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School of Engineering

Assessing the Impact of Tsetse Fly on Livestock Productivity Using Geospatial Technologies, Case Study; Kubo South Location, Kwale County, Kenya

BY

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A Project submitted in partial fulfilment for the requirement of the Degree of Master of Science in Geographic Information System, in the Department of Geospatial and Space Technology of the University of Nairobi

May 2019

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I Winny cherono, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

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Dedication

I dedicate this work to my Mother who worked very hard to ensure that I achieve my academic dreams. She is my role model and has always encouraged me to be the best that I can be.

Acknowledgement

First, I would like to thank my supervisor Dr.-Ing. Faith Njoki Karanja, the chairperson of the Department of Geospatial and Space Technology for the guidance, encouragement, support, valuable time, cooperation and insightful comments during the project.

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Abstract

Livestock production plays an important role as subsistence, for draught power and as an income earner. According to KENTTEC 2017 report, the agricultural sector in Kenya contributes 24% of the country's Gross Domestic Product (GDP); 12% of this is contributed by the livestock subsector. However, the livestock production sector has been facing some challenges such as animal diseases and scarce pastures for the livestock. The common disease affecting livestock productivity in the study area around Shimba Hills is Animal trypanosomiasis which is a parasitic disease that is transmitted by tsetse flies. Tsetse flies use various land cover and land use as their habitats, Tsetse fly presence is usually related to the characteristics of land use and land cover such as vegetation. Therefore, mapping the distribution and abundance of tsetse flies in various land covers and land use and hence determining the land covers and land uses preferred by tsetse flies and those that are not preferred as habitats is necessary.

This research aimed at enhancing livestock productivity using remote sensing and GIS technologies. It involved mapping the land use and land cover around Shimba Hills National Reserve using remote sensing technology and overlaying it with the entomology datasets in order to establish the relationship between land use land cover and the tsetse distribution in the study area. Entomology data shows total number of tsetse flies collected in 171 traps which are distributed in various land covers and land uses in the study area. The impact of tsetse flies on livestock productivity was then assessed by processing various livestock productivity indicators in the area of study. An overlay with tsetse fly distribution maps established that there were cases lying outside the areas considered as tsetse flies' hotspots. This could be that the infections were due to T. vivax, which is a type of trypanosome known to be transmitted both biologically by tsetse and mechanically by biting flies such as stomoxys. It was established that some households have lost up to 8 cattle due to trypanosomiases which is a great loss to farmers as each cattle costs an average of Kshs. 30000. The frequency of livestock treatment in all the villages in the study area was alarming considering that the cost of treatment per animal was high. Some households recorded up to 8 times treatment of animals within six months It was established that most households spend up to 5000 Kenyan shillings annually to treat an animal and this is very costly to the farmers. It was recommended that interventions and tsetse control should be done in Msulwa village and in the areas that are close to the fence of the park as this will prevent tsetse flies from

moving to places farther away from the park. It was recommended that also further research should be done on the biting flies that have the possibility of transmitting trapanosomosis.

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Acronyms

SHNR - Shimba Hills National Reserve

KENTTEC - Kenya Tsetse fly and Trypanosomiasis Eradication Council

AAT- African Animal Trypanosomiasis

NDVI - Normalized Difference Vegetation Index

GLCF - Global Land Cover Facility

LULC - Land Use Land Cover

FOSS - Free Open Source Software

AU/IBAR - African Union Inter-Africa Bureau for Animal Resources

WTO - World Trade Organization

CAADP - Comprehensive Africa Agriculture Development Program

MDG - Millennium Development Goals

CHAPTER 1: INTRODUCTION

1.1 Background

Livestock production plays an important role as subsistence, for draught power and as an income earner in the area surrounding Shimba Hills National Reserve. Livestock production contributes significantly to the economy of East African countries, it is among the most significant sources of revenues in the region. According to KENTTEC 2017 report, the agricultural sector supports 24% of Kenya's Gross Domestic Product (GDP); 12% of this is supported by the livestock subsector. However, the livestock production sector has been facing some challenges such as animal diseases and scarce pasture for their livestock.

The major livestock productivity sub-sector constraint is animal diseases (KENTEC 2017). The most common disease among livestock in the study area is Animal Trypanosomiasis, it is a parasitic disease that is transmitted by a tsetse flies which are found in a large part of sub-Saharan Africa (about 107 km2) and are the common vectors of the trypanosome that causes serious disease in both livestock and humans (Kristjanson *et al.*, 1999,). In regions under challenge of trypanosomiasis, land cannot be exploited for livestock rearing (Duguma et al., 2015). The resulting lack of draught power is further compromising crop production. In Africa, animal trypanosomiasis and human trypanosomiasis commonly referred to as sleeping sickness and nagana in man and in animals respectively, have negatively affected about 40 million people and has caused social economic consequences such as low livestock productivity and also livestock loss (Maudlin, 2006). Spatial data shows that Sub Saharan African is infested by different species of tsetse flies which affect both human beings and livestock Cecchi et al., 2014) it causes huge economic losses in livestock production

According to KENTEC (2017), the distribution of tsetse fly has a positive correlation with wildlife conservation areas, game parks and reserves. This is because they offer favorable habitats for tsetse flies while the wild animals are natural reservoirs of the disease. Tsetse fly depend on host species to feed pregnant female and adult tsetse hence leading to circulation of the trypanosomes between wildlife, human, livestock and tsetse flies hence the spread of animal trypanosomiasis and human trypanosomiasis diseases. All tsetse flies, males as well as females, feed on blood, but the species differ in their preferences for the source of blood. Most tsetse flies feed preferentially on animals and only accidentally on humans.

The study area for the project was Kwale County Kubo South Villages which surrounds Shimba Hills National Reserve. The populations of Kubo south division based on 2009 census were estimated to be 649,931. It borders Taita Taveta to the West, Kilifi district to the North West, Mombasa and Indian Ocean to the East and Republic of Tanzania to the South. Shimba hills National Reserve is a protected area for wild animals such as Elephants, warthogs, leopards, cheetahs, buffaloes and others. This has however led to the presence of tsetse flies around the park hence inhibiting agricultural activities, specifically livestock keeping. It has a total land area of 192.51 km^2. It is classified as hot humid coastal climate with an agricultural potential. The Reserve is basically a coastal rainforest, woodland and grassland which supports a wide range of flora and fauna.

Habitat plays a role in supporting the parasite by providing favorable climatic conditions during incubation period, it provides a place of breeding and resting during adverse weather conditions (Wamwiri *et al.*, 2016;). Tsetse flies use various land cover and land use as their habitats. Strategies to control the tsetse have been put in place such as using repellents and it has worked, thou not fully. This research seeks to establish the tsetse abundance in various land covers and land use present around Shimba Hills National Reserve, this will help in identifying the hotspots and hence planning effectively for the control of the tsetse flies. It also aimed at assessing the impact of the presence of tsetse flies on livestock productivity.

The geographic location of the grazing sites determines whether livestock are affected by Animal trypanosomiasis or not. Around the Shimba Hills National Reserve fence, there is high concentration of tsetse flies and thus livestock grazing around the area due to lack of pastures in places away from the SHNR are mostly affected by Animal trypanosomiasis. The impact of tsetse fly on livestock productivity hasn't been much researched especially in the area of study.

1.2 Problem Statement

Shimba Hills, is one of the earliest foci for human sleeping sickness in East Africa, and widespread animal trypanosomiasis, both spread by tsetse fly. This has limited human occupation despite its suitability for most of agricultural practices (Muriuki et al., , 2003). In 1952 on the Kenya south coast, the colonial administration started a settlement of farmers in the Shimba Hills however, they experienced problems (Palmer, 1971). These problems included; tsetse fly infestation, and a high incidence of Livestock deaths, more groups of people were brought from other parts of the Coast region and upcountry and settled in the scheme. Majority of them came from overpopulated areas in Machakos and Kitui Districts however, despite the effort's settler population did not grow, many of the early settlers abandoned the scheme because of the death of their livestock due to Animal trypanosomiasis.

Trypanosomiasis has been a major constraint of the development of the livestock industry in the area surrounding Shimba Hills National Reserve. It causes livestock to be weak or even die if not treated. A lot of research has been done regarding the control of tsetse flies that transmits Animal trypanosomiasis however, information on spatial dynamics of tsetse and trypanosomes and its impact on livestock productivity remain limited and may be a reason that control strategies are not fully effective. Strategies to control or eventually eliminate the problem posed by trypanosomiasis must rely on tsetse ecology and suitable fly distribution data (G. Cecchi et al., 2008). Tsetse abundance is affected by the surrounding land cover, however, despite the enormous scientific attention towards tsetse control in SHNR, there has been less studies on the land cover and land use which is the main determinant of tsetse habitat. Recent studies on tsetse fly and animal trypanosomiasis disease have majorly looked at the biological aspects of the vector, and the knowledge about the effect of land use and land cover on risk of infection haven't been studied in Shimba Hills National Reserve.

This study goal was to determine the effect of land cover and land use on tsetse abundance around Shimba Hills National Reserve and the impact of the presence of the tsetse flies on livestock productivity. This was achieved through mapping the land use land cover around SHNR using the Remote Sensing technologies and overlaying the layers with tsetse distribution data that had been collected through setting up of NGU traps in different villages in Kubo South Ward that surrounds Shimba Hills National Reserve. Land cover and land use mapping was done using high resolution satellite imagery that was acquired through remote sensing technology. The study also aimed at assessing the impact of tsetse fly on livestock productivity in the tsetse fly hotspots areas.

1.3 Objectives

Main Objective

The overall objective of this study was to assess the impact of tsetse flies on livestock productivity using Geospatial technologies using a case study of Kubo South Location, Kwale County in Kenya.

Specific Objectives

The specific objectives were to:

1. Review the role of Geospatial Technologies in assessment of tsetse fly impact on livestock productivity.
2. Identify suitable data for mapping Tsetse fly habitats.
3. Map tsetse fly habitats.
4. Estimate the impact of tsetse fly on livestock productivity.

1.4 Justification for the Study

This research is significant because it will benefit the farmers in Kubo South Villages surrounding Shimba Hills National Reserve in that there will be reduced livestock deaths due to Animal trypanosomiasis. It will establish the land covers and land uses that are preferred by the tsetse fly for habitat, the project team involved in controlling the tsetse flies will therefore be able to know the hotspots and thus channel their energies and resources towards controlling the tsetse flies. The Land cover land use map will help in determining the distribution of pasture lands in Kubo South Location hence determining the availability of food for livestock. This will help the County Government of Kwale to plan on training farmers on alternative food for livestock in areas that have scarce pastures. The assessment of the impact of tsetse fly on livestock productivity will help the county government know the impact of the disease and hence prioritize on controlling the tsetse fly in the area of study. The output to this research will ensure that the livestock productivity is improved hence improving the GDP of the Kenyan economy.

1.5 Scope of work

The study is limited to the villages that are less than five kilometres from the SHNR. The research involved mapping the land use and land cover using a high-resolution satellite imagery and thus getting to know the tsetse fly habitats. Remote sensing and Geographic information System was applied in this project. ArcGIS software was be used to classify the various land cover and land use types available in Shimba Hills, they include; farmlands, grasslands, forests, bare land and shrubs.

The entomology data showing the spatial distribution of the scientific traps used to trap tsetse flies in the area, was then overlaid with the land cover land use data in order to establish whether the tsetse abundance is affected by the surrounding land use and land cover .The traps used for entomological study are spread across the study area in various land covers, there is one trap in every one square kilometre. The total number of traps used in this research was 171 and the data was collected. Livestock parameter data collected in 2018 was then used to assess the impact of tsetse fly on livestock productivity.

1.6 Organization of the report

This report is comprised of five chapters. It starts with chapter one which introduces the background of the research project, the objectives of the project, the justification of the project and the scope of the project. Chapter two shows a review of the literature which are of interest in the project. Chapter three describes the materials and the data used in the project, it also explains the area of study and the methodology used during the project. Chapter four describe the results achieved and discussion of those results. Finally, chapter five states the conclusions and recommendations drawn from the project.

CHAPTER 2: LITERATURE REVIEW

This Chapter highlights the information on the evolution and present state of theory, practice and research of the project. A review of most recent and relevant publications are presented in this section and cited in the references this will be done in form of subheadings in order to cover all the topics that are involved in this research. The policies and regulations governing Livestock Production will also be discussed in this section.

2.1 Policies and guidelines of livestock management

2.1.1 National Livestock Policies

In Kenya, livestock production is governed by the National Livestock Policy, it addresses the challenges in the livestock sub-sector in the context of livestock breeding, nutrition and feeding, disease control, value addition and marketing, research and extension. It has been designed so as to improve farms productivity and incomes for small-holder farmers, it emphasises on irrigation in order to reduce over dependence on rain-fed agriculture in the face of limited potential farmland. The policy encourages diversification of agricultural products and addition of value so as to reduce vulnerability and improve food security by reducing the number of those suffering from hunger and hence the achievement of MDGs, (Kenya Ministry of Livestock Development , 2008)

2.1.2 Regional Livestock Policies

East African Countries have developed a clear East African Community Livestock policy which addresses livestock sector. The mission of the EAC Livestock Policy is to develop a livestock subsector growing by at least 5.0% annually with a significant contribution to the agricultural GDP surpassing 50% and to reduction of poverty, hunger, unemployment and degradation of natural resources. The livestock development policies are being informed by the Comprehensive Africa Agriculture Development Program (CAADP) and the AU Policy Framework for Pastoralism which is continental.

The animal diseases cause huge economic loses directly due to mortality and indirectly through slowed growth and production, decreased fertility and work output resulting from morbidity. Major diseases in EAC region include Transboundary Animal Diseases (TADs) such as

Contagious Bovine Pleuro-Pneumonia (CBPP), Rift Valley Fever (RVF), Newcastle disease, Foot and Mouth Disease (FMD), tick-borne diseases, Trypanosomiasis and parasitic diseases. Trypanosomosis and Tick-borne diseases, present major impediments to livestock production in smallholder dairy, pastoral and agro-pastoral systems (*EAC LIVESTOCK POLICY*, 2014).

EAC livestock policy has set targets relevant to propelling Partner States beyond outcomes attained with the past and current policy practices in order to foster attainment of the policy goal. The targets reflect the outcomes in the various development frameworks guiding overall development of regional agriculture. The Policy targets by 2030 include; increase in the annual growth rate in livestock production by more than 5.0 % to spur 10 percent economic growth targeted by Partner States, increase in productivity and value of the multiple functions of livestock to more than 60%, to reduce degradation of the ecosystems supporting livestock assets by over 50% and to reduce the proportion of livestock dependent people living below the absolute poverty line and food insecure from 60 percent to less than 25%, in order to achieve the first MDG (*EAC LIVESTOCK POLICY*, 2014)

2.1.3 Global Livestock Policies

At the continental level, the Livestock Sector is aligned to Millennium Development Goals (MDG), the Comprehensive Africa Agriculture Development Program (CAADP), the African Union – Inter African Bureau for Animal Resources Strategic plan (AU-IBAR 2010-14) and the African Union Policy Framework for Pastoralism and Africa in 50 years' time which outlines the path to inclusive development. World Bank, FAO, IGAD, WTO are the organizations that also participate in the formulation of livestock management policies. They prioritize and emphasize pro-poor livelihoods with focus on reduction of poverty and degradation of natural resources (*EAC LIVESTOCK POLICY*, 2014)

2.2 Challenges facing Livestock Production Sector

2.2.1 Animal Trypanosomiasis

Research on tsetse fly has been done by many researchers, G. Cecchi et al., 2008 described tsetse fly as the primary vector of African Trypanosomiasis disease which affects livestock and human beings. It causes African animal trypanosomiasis (AAT) in livestock which is a parasitic disease that causes serious economic losses in livestock, it has robbed farmers a source of livelihood as it affects all domesticated animals such as cattle, sheep, goats, camels, horses, donkeys, pigs, dogs, cats and other species. In most parts of Africa, cattle are the most affected due to the feeding preferences of tsetse flies (African Animal trypanosomiasis report, 2009). However, most of the studies focus so much on the structure of the vector transmitting the diseases and not of the preference of the disease-causing vector to the environment surrounding it.

When an infected tsetse fly bites an animal, the parasites are transmitted in the saliva (AAT, 2009) to the animal. AAT makes animals become weak hence cannot plough or produce milk, pregnant females abort their young ones and it may also lead to the death of the animals. It therefore causes food insecurity by limiting the use of animal draught power and constraining maximum use of the prime lands (Shawn, 2014). AAT disease results in very direct losses to livestock keepers by reducing productivity due to high mortality rate. Approximately three million cattle die from nagana across Africa every year, costing the continent several billion dollars (Cecchi, 2014). There is therefore need to focus on controlling and eradication of the tsetse fly. In the area surrounding SHNR, efforts towards controlling the tsetse flies have done, the include using a repellant which is placed on the collar of the animals and thus has to be refilled regularly. This has helped in ensuring that there is no contact between the animal and the tsetse fly however tsetse flies haven't been eradicated completely in the area and incase the repellent has finished and has not been refilled, the animal will still be at risk of contracting African animal trypanosomiasis.

2.2.2 Pastures

Pastures are the common food for livestock in Kenya, however due to the increase in human population, pasture lands are been converted to farming hence leaving less pastures for livestock. As pasture challenges increases, remote sensing technology aid in providing critical information on spatial distribution of pasture land Schellberg et al., 2008 suggested that it is necessary to use high spatial and spectral resolution sensing systems in order to quantify pasturelands. Pasture areas are often less heterogeneous as compared to many other landscapes, pasture analysis can be complex because of the characteristics of soils, and because pastures are dynamic with constantly changing conditions. Remote sensing technologies solves the complexity through an understanding of plants and soils and their interactions with the electromagnetic spectrum (Allen et al., 1970)

There has been achievements in agriculture using the remote sensing technology CSIRO and partners in Australia developed a programme that delivers real time pasture growth rate and feed on offer directly to the grazers for management of feeds (Donald et al., 2010). The estimates are made using MODIS and NDVI combined with soil and climate data. (Ramoelo et al., 2012) showed the potential of Rapid Eye satellite sensor with its spatial and temporal resolution to successfully map grass over large spatial extents. High spectral resolution images are required in mapping pastures because it enables spectral features to be identified (Pullanagari et al., 2015)

(Miller, 2012) used a combination of Geographic Information Systems (GIS) with Remote Sensing (RS) to analyze environmental variables and track movement patterns of sheep and tested at the Lava Lake Livestock and Landscape Ranch. A GIS model utilizing remotely sensed imagery was built to identify areas capable for grazing by sheep across the study area. Tracking Analyst and Time Slider, which are GIS based time analysis tools, utilized point data collected from Global Positioning System (GPS) collars to visualize the rate at which sheep are traveling(Miller, 2012). GIS was applied in the determination of suitable areas for sheep grazing across the Awash River Basin, located in Ethiopia.

The existing research lack large scale maps of pasture areas hence the need to use GIS technology and Remote Sensing to provide spatial information of pasture distribution. No research has been done in the study area concerning pasture distribution and its influence on the spread of transmission of trypanosomiasis. This research will aid in livestock sectors planning in order to ensure maximum productivity and thus improving the economy of our country.

2.3 Application of GIS and Remote Sensing in the control of tsetse flies

GIS and remote sensing technologies have proved to be effective in studies concerning tsetse fly spatial distribution (G. Cecchi et al., 2008). Remotely sensed data can be used to provide information on land cover such as different vegetation types and hence habitat (Innes & Koch, 1998). The spatial distribution of diseases is related to the habitat of their vector (Pavlovsky, 1966) therefore, remotely sensed data can be used to provide information on the spatial distribution of tsetse flies in various land covers. The introduction of affordable satellite imageries from Global Land Cover Facility mapping (GLCF) has now made it possible to study LULC data. The first remote sensing satellite (Landsat-1) was launched in 1972, since then LULC studies have been carried out on different scales for different users (Rajendra, 2011). Satellite imagery is used for recognition of synoptic data of earth's surface.

2.4 Applications of Geospatial Technologies in livestock management

GIS is one of the Geospatial Technologies that is good for decision making, its application is increasing every day. This section will discuss how these technologies have been applied in Livestock management. (Sturaro et al.,, 2010) reports that GIS applications has been increasing in many scientific areas over the years since it has found fundamental application in environmental science and ecology. There is an increase in the use of GIS in livestock management, for example in the study of the relationship between livestock and environment, it is also applied in land use management and disease mapping and monitoring (Joost et al., 2010). The veterinary field is an example of the application of the GIS in management of livestock, the use of the technology has developed over the past years because GIS software are becoming more affordable due to the presence of free open source software (FOSS), and user friendliness.

(Paudel et al.,, 2009) and (Infascelli et al.,, 2010) researched on the environmental effects on livestock farms using Geospatial technologies. The first research involved developing GIS models in order to identify dairy manure transportation routes minimizing environmental costs and other constraints in Louisiana (USA). The second research involved using geostatistical tools, to predict and visualized the spatial distribution of average nitrogen production in buffalo farms in a region of Southern Italy. These researches are however farm based and there is need to upscale the use of geospatial technologies to large scale to be able to reach and help farmers in the management of their livestock.

(Sturaro et al., 2009) researched on the management of landscape and pasture surfaces, the research involved georeferencing and analysis of surfaces managed by livestock farms in the Belluno province (north-eastern Italy). It demonstrated that traditional extensive farms maintain steepest meadows and pastures, whereas intensive arms are able to maintain only crops and flat meadows. The second study by (Bernués et al., 2005) involved identification of key imbalances that threatens the sustainability of Sierra de Guara National Park (Spain). The imbalances involved low continuity of farming families, intensification of the management system, degradation of grazing resources and concentration of grazing areas.

GIS has also been used in the control of diseases and Epidemiology, (Cringoli et al., 2007) used it to study the spatial structure of livestock populations so as to understand the role of sheep as reservoir for the transmission of cystic echinococcosis to cattle and water buffaloes in Southern Italy. The study however didn’t focus on the spatial distribution of the vector of the disease, this would have helped in controlling the disease. The other application involved the use of Remote Sensing technology in Namibia to analyze livestock movement patterns in a semi-arid communal environment. A strong effect of land use (quality of grassland) and water point’s availability was observed by (Verlinden & Kruger, 2007)

2.5 Relationship between land cover, land use and tsetse habitat

Land cover is defined as the observed (bio) physical cover on the earth’s surface, it describes vegetation and man-made feature.(Comber et al., 2005) defined it as natural or human-engineered materials covering the earth’s surface. Land use on the other hand is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it. (Gregorio et al., 2005) defines it as the function of the surface cover, which is usually expressed in economic terms. Land cover is among the factors that are important for tsetse reproduction and survival, the other factors are temperature, normalized difference vegetation index (NDVI), elevation, and rainfall, this is according to (Moore & Messina, 2010) Tsetse fly presence is usually related to the characteristics of land cover (i.e. vegetation), which is affected primarily by climate and human activities, presence of a suitable source of food is also essential for tsetse fly. The analysis of the vegetation cover has often played a major role in the estimates of the tsetse distribution and in the description of their habitat (Katondo, 1984).

(Katondo, 1984) highlighted the factors influencing the suitability of habitats for tsetse flies, land cover was highlighted as one of the most relevant factors. Vegetation is affected by and affects temperature and humidity, the two major abiotic determinants of tsetse distribution; trees in particular provide shade for developing pupae and resting sites for adults. The analysis of the vegetation cover has a role in the estimates of the tsetse distribution and in the description of their habitat.(G. Cecchi et al., 2008) suggested that the efforts aimed at controlling or eliminating trypanosomes should be informed by contemporary and accurate information on the geographic distribution of tsetse flies. Some land cover provides habitat to tsetse flies, it plays a key role in supporting the parasite through the provision of favorable climatic conditions important during the incubation.

According to (Mugenyi et al., , 2015) mapping the distribution and population of tsetse flies in various land covers and land use assists in predicting trypanosomiasis distributions and developing rational strategies for disease and vector control. Despite this knowledge less has been done in mapping the spatial distribution of land covers especially in Shimba Hills which is the study area for this research. (Ngonyoka et al., 2017) reported a difference of tsetse fly species abundance and infection rates among habitats in villages that were surveyed, he noted that the abundance of tsetse in various habitats is influenced by vegetation cover. (Shereni et al., 2016) noted that tsetse fly distribution appeared to be supported by factors such as variation in land use and altitude-mediated climatic patterns.

CHAPTER 3: METHODOLOGY

This chapter describes the methodology adopted in the study. It contains subsections which has information on the materials and specific procedures used in carrying out the project.

3.1 Area of Study

The study area is Kwale County Kubo South Villages which surrounds Shimba Hills National Reserve. It is located between latitudes 3°3'S and 4°45'S south and longitudes 38°31'E and 39°831'E. It borders Taita Taveta to the West, Kilifi district to the North West, Mombasa and Indian Ocean to the East and Republic of Tanzania to the South. Shimba Hills National Reserve contains one of the largest coastal forests in East Africa, it is a home of many elephants and the only park in Kenya where there is Sable Antelope. It is approximately 300 square kilometers and is protected by the Kenya wildlife services.

Kubo south location surrounding SHNR has a hot and humid coastal climate. Rainfall is very common throughout the year, the long rains happen in April and May, these months are the wettest in the year. Short rains are experienced in October to November while December, January, February and March are the dry months in the area with little rains and high temperatures of around 31 degrees Celsius. The average rainfall ranges between 400mm and 1680mm per annum and this makes it suitable for livestock rearing (Kwale County Government, 2013).

The main economic activities in the area are livestock rearing, mixed farming, fishing and eco/tourism. The species of the livestock reared include dairy cattle's, oxen, goats, sheep and poultry. Figure 3.1 is a map of the study area.

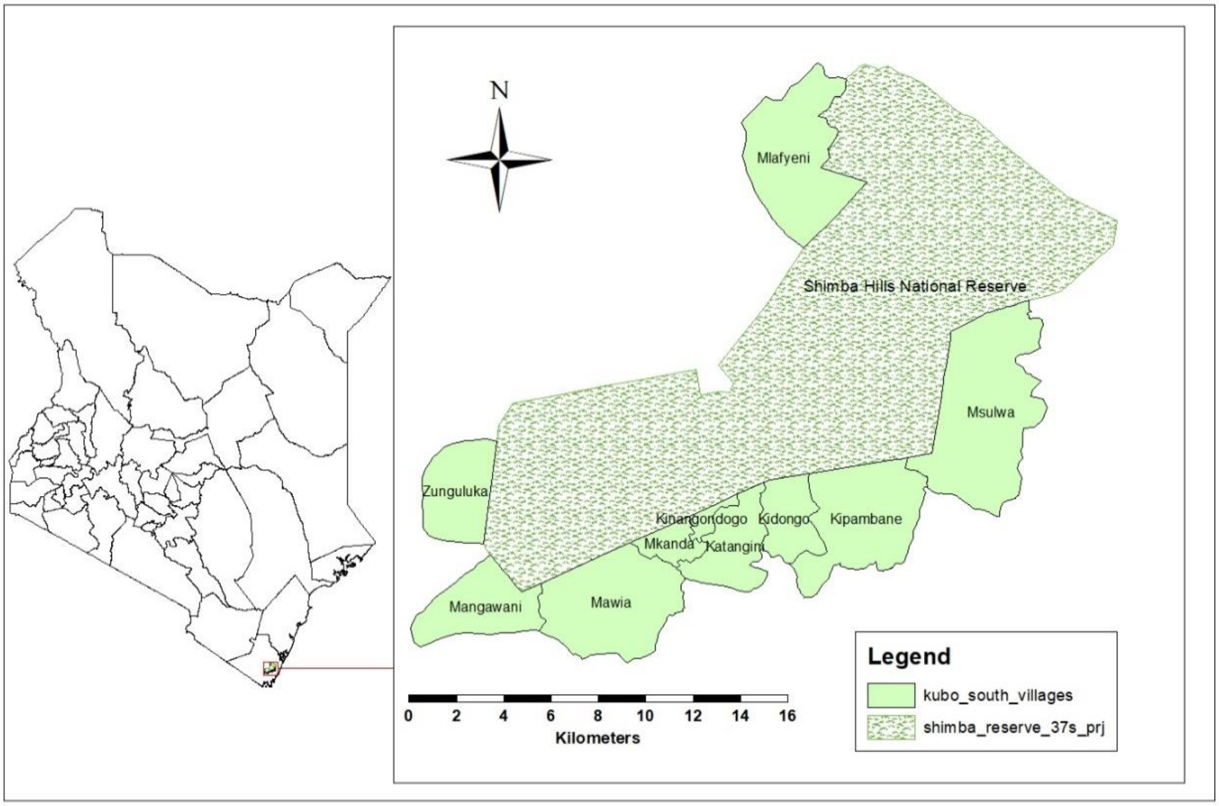

Figure 3.1: Study Area Map

3.2 Data sources and tools

The following is a list of the materials that were used in the project

3.2.1 Data Sources

The data used in the study for land use/land cover classification was obtained from the Sentinel-2, which is a space borne sensor that was launched by the European Space Agency (ESA). The image was collected on the 5th June 2018, the imagery specification are as shown in table 3.1.

The entomology datasets were obtained from International Centre for Insects Physiology and Ecology (ICIPE) Animal Health Department. It contains spatial data of the population of tsetse flies in 171 traps distributed in the area of study.

Livestock productivity indicators data were acquired from ICIPE Social Economics Department. The data was collected in a survey done in the study area in September 2018. The survey focussed on collecting data on the social economic effects of tsetse flies on farmers living within the wildlife livestock interface. It was done on selected villages surrounding Shimba Hills National Reserve. Table 3.1 shows a summary of the data used in the project and the source.

Table 3.1: Datasets used

Data	Source	Characteristics
Sentinel 2 imagery	ESA	Acquired in June 2018 Resolution is 10m for Band 2,3,4 and 8 Processing level is Level-1c Cloud cover is 0.49%
Entomology Dataset	ICIPE Animal health department	Contains Population of Tsetse fly collected every month in 2018 in 171 traps using Biconical traps
Livestock Productivity Indicators Data	ICIPE Social Economics Department	Household survey carried in 2018 in Kubo south Ward

3.2.2 Tools

A 4GB Ram Laptop was used in the project for data processing, analysis and also for report writing. ArcGIS 10.6 is a GIS software which is good in processing spatial data. It was used to process, analyse and display the results of the project. SNAP software is a desktop imaging software for raster data. It is a free software by ESA SNAP distributed under GNU licence. It was used to process Sentinel 2 imagery data before been loaded to ArcGIS for further processing. GPS Garmin device was used to pick spatial coordinates which were used for ground truthing. Stata 15 Statistical Software from StataCorp was used to analyse livestock productivity data.

Table 3.2: Tools

Tool	Source
4GB RAM Laptop	Personal
ArcGIS Software	ESRI
GPS Device	ICIPE
Stata 15 Statistical Software	StataCorp
SNAP software	ESA

3.3 Methodology

3.3.1 Acquisition of data

This step involved acquiring relevant data required for the project for the area of study from the relevant authorities. Very high-resolution satellite images for the area of study were acquired from the relevant authorities. The data used in the project were; tsetse fly distribution data, livestock productivity data and sentinel imagery. The tsetse fly spatial distribution data shows the number of tsetse collected by the traps distributed within the 12 villages in the area of study, which was done repeatedly for a period of one year. Livestock productivity data and tsetse fly data was acquired from International Centre of Insect Physiology and Entomology (ICIPE) Animal health Department and the Social Economics department.

3.3.2 Preprocessing of images

The pre-processing involved clipping the images to the required extent, before data analysis so as to correct for any distortion due to the characteristics of the imaging system and imaging conditions. The preprocessing of the images was done using the SNAP image software. The procedure included resampling which was done in order to ensure that images of each band have the same number of pixels same resolution. Atmospheric corrections were also performed using SNAP software in order to account for various atmospheric conditions such as ground elevations and solar geometries. This was achieved using SNAP plugin which is known as Sen2cor. Subset selection was then done in order to allow focus on the area of interest.

The image from SNAP was then exported in tiff format and loaded in ArcGIS software where further processing was done. These processed included clipping of the image to the required area of study as shown in figure 3.2. This was done using the data management tools in the Arc toolbox of the ArcGIS software. The composite tool in the image analysis window of ArcGIS software was used to combine single bands into a multiband image which for this case was an RGB composite. This composite aided in the analysis done to the image. The bands used were band 2, 3, and 4. A false color composite was also generated, it aided in the interpretation of the imagery

Figure 3.2: A clipped image of the study area

3.3.3 Image classification

Image classification is the process of categorizing all pixels in an image into different land cover and land use classes or themes. In this project drawing tools which are provided by the ArcGIS Software image classification tool were used to create new geometries in the area of study for different classes. The new geometries were then used as training samples (vectors) when classifying the image. Classes selected included, bare land, tree cover, grasslands, shrubs and croplands. Maximum Likelihood Classification Algorithm method was used since it provides a consistent approach to parameter estimation problems. This algorithm considers both variances and covariance of the class signatures when assigning each cell to one of the classes represented in the training file.

Accuracy assessment was done for the classification using ArcGIS 10.6 software. A reference data set including a total of 250 points was created using ground truth data. These points were selected over different locations representing different land cover/use classes. A Random Sampling Method procedure was used for the accuracy assessment.

3.3.4 Mapping tsetse habitats

Entomology data is the data collected by setting NGU traps in random areas distributed within Kubo south villages every month. The total tsetse flies collected within 9 months of 2018 was calculated and the result overlaid in ArcGIS 10.6 software with the classified map. The distribution of the tsetse fly in different land covers was then studied and the land cover with abundant tsetse is identified. The land covers included grasslands, crop lands, tree cover, shrubs and bare lands.

3.4 Establishing the impact of tsetse fly on livestock productivity

This process involved displaying the productivity data in the study area. The livestock productivity indicators used in this research included, milk production, mortality rate and disease incidence and calving intervals. The indicators were displayed using the data that was collected in the area of study in 2018. Stata software was used to do the statistical analysis of the data. Four villages where the data was available were used, these villages are; Msulwa, Kipambane, Kidongo and katangini.

The livestock productivity indicators were then overlaid on a layer showing the tsetse density in the study area which was generated using the tsetse fly population data collected in 2018.

3.5 Validation of the results

The process of validating the results included undertaking accuracy assessment in order to establish the accuracy of the classified image. Accuracy assessment involves comparing the classified image with the data that is considered accurate or the ground truth data. A confusion matrix was created in ArcGIS software. Ground truth data collected in the study area was used as the reference data. The other results were validated through a thorough literature review done previously.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Introduction

One of the objectives of the project was to map tsetse fly habitats in the study area and to understand tsetse fly abundance in various land cover classes. Secondly, the project was to assess the impact of tsetse flies on livestock productivity in the area of study. The results and outcomes of the project are presented in the form of maps, charts and statistical graphs.

The results of the pre-processed image are as follows. Figure 4.1 shows subset selection results in SNAP software. It shows the imagery of the area of interest thou not clipped to the exact administrative boundaries. The results were obtained from processing sentinel 2 image. Figure shows the image of Shimba Hills National Reserve in the middle shown by a dark green colour and the surrounding areas. SHNR has a very dense vegetation hence the dark green appearance.

Figure 4.1: Subset of the imagery showing the area of study

Figure 4.2 shows the false colour composite of the area of study generated in ArcGIS software. The boundaries are not gazetted, it is a merged grid generated during the selection of the spatial location of the 171 traps in the study area. The false colour was generated by combining infrared, red and green bands which have spatial resolution of 10 meters. False colour visualizes the wavelengths that the human eye does not see, it allows vegetation to be detected readily in the image. The false colour composite aided in the interpretation of the image, it was useful in identifying different land cover classes in the area of study. Vegetation appears in the various shade of red depending on its condition, this is because vegetation reflects more light in the near infrared.

Figure 4.2: False colour composite of the area of study

Figure 4.3 is an RGB composite of the imagery, it was generated by combining band 2, 3 and 4 with 10m spatial resolution. It is an image whereby each pixel is given by three values, that is one each for the red, blue, and green components of the pixel's color. In this composite image, the color of the object appears the same to an observer as viewing the image directly. It shows the area in the actual colors as seen by the human eye. Vegetation is therefore depicted in green color. This was to help in interpretation of the image during the study.

Figure 4.3: An RGB composite of the study area.

4.1.1 Characteristics of Tsetse habitats data

Sentinel two data was found to be suitable for mapping tsetse fly habitats because it is of high spatial resolution and high revisit frequency. Four bands (band 2, 3, 4 and band 8) of 10m resolution were of interest in this study. The sentinel 2 imagery is freely available and that is the reason it was used in this research. The other data used was the entomology dataset which shows the population of tsetse flies collected in each trap every month, the collection is done four times with an interval of 48 hours every month. The data was collected using biconical traps baited with cow urine and acetone chemical to attract the tsetse flies. The entomology datasets were in point format and thus it made it good to be overlaid with the classified image hence determination on suitable tsetse habitats in the area of study.

4.1.2 Tsetse fly habitats

The figure 4.4 shows the various land covers of the study area, they are tree cover, shrubs, grasslands, farmlands and bare lands. Tree cover represents the land cover where the trees are dense and more than five meters in height. Shrubs represent covers where land cover has a vegetation made of trees that have a height of less than five metres and not dense. Grass land represent land covers made of pastures; Crop lands is a land cover class where agricultural activities are practised. Bare lands are land covers where there is no vegetation. Maximum Likelihood algorithm was used in the classification of the image.

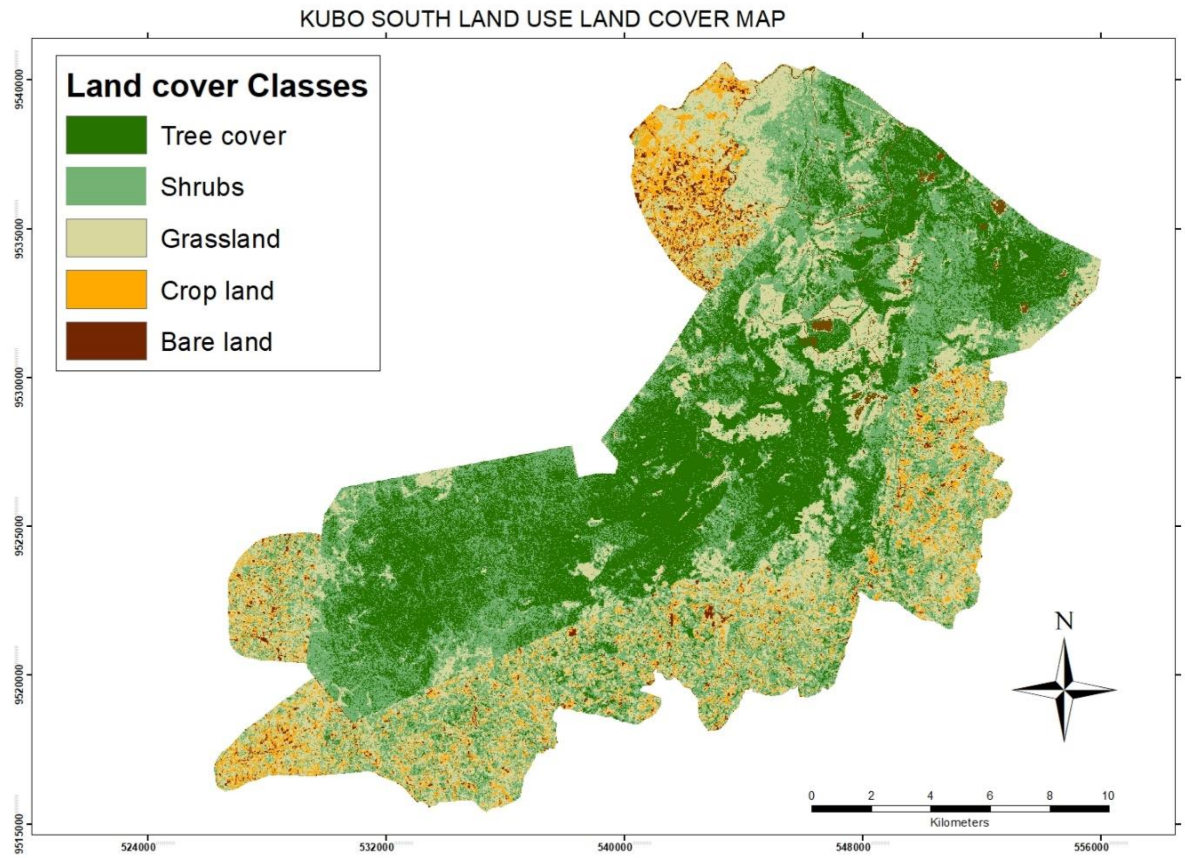

Figure 4.4: Land cover land use map of the area of study

The area is largely covered by dense vegetation with an area of 126.32 Square kilometres, followed by shrub cover which covers an area of 109.30 square kilometres, then grass lands which covers an area of 96.05 square kilometres. Crop land covers an area of 41.12 square kilometres and bare lands covers an area of 11.01 square kilometres. The dense vegetation is mostly inside the park where there is less interference of the vegetation by human beings.

The other result of the study was a map showing the tsetse fly population in various land covers. The tsetse fly data shows a total of all tsetse flies collected per trap in the year 2018. The black dots represent 0 flies collected; the brown dots represent the number of flies collected with the size of the dot been proportional to the number of traps collected per trap. 26% of the traps deployed had zero flies captured through out the whole period, 81% of the total flies captured were from 13% of the traps deployed. The map is as shown in of the tsetse fly distribution is as shown in figure 4.5.

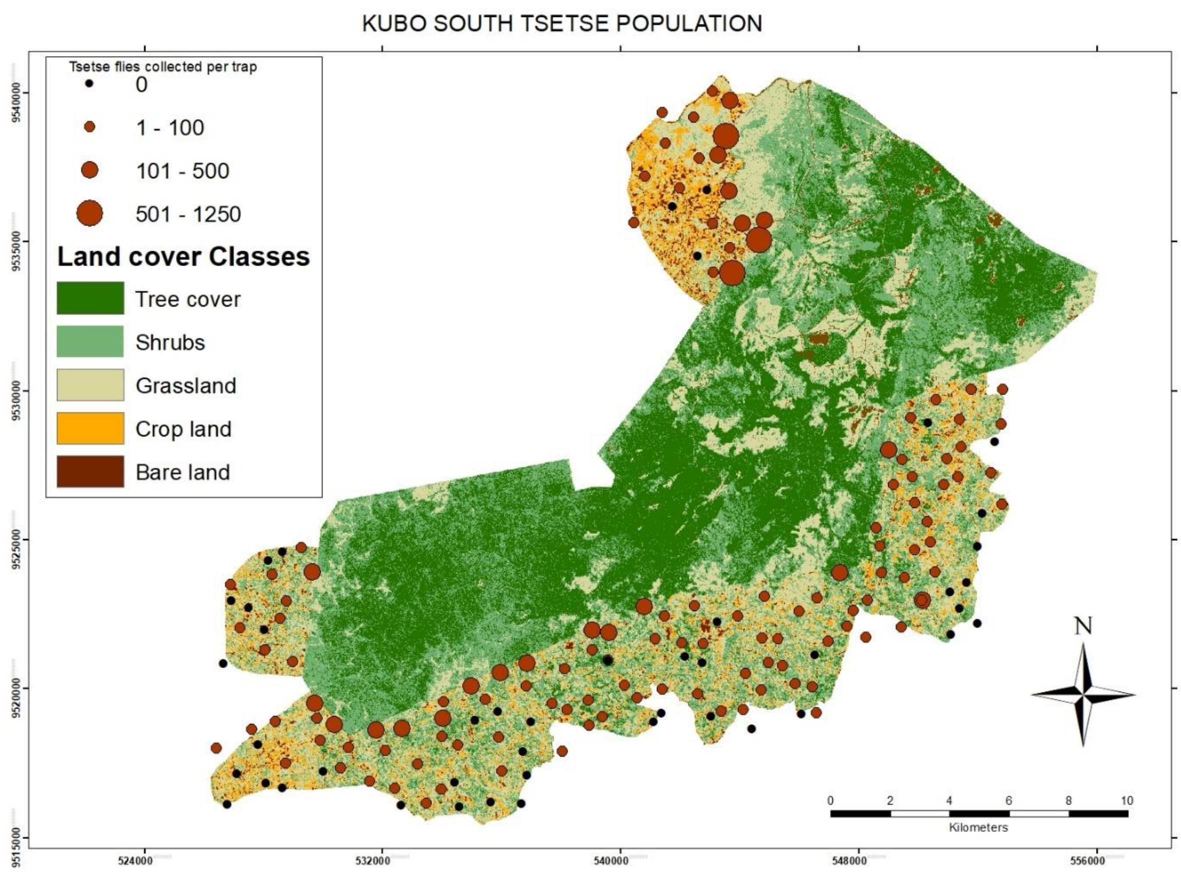

Figure 4.5: Tsetse fly population overlaid on various habitats

Tsetse flies were found to be abundant in areas with vegetation in all the villages in the area of study except for Mlafyeni village which is found at the North West side of the Shimba Hills

National Reserve. In this Village, tsetse flies are abundant in crop lands. Tsetse flies are abundant in areas that are close to the fence of the park and the abundance reduce as one move further from the fence.

A cluster chart showing tsetse fly abundance in various habitats was generated as shown in figure 4.6. The vertical axis represents the total number of tsetse flies collected in 2018 in various traps while the horizontal axis shows the land cover classes found in the study area. Tsetse flies were found to be abundant in grasslands and very few in bare lands.

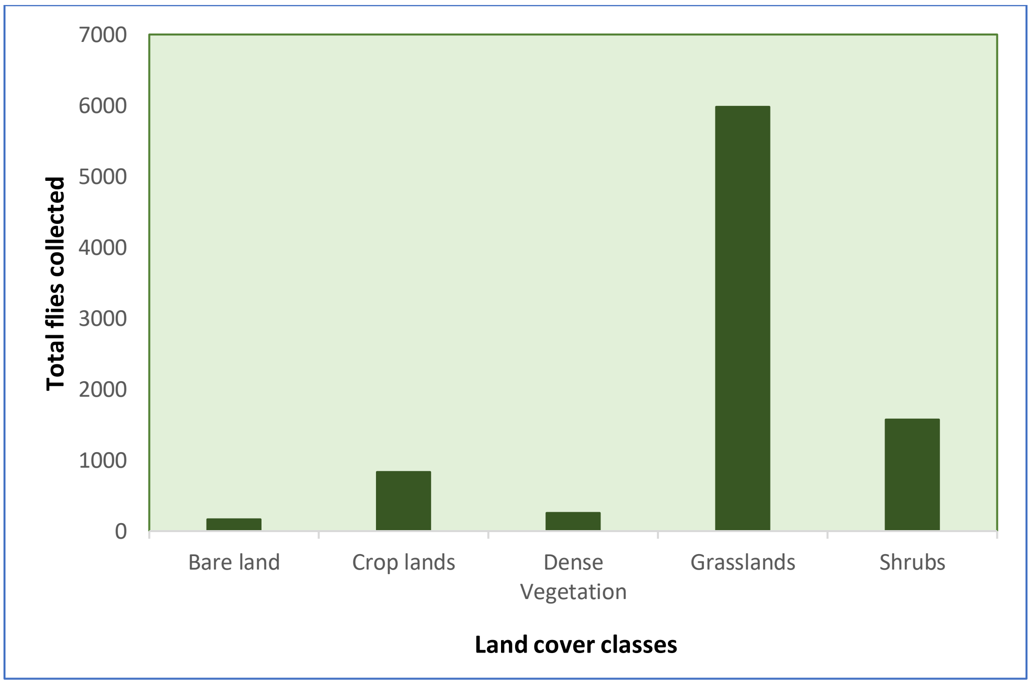

Figure 4.6: Tsetse abundance in various land covers

The x axis in the graph represent the various land covers found in the study area while the y axis represents the total number of tsetse flies collected in various traps in the year 2018.The trap that collected the highest number of traps in the area of study is found in grassland land covers. It was also noted that the traps that collected more than 400 tsetse flies in the study area were also found in the grasslands. The traps in the shrub land covers collected a good number of tsetse flies with highest being 295 traps. The bare land classes, croplands and dense vegetation recorded low collection of tsetse flies.

4.1.3 Impact of Tsetse Fly on Livestock productivity

Trypanosomosis disease which is caused majorly by tsetse fly has various symptoms such as low milk production, long calving intervals, high abortion rates and even deaths if livestock are not treated. The livestock productivity parameters were therefore analysed, and the results are as displayed in the figures 4.7, 4.8, 4.9, 4.10, 4.11 and Figure 4.12. Figure 4.7 shows the proportion of income from livestock farming in percentage, of the households in the study area overlaid on tsetse fly density data. The brown dots show the household income, its size is proportional to the proportion of income from livestock farming. The colourless dots represent households that do not depend on income from livestock for livelihood.

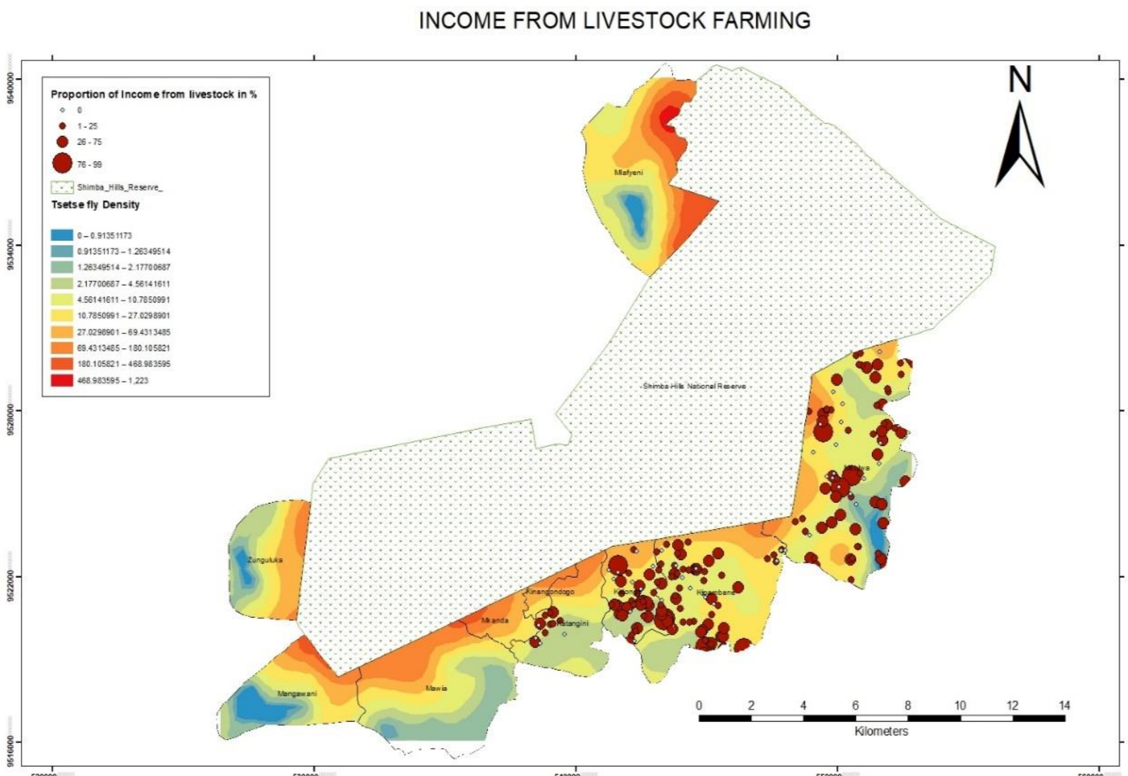

Figure 4.7: Map showing the proportion of income from livestock farming

It was established that few farmers have zero dependency on the income from livestock farming in all the four villages. Most household income fall between 25% and 75 % dependency on the income from livestock farming. This income is from sale of milk produced by cattle's, sale of livestock for meat production, use of oxen for farming and other benefits a farmer gets from owning livestock. African Animal Trapanosomosis causes death of livestock and reduced milk production therefore leads to huge losses to the residents of the area who dependents on livestock for livelihood.

The normal Calving interval for livestock is 12 to 13 months. Figure 4.8 shows the households that had animals with calving intervals more than the normal for healthy livestock.

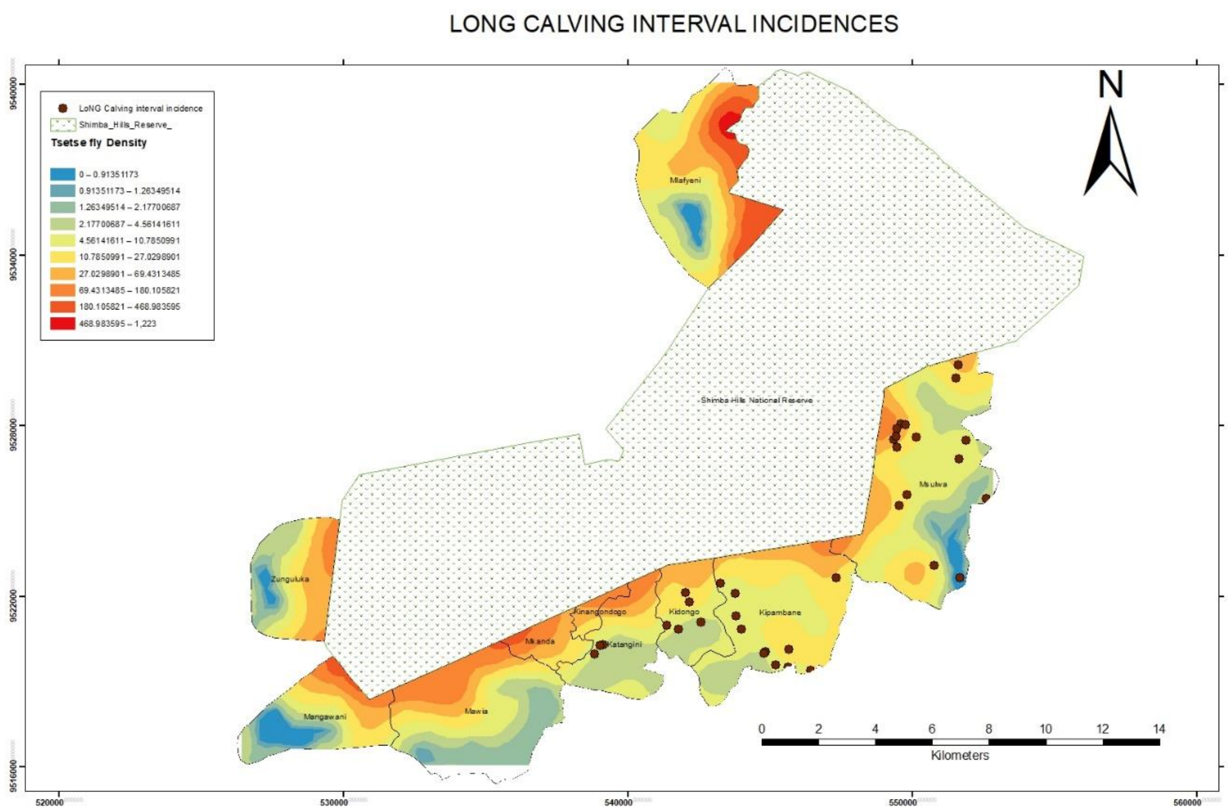

Figure 4.8. Map showing the households with livestock with long calving interval

It was established that all the villages have incidences of long livestock calving interval and in Msulwa village, most of the households that have livestock with long calving rate fall in the areas that tsetse fly density is high. However, there are some incidence of long calving interval reported in areas with low tsetse fly's density. This could be explained by the fact that trapanosomosis can also be transmitted mechanically by biting flies such as stomoxys.

The other negative effect caused by tsetse fly is livestock deaths. Figure 4.9 shows the number of death incidences due to trypanosomiasis in various households recorded in 2018. The blue dots show the number of livestock death incidences recorded on the study area.

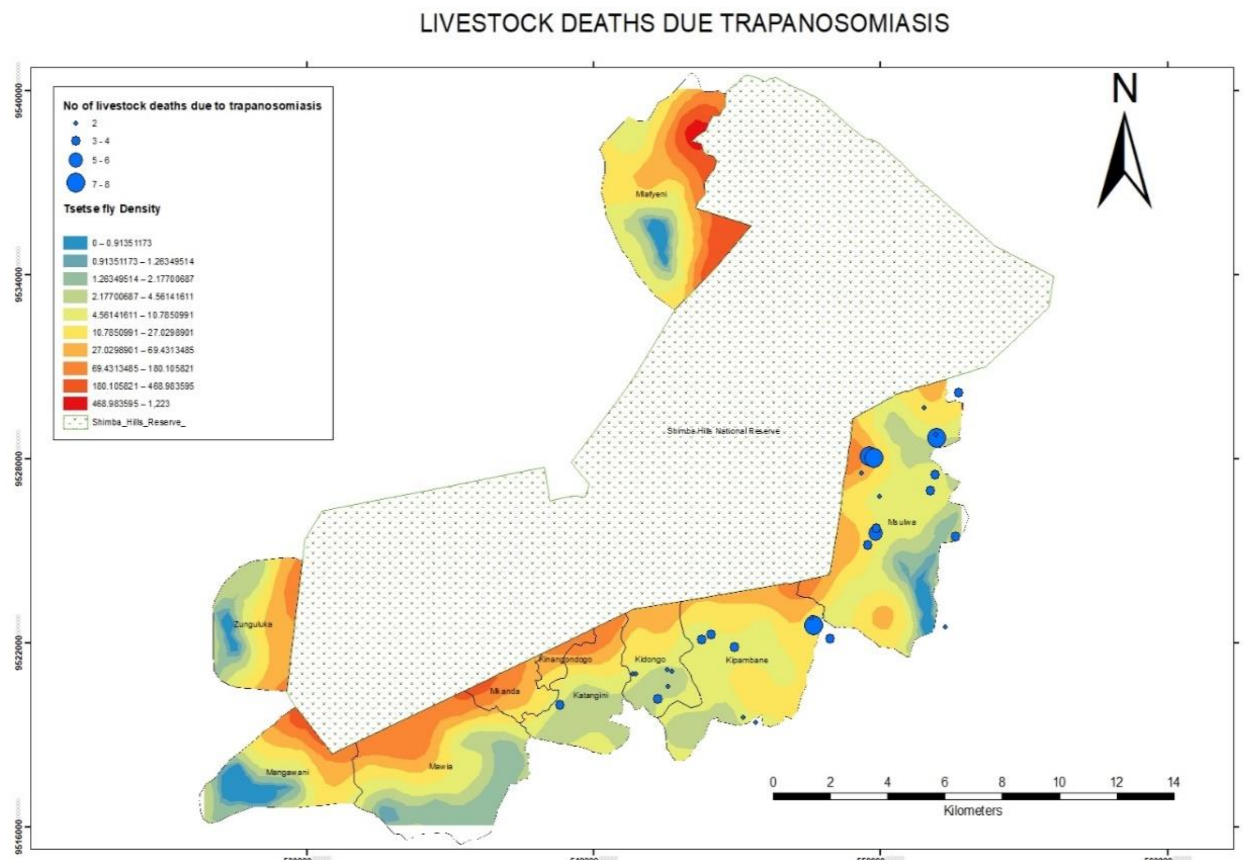

Figure 4.9: A map showing the number of deaths due to trypanosomiasis in the area of study

It was established that a high number of deaths due to trypanosomosis had been recorded in the last seven years with the highest being eight deaths per household. Some of the deaths recorded in the village was in the tsetse hotspots near the fence of the park however, deaths were also reported in the areas that have low fly density and as earlier discussed, this could be due to the presence of biting flies which transmit *T.vivax* trypanosomes.

Due to tsetse fly presence, livestock fall sick due to trypanosomiasis frequently, figure 4.10 shows the frequency of livestock treatment per various households recorded in a six-month interval. The blue dots represent the frequency of treatment and the size of the dot increases with the increase in the frequency.

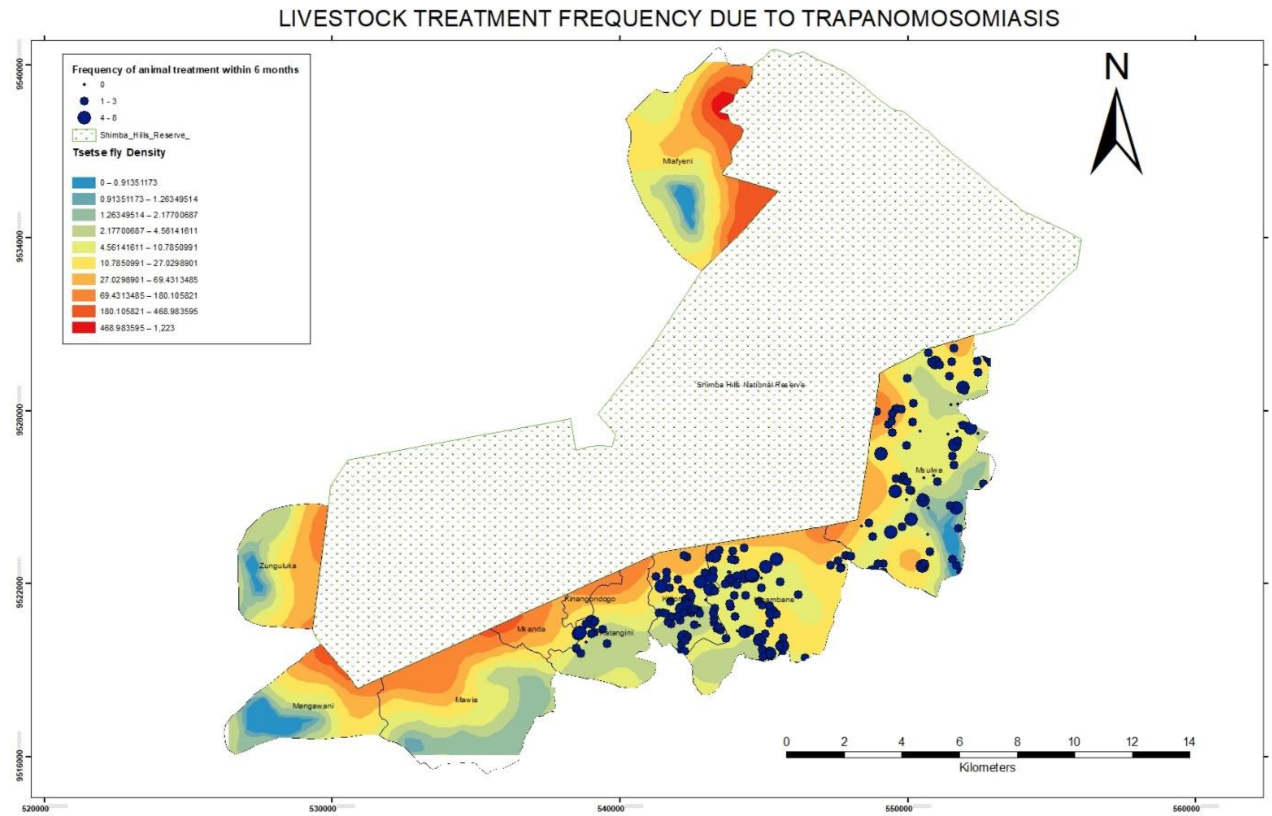

Figure 4.10: A map showing the frequency of treatment of the animals due to trypanosomiasis

It was established that nearly all households in the four villages have had their livestock sick due to trypanosomosis within a period of 6 months. All the villages had households whom their livestock have had been treated 4-8 times within a period of six months. This therefore shows that the disease is very common in the area and urgent measures should be undertaken to ensure that the farmers do not incur any loss again due to the disease.

The cost of livestock treatment annually per cow is as shown in figure 4.11 by the red dots with the increase in size showing higher cost spent on livestock treatment per year.

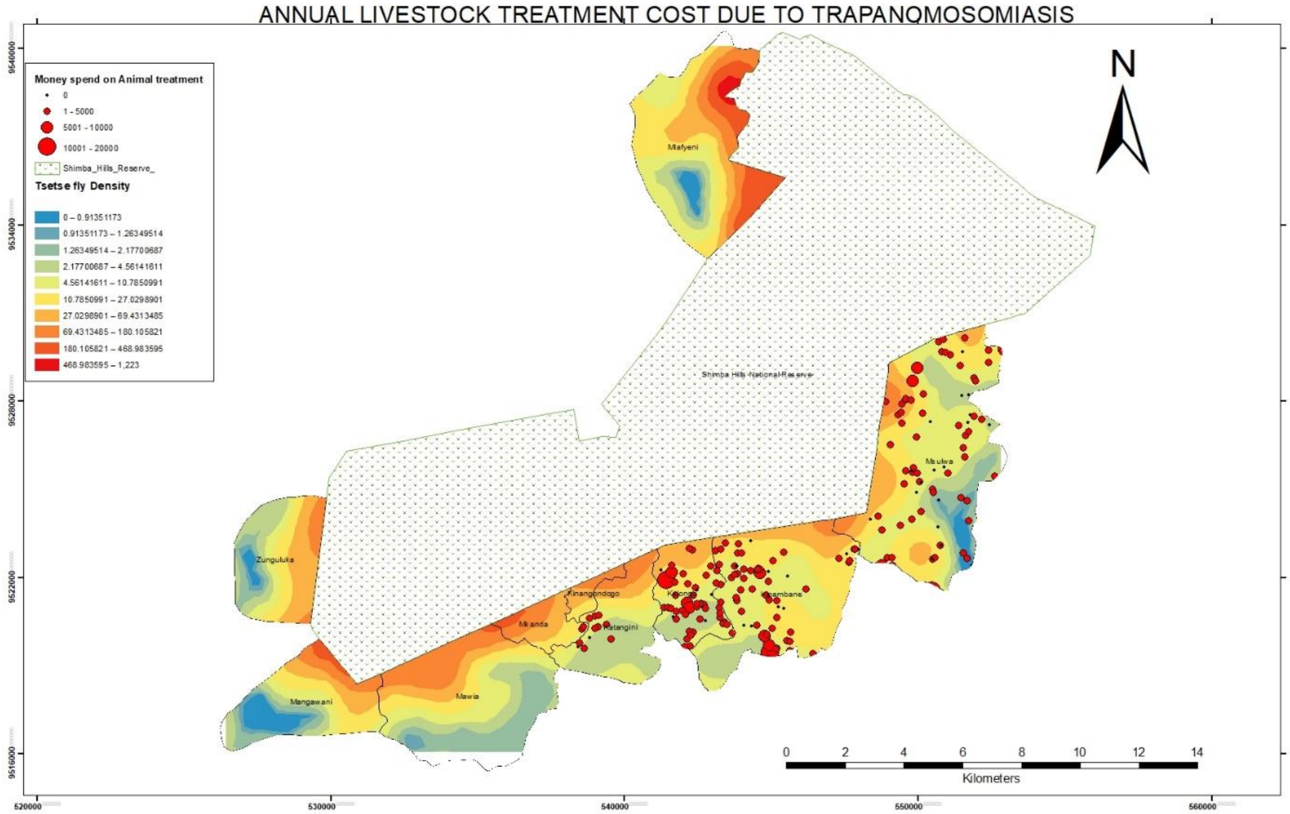

Fig 4.11: A map showing the cost of treatment per cow within per year.

It was established that most households in the area of study spend more than Kshs. 5000 to treat one livestock per annum. Kidongo village recorded several households that had spent more than kshs. 10000 per year to treat their animals. It was noted that only few households hadn't suffered any loss due to the disease. A lot of money is spent on the treatment and therefore the county government and the relevant authorities should take an urgent action so as to reduce the losses that farmers incur in treating their livestock.

The results shown in figure 4.12 shows the number the combined effects of trypanosomiasis and it shows the house holds that may have experienced all the effects of the tsetse fly disease.

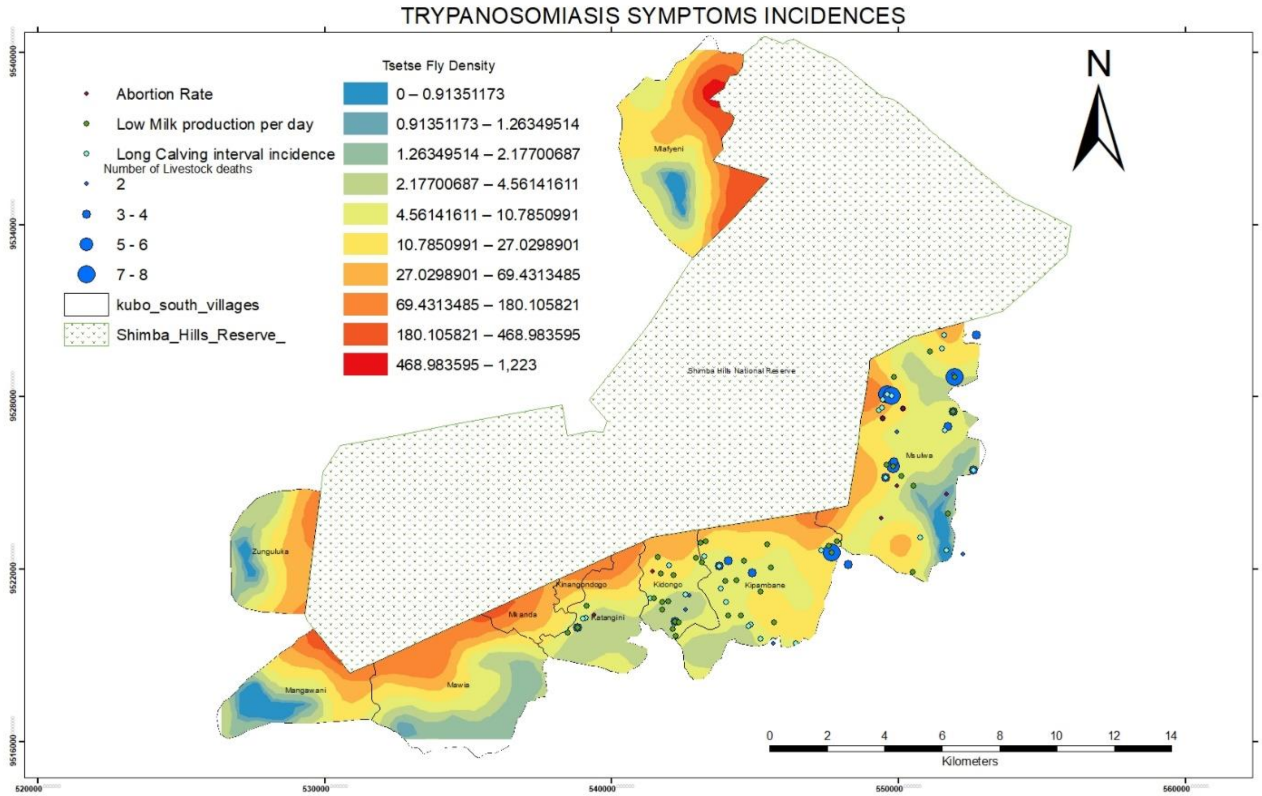

Figure 4.12: A map showing the combined trypanosomiasis symptoms incidences

It was established that Msulwa had the highest number of household that had experienced the various effects of trypanosomiases which include 25% of abortion rate in livestock, Less than 1 litre milk production per animal per day, long calving intervals of more than 15 months and high number of livestock death.

4.2 Discussions of the Results

The research aimed at identifying suitable data for mapping tsetse habitats and assessing the impact of tsetse flies on livestock productivity. Sentinel 2 images were used to map the tsetse fly habitats, as shown in Figure 4.1, it proved to be reliable in the study as it is easily available, has a frequency revisit time and high spatial resolution.

One of the objectives of the research was to establish the most suitable tsetse habitats in the study area. As shown in Figure 4.6, it was found that Grass lands are the main tsetse fly habitats around SHNR while they are few tsetse flies in bare lands where there is barely any vegetation. This could be explained by the fact that tsetse flies need a vegetated area for breeding. This is in agreement with what was noted by (Ngonyoka et al., 2017) that flies tend aggregate in the vegetated areas, which gives them suitable microclimate conditions and breeding sites.

The other objective was to assess the impact of tsetse flies on livestock productivity in the study area. The results showed that the impact of tsetse flies based on the effects caused by the disease are experienced not just in the tsetse hotspots but in all areas that have traces of tsetse flies in the study area. It was also established that most households do not live on the tsetse hotspots that is the areas near the fence of the national reserve. This could be that the trypanosome infections were due to *T. vivax* trypanosome which is can be transmitted biologically by tsetse fly or mechanically by biting flies such as stomoxys.

Most of the livestock deaths and long calving intervals were reported in Msulwa village, this could be due to the presence of dense vegetation in the area which acts as tsetse fly habitats by providing shade. It was established that most of the households depend on livestock farming as a source of income as shown in figure 4.7. The livestock deaths as shown in figure 4.9 therefore bring huge losses to the affected households. The long calving interval due to trypanosome infection which reduces the chances of a cow calving again and abortion rates causes slow increase in the number of livestock and low milk production due to short lactation period. The normal calving interval is between 12 to 13 months, the figure 4.8 shows the households whose animals had calving intervals of more than 15 months. The map in figure 4.9 and figure 4.10 shows the frequency of treatment in six months period and the cost of treatment per livestock annually respectively. It was established that most households spend up to 5000 Kenyan shillings annually to treat an animal and this is very costly to the farmers. The various symptoms of trypanosomiasis have had an effect on almost all households sampled in the study area hence affecting the livestock productivity of the study area.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This research study demonstrates the ability of Geospatial technologies in mapping the tsetse habitats and assessing the impact of the tsetse flies on the livestock productivity. Geospatial technologies proved to be important in the control of tsetse flies and assessment of their impact on livestock productivity. Tsetse fly habitat mapping is important in strategizing for tsetse fly control and eradication and this is achievable using Geospatial technologies. High resolution satellite data has an advantage in providing a high accuracy image in land use/land cover mapping. In this research, sentinel 2 imagery was used to map the LULC in the area of study. It proved to be reliable in the study as it is easily available, has a high frequency revisit time and high spatial resolution.

An attempt was made to map the land cover and land use of the study area and using the tsetse fly distribution and the population data, tsetse fly habitats were identified. A comprehensive LULC map for the study area was developed for the year 2018. The results for LULC classification, showed that the area around Shimba hills is mainly covered by vegetation which tsetse flies prefers as habit because it provides shade during harsh weather conditions (Ngonyoka et al., 2017). Grass lands were found to be having abundant tsetse flies and thus the main tsetse fly habitat in the study area. Livestock graze mostly in grass lands and tsetse fly prefers to feed on livestock blood and this could be that reason why they are abundant in grass lands.

Livestock productivity parameters was used to assess the impact of tsetse flies in the area of study. It was established that most household in the study area have suffered from various effects of the tsetse fly bites which has financial implications hence low productivity and therefore intervention is needed in the whole study area urgently. It was established that some households have lost up to 8 livestock due to trypanosomiases which is a great loss to farmers as each livestock costs an average of Kshs. 30000. The frequency of livestock treatment in all the villages in the study area was alarming considering that the cost of treatment per animal was high. Some households recorded up to 8 times treatment of animals within six months.

Generally, all the objectives of the study were achieved. Geospatial technologies proved to be very important and necessary as it can isolate various incidences of trypanosomiases symptoms and make it understandable by an ordinary person who is not geospatial specialist. The technology also helped in identifying the tsetse fly habitats and understanding the spatial distribution of tsetse flies in various land covers this is useful to the authorities who are concerned with eradication of the tsetse flies.

5.2 Recommendations

The following are the recommendations deduced from the project;

1. Geospatial technologies should be embraced in the research of harmful insects such as tsetse flies and other insects affecting animals and human beings. This research project shows that with spatial data it is possible to make very important decisions that will help in the control and eradication of such flies. It is also possible to study the nature of the habitats of such insects using the technology hence helping in controlling the impact of such insects.
2. Considering the effect Tsetse fly on the four villages studied, tsetse control should be targeted on the areas with grass lands vegetation where cows graze and mostly in areas near the fence of the park. This will prevent tsetse flies from moving to the other parts that are further away from the park.
3. Urgent interventions actions should be taken by the relevant authorities to ensure that livestock farmers in Kwale County do not incur losses again due to trapanosomosis. This will improve their livelihoods and also the economic income of the county and national government.

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