Faculty of Science

Addis Ababa University

A Better Way to Learn ! (Since 1950)


**Addis Ababa University**
**School of Graduate Studies**
**Department of Earth Sciences**


# Remote sensing and GIS based Wildlife corridor suitability for Nile Lechwe Species in Gambela National Park, Ethiopia

*A Thesis Submitted to the School of Graduate Studies of Addis Ababa University, in Partial fulfillment of the Requirements for the Degree of Master of Science in Geoinformation Science*


By:

Eyassu Lemma


June, 2012

**Addis Ababa University**
**School of Graduate Studies**
**Department of Earth Sciences**

# Remote sensing and GIS based Wildlife corridor suitability for Nile Lechwe Species in Gambela National Park, Ethiopia

*A Thesis Submitted to the School of Graduate Studies of Addis Ababa University, in Partial fulfillment of the Requirements for the Degree of Master of Science in Geoinformation Science.*

By:

Eyassu Lemma

Advisor: Dr. K.V. Suryabhagavan

June, 2012

# Addis Ababa University
# School of Graduate Studies
# Department of Earth Sciences


# Remote sensing and GIS based Wildlife corridor suitability for Nile Lechwe Species in Gambela National Park, Ethiopia


**By:**
**Eyassu Lemma**


## Approval by Board of Examiners

Dr. Seifu Kebede

Chairman, Department Head ______________________

Dr. K.V. Suryabhagavan

Advisor________________________________________

Dr. Bekele Abebe

Examiner ____________________________________

Dr.Dereje Ayalew

Examiner _____________________________________

# Declaration

I hereby declare that the thesis entitled **“Remote sensing and GIS based Wildlife corridor suitability for Nile Lechwe Species in Gambela National Park, Ethiopia**” has been carried out by me under the supervision of Dr. K.V. Suryabhagavan Department of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2012 as part of a Master of Sciences Programme in Remote Sensing and GIS (Earth Sciences). I further declare that this thesis is my original work and has not been submitted to any other University or Institution for the award of any degree or diploma and that all sources of material used for the thesis have been dully acknowledged.

Name: Eyassu Lemma

Signature: ___________________________

Date: ___________________________

This thesis have been submitted for examination with my approval as a university advisor

Major advisor: Dr. K.V. Suryabhagavan

Signature: ______________________________

Date: ______________________________

# ACKNOWLEDGMENTS

First and foremost, this research work is achieved in success with the blessing of God. I would like to thank the 'Almighty God' who gave me the strength to begin and finish successfully. I would like to express my deepest gratitude and sincere thanks to my advisor Dr. K.V. Suryabhagavan for his valuable support in all aspects of my work.

I would like to express my gratitude to my employer Information Network Security Agency (INSA) for permitting me to pursue this study. I am also thankful to National Metrological Service Agency (NMSA), Gambela National Regional State Agriculture and Natural Resource Office for their cooperation in supplying the relevant data.

I do not have adequate words to express my feelings to Robel Tamrat, Getayawkal Tamrat, Mekete Tsegaye and Tatek Dejenie for their constant encouragement, support and motivation which helped me to complete the thesis work successfully. My heartfelt thanks go to my parents and family members for their love. Finally, I would like to convey my special thanks to all my friends who have contributed something for the completion of my study.

# Table of Contents

**Contents** **Page**

# List of Figures

## List of Tables



## List of Plates



## Annex

# Acronyms

| | |
|---|---|
| CSA | Central Statistics Authority |
| DEM | Digital Elevation Model |
| EMA | Ethiopian Mapping Agency |
| ESRI | Environmental System Research Institute |
| ETM+ | Enhanced Thematic Mapper plus |
| FCC | False Color Composite |
| FOA | Food and Agricultural Organization of The United Nations |
| GCP | Ground Control Points |
| GIS | Geographic Information System |
| GPS | Global Position System. |
| Ha | Hectare |
| IR | Infrared |
| MARF | Mean Annual Rainfall |
| MAT | Mean Annual Temperature |
| MSS | Multi-Spectral Scanner |
| NIR | Near Infrared |
| PPT | Precipitation |
| HSI | Habitat Suitability Indices |
| USFWS | U.S. Fish and Wildlife Service |

# ABSTRACT

Gambella National Park is known for its wealth of wetlands and associated wildlife species like Nile Lechwe And Kobs which are currently in International Union for conservation of Nature Red List: Endangered in 2008. The aim of this research is to assess the suitability of wildlife corridors in Gambela National park for utilization and conservation of Nile Lechwe species With the help of remote sensing softwares and geospatial tools, so as for conservation and utility purposes, It was considered land use, wetlands and settlements proximity, slope and soil factors as principal elements for Nile Lechwe wildlife corridor suitability analysis. Different weights heave been given to these factors based on the responses of focus group discussions and key informant interviews regarding the relative influences of each of these factors on wildlife habitat of the area. The weights were calculated using pair-wise comparison method. Then weighted factors maps were integrated using weighted overlay analysis to run the wildlife corridor suitability model. Finally wildlife corridor map for Nile Lechwe was produced. The result of the land suitability analysis of wildlife corridors for selected species showed five classes of suitability ; From the total land of the study area 201.63 $km^2$ (42.92%) was Highly suitable, 188 $km^2$ (40.01%) Moderately suitable, 32.52 $km^2$ (6.92%) marginally suitable, 28.47 $km^2$ (6.06%) not suitable and 19.21$km^2$ (4.09%) was permanently unsuitable area to be a Wildlife corridor for Nile Lechwe species. Building this information into conservation plans and management for Gambella area protected areas will help to address for conservation and management Nile Lechwe wildlife's and its habitat landscapes.

*Key words:* Wildlife Corridor, Nile Lechwe, Suitability Analysis, GIS and Remote Sensing, Conservation, Gambella National Park.

## CHAPTER ONE

# 1. INTRODUCTION

## 1.1. General Background

Wildlife Habitat fragmentation is one of the major biodiversity conservation issues facing the world today. This fragmentation may be natural or human-induced, and may occur on many scales. However, when habitat fragmentation is discussed in conservation terms, it is generally regarded as referring to anthropogenic alterations on a landscape scale. Stratford and Robinson, (2005). The causes of such fragmentation have mostly been land clearance for agriculture, forestry, or urban development.

It is in this context that corridors have become a significant factor in conservation management systems, Landscape corridors can be used to connect large patches of natural land in fragmented landscapes to form a network of natural lands. Because corridors are used as a means of regular travel by wildlife, in an attempt to reduce the isolation of spatially separated populations and to potentially increase the total area of habitat available. Soulé and Gilpin (1991) defined a wildlife corridor as 'a two-dimensional landscape element that connects two or more patches of wildlife (animal) habitat that have been connected in historical time...', while Parminter (1998) defined a corridor as '...a narrow strip or linear element that differs from the elements on either side'.

The connections in a landscape are typically quantified by its structural elements such as stepping stone patches or habitat corridors. The importance of these elements has been widely advocated in ecological theory, although empirical evidence that corridors improve movement across the landscape remains equivocal. The effectiveness of potential wildlife corridors depends, for example, on the species, the quality of habitat within the corridor, and the width, length and redundancy of the corridor network, among other factors (Malanson, 2003, Baum et al. 2004, Bender and Fahrig, 2005).

In practice, the identification of functional connectors (i.e., pathways for dispersal and immigration) remains an open issue due to at least two challenges: (1) the absence of observational data required to make species-specific assessments of movement potential, and (2) the lack of quantitative and objective methods for analyzing the movement data in a spatial context (Lambeck, 1997; Vos et al. 2001).

Habitat suitability modeling has been advanced by Geographic Information Systems and Remote sensing. GIS is an excellent tool for identifying areas of conservation significance and assessing the habitat potential of unstudied sites (Lenton et al. 2000).and also suitability models are available for establishing potential connectivity among patches (as defined by Calabrese and Fagan, 2004), but these methods generally provide a list of patches that are connected rather than a description of the preferred pathways used to successfully move between patches. However, it is precisely this spatially explicit mapping of functional corridors that is necessary from a management perspective in order to preserve, and, in some cases, restore connectivity.

## 1.2. Problem Statement

Human activities such as agricultural development, commercial conifer afforestation and urbanization have led to habitat fragmentation, namely loss of the original habitat, reduction in habitat patch size and increasing isolation of habitat patches (Andrén, 1994). These processes result in heterogeneous landscapes, which are composed of more or less isolated, smaller patches of suitable habitat within a matrix of less suitable habitat for reproduction or for providing food and shelter for species confined to the original habitat. The process of landscape change as a result of habitat fragmentation has far-reaching consequences for species survival. In particular, for area-sensitive species, the patches of suitable habitat may be too small to support a breeding pair or a functional social group (Lambeck, 1997), whereas species with low dispersal capacity are unable to recolonize the habitat patches following the extinction of their local populations (Collinge, 1996).

The Gambella National Park was first proposed to help protect the diverse and abundant wildlife, particularly the thousands of Nile Lechwe and White eared Kob that migrated to and from the park each year. Even though proposals to set up this conservation area have been planned since 1973, the area proposed is very large and the available infrastructure is completely inadequate to manage it effectively. Excessive hunting seriously affects the larger mammals in the area and the number of Wild Lechwes decreasing from time to time (EFAP, 1994). Visitors have reported a noticeable reduction in the woody vegetation both inside and outside the park. The park is frequently burnt: the fires are started when the ground is still moist to control the long grass and thus open up access to the new growth for cattle to graze. The biggest threat to the park is the Alwero dam and the expansion of irrigated farms to areas currently inside the park. (Barnes et al. 2003).

The GIS model presented here is devised to remedy this deficiency by proposing suitable wildlife corridors for Nile lechwes therefore to conserve and protect them properly. Geographic Information Systems (GIS) is used to evaluate habitat suitability for wildlife on a landscape scale, Distribution maps of landscape species and wildlife corridors, combined with spatial analyses of existing and potential threats to the landscape, have enabled us to identify critical areas for conservation action. Increasing our monitoring and collection of ecological data for our landscape species will allow us to continually improve the biological, threats and conservation landscapes which form the core of the landscape conservation approach, reducing the number of assumptions currently used to design these landscapes. In addition, information regarding landscape species' abundance and home ranging requirements will assist us in establishing reasonable landscape population estimates and thereby assess the global importance of the landscape for the conservation of wild lives. Building this information into conservation plans and management for Gambella area protected areas will help to address for conservation and management Nile Lechwe wildlife's and its habitat landscapes.

## 1.3. Objective

### 1.3.1. General Objective

The main objective of the study is to evaluate the land suitability using multi-criteria evaluation technique for functional landscapes and wildlife corridors for utilization and conservation Nile Lechwes and produce map for sustainable land use.

### 1.3.2. Specific Objective

- To evaluate the ability of currently used GIS and remote sensing techniques to distinguish the Wildlife Corridors for Nile Lechwe Species.
- To identify the degree of role of controlling parameters of wildlife corridor for Nile Lechwe Species in the study area and their relationship to each other.
- To produce thematic maps of suitable areas of wildlife Corridors for Nile Lechwe Species.

## 1.4. Significance of the Study

The research study is expected to produce suitable areas map of wildlife Corridors for Nile Lechwe Species that demarcates the study area into different zones according to their potential. The resulted detail map of the area can be one input for understanding of wildlife corridor of the area for Nile Lechwe species, and used as data for further research work. In addition The information generated by this study is believed to provide background information to exercise a right judgment in functional landscapes and wildlife corridors utilization and conservation around the Gambella National Park.

# CHAPTER TWO

# 2. LITERATURE REVIEW

## 2.1. Wild Life

Wildlife includes all non-domesticated plants, animals and other organisms. Domesticating wild plant and animal species for human benefit has occurred many times all over the planet, and has a major impact on the environment, both positive and negative. (Sanderson et al. 2006, Plumptre et al. 2010) Wildlife can be found in all ecosystems. Deserts, rain forests, plains, and other areas including the most developed urban sites, all have distinct forms of wildlife. While the term in popular culture usually refers to animals that are untouched by human factors, most scientists agree that wildlife around the world is impacted by human activities. (Faith and Surovell 2009)

### 2.1.1. Wildlife's spatial distribution

Simply stating that the three large carnivores are present in the Carpathian Mountains can have a biodiversity value when considering species distribution at continental scale. However, at regional scale we must be able to say where within the Carpathian they actually are and/or may be in order to direct conservation efforts towards the most effective targets. Each species has a characteristic life history, reproduction rate, behavior and means of dispersion. These determine the way the species interact with the environment and, as a consequence, their spatial distribution. (Barnosky 2008).

Stating that a species is distributed over a given area is a limited representation of reality. In fact, our experience of nature represents just one point in a multidimensional and constantly-changing mosaic of animals and plants that are responding to an endless course of social, environmental and climatic changes. There are a series of factors that make the distribution of species highly dynamic. These are of a biological or physical nature, in both the spatial and temporal dimensions (Cox and Cox 2001). Although the current distribution of a given species may only be a snapshot of the actual situation, the information is of great importance when conservation plans and monitoring programmes are to be put in place. When the information is further manipulated for predicting distributions and gaps in management practices, the geographical analysis has an increased value. The present work represents a significant contribution to the identification of areas that may need to be protected from human activity. In order to understand the differences between the depiction of a species' distribution at continental scale and the identification of areas actually and/or potentially occupied by any target species, some concepts related to the species' range and its internal structure will be introduced.

### 2.1.2. The species' geographic range

The spatial distribution of a species is considered to be its geographic range. A species' range can be defined as the area occupied by its breeding, reproductive populations (Watts 2005). It is characterized by a series of properties of biological, physical and chemical nature and its shape and extent are the result of the interactions of such factors. The influence that external social pressures posed by human populations may have on the specie's range shall not be underestimated, as this can sometimes be fatal. The actual range is the region where a species presence has been recorded. This may be different in shape and extension to the potential range, which comprises all the areas that have environmental characteristics that make them technically suitable for being occupied by the species (Watts 2005). The actual range may suffer even more severely from the pressures coming from human presence. (Gaston 2000) uses the term extent of occurrence to represent the areas often considered generally as the species range, as opposed to the area of occupancy, which falls within the extent of occurrence but excludes the places not actually occupied by the species (i.e., the actual range sensu Watts). The main difference between these two kinds of range, apart from the straightforward one of recorded presence in the area of occupancy, is one of spatial scale. It is very likely that at coarse scale the extent of occurrence is easier to consider than the area of occupancy, which may consist of many isolated patches within it, many of them being undetectable at small geographic scale (Gaston 1991). But more importantly, the area of occupancy is represented by those areas selected by the species among all available ones. It must be noted that the selection can be driven by active preference for some environments over others or it may be induced indirectly by physical or biological factors such as obstacles to free movements (geographical barriers) or competition with other species, including humans (Cox and Cox 2000). In terms of wildlife management the area of occupancy is more relevant than the extent of occurrence, as it brings information about the relationships between the target species and the environment.

Most representations of geographic ranges are maps that only draw the boundaries of areas actually or potentially occupied by a species. Such outputs are very frequently based on data of unknown accuracy and precision, that may be out of date or of a very diverse nature (Karl et al. 1999). This technique is a simplification of the actual situation, as it often fails to consider holes within the range boundaries where a species does not occur or islands beyond the perimeter where the species does occur (Brown et al. 2006).

### 2.1.3. The species-habitat relationships

The spatial distribution of species depends on their requirement and their response to environmental characteristics (Elton 2007). Traditional wildlife management considers three fundamental physical variables of the environment, which represent basic vital requirements: food, water and shelter (Dasmann 2001). The local conditions and available resources contribute to define the habitat of a given species, and the presence and survival of species are directly dependent on environmental conditions (Anderson and Gutzwiller 1994). The identification of key habitats for wildlife species is essential for development programmes, where drastic land changes could cause the disappearance of some environmental structure (Litvaitis et al. 2000)

When sampling wildlife environmental preferences for management purposes, the consideration of all areas occupied by a species can be difficult if basic information about the species' life history are not available. Behavioral studies give a fundamental contribution to conservation and little management action can be successful without knowledge of species' habitat requirements, range size, mating system, and inter-specific relationships (Sutherland 2006).

Although the description and understanding of all requirements of any species is often impossible because of costs and time involved, some key factors that strongly influence the distribution of many species may be identified and used for modeling the relationships between the species and the environment they live in. The quantification of the relationships between a species and the environment it inhabits represents one of the key aims of environmental management. Species-habitat relationship models give a representation of goodness of habitat patches for any target species, and predict the probability of detecting a species, given a set of environmental conditions (Stauffer 2002). They can be developed as binary system (i.e., suitable/unsuitable), ordinal (i.e., high, medium, low) or ratio (i.e., index scores) values (Stoms and Estes 1993). The fundamental assumption underlying these models is that once the key environmental variables have been identified, the distribution of a species can be estimated by knowing the distribution of such variables (Scott et al. 2003).

With the relatively recent development of geographic information tools, it has become easier to represent the spatial distribution of environmental variables and produce visual presentation of spatial models as maps of habitat suitability or probability of occurrence of the species. Geographically-explicit models have become extremely powerful tools for representing the species-habitat relationship and they are extensively used in applied contexts for management. A variety of statistical and mathematical models have been developed in the last decades for the representation of species-habitat relationships (Guisan and Zimmerman 2000).

## 2.2. Wild life corridors

Patches of suitable habitat can be connected by biocorridors. A corridor is ‘a linear two-dimensional landscape element that connects two or more patches of wildlife habitat that have been connected in historical time...’ (Soulé and Gilpin 1991). Corridors give habitat patches the property of connectivity, which can affect both demographic and genetic processes. There are different reasons why connectivity between patches can be vital for wildlife populations, and these are a function of the species characteristics. For example, the size of a single patch can be too small for the population to be viable (Gilpin and Soulé 1986). Examples of corridors in the landscape include hedges, shelterbelts, roads and power lines (Lavers and Haines-Young 1993).

Wildlife corridors have been proposed as a means to moderate some of the adverse ecological effects of habitat fragmentation. It is in this context that corridors have become a significant factor in conservation management systems, Landscape corridors can be used to connect large patches of natural land in fragmented landscapes to form a network of natural lands. Because corridors are used as a means of regular travel by wildlife, in an attempt to reduce the isolation of spatially separated populations and to potentially increase the total area of habitat available. Soulé and Gilpin (1991) defined a wildlife corridor as ‘a two-dimensional landscape element that connects two or more patches of wildlife (animal) habitat that have been connected in historical time...’, while Parminter

(1998) defined a corridor as '...a narrow strip or linear element that differs from the elements on either side'.

In practice, the identification of functional connectors (i.e., pathways for dispersal and immigration) remains an open issue due to at least two challenges: (1) the absence of observational data required to make species-specific assessments of movement potential, and (2) the lack of quantitative and objective methods for analyzing the movement data in a spatial context (Lambeck, 1997, Vos et al. 2001, Vos et al. 2002, Lindenmayer et al. 2002).

Wildlife movement corridors, also called dispersal corridors or landscape linkages as opposed to linear habitats, are linear features whose primary wildlife function is to connect at least two significant habitat areas (Beier and Loe 1992). These corridors may help to reduce or moderate some of the adverse effects of habitat fragmentation by facilitating dispersal of individuals between substantive patches of remaining habitat, allowing for both long-term genetic interchange and individuals to re-colonize habitat patches from which populations have been locally extirpated. Many natural areas are critical core habitat, and are therefore inappropriate for any human development; thus the preservation of corridors will not mitigate against additional loss of core habitat (Beier 1993, Rosenberg 1997). In cases where some development may be acceptable, corridors can be incorporated into the design of a development project by conserving an existing landscape linkage or restoring habitat to function as a connection between larger protected areas. The level of connectivity needed to maintain a population of a particular species will vary with the demography of the population, including population size, survival and birth rates, and genetic factors such as the level of inbreeding and genetic variance (Rosenberg et al. 1997). These demographic parameters are important baseline data to determine the efficacy of a corridor.

## 2.3. Corridor Evaluation

Beier and Loe (1995) outlined a six-step "checklist" for evaluating corridors:

*Step 1*: Identify the habitat areas the corridor is designed to connect.

*Step 2*: Select several target species for the design of the corridor (i.e., select "umbrella species").

*Step 3*: Evaluate the relevant needs of each target species3.

*Step 4*: For each potential corridor, evaluate how the area will accommodate movement by each target species.

*Step 5*: Draw the corridor on a map.

*Step 6*: Design a monitoring program.

Evaluating how the potential corridor will accommodate movement by each species (*Step 4*) is a critical step in the process. This evaluation includes the consideration of how likely the animal will encounter the entrance to the corridor, actually enter the corridor, and follow it to the end. Additionally, it is important to consider whether there is sufficient concealing cover, food, and water within the corridor for the animal to reach the full length of the corridor, or whether such elements need to be created and maintained. Finally, specific impediments to movement within the potential corridor must be assessed, including topography, roads and type of road crossing, fences, outdoor lighting, domestic pets, noise from vehicle traffic or nearby buildings, and other human impacts.

The value of a corridor depends on its spatial configuration, landscape context, habitat type, scale, the nature of the connected areas, and the species likely to use the corridor. These factors determine corridor 'quality', which also varies depending on the species concerned (Anderson and Danielson 1997). Conservation aims also determine how valuable a corridor is from a human perspective, and explicit goals are recommended in corridor design (Wilson and Lindenmayer 1995).

Other spatial characteristics can be important in determining the value of corridors. Corridor length has not been as thoroughly investigated as corridor width, but optimal corridor length has been considered to be a function of species-specific behavior and habitat quality. Minimizing corridor length, especially when animals do not breed within the corridors, is recommended (Wilson and Lindenmayer 1995). Habitat quality is important in its own right, and has been shown to influence the effective connectivity of corridors (Harrison 1992; Bennett et al. 1994).

Another characteristic that influences the value of a corridor is its position in the landscape. Bennett (1999) proposed that, in general, corridors should be located along environmental contours to ensure habitat continuity, and there has been emphasis on riparian corridors. This is partly because they are also important for protection of water catchments and partly because they tend to be species rich and structurally diverse relative to surrounding areas (Brinson and Verhoeven 1999). However, retaining a range of topographies has been shown to be important for mammals in south-eastern Australia (Claridge and Lindenmayer 1994) and for birds in Oregon (McGarigal and McComb 1992). Species that use a range of resources may require a variety of landforms, and it may be necessary to link similar habitats by crossing different habitat (e.g. linking two riparian areas with a corridor across a ridge top).Harrison and Voller (1998) considered that ‘corridor location and design should reflect the ecology of an area’.

## 2.4. Habitat patches

Habitat patches need not be physically connected by contiguous habitat in order for organisms to move among them. A species may be capable of crossing habitat gaps, or the matrix separating patches, and thus functionally connect areas that are not structurally connected. The matrix between two patches may consist of complex ensembles of multiple land uses, some more amenable to organism movement than others. Preferred movement pathways through matrix elements are thus functional (but not necessarily structural) corridors (Andrén 1994).

## 2.5. Habitat Fragmentation

Habitat fragmentation is a landscape scale process in which continuous unaltered habitat is reduced into smaller habitat remnants. This implies a variable number of remaining fragments scattered within a matrix of modified habitat (Andrén 1994). Besides the loss of unaltered habitat, the process of fragmentation results in four other effects: an increase in number of fragments, a decrease in fragment size, and an increase in both fragment isolation and total forest edge (Andrén 1994, Fahrig 2003).

Habitat fragmentation alters both the abiotic, e.g., radiation, temperature, humidity, winds speed, and biotic, e.g., population size, biodiversity, conditions near habitat edges: the so called edge effects (Saunders et al. 1991). In general, edge effects modify plant composition and vegetation structure in the fragments by increasing the mortality rate of large old-growth tree species, and decreasing the total basal area in smaller and more irregularly shaped fragments (Arroyo-Rodríguez and Mandujano 2006a). These vegetation changes can affect important plant species for primates, reducing the quantity and quality of food resources available to them (Arroyo-Rodríguez and Mandujano 2006b; Tutin 1999). Therefore, primates in habitat fragments are confronted with a modified environment of reduced area, increased isolation, and novel ecological boundaries.

Wildlife Habitat fragmentation is one of the major biodiversity conservation issues facing the world today. This fragmentation may be natural (such as the distribution of alpine habitat) or human-induced, and may occur on many scales. However, when habitat fragmentation is discussed in conservation terms, it is generally regarded as referring to anthropogenic alterations on a landscape scale. The causes of such fragmentation have mostly been land clearance for agriculture, forestry, or urban development.

## 2.6. Wildlife and their conservation in Ethiopia

Ethiopia, located in the horn of Africa, has long been recognized for its wealth of natural resources, endemic species, and high biodiversity (Table 2.1). While Ethiopians have recognized the commercial value of their natural assets for some time, these assets remained largely unprotected until the mid-1960s, when the government instituted a conservation- and protected-area program. The primary intention of this program was to establish bylaws and areas for the conservation and protection of a range of species and habitats. The promotions of tourism and income generation were secondary priorities (Turton, 1987; Abraha Misginna, 1991).

Despite getting a late start on conservation, Ethiopia has accomplished a considerable amount and should be commended for its efforts. Most important has been its attempt to conserve the largest area of afro-alpine habitat on the continent and ensure the survival of several endangered species and endemics (Table 2.1). These include the Ethiopian wolf (Canis simensis), African wild dog (Lycaon pictus), Mountain Nyala (Tragelaphus buxtoni), Walia ibex (Capra walie), African elephant (Loxodonta africana), African wildass (Equus africanus), Soemmerring’s gazelle (Gazella soemmerringii), Swayne’s hartebeest (Alcelaphus buselaphus swaynei), and the genetic material of many other species. Other notable activities include the establishment of numerous protected areas and the conservation of diverse native species within these areas.

Table 2.1 Endemic wildlife's and total number of species in Ethiopia

| **Group** | Birds | Mammals | Reptiles | Amphibians | Freshwater Fish | Butterflies | Plants |
|---|---|---|---|---|---|---|---|
| **Number of species** | 861 | 280 | 201 | 63 | 150 | 324 | ~ 6,044 |
| **Number of endemics** | 28 | 31 | 9 | 24 | 4 | 7 | ~ 1,150 |

Source: Michael J. Jacobs Catherine A. Schloeder, 2001

These initiatives were undertaken for the sake of education, research, and recreation, and because these areas provide such essential items as fuel wood, building materials, forage, traditional medicines, and wild foods, Ethiopia's conservation- and protected-area program has provided varying levels of protection to certain watersheds and many essential natural processes and cycles (e.g., pollination, seed dispersal, and soil hydrology). Furthermore, it has generated income both nationally and locally through tourism, hunting, and the sale of wildlife (e.g., primate exports) and wildlife products, i.e. crocodile (Crocodylus niloticus) skins, ostrich (Struthio camelus) skins, and civet (Viverra civetta) musk).

Additionally, several of Ethiopia's protected areas exist on paper only, while others have declined in size or quality (Schloeder, 1993). (http://lcweb2.loc.gov/frd/cs/ettoc.html 2000). The majority of conservation problems, however, can be attributed to Ethiopia's adoption and implementation of an exclusionary protected area policy and to the causes and consequences of its prolonged engagement in different conflicts. (Table 2.2)

Table 2.2. Ethiopia's National Parks and Wildlife Sanctuaries, the reasons they were established

| **Protected area** | **Reason established** | **Ongoing projects** |
|---|---|---|
| Abijatta-Shala National Park | Protects aquatic birds; two rift valley lakes | Biologist training project, WCS Infrastructure Improvements, UNDP and WCS |
| Awash National Park | Protects the Beisa Oryx, Soemmerring's Gazelle, and Swayne's Hartebeest | Development of a management plan, WCS |
| Babille Elephant Sanctuary | Protects endemic sub-species of elephant | |
| Bale Mountains National Park | Protects endemic Mountain Nyala, Ethiopian wolf, and giant mole rat; also protects a rare Afro-alpine habitat and moist highland forest | Conservation research for the Ethiopian wolf, WCS and WWF Infrastructure development project, WWF |
| Gambella National Park | Protects Nile Lechwe, white eared kob, and whale-headed stork in extensive swamp habit | |
| Kuni-Muktar Mountain Nyala Sanctuary | Protects Mountain Nyala and remaining highland forest | Conservation project for the protection of Mountain Nyala, ZSL |

Source: Michael J. Jacobs Catherine A. Schloeder, 2001

### 2.6.1. Nile Lechwe (Kobus megaceros)

**Population:** The Nile Lechwe is confined to seasonally flooded swamps and grasslands within Sudan and Ethiopia. In Sudan, the bulk of the population is found in the Sudd swamps, with smaller numbers in the Machar marshes near the Ethiopia border. In Ethiopia, the Nile Lechwe occurs marginally in the south-west, in the Gambella National Park, where its survival is probably highly precarious because of expanding human activities (Hillman and Fryxell 1988; East 1999; Falchetti in press).

Most animals were concentrated mainly within the swamps on the west bank of the Nile (Mefit-Babtie 1983). Probably less than 1,000 animals were present in Machar-Gambella (Hillman and Fryxell 1988). An aerial survey carried out by WCS in the early dry season in southern Sudan in 2007 yielded an estimate of 4,291 animals, and identified the Zeraf Reserve as the most important protected area for this species (Fay et al. 2007).

**Movement:** They are almost always in shallow waters on the edge of deeper swamps where the water is between 10 and 40 cm deep. Nile Lechwe undergoes short seasonal movements (30-40 km) to follow the rise and fall of floodwaters. (Mefit-Babtie 1983).

**Diet:** Nile Lechwe feed on succulent grasses and a few other water-dependent swamp plants. Wild rice is thought to be a preferred food at the start of the flood season, while a larger proportion of swamp grasses are consumed when the waters recede. Nile lechwes have the special capability to wade in shallow waters and swim in deeper waters. It may feed on young leaves from trees and bushes, rearing up to reach this green vegetation. Nile Lechwes are also found in marshy areas where they eat aquatic plants. (Echinochloa and Digitaria, 1982).

**Habitat:** Nile Lechwe, as with red Lechwe, dwell almost exclusively in flood plains and wetlands where they are uniquely adapted to the area's wetlands, swamps and marshes; Lechwe are adept swimmers and waders. These swamps are an ancient, major world swamp system that is very little known or understood. The remote habitat has most probably afforded the species adequate protection, despite its limited range in a difficult war torn region (Mefit-Babtie 1983).

Social Organization: Female Lechwe live in cow/calf herds of up to 50 individuals. Near Lakes Yirkol and Nyubor, herds are larger and reach several hundred individuals in areas possessing good food resources. Female herds contain a single adult male. Other males form bachelor herds.

**Threats to Survival:** The status of this species is satisfactory, the inaccessibility of their habitat providing considerable protection against hunting. Regardless, it is potentially vulnerable because the species largely occurs in only one area.

## 2.7. Remote Sensing and GIS for Wildlife Management

Human-caused disruptions, such as habitat loss, pollution, invasive species introduction, and climate change, are all threats to wildlife health and biodiversity. GIS technology is an effective tool for managing, analyzing, and visualizing wildlife data to target areas where interventional management practices are needed and to monitor their effectiveness. GIS helps wildlife management professionals examine and envision; Habitat requirements and ranges, Population patches and linkages, Disease levels within populations, Progress of management activities, Historical and present wildlife densities among others (Coppin et al. 2002)

Understanding the specific needs of wildlife populations is a key to preventing local or global extinctions, rehabilitating populations, and restoring habitat. In the following case studies, you will learn how wildlife management professionals around the world have successfully implemented GIS to respond to invasive species, manage and facilitate disease prevention, minimize mortality, and determine wildlife movement and habitat ranges.

Recent technologies such as Geographical Information Systems (GIS), and Global Positioning Systems (GPS) and Remote Sensing are being used in combination for the input, storage, manipulation, analysis, and display of geographic information and its associated attribute data (Coulson 1992). These spatial techniques provide an effective and efficient means of generating habitat spatial information as well as more accurate measures of damage caused by wildlife (Anderson 1996).

GIS is increasingly being used in combination with habitat models as a source of environmental variable predictor and as a method of displaying model results. With advances in computer technology and an increasing interest to understand spatial relationships within wildlife habitat ecology, GIS technology has become increasingly useful in wildlife management and research. Recently, further advances in the acquisition of digital remotely sensed image data such as hyper spectral remote sensing provides a valuable source of data for the modeling of wildlife-crop raiding incidences (Austin et al. 1996).

## 2.8. Land Suitability Analysis

The process of land capability classification is the evaluation and grouping of specific areas of land in terms of their suitability for a defined use. The main objective of the land evaluation is the prediction of the inherent capacity of a land unit to support a specific land use for a long period of time without deterioration, in order to minimize the socioeconomic and environmental costs (FAO, 2003). Land suitability analysis is an interdisciplinary approach by including the information from different domains like soil science, crop science, meteorology, social science, economics and management. Being interdisciplinary, land suitability analysis deals with information, which is measured in different scales like ordinal, nominal and ratio scale. Based on the scope of suitability, there are two types of classifications.

*Current suitability*: This refers to the suitability for a defined use of land in its present condition, without any major improvements in it.

*Potential suitability*: This refers for a defined use of the land units in their condition at some future date, after specified major improvements have been completed where necessary.

### 2.8.1. Habitat Suitability Indices

In the last decades there has been a considerable amount of work done towards the identification of relationships that would express how species relate to the environment, thus guiding towards the conservation of particularly valuable areas. One approach used extensively for this purpose is the development of Habitat Suitability Indices (HSI). They were developed by the U.S. Fish and Wildlife Service (USFWS) in the attempt to establish linear relationships between species and environmental variables (Conway and Martin 1993, Donovan et al. 1987, Duncan et al. 1995, Thomasma et al. 1991) in a standardized way across all the United States (U.S. Fish and Wildl. Serv. 1981).

HSI are models that incorporate a number of environmental variables considered to be important for the presence of a given species. They are related to the species presence in a quantitative way using data from field studies and combined spatially in a GIS (Donovan et al. 1987). Despite representing a step towards standardization and objectivity, the HSI contain a great deal of subjectivity in various steps of their development. The selection of significant variables is left to subjective decision by scientists and experts who have conducted field studies (Scott et al. 1993). More importantly, the weight that each variable is assigned can be highly subjective and strongly location-dependent (Heinen and Lyon 1989). The applicability of the models is therefore restricted to specific areas and generalization can hardly be done unless the model is developed upon information coming from a large number of sites throughout the species' range (O'Neil et al. 1988).

### 2.8.2. GIS Layers

GIS analysis is widely used in transportation and natural resources management today. Analyses can be done in multiple spatial scales ranging from project to landscapes and regions. Many of the map and data resources listed above are available in digital format and can be overlaid and analyzed in ArcView/GIS® or ArcMap®. Basic GIS layers useful for identifying habitat linkages and sitting wildlife crossings at the systems-level include:

- Digital elevation model (DEM; characterizes topography, preferably <30m resolution)
- Water or hydrology (includes all lakes, ponds, rivers, streams)
- Vegetation or ecological land classification system (general habitat types)
- Wildlife habitat suitability (species-specific habitat map)
- Built areas (areas of human development and activity)
- Roads (network of all paved and unpaved roads)

## 2.9. Habitat modeling

Habitat suitability modeling has been advanced by Geographic Information Systems (GIS) and Remote sensing. GIS is an excellent tool for identifying areas of conservation significance and assessing the habitat potential of unstudied sites (Lenton et al. 2000).and also Mathematical models are available for establishing potential connectivity among patches (as defined by Calabrese and Fagan, 2004), but these methods generally provide a list of patches that are connected rather than a description of the preferred pathways used to successfully move between patches. However, it is precisely this spatially explicit mapping of functional corridors that is necessary from a management perspective in order to preserve, and, in some cases, restore connectivity.

Habitat modeling has become a popular method to identify areas for conservation consideration for single and multiple species. The popularity of these methods has increased with the availability of new software programs that are capable of manipulating the vast array of datasets available for most areas of the United States. Modeling can become a cost-effective tool to identify areas that should be surveyed for species presence. Once suitable habitat is identified, then monitoring of species abundances and population trends can be conducted to provide insight into the impacts of development on these habitats and the species that inhabit them.

The growth of geographic information systems (GIS) throughout natural resources, county, and city planning agencies has furthered the need and necessity of including habitat into future development strategies. Identification of key habitats can assist planners in locating new developments, ensure open space with connectivity, and provide ecosystem services to city and county inhabitants. Ecosystem services are services that the ecosystem provides to humans and can increase the value (financial, emotional, or physical) for occupants. (Calabrese and Fagan, 2004)

### 2.9.1. Types of modeling

There are several approaches available for the habitat modeler based on deductive and inductive logic, though both use environmental variables. Environmental variables are GIS datasets that portray some type of ecological, topographical, or management surface. Deductive habitat models use literature and expert knowledge to identify suitable combinations of environmental variables. The deductive model is a descriptive model based on the suitability or unsuitability of the individual attributes of each environmental variable. A weighted or ranked method can be employed by identifying certain habitats as having greater suitability or probability of occurrence.

Inductive habitat models use species occurrence records to drill through environmental variables. This process identifies associations through mathematical algorithms and species presence. Traditionally, there has been a need to identify both presence and absence of species for these algorithms to work such as in logistic regression. Recently, several algorithms (e.g. Maximum Entropy; Phillips et al. 2006, Phillips and Dudek 2008) have been created that use presence-only occurrence datasets for modeling. Santa Fe County wildlife modeling efforts and in general land suitability analysis have incorporated deductive modeling to create a baseline starting point. More detailed models with greater accuracy will incorporate field studies and the collection of species occurrence data.

# CHAPTER THREE

# 3. MATERIALS AND METHODS

## 3.1. DESCRIPTION OF THE STUDY AREA

### 3.1.1. Location

Gambella National Park located about 600 kilometers from Addis Ababa on the river Baro, Gambella National Park is in the centre of Gambella Region. It lies between the Baro and Gilo rivers, the Baro River forming the northern boundary, 15 km south of Gambella town.

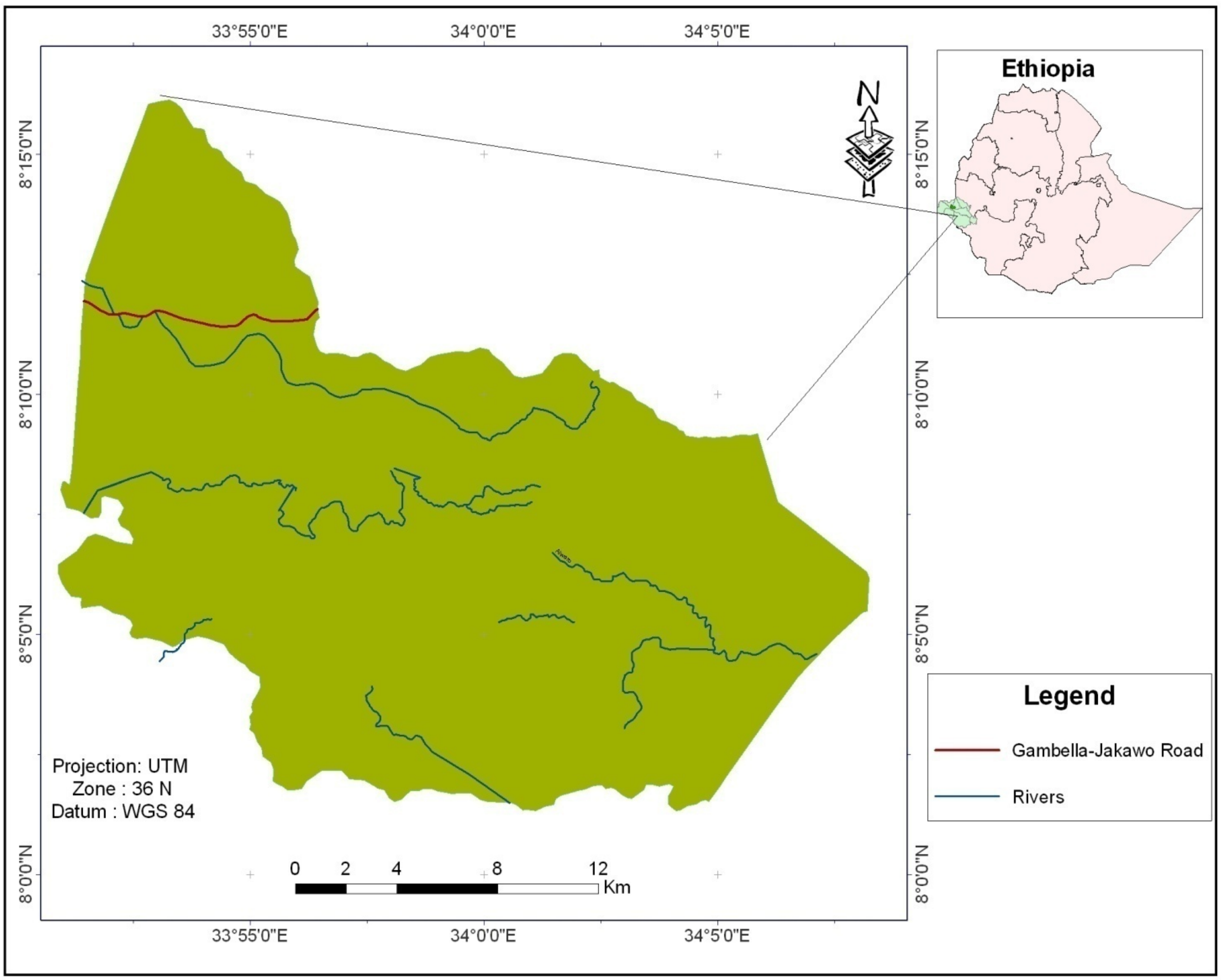


Figure 3.1 Location map of Study Area

The Gambella National Park shares Boundaries with Itang wereda in the North East, Jikawo Wereda in the North and South West and Abobo Wereda in the South. The geographic location extends from $8^{\circ}1'22''$ N to $8^{\circ}16'14''$N latitude and $33^{\circ}50'54''$ E to $34^{\circ}8'12''$ E longitude covering a total area of 472.2 $km^2$(Fig 3.1).With an elevation ranges from 300 meter to 2000 meter above mean sea level.

### 3.1.2. Relief and Topography

Gambella is characterized by a variety of elevation. The eastern part has an elevation of 2000- 1000 meter above sea level. The middle part has an elevation of 900-500 meter above sea level and the western part has an elevation of 500- 300 meters above sea level (Woube, 1999). This trend shows a progressive decline from east to west. In general the land in the region is characterized as flat plain with some areas of higher ground where deciduous woodland and savanna occur. The higher areas are often rocky with large termite mounds. The park also supports extensive areas of wet grassland and swamps with grasses growing over 3 m tall. Other important habitats include the rivers, their banks and the oxbow lakes.

### 3.1.3. Drainage

The major rivers within Gambella region are the Baro, Alwero, Gilo and Akobo with their tributaries originating from the highlands which have immense potential for diversified species. The eastern foothills that lie below the main escarpment are between 1,300 and 600masl and the plains to the west of the foothills between 450 to 600masl.  There are 12 major river basins in Ethiopia seven of which flow across the international border to Sudan, Somalia or Kenya. Some 74 percent of the estimated annual flow of 110 billion cubic meters flow out of Ethiopia. Irrigation and hydroelectricity generation are the main economic uses to which the water is put. Some 161,010 hectares are currently irrigated out of a potential area of 3.5 million hectares, and some 1,698 GWH generated per annum out of potential power generating potential of 135, 311 GWH per annum (or 1.25 percent).

### 3.1.4. Climatic conditions

The climate of the Region is formed under the influence of the tropical monsoon from the Indian Ocean, which are characterized with high rainfall in the wet period from May to October and has little rainfall during the dry period from November to April.

#### 3.1.4.1. Temperature

The mean annual temperature of the Region varies from 17.3$^oC$ to 28.3$^oC$ and annual monthly temperature varies throughout the year from 27$^oC$ to 33$^oC$. The absolute maximum temperature occurs in mid March and is about 45$^oC$ and the absolute minimum temperature occurs in December and is 10.3$^oC$.

#### 3.1.4.2. Rainfall

Rainfall generally increases with altitude, from 850 mm in the west to over 2,000 mm at the highest parts of the escarpment. Temperature is inversely related to altitude, the annual rainfall of the Region in the lower altitudes varies from 900-1,500mm. At higher altitudes it ranges from 1,900-2,100mm. The annual evapo-transpiration in the Gambella reaches about 1,612mm and the maximum value occurs in March and is about 212 mm. Normal rainfalls in Gambella starts in May and ends in late September (Akobo Baro Basin Study, 1999). Total rainfall is 720 to 1350mm in areas between 500 and 1000 m.a.s.l. during this period. This is approximately 80-90% of total annual rainfall (900 to 1500mm).

### 3.1.5. Vegetation Cover

According to the Woody Biomass Inventory and Strategic Planning Project (2001) the region falls into three broad ecological-vegetation zones: (i) the main escarpment largely covered with high forest; (ii) foothills and plains covered with lowland forest and savanna woodland; and (iii) to the west extensive grassland plains and seasonally flooded swamps. More than 7.7 % of the total surface area of the region is wetland (open water, perennial and seasonal swam/marsh). The swamp areas are very important for wildlife's and breeding sites of many fish species.

The Eastern part of Gambella Region is covered with high forests, ranging from a Lowland forest with affiliations to the Guinea-Congo plant realm, a mixed broadleaf montane forest and in between a transitional forest containing both Lowland and Montane Forest species. This rich forest heritage is under threat from rapidly expanding small-scale agriculture. Beyond the forests are open Combretum-Terminalia woodlands which are habitat to a wide range of fauna and site of the Gambella Regional Park.

Agriculture in the foothills comprises a form of forest fallowing that incorporates mulching to suppress weeds, enset with grass-bush fallowing, and coffee cultivation under the forest. In the lowlands rain fed cropping is generally confined to the levees and floodplains of the main rivers. On the extensive grasslands the Nuer practice an oscillating pattern of cattle herding between the slightly higher areas in the wet season, moving down to the alluvial plains as the flood recede. Regionally, bio-fuels provide 99.8 percent of the total energy supplies.

## 3.2. DATA ACQUISITION AND SOFTWARE PAKAGE

### 3.2.1. Materials

The following softwares were used in this study. These are ArcGIS 9.2, ERDAS IMAGINE 9.2, ENVI 4.3, IDRISI Andes 15.0, Global Mapper, 3DEM, Microsoft Word and Microsoft Excel (Table 3.1). In addition, topographic maps of scale 1:50000, time series satellite imageries and diverse ancillary data have been used in order to identify historical and recent land use/ land cover of the study area.

Table 3.1: Details of materials and software's used in the current study

| No | Type of Data | Description | Source of the Data |
|---|---|---|---|
| 2 | Softwares | ArcGIS 9.2, ERDAS 9.1, ENVI 4.3, IDRIS Andes 15.0, Global Mapper, 3DEM, MS Excel, MS Word | |
| 3 | Instruments | GPS (GARMIN), Digital Camera | |

### 3.2.2. Remote Sensing Data Used

The input remote sensing data were taken from various offices where relevant information was expected to be available. Accordingly, the following data shown in table 3.2 were obtained from the respective offices.

Table 3.2. Data used for Analysis

| Item | Data type | Source | Remarks |
|---|---|---|---|
| 1 | SRTM 30 meter data | GSOE | 30m |
| 2 | Spot 5 satellite Image 2009 | INSA | Path/raw: 575-087, 600-087, 575-090, 600-090 |
| 3 | Meteorological data, $T^0$, RF | NMA | 10 Years Data |
| 4 | Topo map 1:50000 | EMA | |
| 5 | Study area Boundary | INSA | Shapefile |

## 3.3. RESEARCH METHODOLOGY

The study is aimed at first identifying functional Landscape areas and then Mapping wildlife corridors for Nile Lechwe Species. For mapping functional Landscape areas for Nile Perch five parameters were selected by consulting a Wildlife expert and depending on related previous works. The factors include distance from settlements, slope, Land Use/Land Cover, Distance from Wetlands and Climate/Rainfall. The wildlife corridor Mapping was done using MCE. (Figure 3.2) To carry out the MCE, weight for the factors depending on their suitability for species was given in IDRISI software. Then the overly analysis was conducted using ArcGIS 9.2 spatial analyst extension. Finally, the wildlife corridor Map for the selected species map was produced by including distance from rivers, distance from wetlands, land use/land cover and functional landscapes layer.

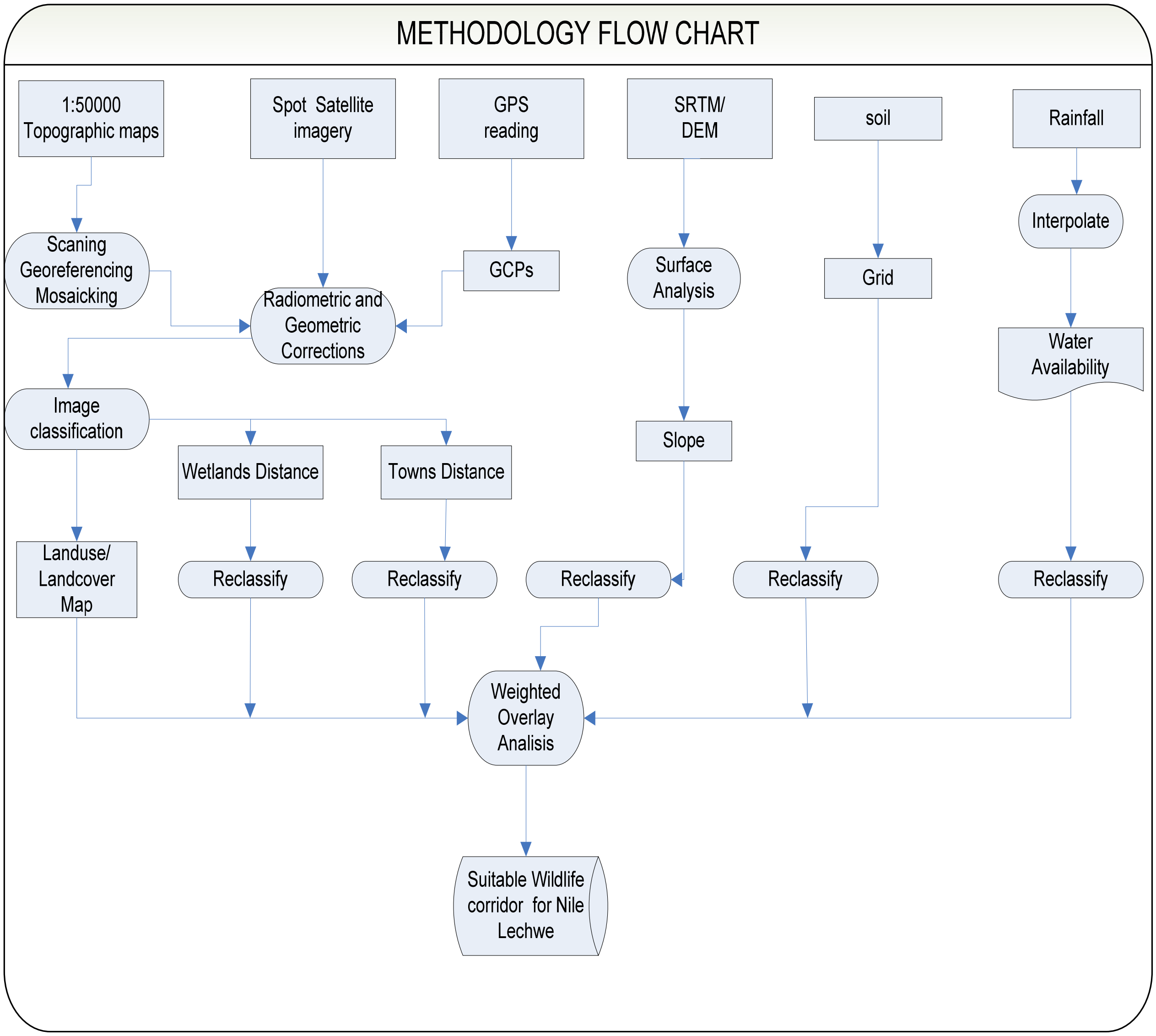


Figure 3.2 Methodology flow chart

## 3.4. DATA PROCESSING AND ANALYSIS METHODS

### 3.4.1. Mapping Parameters

After the data collection, preprocessing satellite images has been made and relevant parameters which can be used for mapping functional wildlife corridor and landscape were extracted. Their relevance for the mapping is described in Table 3.3.

Table 3.3. Mapping parameters and their use

| Parameter /Map | Relevance for mapping |
|---|---|
| Distance from rivers, and wet lands | For identifying surface waters and swamps as they are areas favored by Nile perch. |
| Slope | For identifying of areas receptive to water logging |
| Land use/ Land cover | For identifying vulnerable and receptive areas for the wildlife Species. |
| Distance from settlements | In order to minimize visual, noise, and land use impacts on the wildlife |
| Soil Type | Is crucial for rating functional landscape for suitability because the fodder for wildlife's i.e. grasses and water logging characteristics of the land |
| Rainfall | Water availability for feed growth is one of the single most important factors that determine suitability. |

#### 3.4.1.1. Distance from Wetlands

Wetlands provide habitats for the Nile Lechwe. The Nile Lechwe lives in swamps and flooded grasslands in southern Sudan and western Ethiopia, and are often found in shallow water 10-40 cm deep. The wetlands layer was extracted from land use land cover map of the study area. Then, distance Calculation and reclassification was done on the layer. The wetlands in the study area were mapped (Figure 3.3) and their distance buffered using GIS according to the Nile Lechwe species habitat tied to the wetlands a new value assigned to areas according to their proximity to these wetland areas.

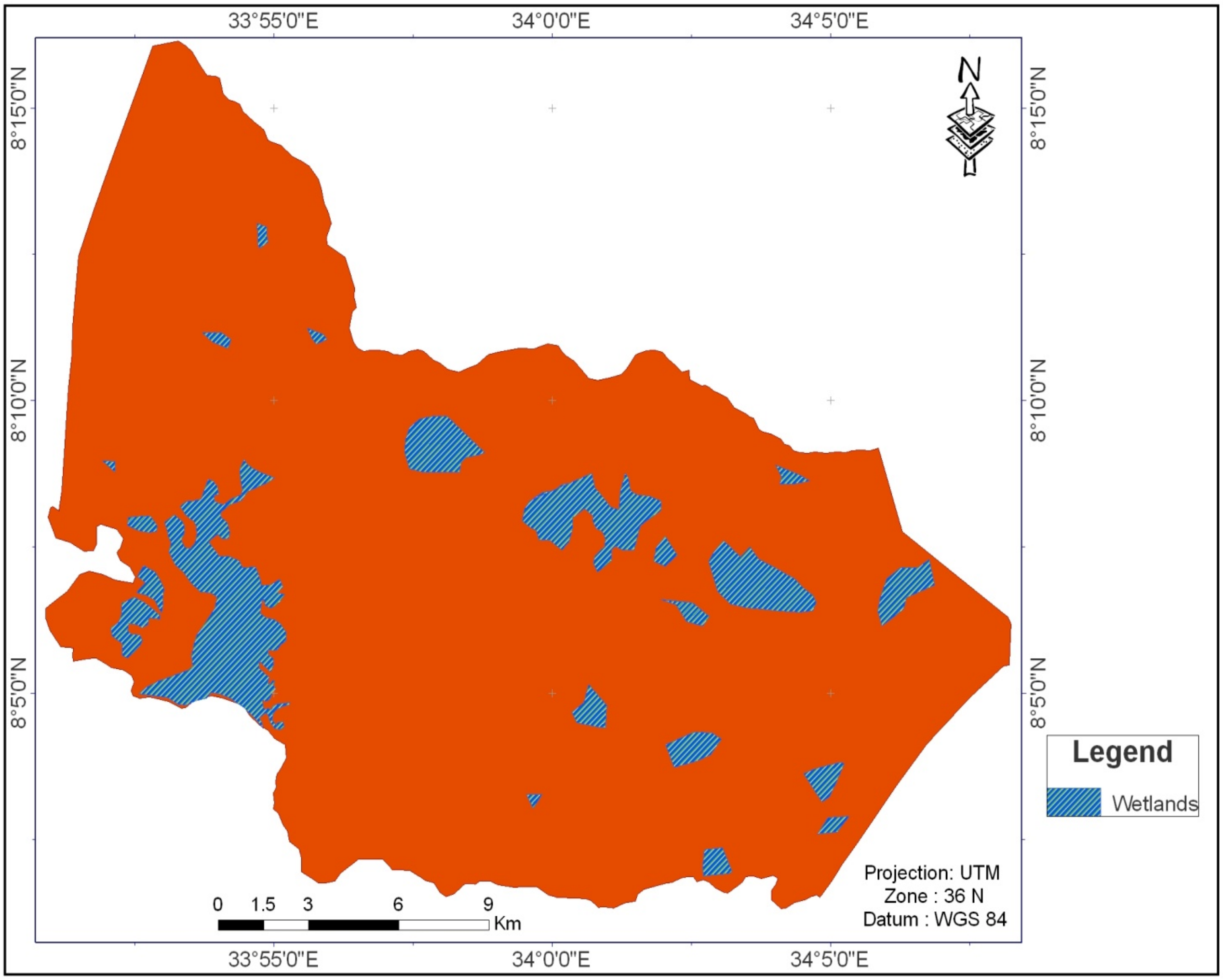


Figure.3.3. Wetlands location Map.

Hence, new values as it is indicated in figure 3.4. were re-assigned as 4, 3, 2, and 1 in order to show the relative susceptibility of the class ranges of 0-3km, 3-9km, 9km-12km,(Table 3.4) The maximum East-West and North-South extent of the study area is 29 km therefore all places fall under weather highly, Moderately or Marginally suitable areas.

Table 3.4 Distance from wetlands suitability of the study area

| Distance from Wetlands (km) | Suitability |
|---|---|
| 0-3 | Highly Suitable |
| 3-7 | Moderately Suitable |
| 7-12 | Marginally Suitable |
| 12-30 | Currently Not Suitable |

The reclassified sub groups of distance from wetlands were ranked according to species movement distance threshold value. Areas out of the maximum Moving distance threshold were considered to be less suitable. (Figure 3.4)

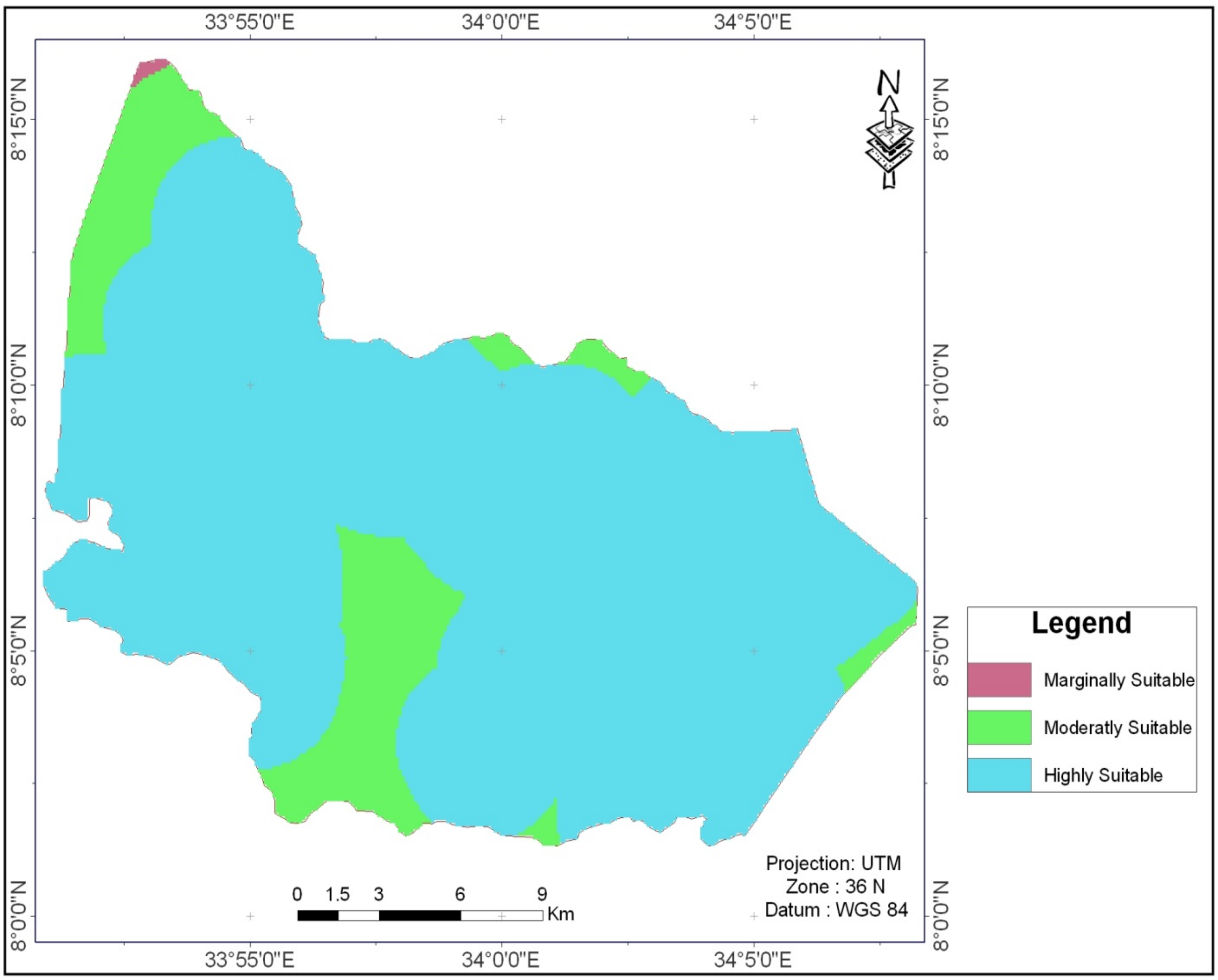


Fig. 3.4 Reclassified Distances from Wetlands map

#### 3.4.1.2. Land Use/Land Cover

The land use should carefully be evaluated to determine how best the functional landscapes and wildlife corridors can integrate with the existing land uses. Accordingly, developing landscape corridors depends on having suitable land for wildlife's survival or not. In addition, vegetation especially grasslands and wet lands are places where Nile Lechwe found abundantly. It requires fresh graze and drinks daily. The Nile Lechwe prefers flat areas close to permanent water and consistent climate and dwell almost exclusively in flood plains and wetlands where they are uniquely adapted to the area's wetlands, swamps and marshes, (Table 3.5).

Table 3.5 Present land use / land cover types of the study area

| Land use/Land cover | Area in ($km^2$) |
|---|---|
| Natural Forest | 13.2 |
| Grassland | 195.2 |
| Wetlands | 92.1 |
| Shrubs | 15.2 |
| Bare lands | 156.2 |
| Total | 472.2 |

Since, it is dependent on water, thus, land use of the study area is ranked according to availability of wetlands and grass lands. Accordingly, wetlands and grasslands are considered as most suitable and moderately suitable land classes respectively while bare lands are considered as least and permanently not suitable land classes as they are not satisfied the species requirement for fodder and shelters respectively (Figure 3.5).

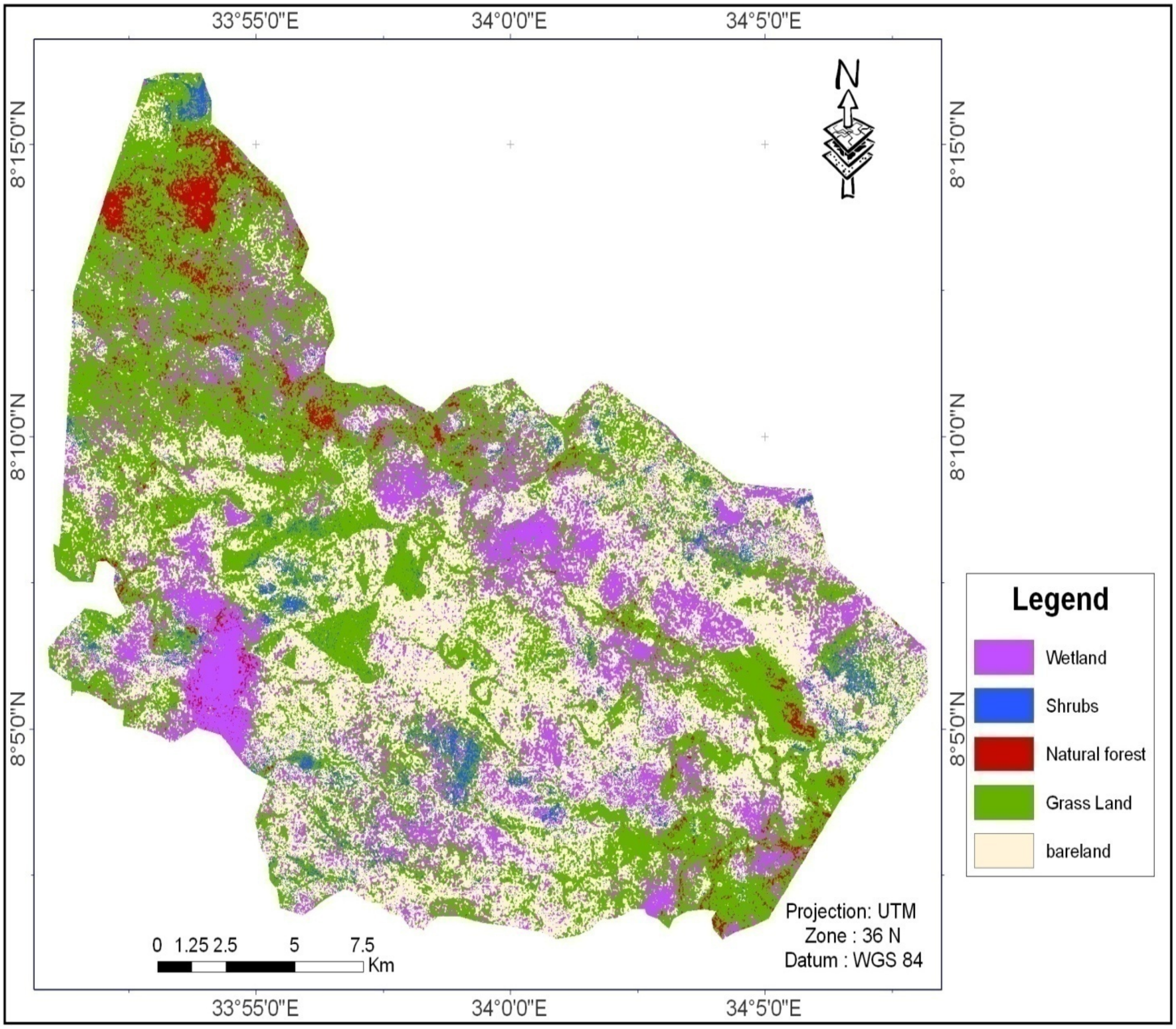


Figure 3.5 Land use/ Land cover map of 2009

#### 3.4.1.3. Slope

Concerning the slope of the study area, the steeper the slope, difficult for movement of species. This is because steep slope will require more grading and earth movement than gentle slope. The slope of the study Area (Figure 3.6) was derived from 30 meter SRTM data and reclassified in to five classes like the other parameters using natural break standard reclassification technique.

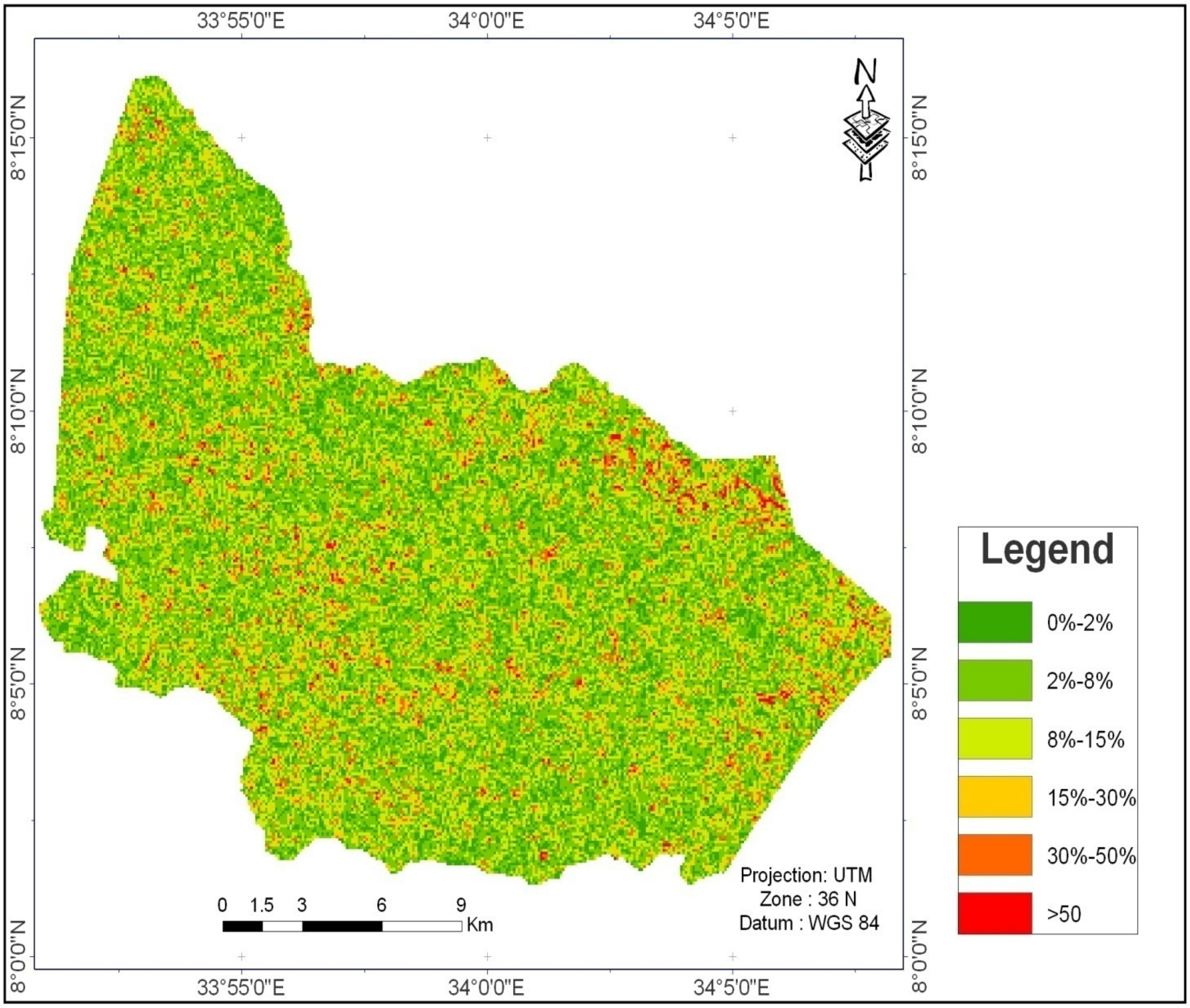


Figure 3.6 Slope Map (%)

Slope gradient has great impact on Nile Lechwe movements , Consequently, the slope is ranked according to its significance for Nile Lechwe shelter, fodder and water resources therefore, the new classes (0-5°, 5-12°, 12-22°, 22-36°, 36-69°) described as high, moderately high, marginally suitable, ,currently not suitable and permanently not suitable respectively based on the relative degree of suitability of the slope class for wildlife corridor for Nile Lechwe (Figure 3.7).This means that relatively, gentler slopes are better suitable for Nile Lechwe .and steeper slopes are less suitable. Steep slope is classified as permanently not suitable and gentle slope was classified as most suitable.

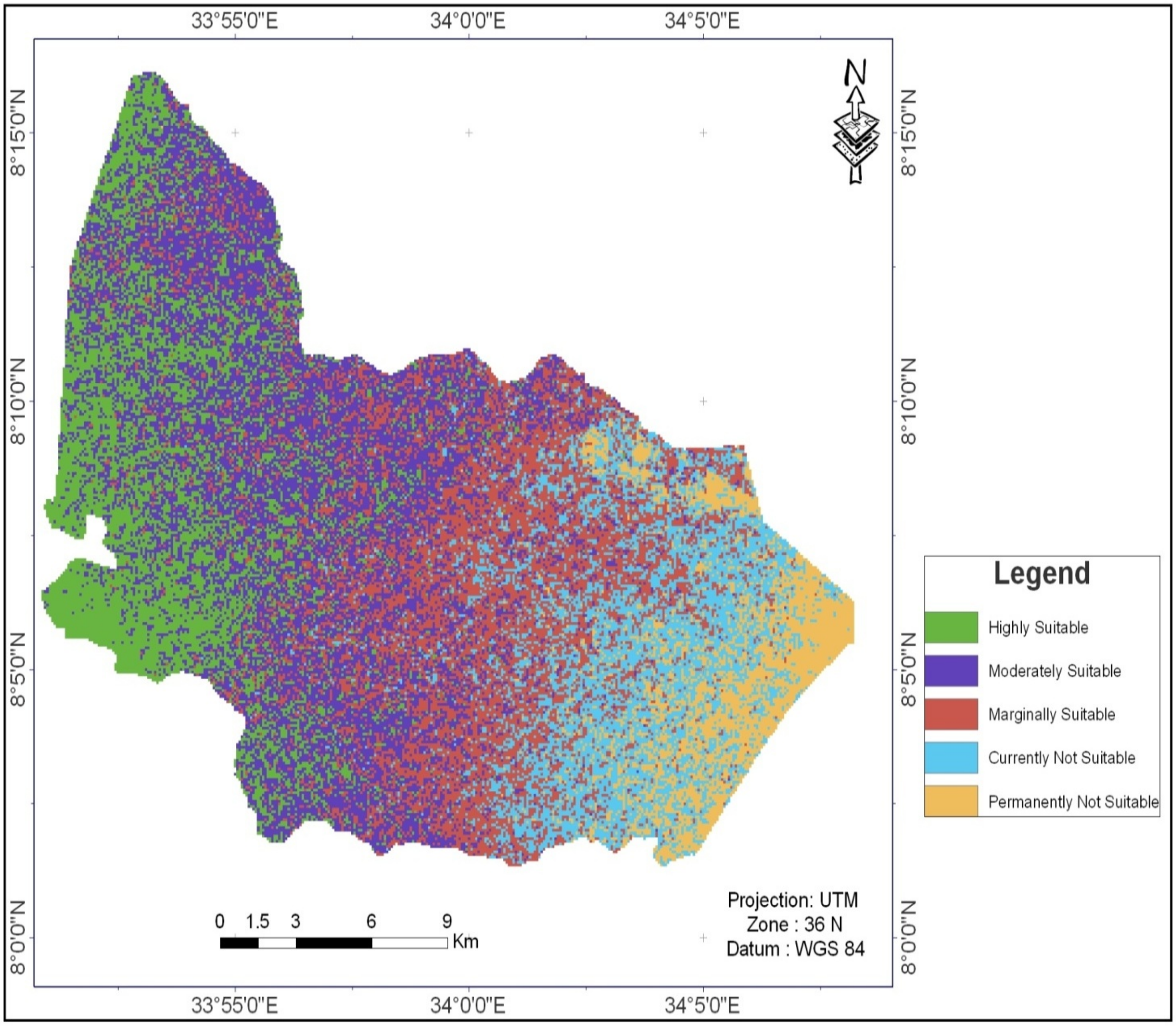


Figure 3.7 Reclassified Slope map

#### 3.4.1.4. Distance from settlements

In order to minimize visual, noise, and land use impacts; wildlife corridors should be established a certain kilometers far from the towns. For this study, distance from nearest towns is considered. (Figure 3.8) Therefore, distance from the town is reclassified into four based on the impacts of the town residents to the wildlife's. As a result, distance between 12km -20 kms is reclassified as the highly suitable, from 9km -12km moderately suitable, 6km-9km, marginally suitable, while distance between 3km-6kms is considered as currently Not suitable and 0km-3km permanently not suitable.

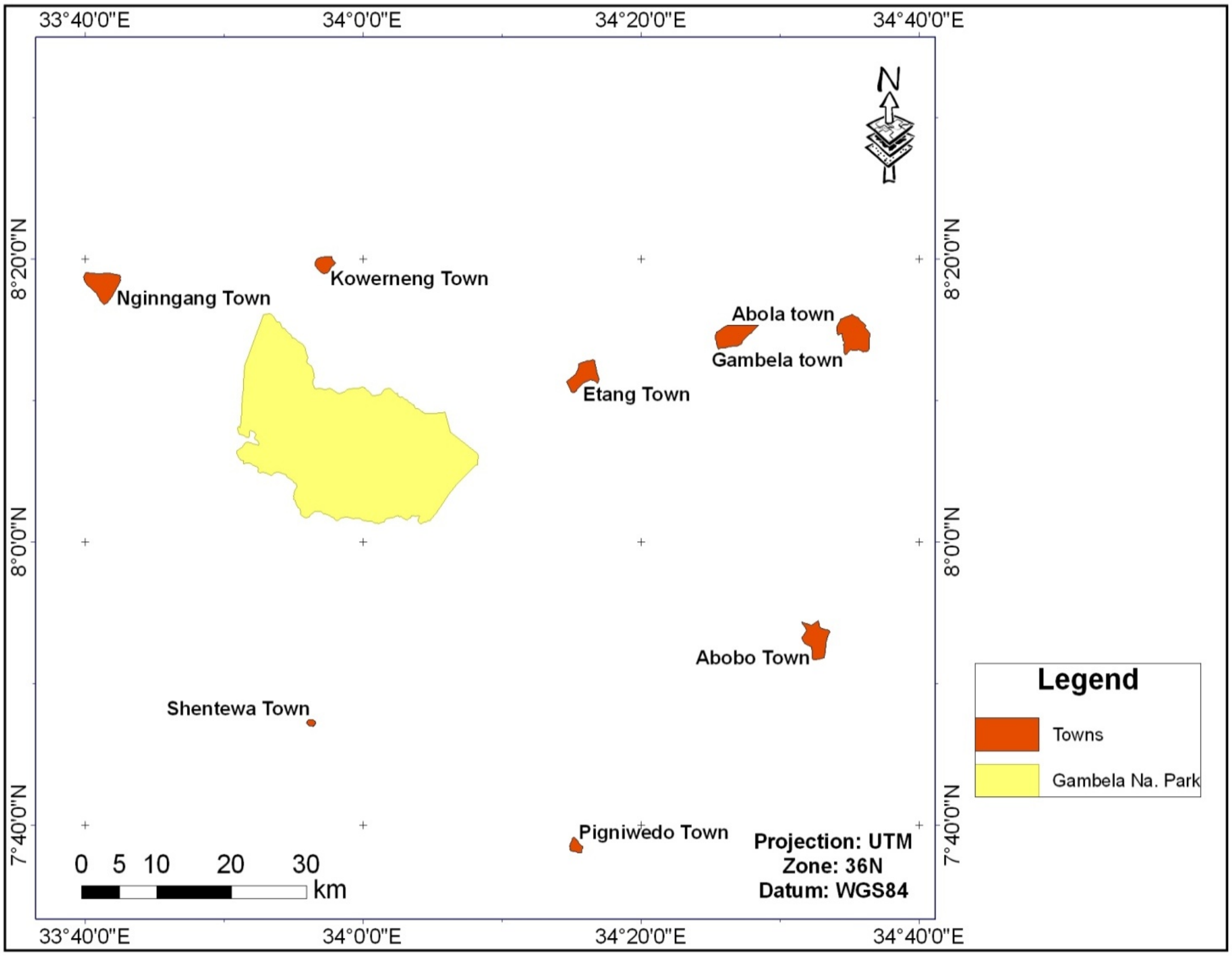


Figure 3.8 Nearest towns map

Proximity to human settlements, Major transportation routes and associated urban land uses often defined the limits of habitat concentrations and wildlife corridors, accordingly by making a buffer rings according to proximity ti the nearby towns the study area divided in to five classes. (Fig 3.9)

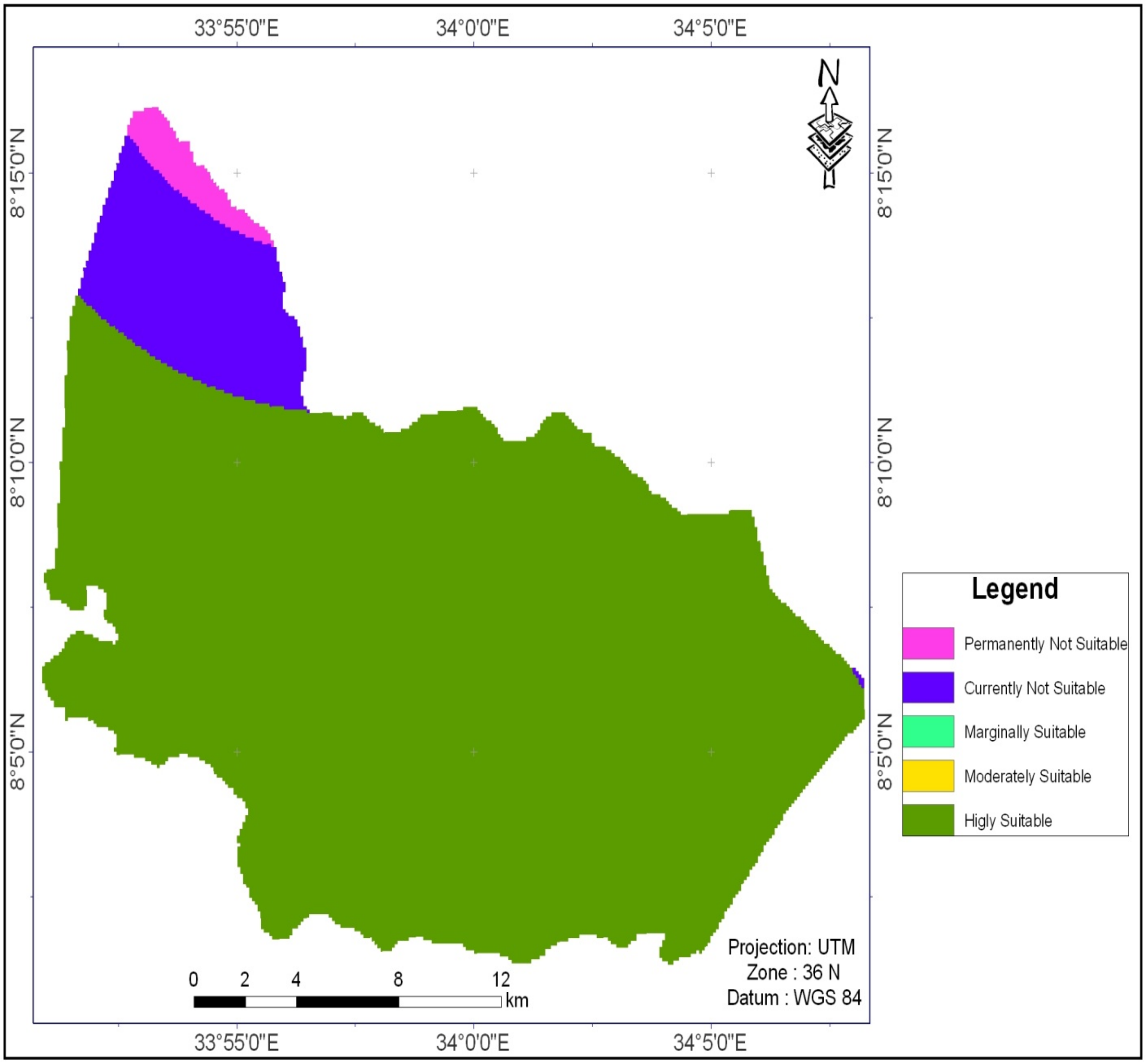


Figure 3.9 Reclassified distance to nearest towns map

#### 3.4.1.5. Soil

Soil is crucial for rating functional landscape for suitability because the fodder for wildlife's i.e. grasses and water logging characteristics of the land dependent on the soil type. According to FAO soil classification (2003) The major soil types in the study area includes; fertile but poorly drained Vertisols covering 47 percent of the Region are found on the low-lying alluvial plains. On the interfluves between the plains are relatively infertile well-drained Orthic Acrisols on 14 percent of the area. On the gently sloping foothills below the escarpment are relatively fertile eutric Fluvisols,

occasionally with high water tables, with 27 percent of the area. On the escarpment with 11 percent of the area are deep well drained Dystric Nitosols of moderate fertility.(Figure 3.10)

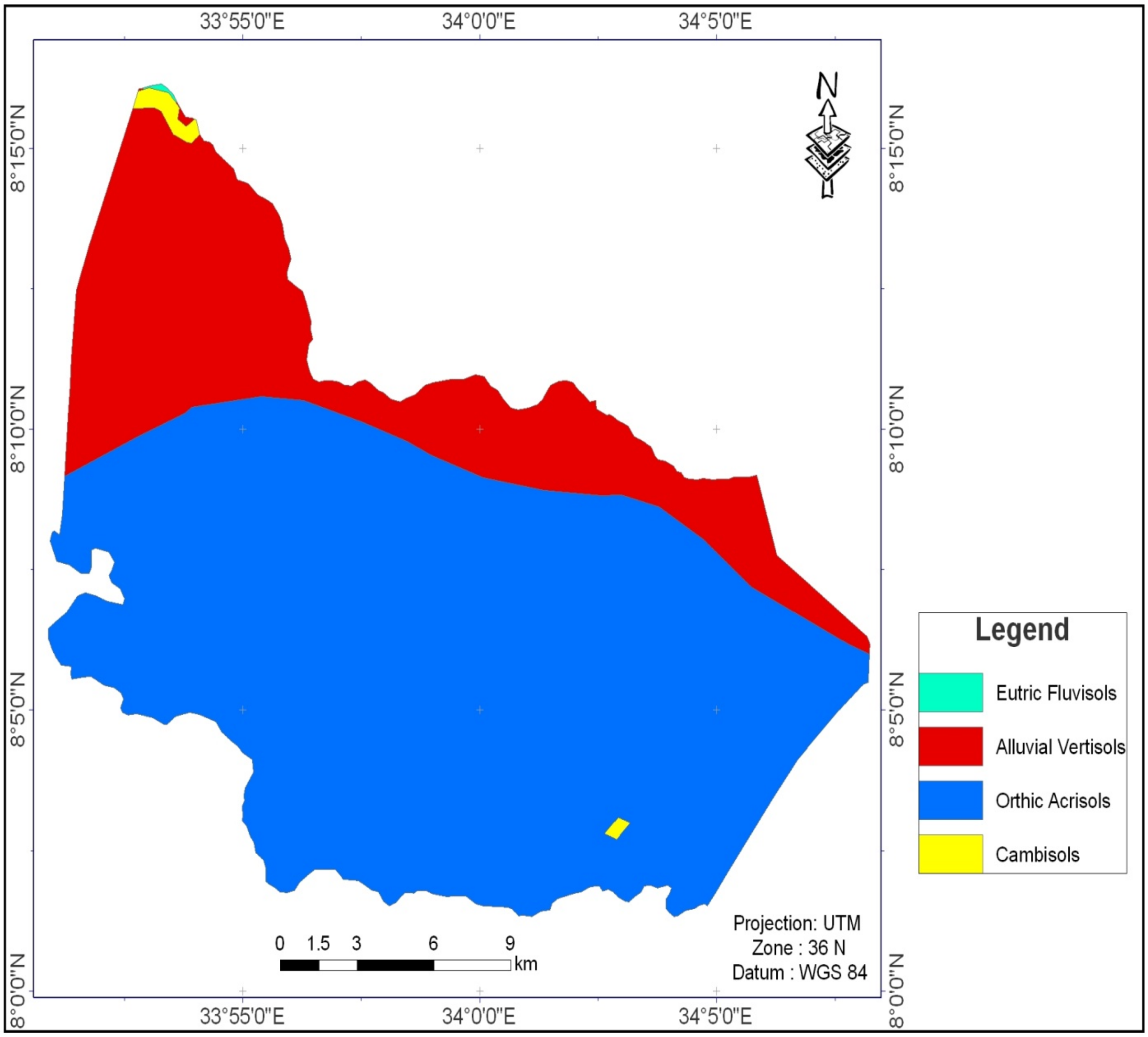


Figure 3.10 Soil map

The major soil types are converted to raster format and then reclassified based on their suitability rate. In the new reclassified evaluation highest suitability for eutric Fluvisols and lowest suitability for Orthic Acrisols. (Figure 3.11)

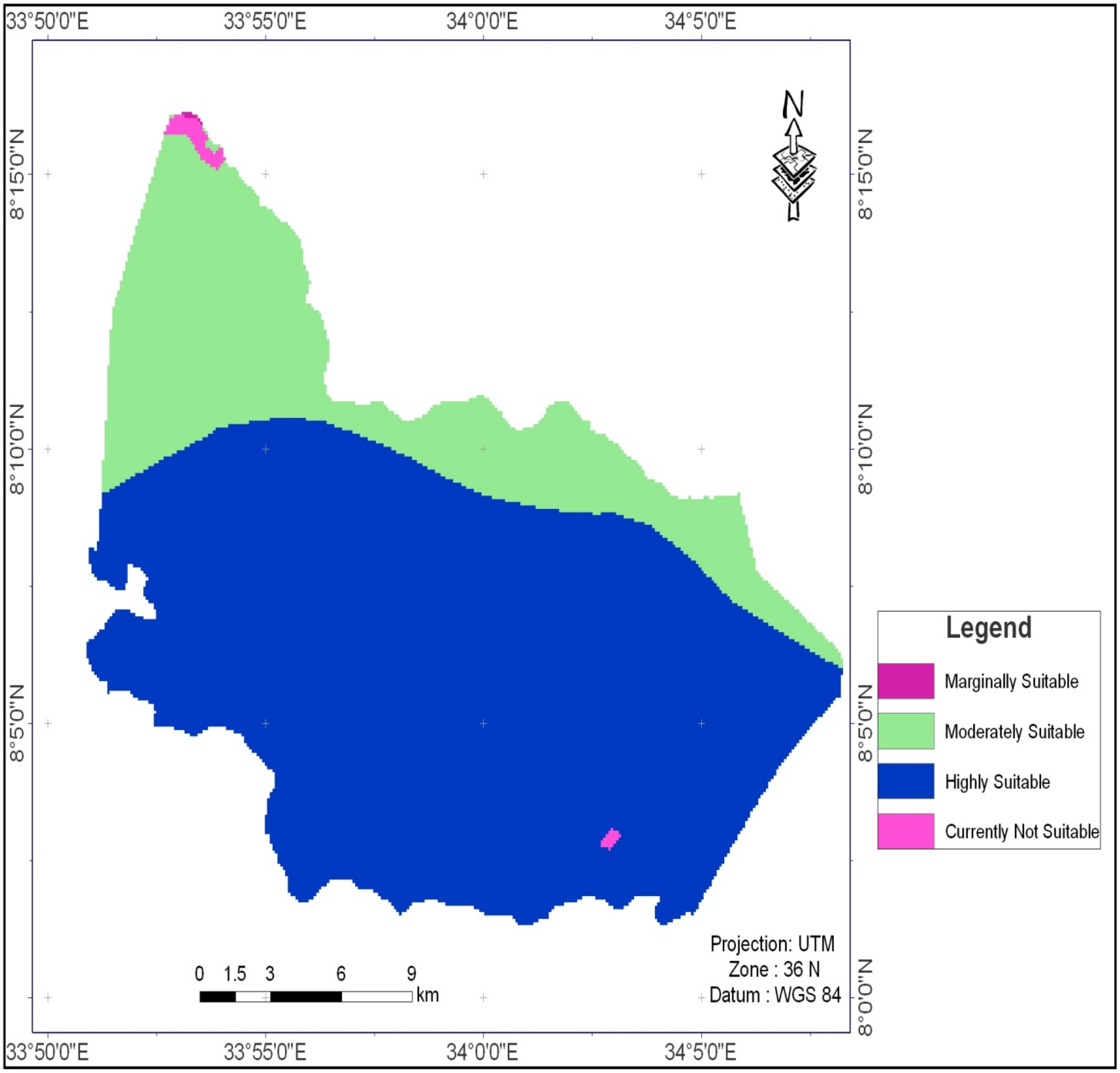


Figure 3.11 Reclassified soil map

### 3.4.1.6. Rainfall / Precipitation

Precipitation forms the principal source of direct recharge which occurs in areas with a surplus of rain fall over evapotranspiration (Ayenew, 1998) and it can be governed by the rainfall distribution, topography, land use /land cover, soil and geology etc. for the analysis of this study the 20 years

average rainfall records of the three nearby metrological station (Itang, Abole and Abobo) was interpolated to the total study area. (Fig. 3.12)

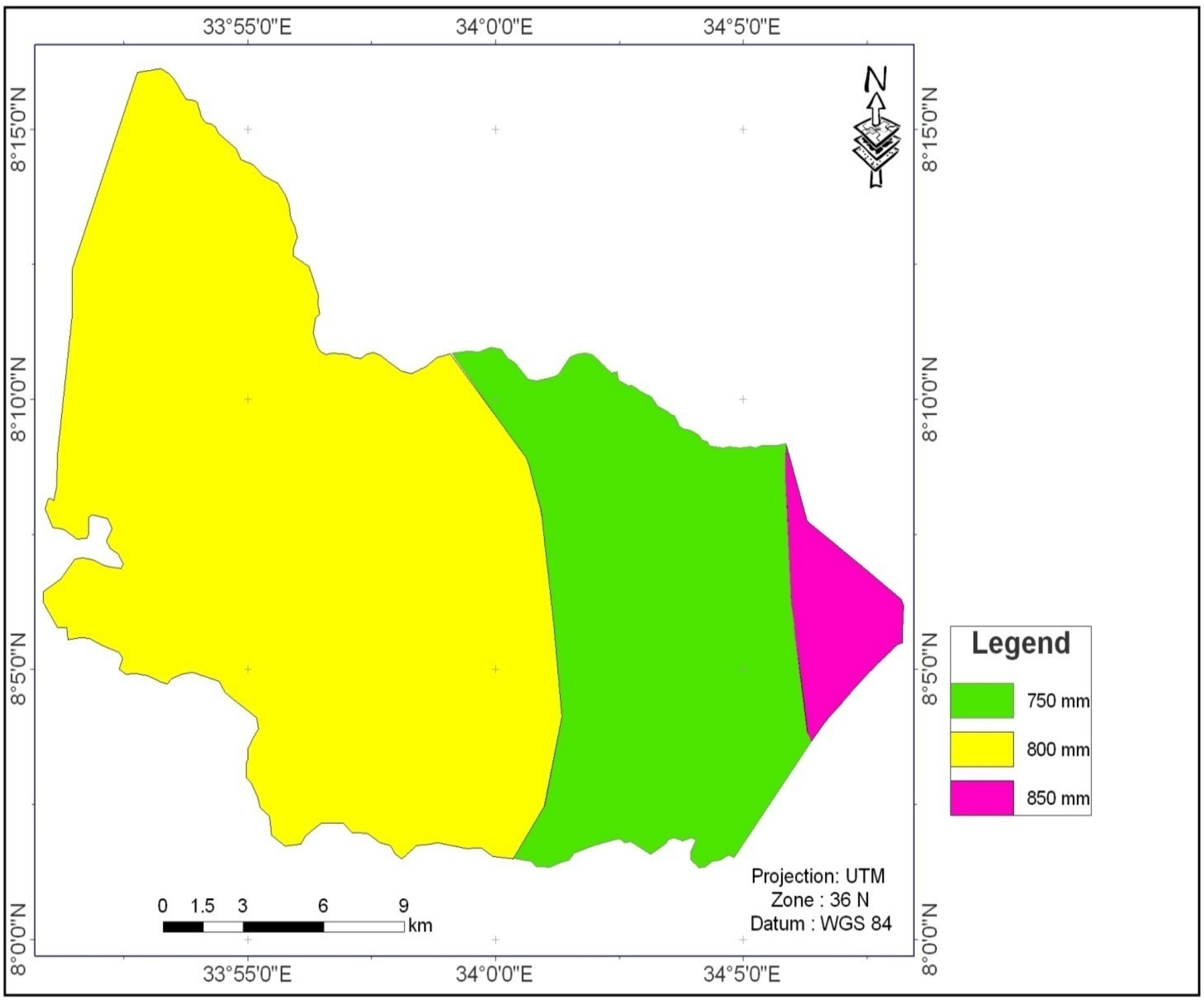


Figure 3.12 Average Isohytal Rainfall map

The rainfall surface was reclassified in to common scale with the assumption that the higher the rainfall amount the more the area is suitable.(Fig 3.13) Like other suitability factors, the rainfall map is reclassified in to five suitability classes ranging from Highly Suitable to Permanently Not Suitable..

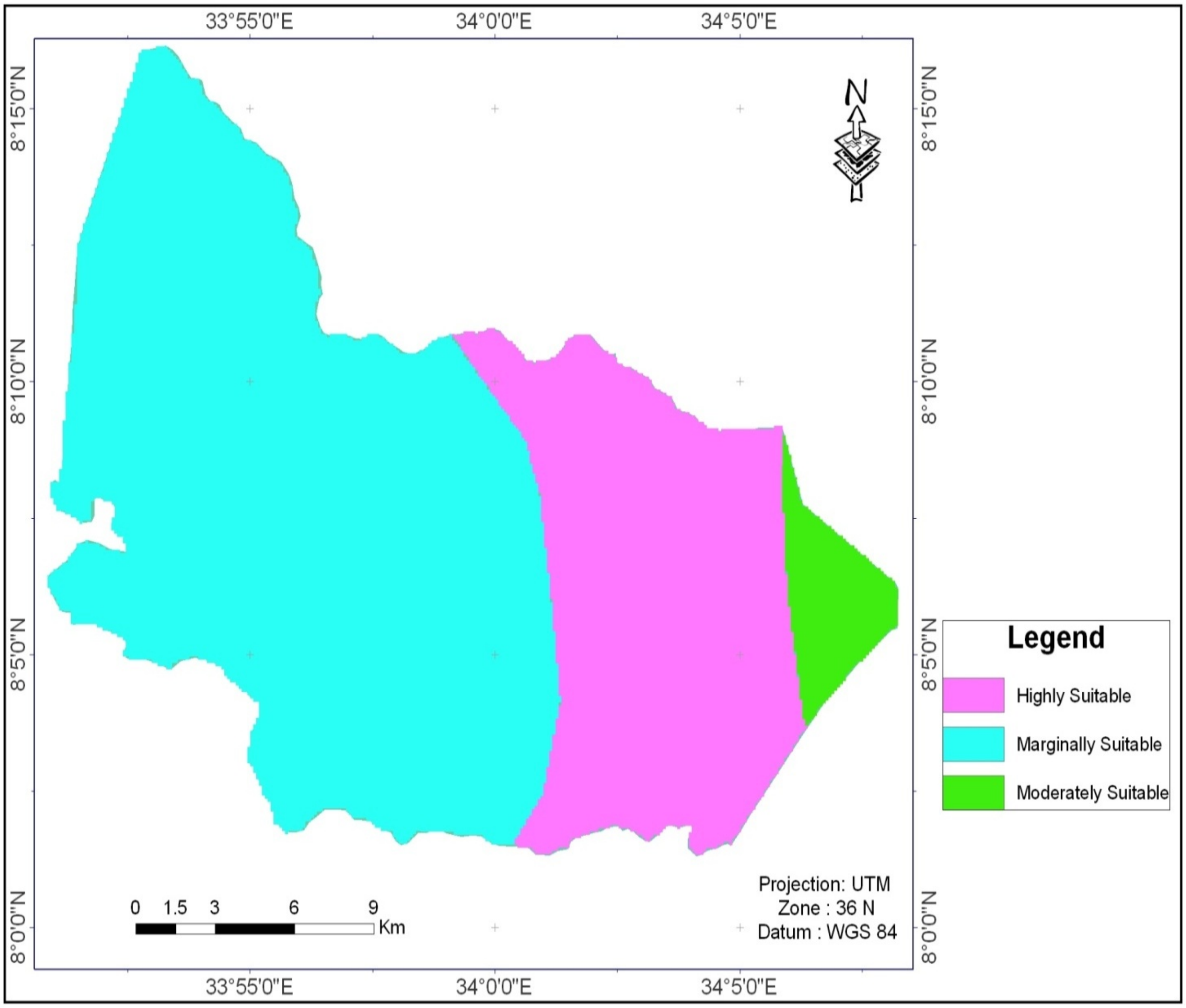


Figure 3.13 Reclassified Rainfall map

## 3.5. LAND SUITABILITY ANALYSIS

### 3.5.1. Multi-criteria decision evaluation

Weight is used to develop a set of relative weights for a group of factors in a multicriteria evaluation (MCE). The weights are developed by providing a series of Pair-wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. These Pair-wise comparisons are then analyzed to produce a set of weights that sum to 1. The factors and their resulting weights can be used as input for the MCE module for weighted linear combination.

### 3.5.2. Criteria and determining factors

For the evaluation of physical land suitability of the study area, sets of factors that influence the capability of physical land for the required purpose in the study area were first established. From these factors, the possibilities and constrains for functional landscapes were analyzed. The following factors (Table 3.6) were considered for the evaluation of the physical land suitability of the study area for functional landscapes and wildlife corridors: Factors includes; Distance from Wetlands, Land use, Soil type, Rainfall, Distance from Settlements/ towns and Slope.

Table 3.6: Characteristic of factors in relation to Wildlife corridor

| **Wildlife species** | **Factor** | **Property Considered** | **Range of suitability** | | | | |
|---|---|---|---|---|---|---|---|
| | | | **Highly Suitable** | **Moderately Suitable** | **Marginally Suitable** | **Currently Not Suitable** | **Permanently Not Suitable** |
| **Nile Lechwe** | Distance from wet lands | Proximity | 0-3km | 3-7km | 7-12km | 12-30km | >30km |
| | Land use | Type | Wetlands | Grass lands | Shrubs | Natural Forest | Bare Lands |
| | Slope | Degree | $0^o$-$5^o$ | $5^o$-$12^o$ | $12^o$-$22^o$ | $22^o$-$36^o$ | $36^o$-$69^o$ |
| | Soil type | Type | Eutric fluvisols | Alluvial vertisols | cambisol s | Orthic acrisols | Dystric nitosols |
| | Rainfall | Amount | 800-1600 | 700-800 | 600-700 | 500-400 | <400 |
| | Distance from towns | Proximity | 12-30km | 9-12 km | 6-9 km | 3-6 km | 0-3 km |

Roads act as barriers for wildlife species. Fragmentation and loss of landscapes and habitats are the consequences. Human mobility therefore restricts wildlife mobility. The possibilities of migration and genetic interchange for wildlife species are nowadays in most of the places confined to wildlife corridors. Therefore the roads are considered as constraints to the wildlife movements (Fig 3.14).

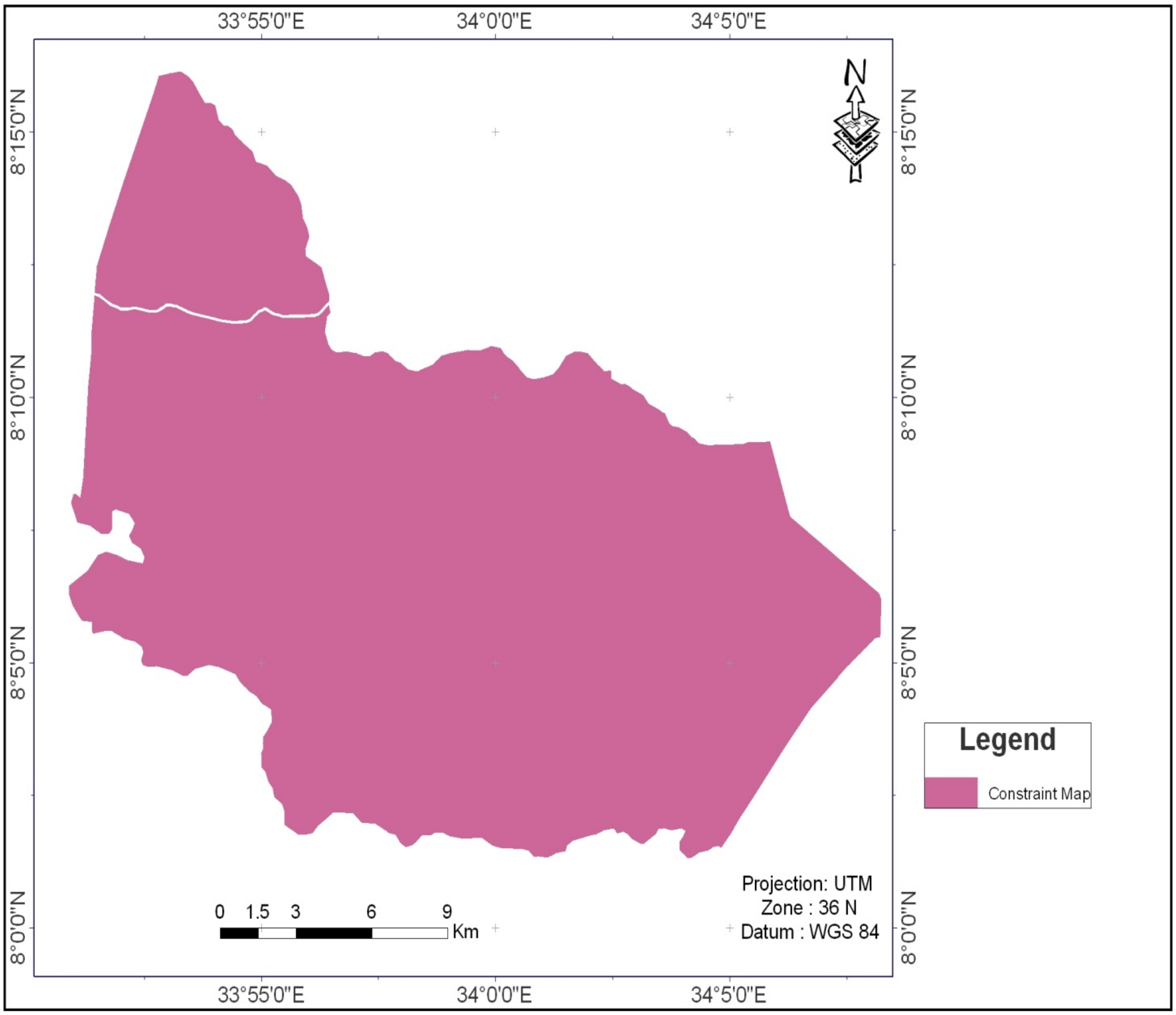


Figure 3.14 Constraint map

### 3.5.3. Determining factor weights

This is the second step in MCDE to establish a set of weights for each of the factors. The technique described here and implemented in IDRISI is that of Pair-wise comparisons developed by Saaty (1977) in the context of a decision making process known as the Analytical Hierarchy Process (AHP). In Saaty's technique, weights of this nature can be derived by taking the principal eigenvector of a square reciprocal matrix of Pair-wise comparisons between the criteria. The purpose of weighting is to express the importance or preference of each factor relative to other factor affect on crop yield and growth rate. Pair-wise comparisons are based on forming judgments between two particular elements rather than attempting to prioritize an entire list of elements. A matrix is constructed, where each factor is compared with the other factors, relative to its importance, on a scale from 1 to 9. (Table 3.6)Then, a weight estimate is calculated and used to derive a consistency ratio (CR) of the Pair-wise comparisons. If the $CR > 0.10$, then some Pair-wise values needs to be reconsidered and the process is repeated till the desired value of $CR < 0.10$ is reached.

All the Six factors, which were selected for the evaluation of Land suitability in the study area, were weighted using pair-wise comparison in Table 3.7. After the Pair-wise comparison matrices were filled, the weight module was used to identify consistency ratio and develop the best-fit weights.

Table 3.7 Nine point importance scale

| **1/9** | **1/7** | **1/5** | **1/3** | **1** | **3** | **5** | **7** | **9** |
|---|---|---|---|---|---|---|---|---|
| extremely | very strongly | strongly | moderately | equally | moderately | strongly | Very strongly | extremely |
| | More Important | | | | | Less Important | | |

Table 3.8 Pair-wise comparison of factor layers

| Layer | wetlands | Land use | soil | rainfall | towns | slope |
|---|---|---|---|---|---|---|
| wetlands | 1 | | | | | |
| Land use | 1/3 | 1 | | | | |
| soil | 1/3 | 1/3 | 1 | | | |
| rainfall | 1/5 | 1/5 | 1/3 | 1 | | |
| towns | 1/5 | 1/5 | 1/3 | 1/3 | 1 | |
| slope | 1/7 | 1/7 | 1/5 | 1/3 | 1/3 | 1 |

The consistency ratio (CR) was 0.07, which was acceptable for weighting the factors to evaluate the physical land suitability of the area. (Table 3.8)

Table3.9 Principal Eigenvector of the pair wise comparison matrix

| Factor | Weight |
|---|---|
| Distance from Wetlands | 0.3863 |
| Land use | 0.2638 |
| Soil | 0.1584 |
| Rainfall factor | 0.1004 |
| Distance from towns factor | 0.0582 |
| Slope | 0.0328 |

**Consistency ratio = 0.07**

### 3.5.4. Weighted overlay analysis and model validation

After the criteria maps (factors and constraints) had been developed, an evaluation (or aggregation) stage was undertaken to combine the information from the factors and constraints. As it is widely used and mostly accepted by many researches, weighted linear combination (WLC) was used to evaluate the factors and constraints maps of the study area. After the weights were established, the module MCE (for Multi-Criteria Evaluation) was used to combine the factors and constraints in the form of a weighted linear combination.

$$S=\Sigma W_i X_j$$

Where **S** = Suitable Wildlife corridor for Nile Lechwe species

$\sum W_i\, X_j$ = Sum of the Weights of each factor

0.3863 **(**Reclassified distance from Wetlands**) +** 0.2638 **(**Land Use**)** +0.1584 **(**soil type**)** + 0.1004 **(**reclassified rainfall**)** + 0.0328 **(**reclassified slope**)** + 0.0582 **(**reclassified distance from the nearest towns**) =** Suitable Wildlife corridor for Nile Lechwe species

### 3.5.5. Land suitability class specification

According to FAO standards, which are widely used to classify land suitability for specified objectives of land utilization types, a land can be divided in to five classes. These include very suitable (S1), suitable (S2), marginally suitable (S3), not suitable (N1) and permanently not suitable (N2).Multiplying the reclassified factors map based on the given weights and adding them by Raster calculator technique, the final wildlife corridor suitability map for Nile Lechwe species in the study area was developed. The values which are obtained from the result are classified in to five classes. These classes were converted to suitability classes (Fig 3.15). These were highly suitable, moderately suitable, marginally suitable, currently not suitable and permanently not suitable.

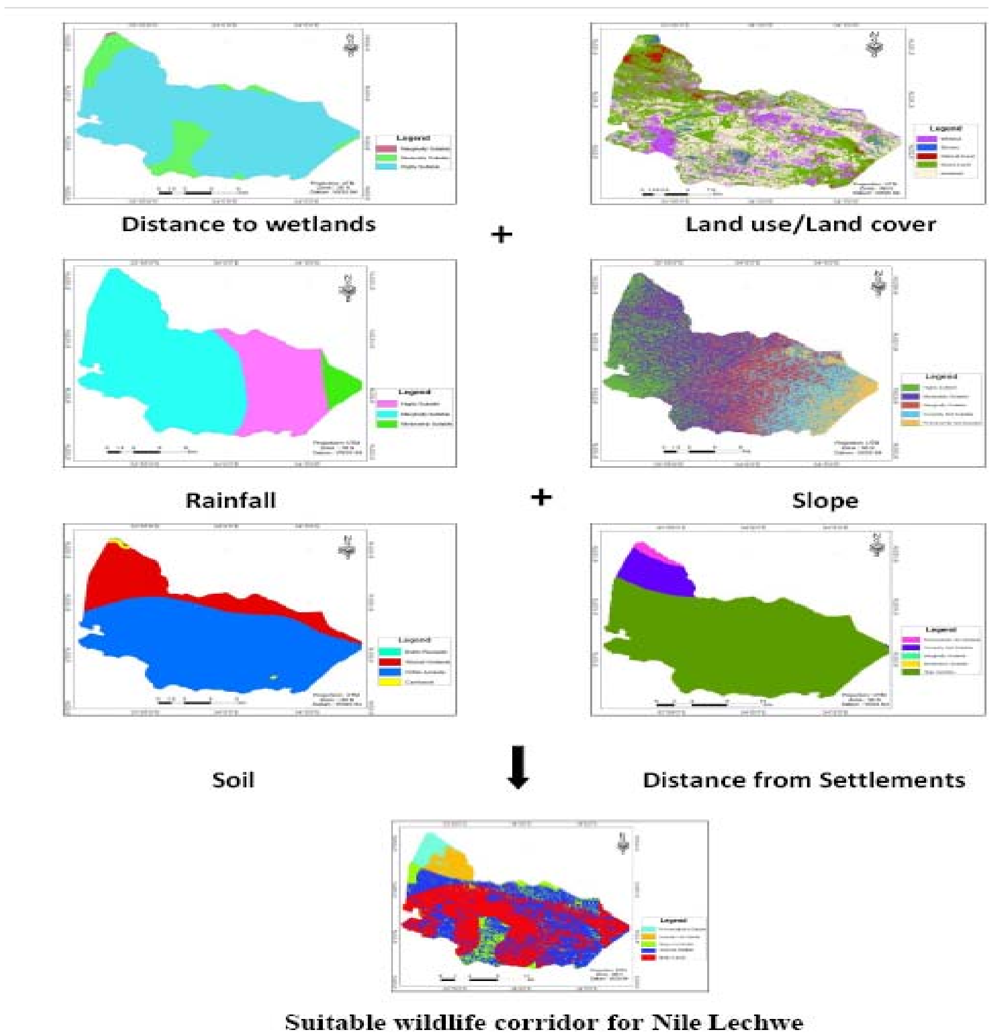


Figure 3.15 Reclassified thematic maps

# CHAPTER FOUR

# 4. RESULTS AND DISCUSSION

## 4.1. Results

The land suitability analysis of wildlife corridors for selected species results showed five classes of suitability ; From the total land of the study area 201.63 $km^2$ (42.92%) was Highly suitable, 188 $km^2$ (40.01%) Moderately suitable, 32.52 $km^2$ (6.92%) marginally suitable, 28.47 $km^2$ (6.06%) not suitable and 19.21$km^2$ (4.09%) was permanently unsuitable for Wild life corridor for Nile Lechwe (Fig.4.1).

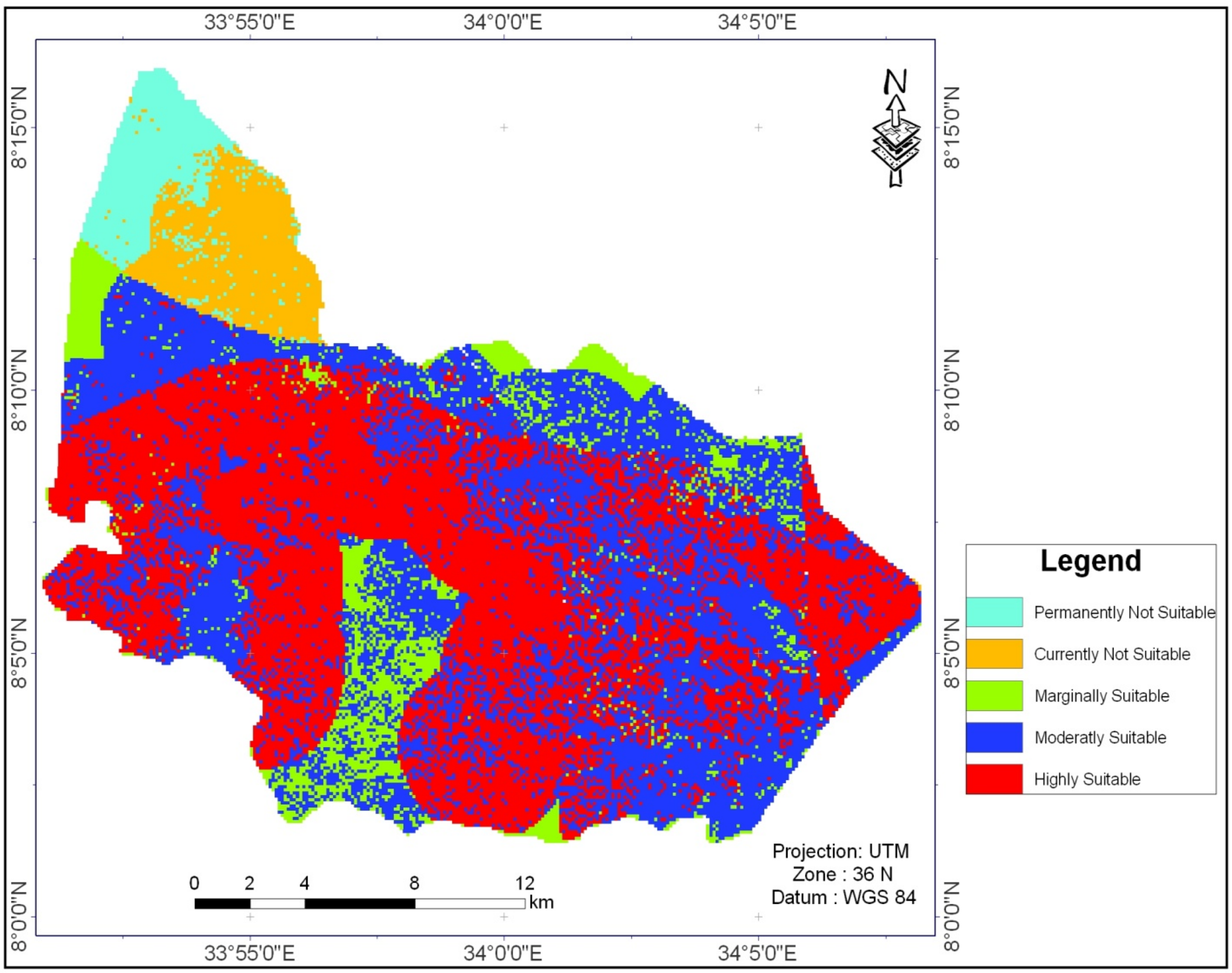


Figure 4.1 Wild life corridor suitability map

From the map the red and blue are the highly and moderately suitable areas for wildlife corridor for Nile Lechwe respectively but the green color indicate marginally suitable places , and the orange and cyan color indicate currently not suitable areas and permanently not suitable areas this areas are of near to settlements and there is a road passing by which makes the area not suitable. (Table 4.1)

Table 4. 1 Area of suitable Wildlife corridors

| Suitability | Area in ($km^2$) | Area in (%) |
|---|---|---|
| Highly suitable | 201.63 | 42.92 |
| Moderately Suitable | 188 | 40.01 |
| Marginally suitable | 32.52 | 6.92 |
| Currently Not Suitable | 28.47 | 6.06 |
| Permanently not Suitable | 19.21 | 4.09 |
| Total | 472.2 | 100 |

## 4.2. Discussion

### 4.2.1. Application of the Model

The results obtained from the land suitability analysis for wild life corridor correspond with the realities of the study area. According to the results obtained, the western part of the study area is highly suitable for The Nile Lechwe. Along the south central part and North Eastern part of the study area the land is marginally suitable for wildlife corridor. The distance from wet lands is farther in these areas. The Northern part of the study area is not currently and permanently used for wild life corridors because of their distance proximity to the nearest towns, In addition to the land use. However, this unsuitability is not entirely based on their proximity and land use but on many other parameters for example the constraint gravel road also can be considered as one factor. Considering the assumption behind procedure that factor maps should be no independent, (Brinson and Verhoeven 1999). The results of this investigation were adequate in terms of the evaluation criteria set used here. Thus, the final suitability map represents a more realistic outcome, given that it takes into account the land characteristics instead of land qualities to evaluate land suitability, because land quality information was not available for the study area. Land characteristics were used as a means to describe the land qualities.

In this paper, Six factors were considered to determine wildlife corridor suitability namely land use-land cover, soil, Distance from Settlements, elevation, slope, Distance from Wetlands and rainfall, these factors are similar to the works mentioned above. Though the applied method can have limitations due to time and basic information, it has shown that it can be extended to other areas. Mapping of Wildlife corridor for Nile Lechwe helps to develop the sites for economic purposes, to protect them from human threats and therefore to conserve them.

The suitability model shows that 42.92 percent of the study area is highly suitable for wildlife corridor for Nile Lechwe. This implies that the area is very significantly important for conservation, maintaining equitable environment and environmental sustainability. In terms of ecotourism activities, 40 percent of the study area is moderately suitable for Wildlife corridor and this implies that the area is significantly important for conservation and environmental sustainability. 6.06 and 4.09 percent respectively represents less and very less suitable sites for Wildlife Corridor. This indicates the area is less important for the survival of the wildlife species mentioned and its environmental sustainability. Thus, it requires impact assessment and environmental management.
Water is a necessary component of organisms, and a medium in which metabolic reactions take place. Most terrestrial mammals, however, require the presence of, and regular access to, drinking water. This is outlined in Caughley and Sinclair (1994) and Pomeroy and Service (1986).

Boitani et al. (1999) have conducted a comprehensive review of known habitat preferences of the large and medium sized mammals of Africa, in order to model species distribution in relation to several environmental factors. They have included distance from water as a variable useful in identifying suitable habitats for a series of species, distinguishing between three main categories: species occurring in or near water, species occurring in riverine or gallery forests, and water dependent species. For a total of 99 species the distance from permanent water bodies was then used, on the basis of what was found in the literature, as a factor defining the species' potential distribution. A word of caution is however needed at this point. While for some species proximity of permanent standing/flowing water bodies can be considered a pre-requisite for that species' survival in an area, for several other species presence of water bodies has so far only been recognized as a factor with the presence of the species. In other words, there is as yet only a correlation rather than a proven cause-

and-effect relationship. Boitani et al. (1999) It is not surprising then that the presence of many mammal species is restricted to a limited distance from surface water, especially in hot and arid or semi-arid regions. At the same time the availability of water, often through rainfall, also affects the productivity of ecosystems and the structure of the vegetation. In this way water greatly influences the availability of feeding resources as well as the availability of other limiting factors such as cover. Put more simply, rainfall and surface water greatly influence the presence and extent of different habitat types suitable for different species.

Water requirements of African wildlife species in the wild have been thoroughly studied in only a few cases, and mostly for ungulates such as the waterbuck (e.g. Taylor et al. 1969). For several other species water dependency has been mainly inferred from observations on behaviour, movements, habitat selection, etc. For many species, however, no systematic knowledge is available about the water requirements of free-living individuals.

Slope and distance to water have a strong effect on wildlife distribution. When a mixture of gentle and steep terrain exists, wildlife typically congregate on the gentler terrain, preferring slopes of 10 percent or less. As slope and horizontal distance to water increase, grazing use often decreases (Table 4.2). In gentler topography, horizontal distance to water has a stronger influence on grazing capacity than vertical distance to water. In rough topography, the relationships between grazing use and distance to water may differ from those observed in gentle terrain. Nile Lechwe preferred areas within 183 m of water and avoided areas greater than 600m from water in mountainous terrain (Gillen et al. 1984). In another study Lechwes avoided areas further than 1500 meter from water but vertical distance appeared to be more important than horizontal distance to water. (Table 4.3 ) (Roath and Krueger 1982).

Table 4.2 Relationship between slope and grazing capacity

| Slope (%) | Reduction in grazing capacity (%) |
|---|---|
| 0-10 | 0 |
| 11-30 | 30 |
| 31-60 | 60 |
| >60 | 100 |

Source: Holechek 1988.

Table 4.3 Relationship between grazing capacity and distance from water

| Distance from water (km) | Reduction in grazing capacity (%) |
|---|---|
| 0-1.6 | 0 |
| 1.6-3.2 | 50 |
| >3.2 | 100 |

Source: Holechek 1988.

According to the final analysis, the Gambella National Park contains large sections of land that are considered suitable wildlife corridor for Nile Lechwe species and habitat for them.(Figure 4.2) This is important for the health of the population in the study area. Wildlife corridors serve as conduits for animal movement and provide habitat for them. Therefore, large areas of suitable wildlife corridor habitat ensure that there will be sufficient land for new packs to form and allow for minimal conflict between humans and Nile Lechwes as both populations rise.

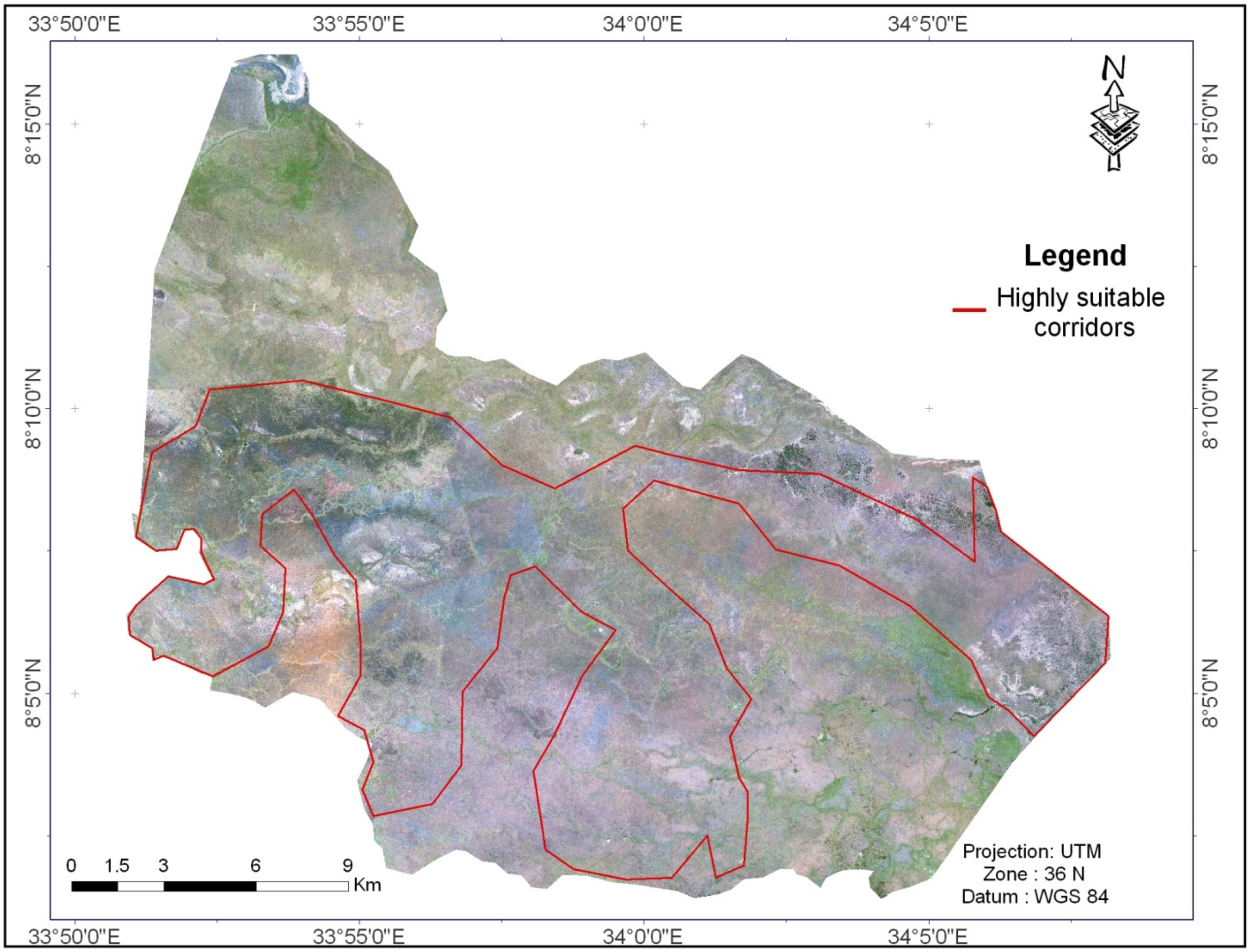


Figure 4.2 Suitable Wildlife corridors on Spot Satellite Image (2009) of the study area

# CHAPTER FIVE

# 5. CONCLUSION AND RECOMMENDATION

## 5.1. Conclusion

This paper addressed to produce potential wildlife corridors for Nile Lechwe in the Gambella national Park. The study area covers an approximate area of 472.2 square kms. Gambella National Park is found at the centre of Gambella Regional State. Nile Lechwe is one of the endangered wildlife, the number of species decreasing. One of the conservation mechanisms of Nile Lechwe species is proposing a good wildlife corridor area so that the species is kept and conserved properly. GIS is widely employed towards assessing and selecting suitable areas for wildlife corridors.

The result of the suitability analysis shows that out of the total 172.2 $km^2$ area 201.63 $km^2$ of the study area is highly suitable for wildlife corridor for Nile Lechwe. This implies that the area is very significantly important for conservation, maintaining equitable environment and environmental sustainability.

Wildlife corridors are not proposed as mitigation for loss of core habitat. However, with careful planning and design, wildlife corridors can help reduce the negative effects of habitat fragmentation by allowing dispersal of individuals between large patches of remaining habitat. While additional study on the efficacy of wildlife corridors is necessary, some general principles of evaluation and design are available and should be implemented. Monitoring the use of corridors by target wildlife species is an important step in corridor planning, to allow for adaptive management.

## 5.2. Recommendation

In the light of the findings obtained and conclusions reached the following recommendations are forwarded.

- Future research should explore the application of integrated technologies to assess wildlife habitat and environmental and social pressures to Wild Lechwe and other Species in the National Park.

- The primary spatial datasets can be made readily available to decision-makers and landscape assessment tools could be developed to assist in the interpretation of results within a natural resource and urban planning process.

- Additional conservation areas to be proposed and which serve a broader purpose of landscape connectivity between protected areas for Wildlife movements.

# REFERENCES

Anderson, G.S., and Danielson, B.J. (1997). The effects of landscape composition and physiognomy on metapopulation size: the role of corridors. Landscape Ecology, 12, 261-271.

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. - Oikos 71:355-366

Arroyo-Rodríguez, V., Asensio, N., & Cristóbal-Azkarate, J. (2008a). Demography, life history and migrations in a Mexican mantled howler group in a rainforest fragment. American Journal of Primatology, 70, 114–188. doi:10.1002/ajp.20463

Bender DJ, Fahrig L (2005) Matrix structure obscures the relationship between interpatch movement and patch size and isolation. Ecology 86:1023–1033

Brown, J.H., and Kodric-Brown, A. (2006). Turnover rates in insular biogeography: effect of immigration on extinction. Ecology, 58, 445-449.

Collinge, S.K., 1996. Ecological consequences of habitat fragmentation: implications for landscape architecture and planning. Landscape Urban Plann. 36, 59–77

Conway, G. R. (1987). "The properties of agro ecosystems." Agricultural Systems 24: 95- 117

Coulson, RN 1992. Intelligent Geographic Information Systems and Integrated Pest Management. Crop Protection 11:507-516

Cox, G. W. (2001). The linkage of inputs to outputs in agro ecosystems. Agricultural ecosystems: unified concepts Eds. R. Lowrance, B. R. Stinner and G. J. House. New York, Wiley. 187-208.

Elton, C. 1927. Animal Ecology. London: Sidgwick and Jackson.

Fahrig, L. 2007. Landscape heterogeneity and metapopulation dynamics. Pages 78-91 in J. Wu and R. Hobbs, editors. Key Topics in Landscape Ecology. Cambridge University Press, Cambridge,UK.

FAO 2003.theoretical framework for land Evaluation. Geoderma 72: 165-190

Gaston, K., Thompson, T., 2002. Gardens: Heavens or Hell for Wildlife? Evidence for Significance. Presentation given at RHS Conference in Association with The Wildlife Trusts and RSBP, London, 3 December 2002. Mscr. Downloaded December 2003 from http://www.sheffield.ac.uk/uni/projects/bugs.

Gillen R.L 1988.Cattle distribution on Mountain rangeland in northeastern Oregon. J Range Manage 37:549-553

Holecheck .J.L 1988. An Approach for setting the stocking rate. Rangelands 10:10-14

Hillman, J. C. 1986a. Bale Mountains National Park: Management Plan. Ethiopian Wildlife Conservation Organization, Addis Ababa, Ethiopia. Vol.1-Plan (72 pp.); Vol.2-Appendices (250 pp.).

Hurni, H. 1975. Park warden's reports. EWCO, Addis Ababa. Mimeo.

Jacobs, M. J. 1999. Influence of grazing fire and rainfall regime on plant species dynamics in Ethiopian perennial grassland. PhD. Dissertation, Utah State Univ., Logan.

Lambeck RJ. 1997. Focal species: A multi-species umbrella for nature conservation. Conservation Biology 11: 849–856.

Laurance, S. G. W. 2001. The effects of roads and their edges on the movement patterns and community composition of understorey rainforest birds in central Amazonia. Ph.D. Thesis, University of New England, Armidale, Australia. Lenton TM, Held H, Kriegler E, Hall JW,

Lindenmayer, D. B., G. L. Benwell, et al. (1994). A generic approach for the spatial optimization of wildlife corridor design within multi-use forest landscapes. Sixth Colloquium of the Spatial Information Research Centre, University of Otago, 117-130

Lucht W, Rahmstorf S, Schellnhuber J (2008) Tipping elements in the earth's climate system. Proceedings of the National Academy of Sciences of the United States of America 105 (February 12): 1786- 1793

Machtans, C.S., Villard, M-A. and Hannon, S.J., 1996. Use of riparian buffer strips as movement corridors by forest birds. Conservation Biology 10: 1366–77.

Malanson, George P. 1993. Riparian Landscapes. New York: Cambridge University Press.

Martin, G. (1994). South Island high country review. Working Party on Sustainable Land Management. Report to Ministers of Land, Agriculture and Conservation, NZ Govt.

McDowell, R., Sharpley, A.N., and Folmar, G., 2001, Phosphorus export from an agricultural watershed: Linking surface and transport mechanisms. Journal of Environmental Quality, 30: 1587-1595

Merriam, G. and A. Lanoue. 1990. Corridor use by small mammals: field measurement for 3 experimental types of P. leucopus. Landscape Ecology 4, 123-131.

Norton, M. R. 2001. Status of the Bay-breasted Warbler (Dendroica castanea) in Alberta. Alberta Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report No. 32, Edmonton, AB. 21 pp.

O'Neil, T. A. and C. Barrett. 2001. Willamette valley oak and pine habitat conservation project. Final Report, Bureau of Land Management, Eugene, OR. pp 8.

Plumptre, A.J., Rose, R,Furuchi, T., Hashimoto, C., and Bennett, E. (2010). Eastern Chimpanzee (*Pan troglodytes schweinfurthii*): Status Survey and Conservation Action Plan 2010-2020. Gland, Switzerland: IUCN.

P. Beier. 1993. Determining Minimum Habitat Areas and Habitat Corridors for Cougars. Conservation Biology, 7 (1)

Phillips, S.J., and M. Dudik. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31:161-175.

Rosenberg, P.D. Vickery, and T.B. Wigley. 2002. Priority research needs for the conservation of Neotropical migrant landbirds. Journal of Field Ornithology 73:329-339

Sanderson, E.W. and Pascual-Hortal, L. (2007). A new habitat availability index to integrate connectivity in landscape conservation planning: comparison with existing indices and application to a case study. Landscape and Urban Planning, 83, 91-103.

Schloeder, C. A. 1999. Investigation of the determinants of African Savanna vegetation distribution: a case study from the lower Omo basin, Ethiopia. PhD. Dissertation, Utah State Univ., Logan.

Schmiegelow, F. K. A. and Mönkkönen, M. 2002. Habitat loss and fragmentation in dynamic landscapes: avian perspectives from the boreal forest. — Ecological Applications 12: 375-389.

Simberloff, D., Farr, J.A., Cox, J., and Mahlman, D.W. (1992) Movement corridors: conservation bargains or poor investments? Conservation Biology, 6, 493-504

Sutherland, W.J. (2003). Parallel extinction risk and global distribution of languages and species. Nature. 423(6937), 276-9

Turton, D. 1987. The Mursi and National Park Development in the Lower Omo Valley. In D. Anderson and R. Grove, eds, Conservation in Africa: People, Policies and Practice, 169–186. Cambridge: Cambridge University Press.

Tutin, C. E. G. (1999). Fragmented living: Behavioural ecology of primates in a forest fragment in the Lopé Reserve, Gabon. Primates, 40, 249–265. doi:10.1007/BF02557714.

Wilson, F. A. (1994). “Computer support for strategic organizational decision-making.” Journal of Strategic Information Systems 3(4): 289-298.

# APPENDICES

Annex 1. Ground control points

| S. No | X coordinate | Y coordinate | Suitability Evaluation class |
|---|---|---|---|
| 5 | $8^0$ 06′ 43″ | $33^0$ 56′53″ | Marginally suitable |
| 10 | $8^0$ 06′10″ | $34^0$07′21″ | Moderately suitable |
| 17 | $8^0$ 06′10″ | $34^0$07′21″ | Highly suitable |
| 13 | $8^0$ 06′21″ | $34^0$02′20″ | Moderately Suitable |
| 15 | $8^0$ 06′44″ | $33^0$57′03″ | Marginally suitable |
| 16 | $8^0$ 06′53″ | $34^0$04′49″ | Highly suitable |
| 9 | $8^0$ 07′50″ | $33^0$54′29″ | Highly suitable |
| 12 | $8^0$ 09′23″ | $33^0$52′28″ | Highly suitable |
| 7 | $8^0$ 09′58″ | $33^0$54′14″ | Moderately Suitable |
| 4 | $8^0$ 11′ 23″ | $33^0$ 54′49″ | Currently not suitable |
| 11 | $8^0$ 12′20″ | $33^0$55′34″ | Currently not suitable |
| 14 | $8^0$ 14′23″ | $33^0$53′03″ | Permanently not Suitable |
| 6 | $8^0$10′38″ | $34^0$ 03.47″ | Marginally suitable |
| 8 | $8^0$25′09″ | $34^0$33′53″ | Moderately Suitable |
| 2 | $8^o$ 12′ 55″ | $33^0$ 52′39″ | Permanently not Suitable |
| 3 | $8^o$13′ 13″ | $33^0$ 54′35″ | Currently not suitable |
| 1 | $8^o$14′ 22″ | $33^0$ 05′34″ | Permanently not Suitable |

| **Station** | **Mean monthly rainfall over the study area** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duration | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |

Annex 2. Arithmetically estimated mean monthly rainfall

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Itang | 1980 - 2010 | 1985 | 35.3 | 56.21 | 98.36 | 152.16 | 120.17 | 89.17 | 112.7 | 135.32 | 114.61 | 77.96 | 22.37 | 1037.34 |
| Abole | 1988 - 2010 | 32.09 | 47.98 | 103.37 | 164.33 | 158.33 | 125.16 | 149.69 | 139.95 | 109.79 | 83.92 | 43.42 | 38.06 | 1196.09 |
| Abobo | 1976 - 2010 | 28.52 | 34.88 | 49.95 | 104.18 | 92.46 | 84.74 | 99.3 | 75.39 | 62.72 | 78.89 | 23.43 | 32.4 | 766.86 |

Annex 3. Plates

Plate 1.(a) Wetland in Gambela National park.

Plate 2. (b)Wetland in Gambela National park

Plate3.(a) Grasslands in Gambella National Park

Plate 3.(b) Grassland in Gambela National Park