University of Nairobi

School of Engineering

Department of Geospatial and Space Technology

USE OF GEOSPATIAL TECHNIQUES IN SELECTING SUITABLE AREAS FOR REARING DAIRY CATTLE, GOATS AND HONEY BEES IN BARINGO COUNTY

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

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DECLARATION OF ORIGINALITY

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DEDICATION

To my daughter Alynah, my mum Linah, family and friends. You have supported me wholeheartedly throughout my studies and you have been my support system.

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ABSTRACT

Food insecurity has been a major issue all over developing nations including Kenya especially in rural areas where lives are solely dependent on agriculture. This situation has been worsening with the climatic conditions which have been constantly changing negatively. This study intended to analyse and map suitable areas for rearing dairy cattle, goats and honey bees in Baringo County. A spatial model for each the value chains was designed and developed to achieve the objective.

The study area has experienced a lack of food year in year out during the dry season and has led to hunger killing several people. Contrary to this the area is known to have great potential in the production of honey, goat meat, and cowmilk within different spatial extent of the area.

The study entailed data collection, data manipulation and analysis which involved spatial overlay of several factor maps among others to generate the overall suitability maps for each of the value chains. This research aimed to identify and delineate the land that can best support dairy cattle, goat, and honey bees, using the GIS-based Multi-Criteria Evaluation technique and Remote Sensing.

It is possible to increase livestock keeping and apiculture ability in an appropriate area by identifying the important factors and ranking suitability of the land. These factors were therefore considered for each of the value chains. These criteria included: food, water, land use, temperature, humidity, biological hazards, the potential for mechanization, slope, rainfall regime, agrarian culture, market index and root rating for forage growth.

The final output of this project are land suitability maps for dairy cattle, goats and honey bees. According to the study, 95% of Baringo county is moderately suitable to highly suitable for goat rearing, 65% suitable for honeybees and 41% suitable for dairy keeping. Notably, the results from the experiment were validated by actual findings on the ground. The findings of this research therefore should be considered by the farmers and the stakeholders in order to improve food security in the area.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
ASAL	Arid and Semi-Arid Areas
ASDSP	Agricultural Sector Development Support Programme
CIDP	County Integrated Development Plan
DEM	Digital Elevation Model
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GIS	Geographic Information System
GOK	Government of Kenya
ILRI	International Livestock Research Institute
ILWIS	Integrated Land and Water Information System
KARLO	Kenya Agricultural and Livestock Research Organization
KCC	Kenya Co-operative Creameries
KNBS	Kenya National Bureau of Statistics
LSA	Land Suitability Analysis
LULC	Land Use Land Cover
LUT	Land Utilization Type
MCA	Multi-Criteria Analysis
MCDA	Multi-Criteria Decision Analysis
MCDM	Multi-Criteria Decision Method

NGO	Non-Governmental Organization
QGIS	Quantum GIS
STRM	Shuttle Radar Topography Mission
THI	Temperature Humidity Index
USGS	United States Geological Survey

1 INTRODUCTION

1.1 Background

Food insecurity has significantly increased over the years in Kenya. According to (FAO, 2017), Kenya will face exceptional demand for food in the following 30-40 years. It is estimated that the country's population in 2050 will be about double from 47 million today; 50% of this population will have migrated to urban areas against the 25% living in urban areas today (KNBS, 2019). The country's Gross Domestic Product (GDP) is also projected to be 6,500 US dollars in 2050 which is five times the current figure. This development will prompt new and various interactions among individuals and natural resources locally, regionally, and all around, bringing about both unsurprising and erratic changes in all sectors of the society.

The growing, Kenyan populace will consume more high-value nourishment items, specifically, animal source foods such as milk, eggs, meat, and honey. The consumption of beef and milk products is estimated to rise by 170% in 2050. The main livestock species in Kenya include poultry (31 million), goats (28 million), cattle (18 million), sheep (18 million), camels (3 million), and pigs (334,689). (www.countryeconomy.com, accessed on 23rd February 2020).

About 90% of the population of rural areas depend directly or indirectly on agriculture for their household income. Beef is largely produced in arid and semi-arid areas (ASALs), where about 36 percent of Kenya's population lives (KNBS, 2019). In pastoral areas, below-normal livestock productivity and high food prices are constraining household purchasing power and food access, resulting in food consumption gaps or depletion of livelihood assets. Due to poor forage and water availability, livestock trekking distances to water points have doubled in the northeast and atypical livestock migration has led to resource-based conflict. According to (USAID, 2019) Just 20% of Kenyan land is appropriate for cultivating and that land isn't used efficiently.

It has been reflected time and again that cow milk, goat meat, and honey are the main food products in Kenya's food basket which is the backbone of the economy. Not only does the subsector provide the much-needed animal protein for the ever-growing human population, but it also offers employment opportunities for millions of rural and urban dwellers involved in some form of livestock production and marketing. Within Kenya, the demand for these three products continues to grow as Kenyans change their eating habits in rural and urban areas.

In the recent past, the goat meat industry has been growing immensely due to Kenyans' love for 'Nyama Choma' (Roasted meat). On 21st December 2018, the Star Newspaper published about the annual Kimalel Goat Auction in Baringo County. Deputy President Dr. William Ruto who was the main auctioneer in the event was able to sell 2,590 goats with each goat trading at 10,000 shillings. In the previous year, 24 million shillings was raised in the event. In 2019 goat sales dropped by 6 million shillings compared to the sales of 2018. The low sales can be attributed to the reduced number of goats sold in the year's event that stood at 2,000 compared to 2,600 in the year 2018. Baringo county gets at least 2.9 billion shillings from the sale of more than 120,000 animals every year.

Figure 1-1 Kimalel Goat Auction

(Source: Daily Nation Tuesday, December 19, 2017)

Cow milk has sustained several livelihoods since time immemorial. Milk products are in high demand all over the world. The human population has been increasing rapidly in Kenya hence the high demand for cow products especially milk. Most cattle farms do not realize their potential since most farmers do not consider the optimal condition that may influence the production, such as suitable land to rear cows.

The demand for honey in Kenya is growing steadily. While Kenya is not one of the largest exporters of honey globally, it is a trade that is being closely watched as Kenyan producers

strategize on how to pioneer their entry into this lucrative honey market. Honey production in Baringo county is largely subsistent and used as a supplementary food product, for medicinal purposes, and for brewing traditional liquor (Hecklé, et al., 2018). The integration of beekeeping with other crop production has been practiced in other countries and shown to yield higher revenue. Productive beekeeping depends on good colony management and good beekeeping areas (Jacques, et al., 2017). Thus, the management and monitoring of beekeeping activities are more progressively critical to give effective and feasible profitability.

Selecting suitable locations for rearing dairy cattle, goats and honey bees should be determined in the field of land use planning considering ecological, economic, social and environmental aspects (Abou-Shaara H, et al., 2013b). This will greatly increase the production of these products hence fostering food security in the country. Land Suitability Analysis (LSA) can be estimated based on economic, social and physical environmental data (FAO, 1976); (Jafari, 2010) and (Zhang, 2015). According to (Collins, et al., 2001), LSA can aid to devise strategies for upgrading agricultural productivity.

1.2 Problem Statement

Food insecurity has seen the country lose several people due to hunger year in year out. Hunger has been a disaster in most parts of the country and Baringo county is no exception. Although most parts of Baringo county are arid and semi-arid, a few areas are wet and more productive. There is, therefore, a need to find ways of improving the productivity using probable technologies. Cow milk, goat meat, and honey are the main food products in Baringo county and can boost the food basket and the economy of the area.

There is an inefficient production of these products in areas that are highly suitable and have a high potential for greater production. The reason for this is that datasets useful in the decision-making process are not used effectively. Key stakeholders including residents have little knowledge of the suitable areas. Crucially, geospatial technology has not been used before yet they provide a valuable supplement to more traditional ways and provide information and prospective insights that are not otherwise available. The study, therefore, uses geospatial technology to determine suitable areas for the rearing of dairy cattle, goats, and honey bees in Baringo county.

1.3 Objectives

The Overall objective of this study is to apply geospatial technology to determine the land suitable for dairy cattle, goats, and honey bees in Baringo county.

The specific objectives of the study are:

1. To develop spatial models for land suitability evaluation for dairy cattle, goats and honey bees value chains.
2. To generate the criterion factors for the three value chains in Baringo County
3. To prepare land suitability maps for three value chains in Baringo county.
4. To establish the relationship between the three products concerning spatial variation.

1.4 Justification for the Study

There is no doubt that food production in Kenya needs to be improved. Maximizing production is desirable since the country faces a shortage of food. Agriculture is known to be the backbone of Kenya's economy since it contributes enormously to it. According to Deloitte and Touche (2016 and 2017), Agriculture contributed 45 % of government revenue and 75 % of industrial raw materials. It also provided livelihood opportunities to over 80% of the population in rural areas (Abdilatif, et al., 2018).

This, therefore, calls for adequate attention and investment in this sector. Despite much research done on agriculture, none has been done to address the issue of land suitability for honeybee's, goat and dairy cattle rearing, hence generating a gap which this study endeavored to address in the relatively rural Baringo county. Theoretically, this study is aimed at generating and extending knowledge on the use of geospatial technologies on land suitability analysis for high production cow milk, goat meat, and honey.

The results of this study will provide more knowledge to the residents of Baringo county on suitable areas for rearing dairy cattle, goats and honey bees therefore increasing production. The study will also provide GIS-based decision support to all interested parties and stakeholders in the food production sector and agriculture. The end-users of the products of

this study will be agricultural offices and stakeholders, NGOs, and researchers involved in food production.

1.5 Scope of Work

The study focuses on Baringo county. This particular region was selected because of the availability of data and prior knowledge about the areas by the researcher. Weighting criteria were used to generate suitability maps for the rearing of dairy cattle, goats, and honey bees in the county. Remote sensing and geographical information were also applied. ArcGIS, QGIS, and ILWIS software were used to carry out the suitability analysis and preparation of the suitability maps.

1.6 Organization of Report

The project report is covered in five chapters. The first chapter is an introduction of the study, covering the background information, problem statement, the study objectives, justification of the study, and an outline of the project organization. The second chapter covers relevant literature on the study as well as highlighting the food insecurity in Kenya, FAO framework, GIS and land suitability and multicriteria methods used, and finally dairy cattle, goats, and rearing practices reviews. Chapter three describes the research design adopted in the study, setting out the various procedures followed. This encompassing data collection, data manipulation, and analysis. Chapter four reports the findings which involve the suitability maps and relevant discussion on the results, while conclusion, recommendations, and references are presented in chapter five.

2 LITERATURE REVIEW

2.1 Introduction

This chapter highlights the evolution and present theory and practices in the research project.

2.2 Food Insecurity in Kenya

Food security is defined as “ensuring that all people at all times have both physical and economic access to the basic food that they need” (FAO, 2002). According to the Global Hunger Index (2019), with a score of 25.2 percent, Kenya suffers from a level of hunger that is serious. Kenya is position 87 out of the 119 nations ranked as still grappling with food insecurity (Otekunrina, et al., 2019). The report indicates that one out of every three Kenyans is dealing with severe food insecurity and poor nutrition. Some contributing elements to this scenario include poverty, poor governance, and drought. Given that a large percentage of the population depends on rain-fed agriculture and pastoralism which are vulnerable to climate change and drought, it will, therefore, be increasingly vital for Kenya's future.

Agriculture is the backbone of Kenya’s economic growth. About 80% of Kenyans gain all or part of their sustenance from this sector especially those living in rural areas (Maina & Mathenge, 2012). Agriculture accounts for a third of the nation's GDP. Almost a quarter of Kenya's land is suitable for agriculture but not wholly utilized. Repetitive emergencies such as drought add to the agricultural challenges (USAID, 2019).

Food security in Kenya is a very crucial agenda in the country. President Uhuru Kenyatta in 2017 made it agenda number one among the famous Big Four agenda in his tenure. Kenya’s Vision 2030, launched in 2008 by the Government of Kenya (GOK) as the new long-term development blueprint for the country. It focuses on a "Globally competitive and prosperous country with a high quality of life by 2030" The vision also considers food security as a pillar in it. The agricultural sector, therefore, has made the achievement of food security in the country its major objective. There are several policies created by the Government to curb food insecurity. These include subsidy on farm inputs, especially fertilizers, the involvement of the Government; improvement of research and extension services and improving their linkages, provision of rural credit for farming (e.g. the Kilimo Biashara Initiative), encouraging

diversification of crops planted among several others. (Kenya Agricultural Research Institute, 2012)

The impacts of food insecurity have a spatial dimension that inspires new concepts, and integrated approaches for sustainable rural development and improving food productivity in these areas.

2.3 The FAO Framework

Food and Agriculture Organization (FAO) is an organ of the United Nations. In 1976 after a few consultations and contributions from specialists in land assessment all over the world, FAO founded a standardized framework to assess land appropriateness. The structure was created following one of FAO's primary goals which are "*sustainable management and utilization of natural resources, including land, water, air, climate and genetic resources for the benefit of present and future generations.*". Since the eradication of food insecurity is pecked on agriculture there is a need for an organized system that can warrant accomplishing the laid aims without the spatial drawback. Nowadays land can be assessed to a very high degree courtesy of the framework.

In defining Land Utilization Type (LUT), the following three factors need to be considered: the capacity to provide some alternative technical possibilities, the need for accurate statistics about the land performance, and an instrument that gives planners a lot of knowledge based on consolidated idea and process. For land to be productive several inputs must be put in place. These inputs ranged from low, intermediate, and high according to (Beek,1978). Examples of inputs are capital intensity, produce, labour intensity, market orientation, mechanization, infrastructure requirements, and land tenure system.

The three major evaluation criteria recognized by this framework include physical, socioeconomic, and environmental suitability evaluation. Economic suitability, on the other hand, is calculated based on profitable returns expected if the LUT in question is executed on that unit. According to (Elsheikh, et al., 2016), physical suitability assessment is defined as an articulation of the level to which the maintain execution of LUT on a positive land unit is possible without an intolerable chance to the natural community. Factors noted include soil condition, topography, climate-related parameters, erosion, and flood tragedies (FAO,1976).

Presently, the framework is still the major reference and deliberate method that is generally conventional for land appropriateness assessment, particularly for agricultural products. The main advantages of the framework include the following: it indicates physical suitability for each crop and product, land can be assessed economically and physically, and lastly land is marked out largely in a system and not only by earth attributes.

2.4 Geographical Information System for Land Suitability

GIS offers a wide variety of tools to manipulate and analyse spatial data; however, the addition of Multi-criteria Decision Method (MCDM) analytical techniques provides a powerful means to handle the limitations of GIS when multiple complex criteria and objectives are involved (Chakhar & Martel, 2003).

The field of agriculture and land management, for example, has incorporated such methods as land-use suitability analysis using fuzzy quantifiers via ordered weighted averaging (Malczewski, 2006b). (Zoccali, et al., 2017) came up with a novel approach to determining suitable areas for beekeeping in Mediterranean lands using GIS. (Sarı & & Ceylan, 2017) used GIS-based method AHP to determine suitable sites for beekeeping in Konya province, Turkey. (Amiri, et al., 2011) Modeled land suitability analysis to livestock grazing planning using GIS. (Sour, et al., 2013) used GIS multicriteria evolution on coming up with suitable areas in the rangelands for goat grazing in middle Taleghan Rangelands in India. Closer home (Wanyama, et al., 2019) did a spatial assessment of land suitability for maize farming in Kenya. (Rono & Mundia, 2016) also did a study on suitability analysis for Coffee areas in Elgeyo Marakwet county of Kenya using GIS.

GIS is helping examine the spatial links and threats to food sources in a given environment. GIS has become a tool of growing importance in the efforts to better understand the relationships between food availability, agricultural lands, and the effects of climate change on agriculture production.

2.5 Multi-Criteria Decision-Making

Exploring appropriate land use areas inside a given zone requires an adaptable instrument that will empower visual and factual displaying of the interaction among the deciding variables. GIS-based land suitability analysis is a tool used to enable planners and engineers to analyse

the interactions between location, developmental, and environmental action factors. GIS software enables users to perform simple to complex tasks such as developing land suitability models by just using simple spatial operations using map algebra.

There are three important advances towards GIS land-use suitability analysis according to Collins, et al., (2001) (1) soft computing or geo-computation methods, (2) multi-criteria evaluation methods, and (3) computer-assisted overlay mapping. Since the time the world has existed, people have ended up associated with settling on choices that worry their everyday life. For a long time, researchers have been keen on the examination of how the human does this undertaking. It is, therefore, necessary in this context to automate ways to achieve tasks. i.e., in such a way that it simplifies but represents the real system, and with the condition that it is promptly comprehended and is easy to actualize. With this in mind, the options to be picked were studied and determined, just as the criteria on which said options are to be assessed. This, from the start sight, is by all accounts straightforward, shapes some portion of the entire control that is called Multi-Criteria Decision Making (MCDM).

The reason or objective of an MCDM strategy is to examine a few options considering different criteria and clashing goals (Voogd, 1982). MCDM is a technique endeavour to locate the best option among a few practical other options. An MCDM problem is expressed in a matrix format and the unknowns are therefore determined. To appropriately decide the weight of every basis or calculate included the result of the subsequent layers, the Analytic Hierarchy Process (AHP) strategy, proposed by (Saaty., et al., 1980) has been used within the MCDM.

2.6 AHP as an MCDA Tools

The multi-criteria programming made through the use of the analytic hierarchy process is a technique for decision making in complex environments in which many variables or criteria are considered in the prioritization and selection of alternatives or projects.

AHP was developed in the 70s by Saaty 2008, and involves six steps:

- Define the problem
- Develop the AHP of the problem at different stages to determine the objectives and outcomes of the problem based on the aim, criterion, and alternatives.

- Weighting against different criterion using numerical Pairwise comparison
- Estimating the relative weights
- Performing computations to find the maximum eigenvalue, consistency index, consistency ratio (CR), and normalized values for each criterion/alternative.
- Checking the consistency
- Obtain the overall ratings

The application of AHP starts with a problem being broken down into a hierarchy of criteria for ease in comparison and analysis in an independent manner as in Figure 2-1. After this logical hierarchy is developed, the leaders can efficiently evaluate the options by making pair-wise examinations for every one of the picked models. This correlation may utilize solid information from the other options or human decisions as an approach to enter subjacent data, Saaty (2008).

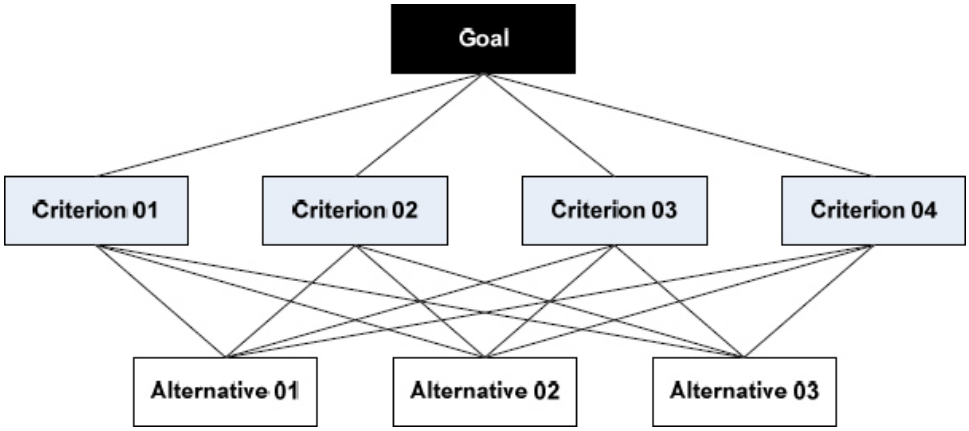

Figure 2-1 Example of a Hierarchy of Criteria/Objectives

Source: **(Vargas., et al., 2010)**

AHP converts the comparisons into numerical data which can be further processed and compared in as percentages. When AHP is compared with the other multi-criteria decision methods the major unique contribution factor is the ability to convert empirical data to mathematical models.

2.7 Dairy Cattle Rearing

There is a large population of dairy cattle in Kenya only that most are used for draught and meat. However, there is a great potential to selectively bread animals in a selected suitable location for milk production (Hayes, et al., 2009). In many regions of the nation, there have been attempts of crossbreeding and upgrading of the native breeds with other breeds to acquire soaring milk production. A few areas have turned to the importation of thoroughbred temperate cattle to maximize milk production. It is observed, however, that adequate attention is not being given to suitable areas with suitable conditions and also proper feeding of dairy animals. Thus, they are not producing what they could (i.e. the full genetic potential for milk production is not expressed and suitable locations of rearing not accurately established) according to (Rosati, 2004).

In Baringo County, dairy farming is well established, particularly in high potential areas where mixed farming is practiced. Farmers keep a mixture of breeds such as Friesians, Ayrshires, Guernsey, Jersey, Sahiwal, and crossbreeds. Dairy management systems vary from one agricultural ecological zone to another ranging from zero-grazing to dairy ranching. Concentrates and mineral feeding is still low in most places and has a bearing on low production and low fertility rates. The bulk of milk produced is marketed through Dairy Cooperative societies which sell locally and deliver excess milk to processors such as Kenya Co-operative Creameries (KCC) and Brookside Dairies, among others. In some areas, the dairy societies are weak or non-existent and hence farmers have to market their milk individually.

The conditions critical in the rearing of cattle include the availability of pasture (fodder crops) (Lugusa, 2015), the moderate temperatures, water availability, moderate Temperature heat index (THI), market proximity, agrarian culture of the region and areas not affected by pest and disease such as tsetse fly. This according to (FAO, 1976), (Le Neindre, 1989), and (Bertoni, 2009)

2.8 Goat Rearing

Goat rearing in Kenya is becoming popular with time. The reason for this is that goats are free moving and are hardly kept hence its ease of rearing. Most farmers venture into meat goat rearing as a source of income. This is because goats are prolific compared to other domestic

animals. They have a short gestation period, high chances of twinning, and requires less space, and feed less than other animals. They are also much easier to invest in considering the initial capital investment and time you need to attend to them. Goats also do well in hotter temperatures compared to other domestic animals. They are generally browsers, if you plant more fodder trees you are good to go. The conditions taken into consideration in goat rearing include temperature, fodder, slope, agrarian culture, market proximity and Tsetse fly risks. This according to (FAO, 1976), (Amiri & Shariff, 2012), (Sour, et al., 2013) who did a study on modelling land suitability for grazing land.

The common breeds suited for commercial goat farming in Kenya include the following: Small East African Goat, Galla Goat, Anglo-Nubians, German Alpine, Boer, Toggenburg, and Saanen. (Ahuya, 2005).

Baringo County being an ASAL area has great potential for goat rearing. The majority of the goats are reared traditionally under extensive free-range management systems with minimum specialized input in management practices in feeding and pest and disease.

2.9 Honey Bees Rearing

In Kenya Beekeeping is practiced in most the livelihood zones in hot and dry areas. Most of these areas are lowlands with a large range of lands (Sarı & & Ceylan, 2017). The honey industry provides income to farmers, traders, and stakeholders directly in hive products production, equipment manufacturing, processing, and marketing of honey. Indirectly the industry contributes to employment creation in herbal medicine, cosmetics, brewing, and other service providers such as retailers, transporters, and suppliers of packaging materials. According to (Ibnouf, 2009) honey plays a very important role also in household food and nutrition apart from it generating income.

In Baringo County there has been a progressive growth in the production of beekeeping equipment, beeswax and honey. The County honey, and beeswax production is currently estimated at 578, 302 kgs, and 2,035 kgs valued at KES 116.6 million this is according to Baringo county Statistics (Baringo County, 2015). The County has annual estimated beeswax and honey production potential of about 5,000 and 500 metric tonnes respectively.

The critical factors considered in honey bees rearing include; distance to water points, distance

from the settlement, distance from roads for easy access and market, aspect, elevation, temperature, land use and land cover. These are according to (FAO, 1976), (Sarı & & Ceylan, 2017), (Mujuni, et al., 2012).

3 METHODOLOGY

3.1 Introduction

This chapter sets out various stages and procedures that will be followed in completing the study and involves a blueprint for the collection, techniques, measurement, and analysis of data that will be valid and reliable. In this stage, most decisions about how the research will be executed and how the data obtained affected the outcome are approached as well as where and when the research is conducted. The strategy here is to come up with suitability maps for cow milk, goat meat, and honey in Baringo which can be used in decision making in improving the food situation in the county.

3.2 Research Design

The approach adopted for the research is an empirical study. The study is based on observed and measured phenomena and derives knowledge from well-functioning systems rather than from belief or theory.

3.3 Area of Study

This study focuses on Baringo County shown in Figure 3-1. It is located in the former Rift Valley Province with an approximate area of 10908.7 sq. km, with a population of 666,763 as per the 2019 census. It is bordered by Nakuru County on the South, Turkana County, and West Pokot County to the North, Elgeyo Marakwet to the west, Uasin Gishu and Kericho Counties to the South West and Laikipia and Samburu Counties on the East. Baringo County lies between latitudes 0-degree, 14 minutes South and 1 degree, 40 minutes north, and longitudes 35 degrees, 30 minutes and 36 degrees, 30 minutes East.

The economy of the county is essentially farming agriculture. The main economic activity in the highlands is cash crop farming although food crops such as maize and beans are also grown in the area. Cash crops produced include cotton and coffee. Livestock is the main activity in the lowlands. Animals kept here include goats, cattle, sheep, and camels. Beekeeping and aloe vera plant cultivation are also practiced in the lowland areas of Baringo. These products are processed locally. The only aloe vera processing factory in the country is situated in Koriema area of Baringo South constituency.

The major urban centres include Eldama Ravine, Mogotio, Kabarnet, Kabartonjo, Chemolingot, and Marigat. The region gets somewhere in the range of 1000mm and 1500mm of precipitation every year in the highlands and 600mm in the lowlands. Baringo encounters two stormy seasons; March to June (long rains) and November (short rains).

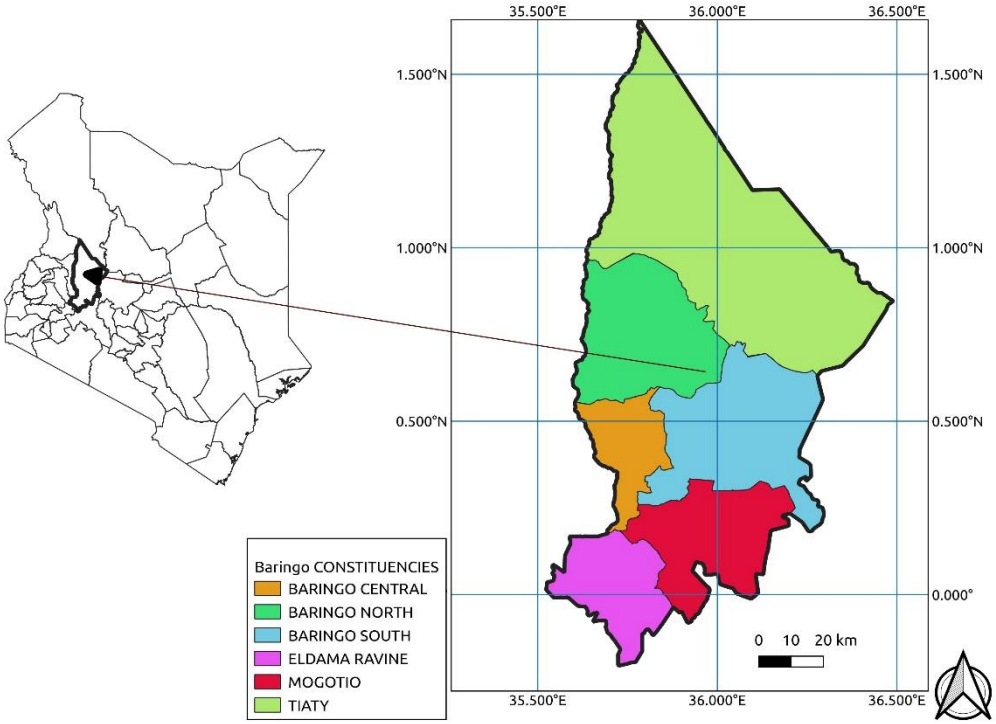

Figure 3-1 Area of Study. Baringo County

3.4 Data Sources and Tools

3.4.1 Data Sources

Several datasets will be used to carry out this project. Table 3-1 represents the datasets that will be used to come up with the final product of this project. The project aims to use mostly secondary data produced by several sources apart from few data collected from the study area by the researcher.

Table 3-1 Project Datasets

DATASETS	DATA SOURCES
Satellite image Landsat 8 2019	United States Geological Survey (USGS) Portal
Kenya Elevation DEM (SRTM 30 Meters spatial Resolution)	United States Geological Survey (USGS) Portal
Soil PH, Drainage, and Depth	International Livestock Research Institute (ILRI) & Kenya Agricultural and Livestock Research Organization (KALRO)
Road Network, Rivers and Lakes	Open Street Maps
Climate Data	Kenya Meteorological Department (KMTD)
Kenya Administration and Kenya Land Use	International Livestock Research Institute (ILRI)
Population Data	Kenya National Bureau of Statistics (KNBS)

3.4.2 Hardware and Software

3.4.2.1 *Hardware* Overview

HP Elite Book 8570p Laptop, Intel Core i7-3520M @2.7 GHz, 8 GB RAM, 500 GB HDD running Windows 10, 64-bit was used. A 32 GB flash disk and 1 TB hard drive was used for the transfer and act as storage of the project datasets of the project.

Printer – was used to print the study report.

3.4.2.2 Software Overview

Windows 10 was the operating software on the laptop at the time of the project. The platform was considered as it was compatible with software programs used for this project.

ArcGIS 10.6 is a suite of Esri's geospatial processing programs and is used primarily to view, edit, create, and analyse geospatial data.

QGIS 3.10 is similar to other software GIS systems but it integrates with other open-source GIS packages, including SAGA, and GRASS to give users extensive functionality. It was used to carry out the suitability analysis for the subjects of this project and also to display the shapefiles stored, edit, manipulate, and effect these changes to the database. It was also used to create several maps.

Microsoft office 2016 will be used as follows:

• Microsoft Word 2016 was used to produce the final project report

• Microsoft PowerPoint 2016 was used to produce the preliminary and final project presentations

• Microsoft Excel 2016 produced a workbook for the CSV files produced when capturing details such as elevation information form google earth.

• MS windows snipping tool was used to process the screenshots taken during software operations.

Google Drive and Microsoft One Drive enabled the project to be backed up on the cloud and be accessed from any computer.

3.5 Methodology Overview

The project was carried out in three stages namely, project planning, database development, and suitability analysis as shown in Figure 3-2. Figure 3.3 illustrates the methodological procedures carried out in this project from the data collection stage to the final stage.

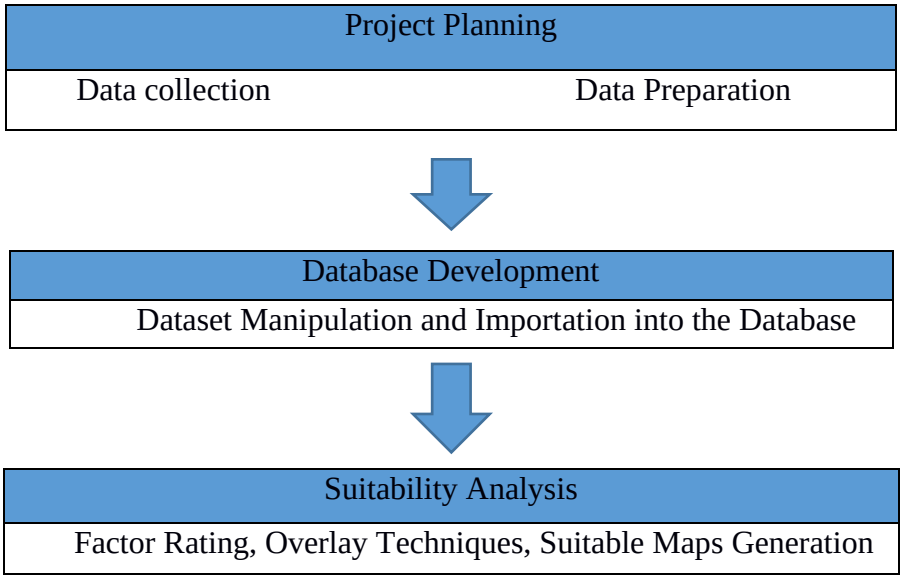

Figure 3-2 Overview Methodology

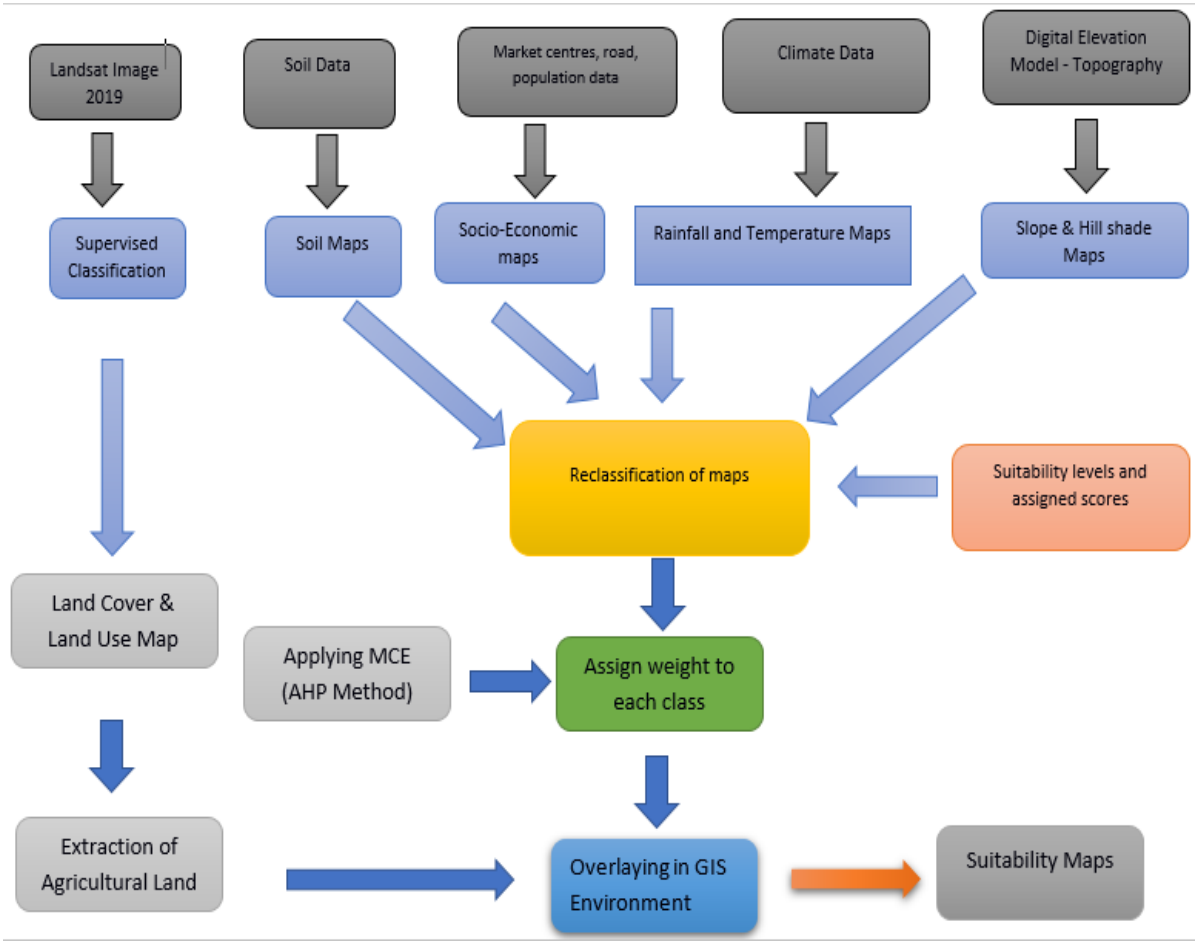

Figure 3-3 Methodological Flow Chart

3.6 Determination of Criterion Factors

Literature review of various references helped in identifying four main criteria (soil, climate, socio-economics, and topography; broadly categorized into biological, physical, social and economic factors) and sub-criteria (soil pH, soil CEC, soil organic carbon, soil texture, soil drainage, soil depth, rainfall, temperature, temperature-humidity index, relative humidity, slope, total population, population density, length of the growing period, stoniness, agrarian culture, proximity to roads, proximity to water resources and proximity to marketing points) necessary to determine suitable areas for promoting dairy cattle, goats and honey bees as illustrated in the methodological chart in the Figure 3-3 above.

3.6.1 Climate

Climate is the most critical factor in any land suitability. Aspects of climate control the type and range of crops that can be grown and hence the animals to be reared, otherwise, climate determines the flexibility of production. Some of these aspects of climate include temperature, rainfall, and relative humidity which is also a key aspect of climate that determines land suitability. The climate data were used to derive the three maps used in the study. The result of determined region climatic condition is described in the next chapter.

3.6.2 Slope

The topography was also determined to play a very important role in suitability. Taking into account the mechanization and stability of rearing certain animals in different location was key. This criterion was determined by the several kinds of literatures done on the subject of suitability together with land suitability requirements provided by FAO. The slope, aspect, elevation was derived from the STRM 30 metre resolution data obtained from the USGS portal.

3.6.3 Land Cover Land use

Land cover land use (LULC) is important in determining the suitability of any land. This, therefore, led to LULC being determined as one of the criteria needed for this study. LULC was created from the classification of the Landsat 8 satellite image of the area.

3.6.4 Socio-Economic and Political Factors

The social factors considered in the study included the cultures of the people in the study area, their religious beliefs, traditional rituals, and other social partaking of the people in the area of study. Economic factors included what people do for their everyday lives. Their way of life influences every economic development in the areas.

To come up with the economic maps i.e. road suitability map, market suitability, buffers were created on the road network and urban centres data. For road suitability; which is the distance from the road network in the area considered suitable three buffers of 2 km 7 km and 12km were made from the network. For market suitability the buffers made from the urban centres in the area of study were 2 km, 7 km, and 12 km. Politics plays a big role in suitability but incorporating these issues in the study was not possible since no variable could be modelled to suit it in the study.

3.7 Data Analysis

3.7.1 Factor Weighting Criteria: Analytical Hierarchy Process

Different evaluation criteria determine the suitability of land: however, the importance of these criteria is different for different land uses. With this, therefore, it is necessary to determine the importance of each criterion in the different value chain products land suitability. Analytical Hierarchy Process (AHP) decision-making guidelines according to Saaty (2008) were used to calculate factor weights for the variables. Suitability analysis model criteria were developed using information from agricultural experts. For the three products in the research, a pairwise comparison matrix was developed to compare weight the significance of each factor. Procedures found in (Al-Harbi, et al., 2001) and (Wedley, 1993) guided the calculation of the priority vector, consistency index, and the random consistency ratio. The values obtained were used in calculating factor weights which were used in the weighted overlay analysis.

An AHP was utilized to decide the relative significance of rules and the subsequent weights were utilized to build the suitability maps utilizing the GIS environment. At last, the appropriateness composite maps were created by overlaying the characteristic guides. The results of the exercise are summarized under the results and discussion topic.

The AHP as a Multi-Criteria Evaluation method was used to obtain the required weightings for different criteria. It was favored as a result of its ability to coordinate an enormous amount of the heterogeneous information utilized.

3.7.2 Applying MCE and Assigning Weight of Factors

To determine the relative importance/weight of criteria and sub-criteria, the AHP method of MCE was used. In order to compute the weights for the four (4) criteria (biological, physical, social, and economic aspects) and the sub-criteria (Soil pH, Soil Texture, Soil Depth, Soil Drainage, Soil Fertility, Slope, Rainfall, Temperature, Relative Humidity, Market Proximity, Road Proximity, Temperature- Humidity Index, and Agrarian Culture), a pairwise comparison matrix (PWCM) was constructed using information obtained from various research already done. During this exercise, each factor was compared with the other factors, relative to its importance, on a scale from 1/9 to 9 according to the scale by Saaty demonstrated in Table 3-2.

Table 3-2 Saaty Rating Scale

Intensity of importance	**Definition**	**Explanation**
1	Equal importance	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgement slightly favor one over the other.
5	Much more important	Experience and judgement strongly favor one over the other.
7	Very much more important	Experience and judgement very strongly favor one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed

Source: **(Triantaphyllou, et al., 1995)**

During the pairwise ranking, inconsistencies were checked by ensuring that the corresponding consistency ratio (CR) was less than 10% according to (Triantaphyllou, et al., 1995). The CR was obtained by working with the Consistency Index (CI) and the Random Consistency Index (RCI).

Equation 3-1 Consistency Index

$$CI = \frac{(\lambda \max - n)}{(n - 1)}$$

Equation 3-2 Consistency Ratio

$$CR = \frac{CI}{RI}$$

Where: CI is the Consistency Index; λ max is the maximum Eigenvalue; n is the number of factors being compared; CR is the Consistency Ratio and RI is the Random Inconsistency Index (RI) which depend on the number of elements being compared, as shown in Table 3-3.

Table 3-3 The Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45

3.7.3 Overlaying Map Layers

The reclassified thematic maps/layers of each variable were weighted using the weights derived from the AHP process and the Boolean algebraic logic. The weighted maps/layers were combined by performing the weighted overlay using ArcGIS, SAGA, Raster calculator, and ILWIS to produce the final suitability maps for dairy cattle goats and honey bees.

3.7.4 Development of Spatial Models

Three models for dairy cattle, goats, and honey bees' suitability were created in a GIS platform. After the identification of all the variables and their threshold, the second step was to prepare the inputs into the ArcGIS model builder. The data were re-projected first from the WGS84 coordinate system to arc 1960 UTM Zone 36N the vector data were converted to raster for ease

in analysis. Reclassification of the critical variables was then done and overlay analysis was done to produce the suitability maps.

3.8 Spatial Suitability Analysis

Land suitability analysis for each of the value chains was done as shown below. Several factors determine land suitability for a product. For the products in question in this study, the following factors were taken into consideration. This is according to the Ministry of Agriculture and (FAO, 1976).

3.8.1 Land Suitability for Dairy Cattle

The criteria that determine suitable areas for dairy cattle rearing includes nutrients availability in the fodder, rainfall/water supply, biological hazards such as tsetse fly infestation risk, Temperature Humidity index (Heat stress), the potential for mechanization (slope), root ratings for forage growth, agrarian culture, rainfall regime, and market index. These are classified into three categories namely biophysical, social, and economic.

The desired factors were categorized into four classes; highly suitable, moderately suitable, marginally suitable, or unsuitable to the rearing of dairy cattle as shown in Table 3-4.

Table 3-4 Suitability Criterion for Dairy Cattle Rearing

	Highly Suitable	**Moderately Suitable**	**Marginally Suitable**	**Not Suitable**
Soil Fertility Index	> 1	0.8 - 1	0.5 – 0.7	> 0.7
Rainfall (mm)	> 1100	1000 -1100	800 -1000	< 800
Tsetse fly risk	< 1	1-1.2	1.2-1.5	> 1.5
Temperature in ^{0} C	15 - 20	20 - 30	30 - 40	>40
Slope (%)	< 8	8 -10	10 - 20	> 20
THI	< 68	68 -72	72 -75	> 75
Agrarian culture	> 4	3 - 4	2 - 3	< 2
Market Index	< 3	3 - 4.5	4.5 - 7	> 7

(Source: FAO and Ministry of Agriculture)

The biophysical factors include rainfall, soil fertility, temperature, heat stress (THI), and slope. The mean rainfall map for the area was prepared. The major system of livestock keeping in Baringo is rain-fed, thus the amount of precipitation is of key importance since it determines the availability of major livestock feeds such as pasture and forage trees, it determines the availability of water for dairy cattle drinking and is used in milk value addition and processing. The choice of pasture varieties depends also on the rainfall availability. Three fundamental qualities of precipitation are its amount, intensity, and frequency, the estimations of which change from place to place, every day, month to month, and year to year.

Temperature condition plays a key role in determining the productivity of dairy animals. Heat stress rises support energy necessities, brings down dry matter consumption, particularly forage intake, making it hard to address energy needs thus coming contributing to diminished milk yield.

Tsetse fly infestation pose a great constraint to dairy production in any area. It is more prevalent in humid and sub-humid areas. It greatly affects production in dairy farming. The preference towards any product is a social factor that should be considered in determination of the suitability of a product. The agrarian culture of the area should therefore be considered. The Dairy cattle preference index map was produced by doing an overlay analysis of the use of

urban centres data, road network, population, and agrarian culture data for the region. The map in Figure 3-4 below shows the dairy cattle preference index map of the region.

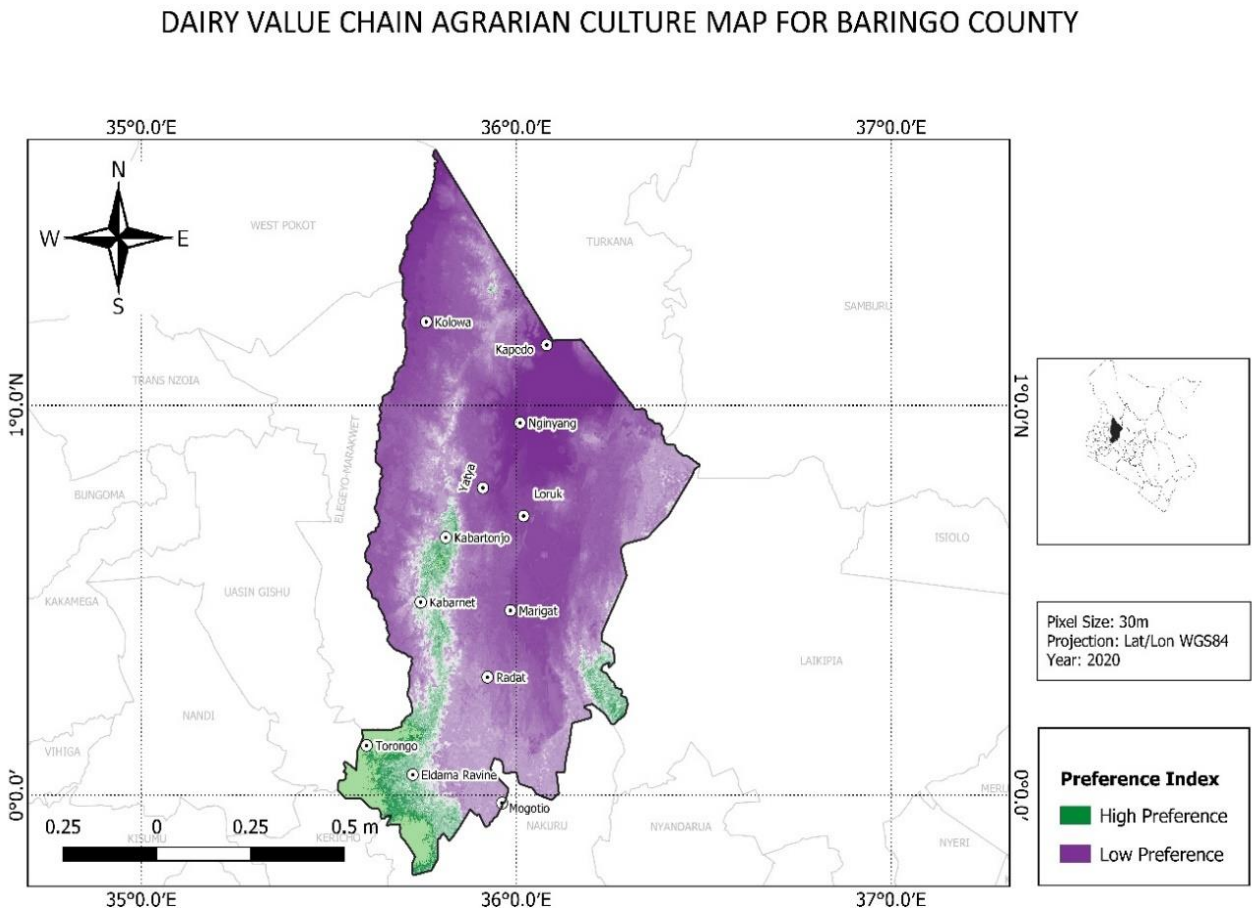

Figure 3-4 Dairy Cattle Preference Index Map

On economic influence, population and location of urban centres in a community highly inform the preferences of one location to another when it comes to a different product. It is therefore prudent to consider the population density of the region, location of market places, and veterinary services to determine suitability for dairy cattle in the region. The Population density distribution map for the region was prepared from the population census data of 2019 obtained from KNBS. The road system also plays a role when it comes to economic factors to be considered. Market proximity and road network proximity map for the area were also prepared from the urban centres and road respectively.

Politics also plays a marginal role in the dairy cattle keeping in the area. Leadership determines the policies, infrastructure development, and monetary allocations in different parts of a region. Therefore, politics plays a very important role in delineating suitable areas for dairy cattle rearing.

Table 3-5 Dairy Cattle Relative Importance Matrix and the Derived Weights

Variable	Temperature	Rainfall	Soil Fertility	Market Proximity	Agrarian Culture	Slope	THI	Tsetse fly risk
	1	5	7	5	4	3	4	5
	0.2	**1**	3	0.25	0.333	2	5	7
	0.1428	0.333	**1**	5	5	2	5	3
	0.2	4	0.2	**1**	0.25	0.333	0.25	4
	0.25	3	0.2	4	**1**	3	0.333	7
	0.333	0.5	0.5	3	0.333	**1**	0.2	5
	0.25	0.2	0.2	4	3	5	**1**	3
	0.2	0.1428	0.333	0.25	0.1428	0.2	0.333	**1**
Derived Weights								
Variable	**Temperature**	**Rainfall**	**Soil Fertility**	**Market Proximity**	**Agrarian Culture**	**Slope**	**THI**	**Tsetse fly risk**
Weights	**30**	**13**	**16**	**7**	**12**	**7**	**12**	**3**

Weight and dataset Combination: The weights derived from the Analytical Hierarchy Process (AHP) gave priority to temperature rainfall and soil fertility in decreasing order. The intensity of importance for every variable was assigned according to their relative importance as given in the matrix in Table 3-5 above. Temperature had the highest score of 30 %, soil fertility at 16 %, and rainfall at 13%. Agrarian culture and Heat Stress (THI) scored 12 % each, while market and market proximity each had 7 % weight. Tsetse fly risk was least weighted at 3 % as shown in Table 3-5 above.

Weights were standardized and raster was determined at the doled-out weights for every factor followed by making the overall suitability map for dairy cattle rearing. The model in Figure 3-5 was created using spatial analysis tools and ArcGIS model builder.

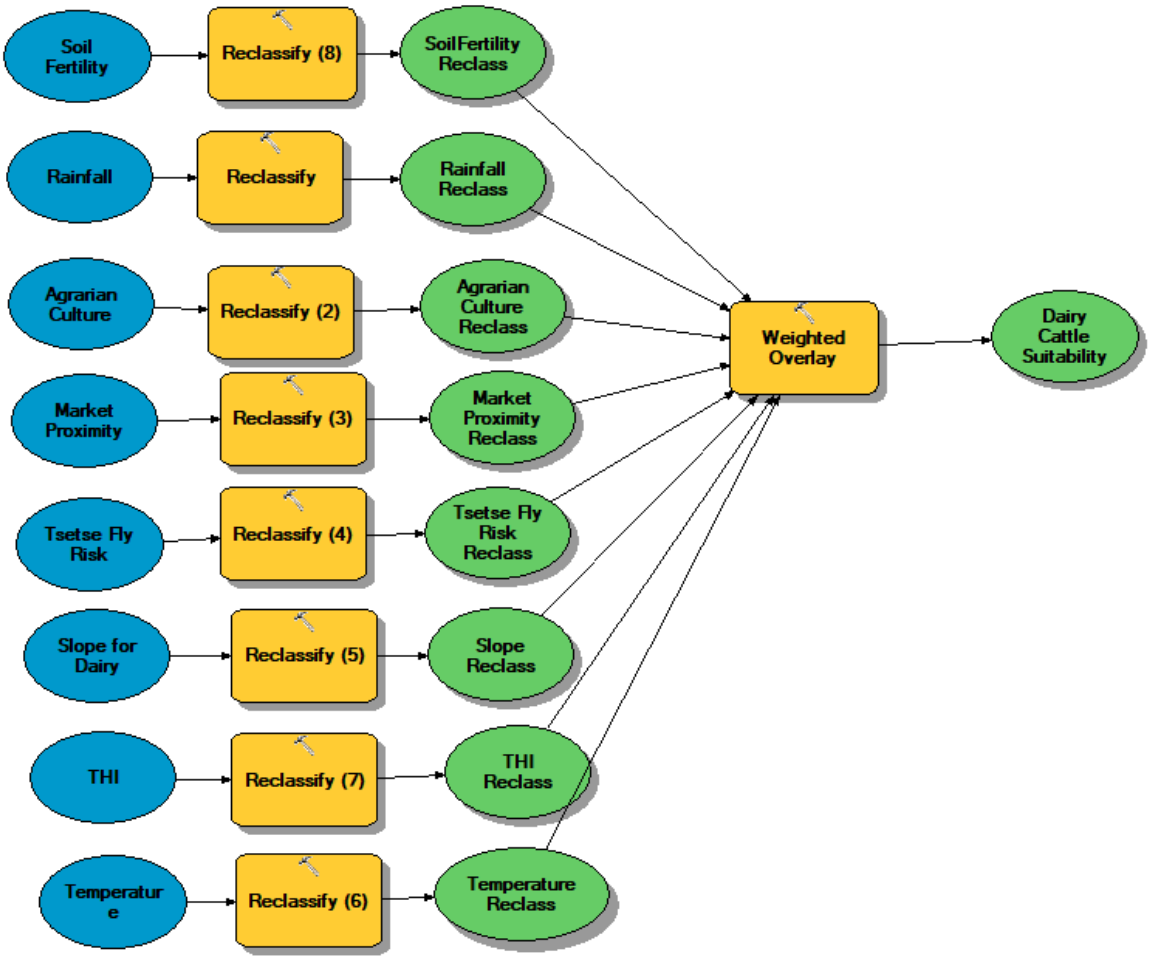

Figure 3-5 Dairy Cattle Suitability Model

3.8.1 Land Suitability for rearing Goats

Baringo County is estimated to be 75% Arid and Semi-Arid hence potential for livestock-based enterprise that thrives in ASAL areas. The majority of the goats are reared traditionally under extensive free-range management systems with minimum specialized input in management practices in feeding and pest and disease.

The desired factors were categorised into four classes; highly suitable moderately suitable, marginally suitable, or unsuitable to the rearing of goats as shown in Table 3-6.

Table 3-6 Suitability Criterion for Goat Rearing

	Highly Suitable	Moderately Suitable	Marginally Suitable	Not Suitable
Soil Fertility Index	>1	0.8 - 1	0.5 – 0.7	>0.7
Rainfall (mm)	< 800	800 - 1000	1000 - 1200	>1200
Tsetse fly risk	None	Slightly to moderate	Moderate to severe	Severe
Temperature in ^{0} C	15 - 20	20 - 30	30 - 40	>40
Slope (%): Goats-Sheep	(0 – 16)	(16 – 30)	(30 – 50)	>50
Agrarian culture	< 2	2 - 3	3 - 4	> 4
Market Index	< 3	3-4.5	4.5 - 7	>7

(Source: FAO and Ministry of Agriculture)

In order to determine suitable areas for rearing goats in Baringo county the following factors which are expert views were taken into consideration: four environmental land parameters were considered such as, soil, rainfall, slope, and temperature. Socio-economic parameters were access to veterinary services. drinking water, and market access. Evaluation of these parameters gives information about the constraints of the land for agricultural development.

For land use/land cover; eight classes such as Forest, Open bushland, Dense bushland, Open shrubland, Dense shrubland, Grassland, Farmland, and Bare land were made. Forests, farmland and dense bushland was considered highly suitable, dense bushlands, grassland was moderately suitable. On marginally suitable rating open bushland, dense shrubland were considered. Bare land was considered unsuitable for goat rearing. Physical properties of soil were considered for interpretation and analysis. FAO Soil Classification was utilised in suitability modelling. The slope was created from SRTM data in GIS platform using the surface analysis technique. Climate data consider were rainfall and temperature of the area of the study. Tsetse fly infestation was also considered in the research.

Socio-economic factors in the research include veterinary clinics and services, road and transport conditions, market outlets, communication systems, abattoirs, health centres/health

posts, skins, and hides collecting and preserving systems. The highly managed goat rearing lands need to have a range management station office to serve in case of emergencies such as monitoring, reporting day to day activities, and executing disease outbreaks. In this study, four infrastructural indicators were used namely access to drinking water, access to veterinary services, and access to market and agrarian culture.

Table 3-7 Goat Relative Importance Matrix and the Derived Weights

Variable	Temperature	Rainfall	Soil Fertility	Market	Agrarian	Slope	Tsetse
	1	5	7	5	4	3	2
	0.2	**1**	3	4	3	2	3
	0.1428	0.333	**1**	5	5	2	5
	0.2	4	0.2	**1**	4	3	5
	0.333	3	0.2	0.25	**1**	0.333	0.333
	0.333	0.5	0.5	0.333	3	**1**	4
	0.5	0.333	0.2	0.2	3	0.5	**1**
Derived weights for each variable							
Variable	**Temperature**	**Rainfall**	**Soil Fertility**	**Market**	**Agrarian**	**Slope**	**Tsetse infestation**
Weights %	31	23	16	10	5	10	5

Weight and dataset Combination: The weights derived from the Analytical Hierarchy Process (AHP) gave priority to temperature rainfall and soil fertility in decreasing order. Intensity of importance for every variable was assigned according to their relative importance as given in the matrix in Table 3-7 above.

Therefore, the contribution of various variables was as follows: temperature, rainfall, soil fertility was 31%, 23%, and 16% respectively since they are the major factors in goat rearing suitability. Market proximity and tsetse fly infestation were weighted at 10 % each while agrarian culture and slope had a lower weight of 5%. Weights were standardized and the raster was determined at the assigned weights for every factor followed by making the overall

suitability map for honey bees. The model in Figure 3-6 below was created using spatial analysis tools and ArcGIS model builder.

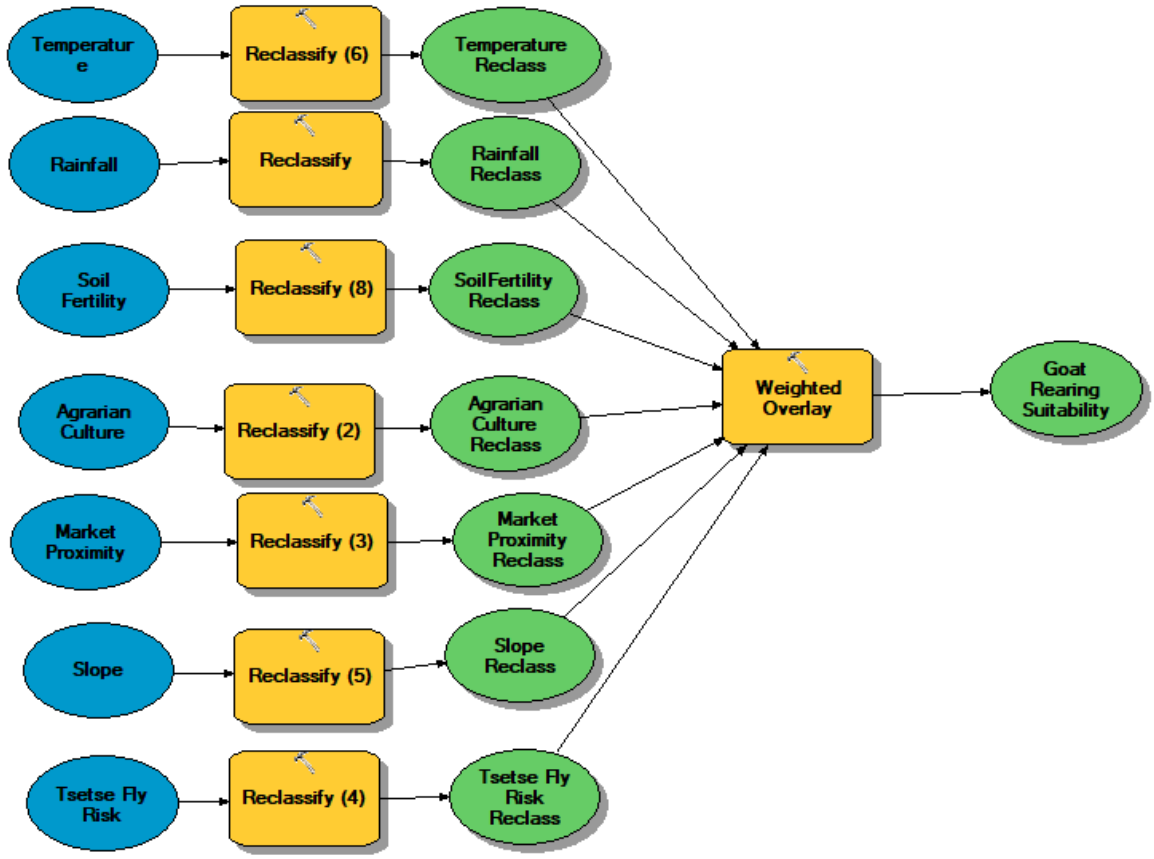

Figure 3-6 Goat Suitability Model

3.8.2 Land Suitability to Honey Bees

Land suitability of honey bees was identified using GIS spatial analysis tool. Factors used in the study were selected based on previous investigations of (Abou-ShaaraF. & Hossam, 2015) (Amiri & Shariff, 2012), (Amiri F, et al., 2011), (Abou-Shaara, 2013a) and (Abou-Shaara H, et al., 2013b). Honey bees are impacted mainly by these factors namely, temperature, distance from settlement areas land cover, distance from water, relative humidity, and slope. Investigated factors were classified into three categories; highly suitable moderately suitable, marginally suitable or unsuitable to honey bees as seen in Table 3-8.

Table 3-8 Suitability Criteria for Honey

	Highly Suitable	Moderately Suitable	Marginally Suitable	Not Suitable
Temperature (^{0} C)	21 - 30	30 - 38	15 -20	<15 >38
Annual Rainfall Average (mm)	600 - 650	450 - 550	400 - 450	350 - 400
Slope (%)	0 - 2	2--10	10--40	>40
Aspect (Direction)	E, S, SE, SW	W	NE, NW	N
Distance to water (m)	500 - 1500	1500 - 2500	2500 - 4000	>4000
Distance to Settlement (m)	>8000	4000 - 8000	2000 - 4000	<2000
Distance to Roads (m)	>8000	4000 - 8000	2000 - 4000	<2000
Land use/Landscape	Natural Plants, forests	Sparse & dense bushland	Grassland	Urban, Open Waters, Agricultural land, Livestock
Elevation (m)	600 - 1500	1500 - 2300	2300 - 3000	>3000

(Source: FAO and Ministry of Agriculture)

Temperature is one of the most important ecological factors that influence the poikilothermic organisms, like insects, playing a crucial role in their biology including their development (Campolo, et al., 2014). It has been found that very low temperatures below 10ºC can hinder foraging activity (Joshi, et al., 2010) as well as very high temperature (Al-Qarni, 2006) & (Blazyte-Cereskiene, et al., 2010). Temperature map (Figure 4-2) for the area was made from data provided and a positive relationship with honey bees suitability determined as per (Regniere, et al., 2012).

Precipitation suitable for beekeeping is relatively low. Rainfall is needed to supply the hydrographic network is vital in honey bee existence. Precipitation also has a negative impact since it prevents worker foraging to gather food as reviewed by (Abou-Shaara, 2014). Altitude plays a very important role in influencing the land cover and everything associated with honey

production. Beekeeping is highly suitable in areas with a slope of less than 10 % and moderately suitable in areas with a 30% slope. The slope determines the vegetation, the shading of hives, and affects the pollen collection by bees. The other factor is Aspect which is the direction of the slope, it determines the vegetation and hence affecting bee forages.

Distance to water is also a factor considered since it determines the time and energy the bees spend in collecting water and nectar. Honeybees' physiological needs highly depend on nectar and pollen floral resources**.** Vegetation is very important as a source of food for honey bee colonies even in desert areas (Zaitoun & ZVorwohl, 2003). Hence land cover is also considered.

Social factors include the cultural practices of the people in Beekeeping has been traditionally practiced in the county for a long time. Many beekeepers used logs, rock, and tree crevices as beehives while others were honey hunters. Honey and other hive products among Baringo communities have an important cultural significance especially during traditional ceremonies such as marriages where honey is used for dowry payment. Honey was also used as food, medicine, preservative and sweetener. The Honey preference map for the area is shown in Figure 3-7.

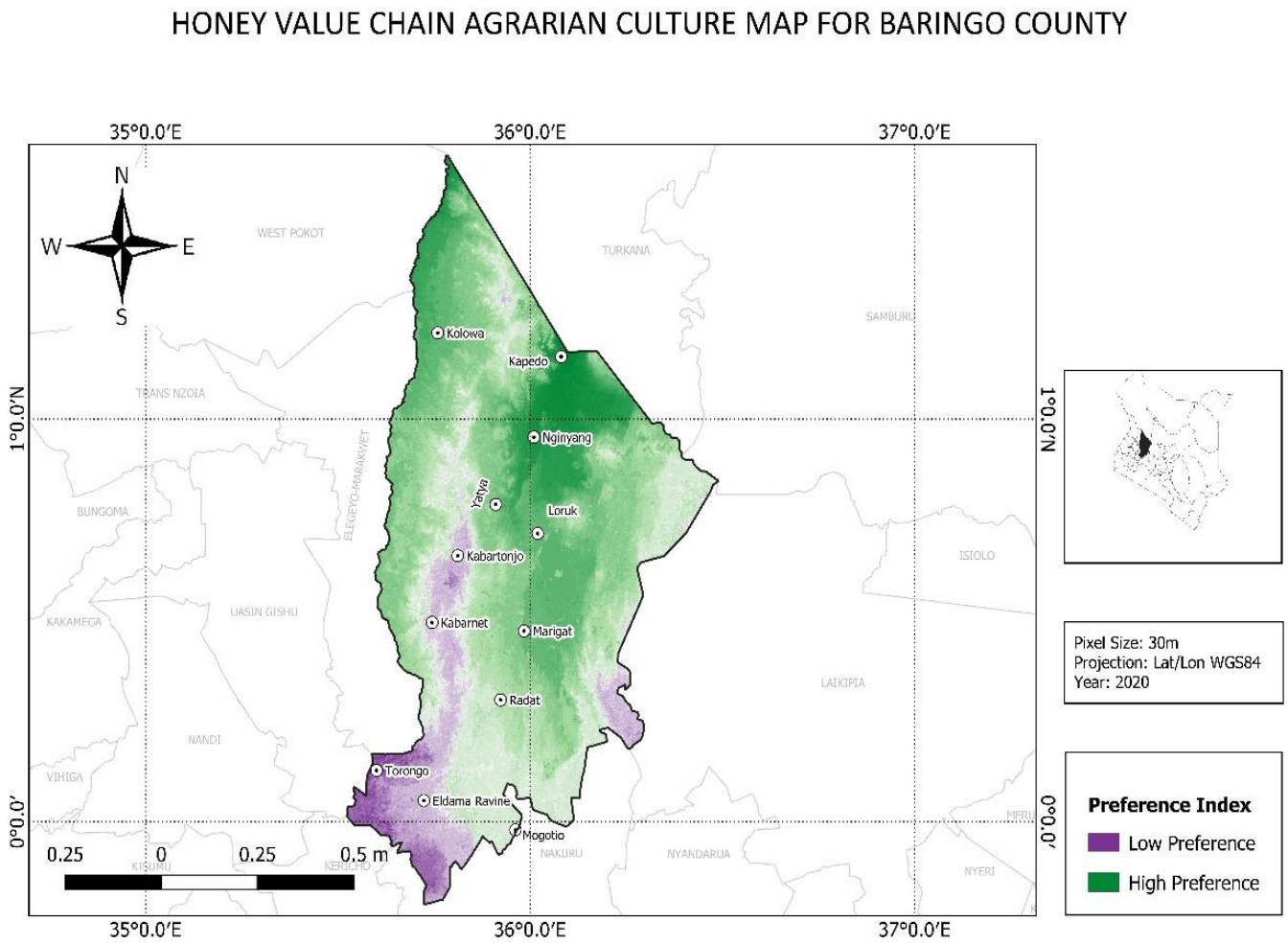

Figure 3-7 Honey Preference Index Map

Road network is a critical factor in beekeeping. It directly influences the suitability of transportation. Political aspects are also factors contributing to beekeeping. This is because policies on physical planning and spatial plans are greatly influenced by existing leadership. The allocation of funds on projects carried out in an area is also a key political aspect that should be considered.

These parameters were selected to ensure that honey bee colonies will not be under any environmental stress, and in accordance with previous studies. The suitability criteria for each of these factors into the four classes were categorised as shown in Table 3-9.

Table 3-9 Honey Bees Relative Importance Matrix and the Derived Weights

	Temperature	**Rainfall**	**Slope**	**Aspect**	**Elevation**	**Land Use**	**Distance to Water**	**Distance to Road**	**Distance to Settlement**
	1	5	3	4	2	3	5	5	6
	0.2	**1**	2	4	0.2	5	3	3	6
	0.333	0.5	**1**	4	3	0.25	5	0.25	7
	0.25	0.25	0.25	**1**	0.2	0.25	6	5	6
	0.5	5	0.333	5	**1**	0.5	0.333	0.25	6
	0.333	0.2	4	4	2	**1**	5	2	2
	0.2	0.333	0.2	0.166	3	0.2	**1**	5	4
	0.2	0.333	4	0.2	4	0.5	0.2	**1**	2
	0.1666	0.166	0.1428	0.1667	0.166	0.5	0.25	0.5	**1**
Derived weights for each variable									
Variable	**Temperature**	**Rainfall**	**slope**	**Aspect**	**Elevation**	**Land Use**	**Distance to Water**	**Distance to Road**	**Distance to Settlement**
Weights %	23	16	14	8	11	10	7	6	5

Weight and dataset Combination: Priority was given to temperature then relative humidity and the other factors thereafter. The Analytical Hierarchy Process (AHP) that was described by **(Saaty, 2008)** was used for evaluation for each variable. Intensity of importance for every variable was assigned according to their relative importance as given in matrix in Table 3-9.

Therefore, the contribution of various variables was as follows: Temperature and relative humidity were 59% and 23% respectively since they are the major factors in honey bees suitability. Distance to water resources and landcover each were given a rating of 7 % each and distance to settlement areas rated at 4 %. Weights were normalized and raster was calculated at the assigned weights for each variable followed by creating the general suitability map for honey bees. Figure 3-16 illustrates model created using spatial analysis tools and ArcGIS model builder.

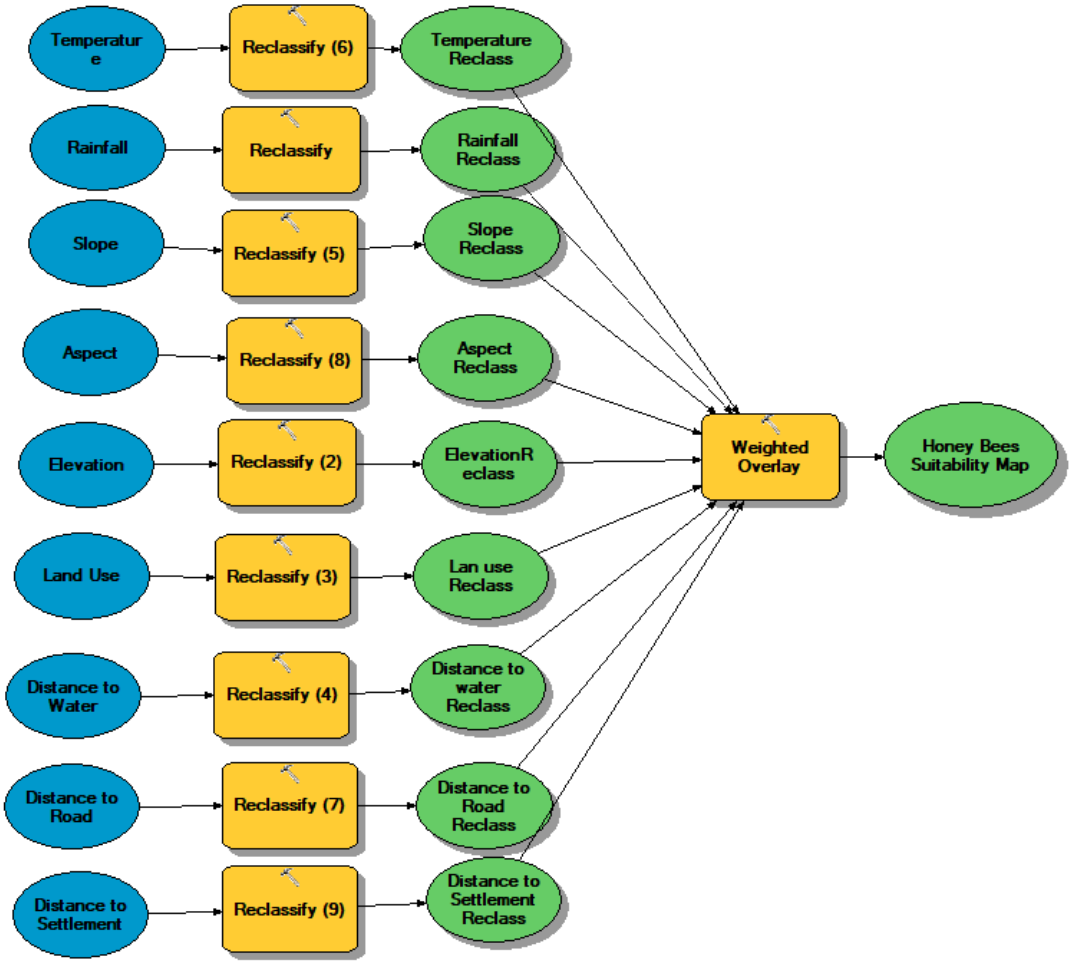

Figure 3-8 Honeybees Suitability Model

4 RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter gives the results as obtained in the analysis from the three models in the research. The results were given in the order of Honey Bees, Goat and Dairy cattle as obtained in the models created in the previous chapter.

4.2 Determined Criteria

After examining the various literatures and FAO publications on land suitability several criteria were determined. These therefore are the determined criteria from the previous chapter included the following:

4.2.1 Climate

The determined climate parameters were rainfall, temperature and relative humidity, these maps were derived from climatic data provided.

4.2.1.1 Rainfall

The rainfall in Baringo County varies from 1,000mm to 1,500mm in the highlands to 600mm per annum in the Lowlands. Due to their varied altitudes, the sub-counties receive different levels of rainfall. Eldama Ravine sub-county receives the highest amount of rainfall. The lowland sub-counties of Mogotio, East Pokot and Baringo North receive relatively low amounts. The Figure 4-1 shows a map of rainfall distribution in the region.

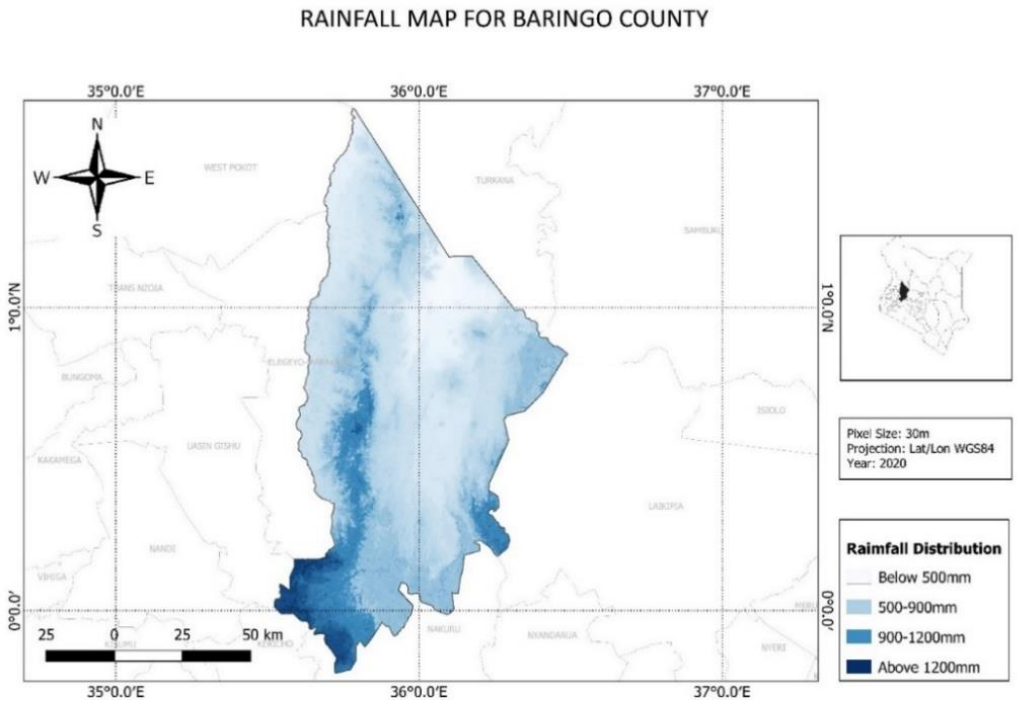

Figure 4-1 Rainfall Map for the Area of Study

4.2.1.2 Temperature

The temperatures range from a minimum of 10°C to a maximum of 35°C in different parts of the county. The coldest parts being in Eldama ravine around Torongo and Mumberes where at times the temperature goes as low as 10°C, while the hottest parts being in Tiaty and Baringo south as shown in Figure 4-2 shows the temperature distribution map.

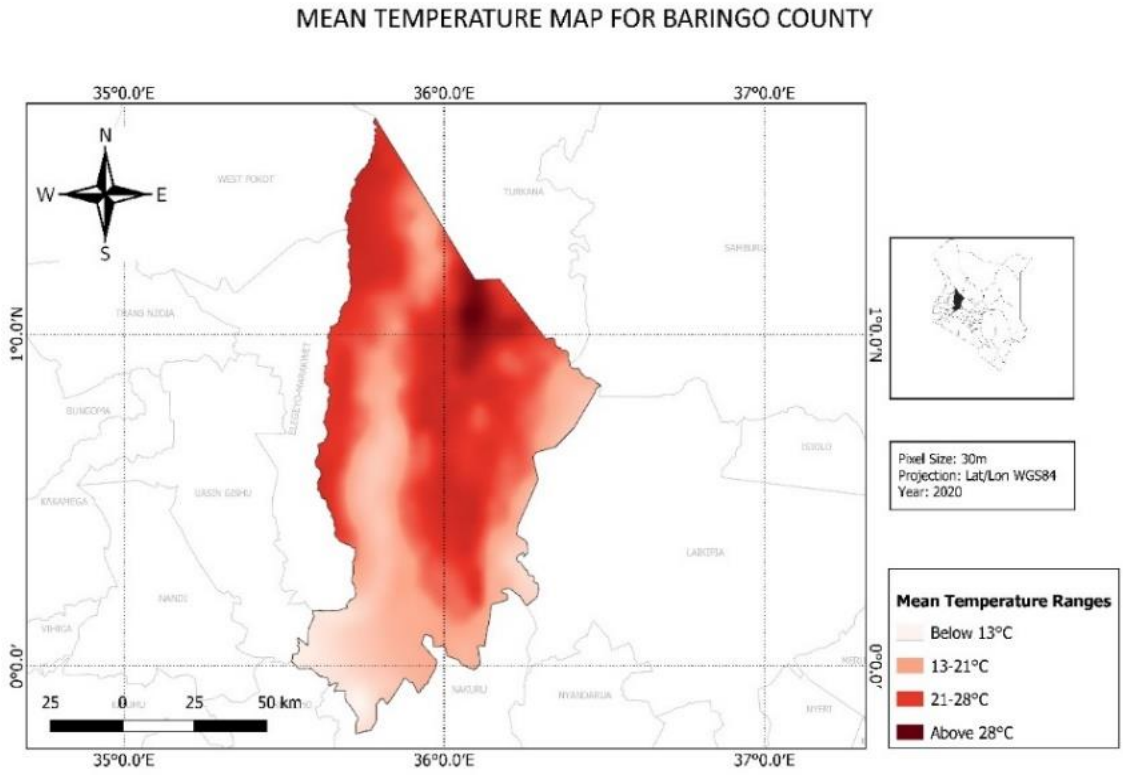

Figure 4-2 Mean Temperature Map

4.2.1.3 Relative humidity

The relative humidity derived from the available climate data. Average wind speed is 2m/s and the humidity is low. The climate of Baringo varies from humid highlands to arid lowlands while some regions are between these extremes. Figure 4-3 shows the relative humidity of the region.

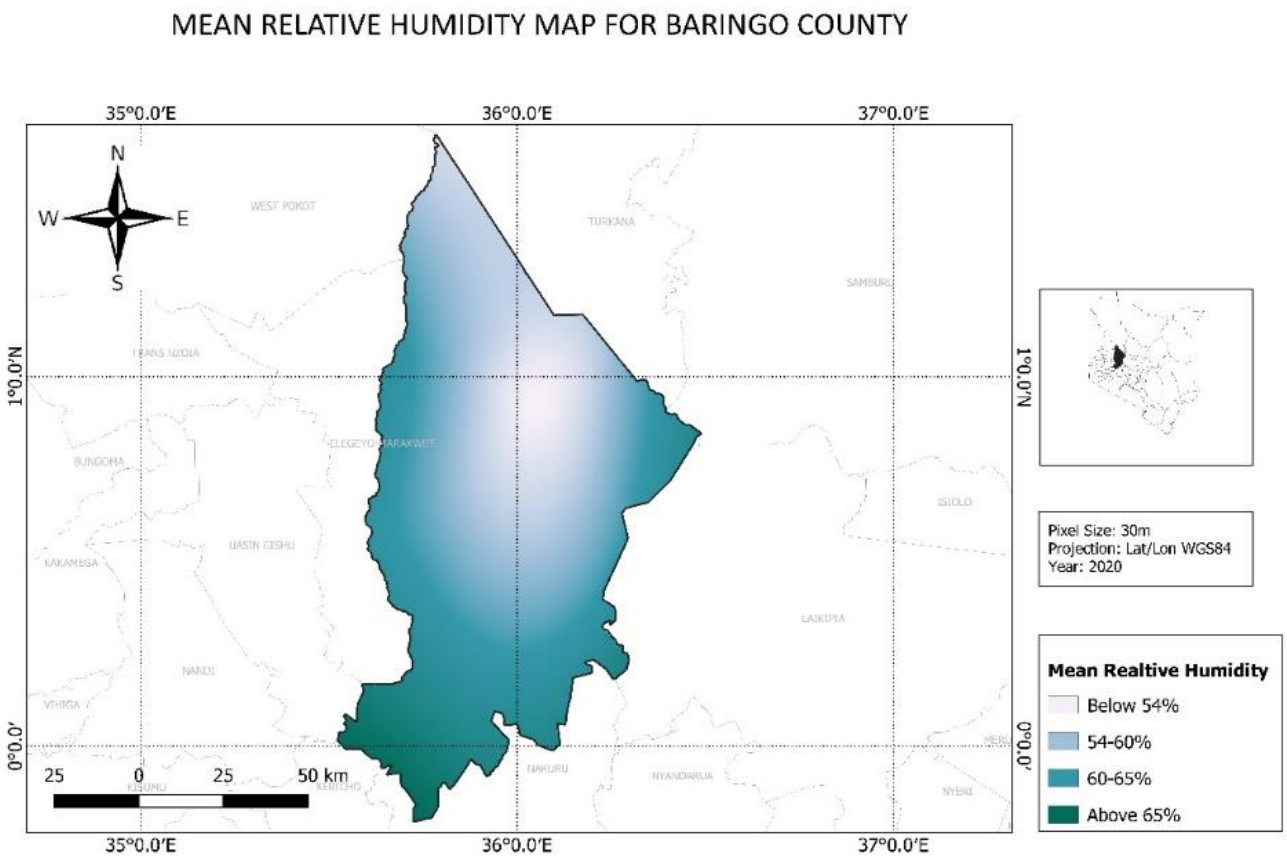

Figure 4-3 Relative Humidity Map

4.2.2 Slope

The topography of Baringo is characterized by hills with steep slopes on either sides and flat plains on the valley bottom. The altitude varies from 1000m to 2600m above sea level. The Tugen Hills form a conspicuous topographic feature in the county. The trend of the hills is north-south and mainly consists of volcanic rocks. The hills have steep slopes with prominent gullies. On the eastern and western parts of the hills are escarpments. One of the prominent features is the Kerio Valley, which is situated on the western part of the county. In the eastern part of the county near Lake Baringo and Bogoria is the Loboi Plain covered mainly by the latchstring salt-impregnated silts and deposits. The slope of the county therefore varies from Less than 3% in the lowlands to over 50% along the steep parts along the Tugen hills. Figure 4-4 shows the slope of the region.

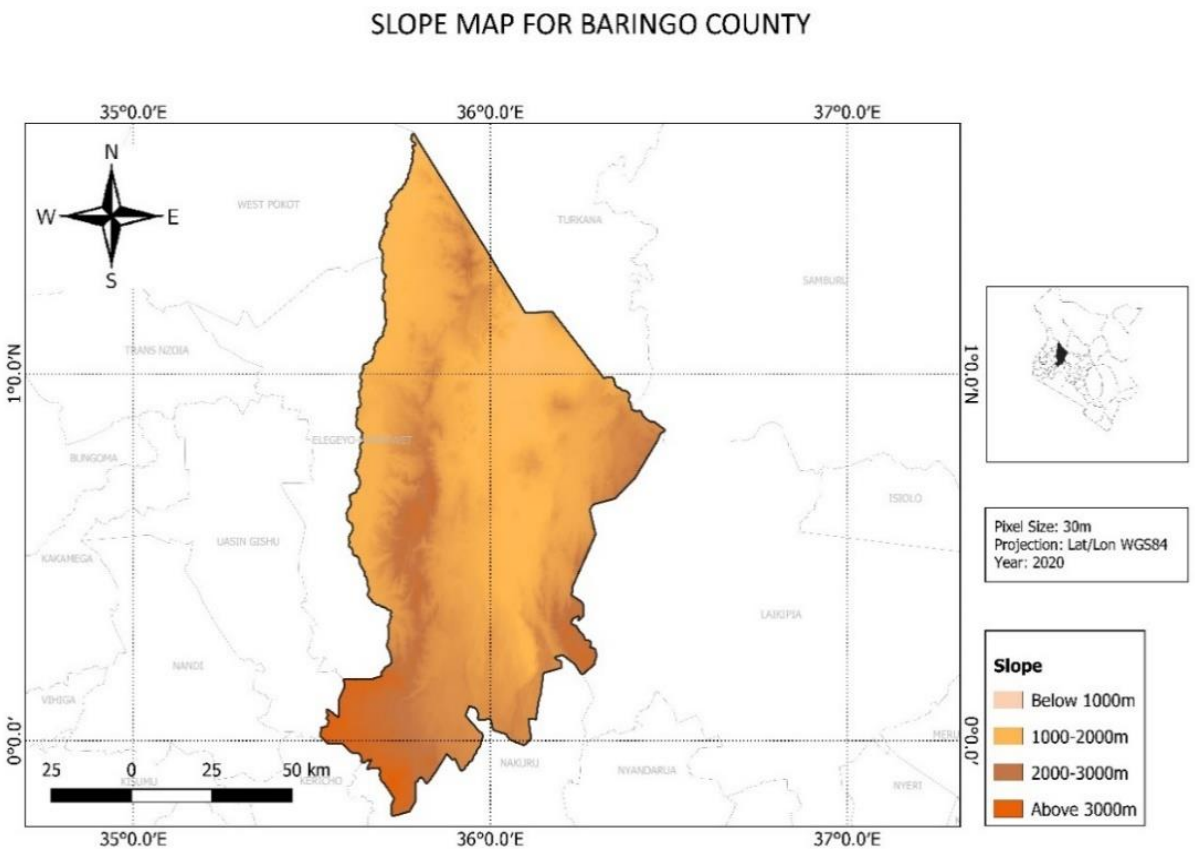

Figure 4-4 Slope Map

4.2.3 Land Cover Land use

The area of study is classified as arid and semi-arid. Most parts of Tiaty, Baringo Central, Baringo South, Baringo North and Mogotio Sub counties are arid and semi-arid except for Koibatek Sub County which is mainly in a highland zone. The satellite images classification produced the land cover land use map in the Figure 4-5. It is covered mainly by range lands and forests in the highlands. Wetlands cover the shores of lakes Baringo, Bogoria and Kamnorok. The other areas are unclassified lands.

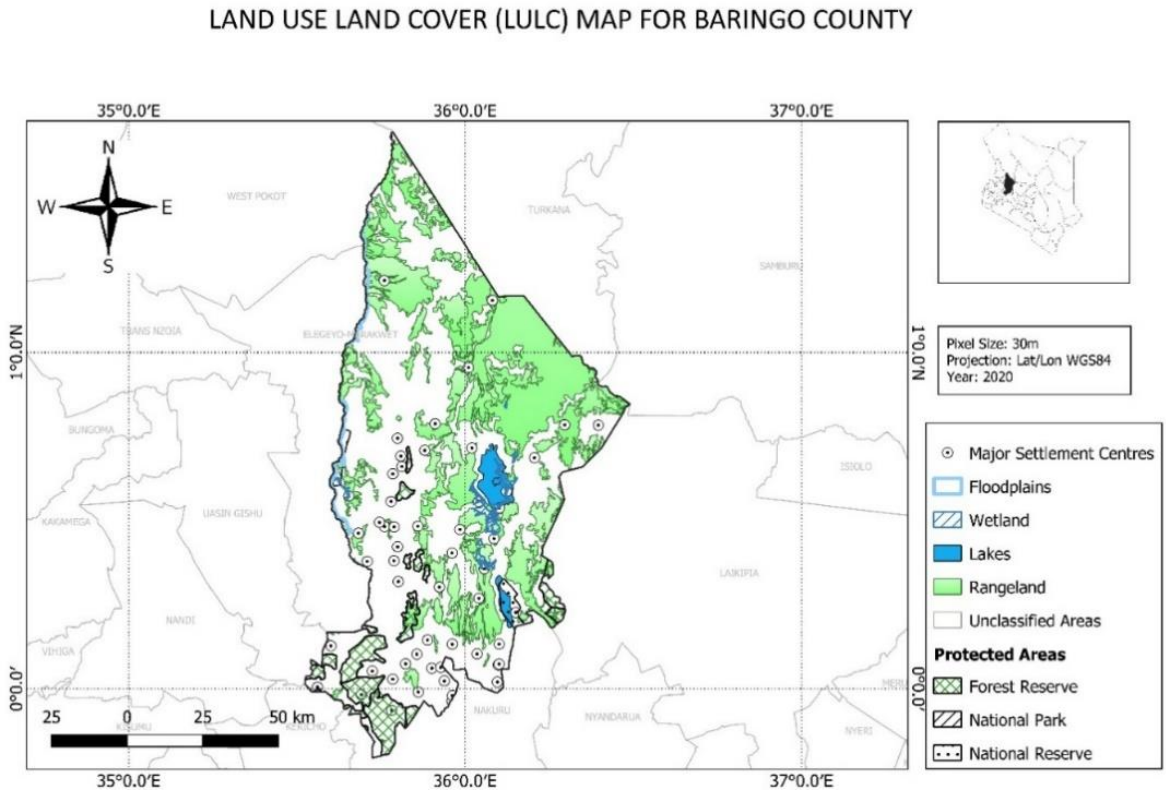

Figure 4-5 Land Cover Land Use Map

4.2.4 Social Factors

Baringo County is inhabited by several tribes which include the Tugen, Pokot and Ilchamus with minority groups such as the Endorois, Nubians, Ogiek, Kikuyu and Turkana. Majority of who are pastoralist and agro pastoralist. The Pokot and Ilchamus community occupy Baringo south, Tiaty East and Pokot East sub counties and derive their livelihoods by keeping livestock and bee keeping, The Tugens occupies the remaining sub counties and practices crop farming, livestock keeping and bee keeping as their main livelihood. Livestock keeping is done both as an economic as well as a cultural practice; it is a source of wealth and a symbol of status. Livestock and livestock products are used for food security, to pay dowry as for economic purposes. Baringo County of late has had several security challenges to the North and East of the county relating to cattle rustling. Some of the neighboring Counties have serious security concerns i.e. in the border between Baringo and West Pokot and Laikipia Counties which are porous and in the hands of cattle rustlers who are in possession of small arms (Baringo County Government, 2018).

Traditional conflicts are due to cultural factors. Tribe-based raiding of livestock has been traditionally practiced and culturally approved among the pastoral communities in especially the Ilchamus, Tugens and Pokots. Competition over scarce grazing fields, water resources and pasture escalate inter-ethnic animosity often resulting in armed conflicts, which are predatory in nature and much more destructive. In some of the pastoralist communities for one to marry he has to participate in cattle rustling so as to get dowry for his bride. In some communities like Pokot there is a belief that all cattle herd belong to them (Nganga, 2012). Morans who participate in raids are regarded as heroes. Cattle rustling involve other communities. Traditionally, these communities had weapons like spears, bows and arrows, however, presently they have graduated to use of modern weapons like guns. This has increased fatalities and in some cases security arms of the government have to intervene to restore sanity.

Cattle rustling has had a negative impact on food security in Baringo County over the years. The affected areas include; Makutani, Arabal, Mochongoi and Chemorongion village. Livestock is usually lost to the rustlers, lives threatened, institutions such as schools, health facilities and markets closed and families displaced leaving households vulnerable. Natural Resource Based Conflicts mainly occurs due to competition over scarce natural resources especially among the pastoralist communities. This is according to (Clement & Muinde, 2018)

Insecurity is one of the development challenges in the county. Conflicts affect the day to day operations of the affected communities. This means that no learning goes on as schools are closed; trade is affected, increased medical expenditure and displacement of people among others according to (Baringo County Government, 2018). These factors therefore influence the suitability of the value chains in the study.

4.2.5 Economic Factors

The main economic activities in Baringo County include livestock farming, crop farming, fish farming, wildlife and tourism, mining, quarrying, lumbering, trade and industry among others. Agriculture sector is one of the main drivers of the county economy where it contributes 58% to the Gross County Product (KNBS, 2019). Livestock sub sector plays an important economic and socio–cultural role in the community. It contributes to the food and cash needs of the pastoralist community and provides employment to 80% of the population therefore; the

economic growth of the County is correlated to growth and development of livestock (Baringo County Government, 2013). Three parameters were used in determining the economic suitability of the county; these were Road, Population and Market access

4.2.5.1 Roads

A modern and well-maintained physical infrastructure is a key catalyst to economic growth and poverty reduction. The county does not have a good road network. It has a total 5,943.92km of road with Class B, D, E, G, R and U having 66.4km, 339.22km, 1810km, 46.85km, 1,538.08km, and 2043.37km respectively according to (Baringo County Government, 2018). The roads are mainly earth and mixed type. These roads are usually impassable during the rainy season. This impedes livestock marketing business commuting, which is the main source of livelihood for majority of the residents. The figure 4-6 shows the road suitability map.

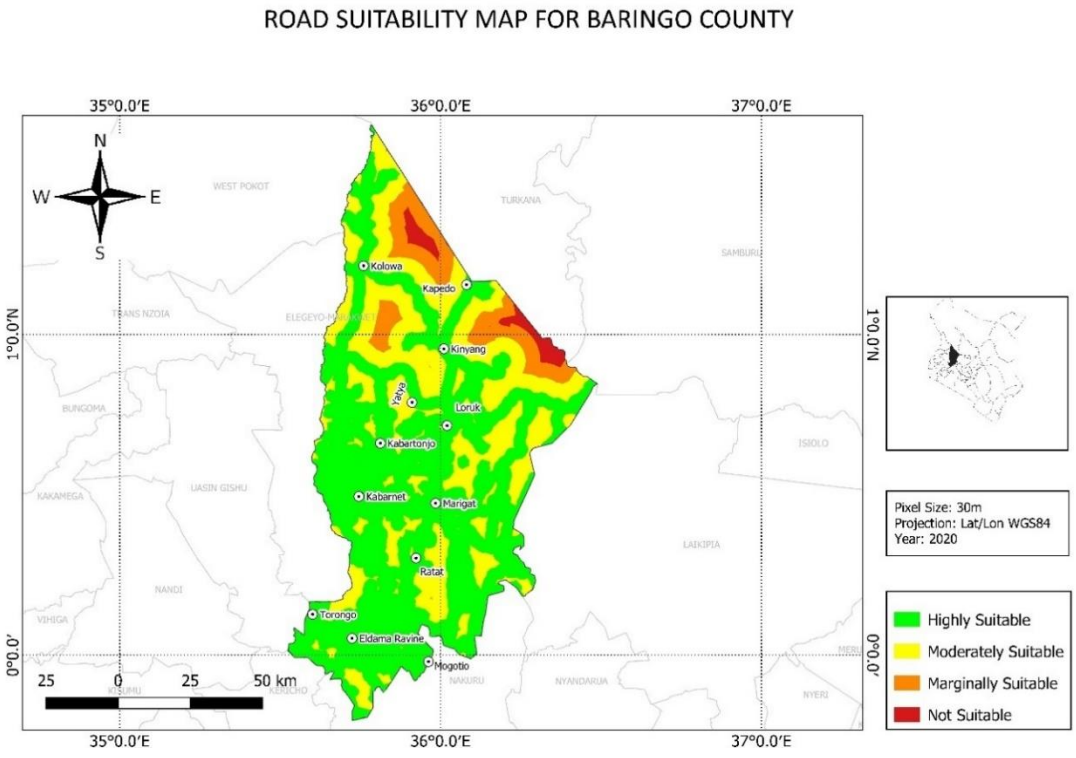

Figure 4-6 Road Suitability Map

4.2.5.2 Markets

The Accessibility to the market plays an important role in determining the suitability of the value chain. The purchasing power of the buyers is determined by the poverty levels and their

income levels; this determines the prices they are willing to offer and the ease of buying the products. Figure 4-7 shows the market suitability map.

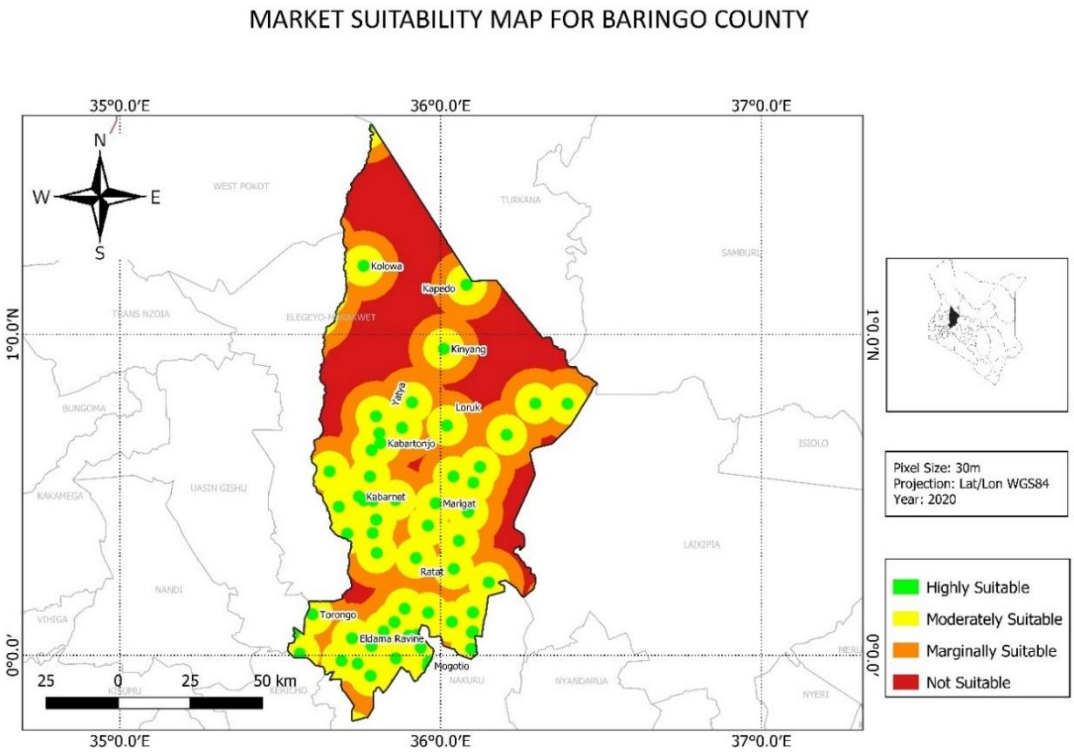

Figure 4-7 Market Suitability Map

4.2.6 Population

Baringo County has a population of 666,763 persons and 142,518 households with an average household size of 4.7 and a population density of 61 persons per square kilometer, (KNBS 2019) as shown in Figure 4-8.

The population is an important parameter in assessment of the economic suitability of the county, it determines the size of the market and the number of value chain actors involved in a certain value chain. Population determines the land holding size and its suitability for agricultural production.

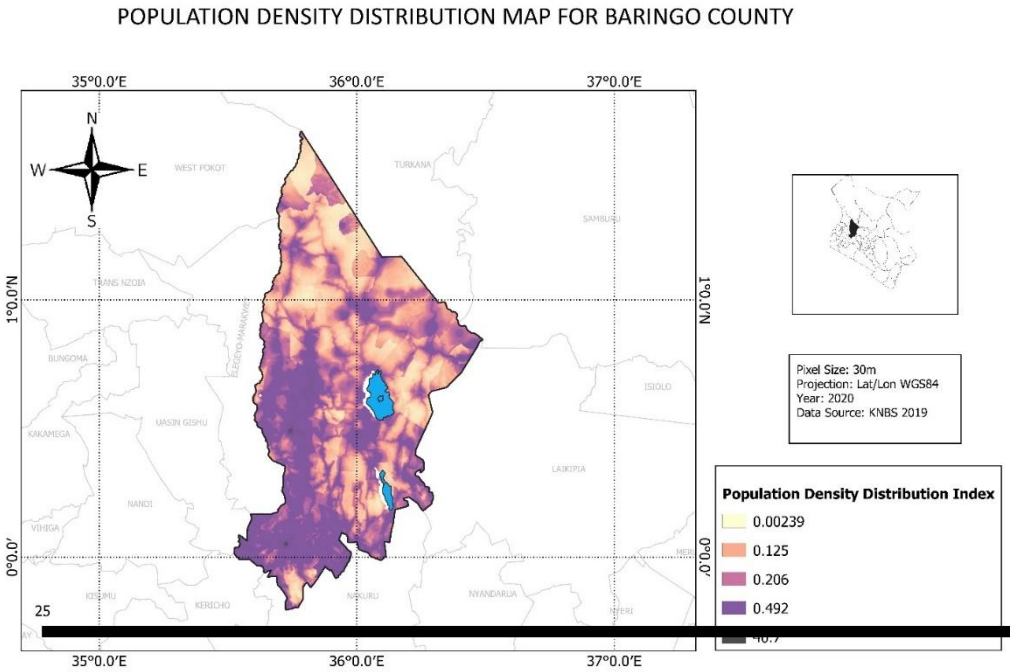

Figure 4-8 Population Density Distribution Map

4.2.7 Political

This parameter examines the extent to which the government intervenes in the priority value; it includes the policies, manifestos, regulation and budgetary allocation. Baringo County CIDP identifies livestock and crop sub sectors as being important in transforming the county economy. It outlines how the county will improve productivity and market access of the livestock enterprises. These include; Infrastructure improvement (water development, road network, livestock markets, dips, slaughter houses), pasture establishment and conservation, milk cooling facilities and processing plant. Livestock upgrading for small stock and large ruminants through provision of AI services, establishment of bull schemes to upgrade local breeds and provision of high-quality breeding stock. Input subsidy programs through provision of pasture seeds. Provision of extension services, disease and pest control for livestock through establishment of laboratories and clinics for disease diagnosis and surveillance to make the county a disease-free zone among others (Baringo County Government, 2018)

The county commits itself to be increasing allocation to the agriculture sector in line with the Maputo declaration. The county has also approved Livestock Sale Yard Bill, developed a livestock marketing policy, dairy policy (draft), bee keeping policy as well as agriculture policy

(draft). The Governor's manifesto outlines food security, road infrastructure and water development as being key pillars of transforming the county. Despite all this the budgetary allocation to the agriculture sector is still low and extension services have been on the decline due to reduction in staff numbers and low resource allocation.

4.3 Dairy Cattle Suitability

The spatial analysis resulted in four most suitable candidates' area for developing dairy cattle suitability. The factor criterion for the development of the suitability maps was done through categorization of factors; altitude, temperature, rainfall, nutrients availability, biological hazards (tsetse fly infestation), soil fertility, agrarian culture and market are the requirements for dairy cattle. Land cover is a criterion to avoid using the restricted places to develop dairy cattle farm. The factor criterion maps were created in the four categories each before it was overlayed to give the final suitability map. The suitability of each parameter is discussed as follows:

Biophysical parameters include the following;

4.3.1.1 Rainfall

The major system of livestock keeping in Baringo is rain fed, thus the amount of precipitation is of key importance since it determines the availability of major livestock feeds such as pasture and forage trees, it determines the availability of water for dairy cattle drinking and is used in milk value addition and processing. The choice of pasture varieties depends also on the rainfall availability. Three main characteristics of rainfall are its amount, frequency and intensity, the values of which vary from place to place, day to day, month to month and also year to year. The suitability of the county for dairy production is ranked from 'highly suitable" to "not suitable depending on the rainfall regime.

4.3.1.2 Temperature

Temperature condition plays a key role in determining the productivity of the dairy animals. Heat stress increases maintenance energy requirements, lowers dry matter intake, especially forage intake, making it difficult to meet energy needs hence resulting to decreased milk yield.

The temperatures range for Baringo varies from a minimum of 10°C to a maximum of 35°C in different parts of the county. Areas around Torongo and Mumberes experiencing the lowest temperatures while Kapedo, Koloa and Marigat areas having the highest temperatures. The region is therefore moderately suitable for dairy cattle rearing as per biophysical parameters involved. The biophysical map and soil fertility map for dairy suitability is shown in Figure 4-9 and Figure 4-10 respectively.

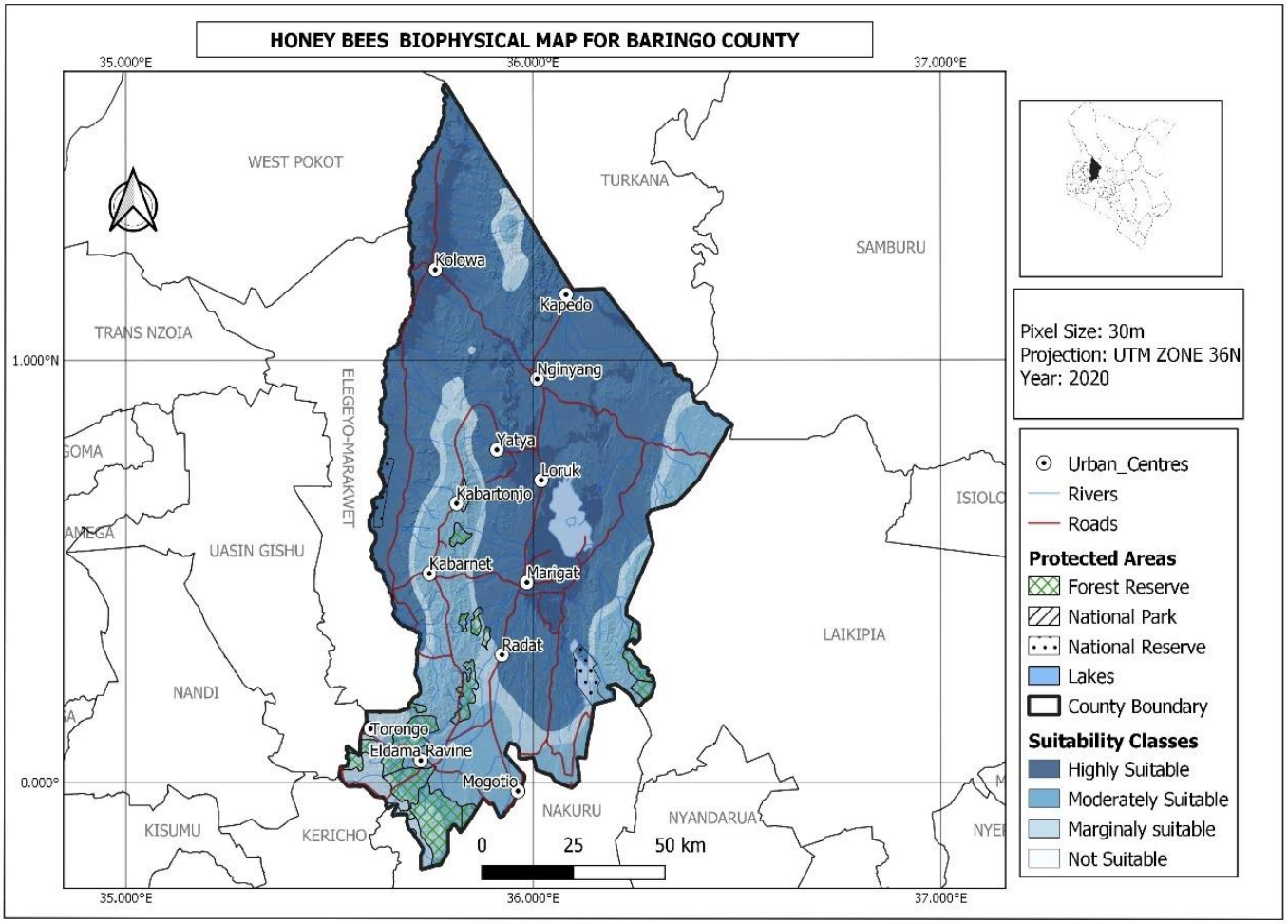

Figure 4-9 Dairy Cattle Biophysical Map

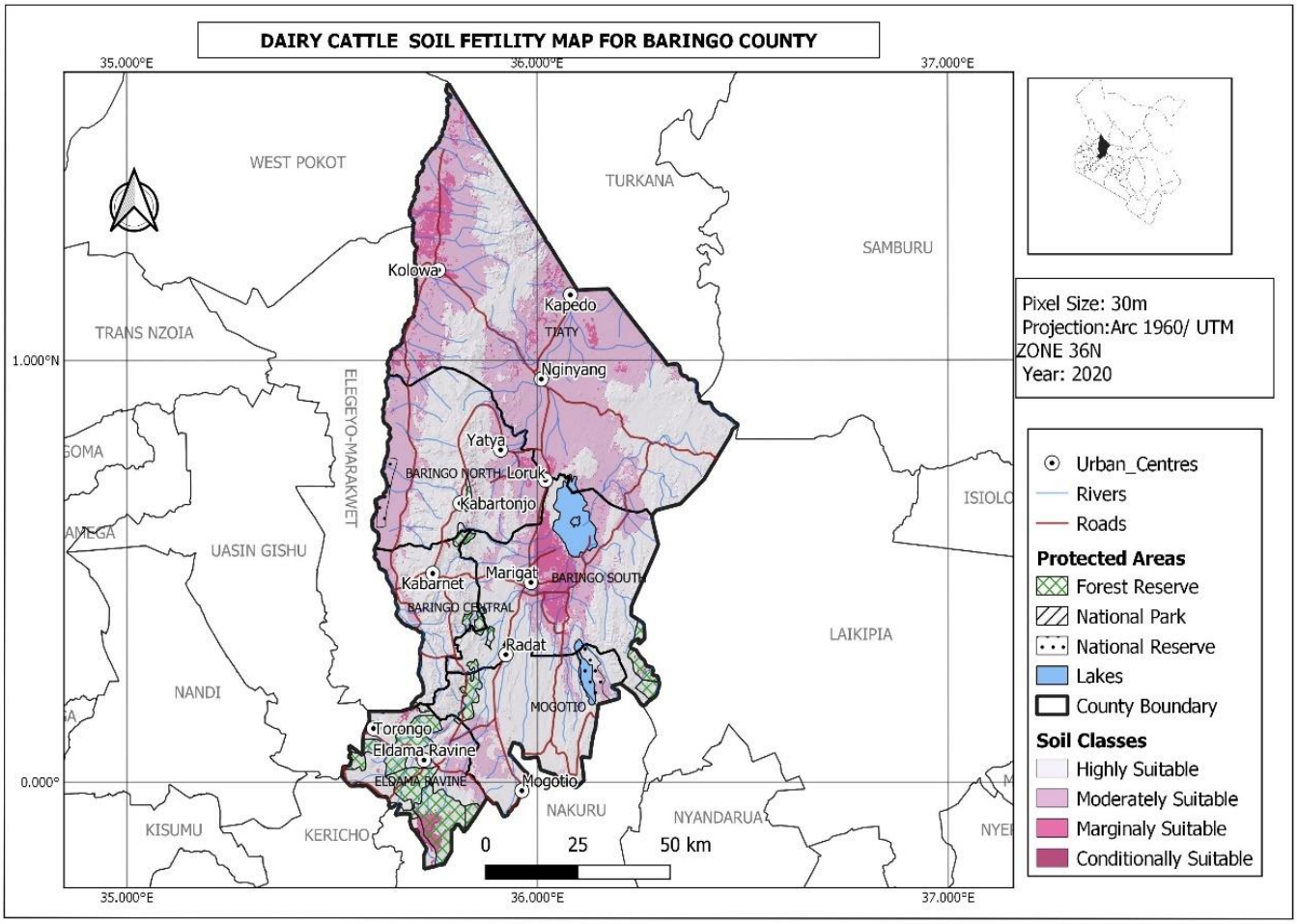

Figure 4-10 Dairy Cattle Soil Fertility Map

4.3.2 Tsetse Fly Infestation

Tsetse fly infestation pose a great constraint to dairy production in Baringo County, it is more prevalent in the humid and sub humid part of the county around Lake Baringo, Lake Bogoria, Emsos, Nyalilbuch and its environs and transmits trypanosomiasis which results to milk reduction, affects reproduction and at times result to livestock losses

4.3.3 Social

The Baringo farmers are generally receptive to dairy farming; livestock is kept both for cultural as well as economic values. The community consumes milk, gives livestock as dowry as well as for commercial purposes. The agrarian culture is therefore moderately suitable to highly suitable for dairy production.

4.3.4 Economic

Baringo County has a population of 666,763 persons and 142,518 households with an average household size of 4.7 and a population density of 61 persons per square kilometer (KNBS 2019.) The average land holding by dairy cattle is 9.5 acres while other areas have an average land size of over 16 acres. This is adequate for keeping livestock and also establishing pasture. The roads system is fairly done and accessibility to the dairy zones are moderately good, there is however poor accessibility during rainy seasons.

4.3.5 Political

Baringo county CIDP identifies dairy farming as a major area of investment and development for improving the livelihoods of its residents. The county is investing in dairy value addition and processing, breed improvement through AI and improved breeds, pest and disease control infrastructure and carrying out routine vaccination. However, the resource allocation is still low, there is diminishing extension services as well as inadequate measures to protect farmers from effect of climate change. It is for this reasons that the county is ranked moderately suitable in terms of political parameters.

4.3.6 Final suitability Map

A wide area of the region was classified to be marginally suitable for dairy cattle approximately 58%. This is because the most highly weighted criteria in Baringo county was marginally mapped by highly weighted parameters. The final dairy suitability map for Baringo County is as shown in Figure 4-11.

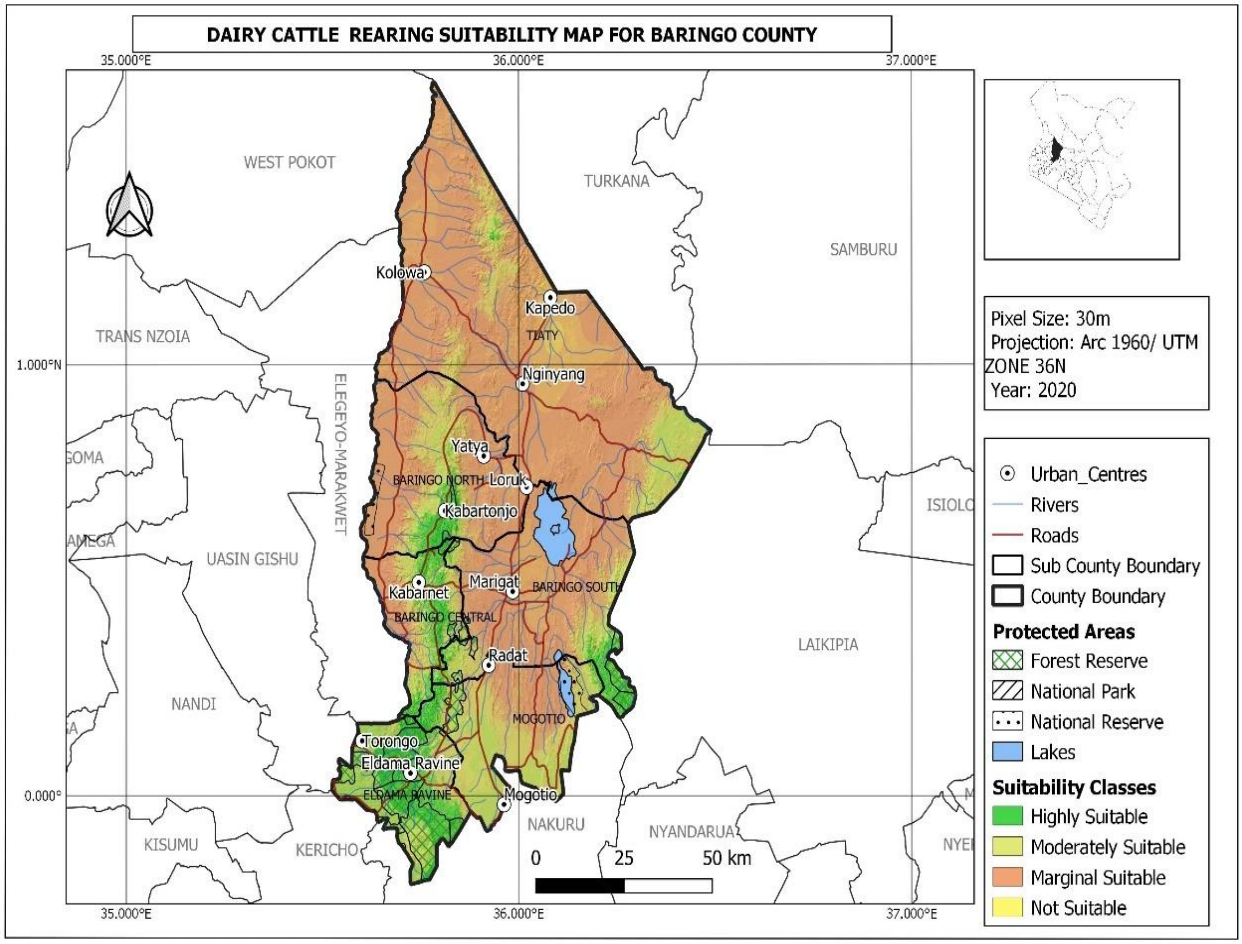

Figure 4-11 Dairy Cattle Rearing Suitability Map

Extracting the surface areas occupied by the individual suitability levels resulted in table. The table shows the Surface area in kilometres squared and estimated percentage of each suitability class of the study area to Dairy cattle activities.

Table 4-1 Areas for Dairy Cattle Suitability

Dairy Cattle Suitability		
Suitability level	**(Approx.) Surface Area in km^2**	**Surface %**
Highly Suitable	**835.3**	**7**
Moderately Suitable	**3675.3**	**35**
Marginally Suitable	**6397.9**	**58**
Not Suitable	**0.2**	**0.00**
TOTAL	**10908.7**	**100**

From the Table 4-1 it is deduced that 7 % of spatial area in Baringo county is highly suitable for dairy cattle rearing. 34% of the total area is moderately suitable whereas the remaining 58 % is marginally suitable. This is also visualized in the graph in Figure 4-12

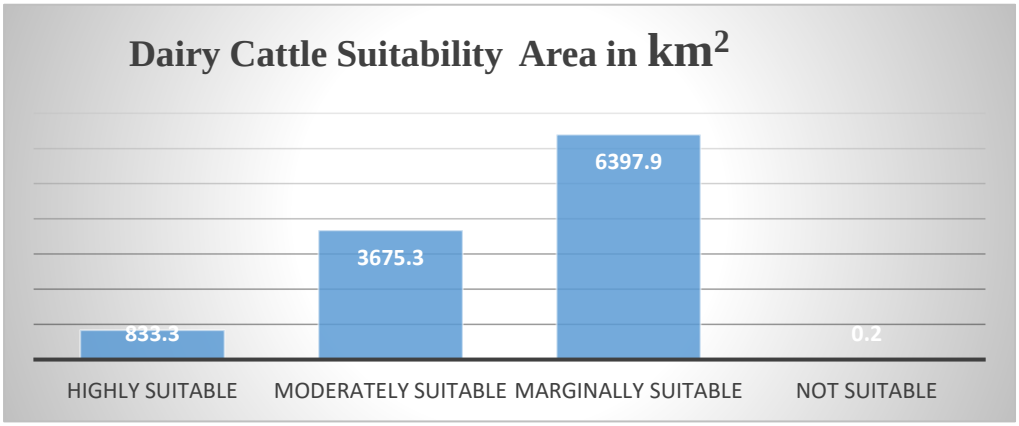

Figure 4-12 Dairy Cattle Suitability Area Graph

4.3.7 Validation and Accuracy Assessment

Based on the data obtained from the dairy stakeholders and Ministry of Agriculture – Agricultural Development Support Programme (ASDSP), an integration of the selected dairy cattle actors; people/organizations who transact dairy products who include farmers, traders, processors, transporters, wholesalers, retailers and final consumers on the various locations of the county were input to determine truthing of the overall suitability for dairy cattle value rearing in Baringo County. The map on suitability validation in the Figure 4-13 depicts the actuality of the various actors in the correct corresponding regions that are highly and moderately suitable.

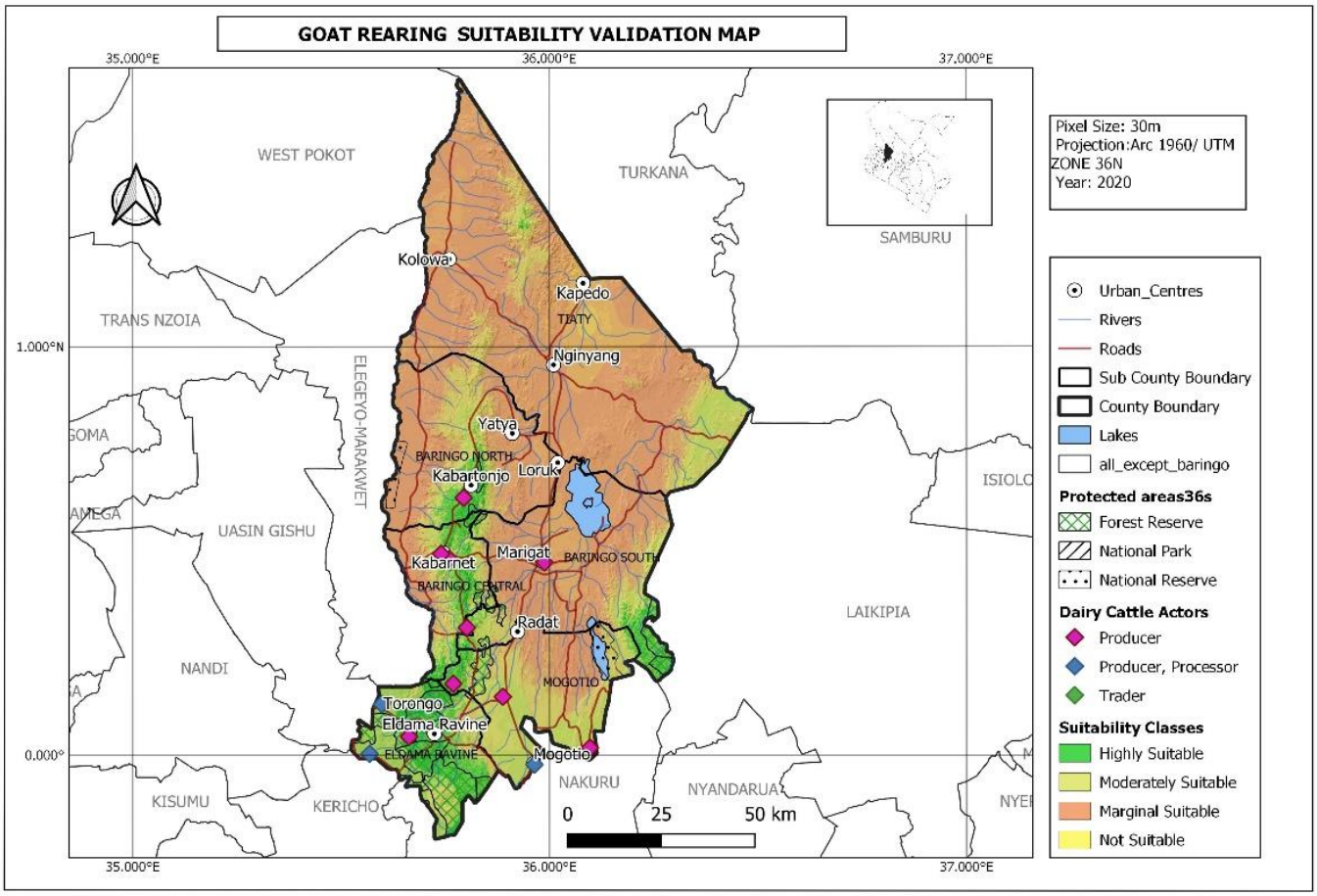

Figure 4-13 Dairy Cattle Suitability Validation

4.4 Goat Meat Suitability

Baringo County is estimated to be 75% Arid and Semi-Arid hence potential for livestock-based enterprise that thrive in ASAL areas. Meat goat is one of the priority value chains in the county that involves 51,605 (34%) households and is majorly practiced in Tiaty, Baringo South, Baringo North, Mogotio and Parts of Baringo Central and Eldama Ravine sub Counties. Meat goat population is estimated at 910,574 contributing about KES 534M annually. Majority of the goats are reared traditionally under extensive free-range management systems with minimum specialized input in management practices in feeding and pest and disease. Goat meat value chain production is mostly affected by a number of parameters categorized into biophysical parameters (Temperature, slope and Tsetse fly risks), Social parameters, economic parameters (population dynamics, status of roads and access to markets) and political parameters.

4.4.1 Biophysical Parameters

Biophysical parameters include the following;

4.4.1.1 Temperature

Goats are homoeothermic animals able to maintain a balance between metabolism heats and heat of the environment; Goats with production demands are susceptible to heat stress in spite of heat resistant characteristic. Depression of feed intake and reduction in production are commonly observed in heat stressed goats. When temperatures are too low the goats use energy to warm the body hence leaving little energy for growth and reproduction. Low temperatures also weaken the goat's immune system and hence make them susceptible to disease. Goats perform optimally in Temperature range of within 20-30^{o}C. According to this parameter the region is highly suitable for rearing goats. Figure 4-14 illustrates goat biophysical map of Baringo County.

4.4.1.2 Rainfall

Excess rainfall is also attributed to low temperatures and hence limits the time goats browse, increases outbreak of pests and diseases such as Helminths, foot rots, RVF among others hence

not suitable. The rainfall received in the area supports the rearing of goats to a higher degree as per the expert's view criteria.

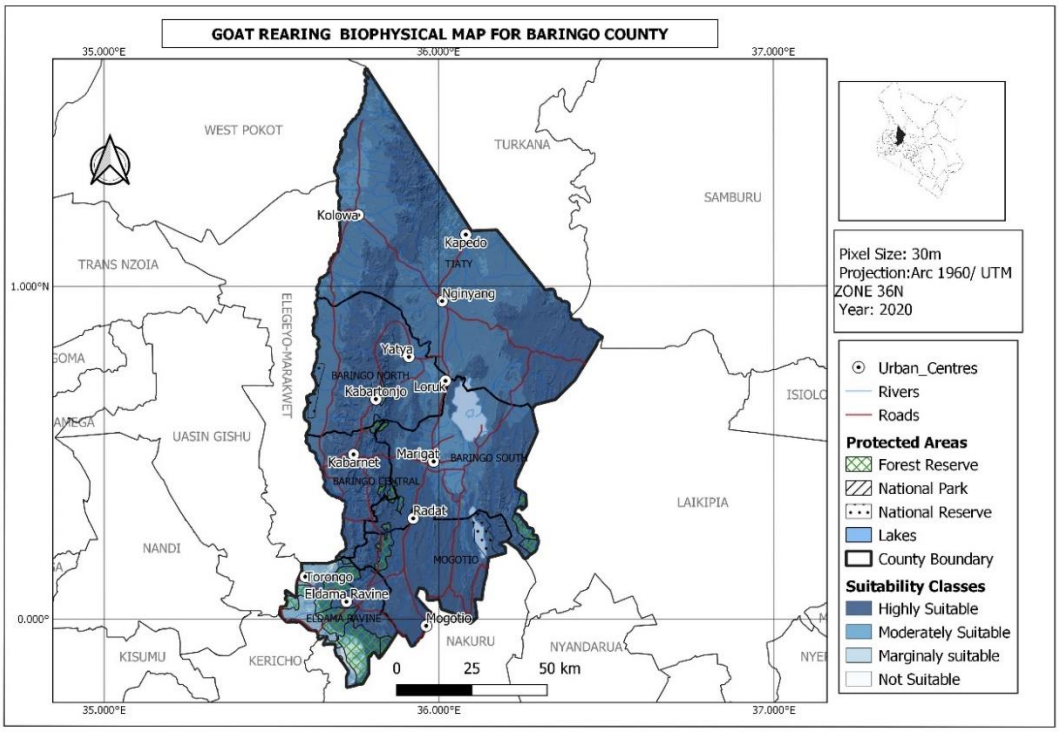

Figure 4-14 Goat Biophysical Map

4.4.1.3 Slope

Baringo county is generally of undulating terrain. The slope map created gave a moderate suitability for goat farming. Slope affects ease of browsing, vegetation cover, predisposes goats to injury, increases soil erosion and is difficult to mechanize hence steep slopes is not suitable for goat meat value chain.

4.4.2 Socio-economic parameter

Socio parameters is ranked second after the biophysical parameter since it is a very important factor. The preference index map produced for goat rearing showed that the area suitability ranges from high in the low lands where people prefer goat meat to moderate in the highlands where the residents prefer other agricultural products to goat meat. Most of the residence of Baringo keeps goats both for economic value and cultural values. It's used for food security, payment of dowry, source of income and a sign of wealth and status highly suitable. Economic parameters are ranked third most important and moderately suitable. The economic parameters

include access to market, roads and population with weights of 2, 1 and 3 respectively. The maps in Figure 4-6 and Figure 4-7 shows the economic suitability as per its sub criteria.

4.4.3 Political parameter

Political parameter also has a greater degree since it affects goat meat value chain in terms of policies, political support and environment, conflicts and resource allocation to support the value chain. Economic parameters are ranked third most important and moderately suitable (weighted score of 3.33).

4.4.4 Overall Goat Rearing Suitability Map

After the suitability analysis was done which involved the overlaying of the several criteria maps identified, it gave the suitability map in the Figure 4-15. It is can be determined that Baringo county is highly suitable for goat production.

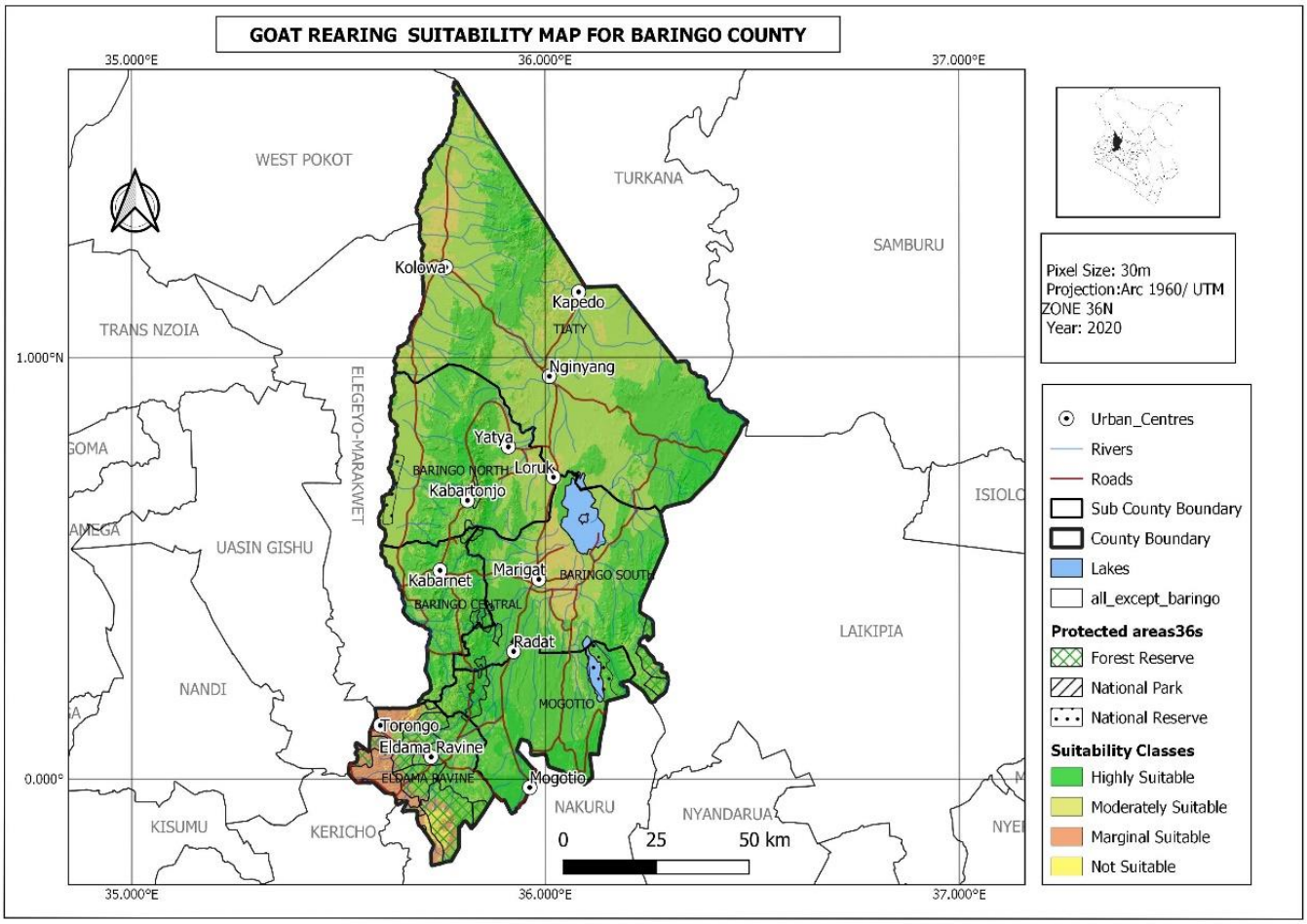

Figure 4-15 Goat Rearing Suitability Map

The exact areas in kilometres squared of the different suitability levels for goat production were also extracted as shown in the table 4-2.

Table 4-2 Areas for Goat Suitability

Goat Suitability		
Suitability level	**(Approx.) Area in km^2**	**Surface area in %**
Highly Suitable	5503.4	50.45
Moderately Suitable	5036.1	46.17
Marginally Suitable	368.8	3.38
Not Suitable	0.5	0.00
Total	**10908.7**	**100**

From the Table 4-2 and the graph in Figure 4-16, Baringo county has high suitability for goat meat production at 50% and moderately suitable at 46%. A very small spatial area in the region is not suitable for goat rearing.

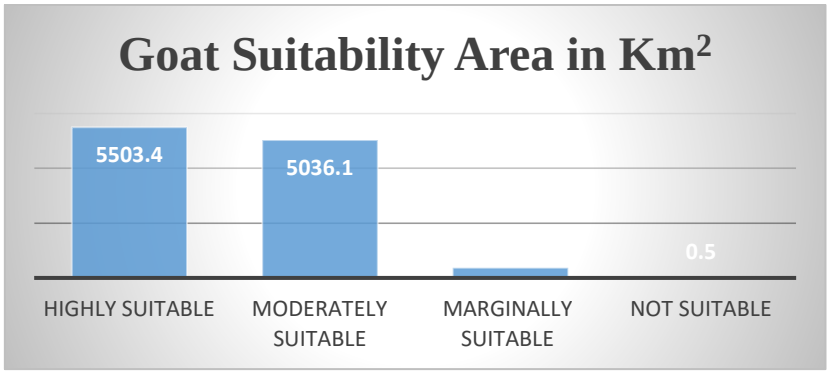

Figure 4-16 Goat Suitability Area graph

4.4.5 Validation and Accuracy assessment

The goatmeat suitability validation map was derived from the amalgamation of the georeferenced data from Agricultural Sector Development Support Programme (ASDSP) on value chain actors and the field study conducted to determine Producers, Processors and Traders. The data was mapped and overlayed to determine the correspondence as depicted on the map in Figure 4.17.

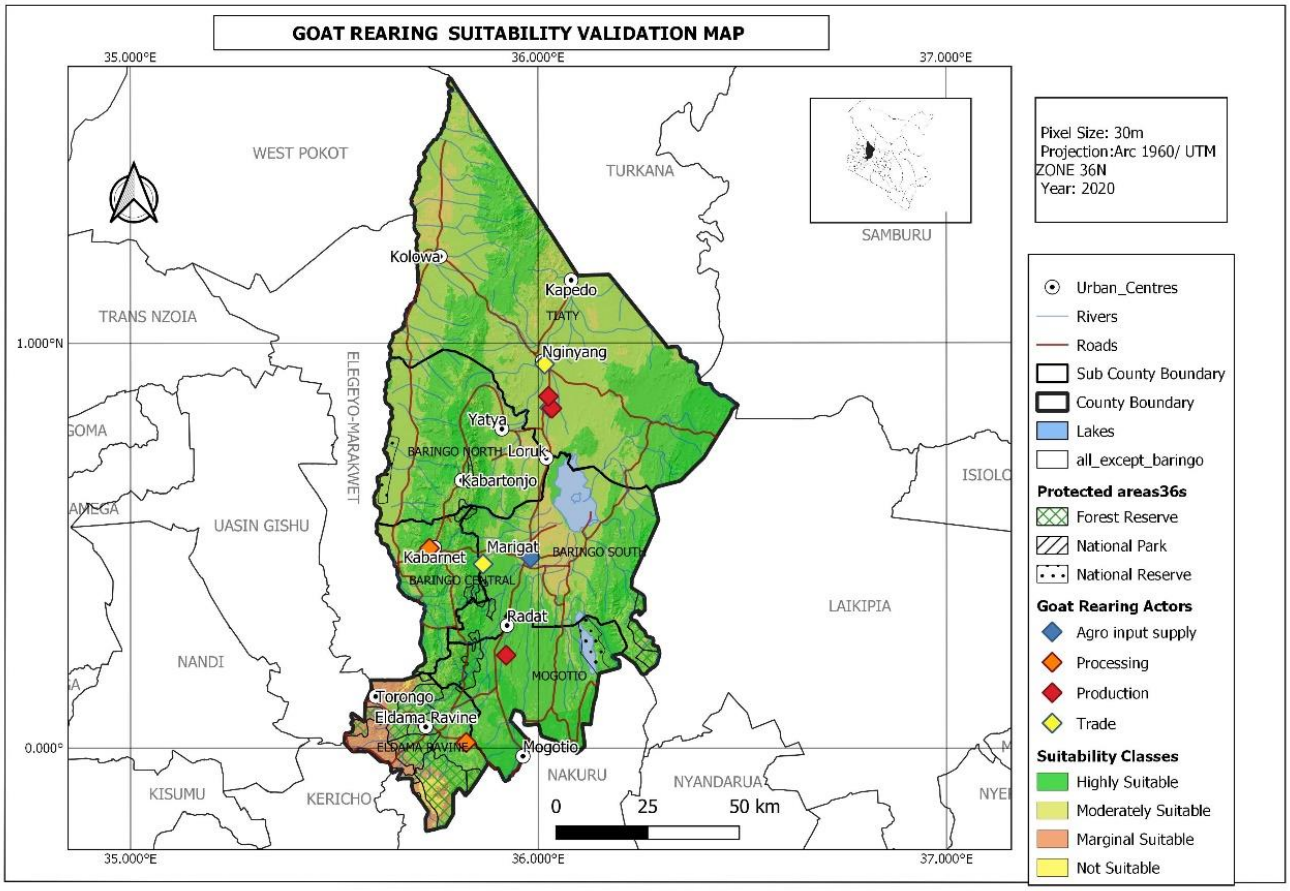

Figure 4-17 Goat Suitability Validation Map

4.5 Honey Bees Suitability

Beekeeping is practiced in all the livelihood zones in the county. The industry provides income to value chain actors directly in equipment manufacturing, hive product production, processing and marketing. Indirectly the industry contributes to employment creation in herbal medicine, cosmetics, brewing, and other service providers such as retailers, transporters and suppliers of packaging materials.

Apart from honey being an income generating activity, it also plays an important role in household food and nutrition security. It still plays an important role in cultural ceremonies. The suitability of the county varies from place to place depending on Bio physical, Social, Economic and Political factors. The following are the base conditions for dairy value chain;

4.5.1 Biophysical Parameters

Biophysical parameters include the following;

4.5.1.1 Temperature

The temperatures range for Baringo varies from a minimum of 10°C to a maximum of 35°C in different parts of the county. Areas around Torongo and Mumberes experiencing the lowest temperatures while Kapedo, Kolowa and Marigat areas having the highest temperatures. The county therefore has moderately suitable temperatures across most part of the county.

4.5.1.2 Rainfall

A large part of Baringo County lies along the valley and had moderate amount of rainfall which is highly suitable for bee keeping, however, areas along the Tugen hills and Eldama ravine Sub county have a relatively higher amount of rainfall and hence moderately suitable for bee keeping. In terms of temperature the county is generally moderately suitable for bee keeping

4.5.1.3 Slope

Baringo slope varies from 0- 50 %, bee keeping is highly suitable in areas with a slope less than 10 % and moderately suitable in areas with 10-30% slope. The slope determines the vegetation, the shading of hives, and affects the pollen collection by bees. Therefore, the county is moderately suitable for bee keeping. The biophysical map is as shown in Figure 4-18.

4.5.2 Aspect

Aspect is the direction of the slope, it determines the vegetation and hence affecting bee forages. The county aspect varies from moderately suitable to highly suitable hence the county is ranked as moderately suitable in terms of slope

4.5.3 Distance to Water

Distance to water determines the time and energy the bees spend in collecting water and nectar. Baringo is an ASAL county with varying distance to water sources; this makes the suitability in the county to vary from highly suitable to not suitable. Hence an average ranking of 'moderately suitable' in terms of Distance to water.

4.5.4 Land use/Landscape

Bee keeping is highly suitable in areas that have natural plants and forest, moderately suitable in areas with Sparse & dense bushland, and not suitable in Urban, Open Waters, Agricultural

land, Livestock areas. The land cover of Baringo varies from sparse bush land to forest and to urban and residential areas hence moderately suitable for bee keeping.

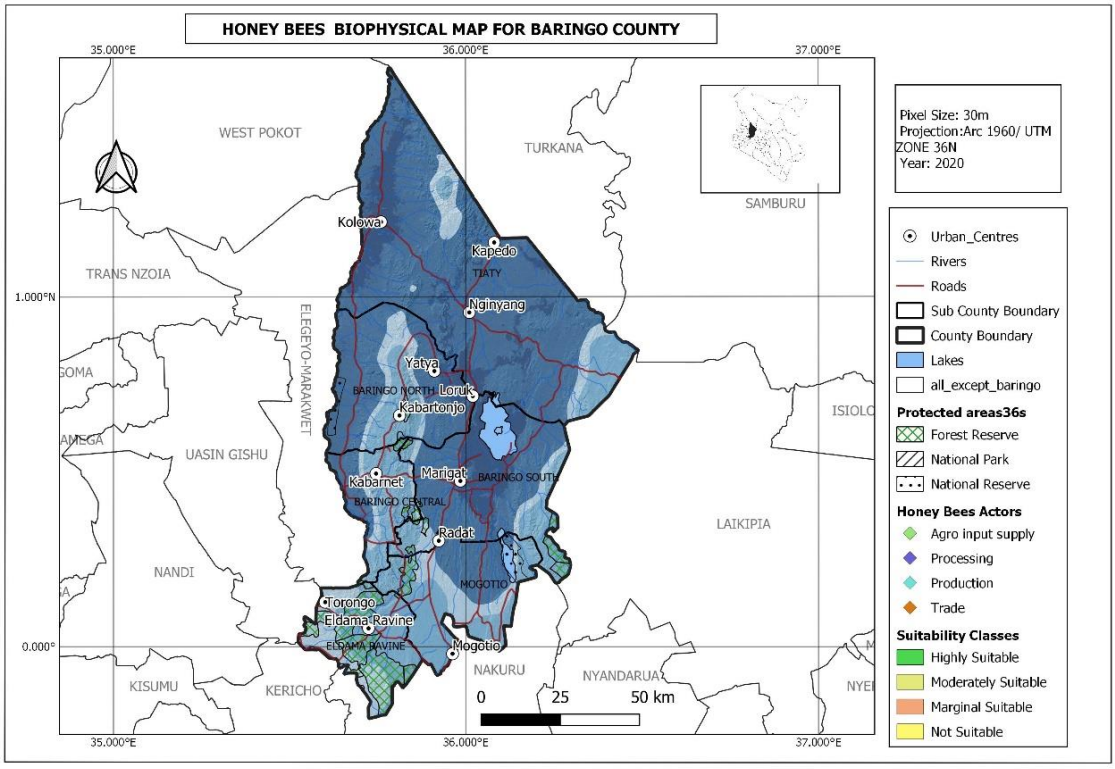

Figure 4-18 Honey Biophysical Map

4.5.5 Socio-Economic Parameter

Beekeeping has been traditionally practiced in the county over a long time. Many bee keepers used logs, rock and tree crevices as beehives while others were honey hunters. Honey and other hive products among Baringo communities have an important cultural significance especially during traditional ceremonies such as marriages where honey is used for dowry payment. Honey was also used as food, medicine, preservative and sweetener. There is however change in adoption and practice of bee keeping due to change in land use to crop, livestock, charcoal burning and residential areas. It is for this reasons that the county is ranked as moderately suitable in terms of social parameter

Most of the land in the lowlands is communally owned hence the bee keepers have access to large track of land for bee keeping. The roads system is fairly done and accessibility to be keeping areas is moderate. Other areas are far from the road hence suitable for bee keeping.

There is therefore ready market for Baringo honey hence the county is ranked as highly suitable in terms market parameter.

4.5.6 Political

Bee keeping has received substantial attention from the county government, this include purchase of hives, training of farmers as well as investment in honey processing. there is however little effort in combating charcoal burning and change of change of land use to crops and that have detrimental effects to be keeping due to use of pesticides, this therefore makes the county to be ranked as moderately suitable.

4.5.7 Overall Honeybees Suitability Map

The analysis done for this particular value chain resulted in the suitability map shown in Figure 4-19.

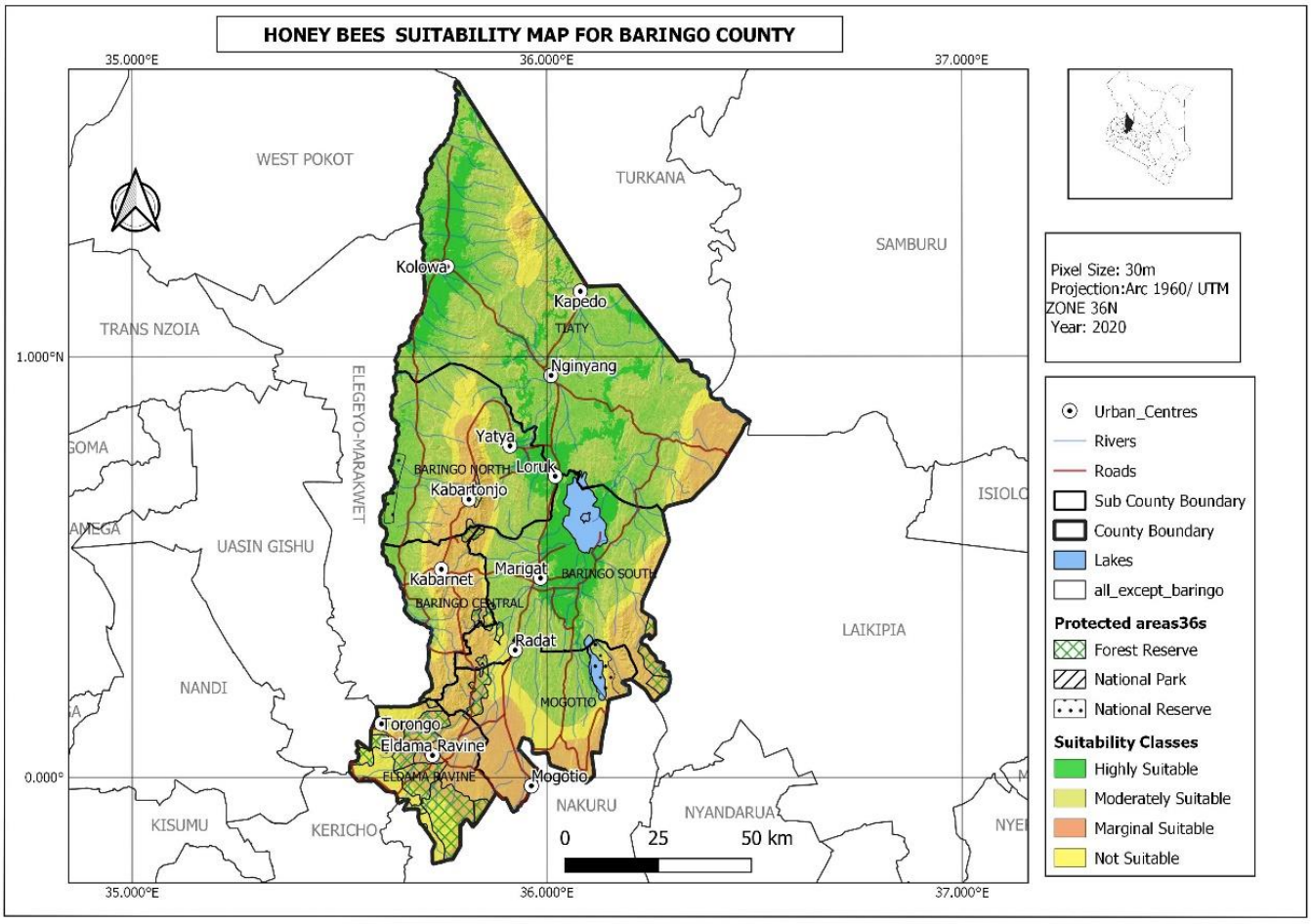

Figure 4-19 Honey Bees Suitability Map

The surface area and the estimated areas of the different suitability levels is as given in the Table 4-3 and its visualization in the graph in Figure 4-20.

Table 4-3 Honeybees suitability Surface Area

HONEYBEES		
Suitability Level	**(Approx.) Area in km^2**	**Surface area in %**
Highly Suitable	1366	13
Moderately Suitable	5667	52
Marginally Suitable	2618	24
Not Suitable	1257.7	11
TOTAL AREA	**10908.7**	**100**

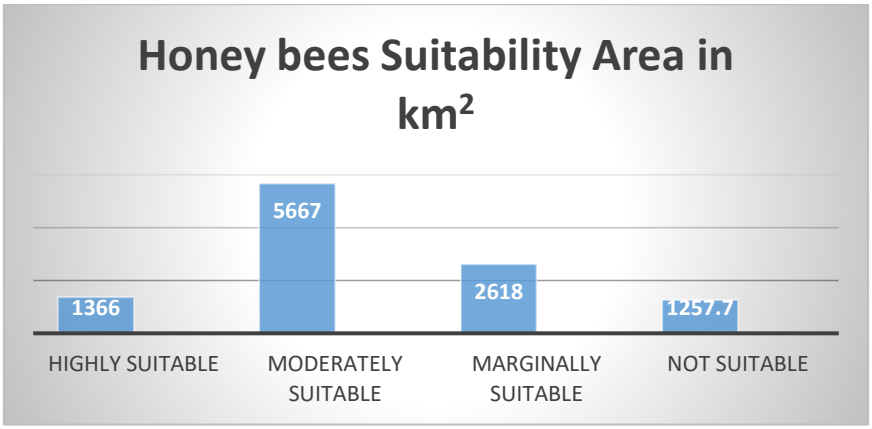

Figure 4-20 Honeybee suitability Area Graph

The combination of all variables at different weights resulted in the general suitability map for keeping honey bees. Three regions only were considered as most suitable regions with total area of 9651 km^2 which represents about 88% of Baringo County while two regions and multi sites were considered as suitable and the rest of Baringo County in general was considered as unsuitable for keeping honey bees. The most suitable regions (Kapedo, Kolowa and Marigat) of the general suitability map exactly fit with the suitable regions in the previous two maps. The more suitable regions are recommended for keeping honey bee colonies during dry season while the suitable regions need some precautions for keeping honey bees.

4.5.8 Validation and Accuracy Assessment

Truthing was done subject to data from site visits as well as Agricultural Sector Development Support Programme (ASDSP) data on value chain actors. There's a clear indication of location of honey producers and traders in a significant portion of the highly suitable to moderately suitable regions of Nginyang, Marigat, Lower Kerio Valley and Radat. This is illustrated in the honey bees suitability validation map in figure 4-14.

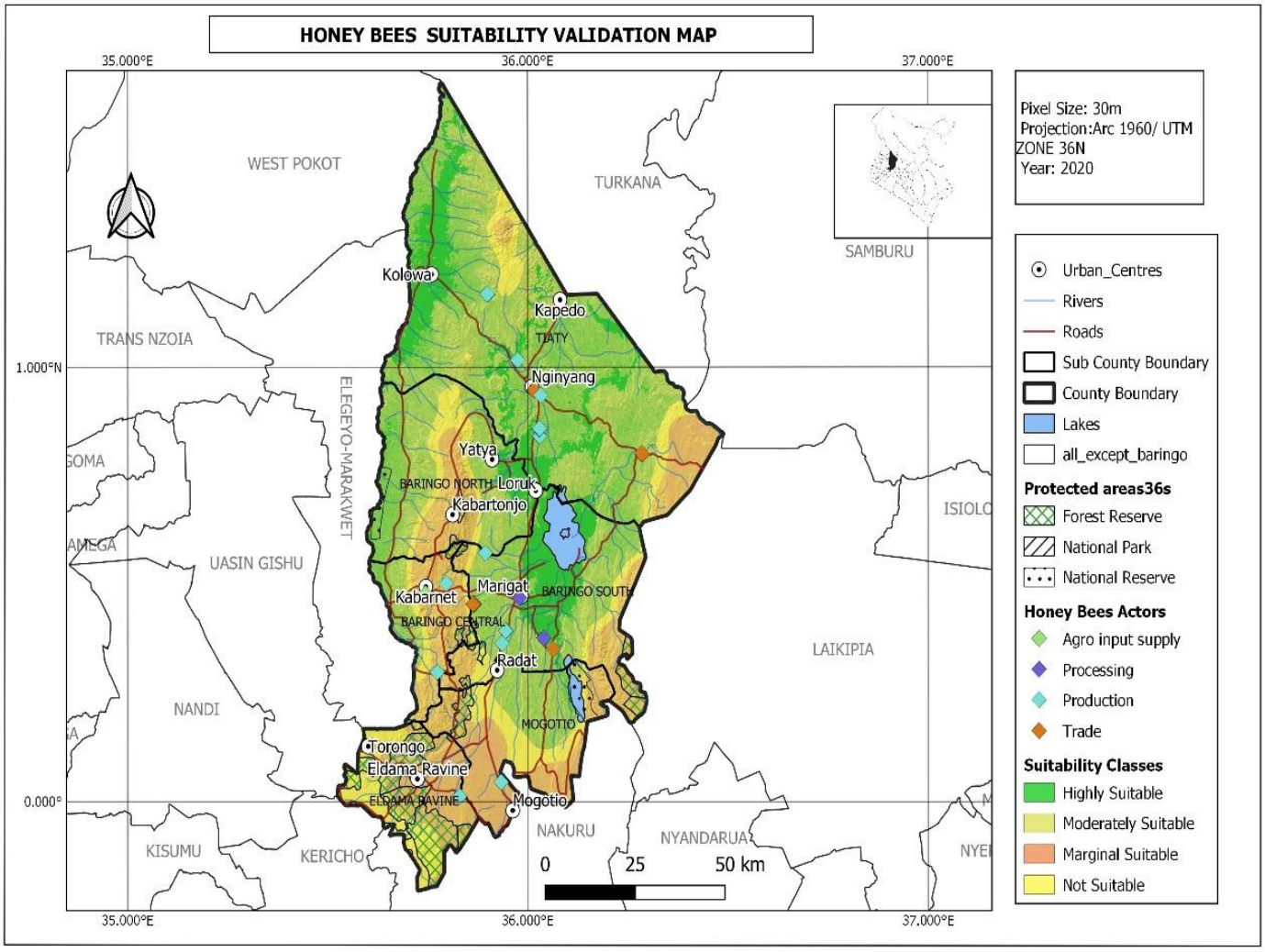

Figure 4-21 Honey bees Suitability Validation Map

4.6 Spatial Variation and Relationship Between the Three Value Chains

A close look on the suitability maps of the three value chains gives some insights on the relationships among them. Most areas which are highly suitable for honeybees are also

accurately suitable for goat rearing whereas areas which are highly suitable for dairy cattle suitability is largely not suitable for honeybees but only slightly suitable for goat rearing. This therefore made difficult the creation of one overall map showing areas suitable for each of the three value chains. The study area is generally moderately to all the value chains as show in Figure 4-22 which is shows an overlay of the three suitability maps.

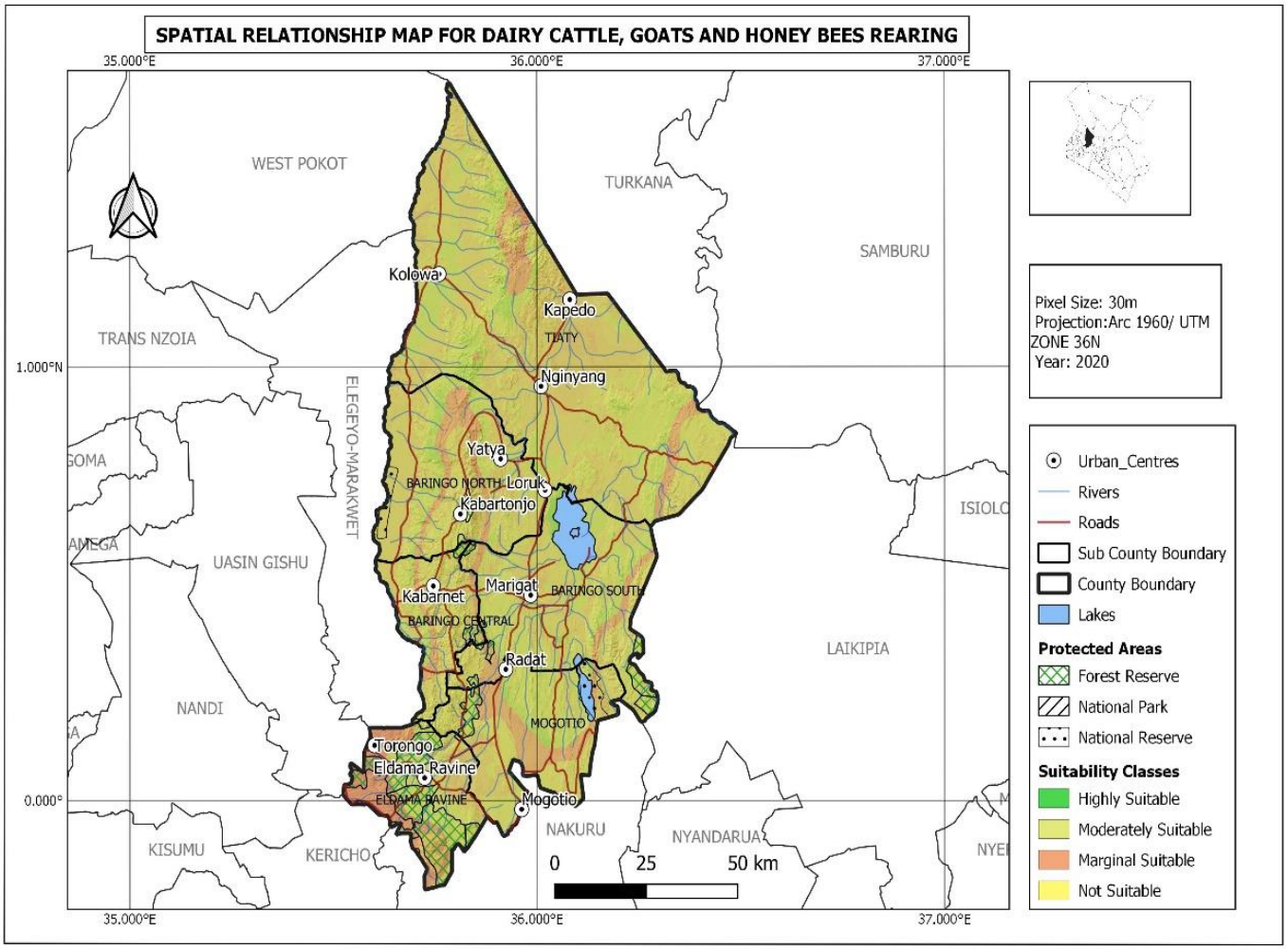

Figure 4-22 Spatial Relationship Map

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter gives the conclusion and recommendation derived from the analysis, results and discussions in the previous chapters.

5.2 Conclusions

The overall objective of the project was to use geospatial technology to determine suitable areas for rearing dairy cattle, goats and honey bees in Baringo county. The following outcomes were achieved, factors contributing to the suitability of each value chain were evaluated and determined, spatial models for each were developed, suitability maps were also prepared for each value chain.

From the suitability maps the following conclusion can be made; 95% Baringo County is moderately suitable to highly suitable for goat rearing, 65% suitable for honeybees and 41% suitable for dairy cattle rearing. The area is moderately suitable for dairy farming with two significant areas; The highly suitable areas around Eldama Ravine and along the Tugen hills (suitable rainfall, temperatures, and slope) and the moderately and conditionally suitable areas along the lowland of Baringo South, Baringo north, Mogotio and Baringo Central (Moderately to marginally suitable temperatures, rainfall with incidents tsetse fly).

The County is also moderately to highly suitable for bee keeping and goat meat value chains, this is because the goat meat and honey value chains does better in temperatures higher that for dairy cows. Bee keeping and goat meat are therefore suitable for the lowlands side of the Tugen hills around Baringo south, Baringo North, Baringo central and some parts of Mogotio. To maximize bee keeping there is need to adopt modern hives at economic numbers, control pest and diseases, provide water and feeds during period of derth and to carry out hives res-stocking using catcher boxes, queen rearing and colony subdivision among other mechanism.

To commercialize meat goat farming there is need to promote good breeds such as Gala goats which are fast maturing and adaptable to the high temperature, establish and conserve pasture through pasture re-seeding, fencing for natural regeneration and establishing drought tolerant

pasture and fodder varieties such as *Cenchrus cilliaries* and *Prosopis Juliflora.* There is also need to control pest and diseases and harvest water for goat s and pasture establishment.

The county has moderately suitable political social and economic environment, there is however, a need to combat cattle rustling in the lower regions, open up new roads, renovate existing roads and to develop entrepreneurship cultures among the value chain actors. The county must also increase allocation of funds for the development of the value chains and enact and implement laws that govern land use in order to minimize land degradation and pollution from charcoal burning. There is also need to revitalize extension services in order to develop the social suitability aspect for the value chains.

Geospatial technologies which is a very crucial tool of this age in all areas of economy should be therefore be employed in land suitability analyses as evident from the above study.

5.3 Recommendations

The same technique and models can be applied in other places to ensure proper and optimal production food to minimize food insecurity in the country. This can be done by modifying on the few factors in the model according to that particular area.

The following adaptations can be adopted in order to increase the area suitable for dairy cattle: In areas where temperatures are high, suitable pasture establishment to be considered maximize on the weather condition. Fodder crops such as lucern, desmodium, calliandra and sebania can be taken in consideration in this aspect.

In order to maximize production on the highly suitable areas, there is need for livestock upgrading using AI, embryo transplant and purchase of pedigrees, investment in pasture and fodder establishment and conservation and management of pest and diseases among other. For the moderately suitable areas; there is need to provide the shade for dairy animals to lower the temperatures, carry out water and soil conservation, control of tsetse-fly as well as promotion of adaptable breeds such as Sahiwal and cross breeds.

In moderately and marginally Suitable temperature zones the following can be done; Appropriate housing facilities and equipment to protect dairy cows from extreme temperatures,

through Zero grazing and agro forestry and establishment of drought tolerant pastures (Cencrus Cilliaries). Making more range land available for goat rearing is highly recommended in order to uplift the living status of persons living the region.

For Honeybees: The unsuitable regions are not recommended for keeping honey bees during dry season. Also, supplying honey bee colonies with artificial feeding as well as water source is very essential during dry season. More research should be done on the spatial relationships of rearing dairy cattle, goat and honey bees taking into consideration the communities who practice these forms of agriculture. There is also need of research in the political aspect modelling as it is a crucial factor in land suitability.

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APPENDICES

APPENDIX A Suitability Adaptations

Parameter	Suitability	Adaptation
Temperature (c)	Moderately suitable	-Agro forestry / planting of trees, -Pasture establishment, conservation and utilization. -Establishment of drought tolerant pastures (*Cencrus Cilliaries*) -Solar driven fan or air conditioners, Housing of cows - Zero grazing)
Rainfall (mm)	Moderately Suitable	-Water harvesting (Water pans, roof water Harvesting,) -Keeping adaptable breeds (Sahiwal, sahiwal-Freshian crosses), -Construction of soil and water conservation structures , facilitate access to adequate water for dairy farming especially to deal with dry periods
Tsetse fly risk	Moderately Suitable	-Tsetse control (spraying with insecticide, trapping using Pheromone , targets) , -Use of sterile insect's techniques. -Surveillance of the insects, use of chemotherapy to treat infected animals , Adaptable breeds (sahiwal, cross)
Biophysical	**Moderately suitable**	
Social	**Moderately suitable**	-conflict resolution and peace building initiativs

Population	Moderately Suitable	-Increase awareness of the nutritional and health benefits of milk consumption, -Facilitation of the organization of interest groups along the value chain to improve performance in the sector, -Encourage production of a diversified range of milk and milk products that meets the wide array of consumer tastes and preferences
Roads	Moderately Suitable	Construction of feeder roads, tarmacking of major roads
Market	Marginally Suitable	-Investment in Milk value addition and distribution to meet the demand in milk deficit parts of the county (Tiaty, Baringo North and Baringo South), Bulking and aggregation, - Promote investment in cold chain infrastructure by marketing cooperatives, and private investors through providing the necessary incentives, -Explore viability of alternative sources of energy, such as solar, wind, mini hydro plants and organic fuels.
Economic	**Moderately suitable**	
Political	**Higly suitable**	Review the dairy sector policy from time to time to take care of emerging land policy issues,Creation and maintenance of a conducive environment (policy) for private sector investment.
Combined	Moderately suitable	

APPENDIX B: Actual Value chain locations (Validation data)

Value Chain	Sub County	Name of VCO	Value Chain Function	Longitude	Latitude
Dairy Cattle	Eldama ravine	Torongo FCS	Producer, Processor	35.59779	0.125209
Dairy Cattle	Eldama ravine	Arama FCS	Producer	35.6628	0.04537
Dairy Cattle	Eldama ravine	Langas FCS	Producer	35.42232	0.3941
Dairy Cattle	Eldama ravine	Kabimoi FCS	Producer	35.47052	0.1475
Dairy Cattle	Eldama ravine	Sabatia FCS	Producer, Processor	35.45346	0.2347
Dairy Cattle	Eldama ravine	Mumberes FCS	Producer, Processor	35.56831	0.0036
Dairy Cattle	Eldama ravine	Kiplombe FCS	Producer	35.49473	0.1025
Dairy Cattle	Baringo South	Perkerra FCS	Producer	35.9882	0.471933
Dairy Cattle	Baringo south	Tuiyobei Baitany	Producer	36.30574	0.151351
Dairy Cattle	Baringo Central	Kasoiyo FCS	Producer	35.75962	0.480367
Dairy Cattle	Baringo Central	TugenHills FCS	Producer	35.74	0.493
Dairy Cattle	Baringo Central	Tenges FCS	Producer	35.80175	0.312495
Dairy Cattle	Mogotio	Kiptoim FCS	Producer		
Dairy Cattle	Mogotio	Mogotio FCS	Producer, Processor	35.96383	-0.02264
Dairy Cattle	Mogotio	Emining FCS	Producer	35.8881	0.1432
Dairy Cattle	Mogotio	Sirwa FCS	Producer	35.76922	0.1752
Dairy Cattle	Mogotio	Kisanana FCS	Producer	36.097073	0.018378
Dairy Cattle	Baringo North	Baringo mosop FCS	Producer	35.79423	0.630233
Dairy Cattle	Eldama ravine	BAMSCOS	Trader	43.728	0.3015
Honeybees	Tiaty	Amaya PlesianSHG	Producer	36.45105	0.864364
Honeybees	Tiaty	Barpello SHG	Producer, Processor	35.89723	1.167567
Honeybees	Tiaty	Tukumoi SHG	Producer	35.72678	1.02305
Honeybees	Tiaty	Chemeril Beekeepers	Producer	36.0268	0.8417
Honeybees	Tiaty	Chesirimion SHG	Producer	36.0268	0.841753
Honeybees	Tiaty	Maron SHG	Producer	35.89723	1.124412
Honeybees	Tiaty	East fields SHG	Producer	36.28571	0.799033
Honeybees	Tiaty	Tapkian	Producer, Trader	36.28571	0.799033
Honeybees	Tiaty	Nginyang Cooperative society	Trader	36.02024	0.935717
Honeybees	Baringo Central	Kimnatetab Bik SHG	Producer	35.71957	0.371785
Honeybees	Baringo Central	Sokobarbei SHG	Producer	35.80375	0.324666
Honeybees	Baringo Central	Kipsegem SHG	Producer	35.78372	0.398149
Honeybees	baringo South	Koriema Honey Packers	Trader	35.86384	0.455334

Honeybees	Baringo South	Koriema Honey Producer Group(2006)	Processor, Trader	35.86262	0.455367
Honeybees	baringo South	Embossos Bee Keepers	Producer	36.16276	0.483221
Honeybees	Baringo South	Kapkuikui Self Help Group	Producer	36.03806	0.376225
Honeybees	Baringo South	Maoi Traders SHG	Trader	35.94316	0.393019
Honeybees	baringo South	Twins S.H. Group	Trader	35.97994	0.471971
Honeybees	Baringo South	Mogoswok Bee keepers Coop. Society	Producer	35.85765	0.500729
Honeybees	baringo South	Noseiya (Salabani) SHG	Producer	36.04807	0.549644
Honeybees	Koibatek	Koibatek Beekeepers	Producer	35.71973	0.047328
Honeybees	Koibatek	Lembus Catchment Integrated Project	Producer	35.72564	0.051841
Honeybees	Mogotio	Cheberen Rural Initiative Development	Producer	35.83336	0.231244
Honeybees	Mogotio	Gabri Jua Kali Asssociation	Producer	35.963892	0.029486
Honeybees	Mogotio	Rachemo Cooperative Society	Procesor, Trader	35.92428	0.299164
Honeybees	Baringo North	Kokomet SHG	Producer	35.649	0.608633
Honeybees	Baringo North	Barwessa Honey Self Help Group	Producer	35.70026	0.702483
Honeybees	Baringo North	Testai Beekeepers	Producer	35.64888	0.609254
Meat Goat	Mogotio	Pombo SHG	Producer	36.10224	0.067426
Meat Goat	Mogotio	Equator SHG	Processor	35.96409	0.011458
Meat Goat	Mogotio	Olbor SHG	Producer	36.097073	0.018378
Meat Goat	Mogotio	Koidep SHG	Producer	35.9241	0.2985
Meat Goat	Mogotio	Chemereng WG	Producer	35.88271	0.14147
Meat Goat	Baringo Central	Kaptara Livestock traders	Trader	35.647024	0.548393
Meat Goat	Baringo Central	Katunoi Farmers	Producer	35.69709	0.378698
Meat Goat	Baringo Central	Amka women group	Producer	35.72053	0.254057
Meat Goat	Baringo Central	Kabarnet Butchers group	Processor, Trader	35.74091	0.492418
Meat Goat	Baringo Central	Kipkabei W.G	Producer	35.83838	0.272718
Meat Goat	Tiaty	Korosi farmers group	Producer	36.1875	0.750208
Meat Goat	Tiaty	Chesirimion WG	Producer	36.0268	0.841753

Meat Goat	Tiaty	Mondi traders Cooperative society	Trader	36.01571	0.937985
Meat Goat	Tiaty	Acheingoror youth group	Producer	36.35712	0.681276
Meat Goat	Tiaty	Kibego youth group	Trader	35.75475	1.216189
Meat Goat	Koibatek	Saos slaughter	Processor, Trader	35.81333	0.104445
Meat Goat	Koibatek	Esageri slaughter house	Processor, Trader	35.80791	0.016667
Meat Goat	Baringo North	Kinyach Traders	Trader	35.69	0.93
Meat Goat	Baringo North	Moinonin SHG	Producer	35.83058	0.730779
Meat Goat	Baringo North	Kipsaraman SHG	Processor, Trader	35.83058	0.730779
Meat Goat	Baringo North	Chergaa SHG	Producer	35.69949	0.702635
Meat Goat	Baringo South	Loboi traders	Producer	36.06323	0.351167
Meat Goat	Baringo South	Kabuswo W.G	Producer	35.88569	0.338015
Meat Goat	Baringo South	Marigat Butchers	Processor, Trader	35.97994	0.471971
Meat Goat	Baringo South	Marigat farmers cooperative society	Producer	35.98375	0.479727
Meat Goat	Baringo South	Koriema traders	Processor, Trader	35.86385	0.454383
Meat Goat	Baringo South	Manyatta youth group	Producer	35.90574	0.363971