability and sustainability of the Masai giraffes in TENP. Predation, poaching, forage quality, habitat suitability and habitat fragmentation are major factors that influence the age structure of wildlife populations within an ecosystem (Jones *et al.*, 2018; Muller, 2018; Muller, Cuthill and Harris, 2018; Kija *et al.*, 2020; Bloomfield, McIntosh and Lambin, 2020). Differences in age structure between different regions in the Tsavo landscape was attributed to poaching, forage availability and habitat fragmentation within the landscape.

Giraffes are not a water dependent species and although their distribution is mainly influenced by forage availability (Fennesy, 2004), the role of water in giraffe distribution cannot be overlooked (Berry, 1978; Pellew, 1984). This study revealed that Masai giraffe population decreased with increasing distance from operational watering points. This study observed that Masai giraffe preferred areas close to permanent rivers and wet artificial water points as opposed to dry artificial water points and seasonal rivers.

5.1.2 Land Use Land Cover change

Analysis of satellite images between 1985 and 2020 revealed that LULC has changed significantly over the years in the Tsavo landscape. The results of this study agree with the findings of similar studies done by Syombua (2013), while analyzing LULC change in the semi-arid southern rangelands of Kenya between 1987 and 2011. In that study, irrigated agriculture and rainfed agriculture increased at the expense of woodlands, shrubland and forests. Kiringe, Mwaura and Warinwa (2016), established that the Chyulu watershed in Kajiado and Makueni counties of Kenya lost huge proportions of forests, woodlands and wetlands to built-up, agriculture bare ground and thicket, the study covered the period between 1987 and 2015.

Increase in human population has led to farming, settlement, over grazing and charcoal burning activities which have accelerated the conversion of sections of the Tsavo landscape into agriculture, settlement, bareland and grasslands. A study carried out in Taveta district, which lies in the southwestern tip of the Tsavo landscape by Syombua (2013), established that LULC change was fueled by population growth and infrastructure development. Masai giraffes core habitats in the Tsavo landscape are TENP and TWNP with the highest concentration occurring in TWNP. Taita Ranches and Rombo Group Ranch which border the protected areas act as effective corridors and dispersal areas (KWS, 2017). Increased human population and inconsistent land tenure systems outside protected areas are the key drivers of LULC change within the Tsavo landscape (KWS, 2017).

Human population growth within the Tsavo landscape has led to severe degradation of Masai giraffe corridors and dispersal areas (KWS, 2017). The Taita ranches link TENP, TWNP and Mkomazi

Game Reserve and are therefore important dispersal areas. Huge portions of the Taita Ranches are increasingly being converted into farms, settlements and charcoal burning havens. Rombo Group Ranch which had the highest Masai giraffe densities during the study, has lost huge portions of its dominant *Acacia* woodland vegetation to agriculture, bare land and grasslands since the 1980's. The situation is likely to worsen with the expected completion of the Loitoktok- Taveta highway which will open up the area to more settlement, charcoal burning, farming and trade. The area south of Rombo Group Ranch which extends through Taveta town towards Lake Jipe is under intense agriculture and settlement. This area can no longer be utilized by wildlife (Syombua, 2013; KWS, 2017).

Unfavorable land use and land tenure systems within the Tsavo Landscape continue to reduce the suitability of the landscape for Masai giraffe utilization. Though national parks have remained largely intact as the core wildlife conservation areas, neighboring ranches and farms have conflicting land use and land tenure systems that do not promote wildlife conservation. Land subdivision, bushmeat poaching, overgrazing, erection of fences and gemstone mining within the Taita ranches and Rombo Group Ranch are impacting on the landscape negatively. Poaching, charcoal burning and over grazing in SKNR which borders TENP to the east are the key LULC change drivers that are linked to low Masai giraffe populations.

The decline in Masai giraffe populations in the Tsavo landscape since the 1980's to 2020 corresponds to LULC change in the area during the same period. More specifically, LULC change in the Tsavo landscape is decreasing the suitability of non-protected areas as viable Masai giraffe corridors and dispersal areas.

5.2 Threats of LULC on Masai giraffe population and habitat

LULC change induced by human activities such as agriculture, mining, fencing, settlement, charcoal burning, poaching, overgrazing and land subdivision outside protected areas is increasing rapidly in the Tsavo landscape. LULC change has affected wildlife populations through habitat loss, habitat fragmentation, habitat degradation and increased human wildlife conflicts.

This study has established that the protected TENP and TWNP are very critical habitats in the Tsavo landscape that support and maintain Masai giraffe populations. Although TENP and TWNP have remained largely immune to human induced LULC change, they risk fragmentation and over exploitation as wildlife avoid the degraded ranches and community areas. The fragmentation and over exploitation of the protected areas by wildlife in the Tsavo landscape, will result to low range productivity and reduced habitat resilience which will ultimately affect wildlife populations negatively. In the effort to secure Masai giraffe populations in the Tsavo landscape, there is need to adopt holistic wildlife management interventions that focus on both protected and non-protected areas.

Lack of Masai giraffe in the SKNR was attributed to overgrazing, poaching and destruction of their food sources through charcoal burning. Rombo Group Ranch had the highest Masai giraffe density in the Tsavo landscape, this was despite the ranch having huge LULC changes. Numerous poaching incidents also emerged as a major threat to Masai giraffe populations in Rombo Group Ranch and the Taita ranches. The overall population trend indicates that Masai giraffes are decreasing in the Tsavo landscape, the decline was attributed to poaching and habitat loss due to LULC change. If the current trend persists, the future of Masai giraffe in the Tsavo landscape is not guaranteed. There is need for urgent action to curb poaching and LULC change within the Tsavo landscape.

5.3 Recommendations

5.3.1 Recommendations for further study

- The scope of this study did not include Mkomazi National Park which is part of the larger Tsavo-Mkomazi landscape, studies should therefore be conducted on Masai giraffe population trends in Mkomazi National Park and also on the status of Masai giraffe in the Kenya-Tanzania borderlands within the cross border Tsavo-Mkomazi landscape.
- The study did not have conclusive results on the connectivity of different regions within the Tsavo landscape and how this affects the Masai giraffe population and distribution. A research study should therefore be conducted to determine Masai giraffe corridors, their status and viability. Studies to determine the impact of the Standard Gauge Railway and other infrastructure on the connectivity of Masai giraffe habitats in the Tsavo landscape should also be carried out.
- Climate change has had tremendous impact on biodiversity in savannah ecosystems due to prolonged cyclic droughts and declining precipitation. It is therefore necessary to conduct

research to determine the impact of climate change on Masai giraffe population, distribution and behavior in the Tsavo landscape.

- During the study, crop damage and livestock losses were the main causes of Human Wildlife Conflict (HWC) in the Tsavo landscape. This study however, did not look at the impact HWC of Masai giraffe in the Tsavo landscape. It is therefore necessary to conduct a study to evaluate the impact of HWC on the population, distribution and behavior of Masai giraffe in the Tsavo landscape.
- Giraffes and their habitats are declining rapidly across Africa. In order to secure the future of giraffe, there is need to replicate this study in other landscapes where giraffe habitats are facing major threats due to LULC change.

5.3.2 Recommendations for Management Actions

- In an effort to curb incompatible LULC practices, wildlife sanctuaries and tourist lodges should be created by local communities to promote wildlife tourism as an alternative income generating activity to mining, charcoal burning, livestock production and agriculture in ranches within the Tsavo landscape
- There is need to secure Masai giraffe corridors and dispersal areas by facilitating formation of wildlife conservancies in private and community ranches within the Tsavo landscape. Furthermore, conservancies, private farms and ranches in the Tsavo landscape should be urged to develop and gazette land use plans.
- So as to curb Masai giraffe poaching in the Tsavo landscape, game scouts and wildlife officers should be trained in Masai giraffe monitoring, intelligence gathering, evidence handling, legal procedures and wildlife crime prevention within the Tsavo landscape. Transboundary collaboration between wildlife departments, investigative agencies, game scouts and community members should also be enhanced between Kenya and Tanzania in an effort to curb Masai giraffe poaching.
- Since water influenced the distribution of Masai giraffe within the Tsavo landscape, it is necessary that non-operational artificial watering points be rehabilitated and new water pans be scooped in areas that are suitable Masai giraffe habitats.

- In order to integrate livestock farming and wildlife conservation, it is necessary to build the capacity of private and community ranches on modern methods of livestock production, range management and wildlife management.

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APPENDICES

Appendix 1: Giraffe data from transect counts in the Tsavo Landscape

NAME	AREA (KM^2)	Transect No.	Transect Length (M)	Direction of the sight	Perpendicular Distance to the sight	Total number
Tsavo West N.P /Season 1	7,000	1	54	90	10	1
				60	500	1
				90	100	3
				0	1000	1
				0	1000	2
				0	0	0
		2	24	0	0	0
				0	0	0
				0	0	0
		3	45	90	108	3
				90	137	1
				90	154	2
				90	100	1
				30	90	5
				90	85	6
				0	1000	3
		4	7	90	34	1
		5	20	90	135	1
				0	0	0
		6	55	0	0	0
				0	0	0
				0	1000	2
				0	0	0
				0	0	0
				0	0	0
		7	50	90	25	12
				0	1000	2
				40	20	3
				20	100	3

				20	100	2
				60	25	1
				0	1000	8
		8	58	60	117	2
				10	80	2
				90	1000	1
				0	1000	5
				90	75	2
				90	10	1
				20	100	2
				50	40	7
				90	36	1
				0	10	16
				90	130	1
				40	335	2
				0	1000	3
				60	239	4
				10	60	3
				90	25	1
				10	60	2
		9	36	0	0	0
				0	0	0
				0	0	0
				0	0	0
		10	50	0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		11	80	0	1000	3
				60	20	2
				90	500	1
				90	20	4
				0	1000	2
				90	30	3
				0	1000	0

				0	1000	0
Tsavo west N.P/Season 2	7,000	1	54	90	38	6
				0	1000	5
				0	0	0
				0	0	0
				0	1000	5
				90	35	6
		2	24	0	0	0
				0	0	0
				0	0	0
		3	45	90	25	2
				90	50	2
				0	1000	3
				60	250	3
				90	50	1
				20	20	4
				20	10	2
				20	20	3
				90	100	1
				50	30	1
				20	25	1
				60	200	3
				90	100	1
				50	30	1
				90	50	1
				20	20	4
				20	20	1
				20	10	2
				30	100	2
				90	15	1
		4	7	10	16	2
				90	100	1
				90	100	7
				90	50	1
				90	80	4
				50	30	9

		5	20	20	20	2
				40	80	4
		6	55	90	100	4
				0	0	0
				0	0	0
				0	0	0
				90	900	2
		7	50	90	10	1
				0	1000	2
				80	35	1
				90	310	12
				90	67	3
				90	25	1
				0	1000	6
		8	58	30	155	5
				90	264	1
				90	195	2
				90	40	1
				0	1000	9
				90	10	7
				60	93	7
				90	129	4
				40	92	2
				90	121	1
				90	52	1
				90	168	7
				60	136	14
				60	108	8
				60	79	3
		9	36	0	0	0
				0	0	0
				90	40	10
				20	250	1
		10	50	0	0	0
				0	0	0
				0	0	0

				0	0	0
				0	0	0
		11	80	90	25	1
				90	1000	5
				90	20	9
				0	0	0
				90	900	1
				0	0	0
				0	0	0
				0	0	0
Tsavo west N.P/Season 3	7,000	1	54	0	0	0
				0	0	0
				0	0	0
				45	100	4
				0	0	0
				0	0	0
		2	24	60	25	1
				60	85	4
				0	0	0
		3	45	90	100	2
				40	500	5
				60	20	2
				90	39	2
				90	103	1
				60	53	13
				90	36	1
		4	7	45	60	1
				40	48	1
				45	25	1
				90	30	2
		5	20	90	63	11
				90	53	2
				90	71	1
				0	1000	3
				10	8	1
				60	66	1

				60	33	3
				0	0	0
		6	55	0	0	0
				60	131	1
				50	80	1
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		7	50	40	27	2
				60	38	3
				60	124	2
				90	176	9
				50	40	1
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		8	58	0	0	0
				70	221	5
				90	99	1
				60	30	5
				45	69	3
				0	0	0
				90	53	6
				60	100	4
				45	355	10
				45	476	4
				42	241	2
		9	36	60	172	12
				60	28	3
				90	162	1
				0	50	1
				90	500	3
				0	0	0
				45	141	5

		10	50	0	0	0
				0	0	0
				46	517	14
				45	162	1
				60	43	6
				45	33	4
				0	0	0
		11	80	60	41	3
				0	0	0
				0	0	0
				0	0	0
				40	40	4
				90	131	1
				0	0	0
				0	0	0
				40	25	2
				90	108	1
				60	20	1
				45	35	2
				90	250	4
				0	1000	1

Region	**Area**	**Transect**	**Transect Length**	**Direction of the sight**	**Perpendicular Distance to the sight**	**Total number**
Tsavo East Sample 1	14,000	1	86	0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				90	50	4
		2	38	0	0	0

				0	0	0
				0	0	0
				0	0	0
		3	79	180	20	2
				180	100	8
				90	50	1
				90	50	1
				40	80	3
				0	20	2
				90	20	3
				90	400	4
				0	0	0
		4	84	0	0	0
				0	0	0
				50	10	3
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		5	32	0	0	0
				0	0	0
				99	20	1
		6	70	0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		7		0	0	0
				0	0	0
				0	0	0
				0	0	0
				90	150	1
				40	200	1

				0	0	0
		8	53	0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		9	62	90	5	1
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		10	62	90	50	1
				0	0	1
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		11	39	0	0	0
				0	0	0
				0	0	0
		12	62	0	0	0
				0	0	0
				90	20	1
				0	0	0
				90	150	2
				0	0	0
				0	0	0
		13	19	0	0	0
				0	0	0
		14	24	0	0	0
				0	0	0

				0	0	0
Tsavo East Sample 2	14000	1	86	0	0	0
				0	12	1
				70	150	1
				90	40	2
				90	150	1
				20	50	1
				0	10	2
				90	50	4
				50	80	4
		2	38	0	0	0
				0	0	0
				0	0	0
				0	0	0
		3	79	0	0	0
				60	50	1
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				90	15	4
				0	0	0
		4	84	0	0	0
				0	10	1
				42	213	7
				40	123	1
				170	50	2
				80	60	1
				45	150	1
				0	0	0
				170	80	2
		5	32	0	10	1
				45	20	4
				0	0	0
				23	10	1
		6	70	0	0	0

				0	0	0
				0	0	0
				0	0	0
				0	10	3
				0	0	0
				0	0	0
		7	70	0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		8	53	0	0	0
				0	10	2
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		9	62	0	0	0
				60	25	2
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		10	62	0	0	0
				0	20	1
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		11	39	0	0	1
				0	0	0
				0	0	0

				0	0	0
		12	62	0	0	0
				90	20	1
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		13	19	0	0	0
				0	0	0
		14	24	0	0	0
				0	0	0
				0	0	0
Tsavo East Sample 3	14000	1	86	10	100	1
				0	0	3
				45	100	1
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		2	38	0	0	0
				0	0	0
				0	0	0
				0	0	0
		3	79	45	150	8
				45	50	7
				10	10	1
				30	10	6
				10	45	2
				45	10	1
				10	10	3
				0	0	0
				10	10	5
				80	250	2
				45	20	1

				45	120	5
				0	0	0
		4	84	90	35	2
				45	25	1
				45	300	4
				40	10	1
				90	150	3
				90	400	4
				45	100	5
				30	800	3
				60	300	7
				45	100	1
		5	32	15	25	5
				10	10	12
				45	100	8
				45	120	2
				45	15	1
				45	300	4
				10	12	3
		6	70	45	80	1
				10	100	1
				90	50	7
				45	100	3
				50	200	1
				45	200	6
		7	70	0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		8	53	0	0	0
				45	10	9
				0	0	0
				0	0	0

				0	0	0
				0	0	0
		9	62	10	10	1
				45	100	1
				20	20	3
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		10	62	45	50	4
				0	20	1
				0	0	0
				0	0	0
				0	0	0
				0	0	0
				0	0	0
		11	39	0	0	1
				0	0	0
				0	0	0
				0	0	0
		12	62	0	100	2
				45	80	1
				45	25	4
				0	100	3
				0	0	0
				0	0	0
		13	19	0	0	0
				0	0	0
		14	24	0	0	0
				0	0	0
				0	0	0

Region	**Area**	**Transect**	**Transect length**	**Direction of the sight**	**Perpendicular Distance to the sight**	**Total number**

Taita Ranches /Season 1	1900	1	24	0	0	0
				180	30	1
				90	50	5
		2	17	90	250	2
				0	0	0
		3	12	90	250	6
				90	250	1
				180	150	1
		4	6	60	100	1
				90	50	1
		5	25	0	0	0
				0	0	0
				0	0	0
		6	10	0	0	0
				0	0	0
		7	10	0	0	0
		8	7	0	0	0
		9	17	0	0	0
				0	0	0
		10	8	0	0	0
		11	22	90	10	1
				90	10	3
		12		0	1000	1
				10	10	2
			7	0	1000	1
		13	11	0	0	0
				90	20	5
		14	7	0	0	0
		15	16	0	0	0
				0	0	0
		16	4	0	0	0
		17	15	0	0	0
				100	25	7
		18	10	0	0	0
Taita Ranches/ Season 2	1900	1	24	90	180	3
				90	200	1

				90	300	2
		2	17	0	0	0
				0	0	0
		3	12	90	200	1
				0	0	0
		4	6	0	0	0
				0	0	0
		5	25	0	0	0
				0	0	0
				0	0	0
		6	10	0	0	0
				0	0	0
		7	10	0	0	0
		8	7	0	0	0
		9	17	0	0	0
				0	0	0
		10	8	0	0	0
		11	22	45	100	1
				120	150	4
				0	0	0
		12		0	0	0
				0	0	0
			7	0	0	0
		13	11	90	20	5
				90	50	5
				90	50	2
				90	20	2
		14	7	0	0	0
				90	120	1
		15	16	80	100	3
				0	0	0
		16	4	0	0	0
		17	15	0	0	0
				0	0	0
		18	10	0	0	0
Taita Ranches/ Season 3	1900	1	24	0	0	0

				0	20	8
				0	0	0
		2	17	45	30	2
				0	0	0
		3	12	0	20	7
		4		50	30	3
			6	60	50	5
		5		60	50	4
			25	0	20	3
				0	0	0
		6	10	0	0	0
		7	10	0	0	0
		8	7	0	0	0
		9	17	0	0	0
				0	0	0
		10	8	0	0	0
		11	22	0	0	0
				0	0	0
		12	7	60	211	5
				45	70	9
		13	11	0	0	0
				0	0	0
		14	7	0	0	0
		15	16	0	0	0
				0	0	0
		16	4	0	0	0
		17	15	60	20	16
				90	500	7
		18	10	0	0	0

Region	**Area**	**Transect**	**Transect Length**	**Direction of the sight**	**Perpendicular Distance to the sight**	**Total number**
Rombo Group Ranch Season 1	359	1	6	0	0	0
		2	3	260	450	1
				90	133	7

				260	900	6
		3	5	0	0	0
		4	10	0	0	1
				0	0	1
		5	1.3	0	0	0
Rombo Group Ranch Season 2	359	1	6	90	142	6
				90	500	6
		2	3	90	226	1
				60	100	3
				90	173	3
		3	5	90	100	2
				90	500	4
				90	700	2
				90	500	2
		4	10	90	600	2
		5	1.3	0	0	0
Rombo Group Ranch Season 3	359	1	6	0	0	0
		2	3	0	0	0
				0	0	0
				0	0	0
		3	5	0	0	0
		4	10	0	0	0
				0	0	0
		5	1.3	110	10	2
				30	10	10
				60	30	4

Appendix 2: Giraffe Population and Density estimates using Distance softwar

Tsavo West N.P Season 1

Effort : 479.0000 kms

samples : 11

Observations: 66

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.68894E-01	0.12275E-01	17.82	0.47310E-01	0.10032
E(S)	2.0303	0.34342	16.91	1.4517	2.8395
D	0.13987	0.34363E-01	24.57	0.85943E-01	0.22765
N	979.00	240.51	24.57	602.00	1594.0

Tsavo West N.P Season 2

Effort : 479.0000 kms

samples : 11

observations: 81

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.84551E-01	0.19639E-01	23.23	0.51490E-01	0.13884
E(S)	2.7407	0.34192	12.48	2.1402	3.5097
D	0.23173	0.61099E-01	26.37	0.13516	0.39731
N	1622.0	427.66	26.37	946.00	2781.0

Tsavo West N.P Season 3

Effort : 479.0000 kms

samples : 11

observations: 83

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.86646E-01	0.10433E-01	12.04	0.67772E-01	0.11078
E(S)	2.2892	0.33920	14.82	1.7075	3.0690
D	0.19835	0.37870E-01	19.09	0.13626	0.28872
N	1388.0	265.01	19.09	954.00	2021.0

Tsavo East N.P Season 1

Effort : 780.0000 kms

samples : 14

observations: 83

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.53548E-01	0.35694E-02	6.67	0.46916E-01	0.61119E-01
E(S)	0.48193	0.13537	28.09	1.0000	0.83381
D	0.25806E-01	0.74502E-02	28.87	0.14711E-01	0.45269E-01
N	361.00	104.22	28.87	206.00	634.00

Tsavo East Season 2

Effort : 780.0000 kms

samples : 14

observations: 91

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.58333E-01	0.55868E-02	9.58	0.48133E-01	0.70696E-01
E(S)	1.7692	0.26523	14.99	1.3157	2.3791
D	0.10321	0.18360E-01	17.79	0.72795E-01	0.14632
N	1445.0	257.06	17.79	1019.0	2048.0

Tsavo East Season 3

Effort : 780.0000 kms

samples : 14

observations: 83

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.53205E-01	0.34541E-02	6.49	0.46775E-0 1	0.60519E-01
E(S)	0.62651	0.13683	21.84	1.0000	0.96254
D	0.33333E-01	0.75948E-02	22.78	0.21328E-01	0.52096E-01
N	467.00	106.40	22.78	299.00	729.00

Rombo Group Ranch Season 1

Effort : 25.30000 kms

samples : 5

observations: 8

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.15812	0.67259E-01	42.54	0.59451E-01	0.42054
E(S)	2.0000	1.0000	50.00	1.0000	6.1114
D	0.31624	0.20760	65.65	0.87052E-01	1.1488
N	114.00	74.837	65.65	31.000	412.00

Rombo Group Ranch Season 2

Effort : 25.30000 kms

samples : 5

observations: 11

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.29785	0.15029	50.46	0.96972E-01	0.91484
E(S)	4.3940	1.0546	24.00	2.5725	7.5052
D	1.3088	0.73129	55.88	0.41154	4.1620
N	563.00	314.59	55.88	177.00	1790.0

Rombo Group Ranch Season 3

Effort : 25.30000 kms

samples : 5

observations: 10

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval	
A(1)	0.1000E+07	0.5389E+12			
f(0)	0.10000E-02	0.17962E-03	17.96	0.66824E-03	0.14965E-02
p	1.0000	0.17962	17.96	0.66824	1.0000
ESW	1000.0	179.62	17.96	668.24	1496.5

Taita Ranches season 1

Effort : 251.0000 kms

samples : 18

observations: 34

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.67729E-01	0.87849E-02	12.97	0.52250E-01	0.87794E-01
E(S)	1.1176	0.32365	28.96	1.0000	1.9909
D	0.75697E-01	0.24019E-01	31.73	0.40586E-01	0.14118
N	144.00	45.692	31.73	77.000	268.00

Taita Ranches Season 2

Effort : 780.0000 kms

samples : 14

observations: 83

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.53205E-01	0.34541E-02	6.49	0.46775E-01	0.60519E-01
E(S)	0.62651	0.13683	21.84	1.0000	0.96254
D	0.33333E-01	0.75948E-02	22.78	0.21328E-01	0.52096E-01
N	467.00	106.40	22.78	299.00	729.00

Taita Ranches Season 3

Effort : 247.0000 kms

samples : 18

observations: 30

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.60729E-01	0.76349E-02	12.57	0.47182E-01	0.78165E-01
E(S)	2.3000	0.70164	30.51	1.2496	4.2334
D	0.13968	0.46086E-01	33.00	0.72899E-01	0.26762
N	265.00	87.437	33.00	139.00	508.00

SKNR Season 1

Effort : 62.00000

samples : 3

observations: 0

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.64516E-01	0.13827E-01	21.43	0.39785E-01	0.10462
E(S)	0.00000	0.00000	0.00	1.0000	0.00000
D	0.00000				
N	0.00000				

SKNR Season 2

Effort : 62.00000 kms

samples : 3

observations: 0

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.64516E-01	0.13827E-01	21.43	0.39785E-01	0.10462
E(S)	0.00000	0.00000	0.00	1.0000	0.00000
D	0.00000				
N	0.00000				

SKNR Season 3

Effort : 62.00000 kms

samples : 3

observations: 0

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	0.64516E-01	0.13827E-01	21.43	0.39785E-01	0.10462
E(S)	0.00000	0.00000	0.00	1.0000	0.00000
D	0.00000				
N	0.00000				

Appendix 3:

Artificial Water Points in the Tsavo Landscape

Type Water Feature	Status	X	Y
Water Pan	Has Water	38.89816	-3.50346
Dam	Permanent water	38.843	-3.85495
Water Pan	Has Water	37.90793	-3.34415
Water Pan	Dry	38.13321	-2.85381
Dam	Permanent water	38.89373	-3.78554
Water Pan	Has Water	38.40046	-2.44973
Water Pan	Has Water	37.88236	-2.91608
Dam	Permanent water	38.84279	-3.85328
Pumped Borehole	Has Water	37.79564	-3.17361
Water Pan	Has Water	38.33398	-3.69443
Water Pan	Has Water	37.90787	-3.34425
Dam	Has Water	38.4267	-2.21547
Water Pan	Dry	38.13986	-2.94173
Water Pan	Dry	37.69658	-3.1226
Water Pan	Dry	38.12765	-2.93685
Pumped Borehole	Has Water	37.74312	-3.13999
Dam	Permanent water	38.22642	-3.61599

Water Pan	Has Water	37.90838	-3.34372
Water Pan	Dry	37.74144	-3.14952
Water Pan	Has Water	38.33646	-3.68562
Dam	Dry	37.69695	-3.12181
Pumped Borehole	Permanent water	38.61688	-2.92009
Dam	Has Water	38.49493	-3.61219
Water Pan	Dry	38.05952	-2.75711
Dam	Permanent water	38.81626	-3.78003
Dam	Dry	38.91371	-1.74915
Water Pan	Dry	38.06151	-2.76044
Water Pan	Has Water	38.93546	-3.6235
Pumped Borehole	Permanent water	37.82175	-2.95978
Dam	Dry	38.582	-3.83799
Dam	Has Water	38.89379	-3.78565

Appendix 4: Landsat images for 2020, 2010, 1999 and 1985

Year	**Path/Row**	**Acquisition date**
2020	167/61	01/12/2020
	167/62	01/12/2020
	167/63	01/12/2020
	166/61	01/25/2020
	166/62	01/21/2020
	166/63	01/21/2020
2010	167/61	02/09/2010
	167/62	02/09/2010
	167/63	03/13/2010
	166/61	02/07/2010
	166/62	02/07/2010
	166/63	02/09/2010
1999	167/61	03/28/1995
	167/62	03/28/1995
	167/63	03/28/1995
	166/61	02/17/1995
	166/62	02/17/1995

	166/63	02/17/1995
1985	167/61	02/02/1985
	167/62	02/18/1985
	167/63	02/18/1985
	166/61	01/26/1985
	166/62	01/26/1985
	166/63	02/02/1985

Appendix 5. LULC Change Accuracy Assessment

Classification Accuracy assessment for the Tsavo Landscape 2020

	1	2	3	4	5	6	7	8	9	Total	UA
1	0	1	1	3	0	14	0	1	22	**42**	0.0000
2	7	1	0	3	0	13	0	0	39	**64**	1.6219
3	0	2	39	0	7	0	0	4	125	**176**	22.1276
4	2	0	0	123	0	8	0	0	47	**180**	68.3290
5	0	0	0	12	0	7	0	0	10	**29**	0.0000
6	7	3	1	8	0	76	0	0	34	**131**	58.0180
7	0	0	0	0	0	0	0	0	0	**1**	0.0000
8	0	0	0	0	0	0	0	44	0	**44**	0.0663
9	5	0	0	42	0	8	0	0	311	**367**	84.7741
Total	**21**	**8**	**42**	**192**	**7**	**126**	**0**	**49**	**590**	**1034**	
PA	0.000	12.915	93.113	64.213	0.000	60.131	0.000	90.778	52.770		
Overall Accuracy	0.57493										

Classification Accuracy assessment for the Tsavo Landscape 2010

	1	2	3	4	5	6	7	8	9	Total	UA
1	43	4	4	9	0	2	0	0	10	**73**	59.42982
2	17	4	2	13	0	4	0	0	36	**75**	5.343915
3	1	0	0	43	0	3	0	0	151	**198**	0.220928
4	4	2	7	99	0	8	0	0	73	**192**	51.68354
5	0	0	1	14	0	3	0	0	11	**31**	0
6	12	1	1	26	0	33	0	0	6	**78**	42.39631
7	0	0	0	0	0	0	0	0	0	**1**	0
8	1	0	0	0	0	0	0	46	0	**47**	97.46622
9	6	1	3	20	0	16	0	0	294	**339**	86.56951
Total	**84**	**11**	**18**	**225**	**0**	**69**	**0**	**46**	**580**	**1034**	
PA	51.2045	35.5634	2.41228	44.2049	0	47.69585253	0	98.886	50.6879		
Overall Accuracy	0.50242										

Classification Accuracy assessment for the Tsavo Landscape 1999

	1	2	3	4	5	6	7	8	9	Total	UA
1	60	3	1	6	0	0	0	0	0	**69**	85.96952
2	37	4	23	7	0	0	0	0	11	**83**	5.401845
3	6	2	17	50	0	0	0	0	143	**218**	7.764234
4	8	0	1	125	0	0	0	0	82	**216**	57.96296
5	1	0	0	18	0	0	0	0	17	**36**	0
6	1	0	0	1	0	0	0	0	4	**6**	0
7	0	0	0	1	0	0	0	0	2	**3**	0
8	0	0	0	0	0	0	0	51	0	**51**	99.43343
9	8	0	28	42	0	0	0	0	272	**352**	77.25823
Total	**122**	**9**	**69**	**250**	**0**	**0**	**0**	**52**	**533**	**1034**	
PA	48.8358	48.4252	24.4479	50.1092				99.0127	51.0703		
Overall Accuracy	0.51309										

Classification Accuracy assessment for the Tsavo Landscape 1985

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**	**UA**
1	0	1	1	3	0	14	0	1	22	**42**	**0**
2	7	1	0	3	0	13	0	0	39	**63**	**0.015873**
3	0	2	20	13	7	0	0	4	125	**171**	**0.116959**
4	2	0	0	100	0	8	0	0	47	**157**	**0.012739**
5	0	0	0	16	0	7	0	0	10	**33**	**0**
6	7	3	1	8	0	76	0	0	34	**129**	**0.589147**
7	0	0	0	10	0	0	0	0	0	**10**	**0**
8	0	0	0	0	0	0	0	44	0	**44**	**1**
9	5	0	19	42	0	8	0	0	311	**385**	**0.807792**
Total	**21**	**7**	**41**	**195**	**7**	**126**	**0**	**49**	**588**	**1034**	
PA	**0**	**0.14**	**0.49**	**0.51**	**0**	**0.60**	**0**	**0.89**	**0.52**		
Overall Accuracy	**0.53**										

Classification Accuracy assessment for the Rombo Group Ranch 2020

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**	**UA**
1	0	0	0	0	0	0	0	0	0	**0**	**0.00**
2	0	0	2	0	0	2	0	0	0	**4**	**0.00**
3	0	0	277	0	0	4	0	0	0	**281**	**0.99**
4	0	0	17	0	0	1	0	0	0	**18**	**0.00**
5	0	0	12	0	0	2	0	0	0	**15**	**0.00**
6	0	0	64	0	0	10	0	0	0	**74**	**0.13**
7	0	0	1	0	0	0	0	0	0	**1**	**0.00**
8	0	0	0	0	0	0	0	0	0	**0**	**0.00**
9	0	0	2	0	0	0	0	0	0	**2**	**0.00**
Total	0	0	376	0	0	19	0	0	0	395	
PA	**0.00**	**0.00**	**0.74**	**0.00**	**0.00**	**0.52**	**0.00**	**0.00**	**0.00**		
Overall Accuracy	**0.7271**										

Classification Accuracy assessment for the Rombo Group Ranch 2010

	1	2	3	4	5	6	7	8	9	Total	UA
1	0	0	0	0	0	0	0	0	0	**0**	**0.00**
2	0	1	11	4	0	8	0	0	0	**24**	**0.04**
3	0	0	228	1	0	9	0	0	0	**238**	**0.96**
4	0	0	16	26	0	1	0	0	0	**43**	**0.61**
5	0	0	3	0	0	0	0	0	0	**3**	**0.00**
6	0	0	58	4	0	22	0	0	0	**84**	**0.26**
7	0	0	1	0	0	0	0	0	0	**1**	**0.00**
8	0	0	0	0	0	0	0	0	0	**0**	**0.00**
9	0	0	2	0	0	0	0	0	0	**2**	**0.00**
Total	0.0	1.4	319.4	34.3	0.0	39.8	0.0	0.0	0.0	**395**	
PA	**0.00**	**0.75**	**0.71**	**0.76**	**0.00**	**0.55**	**0.00**	**0.00**	**0.00**		
Overall Accuracy	**0.7020**										

Classification Accuracy assessment for the Rombo Group Ranch 1999

	1	2	3	4	5	6	7	8	9	Total	UA
1	0	0	0	0	0	0	0	0	0	**0**	**0.000**
2	0	8	18	0	0	0	0	0	0	**26**	**0.305**
3	0	1	272	0	0	0	0	0	0	**273**	**0.996**
4	0	0	24	25	0	0	0	0	0	**49**	**0.505**
5	0	0	3	0	0	0	0	0	0	**3**	**0.000**
6	0	1	38	2	0	0	0	0	0	**42**	**0.000**
7	0	0	0	0	0	0	0	0	0	**0**	**0.000**
8	0	0	0	0	0	0	0	0	0	**0**	**0.000**
9	0	0	2	0	0	0	0	0	0	**2**	**0.000**
Total	0	10	358	27	0	0	0	0	0	**395**	
PA		**0.000**	**0.761**	**0.901**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**		
Overall Accuracy	**0.7714**										

Classification Accuracy assessment for the Rombo Group Ranch 1985

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**	**PA**
1	0	0	0	0	0	0	0	0	0	**0**	**0.000**
2	0	0	19	3	0	2	0	0	0	**25**	**0.000**
3	0	0	283	0	0	0	0	0	0	**283**	**0.998**
4	0	0	21	19	0	0	0	0	0	**40**	**0.477**
5	0	0	2	0	0	0	0	0	0	**2**	**0.054**
6	0	0	40	0	0	1	0	0	0	**41**	**0.017**
7	0	0	1	0	0	0	0	0	0	**2**	**0.000**
8	0	0	0	0	0	0	0	0	0	**0**	**0.000**
9	0	0	2	0	0	0	0	0	0	**2**	**0.000**
Total	0	0	369	23	0	3	0	0	0	**395**	
UA	**0.0000**	**0.0000**	**0.7669**	**0.8225**	**0.0000**	**0.2010**	**0.0000**	**0.0000**	**0.0000**		
Overall Accuracy	**0.7652**										

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