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GIS APPLICATIONS IN SUITABILITY MODELING FOR
LIVESTOCK PRODUCTION IN TANA SUB BASIN-BLUE
NILE RIVER BASIN, ETHIOPIA

By

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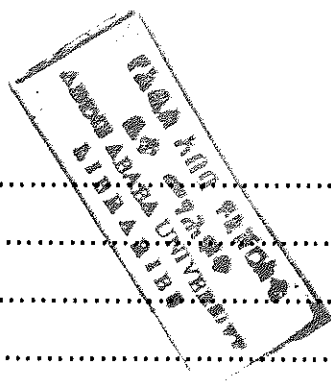
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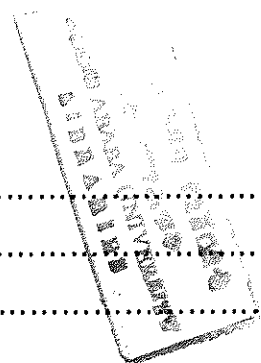
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Abbreviations

AAU	Addis Ababa University
AVHRR	Advanced Very High Resolution Radiometer
BNRB	Blue Nile River Basin
CGIAR	Consultative Group for International Agricultural Research
CSA	Central Statistical Authority
DBMS	Data Base Management System
DEM	Digital Elevation Model
DN	Digital Number
EMR	Electro Magnetic Radiation
ESRI	Environmental Systems Research Institute
FAO	Food and Agricultural Organization
GB	Giga Bite
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GPS	Global Positioning System
ILRI	International Livestock Research Institute
IR	Infra Red
IWMI	International Water Management Institute
LULC	Land Use Land Cover
LWP	Livestock Water Productivity
MCDM	Multicriteria Decision Making
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
RS	Remote Sensing
SRTM	Shuttle Radar Topographic Mapping
TDSS	Tool for Decision Support System
UTM	Universal Transverse Mercator
VI	Vegetation Index

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Abstract

Proper use of the land depends on the suitability of land for specific purposes. It is indeed of paramount importance to identify suitable land for livestock production while causing minimum impact to the environment. In this study, an attempt was made to identify suitable areas for livestock production using GIS methodology.

Spatial modeling techniques are utilized to generate the land suitability model. The model is run in ArcGIS platform by using evaluation criteria: land use/land cover, soil classification slope and water availability through multicriteria decision marking rules. The model results revealed that 40.5% of the study area is most suitable for livestock production. In addition, 30% of the sub basin is indeed moderately suitable for animal production. Further, 8% of the study area is identified to be least suitable. On the other hand, areas that are found to be currently not suitable and permanently not suitable are 0.2% and 0.1% respectively.

Tana sub basin is optimally located on suitable land for livestock production. That is, most of the basin is covered by optimal land use land cover, gentle slope, fertile soil type, and optimal water availability. However, the current livestock distribution exists on unsuitable areas.

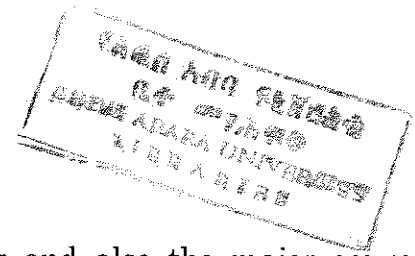
The results of the NDVI indices indicate that the basin has available feed source for animal production especially in the rainy season whereas in the dry season crop residue could serve as a feed source for the livestock.

Furthermore, water availability is the most important factor that determines livestock production. Under this study, water availability is analyzed using buffering tools in a GIS. The results depict that most of the study areas are accessible or proximal to water resources (lakes, water points, and rivers) for livestock drinking. That is, most of the water resources are accessible for livestock production within the study area. This output indeed could be used as a method for assessing livestock water productivity in the basin.

Keywords: GIS, Suitability Model, Water Availability, Feed, Livestock, Tana Sub Basin, Blue Nile

CHAPTER I

INTRODUCTION



1.1 BACKGROUND OF THE STUDY

Agriculture is the mainstay of Ethiopia's economy and also the major source of employment and income. About 85% of the total population is primarily engaged in agriculture and related activities. Thus, agriculture directly or indirectly, forms an important component of the livelihood of more than 60 million people in Ethiopia. Livestock production contributes the highest share to the Ethiopia's agricultural GDP, mainly through meat, milk, eggs, wool, hides, and skins. Livestock play a vital role, adding to stability of farm incomes, food security and farming systems. Besides, livestock are kept as a form of insurance and a means of storing savings (Winrock, 1992). However, the emphasis given to livestock production in Ethiopia is still inadequate. The subject of livestock is also overlooked in the land use policy of the country. Since the land resource is limited, proper usage of land could alleviate poverty in the country (Atesmachew Bizuwerk, 2005).

The Nile River Basin is one of the nine river basins world-wide where a total area of 3.3 million km² encompassing 10 riparian countries with human population of over 300 million and 200 million livestock population. In the basin the challenge is to meet pressing demand for food for the drastically increasing human population.

Ethiopia is one of the 10 riparian Nile Basin countries where the problem of food insecurity is addressed in particular at the Blue Nile River basin with a total area of 199, 812 square kilometers. In this region, meeting the demand for food will require efficient utilization of feed, water resources proper land use policy.

In this region there exists a pressing need for more water. That means, the water resource has to be used more efficiently or productively. As demand of food for

people is rapidly increasing due to increasing population in the Nile Basin states, it is essential that land and water resources of the Nile Basin be efficiently managed to increase livestock water productivity.

Livestock water productivity is defined as the amount of water depleted (withdrawn) to produce livestock, livestock products, and services including energy (Kijne, 2005). One of the best ways to free up water for other uses is to improve the productivity of water in agriculture. With more crops from each drop, there is a need for fewer drops. In agriculture there is considerable scope remaining to increase the productivity of water (Molden, 2003). To improve livestock water productivity optimal allocations of land use and corresponding relocation of water resources are vital steps to be taken (Kijne, 2005).

In general, suitable land use, feeds and water resources are key elements for livestock production. Optimal land utilization, availability of feed and water resource are the most important constraints to livestock production systems in sub-Saharan Africa. Production of livestock feeds requires as much water as human food crops in the Nile River Basin and feed production requirements to maintain livestock population in the basin have been estimated at 26 billion m³/year of water (Peden, 2003).

Although livestock production is a vital component of the agricultural systems, it has so far been overlooked in integrated land and water management for food security in poverty alleviation strategies. Knowledge of the impact of livestock keeping on land and water resources has not been adequately synthesized and applied to integrated river basin management, but degradation of water by livestock may exceed the total amount used (Peden, 2005). There is need for research and capacity building to understand the complex issues of water, livestock and land management, so as to enhance national and local capacity to

deal with water and livestock issues to enhance food security, reduce poverty and speed up national economic development (Ayalneh, 2004). Hence, this research study is expected develop and scrutinize a methodology using spatial modelling for land suitability, water resource availability and feed source to improve livestock productivity in a Geographic Information Systems (GIS) environment at the Tana Sub Basin, Blue Nile River Basin.

To improve livestock productivity optimal allocations of land use and corresponding relocation of water resources are vital steps to be taken (Kijne, 2005). This requires studying the spatial relations of livestock with optimal land and water resources of the basin. Therefore, locating suitable areas of livestock production using spatial models of Geographic Information systems (GIS) would be indispensable input to improve livestock productivity.

As a result, the baseline suitability model for livestock production, in this study, would be central at the basin scale to investigate and monitor the spatial interaction of livestock production with prominent factors: land use land cover, water availability, soil type, and slope. Moreover, the spatial modelling outputs for water availability and feed source analysis would be vital for assessing livestock water productivity. By and large, this study is expected to contribute for better management of livestock that in turn lead to improved resources utilization for integrated agricultural systems for food security in the basin.

The following is a description of the general background to give a sort of insight to where the research undertaking is implemented. It will give a general physiographic of Ethiopia including the physiographic features, topography, climate and water resources of the country.

1.2 GENERAL PHYSIOGRAPHY OF ETHIOPIA

1.2.1 PHYSIOGRAPHIC FEATURES

Ethiopia lies in tropics, in the horn of Africa. The country is unique physically because of the high proportion of its landmass over 2, 000 meters of altitude, where the climate is more temperate than tropical. The heart of the country is formed by a vast mountain mass between 2,100 and 2,500m altitudes with some peaks rising to 4,500m. The massif is divided into two deeply carved out plateaus by the rift valley.

Perhaps the best known physiographic feature of Ethiopia is the Blue Nile, which rises in the mountains surrounding lake Tana (considered the source of Blue Nile) and flows southeast into a picturesque canyon of immense proportions, and from there westwards through an ever-widening canyon, whereupon it flows out into the Sudan plains to meet the white Nile on its way to Egypt.

The prominent feature of Ethiopia topography is its rugged landscapes, mountain chains, flat-topped plateau, deep canyons, river valleys, and rolling plains. The heart of the country is a high tableland, known as the Ethiopian Plateau, which covers more than half the total area of the country. The plateau is split diagonally in a northeastern to southwestern direction by the Great Rift Valley. The country has great geographical, topographical and climatologically diversities.

1.2.2 LOCATION

Ethiopia is part of East Africa region commonly referred to as the "Horn of Africa". Situated between 3°30' and 14°50' North latitudes and 32°42' and 48°12' East longitudes, it has a surface area of about 1.13 million square kilometers, of which 1,119,683 square kilometers land and 7,444 square kilometers water area. The country is bordered by Somalia and Djibouti to the east, the Sudan on the west, Eritrea to the north, and Kenya to the south; Ethiopia is a landlocked country.

1.2.3 CLIMATE

Despite Ethiopia's proximity to the equator, the central and the western highlands enjoy a temperate climate due to the moderating influence of high altitudes, with a mean annual temperature rarely exceeding 20°C. Rainfall generally occurs in a five-month unimodal rainy season from May to September in western parts of the country and averages around 1000mm annually. The eastern and southern parts, on the other hand, have bimodal rainfall averaging annually from less than 200mm in the semi-desert to 1000mm in the high lands. Rainfall can some times be erratic, especially in the eastern Ethiopia and drought is a common feature (Abebe Sine, 2004).

1.2.4 WATER RESOURCES DISTRIBUTION AND DRAINAGE BASIN

Ethiopia is endowed with one of the largest surface fresh water resources in Sub-Saharan Africa. The distribution and quantity of water has strong relationship with the topography and rainfall distribution. Based on topography, Ethiopia is subdivided in to twelve major drainage basins and their respective surface water resources.

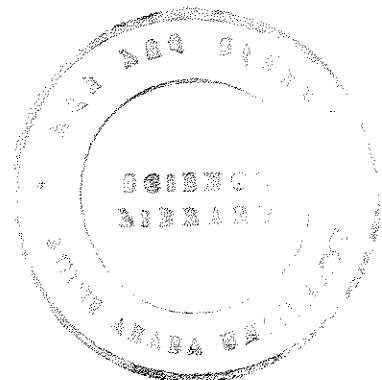
✦ The Specific Objectives are:

- To develop a Land Suitability Model for livestock production as a tool for decision making in the Tana Sub Basin.
- To develop feed availability map using satellite remote sensing techniques
- To assess the spatial distribution of water resources: water points, rivers, and lakes in the sub basin.
- To construct water accessibility maps for livestock drinking.

1.4 RESEARCH QUESTIONS

The study will address the following research questions.

1. What are the most and least suitable areas of the Tana Sub Basin for livestock production?
2. Is there seasonal variation in feed availability in the sub basin?
3. Which areas are spatially closer to the nearest possible water resources required for livestock drinking?
4. How is the spatial distribution of livestock in the sub basin?



CHAPTER II

DESCRIPTION OF THE STUDY AREA

2.1 LOCATION

The study area, Tana Sub Basin is located South in the Amhara Regional State in the Blue Nile River Basin, which encompasses a total area of 15,054 square kilometer. It is located N 1211093, N1410400 and E 253327, E 416676 at UTM coordinate systems.

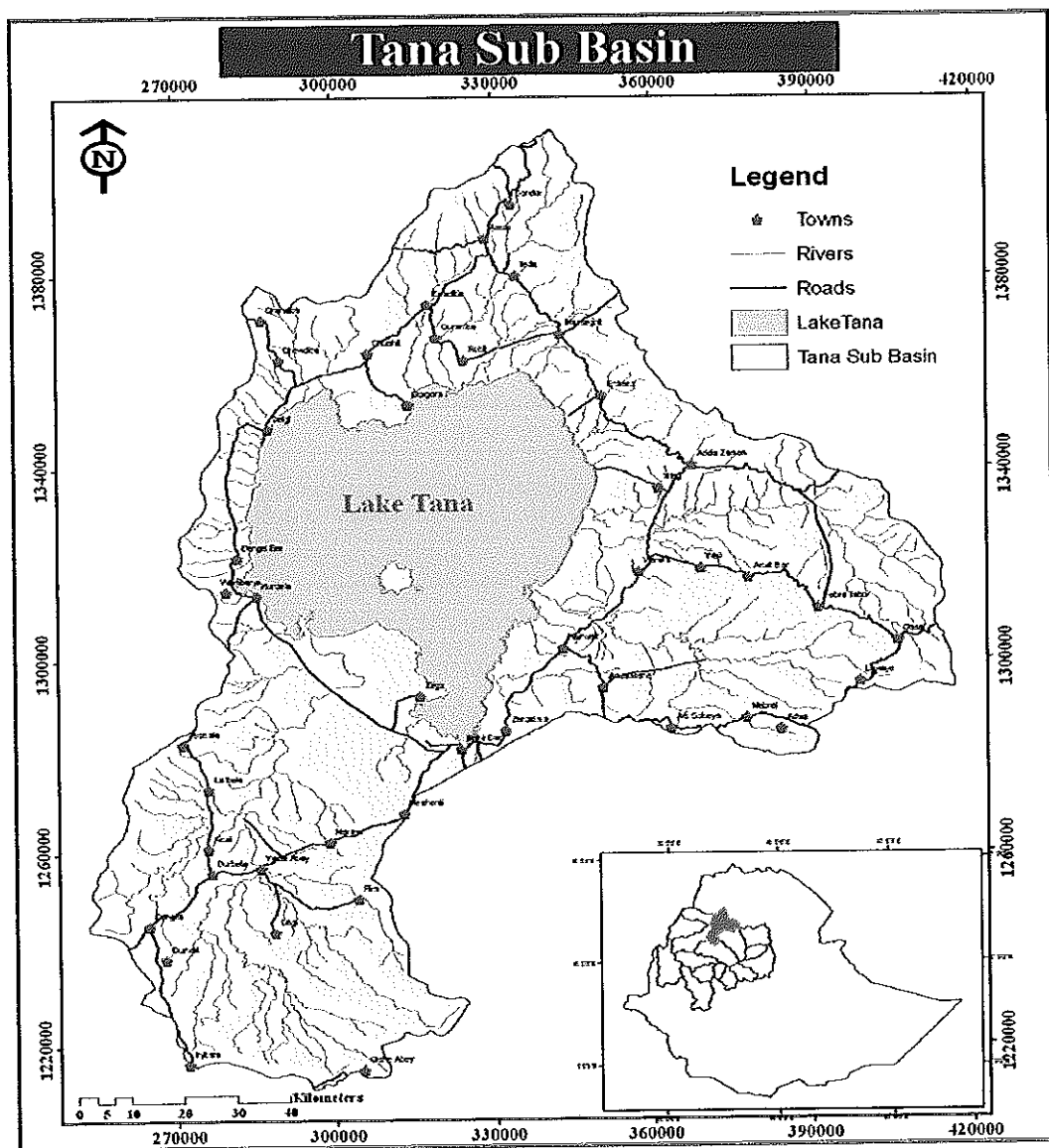


Figure 1 Location Map of the Study Area

The Blue Nile River Basin encompasses a total area of 199,812 square kilometers. It has got a total annual discharge of 52.60 billion m³/year. The river basin comprises of potential irrigation area of 1,700,000 ha. It includes the three administrative regions: Amhara, Oromiya, and Benshangul Gumuz states of Ethiopia.

The Blue Nile River Basin is found in the Northern West part of Ethiopia, between 7° 45' and 12° 45'N latitude and 34° 05' and 39° 45'E longitude. This river basin is, by most criteria, the most important river basin in Ethiopia. It covers about 17.58% of Ethiopia's land area; 43.11% of its total average annual runoff of the country; and 25% of the country's population (Abebe Sine, 2004).

2.2 CLIMATE

The Blue Nile River Basin encompasses a rich variety of local climates ranging from hot to desert-like climate along the Sudan boarder, to temperate on the high plateau, and cold on the mountain peaks.

Annual rainfall varies between about 800 mm to 2,220 mm with a mean annual rainfall of about 1420 mm. The mean temperature of the basin is 18.5°C, with minimum and maximum average daily temperatures of 11.4°C and 25.5°C respectively (Abebe Sine, 2004).

2.3 WATER RESOURCE

The water resources of the basin are dominated by the Blue Nile which rises in the center of the catchments and develops its course in a clock wise spiral. It collects tributaries all along its 992Km length before reaching the Sudan border. Table 2 summarizes the 16 main drainage sub-basins including Rahad and

Dinder. Tana sub basin is one of the 16 sub basins in the Blue Nile River Basin (see Table 2).

Table 2 Main drainage Sub-basin of BNRB

	Sub Basin Name	Area in Km ²	% of area coverage
1	Anger	7,901	3.95
2	Beles	14,200	7.11
3	Beshilo	14,389	7.20
4	Dabus	21,032	10.53
5	Didessa	19,630	9.82
6	Dinder	14,891	7.45
7	Finchaa	4,089	2.05
8	Guder	7,011	3.51
9	Jemma	15,782	7.90
10	Lake Tana	15,054	7.53
11	Muger	8,188	4.10
12	North Gojam	13,242	6.63
13	Rahad	8,269	4.14
14	South Gojam	16,762	8.39
15	Weleka	6,415	3.21
16	Wonbera	12,957	6.48
	Total	199812	100%

(Source:- BNRB Master Plan, section II, Volume III, Part II)

Various mathematical combinations of the AVHRR Channel 1 and 2 data have been found sensitive indicators of the presence and condition of green vegetation. These mathematical quantities are called vegetation indices. Two examples of such indices have been roughly calculated from AVHRR data- a simple vegetation index (VI) and a normalized difference vegetation index (NDVI). These indices are calculated from the equations.

$$VI = Ch\ 2 - Ch\ 1$$
$$NDVI = \frac{Ch\ 2 - Ch\ 1}{Ch\ 2 + Ch\ 1}$$

Where Ch_1 and Ch_2 represent data from AVHRR channels 1 and 2, preferably expressed in terms of radiance or reflectance.

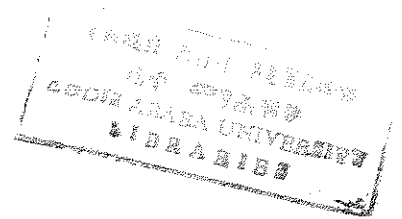
Vegetation areas will generally yield high values for either index because of their relatively high near-IR reflectance and low visible reflectance. In contrast clouds, water, and snow have larger visible reflectance than near-IR reflectance. Thus, these features yield negative index values. Rock and soil areas have similar reflectance in the two bands and result in vegetation indices near zero. In general the normalized difference vegetation index is preferred to the simple index for global vegetation monitoring because the NDVI helps compensate for changing illuminated conditions, surface slope, aspect, and other extraneous factors (Lillesand and Kiefer, 2004).

3.3 GIS IN LAND SUITABILITY MODELING

3.3.1 SUITABILITY MODEL USING WEIGHTED OVERLAY TECHNIQUES

Weighted Overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Geographic problems often require the analysis of many different factors.

Estimating Weights



The next step before running the model using weighted overlay, weight is estimated to the input rasters. Accordingly each model parameters is weighted or assigned a percentage influence, based on its importance to the model objective.

Multicriteria Decision Making (MCDM) problems typically involve criteria of varying importance to decision makers. The derivation of weights is a critical step in eliciting the decision maker's performance preferences. A weight is a critical step in eliciting to an evaluation criterion that indicates its importance relative to other criteria under consideration. The larger the weights, the more important the criterion in the overall utility.

Assigning weights of importance to evaluation criterion accounts for two most important reasons. It is meant for changes in the range of variation for each evaluation criterion, and the different degrees of importance being attached to those ranges of variation. To this end, it is misleading to interpret the weights as general measurements of importance of evaluation criteria. The weight is dependent on the difference between the minimum and maximum value for given criterion. A criterion weight can be made arbitrarily large or small by increasing or decreasing the range. The weights are normalized to sum to 1.

Ranking Method

Ranking methodology is used to estimate the weights for each model parameter. This method assesses the importance of weights to arrange them in rank orders; that is every criterion under consideration is ranked in order of the decision maker's preference. Straight ranking (the most important =1, second important=2) and rank sum is one of the ranking methods. Rank sum weights are calculated according to the following formula:

$$w_j = \frac{n - r_j + 1}{\sum (n - r_k + 1)}$$

Where: w_j is normalized weight for the j th criterion

n is the number of criteria under consideration ($k=1,2,3,\dots,n$)

r_j is the rank position of the criterion

Each criterion is weighted $(n - r_j + 1)$ and then normalized by the sum of all weights, that is $\sum (n - r_k + 1)$.

The ranking methods are very attractive due to their simplicity. However, practical usefulness of these methods is limited by the number of criteria to be ranked. In general, the larger the number of the criteria used, the less appropriate is the method.

It has been demonstrated empirically that in many decision making situations the rank order approximations provide a satisfactory approach to weight assessment. They suggest that the techniques might be used to simplify multicriteria analysis Stillwell et al. (1981) as cited Malczewski, (1999).

3.4 LAND SUITABILITY

Proper use of the land depends on the suitability or capability of land for specific purposes. The suitability of a given piece of land is its natural ability or the biological productivity of the land to support a specific purpose. FAO (1985) analyzes suitability mainly based on the land qualities, such as erosion resistance, water availability, and flood hazard that are not measurable. These land qualities,

however, derive from characteristics that can be quantified. Some of the land characteristics are slope angle, and length, rainfall, and soil texture and others.

The common way of determination of land characteristics is mainly through assessing and grouping the land types in order of suitability ranges from suitable(S), that characterizes a land were suitable use and will give good benefits; to not suitable (N) which indicates a land qualities do not allow the considered type of use, or are not enough for suitable outcomes.

It is a paramount important to identify suitable land for various uses in optimum utilization while causing minimum impact to the environment. Uses of the land to humankind are multifaceted. As a source for primary production system, it serves as a store of water and nutrients required for plants and other living things (organisms). Land resource is one of limited resources. The uses of the land are not only determined by the user, but also by the land capability. The land capability such as the types of soil is crucial for productivity underlying geology, hydrology, etc. These attributes limit the extents of land available for various purposes. To get the maximum benefit one of the lands, proper use is inevitable (FAO, 1985).

Proper use of the land is essential to obtain the maximum benefit out of it. The proper use includes growing of suitable crops and plants, efficient soil and water conservation measures etc. The surface area alone cannot measure land as a resource; hence the type of soil that is crucial for productivity, underlying geology, hydrology, and plants and animal production also have to be considered. These attributes limit the extents of land availability for various purposes. The growing population, industrialization and misuse and overexploitation of land resources have in effect increased the demand for land.

The first stage in evaluating land and preparing a land use data to classify the land according to their use is called land suitability. Land capability, which is also

considered as land suitability (FAO, 1985) is primarily the potential biological productivity of land. Productivity of land can be determined by four main components of the environment namely climate, local topography (roughness, steepness, exposure-which causes local variation in climate and description of soil type and existing vegetation. Land suitability evaluation involves identifying land uses patterns and the economic and environmental feasibility of its use.

Land suitability classification is developed by considering different land characteristics factors. Based on suitability of each land use, a weight value is given from 1 (unsuitable) to 5 (most suitable). The weighted value of each factors were reclassified for each land use. Each parameter is given a value based on its suitability for each land use type. The weighted value of each land characteristics factors is added and the average value of them is taken to determine the suitability of land for each land use type. The average value of them is categorized in to five suitable classes to get the final suitability for each land uses.

Table 3 Suitability Classes

Order	Class	Description
Suitable(S)	S1 (Highly suitable)	S1= land having no, or insignificant limitation to the given type of use.
	S2 (Moderately suitable)	S2= Land having minor limitations to the given types of use
	S3 (Marginally Suitable)	S3= Land having moderate limitations to the given type of use
Not Suitable (N)	N1 (Currently not suitable)	N1= Land having several limitations that preclude the given type of use, but can be improved by specific management
	N2 (Permanently not suitable)	N2=Land that has so severe limitations that are very difficult to be overcome.

Source: FAO (1985)

3.5 WATER AVAILABILITY FOR LIVESTOCK

The availability of permanent drinking water often determines the distribution of various (water dependent and independent) animals in the dry season, including livestock).

The availability of water is a crucial point together with the availability of forage. Therefore, it is essential to know where forage and water is available spatially. The availability of water depends on the existence of artificial water reservoir (boreholes and water tanks, pipelines water supply) and natural water reservoir (permanent rivers, swamps, springs, and wells).

Unless water is provided adequately the output of live animals and of products of animal origin is reduced. It is not always physically possible and more often not economically feasible to provide water to every place where there is a perceived need. In many areas it will always be a scarce resource. Its most effective use in these and indeed in other areas can only be ensured through good organization and management (Wilson, 2002).

Scarcity of water is often a constraint to animal production. The overriding objectives of providing water for livestock should, therefore, not only be to alleviate thirst but also to ensure efficient production and productivity, equity and environmental sustainability.

Natural watering point like permanent rivers and swamps, springs and wells are assumed to be reliable enough to provide water for livestock the whole year round. It is of course possible that some of them become inaccessible for cattle because of fencing or other matters, but that will be considered as an alternative management option and the consequence of such management option can be reckoned. Therefore, natural watering points (like permanent rivers and swamps, springs and wells) will provide water for livestock the whole year round and are considered to be reliable with no limitations for amount or quality of water (FAO, 1985).

Natural sources of surface water include springs, rivers, streams, and lakes. Many surface sources including some swampy or water logged areas are perennial, but many more areas of only a seasonal or even ephemeral nature may last only a few

days. Surface water sources are usually exploited directly by livestock although allowing animals' unimpeded access to water can lead to contamination.

The choice of ground water as a source of watering livestock is governed by the physical factors of its availability; by its location in relation to surface water sources; and by its quality and quantity. Economics also plays an important role in decision- making since ground water requires energy to bring it to surface.

Ground water can be a major contributor to the drinking resources for livestock as well as of people. There are many types of sources including shallow pits dug in river beds during the only season; shallow hand dug wells, deeper handling wells and boreholes. Methods of extraction also vary. Shallow ground water in riverbeds may be exploited directly by livestock.

The choice of spacing and location of water points depends on a number of factors that usually need to be considered in combination. Among these are the production objectives, the level of output expected or required; the availability of surface or ground water, the distance to and quantity and quality of feed sources and the way in which these are fed to the animals. It is also important to remember that it is not always ecologically desirable or economically viable to bring all potential grazing land within reach of permanent water.

Water supply is dominantly important in determining grazing distribution on homogenous landscapes but forage palatability, terrain and density are also important in heterogeneous landscapes. The integrated response to these factors determines which part of the landscape is more heavily grazed than others. It is heavily grazed parts on which range management and the management of the land conditions should focus.

There may be special considerations for different types of agroecological zones, production system and livestock species. Special considerations for different types of agroecological zones, production system and livestock species. Location in relation to feed source is important as it governs to a large extent the time, energy and body water that stock (and their herdsman) needs to spend traveling to the water point.

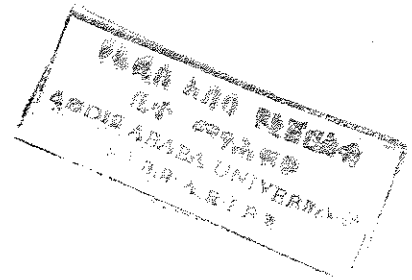
Summarizing the results from FAO (1988 and 1991), Touber (1983), Western (1982) and field survey in 1993 carried out by Kio (warden of Amboseli National Park) the accessibility will be dependent on classification according to drinking water availability in the dry season will be from 0-5 km (daily regime) and from 5-12 km (every other day regime). More than 12 km (other day or third day regime, but under several conditions) will be considered in principle as inaccessible, because the condition of livestock under these range conditions will become worse and worse.

When overgrazing does occur it is usually found first and foremost in proximity to water supply. The phenomenon of concentric rings around a water point has been described as a "piosphere". The total circle of grazing or piosphere influence is up to 3 km for cattle where range conditions are good, up to 4 km in areas of moderate conditions; as much as 7 or 8 km in areas where range conditions are poor.

The piosphere suitability is greatest near the water point and decreases as a function of distance. Five zones can be recognized. The first most suitable zone is up to 100 m from the water point. The second zone extends suitable areas of up to 1 km. The third zone to 5 km is moderately suitable. And the fourth suitable zone is 8 km slightly suitable. The least unsuitable zone is beyond 8 km is not suitable and there usually is some accumulation of unpalatable material.

Water is the critical factor which can be manipulated for management of the rangelands. It is the most important controllable range management technique. It

is the availability of water which largely controls how many livestock can graze an area and over what period of the year.



CHAPTER IV

MATERIALS AND METHODS

4.1 MATERIALS

The following softwares have been used in the present study for data acquisition, design, analysis and presentation of the final research results: ENVI 4.0, Arc view 3.2, Arc GIS 9.1, Global Mapper, Surfer, Microsoft Word, Microsoft Excel, and Microsoft Access.

In the present study topographic maps of 1:50 000 were used. NOAA satellite images, in addition, were utilized to generate NDVI (Normalized Difference Vegetation Index) of the study area. Several sorts of reports were used to back up the study with current literature of the research topic. Digital data are merged in to a GIS platform and have been used: land use land cover, DEM (Digital Elevation Model), Slope, Livestock density, Soil Classification, Water Availability, and drainage datasets under this study.

4.2 METHODOLOGICAL APPROACH

4.2.1 DATA COLLECTION

This section of the study identifies and discusses the types and source of data that were collected for the spatial modeling. Before the spatial analysis is carried out, data was identified and collected. The relevant data for this study are: land use/land cover, water resources, digital elevation model, soil classification, livestock density, NOAA satellite image and rainfall. Land use/land cover data was obtained from the Woody Biomass land use/land cover classification database. In addition, the water resources data was collected from the Ministry of Water Resources: borehole, springs, dams, rivers and lakes that are indeed important to water availability for livestock production.

Furthermore, topography is essential for land suitability modeling. It was derived from 90 meter resolution SRTM (Shuttle Radar Topographic Mapping) data. A DEM (Digital Elevation Model) is helpful for visualizing the area, for various data generation, (contour line generations, basin area delineation, slope, etc...). Then, slope is derived using spatial analysis tools. FAO Soil Classification is used in the Suitability Modeling. It is the only source of soil data in the country. Livestock density is collected from the Central Statistical Authority (CSA). To derive feed availability, NDVI (Normalized Difference Vegetation Index) data is collected from USAID FEWSNET.

4.2.2. DATABASE DESIGN AND CREATION

Geodatabase, short for geographic database, is a core geographic information model to organize a GIS data in to thematic layers and spatial representations. Geodatabase, introduced by ESRI, is a comprehensive serious of application logic and tools for accessing and managing GIS data. Geodatabase is a GIS and Database Management System (DBMS) standards-based physical data store and is implemented on a number of multi-user and personal DBMSs. Two types of geodatabase architectures are available under ESRI's ArcGIS package: personal geodatabase and multi-user geodatabase.

Under this study, personal geodatabase architecture was implemented to store the project database. Personal geodatabase, which are available to all ArcGIS users, integrate the Microsoft Jet Engine database file structure to persist GIS data in smaller databases. Personal geodatabase are much like file-based workspaces and hold databases of up to 2 GB in size. Microsoft access is used to work with attribute tables in personal geodatabase.

Personal geodatabase are ideal for working with smaller datasets for GIS projects and in small working groups. By virtue of personal geodatabase, one can

implement single user editing. Henceforth, in this GIS project personal geodatabase is preferably used to handle, store, and manipulate all project databases in the course of the research study.

The project database was created in Arc GIS 9.1 platform using ArcCatalog. The steps taken in designing and developing the project geodatabase using personal geodatabase are stated hereunder. The first step was designing the database. In designing stage spatial datasets were identified that are needed based on the requirements of the future attributes and analysis.

In addition, the study area boundary has been set and UTM (Universal Transverse Mercator) has been chosen as convenient projected coordinate system for the current project. In the second stage the data has been automated by converting the data sets from other systems in to a usable format. Moreover, coordinate systems were verified. Finally, the project database was built (see Figure 2) in personal geodatabase architecture. Indeed, the last stage of building the project database was a critical and time consuming part of the current GIS project since the completeness and accuracy of the data in the analysis ultimately governs the accuracy of the research results.

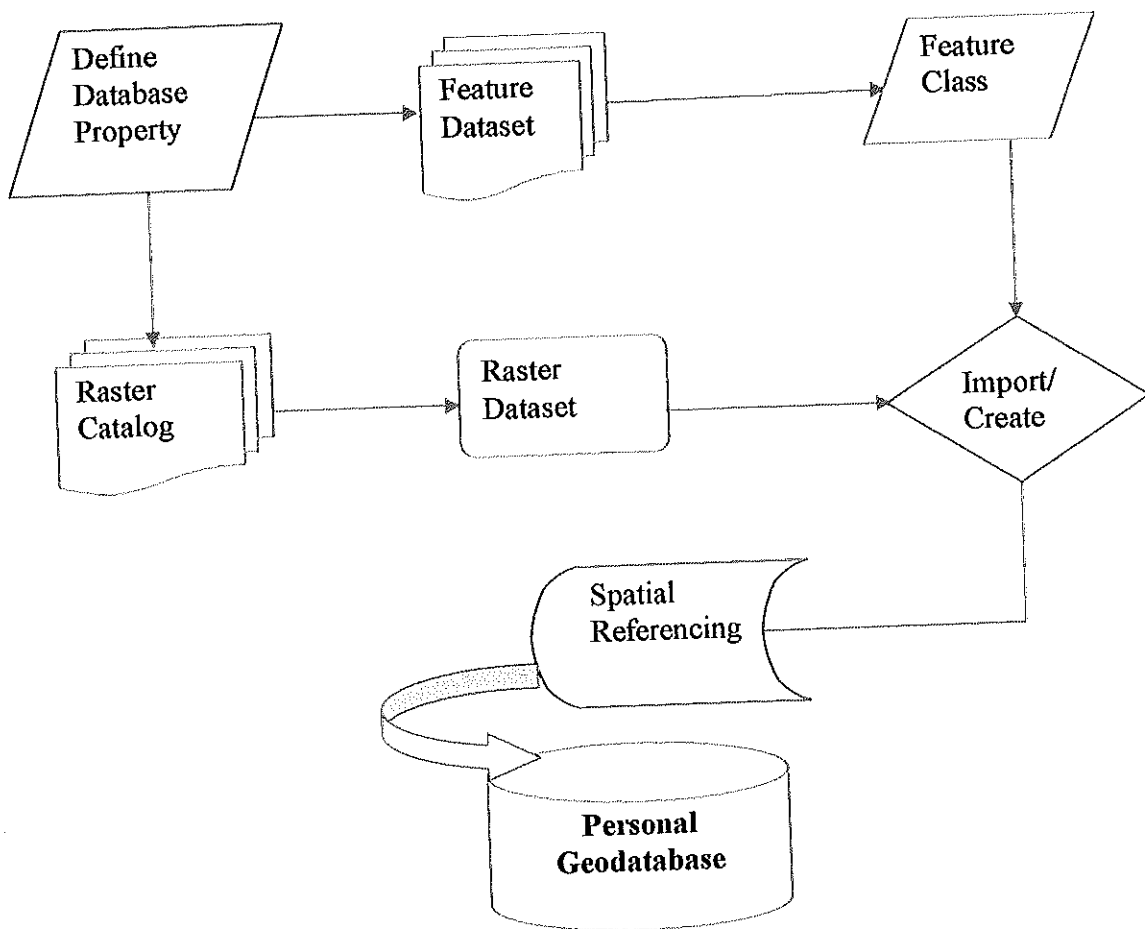


Figure 2 Flow chart of personal geodatabase creation

4.2.3. FIELD SURVEY

4.2.3.1 PRE-FIELD

Before the field survey all relevant data has been organized in a GIS environment. Meanwhile, scale transformation has been manipulated in to a uniform standard. And projection towards UTM (Universal Transverse Mercator) so as to make the input layers compatible in a GIS platform for further GIS analysis. Moreover, after geodatabase was designed preliminary conceptual suitability model is run. Based on

the conceptual suitability model sample sites for the existing land use/land cover has been selected for real time model verification.

4.2.3.2 FIELD WORK

In the field survey, topographic map of the study area, preliminary suitability map, and some selected sample site maps (see Figure 3) of the field observation are used. GPS data has been collected of more than 25 sample sites, and elevation and UTM coordinates of each respective area were recorded.

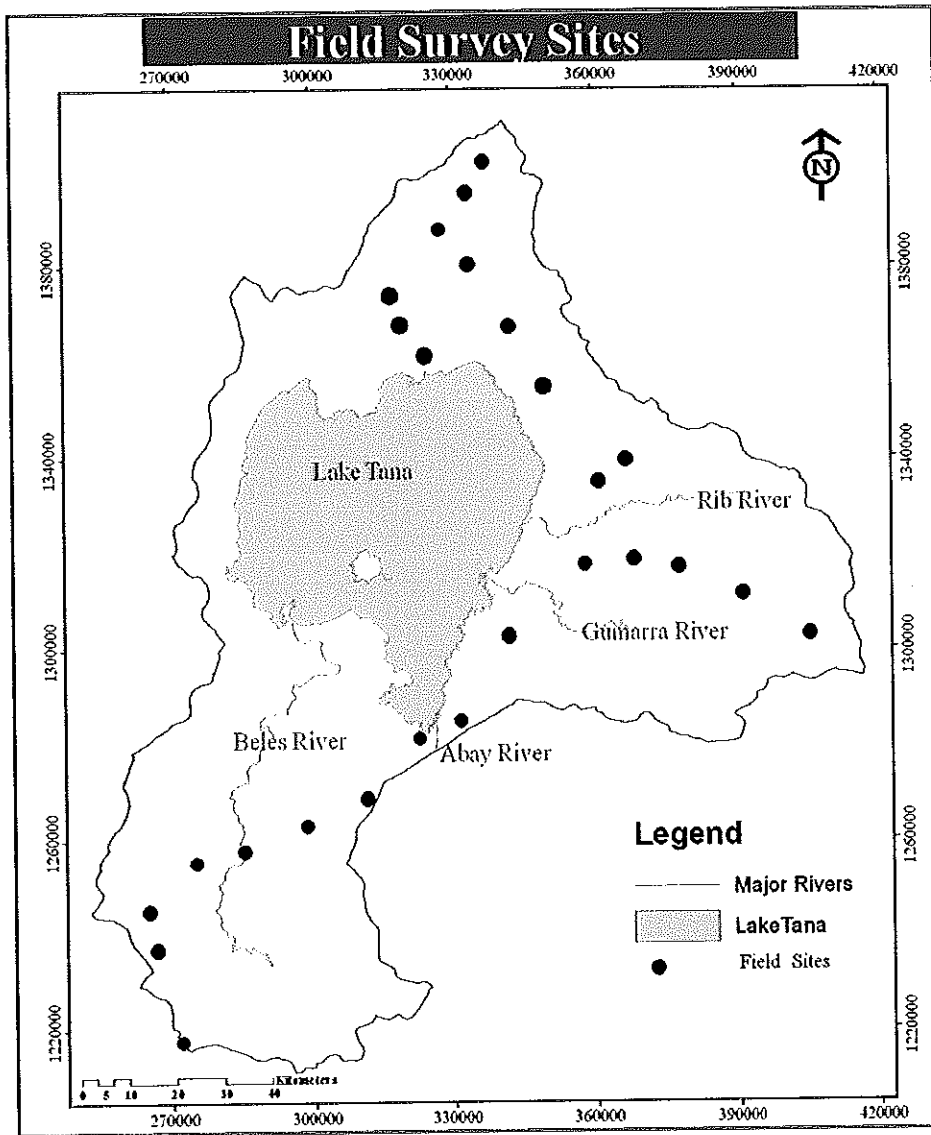


Figure 3 Locations of Field Survey Sites

In addition, the preliminary suitability model has been verified with the real time scenario. Besides the land use/land cover of the sample sites is also observed; it is concluded that some of the marginal lands are cultivated (see Figure 4) by the indigenous farmers. For example, in few of the observed sites it is noticed that forest lands are changed to cultivated land.



Figure 4 Marginal area cultivation of forest land

The soil type of the area is also verified with the current data. Slope of the study area is observed and found that most of the areas around the lake typically the Fogera plain has optimal slope for livestock grazing whereas the most steepest areas of the Tana Sub Basin Debretabor on the sample sites has an altitude of 2800 m above sea level. And this area is dominated by mountainous and steep slopes that are not suitable for livestock production. Furthermore, the livestock density is also observed on field since the survey has been conducted on day time while livestock

are on field. Most of the Fogera Plains avail moderately dense livestock population as compared to other observation sites.

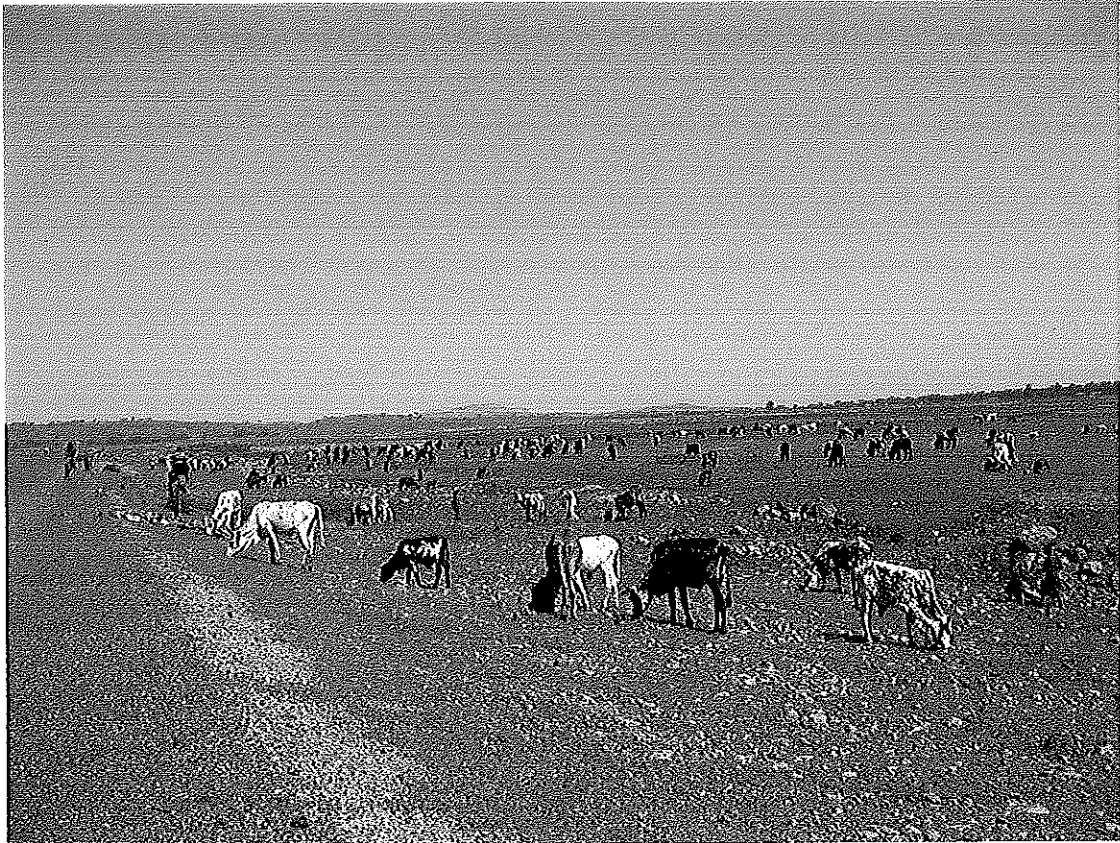


Figure 5 Livestock Population at Fogera Plain

Water resource of the study area comprises tributary streams, lakes, ground water points: springs, boreholes, and dams. It is observed that the area around the lake is swampy for the water level is shallow and near the surface which indeed is conducive for ground water development for livestock production.

During the field survey, it was observed that there were some conducive water points that could be sources of water accessible for livestock drinking. The water point (see Figure 6) shows while livestock are drinking at Debre Tabor site.



Figure 6 Livestock while drinking at Debretabor site

4.3 CONCEPTUAL SUITABILITY MODEL

The conceptual suitability model illustrates (Figure 7) the procedures that are undertaken while running the land suitability model for livestock production. First the input data (grid and shape files) of the study area are merged in to a GIS environment.

The Digital Elevation Model (DEM) of the study area was clipped by the study area. And slope was derived from the DEM using surface analysis. Next the land use/land cover shape file was converted in to a raster data model (grid files) so as to make it compatible to the suitability model using overlay analysis techniques. Likewise, the soil classification shape files of the study area are again converted to grid files. Then, the rainfall point data are interpolated to a grid file.

CHAPTER V

SPATIAL DATA ANALYSIS

Spatial data analysis in a GIS ranges from simple mapping to creating complex spatial models. A model is a representation of reality used to simulate a process, predict an outcome, or analyze a problem.

5.1 SUITABILITY MODELING

Suitability Modeling is a methodology or a set of analytical procedures that simulate real world conditions within a GIS using their spatial relationships of geographic features to locate optimally suitable geographic areas for a specific land use. Hereunder, two of the GIS functionalities are applied. Under the present study, the spatial modeling functions implemented is geometric modeling and coincidence modeling functions. Geometric Modeling Functions include calculating distances, generation buffers, and calculating areas and perimeters. And Coincidence Modeling Functions include overlaying datasets to find places where values coincide. Thus, it has been possible in a GIS to efficiently perform the abovementioned analysis that would be impossible or extremely time consuming if done manually.

5.1.1 MODEL PARAMETERS

In running the suitability model the model parameters used are: slope, rainfall, soil classification, and land use/land cover. Before the model parameters are merged to the weighted overlay analysis, the input model parameters are first converted in to a raster data model. During the conversion of the vector data in to a raster to make the data layers compatible for the raster analysis a 90 m cell size is taken on the basis of the DEM (Digital Elevation Model) resolution. Therefore, all the input parameters are resampled to 90 m raster cell size resolution. In addition, to make the parameters in to a uniform scale value for the overlay analysis, each parameter is reclassified in to five suitability classes ranging from 1 to 5 on the basis of their importance to the suitability model objective, where 1 implies least suitable while 5 represents the most suitable part of the study area. After each model parameter is

reclassified in to a similar scale value, finally each model parameter weighted using GIS methodologies of Multicriteria Decision Making Rules in particular ranking methods. Finally, the model is run in a GIS environment in a spatial analysis tool.

a) DIGITAL ELEVATION MODEL (DEM)

Digital Elevation Model (DEM) of the Tana Sub Basin is clipped from SRTM of NASA satellite 90 m resolution of Ethiopia by using a masking layer of the Tana Sub Basin boundary. The DEM shows an elevation range of very low altitude 1656 meter above sea level (Figure 8) and high peaks of up to 4027 around the periphery of the basin that indeed are enveloped by undulating chains of Semen Mountains.

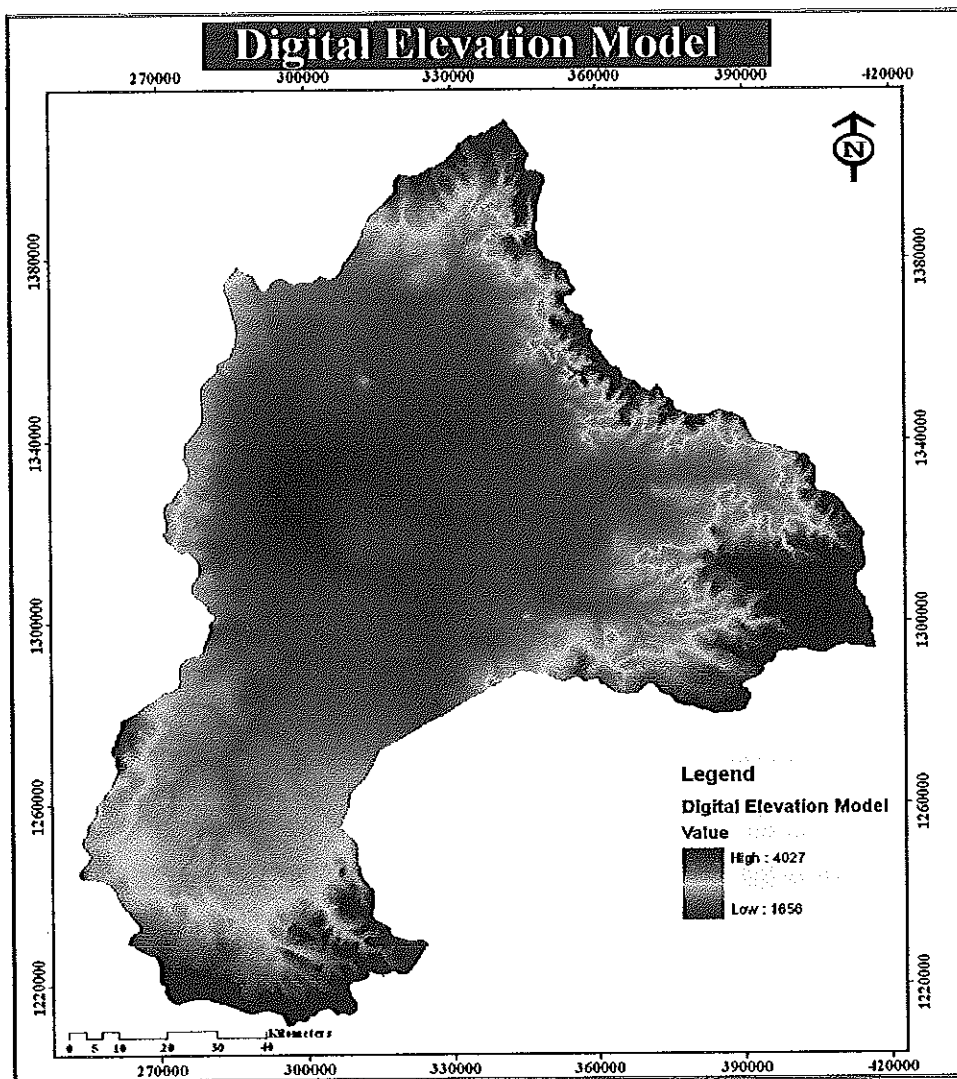


Figure 8 Digital Elevation Model of Tana Sub Basin

The suitability of the rangelands for grazing has to be applied as well to abstract or reduce forage from those rangelands, which are not less suitable for livestock grazing. Factors like slope steepness will reduce the amount of forage. The suitability map will be generated by setting user-defined slope suitability values to the classified slope map (Toxopeus, 2005).

The land suitability model uses slope as an input data. Therefore, the slope input data which is derived from elevation has been reclassified (Figure 10).

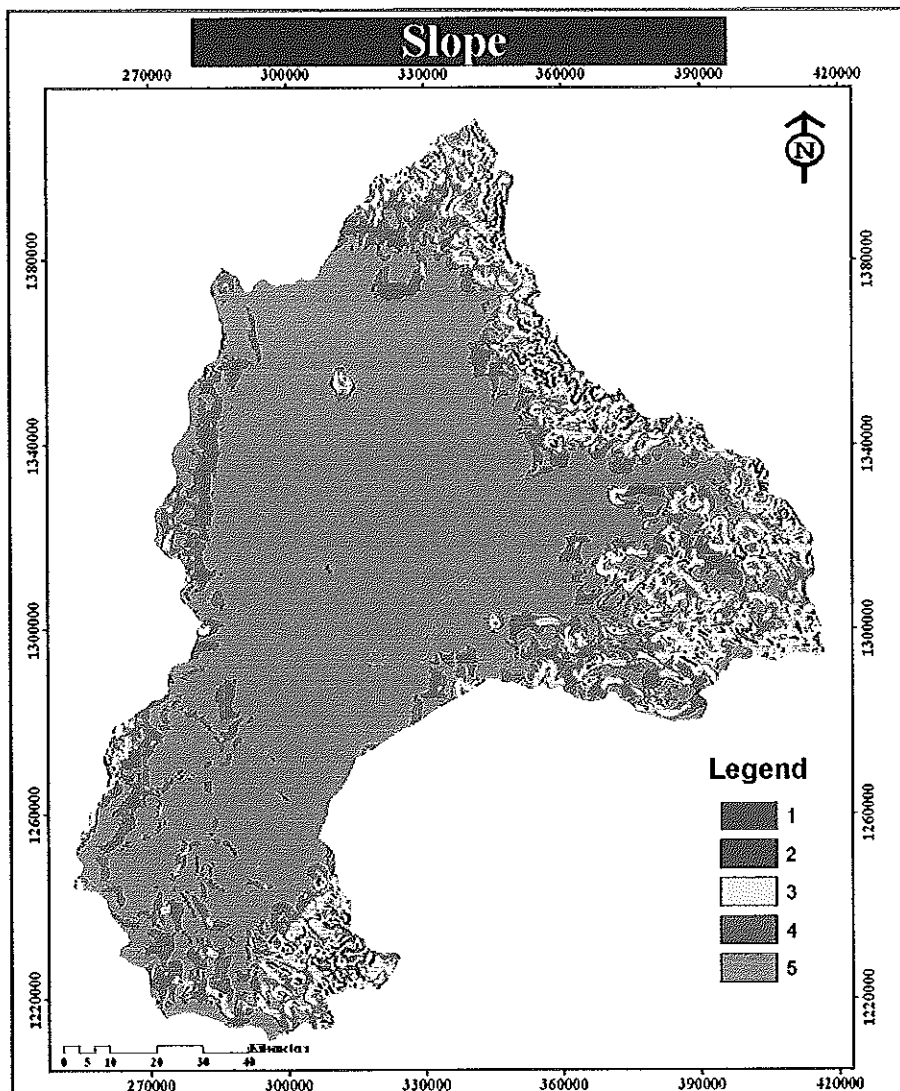
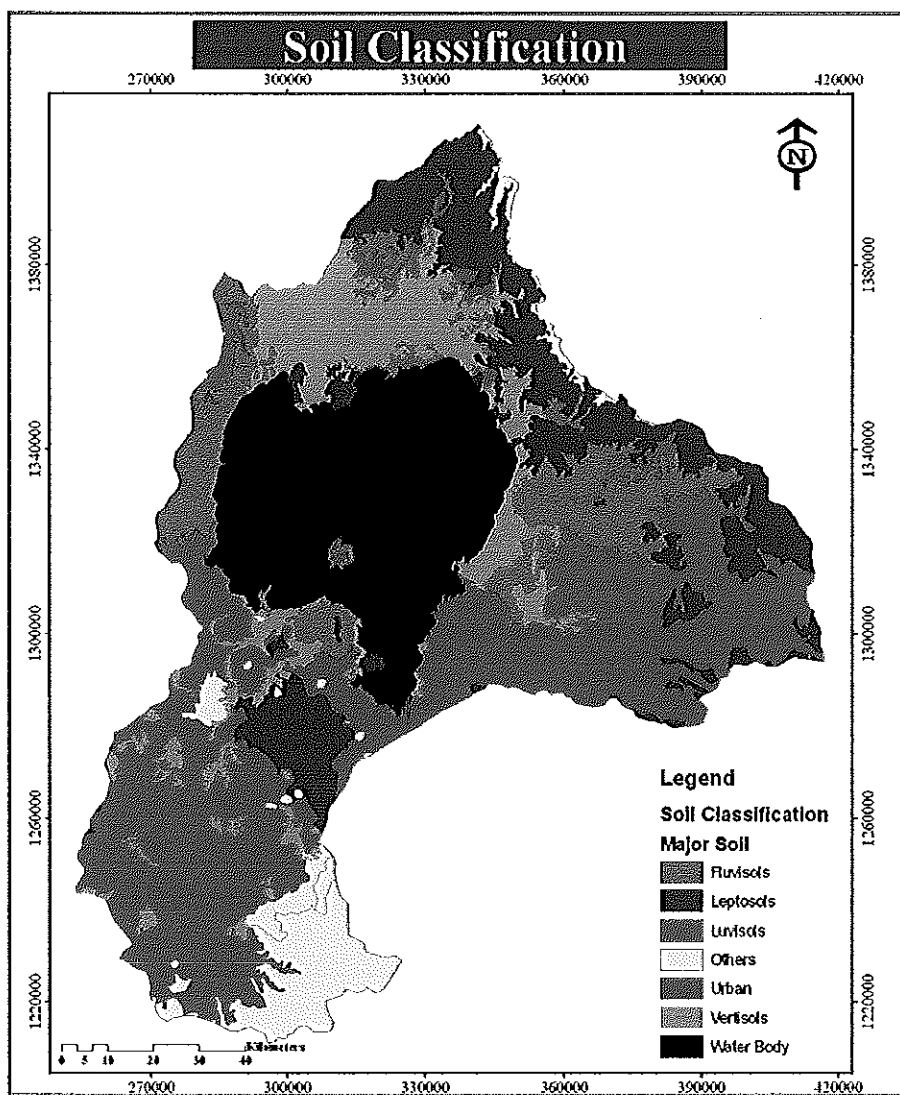


Figure 10 Reclassified Slope of Tana Sub Basin

Reclassification involves assigning higher or lower values to more suitable locations, or cell values. In this study, the suitable slope values are those that represent conducive grazing, and travel. Since the range of the new reclassified value is 1-5, the value of 5 takes the most suitable slope values where as 1 takes the least suitable steepness.

c) SOIL CLASSIFICATION

In the study area there are five major soil classifications (Figure 11) including some minor ones generalized as others in the soil classification for the sake of compatibility to the weighted overlay analysis.



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Figure 11 Soil Classification of Tana Sub Basin

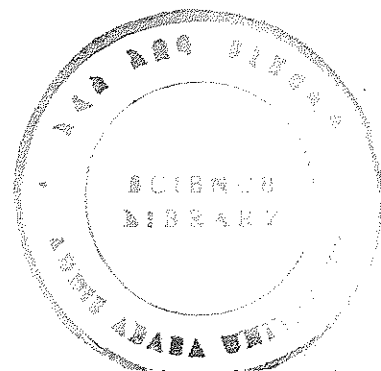
The first soil type in the Tana Sub Basin is Luvisol. The mixed mineralogy, high nutrient content, and good drainage of these soils make them suitable for a wide range of agriculture, from grains to orchards to vineyards. Luvisols form on flat or gently sloping landscapes under climatic regimes that range from cool temperate. Sub humid to humid, mild to very cold climate Parent material rich in calcium carbonate. Grey to Dark Grey subgroups Dominated by eluviation (Ae) and illuviation (Bt) Dominant in the boreal and foothills regions Also in forest-grassland transition zones Develop under forest vegetation.

The second type of soil existent in the study area includes Fluvisols. Fluvisols are found typically on level topography that is flooded periodically by surface waters or rising groundwater, as in river floodplains and deltas and in coastal lowlands. They are cultivated for dry land crops or rice and are used for grazing in the dry season.

Moreover, soil classification type called Vertisol is also dominant in the area. Vertisols are characterized by a clay-size-particle content of 30 percent or more by mass in all horizons (layers) of the upper half-meter of the soil profile, by cracks at least 1 cm (0.4 inch) wide extending downward from the land surface.

In addition, leptosols are present in the study area. Leptosols are soils with a very shallow profile depth (indicating little influence of soil-forming processes), and they often contain large amounts of gravel. They typically remain under natural vegetation, being especially susceptible to erosion, desiccation.

Finally, a soil classification "others" is included to encompass some minor soil types sparsely found in subtle amount in the basin. This group is not suitable for agriculture as compared to the above mentioned soil types: Regosol, Cambisol, nitisol, etc.



The soil classification also is comprised of urban area and water body, which are regarded as restricted from the land suitability modelling. That is based on the premise that the land suitability takes in to consideration only agricultural potentials of the area in particular for livestock. That is to mean, under this study industrial livestock production is disregarded. As a result urban areas are excluded from the suitability modelling.

The soil classification layer is once again reclassified (Figure 12) new reclassified value on an evaluation scale of 1 to 5 where 1 represents the lowest suitability and 5 the highest suitability.

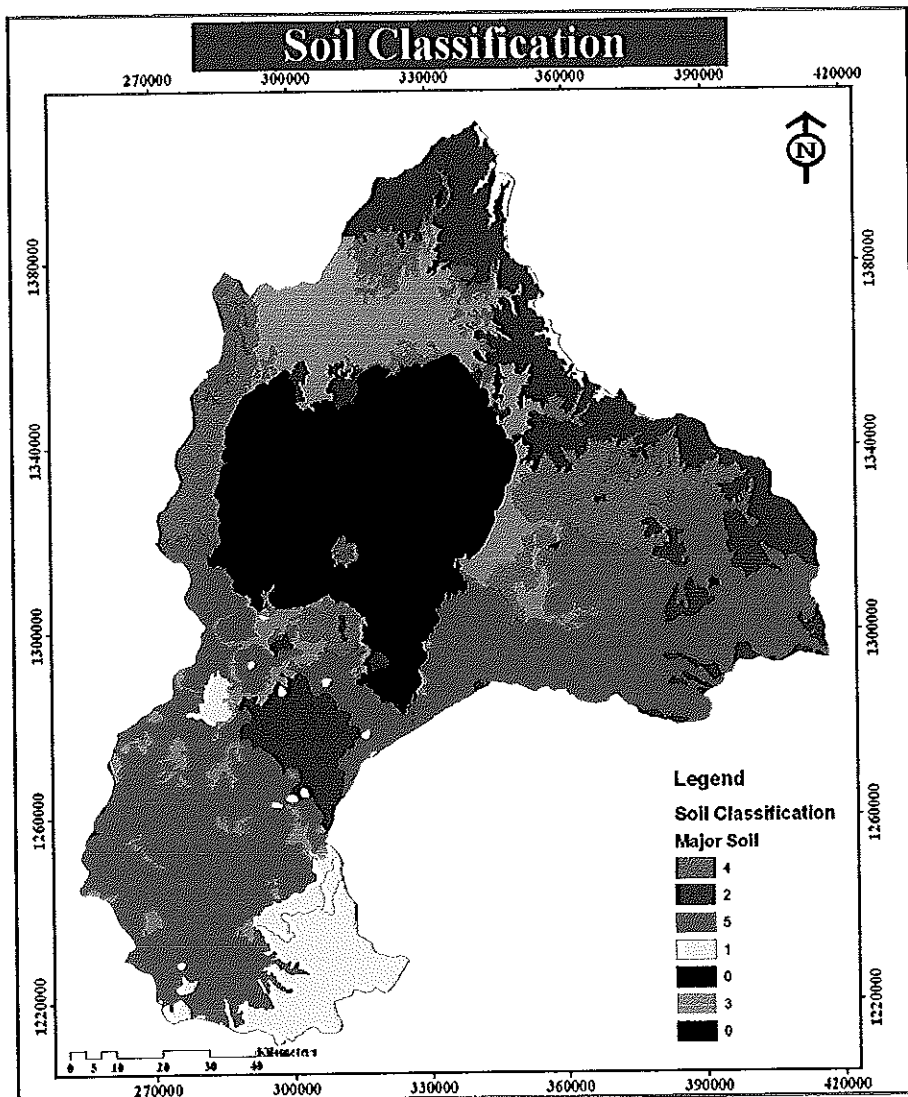


Figure 12 Reclassified Soil Classification

d) LAND USE LAND COVER

The land cover is taken as one major parameter that affects the suitability modeling in the present study area. Land use “is the way in which, and the purpose for which, human beings employ the land and its resources” (Meyer 1995:25).

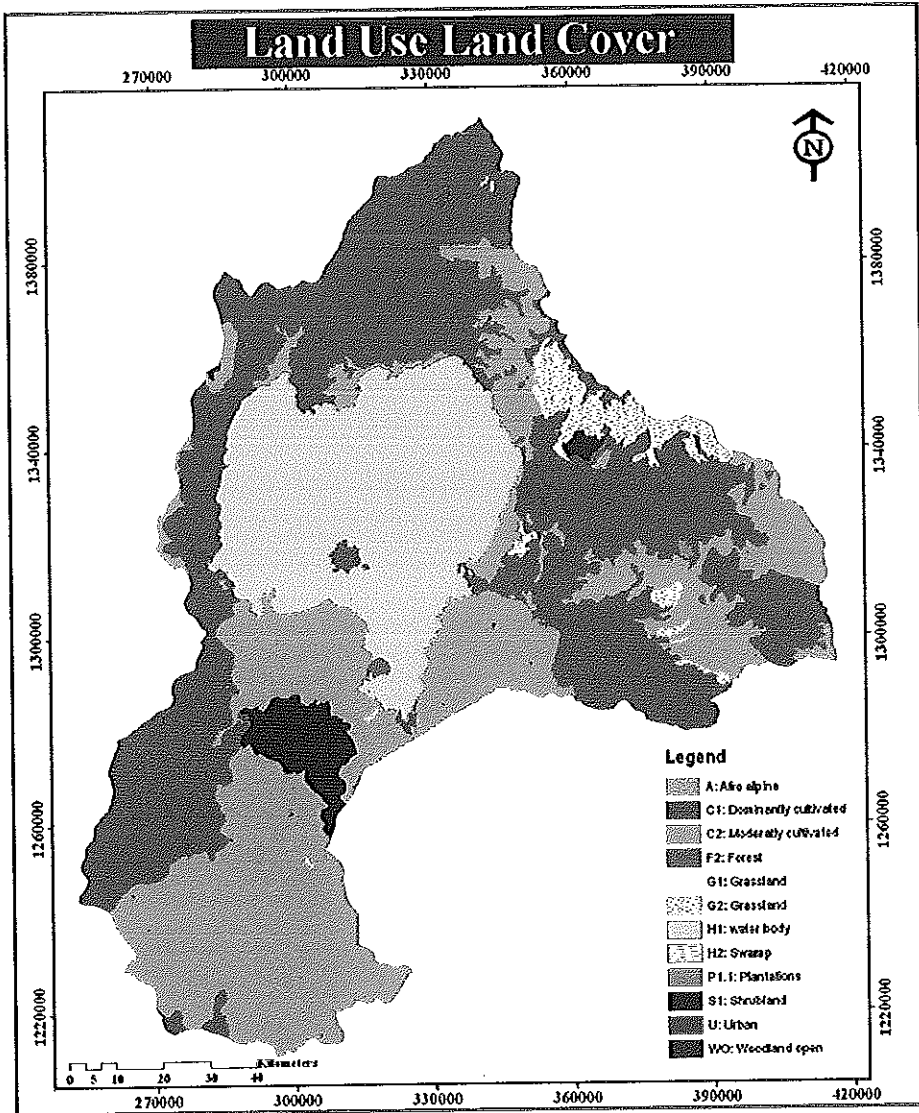


Figure 13 Land Use Land Cover Map of Tana Sub Basin

Examples include farming, mining and logging. Land covers, by contrast, “the physical state of the land surface as in cropland, mountains, or forests” (Meyer 1995:25). The term originating referred to the type of vegetation that covered the land surface, but has broadened subsequently to include human structures, such as

buildings or pavement, and other aspects of the physical environment, such as soils, biodiversity, and surface and ground water. Land Use /Cover map is useful for resources assessment, land use planning, land evaluation, and land use/ land cover change detection. Likewise, (Figure 13) depicts the land use/land cover map of the study area.

The land use land cover layer is reclassified to make the parameter compatible for GIS analysis in the suitability model with other model parameters. The forthcoming (Figure 14) figure depicts the reclassified version.

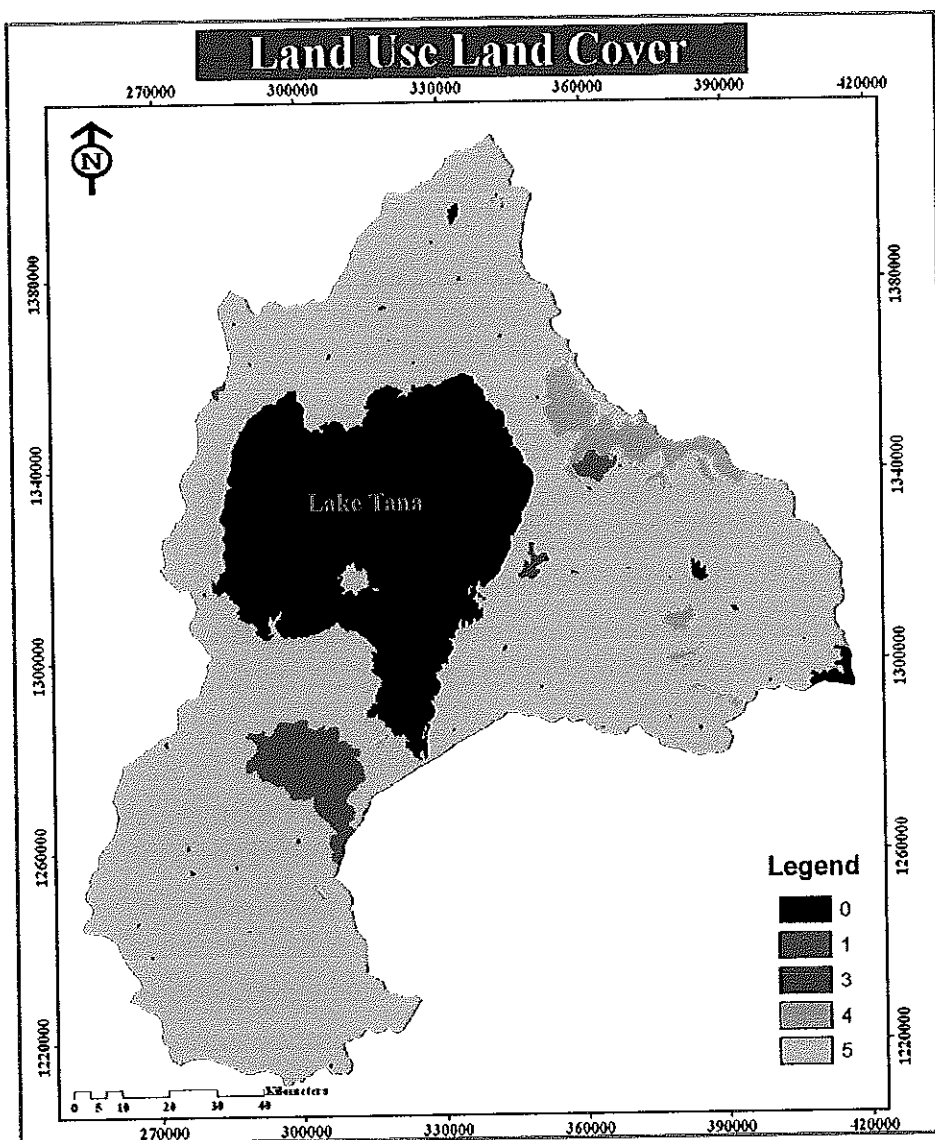


Figure 14 Reclassified Land Use Land Cover

Thus, the reclassified version implies 1 to 5 where 1 stands for the least suitable and 5 for the most suitable.

e) WATER AVAILABILITY (RAINFALL)

One of the single most important factors that determine livestock production is water availability for feed growth. That is, feed need water for growth in the form of rainfall. Hence, feed source is abundant in areas of high rainfall. As a result, the availability of water for feed growth of the study area is identified by mapping mean annual rainfall. The mean annual rainfall of the Tana Sub Basin (Figure 15) depicts the available water for feed growth for livestock production.

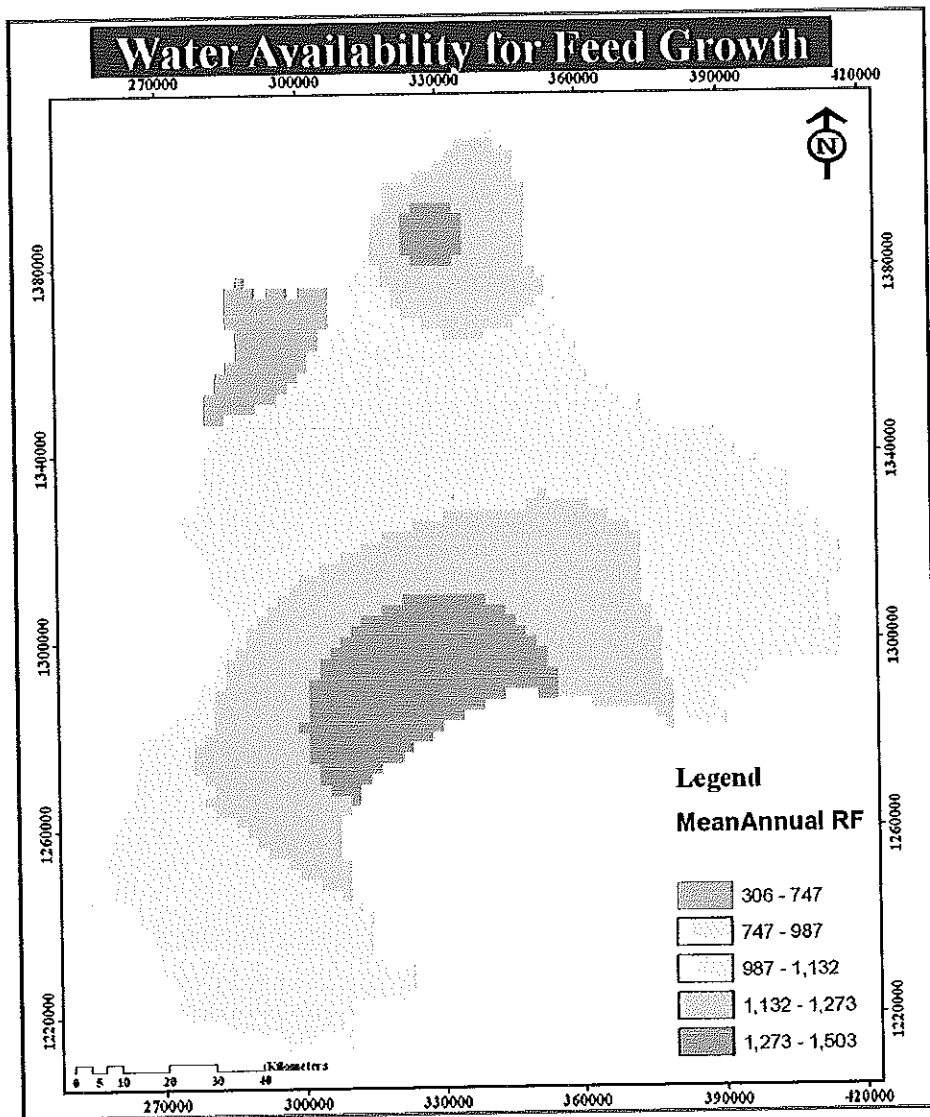


Figure 15 Water Availability for Feed Growth (Rainfall)

First, mean annual rainfall of the study area is designed in a geodatabase. Then, a surface is interpolated from the point data in a GIS platform using IDW (Inverse Distance Weighted) interpolation technique. The resulting raster data model shows the water availability map based on the mean annual rainfall of the study area. As indicated in (Figure 15) the mean annual rainfall ranges from the minimum of 306 mm to 1, 503 mm. More importantly, water availability is one prominent input to assess livestock water productivity.

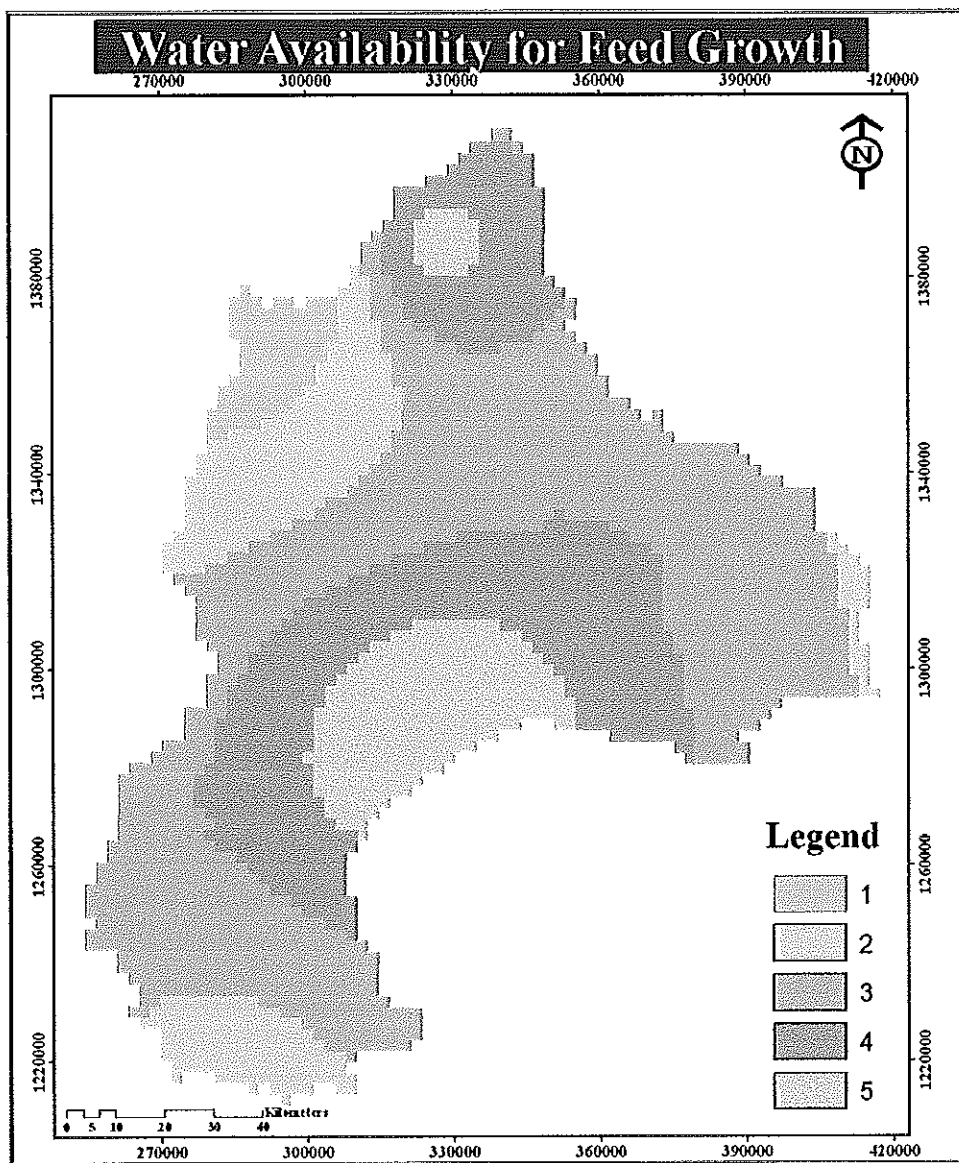
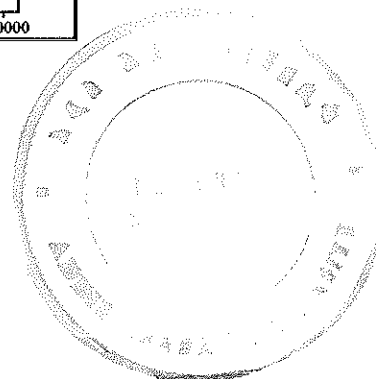


Figure 16 Reclassified Water Availability (for Feed Growth)



Like other model parameters, the water availability map is reclassified (Figure 16) in to five suitability classes ranging from 1 to 5 where 5 indicates “the most suitable” and 1 “the least suitable” areas. Then the reclassified water availability map would be, indeed, will be compatible to run the weighted overlay analysis of the suitability model.

Under this study, choosing the site for optimal livestock production implies assessing such things as land use land cover, slope, soil type, and water availability. This information exists in different raster layers with different value scales; therefore, each data layer is reclassified in to uniform scale value to obtain meaningful result.

Because weighted overlay only accepts integer raster as inputs, all the input data layers are converted in to a raster data model. And then, the continuous raster such as slope are also once again reclassified before they are used in the analysis. The cells in the raster will already be set according to suitability. The output raster is weighted by importance and added to produce an output raster.

The suitability model for livestock production using weighted overlay analysis in the present study encompasses four evaluation criteria. These criteria considered in the model are: land use land cover, slope, soil type, and water availability.

In this study, water bodies, forests and urban areas are assigned a restricted value, which means that the corresponding areas cannot be used for livestock production. Therefore, water bodies, urban areas, and forest cover are restricted from analysis in the Suitability Model.

5.1.2 MULTICRITERIA DECISION MAKING RULES (MCDM)

After preparing all the model parameters compatible to the suitability model, estimating weights for the model parameters is what comes next. Running a

suitability model requires to estimate weights for each individual model parameters. As a result, the following section demonstrates the procedure of Multicriteria Decision Making as means of calculating weights for model parameters.

To illustrate, the following are the steps carried out to estimate weights during the suitability modeling by the ranking method. This method has been taken in to consideration to find optimal location for livestock production. Under this study, four evaluation criteria have been considered: land use/land cover, slope, soil classification, and water availability for feed growth (Table 3). The criteria are first ranked based on the following formula on top of their importance to the model objective. In that regard, the criteria land use/land cover, slope, soil type, and water availability are ranked on the basis of importance from most important to least important.

$$w_j = \frac{n - r_j + 1}{\sum (n - r_k + 1)}$$

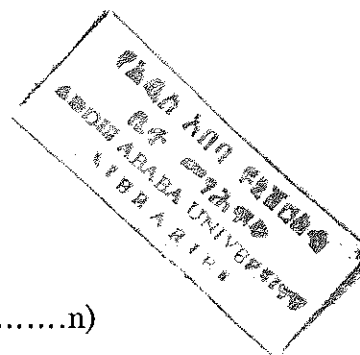
Where: w_j is normalized weight for the j th criterion

n is the number of criteria under consideration ($k=1,2,3,\dots,n$)

r_j is the rank position of the criterion

Each criterion is weighted $(n - r_j + 1)$ and then normalized by the sum of all weights, that is $\sum (n - r_k + 1)$.

Using this straight ranking method, each rank is converted to a weight; the higher the weight the more the important the criterion. Then the weights are summed. The sum of the criteria is 10. Next each weight is normalized by dividing the weights by the total. Finally, the resulting weight is multiplied by 100 to find percent of influence. The percent of the influence is the raster in comparison to the other criteria as a percentage of 100.



Therefore, the resulting weight derived using Multicriteria Decision Making Rules (MCDM) for the land suitability model is as follow (see Table 4). According to this method, land use has 40% influences whereas slope is estimated to have a 30% influence as compared to other criteria evaluations. In addition, soil is given an estimated weight of 20%; while water availability has the remaining 10% of influence.

Table 4 Assessing weights by Ranking Procedure

Criterion	Straight Rank	Weight (n+r _j +1)	Normalized Weight	% of Influence
1	2	3	0.30	30
2	3	2	0.20	20
3	1	4	0.40	40
4	4	<u>1</u>	<u>0.10</u>	<u>10</u>
Total		10	1.00	100

Criterion: 1* Slope, 2* Soil, 3* Land Use Land Cover, 4* Water Availability

While running the suitability model using a weighted overlay, the cell values of each input parameter are multiplied by the estimated weight (percent of influence). The resulting cell values are added to produce the final output raster model. To this end, higher values generally indicate that a location is more suitable whereas lower values imply least suitable location.

Finally, raster of overall suitability model is created with five suitability classes ranging from 5 implying the most suitable locations to 1 indicating the locations that are not suitable for livestock production. Moreover, there is one additional class with 0 value indicating areas which are restricted from the suitability model.

The suitability model outcomes (Figure 17) are reclassified in to six suitability classes in accordance with the FAO (1985) suitability class. Thus, S1 indicated that

Normalized Difference Vegetation Index (NDVI)

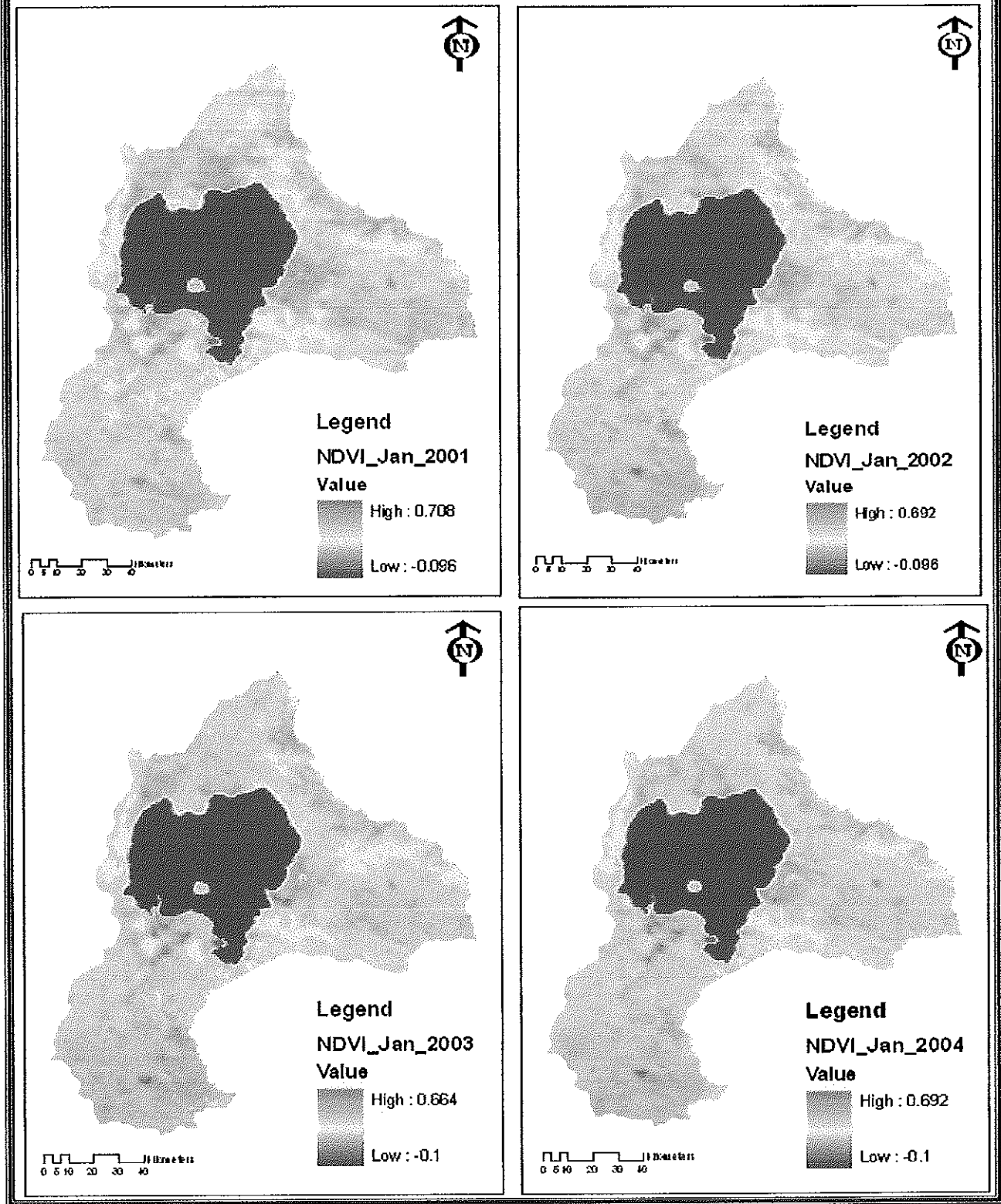


Figure 18 NDVI index for dry season-January (NOAA Satellite image)

As a result, it is advisable to look for other alternatives of meeting feed source for the livestock during the dry periods. For instance, crop residue can be utilized for livestock feed rather than relying grazing land as a sole source of feed for livestock in such seasons to sustain life.

On the other hand, the forthcoming (Figure 19) illustrate NDVI (Normalized Difference Vegetation Index) of the study area Tana Sub Basin for four consecutive years. The series of images reveal vegetation index in the wet season. For the sake of convenience the month of July has been selected representing the wet season (rainy season).

Feed for livestock depends on spatial and temporal distribution of rainfall in the area. Unlike the dry season in the wet season the NOAA AVHRR satellite images depict the presence of healthy vegetation, which are primary source of feed for livestock. Thus, most of the study area is covered by healthy vegetation cover in the month of July. In addition, most of the study area in almost the four years depict adequate feed source for livestock production.

The dominance of green color on the satellite image depicts that higher NDVI index that in turn implies healthier vegetation cover on most parts of the study area in the rainy season. There is abundant source of feed for the livestock in the rainy seasons as compared to the dry periods.

However, it should be noted that in the rainy seasons the presence of the high NDVI (Normalized Difference Vegetation Index) which indicates the abundance of green and healthy vegetation cover does not necessarily guarantee all the vegetation is a palatable feed source for the animals. That is to mean, there might exist also plant cover that is not used as feed source by the livestock. Therefore, the vegetation index is a generalized indication of the presence of healthier plant cover than a detailed feed availability palatable for the respective animal species

Basically, among the prominent water resources that serve as a source of drinking water for livestock streams and rivers are one. Usually livestock get drinking water from locally proximal streams and rivers. Because rivers encompass fresh water that is favorable water resources for drinking. Livestock populations often get drinking water from tributary rivers.

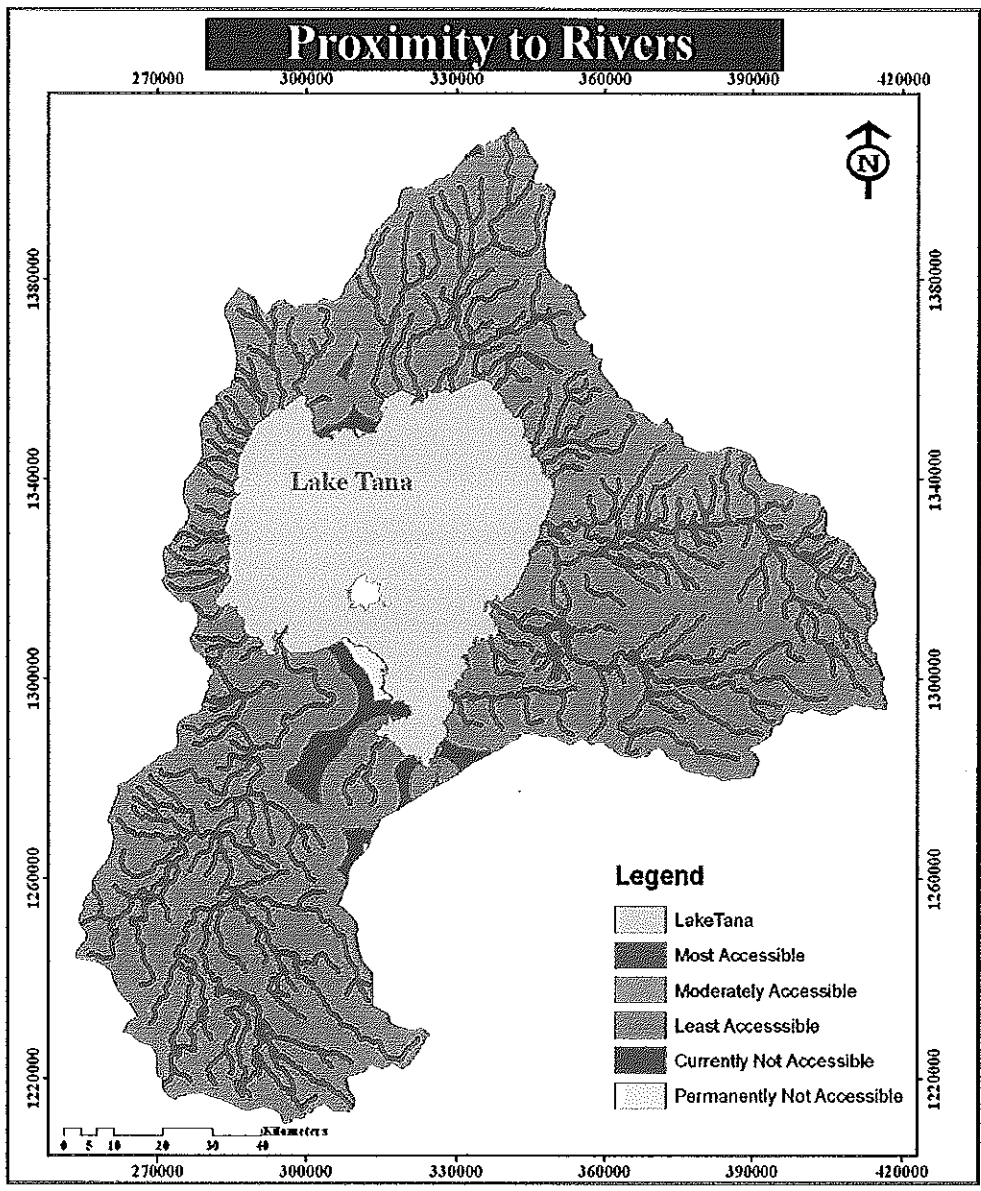


Figure 23 Proximity to rivers

Spatial modeling is applied to calculate proximity analysis using buffering of rivers on the basis of some defined distances. Likewise, accessibility from rivers is also done to find which areas are accessed for livestock drinking based on proximity.

In the GIS analysis, rivers are buffered (see Figure 23) in to five accessibility classes: : 0.5 km as Most Accessible, 1km from rivers as Moderately Accessible, 5 km as Least Accessible, 8 km as Currently Not Accessible, and finally 12 km from rivers as Permanently Not Accessible.

CHAPTER VI

RESULTS & DISCUSSION

The forthcoming results of the research findings are presented based on the spatial modeling. According to the results of the land suitability model, five suitability classes are identified with varying degree of suitability. Using the FAO suitability classification as the current standard, the findings suggest a range of suitability of land resources from most suitable to permanently not suitable.

The results portray that areas with gentle slope, fertile soil types that are suitable for agriculture, and with more agriculture that in turn provide feed for the livestock population through crop residue in mixed crop livestock systems of the Tana Sub Basin and high water availability for feed growth (rainfall) are identified as most suitable (S_1) locations for livestock production. That is, 40.5% of the study area is found to be within this class (most suitable land resource for livestock production) that encompasses a total area of 5 945 km². Furthermore, areas with moderate slope gradient, optimal water availability, grassland and moderate fertile soil types are identified to be moderately suitable (S_2) for livestock production. This in turn comprises of 30% of the study area taking a total area of 4 392km², which indeed is the largest in the suitability classification results. Additionally, out of the total area 8% are identified to be least suitable (S_3) that lies on a total area of 1 209 km².

On the other hand, the suitability model resulted that 0.2% covering an area of 27 km² are found to be Currently Not Suitable (N_1) for livestock production. That is, areas with steep slope gradient, infertile soil type, low water availability and land use and lands cover type of shrub and woodland are identified as Permanently Not Suitable (N_2) for livestock production. This part of the study area encompasses 0.1% with a total area of 0.5 km².

In the land suitability model, some areas such as water body, urban areas and forests are excluded from the GIS analysis. As a result, 21.2% of the study area comprising 3115 km² is Restricted(R) from the suitability modeling. That is to mean, urban areas are identified as restricted due to stipulations from city administration for development of infrastructure. Similarly, fresh water body especially lakes are restricted from the land suitability analysis for environmental sustainability of the basin. Likewise, forests are excluded from the spatial analysis so as to maintain a sustainable environment and prevent deforestation of natural forest cover.

The largest part 40.5% falls under Most Suitable class. In addition, 30% of the total area is identified to fall on moderately suitable class. In contrast, only 0.1% of the study area is found to be permanently not suitable, which is almost negligible. Thus, the largest portion of the study area is identified to be optimally suitable for livestock production.

The NDVI (Normalized Difference Vegetation Index) analysis, on the other hand, portrays four consecutive years in the dry season. The results depict that feed for livestock highly depends on rainfall, which is a single most important factor. Most of the study area has scarce vegetation cover in the dry season. This implied that there is lack of adequate feed source for animal production in the dry season. Thus, it is necessary to look for other alternatives to meet the demand for animal feed source during the dry periods. Crop residue is one ideal option for livestock feed.

Unlike the dry season the NDVI indices depict the presence of healthy vegetation, which are primary source of feed for livestock. Thus, most of the study area is covered by healthy vegetation cover in the wet season. This implied the presence of adequate feed source for livestock production. There is abundant source of feed for the livestock in the rainy seasons as compared to the dry periods. However, it also needs further detailed study on the palatability of all the healthy vegetation cover

in the wet season as revealed by the NDVI indices. Therefore, a detailed study of vegetation monitoring is significant to get fine tuned spatial information to assess feed availability for livestock production.

The results, further, show that the availability of water for livestock drinking. The spatial modeling findings based on the proximity from water resources resulted in five accessibility classes ranging from most accessible (- 0.5 km from water sources) to Permanently Not accessible(- 12km from a water source). As a result most areas are accessed with water sources for livestock drinking. In other words, animals often travel short distances to find water for drinking in the study area. Though the water resources are accessible for livestock consumption, it is not advisable to deplete the water resources with out the taking environmental degradation in to practice. Therefore, it should be underscored that some water points and streams should be protected from overexploitation, and degradation to maintain a sustainable ecosystem in the basin.

According to Atismatchew Bizuwerk (2005) similar study of land suitability classification at Upper Awash Basin has been undertaken. The land characteristics factors taken in to consideration are soil type, slope gradient, erosion risk, distance from water body and rainfall. Based on the suitability of each input factor for each land use a weight value was given from 0 (Unsuitable) to 1 (most suitable). However, in the current study the land characteristics factors used in the land suitability model are soil type, slope gradient, land use land cover, and water availability. And each input model parameter is given weights from 1(Permanently Not Suitable) to 5 (Most Suitable). On the other hand, rather than taking proximity from water source as one model parameter, under this study it is treated separately in water availability mapping; proximity from each water resources has been operated in GIS: proximity from lakes, rivers, and water points. At the end, accessibility from water source is obtained for each water resources.

Atismatchew Bizuwork (2005) has also taken FAO suitability classification at the end of the analysis to get the final suitability map. Similarly, under the present study for the land suitability model FAO suitability classification is used as the standard for the land suitability model. Based on the FAO standard five suitability classes are derived ranging from S_1 = Most suitable to N_2 = Permanently Not Suitable.

Dayawansa (2003) also has done a much similar work on land suitability identification for a production forest using GIS techniques a case study of Sri Lanka. Even though the suitability modeling is done for forest production the methodology has much to do with the present study. In the aforementioned study, the suitability model parameters implemented are: land use land cover, proximity from roads, and slope. Weights are assigned to existing land use, slope, and accessibility; only three suitability classes were used: Suitable, Moderately Suitable, and Not Suitable.

6.1 MODEL OUTPUT VERSUS LIVESTOCK DENSITY

This section of the study attempts to compare the land suitability model with the existing spatial distribution of livestock population in the study area. The current livestock population of the Tan Sub Basin (see Figure 24) depicts dense livestock population especially at higher altitudes around peripheries of the basin. But the density of livestock in most central parts of the study area is sparse. That is, the concentration of denser animal population exists on the highlands. In contrast, the suitability model result (see Figure 25) shows that the central parts of the study area are found to be optimally suitable for livestock production. Moreover, the model results also depict that the peripheral regions are found to be relatively marginal for livestock production. As depicted in the model, most of the evaluation criteria taken in to account in the spatial modeling for the peripheral regions were

not conducive for animal production. For example, these areas are found to be land resources with steep slope, infertile soil characteristics, and least water availability as compared to the central parts of the study area.

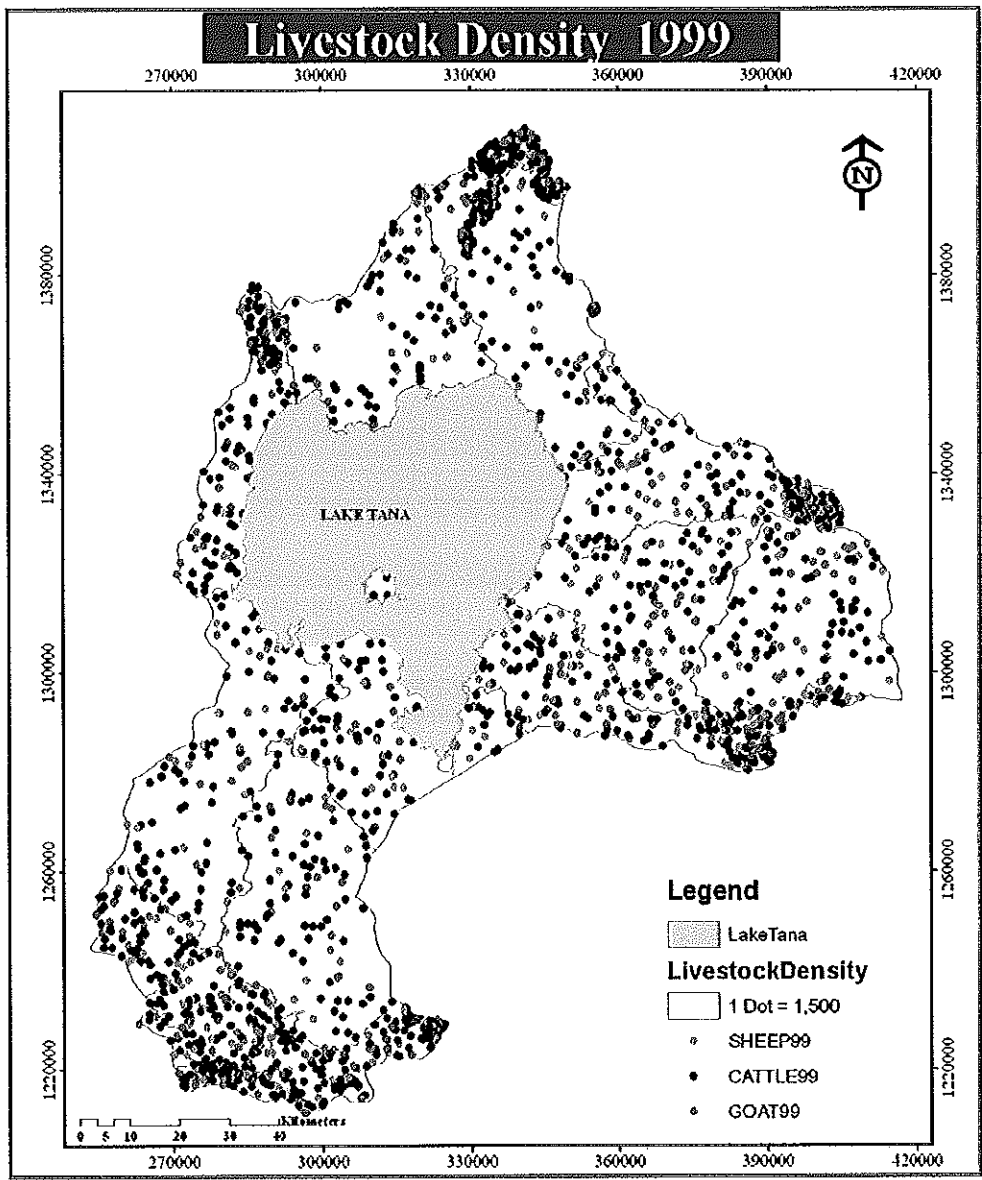


Figure 24 Livestock Density of Tana Sub Basin

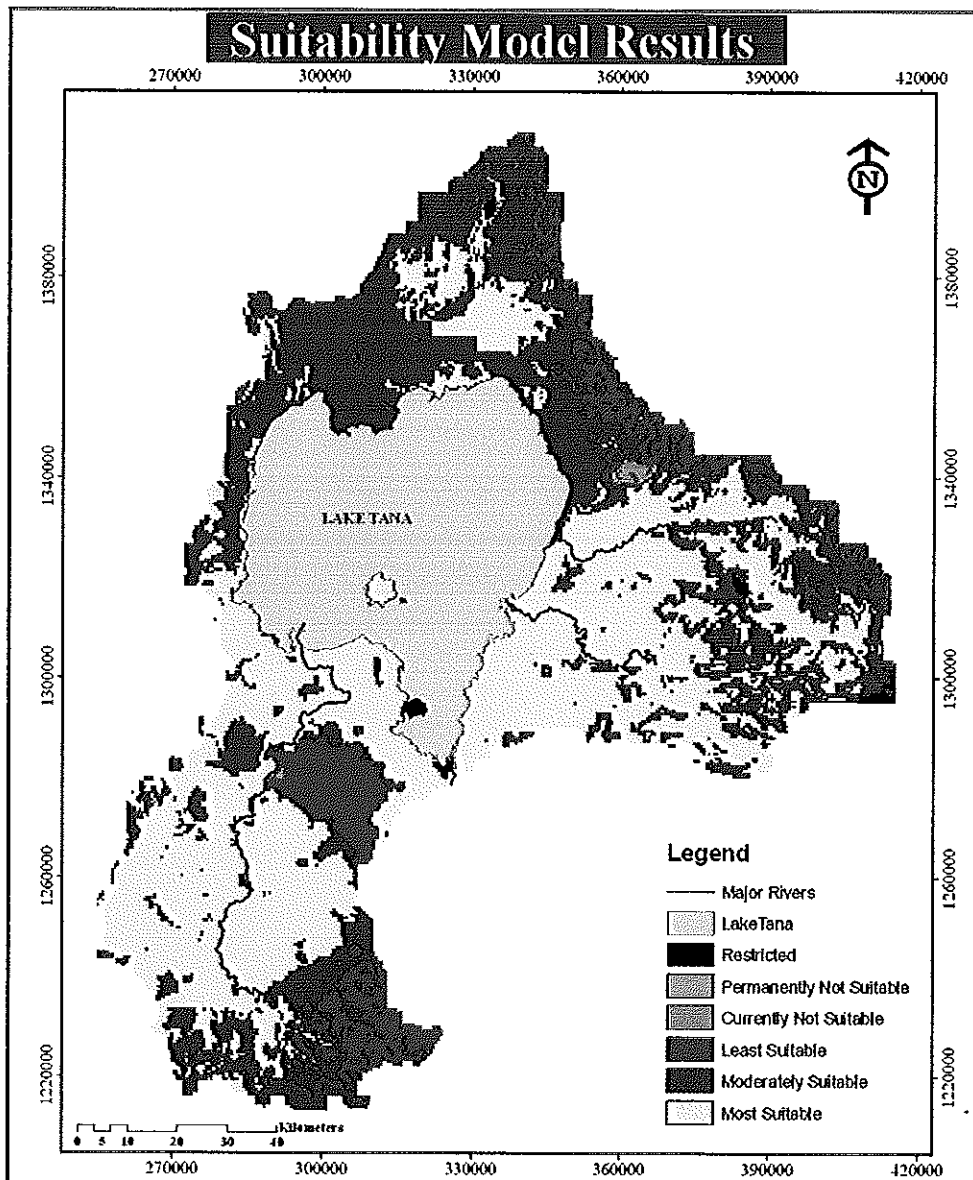


Figure 25 Suitability Model Result

The comparison of the model results with the existing spatial distribution of livestock population shows incongruity. There are several assumptions made towards the discrepancy of the spatial distribution of livestock with the model results. The highlands are densely populated by human settlement than the lowlands for several reasons. The first argument is that most of the settlement in human population favours the highlands for several reasons. The most elevated peripheral areas (see Figure 8) of the basin have suitable climatic condition for

human settlement. In addition, the rural population preferably settles in higher altitudes for security purposes. Besides, the highlands often are conducive for human settlement from the point of view of spread of contagious disease. All in all, the above mentioned assumptions are prospected towards justifying intense settlement to human population. Therefore the dense settlement in the farming population leads to an implied dense distribution in livestock population. That is, livestock population is governed by settlement in the farming population.

As result, the current spatial distribution of livestock production needs intervention so as to keep the land resources sustainable and maintain productivity. To this effect, the current livestock distribution should be evenly relocated to those areas with optimally suitable land resources for livestock production in accordance with the findings to protect the land resources from degradation, and overgrazing.

Generally, the results of the spatial modeling indeed could suggest the constraints of animal production. Based on the evaluation criteria of the suitability model the following are considered as constraints for livestock production. Areas with steep slope, infertile soil type, inadequate rainfall (water availability for feed growth) and land use/land cover of unfavorable for agricultural production are regarded as some of the remarkable constraints of livestock production. Equally important, the results of water availability analysis reveal that distance from water sources for livestock drinking is a remarkable constraining factor, too. Similarly, the scarce availability of feed source for livestock is also another most constraining factor for livestock production.

6.2 SUITABILITY MODEL STIPULATION

Proper use of the land depends on the suitability of lands for specific purposes, in this study particularly it is paramount important to identify suitable land for animal production. Nevertheless, it must be with optimum utilization while causing

minimum impact to the environment. Maintaining a sustainable environment is a prerequisite to utilize natural resources. Therefore, a robust suitability model should consider the sustainability of the environment parallel with optimal land capabilities.

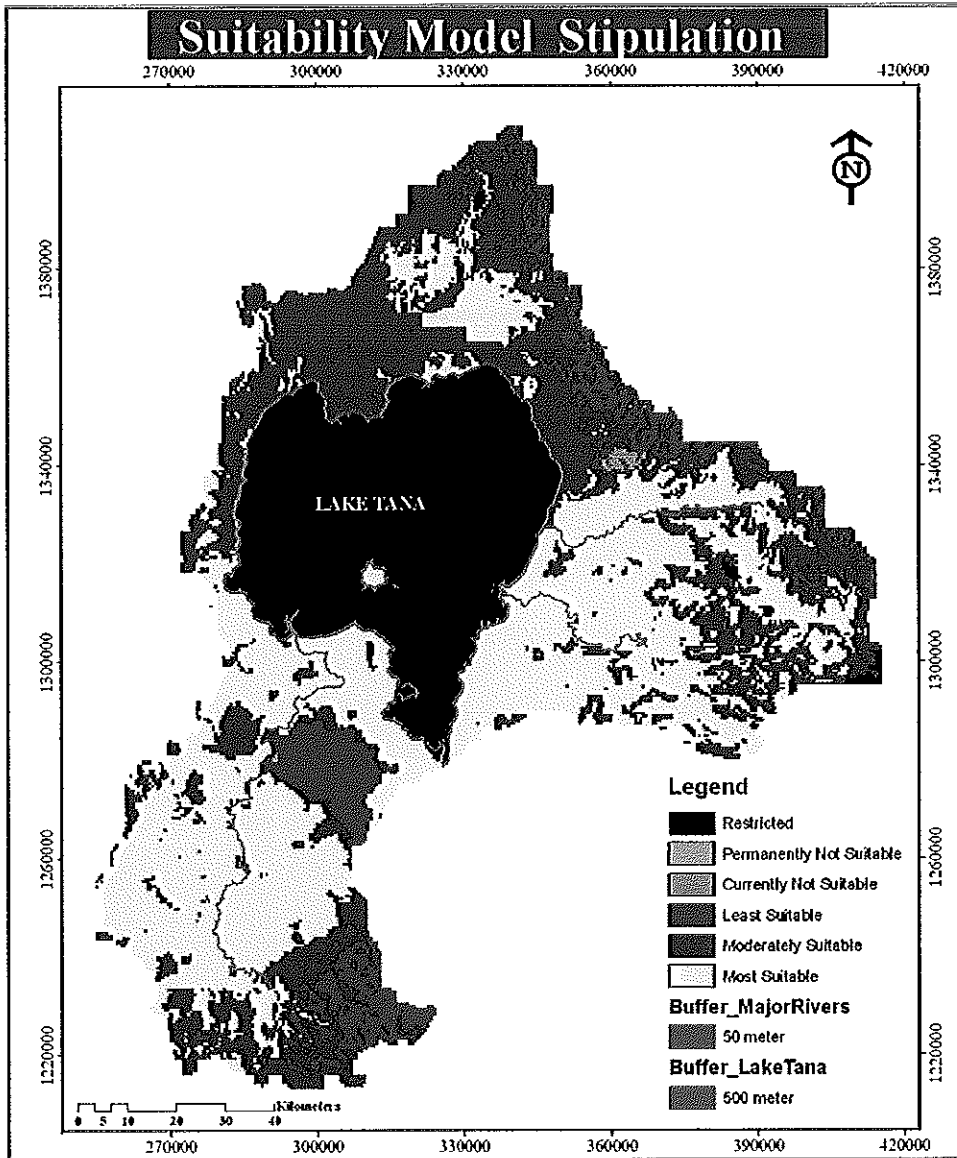
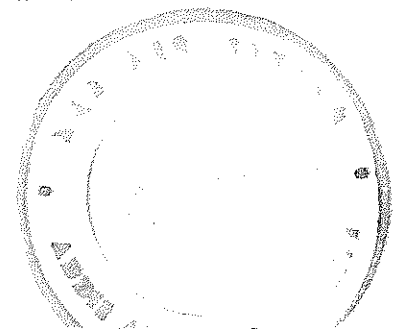


Figure 26 Suitability model stipulations (-with environmental stipulations)

In a similar fashion, this study has considered such environmental friendly options for optimal resource utilization. That is, the land suitability model is once again considered some sorts of stipulation to fresh water reservoirs: lakes and rivers. In



the study there are three major rivers: Rib, Gumara, and Beles, where as Lake Tana is the most abundant source of fresh water in the sub Basin, and the Blue Nile Basin at large.

To keep these fresh water reservoirs from contamination, pollution and depletion some restriction of utilization is suggested. The suitability model stipulations (see Figure 26) are developed by making buffer zones from both the major rivers in the sub basin and Lake Tana. The stipulation states that major rivers should be buffered within 50 meters distance. In addition, it also states that Lake Tana should be restricted from contamination with in a distance of 500 meters around the lake.

To this end, the researcher believes that by making such restrictions of fresh water reservoirs from direct contamination by livestock drinking, the suitability model result will be more realistic. Even though the results of the water accessibility analysis result that the lake and major rivers are accessible for consumption for livestock drinking, the aforementioned stipulations should be taken in to account to make the sub basin environment profoundly sustainable. Finally, some means of utilizing the water resources from the Lake Tana and major rivers should be designed outside of the buffer zones of the stipulations without disturbing the wetland ecosystem.

CHAPTER VII

CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

This study attempted to develop a suitability model that could support decision making process in the Tana Sub Basin-Blue Nile River Basin, Ethiopia using GIS applications to carry out spatial data modeling.

Findings of the study disclose that 40.5% of the study area is identified as most suitable for livestock production. And 30% is found to be moderately suitable for livestock production while only 8% is least suitable land. In other words, according to the results of the findings larger area of the basin is located on suitable land for livestock production. Most of the study area is covered by optimal land use/land cover, gentle slope, fertile soil type, and adequately available water for feed growth that make it highly favorable. In contrast, only less than 0.1% of the basin is permanently not suitable for livestock production and 0.2% currently not suitable for animal production.

Furthermore, the spatial distribution of the existing trend on livestock population depicts the fact that they are distributed on peripheral higher altitudes, whereas most of the suitable land in the basin has sparse livestock density. If the current trend on livestock distribution continues, degradation of the land resources, and decline in livestock productivity would consequently result.

The findings also show that most of the livestock find drinking water with in short distances. That is, the basin encompasses numerous rivers and streams for livestock drinking. Even though, the currently available water points are limited in number relative to the larger basin area, the ground water level is shallow especially near by the Lake Tana. The basin also avails abundant water resources both ground and surface water that in turn makes it suitable for livestock

production. In addition, the region has rich sources of water available for feed growth (rainfall) especially in the wet rainy seasons.

The basin has available feed source for animal production as indicated in the results of the feed availability analysis especially in the rainy seasons. But there is a relative scarcity of feed for livestock consumption in the dry seasons. Crop residue could serve as feed source for livestock since the agricultural system in the basin is mixed crop livestock system.

The Tana Sub Basin according to the findings of the study is identified to have immense potential for livestock production. Added with the relatively optimal vegetation cover in the rainy season, the basin has vast water resources, and optimally suitable land resources for livestock production. Thus, the basin has a remarkable potential to reduce poverty and improve food security for the drastically increasing human population in the basin.



7.2. RECOMMENDATIONS

- In most of the study areas animal production is practiced in steep slope, highly elevated peripheral areas where the soil is less fertile, and exposed for degradation while most suitable areas for livestock production are in the central plains. Such practices end up disturbing the environment and decrease in the productivity of livestock products. Therefore, it is recommended that the relocation of livestock production to more suitable areas from unsuitable areas based on the suitability model result.
- More ground water point (wells) should be dug for better water resources for livestock. During the field investigation it is observed that most of the areas around the lake are swampy and waterlogged; the ground water level is near

the surface. There is great potential to satisfy the demand for water for livestock drinking.

- Relocation of animal production to proximal water points keeping the balance in sustainable environment in the basin to increase livestock water productivity.
- Integrated crop livestock production system should be adapted to serve crop residue as a feed source in the dry season when grazing land is scarce.
- Prevent cultivation of marginal grazing land. In the field observation some areas that are ideal for grazing land and have sound carrying capacity to maintain a large number of livestock populations are observed to be cultivated. There should be interference by concerned body to prevent such degradation of grazing land.
- Some ways should be devised to use the Lake Tana as source of water for livestock with out disturbing the wet land ecosystem and designing environmental friendly water management systems.
- As any model is a simplification of the real world and as no model is immune of limitations, the suitability model under this study has subsequent limitations. For instance, flaw in data accuracy, timely data acquisition, and scale might be limiting factors to the suitability model. Thus, limitations of the model should be taken in to consideration when applying the land suitability model as a tool for decision support system and management strategies.

- The suitability model is recommended to be refined with additional model parameters, improved data accuracy to advance the precision of the model to be used as a Tool for Decision Support System (TDSS).
- The spatial modeling results of water availability for drinking and water availability for feed growth could be used as a method to assess livestock water productivity in the Tana Sub Basin and the Blue Nile River Basin by large.
- Future water availability studies should incorporate the quantity of water points (dams, bore holes, springs, rivers, and lakes) to develop a more reliable spatial information system on the availability of water for livestock drinking.

BIBLIOGRAPHY

- Aronoff, S. 1989. *Geographic Information Systems: A Management perspective*. WDL Publications:Ottawa.
- Ayalneh, W. 2004. *Livestock water productivity of four community based small Scale irrigation schemes in the Upper Awash River Basin of Ethiopia*. ILRI, Addis Ababa Ethiopia.
- Bizuwerk, A. 2005. *GIS Application for analysis of Land Suitability and Determination of Grazing Pressure in Upland of the Awash River Basin, Ethiopia*. International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia.
- Burrough, A. 1986. *Principles of geographic Information Systems and Geostatistics*. Oxford University Press: New York.
- Dayawansa.2003. *Land suitability Identification for a Production Forest through GIS technique*.
- Food and Agricultural Organization (FAO). 1985. *Guidelines: Land Evaluation for Irrigated agriculture*. FAO Soils Bulletin 55,Rome.
- Kijne, J. 2005. *Water productivity in agriculture: what it is in livestock rearing and can it be improved?* ILRI, Ethiopia.
- MoWR. 1964. *Land and Water Resources of the Bluer Nile Basin Ethiopia*. Appendix II-Geology. The United States Department of the Interior Bureau of Reclamation.
- Lillesand, T &Kiefer, R. 2004. *Remote Sensing and Image Interpretation*. New York: John Wiely & Sons, Inc.
- Malczewski, J. 1999. *GIS and Multicriteria Decision Analysis*. New York: John Weily&Sons. Inc.
- Molden, D. et al. 2003. *A Water-productivity Framework for Understanding and Action*. IWMI, Colombo, Sri Lanka.
- Peden, D. 2003. *Nile Basin Livestock-Water productivity*. ILRI: Addis Ababa, Ethiopia.
- Peden, D.2005. *Nile Basin Water Productivity: Developing a Shared Vision for*

Livestock Production a Workshop of the CGIAR Challenge Program on Water & Food. Kampala, Uganda

Sine, A. 2004. *Regional Flood Frequency Analysis for the Blue Nile River Basin, Ethiopia.* Arba Minch University, Ethiopia.

Toxpeus, G. 2005. *Spatial and Temporal Modelling for Sustainable Management of Semi- Arid Rangelands: The Wildlife Livestock Issue in the Amboseli Ecosystem, Southern Kenya.* ITC, Enschede, Netherlands

Wassenaar, T. 2005. *Mapping water – relevant Nile basin livestock production systems and assessing their status.* ILRI, Kampala, Uganda.

Wilson, T. 2002. *Livestock Water Demand and Supply.* Ministry of Water Resources, FDRE, Ethiopia.

Winrock, I. 1992. *Assessment of Animal Agriculture in Sub-Saharan Africa.* Morrilton, Arkansas, USA, Winrock International.

Websites:

<http://ilrinet.ilri.cgiar.org/>

<http://www.gisdevelopment.net/application/environment/overview/mi03148.htm>

<http://www.esri.cpm/industries/agriculture/research/suitability.html>.