Addis Ababa University

College of Social Science

Department of Geography and Environmental Studies

Application of GIS and Remote Sensing in Mapping Wildlife Land Suitability for Mountain Nyala Species at Bale Mountains National Park, Ethiopia

A Project Submitted to the School of Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Art in Geography and Environmental Studies (GIS, Remote Sensing & Digital Cartography)

By:

Zerihun Fayera

Advisor:

Dr. Muluneh Woldetsadik (PhD)

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Approval by Board of Examiners

Dr. Tebarek Lika (PhD)

Chairman, Department Head ______________________

Dr. Muluneh Woldetsadik (PhD)

Advisor ________________________

Dr. Mohammed Assen (PhD)

Internal Examiner _________________________

Dr. Shimelis Damene (PhD)

External Examiner ____________________________

Declaration

I hereby declare that the Project thesis entitled **"Application of GIS and Remote Sensing in Mapping Wildlife Land Suitability for Mountain Nyala Species at Bale Mountains National Park, Ethiopia**", has been carried out by me under the supervision of Dr. Muluneh Woldetsadik(PhD), Department of Geography and Environmental Studies, Addis Ababa University, during the year 2014 as part of a Master of Art in Geography and Environmental Studies (GIS, Remote Sensing and Digital Cartography). I further declare that this project 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 project have been dully acknowledged.

Zerihun Fayera

Signature: __________________________Date: __________________________

Dr. Muluneh Woldetsadik (Advisor)

Signature: _____________________________Date: _____________________________

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Acronyms

AHP	Analytical Hierarchy Process
BMNP	Bale Mountains National Park
CR	Consistency Ratio
DEM	Digital Elevation Model
EWCA	Ethiopian Wild Life Conservation Authorities
FAO	Food and Agriculture Organization
FZSBMNPCP	Frankfurt Zoological Society's to Bale Mountains National Park Conservation Project
GIS	Geographical Information System
GPS	Global Positioning System
Ha	Hectare
HQ	Head Quarter
HSI	Habitat Suitability Index
LC	Land Cover
LU	Land Use
MCE	Multi-Criteria Evaluation
MCE-DS	Multi-Criteria Evaluation-Decision Support
MN	Mountain Nyalas
NFPA	National Forest Priority Area
NMSA	National Metrological Service Agency
RS	Remote sensing
SI	Suitability index
TIN	Triangulated Irregular Network
UTM	Universal Transverse Mercator
USGS	United State Geodetic Survey
WCS	Wildlife Conservation Sanctuaries
WLC	Weighted Linear Combination
WLC-PWC	Weighted Linear Combination-Pair wise compression
WWF	Wolf Wildlife and Forest

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Abstract

The Bale Mountains are the largest remaining alpine habitats, whereby Bale Mountain National Park is found in the African continent. The Bale Mountain National Park was first proposed to help protect the diverse and abundant wildlife, particularly the Mountain Nyalas and Red Foxes that are endemic to the world wide. 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 and this led to extensive wildlife habitat fragmentations. Thus, the intension of this study is to assess the habitat suitability range of Mountain Nyala species in Bale Mountains National park so as to aid an effort for utilization and conservation as well as to provide a background information to guide park managers in making appropriate decision using GIS and remote sensing technologies.

By implementing GIS spatial analyst techniques, the study was attempted to identify potential habitat for Mountain Nyala (one of wild life species) at BMNP. Eight datasets i.e. vegetation types, soil types, topographic factor (elevation and slope), climate factor (temperature), proximity factors (distance to settlement, road and river) have been employed to map out wildlife land suitability corridor for Mountain Nyala specie. The weights were calculated using IDRISI32 Multi-criteria Evaluation in weight module 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 Nyala was produced.

In general, the result of the land suitability analysis for selected species shown five classes of suitability; from the total land of the study area 137.5 km^2 (% 5.96) was highly suitable, 395.6 km^2 (% 17.14) was moderately suitable, 561.8 km^2 (% 24.34) was marginally suitable, 501.6 km^2 (% 21.73) was currently not suitable, and 711.5km^2(% 30.83) was permanently not suitable areas. The suitability analysis shows that 1091.5km^2(47.5%) of the study area is habitat suitable range for Mountain Nyala species where as 1213.1km^2 (52.5%) of the study area are currently and permanently not suitable areas respectively.

Key Words: *Land suitability analysis, Wildlife corridor, Mountain Nyala, GIS, RS, MCE, BMNP*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Wildlife habitat fragmentation is one of the major biodiversity conservation issues facing the world today. Habitat fragmentation may be occurred due to natural or human-induced at 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, deforestation, urbanization and land use land cover dynamics at large.

It is in this context that land suitability analysis has 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).

Thus, habitat suitability modeling has been advanced by Geographic Information Systems (GIS) and remote sensing (RS). GIS is an excellent tool for identifying areas of conservation significance and assessing the habitat potential of unstudied sites (Lenton et al. 2000). 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.

In addition to this, remote sensing (RS) and Geographic Information Systems (GIS) are providing new tools for advanced ecosystem management.

The collection of remotely sensed data facilitates the synoptic analyses of earth-system function, patterning, and change at local, regional, and global scales over time; such data also provide a vital link between intensive, localized ecological research and the regional, national, and international conservation and management of biological diversity (Wilkie and Finn, 1996).

Generally, by utilizing remote sensing technologies and implementing GIS mapping techniques, wildlife land suitability of designated areas can be monitored and mapped for specific research and analysis.

1.2. Statement of the Problem

The Bale Mountain National Park was first proposed to help protect the diverse and abundant wildlife, particularly the Mountain Nyala and Red Foxes that are endemic to Ethiopia. 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. The proportion of endemic species in the Bale Mountain National Park is so high that with the loss of the Park's natural resources more species would become extinct than in any other area of comparable size worldwide.

The loss of natural resources or habitat fragmentation is caused by human settlements, extensive grazing, commercial conifer forestation, urbanization and agricultural cultivation has negatively affected the animals' potential to inhabit its suitable range. These factors have led to habitat fragmentation, namely loss of the original habitat, reduction in habitat patch size and increasing isolation of habitat patches (Andrén, 1994).

Excessive hunting seriously affects the larger mammals in the area and the number of Mt.Nyala decreasing from time to time. 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 high way of road constructed at the north of the park, livestock encroachment and the expansion of farms as well as settlements to areas currently inside the park; (Barnes et al. 2003).

Habitat fragmentation may also affect population dynamics by enhancing population decline and dividing widespread wildlife populations into sub-populations within restricted areas (Refera and Bekele, 2004), although the population has decreased across the entire area of BMNP. As a result, the habitat ranges of mountain Nyala species has decreasing, and leaving the animal confined to unprotected areas.

Therefore, GIS model presented here is devised to remedy wildlife habitat fragmentations deficiency by identifying potential habitat and mapping out suitable wildlife corridors for Mt.Nyala within the park, 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.

In general, the need for wildlife land suitability analysis and management information has become a focus in current strategies for managing natural resources and monitoring environmental change.

The understanding of the environmental conditions and factors involved in the deterioration of the eco-systems found inside the park areas are fundamental for appropriate management. Chronic disturbances can lead to habitat loss and subsequent reduction of the number of wild life population.

1.3. Objective of the Study

1.3.1. General Objective

The main objective of the study is to assess wildlife land suitability and map out suitable area using GIS and remote sensing techniques so as to aid conservation effort of Mountain Nyala species.

1.3.2. Specific Objectives

- To evaluate wildlife land suitability through employing multi-criteria's for Mountain Nyala species.
- To model habitat suitable range for Mountain Nyala species,
- To identify potential habitat for Mountain Nyala in the study area and
- To produce thematic maps of suitable areas of wildlife Corridors for Mountain Nyala species.

1.4. Significance of the Study

The study has expected to produce suitable areas map of wildlife Corridors for Mountain Nyala 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 Mountain Nyala species, and beyond academic purpose it can 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 Bale Mountain National Park.

1.5. Demarcation of the study

The scope of the study has intended in mapping wildlife land suitability for Mountain Nyala species at BMNP, employing geospatial technologies i.e. geographic information system (GIS), remote sensing (RS) and global positioning system (GPS) that provide the capabilities to acquire analyze and interpret wildlife corridor effectively.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Wildlife

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 and 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).

2.2. 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.

These vegetation changes can affect important plant species for primates, reducing the quantity and quality of food resources available to them. Therefore, primates in habitat fragments are confronted with a modified environment of reduced area, increased isolation, and novel ecological boundaries.

2.3. 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 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).

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 this area.

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 et al, 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: Ethiopian National Parks and wildlife Sancturies, the reason they are eastablished

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 et al, 2001

2.3.1. Mountain Nyala (Tragelaphus buxtoni)

2.3.1.1. Population

The population was estimated at 7,000 to 8,000 (and perhaps up to 12,500) in the 1960s (Brown 1969), and at 2,000 to 4,000 individuals in the 1980s (Hillman 1986). Numbers have declined since then. Mountain Nyalas may be extinct in the eastern and southern extremes of their distribution, but a few may still occur in Asba Tafari and in the border between Bale and Sidamo, south of Kofele. East (1999) calculated the population at 2,650, but subsequent information indicates that this may have been an overestimate.

The main populations formerly occurred in and around the Gaysay grasslands area at the northern end of the Bale Mountains, and its numbers have been monitored since 1983. Numbers here increased to 1,050 by the late 1980s (Hillman 1986) as a result of creation of a national park in the 1970s which provided protection from poaching and excluded cattle grazing. Woldegebriel (1997) estimated the population prior to 1990 at 1,500 to 1,900. Unfortunately, following political unrest after the end of the war in 1991, most mountain Nyala habitat in northern Bale was encroached by cattle and there was extensive hunting. As a result, the Gaysay population decreased to a fraction of what it was earlier. National Park staff estimated it to be 150 to 260 by 1994 (Woldegebriel 1997). There has been some recovery since, and the Gaysay population was estimated at 550 by Refera and Bekele (2004) and Malcolm and Evangelista (2005).

In addition to Gaysay, there may be 80 to 120 mountain Nyalas in other parts of Bale Mountains National Park, less than 100 in adjacent hunting areas to the north of the National Park, and 30 to 60 in Somkaro in west Bale (Sillero-Zubiri C, 2011).

Malcolm and Evangelista (2005) estimated as many as 500 Nyala may occur in hunting blocks east of Bale. This would give a total population estimate for the Bale massif of 1,000-1,400. Small fragmented populations found in Arsi (Galama, Chilalo, Kaka and Munesa), and elsewhere (Kuni Muktar, Din Din, Arba Gugu) would total around 600 (Malcolm and Evangelista 2005). Therefore, it is likely that only 1,500 to 2,000 mountain Nyalas survive throughout the range**.**

A recent survey has indicated the total population may be higher, perhaps up to 4,000 (Evangelista et al. 2007). No Nyalas are currently kept in captivity (East 1999). Most recently, a research has shown that the largest population currently occurs outside Bale National Park on the eastern escarpment of the Bale massif, mainly in Besemena Odobullu and Shedom Berbere (Anagaw Atickem in litt. 2009), and is has indicated the population decreasing.

2.3.1.2. Habitat

Mountain Nyalas occur at elevations of 1,800-3,400m but are most abundant from 2,400-3,200m (Atickem in litt. 2009). They frequent the fringes of woodland vegetations (2,800 to 3,100m) dominated by Artemesia afra, Kniphofia foliosa and Hypericum spp; (Sillero-Zubiri C, 1995). Highest densities (up to 21/km^2) have been recorded in the montane grasslands of Gaysay, Bale, where there is a combination of browse and grass with woodland cover to retreat to during the day,(Hillman,1986).

The formerly large continuous blocks of suitable woodland and Afro alpine habitat have now been reduced to a series of habitat islands in a sea of cultivated fields.

It seems likely that Mountain Nyalas have been forced into higher areas by human increase and livestock grazing, and are also found above 3,400 m in heath forest and heath lands (Erica and Phillippia spp.) and on Afro alpine grasslands (Alchemilla spp., Festuca spp.) up to 4,300 m (Sillero-Zubiri C, 2011). In the eastern extreme of its distribution, a relict population was recorded in forests as low as 1,800m (Bolton D., 2003).

2.3.1.3. Threats to Survival

Fully protected by law but enforcement is generally absent. Effective protection is limited to around 20 km^2 of habitat in Gaysay and around headquarters. The Bale Mountains National Park harbors more than the half the total population of Mountain Nyalas. The small Kuni-Muktar Wildlife Sanctuary was established in 1990 as a second protected area for Mountain Nyala, but by 1996 this sanctuary had suffered severely from poaching, deforestation, cultivation, grazing and extreme gully erosion and the species no longer occurred due to fragmentation extensively.

The Mountain Nyala, along with the Ethiopian wolf, is a key flagship species for Bale Mountains National Park and its future will be closely tied to the future of this protected area. It is also very important to spread the risk by establishing effective protection and management of Mountain Nyala populations elsewhere within its range. Sustainable trophy hunting in some of these areas has very high potential for generating the revenue needed to fund effective conservation of this species and the other endemics which share its habitat.

It may also be advisable to establish a self-sustaining captive population in collaboration with the Ethiopian Wildlife Conservation Authorities (EWCA), as an insurance against future adversity for the wild population.

Threatened by illegal hunting, destruction of montane forest and heath lands, encroachment by cattle, expansion of high-altitude cultivation, roads, and harassment by dogs. Permanent occupation of suitable habitat as a result of increasing human and livestock populations is exerting tremendous pressure on Nyala habitat throughout the range, with anecdotal evidence suggesting Mountain Nyalas actively avoid livestock (Sillero-Zubiri C, 2011). Mountain Nyalas are extensively hunted for meat and horns, the latter used for local medicine and to make nipples for traditional milk bottles. Trophy hunting blocks in Arsi have been hunted out and concessions moved to Bale, with continued pressure by the industry for additional hunting blocks and larger quotas. Effects of current trophy-hunting programs are not well understood and current trophy hunting quotas may be unsustainable in the long-term (Sillero-Zubiri C, 2011). Its restricted range, and fragmented populations, makes it highly vulnerable to human activities and stochastic events.

2.4. GIS and Remote Sensing 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).

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).

2.4.1. 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 as below 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; sited in work of Walelign, (2007):

- ❖ 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) and,
- Roads (network of all paved and unpaved roads)

2.5. 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 proper utilization of land contributes a lot towards development of the economy of any country. This also helps in reclaiming and conserving the soil and other resources of a region through scientific approach to achieve its balanced development. 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 the process of determining the fitness of a given tract of land for a defined use (Steiner, McSherry et al. 2000). In other words, it is the process to determine whether the land resource is suitable for some specific uses and to determine the suitability level. In order to determine the most desirable direction for future development, the suitability for various land uses should be carefully studied with the aim of directing growth to the most appropriate sites.

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.

2.6. Multi-Criteria Evaluation (MCE)

In decision theory, Multi-Criteria Evaluation is the process of applying a decision rule to a set of alternatives. A decision rule is a procedure by which criteria are combined to arrive at a particular evaluation, and by which evaluations are compared and acted upon. A decision is a choice between alternatives, Eastman (2001).

The basis for a decision is known as a criterion. Criteria may be of two types: factors and constraints. Factors are generally continuous in nature (such as the slope gradient or road proximity factors); they indicate the relative suitability of certain areas. Constraints, on the other hand, are always Boolean in character (such as the reserved lands constraint in the example above). They serve to exclude certain areas from consideration. Factors and constraints can be combined in the MCE module using one of three methods (Boolean intersection, Weighted Linear Combination and Ordered Weighted Average); each method is characterized by different levels of control over tradeoff between factors and the level of risk assumed in the combination procedure; Eastman (2001).

Trade off is the degree to which one factor can compensate for another; how they compensate is governed by a set of factor weights sometimes called tradeoff weights.

Factor weights are given for each factor such that all factor weights, for a set of factors, sum to one; they indicate the relative importance of each factor to the objective under consideration. A factor with a high factor/tradeoff weight may compensate for low suitability in other factors that have lower factor/tradeoff weights. In a Multi-Criteria Evaluation, an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective. For example, a decision may need to be made about what areas are the most suitable for industrial development. Criteria might include proximity to roads, slope gradient, exclusion of reserved lands, and so on. Through a Multi-Criteria Evaluation, these criteria images representing suitability may be combined to form a single suitability map from which the final choice will be made Eastman (2001).

Weighted Linear Combination (WLC) is a method where criteria may include both weighted factors and constraints. WLC-PWC/ Pair wise compression starts by multiplying each factor by its factor/tradeoff weight and then adding the results; constraints are then applied by successive multiplication to "zero out" excluded areas. This procedure is characterized by full tradeoff between factors and average risk. Factor weights, not used at all in the case of Boolean intersection (no tradeoff), are very important in WLC because they determine how individual factors will tradeoff relative to each other. In this case, the higher the factor weight the more influence that factor has on the final suitability map.

Along with full tradeoff, this combination procedure is characterized by an average level of risk, as it is exactly midway between the minimization (AND operation) and maximization (OR operation) of areas to be considered suitable in the final result Eastman (2001).

2.7. Wild life habitat Modeling

Quantifying habitat quality is important for management of wildlife populations and conservation planning. Habitat suitability index (HSI) models have been used to evaluate wildlife habitat and the effects of management activities and development since the early 1980s (U.S. Fish and Wildlife Service 1980, 1981). These models are based on functional relationships between wildlife and habitat variables. Values of habitat variables (e.g., herbaceous canopy cover, tree canopy cover, tree height) are related to habitat quality on a suitability index (SI) scale from 0 = “not habitat” to 1 = “habitat of maximum suitability.”

Habitat suitability index scores, also on a 0–1 scale, are usually calculated using a mathematical formula representing hypothesized relationships among the individual SIs. Wildlife–habitat relationships may be supported by empirical data, expert opinion, or both (U.S. Fish and Wildlife Service 1980, 1981). Traditionally, HSI models are applied to a sample of locations within land cover types or dominant over story vegetation types.

Habitat quality in an area is typically summarized in terms of habitat units, which represent the product of the mean HSI score in each vegetation type and the area of land in that vegetation type, summed across the study area.

Now that geographic information system (GIS) software and high-speed computer hardware are widely available, their use among biologists is increasing.

In addition to providing a new, powerful analytical tool, GIS technology allows land and wildlife managers to utilize novel sources of land cover, vegetation, and other habitat data, namely remote imagery from aerial photographs and satellite sensors and GIS databases of elevation, surface water, climate data, and ecological land types. Concurrent with GIS developments have been advances in our understanding of wildlife–habitat relationships, especially at landscape scales Using GIS for HSI-type habitat evaluations has several advantages over traditional HSI modeling.

It is easier and faster to apply GIS-based habitat models to large geographic areas because time- and labor-intensive collection of field data is not necessary. Spatial structure and landscape patterns are often important aspects of habitat quality (Donovan, and Robinson et al. 1987) and are much easier to incorporate in GIS models. Furthermore, GIS based habitat models can be used to evaluate landscapes simulated by spatially explicit forest landscape models LANDIS; which are useful for comparing alternative land management scenarios over time (e.g., Marzluff et al. 2002, Shifley et al. 2000). The full use of GIS in habitat modeling, however, requires the revision of existing HSI models or the development of new ones. Whereas most existing HSI models are based on relatively small-scale habitat variables measured by biologists in the field, GIS-based HSI models have the capability to more readily focus on larger scale habitat variables that can be quantified without going a field.

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).

2.7.1. 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.

2.8. Mountain Nyala Land suitability Analysis

The mountain Nyala is the magnificent antelope restricted a small part of the southeast Ethiopia. The species has only been recorded in a series of volcanic mountain range that lie parallel to the southeast escarpment of the Great Rift Valley. The species is known to occur in six locations. These sites are the Bale Mountains, the Arsi Mountains, Munnessa, Arba Gugu, Dindin and Kunni Muktar. The largest area of habitat lies in Bale Mountain National Park, about 75% of the Nyala habitat. Their habitat extends from 2000_3600m. Variation in slope, aspect and rainfall produce considerable variability across the range of Nyala. http://balemountains.org/

However in most places the forest are ever green with a canopy from 20-40m, Podocarpus gracilor, Croton macrostachyus and Warburgia ugandensis are common, (Refera B. 2004). Above 2700 Hagenia abyssinica is often dominant in drier and well drained area and Hypericum revoltom may extend above the Haginia to 3200m. The limit of the giant heath zone (Erica and Philippia) is variable with some heather occurring as low as 2400m on dry slope; however it is the dominant vegetation from 2800-3400m.

The plants can vary from small trees up to 10m in lower protected sites to 2-3 thickets above the tree line. Much of the remaining habitat is in the heath zone.

This ecosystem is susceptible to both human and natural fire. Between 3600-3800m, the heath zone gives away to alpine moorland. These are dominated by annual grass with small ever green shrubs in the genus Helichrysum common in the drier area. A small area of montane grassland at 3000m by Dinsho in the Bale Mountain has provided an important habitat. Grasses in the genera Bromus, Festuca and Poa cover a small opening in the surrounding montane forests.

The mountains which the Nyala inhabit intercepts rain both from the Atlantic (March June) and from the Indian Ocean (June_ October). Rainfall above 2500m usually exceeds 1000mm annually. http://www.yellowstonepark.com/natural-wonders/wildlife/. There are numerous perennial streams through the mountain. There is a steep rain fall gradient with elevation. Mountain Nyala requires two kind of habitat, cover in which to conceal themselves and foraging grounds. In the Bale Mountains the species uses almost any tall vegetation for covering including Juniperous, Hagenia and Hypercom forest, and especially tall stand of gaint heath, which is found at the northern and along the peak of Harrena forest. They have also been recorded feeding in most of the habitat available in the bale mountain including, grass land, heath lands, moorlands and wood lands. They also make incursion in to farm land outside the parks boundary.

They have not seen in two areas. One is the short grassland and rocky barren land at lower elevation of less than 1900m and high elevation 3600-4220m of the Weyb valley respectively. This area is very exposed and heavily grazed. The other area is the forest that covers the southern ranges of the slope called Harenna forest. This is the largest track of high altitude forest left in Ethiopia and includes large clearings as well as closed canopy forest.

Apart from the first record of Nyala in Bale by Hodson (1927) who might have seen them at the top of the denser Harenna forest, which is open space and dry ever green forest, there is no evidence that they exploited this area. Most of the Tragelaphine antelope to which the Nyala belongs are forest dwellers and there is no large browsing species in the Harenna. The reason for their absence is not clear but it is possible that the lower elevation and the denser forest have always been settled at lower slope, space less forest to exclude Nyala.

Leslie Brown (and many of the hunters report's) considered the stronghold of the mountain Nyala to be in the heath lands, and the great majority of his sighting were in the heather. Once the Bale Mountain National Park was established and some protection was provided the Nyala congregated on the grassland and woodlands around Gaysay at about 3000m.

Data from other part of the species range show that the species can flourish in forest and wood areas. Hillman (1986); considered the grassland and woodlands as the Nyala species very optimum habitat of the higher vegetation zone (Annex 1). This area includes heath and moorlands, which were used as refugees which was from human disturbance, livestock encroachments and road harassments. However, the population of Mountain Nyala declined from time to time, owing to habitat degradation.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. Location

Bale Mountains National Park is located at 6º30'-7º00'N and 39º30'-39º55'E, 400km southeast of Addis Ababa in Oromia region in southeastern part of the country. It belongs to Bale-Arsi massif, which forms the western section of the southeastern highlands of Ethiopia. Geographical boundary of the park lies within five woreda of the Bale zone: Sinana-Dinsho in the North, Adaba in the west, Goba to the Northeast, and Mena-Angetu to the south and Haro to the East. National Forest Priority Areas (NFPA) and Controlled hunting area circumscribe the park. These include Aloshe-Batu in the East Mena-Angetu in the South, Harena-Kokosa and Adaba-Dodola in the west. The controlled hunting areas are: Hanto in the North, Besmena Odubulu and Abasheba Demero in the east.

The NFPAs and the controlled hunting area adjacent to the park are meant to serve as buffer zone for protecting water catchments of the park, wildlife corridor and dispersal areas. The park possesses a total area of 2316km², but not the whole of the park area is under full control at present. It is only a portion of the northern part, which is relatively protected or managed.

Based on the landscapes and altitudinal differences, the park can be divided into three major parts such as the Northern Gaysay area, Central Peaks and Sanete Plateau and Southern part of the park-Harenna Forest.

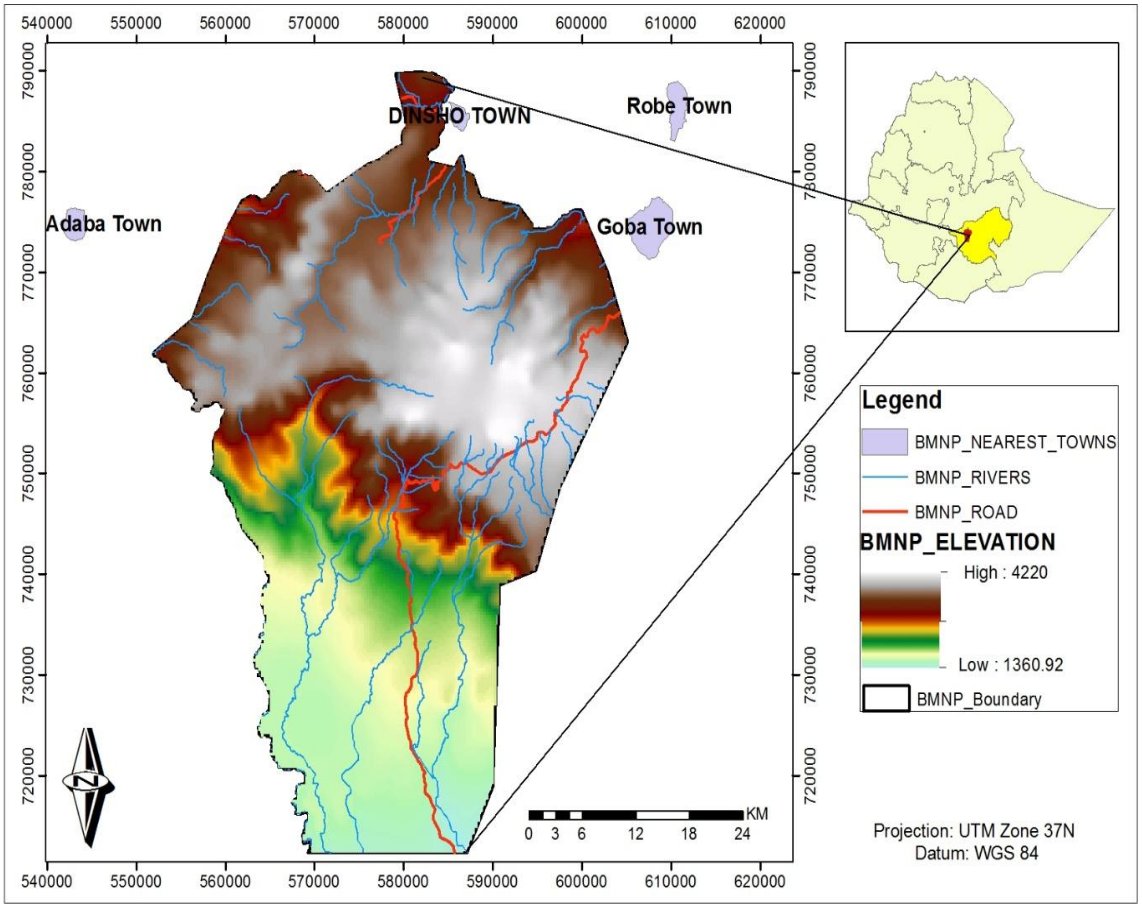


Fig 3.1: Location map of the study area

3.1.2. Physical Environment

3.1.2.1. Geology

Geologically, the Bale massif consists of Tertiary (Oligocene) lavas, which covered the Mesozoic marine sediments by underlying the Precambrian rocks after the Eocene uplifting of Ethiopian highlands.

During the Plio-pleistocene rifting phase, the Arsi-Bale massif was separated from the northwest Ethiopian mountains by the rift valley system, which also isolated the southwest Arabian part of land mass (Miehe G, 1994).

Hence Bale Mountains were formed from volcanic eruption lava in the Miocene and Oligocene geological periods early before the formation of the Great Rift Valley system, probably about 4025 million years ago (Mohr, 1963). Since the crust of the Bale Mountains is of volcanic origin, are fairly fertile silty loams of reddish-brown to black colors.

There is an evidence of glaciations occurred in the Bale Mountains in the past, about 2000 years ago (Smeds, 1959; Mohr, 1963). It is believed that glaciations were in parallel with the glaciations of the Semien Mountains, and East African mountains such as Mt Kilimanjaro and Mt Ruwenzori (Mohr, 1963). Traces of former glaciers are common in the ericaceous and Afro alpine belt. The present topography of Bale Mountains and or BMNP is a reflection of long term, probably over 20 million years of weathering processes that underwent due to heat and pressure that had been originated from the Oligocene lava outflows.

3.1.2.2. Climate

As a result of the great altitudinal variation in Bale mountains massifs, considerable variations of climatic conditions are recorded in the National Park. Bale highlands belong to the east African Climatic domain, which is influenced by low level easterly winds from the Indian Ocean causing small rains in January.

The general rainfall patterns in the central Bale highlands are adjective and the northern part somehow conducive for plant growth, with ample amount of rainfall, and moderate temperature and relative humidity. The central plateau consists of extremely harsh climatic conditions-an erratic rainfall, usually wet and waterish air, icy and frostiness, frequent mist and some 13 times-random falls of hail. Additionally, due to macroclimate variations highlands and valleys create microclimatic conditions usually favored by plants and animals, particularly at the central plateau.

The Bale Mountains is characterized by having eight months rainy season (March to October) and followed by another four months dry season (November to February). Rainfall is well distributed throughout the wet season, ranging from 1000 to1400mm annually (Daniel Gamachu, 1977). Temperature records from the Bale Mountains indicate that the wet seasons are comparatively warm and the dry seasons are extremely nocturnal cold and diurnal warm vis-à-vis. The lowest recorded temperature at highest plateau of Bale (Sanete) was -15ºc and the maximum record was 26ºc (Hillman, 1986). Similarly the lowest recorded temperature in Dinsho area was -6ºc. Relative humidity measured using thermo hygrograph ranged from 17% to 100% during the dry and wet periods respectively (Hillman, 1986).

3.1.2.3. Hydrology

The Bale Mountains are important water source like a tower that supports the life of millions of people and other organisms in the adjacent lowland areas. There are more than forty streams arise within the BMNP.

These join to form four major rivers-the Wabe shebele, the Weyb (leading to the Genale and Juba Rivers), the Welmel and Dumal Rivers; (Table 3.1).

In addition, the water for the numerous springs emerging in the lowlands originates from the Bale Mountains. These rivers and springs are the only sources of perennial water for the critical and lowlands of the east and southeast of Ethiopia, including the Ogaden and Somali areas. In these areas there is an extreme water deficit, particularly during the dry season.

Table 3.1: Major Rivers and their tributaries in the BMNP

No	Major River	Tributaries
1	Wabe shebele	Abasa, Arba, Baranda, Boko, Furuna, Gondedoh, Layleeso, And-Solay, Wachekora, Mararo, Malka Sege
2	Weyb	Albabo, Dalcha, Danka, Dimbeba, Gareno, Gaysay, Kebesha, Kaficho, Keyrensa, Lolla, Micha, Shaya, Shaya-Gugesa,Teynta,Tegona, Toroshoma, Wolla, Wasama, and Zetegn melka
3	Dumal	Six un-named tributaries
4	Welmel	Geremba, Rira, Shawe, Shisha and Yadot

Source: Michael et al, 2001

3.1.2.4. Biological Diversity

3.1.2.4.1. Fauna

The BMNP supports the world’s highest density of endemic mammals together with a rich bird and lower vertebrate fauna.

The great altitudinal variation and habitat diversity in the different part of the park creates conducive environment to harbor varieties of faunal resources. So far 78 mammal and 278 Bird species are recorded in the park as indicated in table 3.2; (sited in the work of Walelign 2007).

The largest percentage of mammal distribution in the park is found in the northern woodlands of the park. As it is evidently found in the fossils, mineralized ivory and teeth in Shisha river during the 1984 expedition, the Harenna forest is used to harbor big mammals such as Elephants (Loxodonta africana) and Buffalo (Syncerus caffer). The park preserves the last large and viable populations of two spectacular species, the Mountain Nyala (Tragelaphus buxtoni) and the Ethiopian Wolf (Canis siemensis).

A number of less dramatic species of rodent, frog and others would probably also be doomed if the habitat in the Bale Mountains were to be irreparably degraded.

Table 3.2: Faunal endemism of BMNP

No	Animals group	BMNP	Endemic Species	%	Ethiopia	Endemic	%	%Endemism-Bale/ Ethiopia
1	Mammals	78	11	14	260	22	9	2
2	Birds	278	2	16.7	816	16	3	1.5
3	Snakes	2	0	0	77	3	3.9	-
4	Frogs	8	7	87.5	55	20	36.4	35

Source: Michael et al, 2001

3.1.2.4.2. Flora

The diversity of Bale Mountains in comparison to that of diversity of plants in the flora of Ethiopia and Eritrea has been studied and documented, from the published volumes and unpublished manuscripts. According to the National Herbarium reports the total number of species of vascular plants is about 6000. The total number of taxa for the Bale floristic region is estimated about 1650 species.

Of these, about 1400 species occur between an altitude of 1500 and 4377m a.s.l. There about 600 endemic taxa in the Flora of Ethiopia and Eritrea, of which 177 (29.5%) are also endemic to Bale floristic region (BMNP). The Bale Mountains National Park and surrounding areas could be divided into southern and northern sides of Bale Mountains. The vegetation in the southern side falls within moist montane forest vegetation type while the northern side classified as Dry evergreen montane forest.

The BMNP and surrounding areas provide a complete altitudinal zonation of vegetation starting from the broadly deciduous woodland in the lower parts, extending through various types of moist montane forests to ericaceous woodland, and culminating at Helichrysum dominated moorland. The study of the National Herbarium generally categorized the vegetation of the southern part of the park into; (sited in the work of Walelign, 2009).

- Octea-Olea-Podocarpus-Syzigium
- Syzigium-Polysciass-Allophylus-Erythrina
- Shefleria-Hagenia-Erythrina-Galiniera
- Hagenia-Hypericum-Schefflera-Myrsine

- Erica arborea trees
- Erica arborea- E.trimera
- Helichrysum citrispinum- H.splendidum

3.2. Data Acquisition and Software Package

3.2.1. Materials

The following softwares were used in the study. These were ArcGIS 10, ERDAS IMAGINE 9.2, IDRISI32, Microsoft Word and Microsoft Excel (Table3.3). In addition to this, satellite imageries and diverse ancillary data have been employed in order to analyze land suitability of the study area.

Table 3.3: Details of materials and software's used in the study

No	Types of materials	Descriptions	Remarks
1	Soft wares	ArcGIS 10 ,ERDAS 9.2, IDRISI32 MS Excel, MS Word	
2	Instruments	GPS (GARMIN), Digital Camera	

Source: Own computation, 2014

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 3.4 are obtained from the respective offices.

Table 3.4: Data used for Analysis

Item	Types of data	Source	Spatial Resolution	Date
1	Contour map	FZSBMNPCP	(20m interval)	2012
	River shape file			
	Settlements Shape file			
	Road Network shape file			
2	Climate data(Temperature)	NMSA	10yrs	2004-2013
3	Soil types	FAO		2011
4	Study area Boundary	BMNP	Shape file	
5	Landsat8	USGS data portal	30m (Path168/55) and (Path167-Row/55/56)	02/07/2014

Source: Own computation, 2014

3.3. Research Methodology

The study is aimed at first identifying functional landscape areas and then mapping out wildlife corridors for Mountain Nyala Species. For mapping functional landscape areas for Mountain Nyala Species eight parameters were selected by consulting Expert of wildlife suitability analysts, based on literatures, visitors' reports and depending on related previous works.

The factors include vegetation types/land uses, soil classifications, slope, elevation, climate factor (temperature), distance from settlements, roads and water recourses. The wildlife corridor mapping was done using GIS analysis and decision support weighting of factors was employed using MCE (Figure 3.2). To carry out the MCE, weight for the factors depending on their suitability for species and then the overly analysis was conducted using ArcGIS10 weighed overlay spatial analyst extension.

Finally, the wildlife corridor model for the selected species was built and map was produced with functional landscapes layer.

METHODOLOGY FLOW CHART

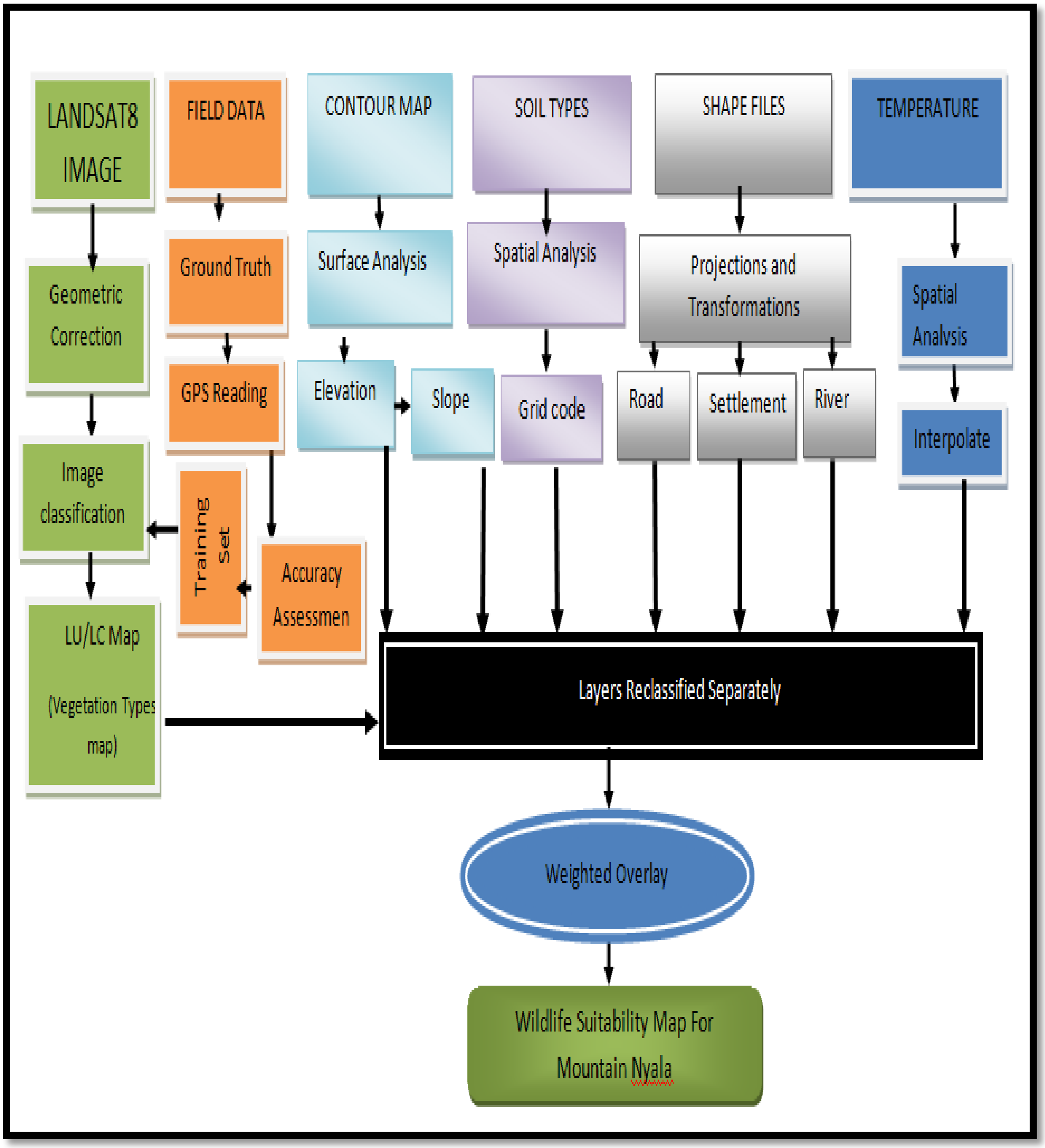


Fig 3.2: Flow chart showing the general methodology

3.3.1. Data Processing and Analysis Methods

3.3.1.1. Mapping Parameters

After data collection, preprocessing of satellite images was conducted and relevant parameters which can be used for mapping functional wildlife corridor and landscape were also extracted. Their relevance for the mapping is described in (Table 3.5).

Table 3.5: Mapping parameters and their relevance

No	Parameters	Expected Relevance for mapping
1	**Climate data(Temperature)**	Conducive condition for feed growth is one of the single most important factors that determine suitability/wildlife habitat obtained through interpolation
2	**Slope gradient**	For identifying of areas receptive to water logging and identify suitable area for MN
3	**LU/LC (Vegetation types)**	For identifying habitat potential as well as vulnerable and receptive potential areas for the wildlife Species.
4	**Distance to river**	For identifying surface waters and wetland/swamps as they are areas favored by MN.
5	**Distance from settlements and roads**	In order to minimize visual, noise, and land use impacts on the wildlife
6	**Soil types**	Is crucial for rating functional landscape for suitability because the fodder for wildlife's i.e. vegetations/ grasses and water logging characteristics of the land

Source: Own computation, 2014

The process of identifying Mountain Nyala habitat suitability in BMNP is based on its life requisites. Accordingly a lot of reports, published relevant references has been reviewed and evaluated up on assessing some literatures. In addition, field investigation was conducted to examine the existing habitat of the defined wildlife species in relevant to its life requisites. The life requisites identified in this study consists of vegetation types/land uses, soil classifications, slope, elevation, temperature, buffer regions within/beyond specified distance from existing human settlement center, water resources and proximity to road, but it does not mean that these parameters are the only wildlife requisites for modeling land suitability for Mountain Nyala species.

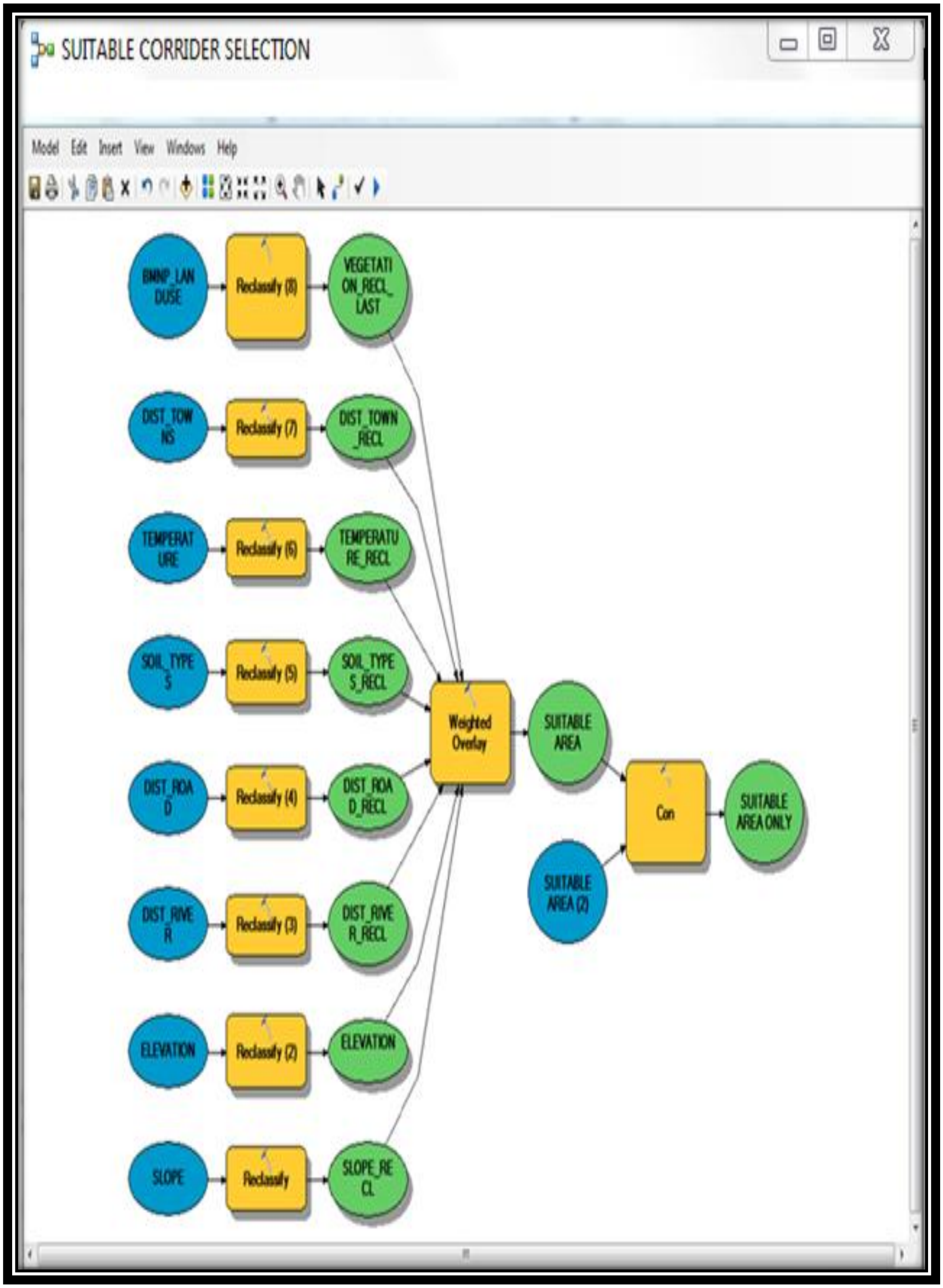
In this study interpretation and classification was carried out in such a way that preprocessing image classification was employed, such as landsat8 image of resolution 30m (path and row 167/055/056 and 168/055) of year 2014 was downloaded from USGS/earthexplorer. Then Image geometric correction and stacking layer of each scene's band has been conducted subsequently. After stacking layers conducted, then the three scenes were mosaic together in order to subset the study area.

After similar band combination has applied supervised classification has been done to classify the present land use land cover/ vegetation types of the study area. Accuracy assessment of classified image was done in to two ways. In the field observation and a GPS data was collected from sample areas to make accuracy assessment of classified image with ground features. The other way was through generating random points over the settled trainings. In almost all cases different features appeared to be similar in reflectance. Finally the reclassified vegetation types were crosschecked with Google earth image.

Settlement, river and road shape files were obtained from BMNP Frankfurt Zoological Societies Conservation Project which extracted to identify the parks' infrastructure produced at 2012. The proximity factors were processed in ArcGIS10 using Analysis tools i.e.; Proximity (buffer), Overlay (erase) and finally the erased datasets were merged together. Soil types were obtained from FAO soil category of Genale, Dawa and Wabe shebele of river basin master plan development studies report in 2011. The soil types converted to polygon feature and then dissolved to grid code which enables to know the area coverage of each category.

The Elevation and slope gradient in the area was generated from Contour map which has 20m interval obtained from Frankfurt Zoological Society's BMNP Conservation Project and extracted using Arc GIS soft ware. Temperature data was collected from National Meteorology Service Agency (NMSA) i.e. the 10years average temperature of five nearby stations (Goba, Robe, Sinana, Adaba and Dinsho) and then interpolated to the surface or to elevation difference of the study area using kriging method. Each of the datasets with its associated attribute data are digitally encoded in GIS data base. A geo database consisting of all factor layers was created in ArcGIS10 software then each datasets were raster zed using conversion tools to make ready for reclassification.

Each layer was subjected to undergo reclassification process on model builder and weight influence was calculated through pair wise compression matrix on weighted module of MCE. Eventually weighted overlay technique was performed to come up with Nyala habitat suitability map. Schematic view of the model building process for Nyala habitat suitability map is illustrated in (Figure 3.3).



Figures 3.3: Schematic diagram of Wildlife land suitability model building process

CHAPTER FOUR

4. DATA ANALYSIS AND DISCUSSION

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 for functional landscapes were analyzed. The following factors (Table 4.1) were considered for the evaluation of physical land suitability of the study area for functional landscapes and wildlife corridors i.e. vegetation type, soil types, topographic factors (elevation and slope), climate factor (temperature), proximity factors (distance from settlement, road and river).

Based on the structure of FAO land suitability classification/ 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 most suitable (S1), moderately suitable (S2), less suitable (S3), not suitable (N1) and permanently not suitable (N2). Whereby, this study has put in consideration the anthropological /landscape factors and other relevant review of literatures as well as researches specific to suitability level per parameter for Mountain Nyala wildlife corridor has been conducted through adopting measuring suitability ranks; giving value 5 is the highly suitable and value 1 is permanently not suitable area/ improbable area for wildlife corridor.

Likewise, highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently not suitable (N1) and permanently not suitable (N2).

This means that highly suitable area is whereby Nyala species habit and occur mostly, moderately suitable area is the medium habitat suitable range for mountain Nyala species and marginally suitable area is a range where less suitable for the Nyala species, which in general called wildlife corridor or habitat suitable range.

Whereas the area which is currently not suitable is the range which would seeks to be modified and improved to be suitable range potentiality for selected species. An area which is permanently not suitable for Nyala species is the area where they no longer occurred at such ecosystem based on the sum of land characteristics factors considered in this study.

Accordingly, based on various reviews, national manuals, guidelines, research station publications and relevant literatures suitability levels per parameters for Mountain Nyala wildlife corridor was defined in the following table 4.1.

Table 4.1: Characteristic of factors in relation to wildlife corridor of Mt. Nyala species

Land Characteristics	Unit	Suitability Ranges/Values				
		S1=5	**S2=4**	**S3=3**	**N1=2**	**N2=1**
Vegetation type	**types**	Woodland	Grass Land	Dry Ever green Forest /Alpine Bush Land	Bare land/Scattered farm plot	Moist montane Forest /Water Bodies
Temperature	**°C**	10-12.5	12.5-15	15-17.5	17.5-20	> 20
			7.5-10			< 7.5
Slope gradient	**%**	0-12.5	12.7-25	25-38.2	38.2-51	>51
Elevation	**m**	2632-2950	2950-3267	3267-3585	3585-3902	3902-4220
			2314-2632	1996-2314	1679-1996	1360-1679
Settlement proximity	**km**	>15	12-15	9-12	6-9	<3
Road proximity	**km**	>9	6-9	3-6	0.5-3	< 0.5
River proximity	**km**	<2.7	2.7-3.9	3.9-5.1	5.1-6.3	>6.3
Soil types	**Class**	Chromic Luvisols	Eutric Nitisols	Dystric histosols	Eutric Fluvisols	Pellic Vertisols
			Eutric Cambisols	Chromic Cambisols	Orthic Luvisols	Chromic Vertisols

Source: Own computation, 2014

4.1. Datasets Reclassification

The factors have been developed based on literature review. Accordingly the above eight land characteristics/ factors (table 4.1) above were considered in this study for Nyala habitat suitability analysis was reclassified as follows.

4.1.1. Vegetation Types

Vegetation Type is one of life requirement of Mountain Nyala species. Mountain Nyala requires two king of habitat cover in which to conceal theme selves and foraging grounds. In the Bale Mountains the species uses almost any tall vegetation for covering including Juniperous, Hagenia and Hypericum forest, and especially tall stand of giant heath. They have also been recorded feeding in most of the habitat available in the Bale Mountains including, grass land, heath lands, moorlands and wood lands.

Hence, the analysis of land suitability for Nyala species, knowing vegetation types is the curtail one. To do so, the interpretation and analysis of remote sensing imagery that involved the identification and measurement of various targets in images in order to extract information about the targets was conducted.

Interpretation and classification was carried out in such a way that preprocessing image classification was employed, such as landsat8 image of 30m resolution (path and row 167/055/056 and 168/055) of year 2014 was downloaded from USGS/earthexplorer. Then Image geometric correction and stacking layer of each scene's band has been conducted subsequently. After stacking layers conducted, then the three scenes were mosaic together in order to subset the study area. After similar band combination has applied supervised classification has been done to know the land use land cover/ vegetation types of the study area. Accuracy assessment of classified image was done in to two ways. In the field observation and GPS data was collected from sample areas to make accuracy assessment of classified image with ground features. In almost all cases different features appeared to be similar in reflectance.

Hence, an accuracy assessment was carried out to assess the quality of the land cover maps. One of the commonly used methods to assess the accuracy of classified image is the kappa statistics which has acceptable range, a technique that provides some statistical and analytical approaches to explain the accuracy of the classification. In this study kappa statistics (confusion Matrix) was applied with some quality measures like user and producer's accuracy; overall accuracy was 82.50% and Kappa analysis 0.76 (Annex 3: Table of classification accuracy assessment report). This could be best exemplified by where about 75% of Nyala species are found at north part of the park so called Gaysay, and also simple to identify moist montane forest, the bare land and farm plot land.

Accordingly, eight vegetation types were identified from supervised classification of Landsat8 USGS, 2014 image. These include moist montane forest, dry ever green forest, wood land, alpine bush land, montane grass land, water bodies, barren land and scattered farm plots. Water and shadow area showed an overlap in their spectral reflectance and posed some difficulties in the course of classification. The moist montane forest areas however, showed a good textural difference from dry ever green forest and alpine bush land forests. The description and the map that reveals location of identified vegetation types in the study area is here as follows; (table 4.2).

The moist montane forest: The moist montane forest is the dominant vegetation type that occurs in the southern escarpment of the park**,** which is covered by one of the most extensive natural forests remaining in Ethiopia, called "Harrena forest".

Dry ever green forest: Dry ever green forest mainly occur on the tree line of Harrena forest escarpment which is about 3200m.a.s.l and north eastern part of the park or around the periphery of the park. The types of dominant vegetation include Hagenia abyssinica and Juniperous procera.

Bare land: Bare land occurs around the Northeast central part of the park which is characterized by higher altitude.

Wood land: Wood land is dominantly occurring in the northern part of the park which is considered as the Nyala species optimum habitat and the higher vegetation zone.

Alpine bush land: Alpine bush land is second to moist montane forest, the largest land cover type which can be found almost in all direction of the park.

Scattered Farm plot: Pasture and Farm plot occur on the scattered pattern by existing homesteads mainly at northwest part of the park.

Montane grass land: Montane grass land area mainly occurs around the Northwest and Northeast part of the park beneath to Boddetti and Kara Roba hills, which is optimum habitat for Nyala species next to woody vegetation types.

Water bodies: Water class refers to all main rivers and newly emerged alpine lakes which are found at north east and center of the park. The vegetation types/land use land cover of the study area was mapped out as follow (Figure 4.1).

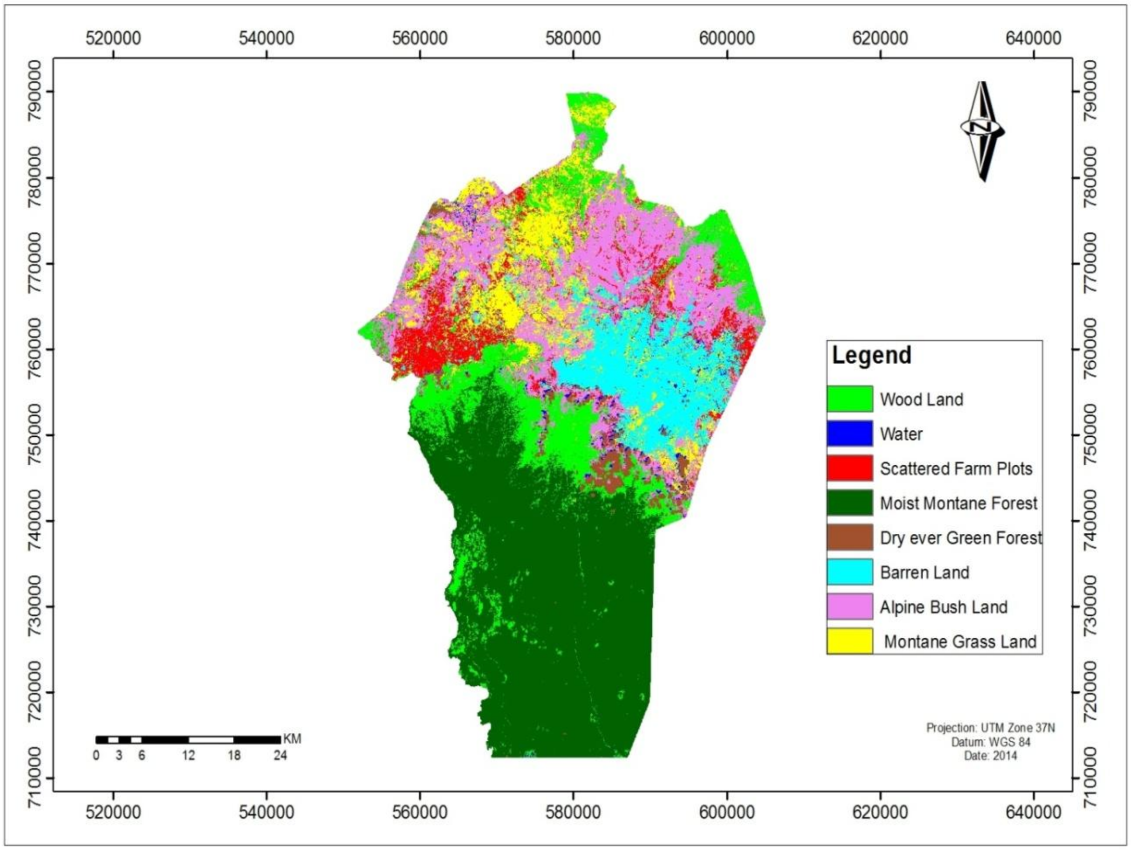


Fig 4.1: Land use/land covers Map

Table 4.2: Present land use land cover of BMNP

No	Class names	Area (Ha)	Area (Km^2)	Area (%)
1	Moist Montane Forest	86093.6	860.9	37.10
2	Alpine Bush Land	41199.4	412	17.76
3	Wood Land	33223.3	332.2	14.32
4	Barren Land	24033.3	240.3	10.36
5	Scattered Farm Plots	14887.4	148.9	6.42
6	Dry ever Green Forest	5956.9	59.6	2.57
7	Montane Grass Land	24650.1	246.5	10.62
8	Water resources	1978.3	19.8	0.85
Total		**232022.3**	**2320.2**	**100.00**

Source: Own computation, 2014

According to the importance of the types of vegetation the identified land use/ land cover of the study area was reclassified in to five suitability ranking. Hence, the scale value was given based on their influence on Nyala species habitat. Likewise; wood land, grass land, alpine bush and dry ever green forest were given 5, 4, and 3 values which were highly suitable, moderately suitable and marginally suitable area ranges respectively.

Whereby bare land and scattered farm plots valued as 2 as well as moist montane forest and water was ranked as the value of 1, were currently not suitable and permanently not suitable areas respectively. This implies that, land use/ cover ranked as the value of 2 was bare land and scattered farm plots mean to currently not suitable areas i.e. if there would be some treatment, it would have a probability to be Nyala species habitat. Beyond this, since moist montane forest is denser and Nyala doesn't live within water bodies, ranked as permanently not suitable. The reclassified vegetation type's suitability map is demonstrated as follow. (Figure 4.2). The area suitability level of vegetation types of the park, after reclassification has been done was generated through dissolving the features of layer as follow table 4.3.

Table 4.3: Area of suitability level in terms of Vegetation types (BMNP)

No	Suitability Class	Area (Km^2)	Area (%)
1	Permanently not suitable	882.296043	38.10
2	Currently not suitable	390.239428	16.85
3	Marginally suitable	476.969031	20.59
4	Moderately suitable	236.927466	10.23
5	Highly suitable	329.523052	14.23
	Grand total	**2315.95502**	**100.00**

Source: Own computation, 2014

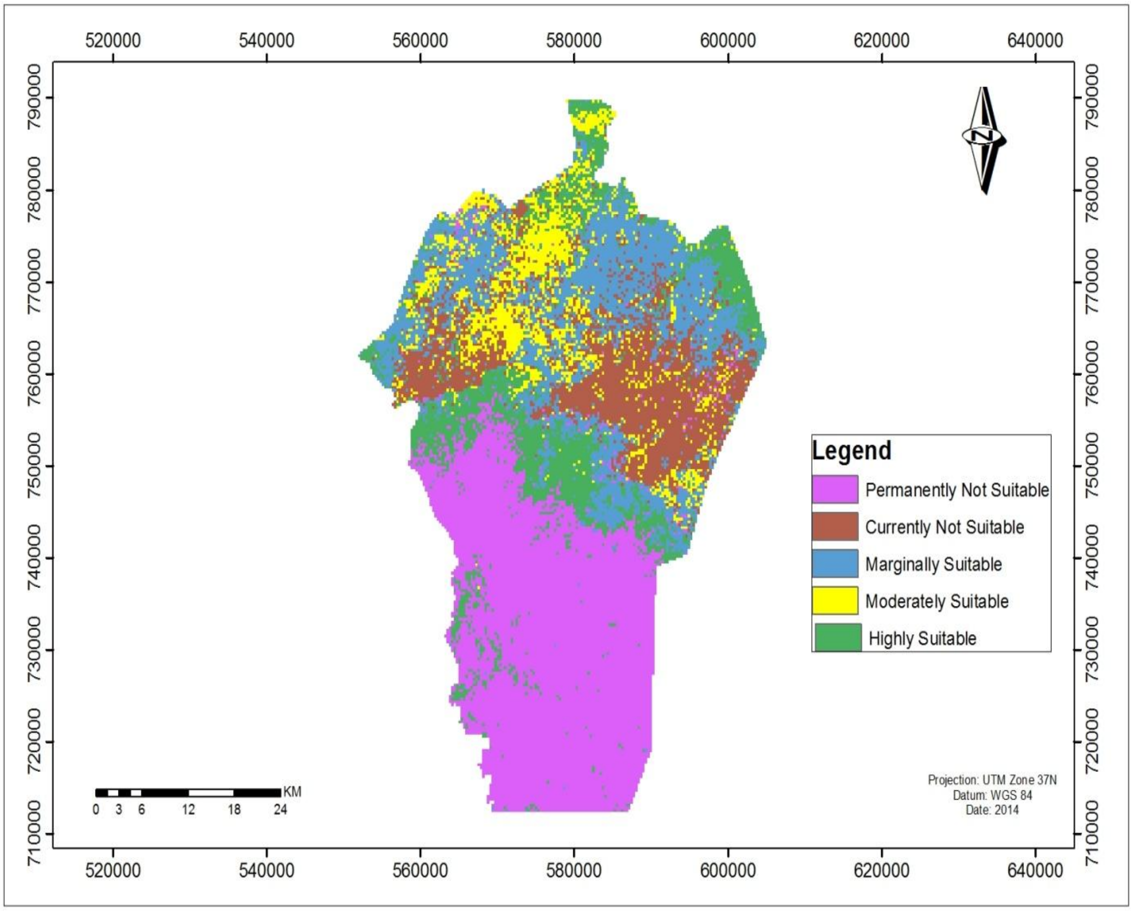


Fig 4.2: Reclassified Vegetation Map

From the above map of vegetation type shown with green color is highly suitable area, yellow color is moderately suitable, apatite blue is marginally suitable, Purple Heart color is currently not suitable and amethyst color is permanently not suitable.

4.1.2. Elevation

Mountain Nyalas occur at elevations of 1,800-3,400 m but are most abundant from 2,400-3,200 m (Atickem in litt. 2009). They frequent the fringes of montane grasslands (2,800 to 3,100 m) dominated by Artemesia afra, Kniphofia foliosa and Hypericum spp. (Sillero-Zubiri C, 2011). Highest densities (up to 21/km²) have been recorded in the wood land and montane grasslands of Gaysay, Bale, where there is a combination of browse and grass with woodland cover to retreat to during the day (Hillman 1986). Thus, elevation provides habitats for the Mountains Nyala species.

The elevation layer was extracted from contour map that has 20m interval using 3D analyst tool, through creating TIN of the study area. Then, the created TIN was converted to Raster and reclassification was done on the layer using GIS, according to the Mountains Nyala species habitat tied to the elevation a new value assigned to elevation. So that, elevation is one of important topographic factor which need to be considered in the analysis Mountains Nyala corridor. In general, suitable elevation extends from 2500 to 3600 m.a.s.l. The Elevations in the study area were mapped as follow (Figure 4.3).

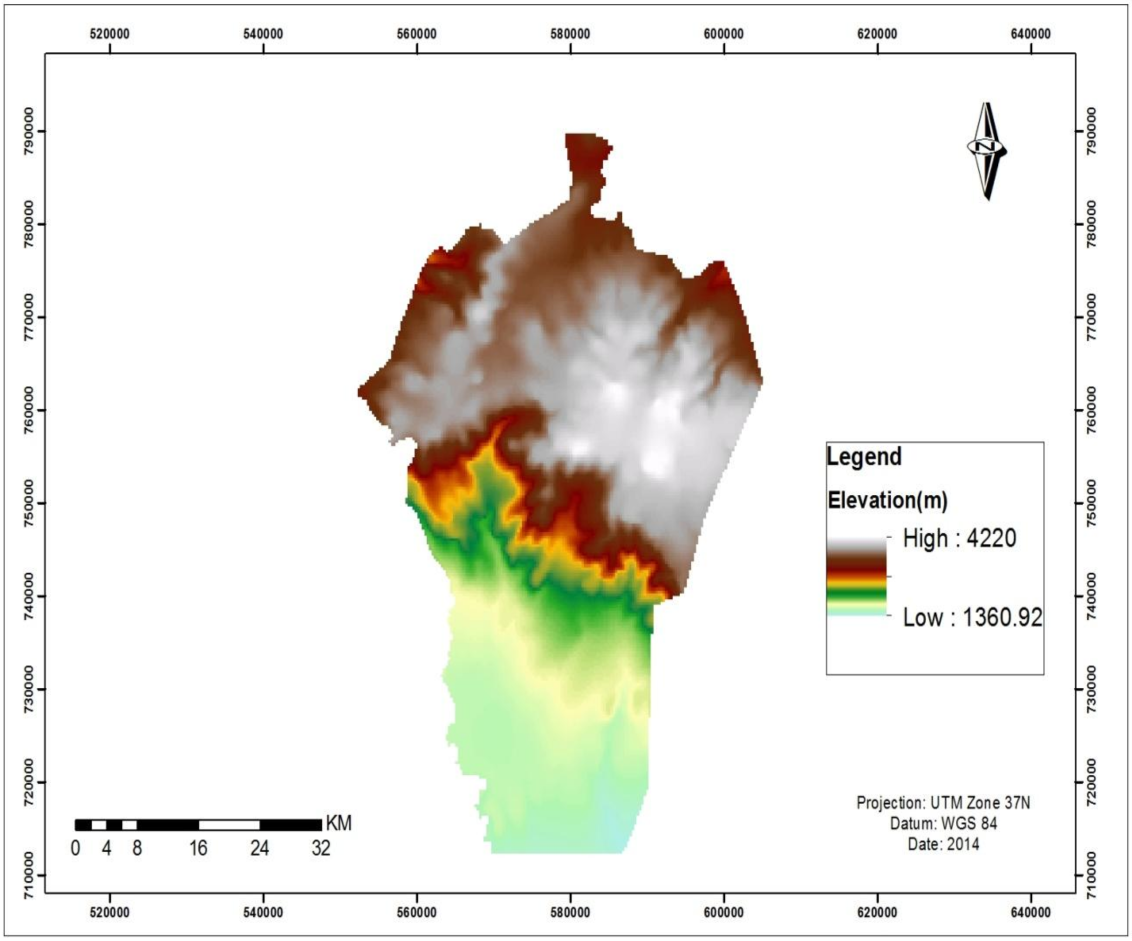


Fig 4.3: Elevation Map

Hence, new values as it is indicated in (Table 4.1), were re-assigned as 5, 4, 3, 2 and 1 in order to show the relative suitability rank of the class ranges of 2632-2950, (2950-3267 and 2314-2632), (3267-3585 and 1996-2314), (3585-3902 and 1679-1996), and (3902-4220 and 1360-1679) as highly suitable, moderately suitable, marginally suitable, currently not suitable and permanently not suitable areas respectively.

The area suitability level of elevation of the park after reclassification has been done was generated through dissolving the features of layer as follow table 4.4.

Table 4.4: Area of suitability level in terms of Elevation (BMNP)

No	Suitability Class	Area (km^2)	Area (%)
1	Permanently not suitable	676.91	29.249
2	Currently not suitable	851.48	36.7922
3	Marginally suitable	449.09	19.4049
4	Moderately suitable	250.54	10.8258
5	Highly suitable	86.28	3.72807
	Grand total	**2314.30**	**100**

Source: Own computation, 2014

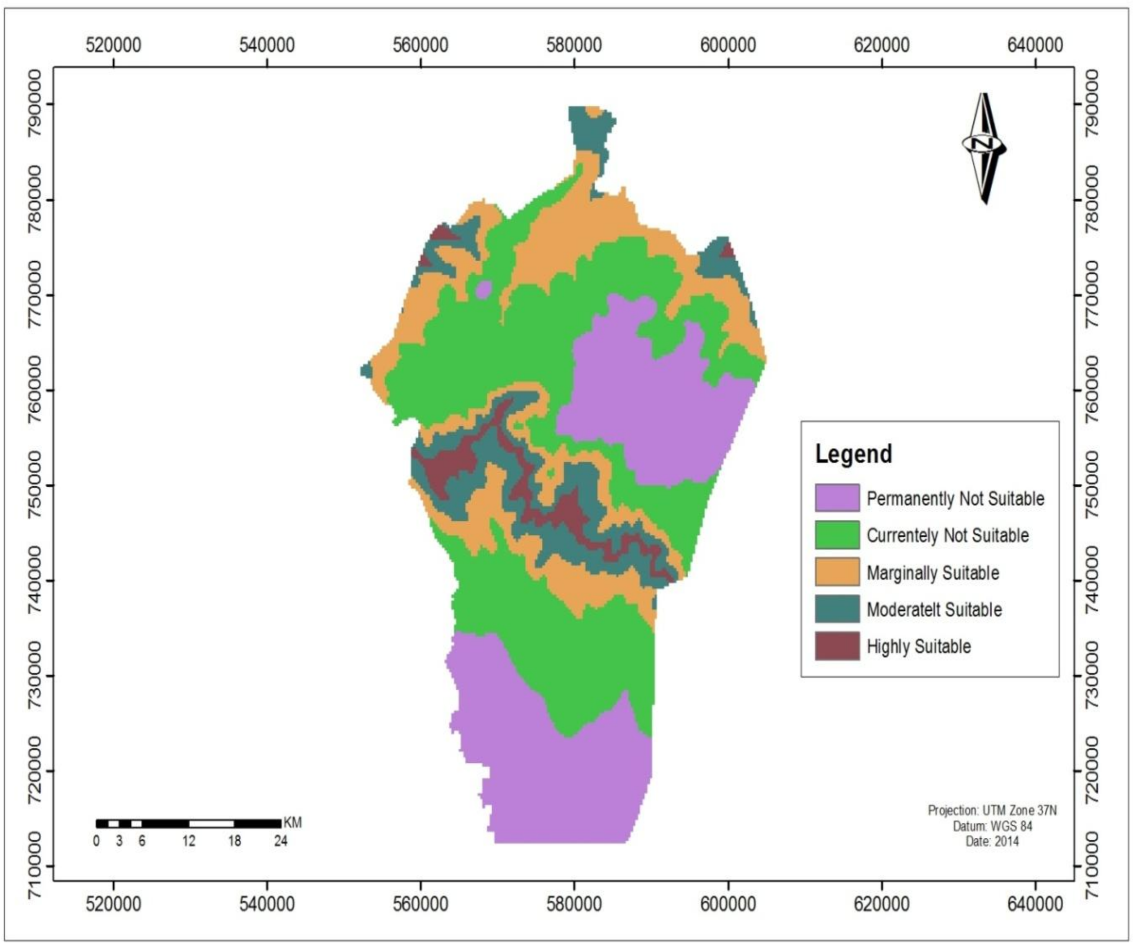


Fig 4.4: Reclassified Elevation Map

Accordingly, the values of derived dataset representing elevation have all been reclassified to a common measurement scale, giving each integer value 1 to 5. Higher values have been given to attributes within dataset that is more suitable for locating the Nyala habitat. From the reclassified elevation map the higher elevation (3902-4220 and the lower elevation 1360-1679) demonstrated by violet color shows permanently not suitable area, the green color reveals currently not suitable area, dark yellowish color represent less suitable, dark blue color is moderately suitable, and dark and purple heart color is most suitable areas. The reclassified Elevation layer is indicated in Figure 4.4 above.

4.1.3. Slope gradient

Slope is also one of the factors identified to model wildlife land suitability for Nyala species. Thus, the slope of the study area was derived from the elevation using slope spatial analysis tool (Figure 4.5).

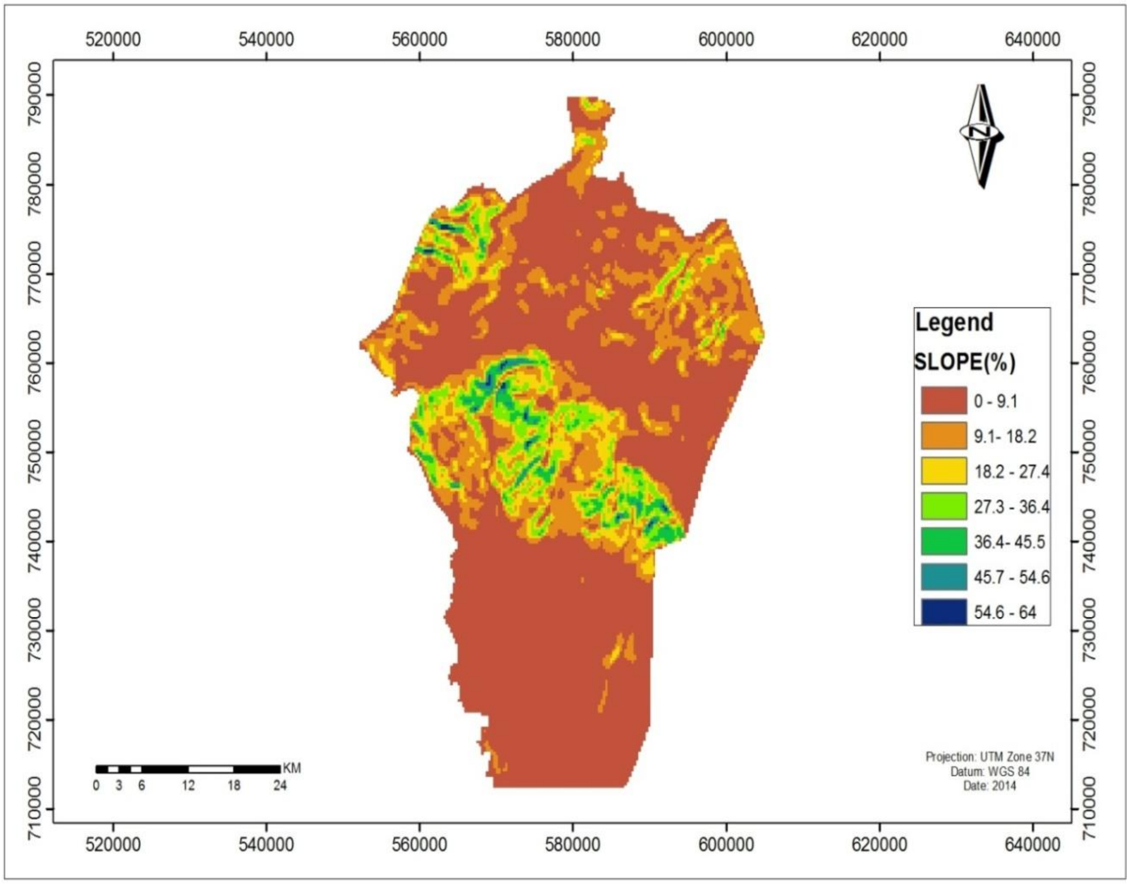


Fig 4.5: Slope Map

The slope gradient has great impact on Mountain Nyala movements; consequently, the slope is ranked according to its significance for Nyala shelter, and fodder and water resources. Therefore, and the new class of the slope was reclassified in to five classes like 0-12.5, 12.7-25, 25-38.2, 38.2-51 and 51-64 that contends highly suitable, moderately suitable, marginally/less suitable, currently not suitable and permanently not suitable area (Figure 4.6).

The area suitability level of slope gradient of the park after reclassification has been done was generated through dissolving the features of layer as follow table 4.5.

Table 4.5: Area of suitability level in terms of slope gradient (BMNP)

No	Suitability Class	Area_km^2	Area (%)
1	Permanently not suitable	7.94	0.34
2	Currently not suitable	43.82	1.89
3	Marginally suitable	167.55	7.24
4	Moderately suitable	397.00	17.15
5	Highly suitable	1698.13	73.37
	Grand total	**2314.44**	**100.00**

Source: Own computation, 2014

The steeper the slope, the difficult for movement of species. This is because steep slope will require more grading and earth movement than gentle slope. As a result of this, the landscape which ranges up to 38% gentle slope is the optimum and slope reveals that the area which is greater than 51% is permanently not suitable Mountains Nyala species habitat (Figure 4.6).

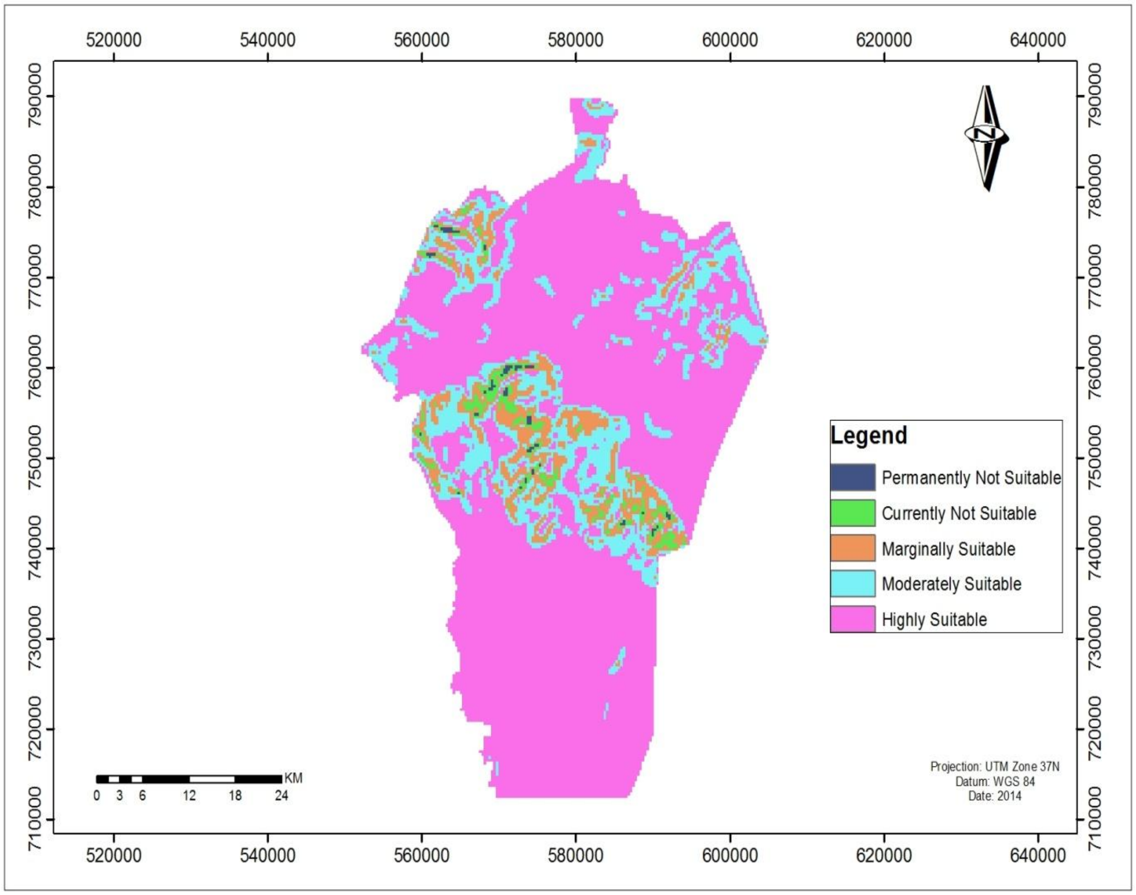


Fig 4.6: Reclassified Slope Map

This means that relatively, gentler slopes are better suitable for Nyala species and steeper slopes are less suitable. Steep slope is classified as permanently not suitable and gentle slope was classified as most suitable.

4.1.4. Temperature

Temperatures vary widely throughout BMNP; on the plateau, daytime temperatures are usually around 10°C (50°F) with strong winds; in the Gaysay Valley average daytime temperatures are around 20°C (68°F), and the Harenna forest is around 25°C (77°F).

However, weather changes frequently and sometimes drastically. In elevations over 3,000 meters, night frosts are common.

The rainy season is from May until November. This implies that the extremely higher and lower the temperature becomes, the lower the Nyala species habitat potential suitability. http://en.wikipedia.org/wiki/Bale_Mountains_National_Park. Thus, this study has considered a climate factor (temperature) to model wildlife suitability corridor for Mountain Nyala. The 10years average temperature record of the five nearby metrological station (Dinsho, Goba, Sinana, Robe and Adaba) was interpolated to the total study area, (Figure. 4.7).

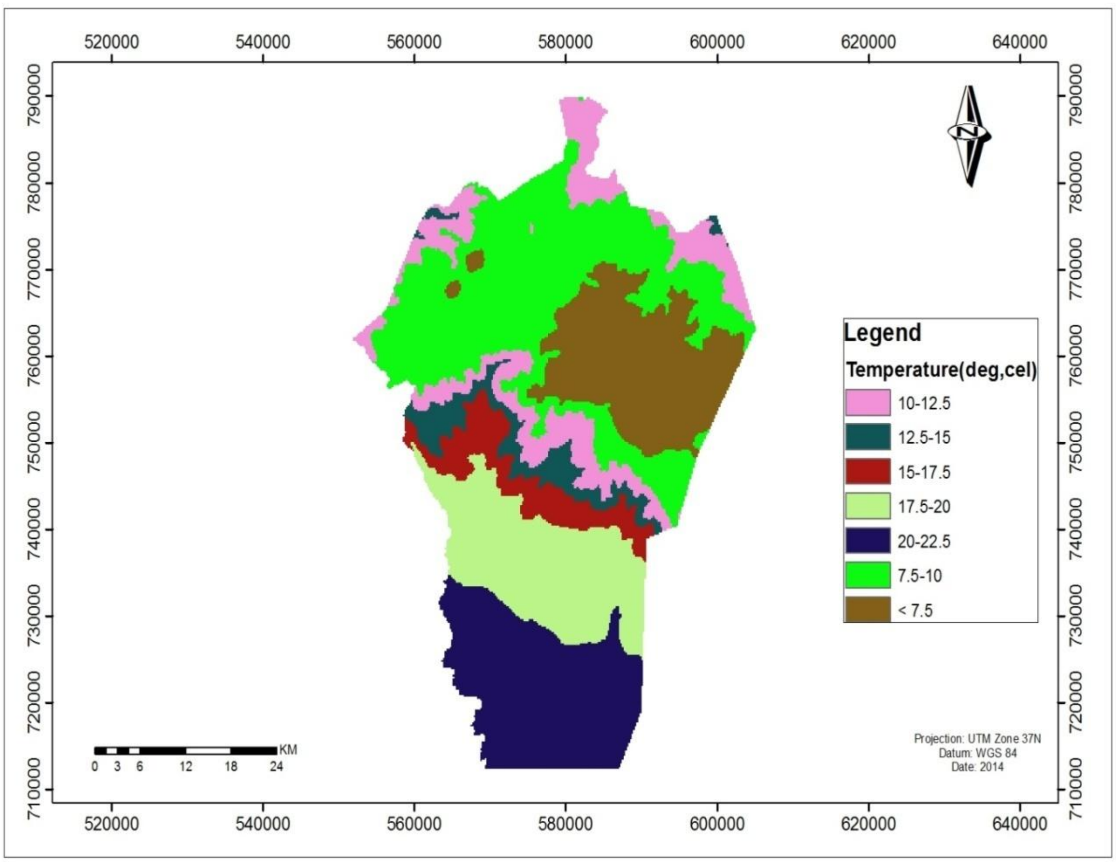


Fig 4.7: Temperature Map

The temperature surface was reclassified in to common scale with the assumption that the medium the temperature amount the more the area is suitable for Nyala wildlife corridor.

The area suitability level of temperature after reclassification has been done was generated through dissolving the features of layer as follow table 4.6.

Table 4.6: Area of suitability level in terms of Temperature (BMNP)

No	Suitability Class	Area_km^2	Area (%)
1	Permanently not suitable	766	33.07
2	Currently not suitable	343	14.81
3	Marginally suitable	137	5.92
4	Moderately suitable	791	34.15
5	Highly suitable	279	12.05
	Grand total	**2316**	**100**

Source: Own computation, 2014

As a result of this, the temperature surface was reclassified into five class i.e. the higher value was given for a temperature ranges from 10-12.5°C highly suitable, (12.5-15°C and 7.5-10°C) was moderately suitable, 15-17.5°C marginally suitable, 17.5-20°C currently not suitable and (> 20°C and < 7. 5°C) permanently not suitable. Like other reclassified suitability factors, the reclassified temperature was mapped out (Figure: 4.8).

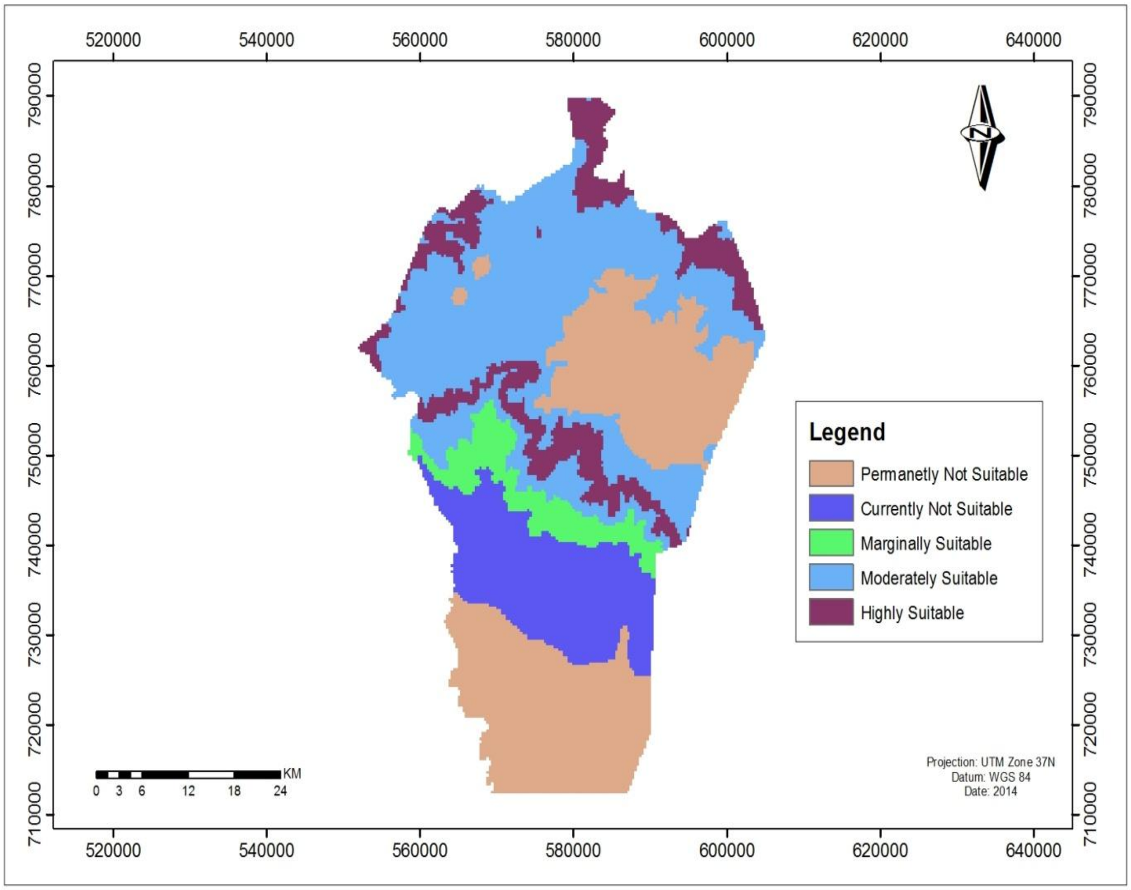


Fig 4.8: Reclassified Temperature Map

4.1.5. Soil Types

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. Here to identify the Nyala corridor the physical properties of the soil types were considered mainly i.e. the drainage capacity, erosion and water logging characteristics of soil classification.

The soil type's data was obtained from FAO soil classification from Genale, Dawa and Wabe shebele river basin master plan development studies' report in 2011.

The major soil types in the study area include; fertile but poorly drained pellic vertisols and chromic vertisols covering about 31. 8 percent of the park is found on the low-lying plains. The higher elevation plains are relatively infertile well-drained Eutric cambisols and Orthic luvisols on 14 percent of the area. On the gently sloping foothills below the escarpment are relatively fertile chromic luvisols and Eutric nitisols occasionally with high water tables, with 50 percent of the area. On the escarpment with 5 percent of the area are deep well drained Chromic cambisols and Dystric histosols of less fertility (Table 4.3).

Table 4.7: Soil types distribution of BMNP.

No	Soil types	Area(Ha)	Area(km^2)	(%)Area
1	Chromic cambisols	246.4	2.5	0.1
2	Chromic luvisols	75137.3	751.4	32.5
3	Chromic vertisols	33.1	0.3	0.0
4	Dystric histosols	9306.9	93.1	4.0
5	Eutric cambisols	30881.2	308.8	13.3
6	Eutric fluvisols	770.9	7.7	0.3
7	Eutric nitisols	40853.2	408.5	17.6
8	Orthic luvisols	640.0	6.4	0.3
9	Pellic vertisols	73643.0	736.4	31.8
Total		**231512.0**	**2315.1**	**100**

Source: Own computation, 2014

Hence the soil type's map of the study area was generated to reveal their thematic map including nine classes likewise: Chromic cambisols, chromic luvisols chromic vertisols, Dystric histosols, Eutric cambisols, Eutric fluvisols, Eutric nitisols, Orthic luvisols, and Pellic vertisols (Figure 4.9).

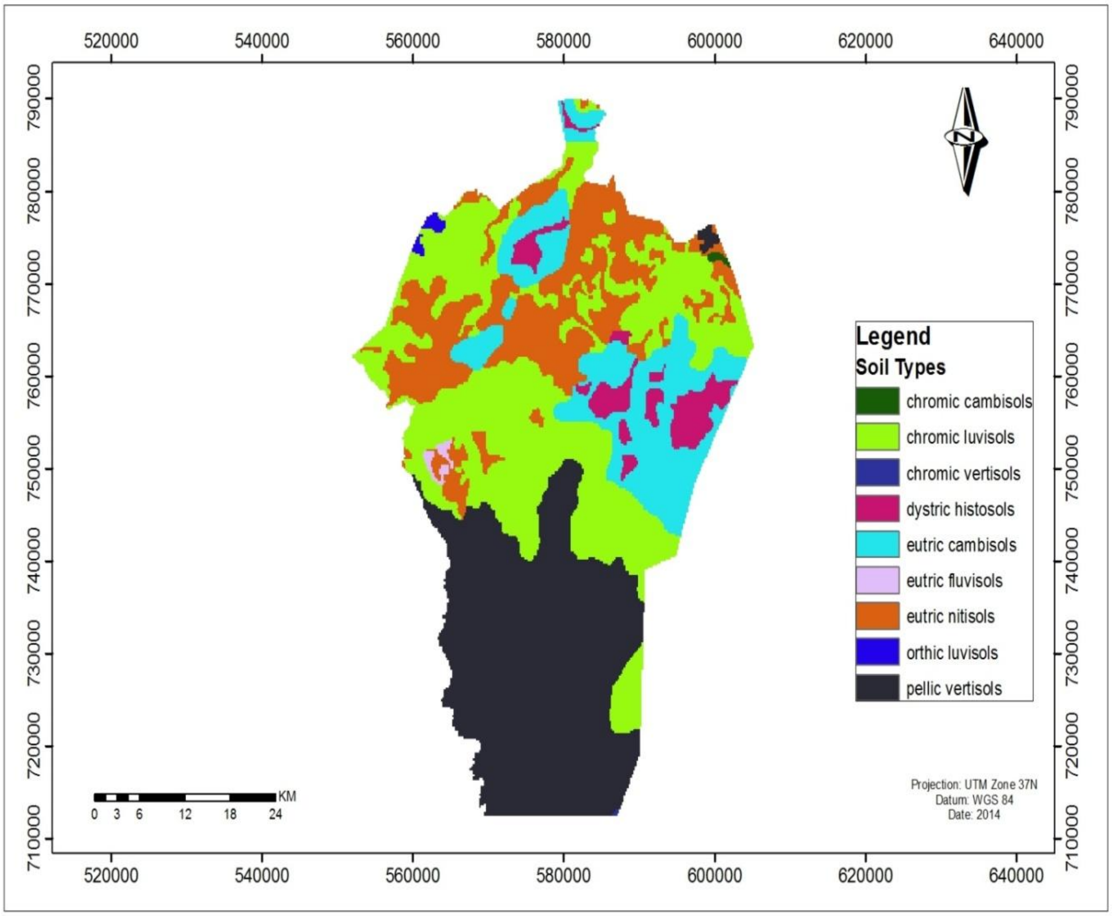


Fig 4.9: Soil Types Map of BMNP

The major soil types are converted to raster format in GIS Conversion tool and then reclassified on model builder using reclassify spatial analysis tool based on their suitability rate.

In the new reclassified evaluation; highest suitability value 5 was given for chromic luvisols, value 4 for Eutric Nitisols and Eutric Cambisols, value 3 for Dystric histosols and Chromic Cambisols, value 2 for Eutric Fluvisols and Orthic Luvisols and the lowest suitability value 1 was given for Pellic Vertisols and Chromic Vertisols (Figure 4.10).

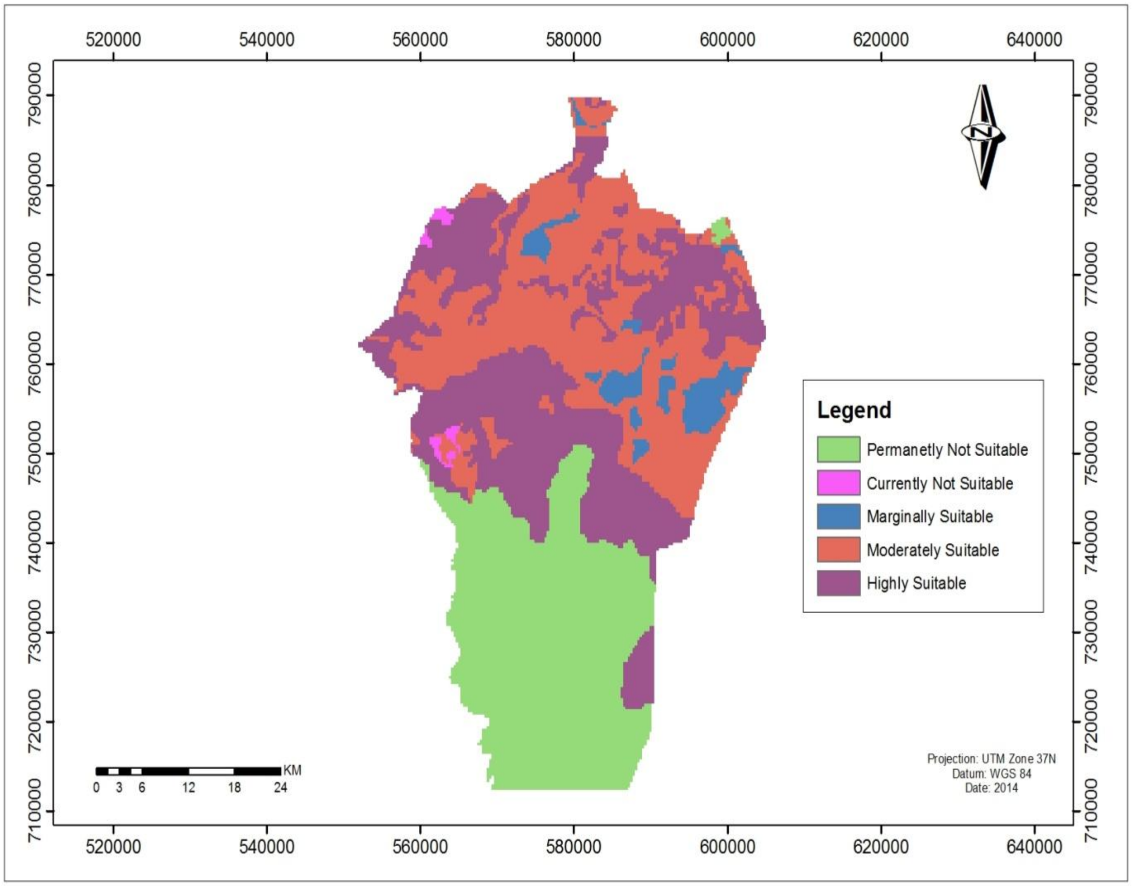


Fig 4.10: Reclassified Soil Types Map

The area suitability level of the soil types after reclassification has been done was generated through dissolving the features of layer as follow table 4.8.

Table 4.8: Area of suitability level in terms of Soil types (BMNP)

No	Suitability Class	Area (Km^2)	Area (%)
1	Permanently not suitable	739.15	31.87
2	Currently not suitable	12.77	0.55
3	Marginally suitable	92.68	4.00
4	Moderately suitable	720.49	31.07
5	Highly suitable	753.84	32.51
	Grand total	**2318.93**	**100.00**

Source: Own computation, 2014

4.1.6. Proximity Factors

Mountain Nyala are threatened by illegal hunting, destruction of montane forest and heath lands, encroachment by cattle, expansion of high-altitude cultivation, roads, and harassment by dogs. Permanent occupation of suitable habitat as a result of increasing human and livestock population is exerting tremendous pressure on Nyala habitat throughout the range, with anecdotal evidence suggesting mountain Nyalas actively avoid livestock (Sillero-Zubiri C, 2011). Mountain Nyalas are extensively hunted for meat and horns, the latter used for local medicine and to make nipples for traditional milk bottles. Trophy hunting blocks in Arsi have been hunted out and concessions moved to Bale, with continued pressure by the industry for additional hunting blocks and larger quotas

Effects of current trophy-hunting programs are not well understood and current trophy hunting quotas may be unsustainable in the long-term (Sillero-Zubiri C 1995). Its restricted range, and fragmented populations, makes it highly vulnerable to human activities and stochastic events.

Hence, in order to model land suitability for mountain Nyala species, considering proximity factors are very significant.

4.1.6.1. Distance to settlement

Many wild life species including mountain Nyala species need safe area with no human disturbance/interference. In order to minimize visual, noise, and land use impacts; wildlife corridors should be established a certain kilometers far from settlements and or from any encroachment. For this study, distance from nearest towns is considered.

Proximity to human settlements, and associated urban land uses often defined the limits of habitat concentrations and wildlife corridors, accordingly by making a buffer rings according to proximity to the nearby towns the study area divided in to five classes. Thus, potential habitat for Nyala should preferable is some distance away from human settlement (Figure 4.11). Accordingly areas which are found away from the settlement have given relatively higher weight/value.

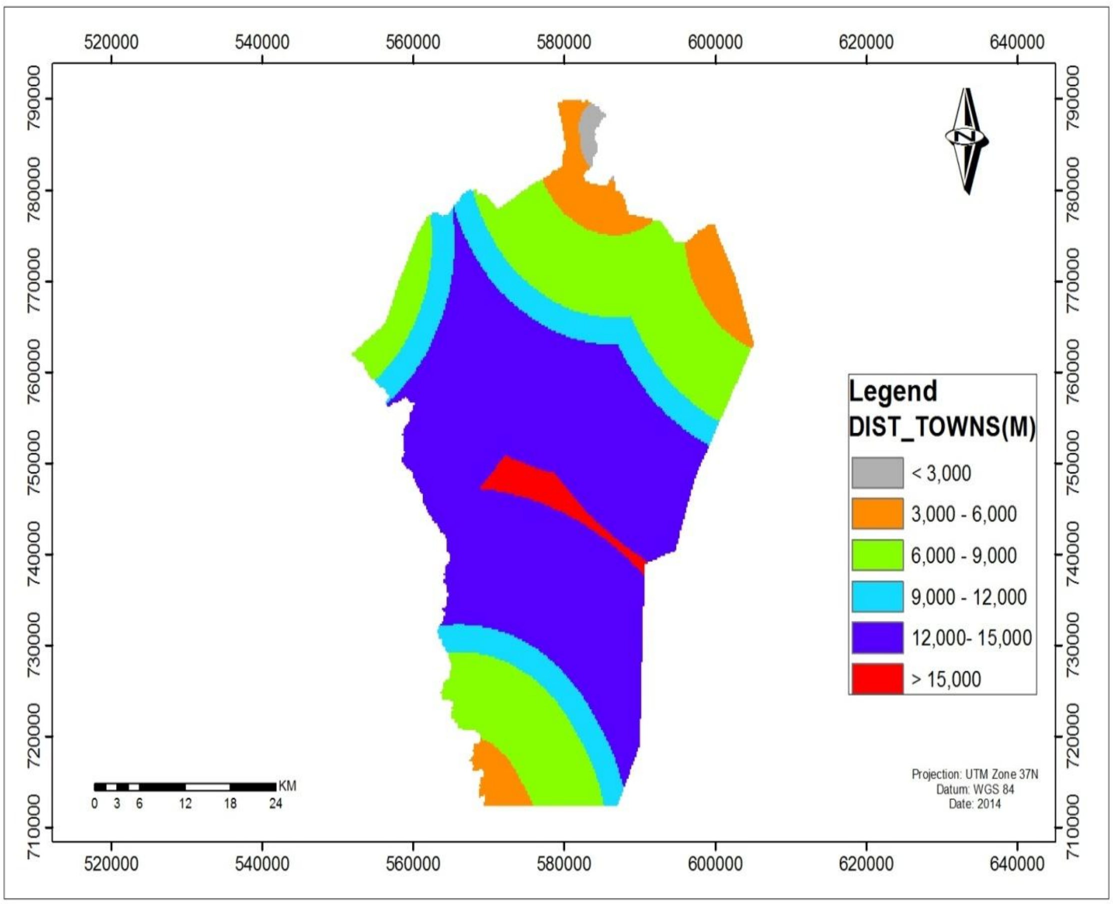


Fig 4.11: Distance to Nearest Towns Map

Therefore, distance from the towns buffered within 15km was reclassified into five based on the impacts of the town residents to the wildlife's.

As a result, distance greater than 15km is reclassified as the highly suitable, from 12km-15km moderately suitable, 6km-12km, marginally suitable, while distance between 3km-6kms is considered as currently not suitable and 0km-3km permanently not suitable (Figure 4.12). The area suitability level of proximity to settlements' outside the park after reclassification has been done was generated through dissolving the features of layer as follow table 4.9.

Table 4.9: Area of suitability level in terms of proximity to settlement outside the park

No	Suitability Class	Area_km^2	Area (%)
1	Permanently not suitable	185.58	8.01
2	Currently not suitable	612.31	26.44
3	Marginally suitable	296.80	12.82
4	Moderately suitable	1168.92	50.48
5	Highly suitable	52.13	2.25
	Grand total	**2315.74**	**100.00**

Source: Own computation, 2014

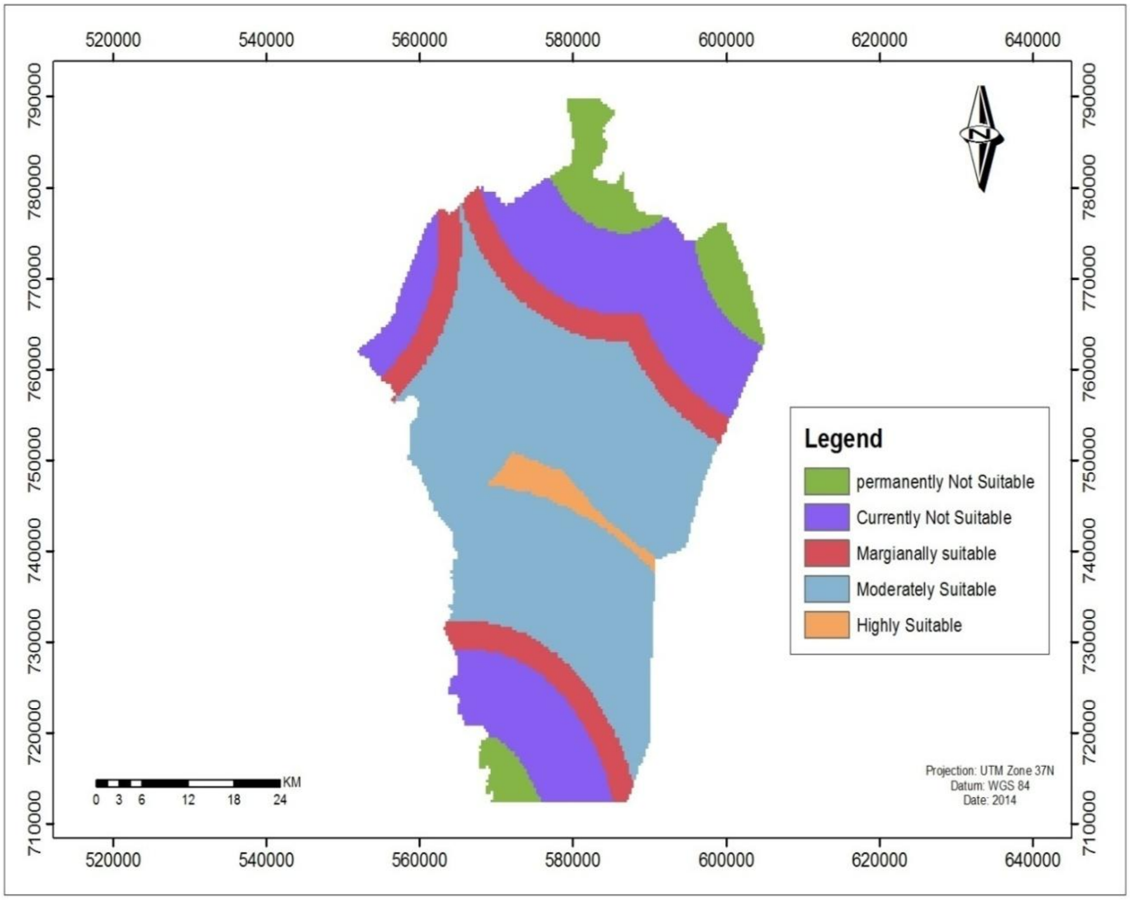


Fig 4.12: Reclassified Distance to Nearest Towns Map

4.1.6.2. Distance to road

Accessibility is one of important infrastructure consideration with regard to tourism development. In order to have good access for the tourist to visit/admire this endemic creature, suitable habitat for Nyala preferably be situated near to all weather road or access road. However, 500m buffer distances were masked from the analysis for safety purpose.

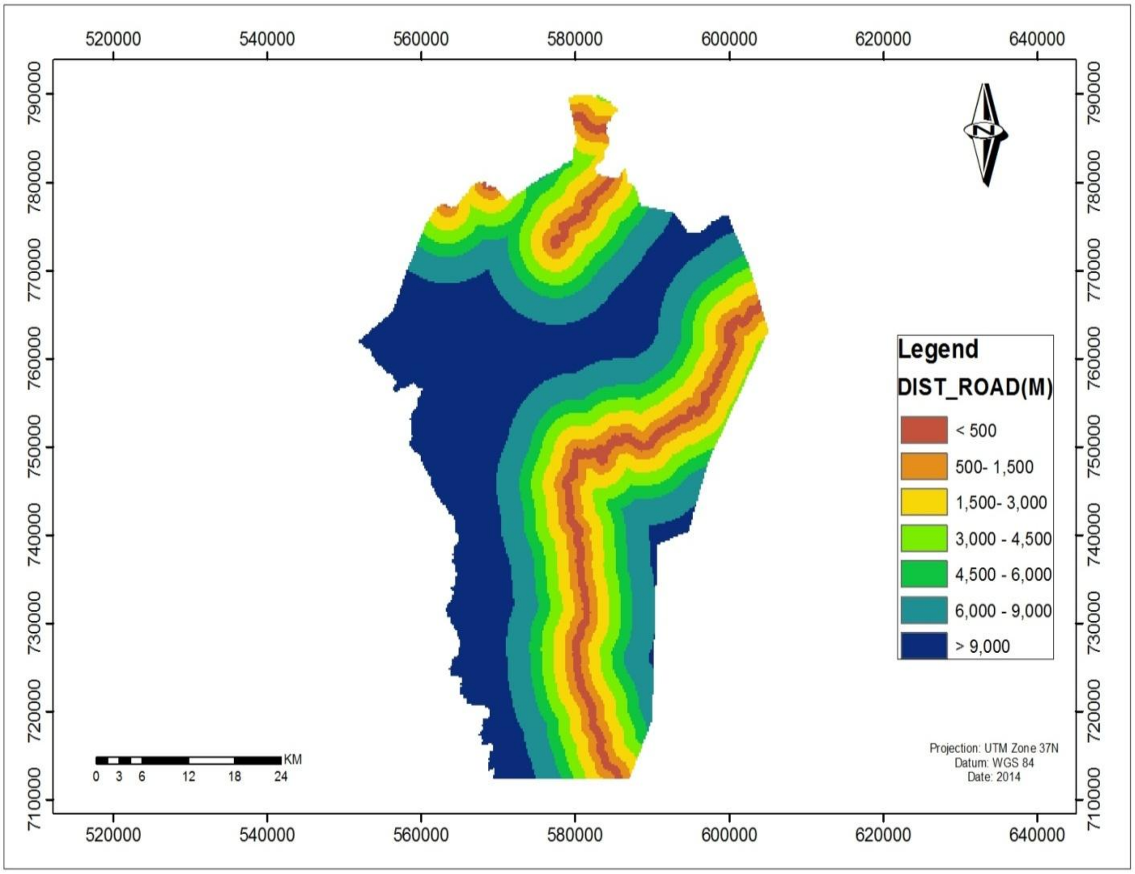


Fig 4.13: Distance to Road Map

The distance to road was reclassified on model builder using GIS spatial analysis tool. Thus, the closest distance to road, the permanently not suitable for mountain Nyala species and the reverse is true (Figure: 4.14).

The area suitability level of distance to road network of the park after reclassification has been done was generated through dissolving the features of layer as follow table 4.10.

Table 4.10: Area of suitability level in terms of proximity road network (BMNP)

No	Suitability Class	Area_km^2	Area (%)
1	Permanently not suitable	589.86	25.48
2	Currently not suitable	518.71	22.41
3	Marginally suitable	456.94	19.74
4	Moderately suitable	378.24	16.34
5	Highly suitable	370.87	16.02
	Grand total	**2314.62**	**100.00**

Source: Own computation, 2014

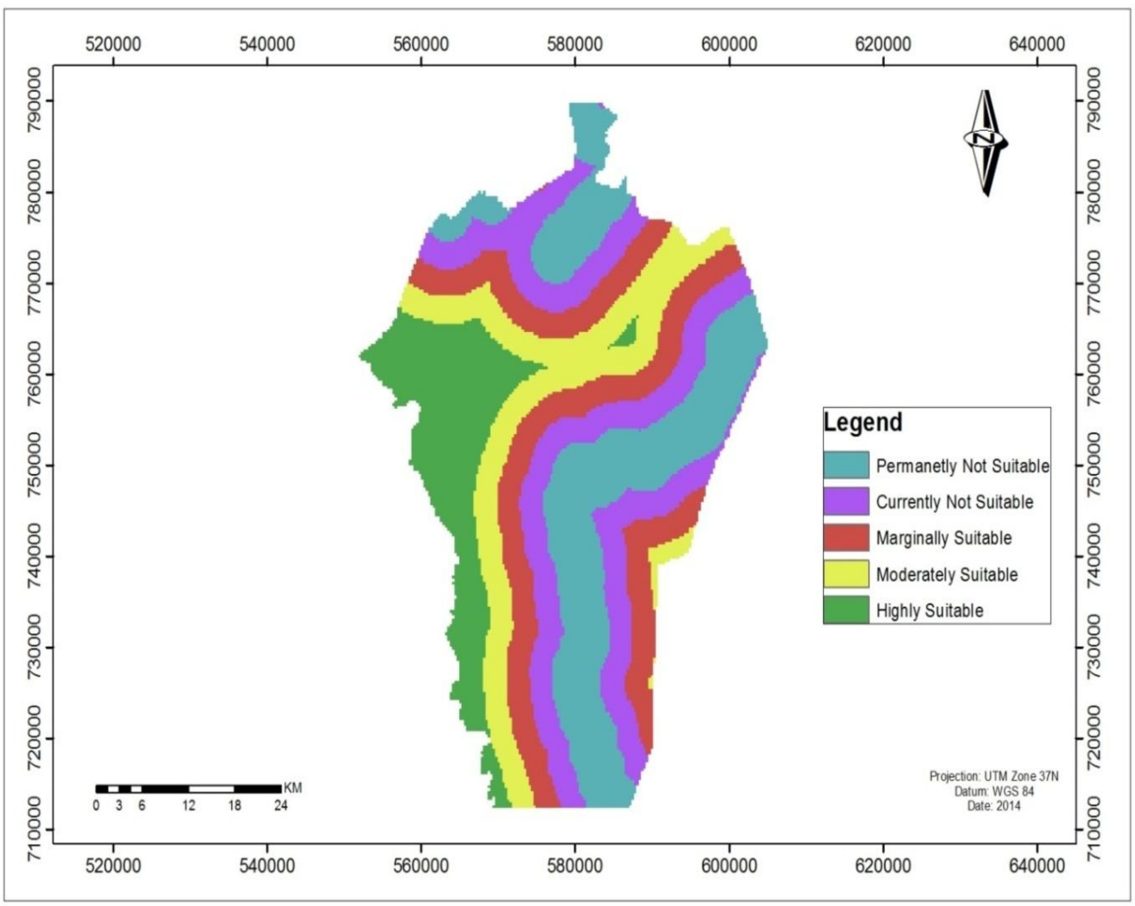


Fig 4.14: Reclassified Distance to Road Map

4.1.6.3. Distance to river

It is another important life requirement for the survival of the species including Nyala. Obviously, suitable habitat for the species should be located near to river. Area which is proximate to the river provides wetlands/ grasses habitats for the Nyala. The Nyala species habitat suitability area is near to river to get wetlands and grasslands found often in 5000m. Thus, this study has considered distance to main rivers to model Nyala habitat suitability. The buffer distance to river was done using GIS on the layer. The distance to river of the study area were mapped (Figure 4.15).

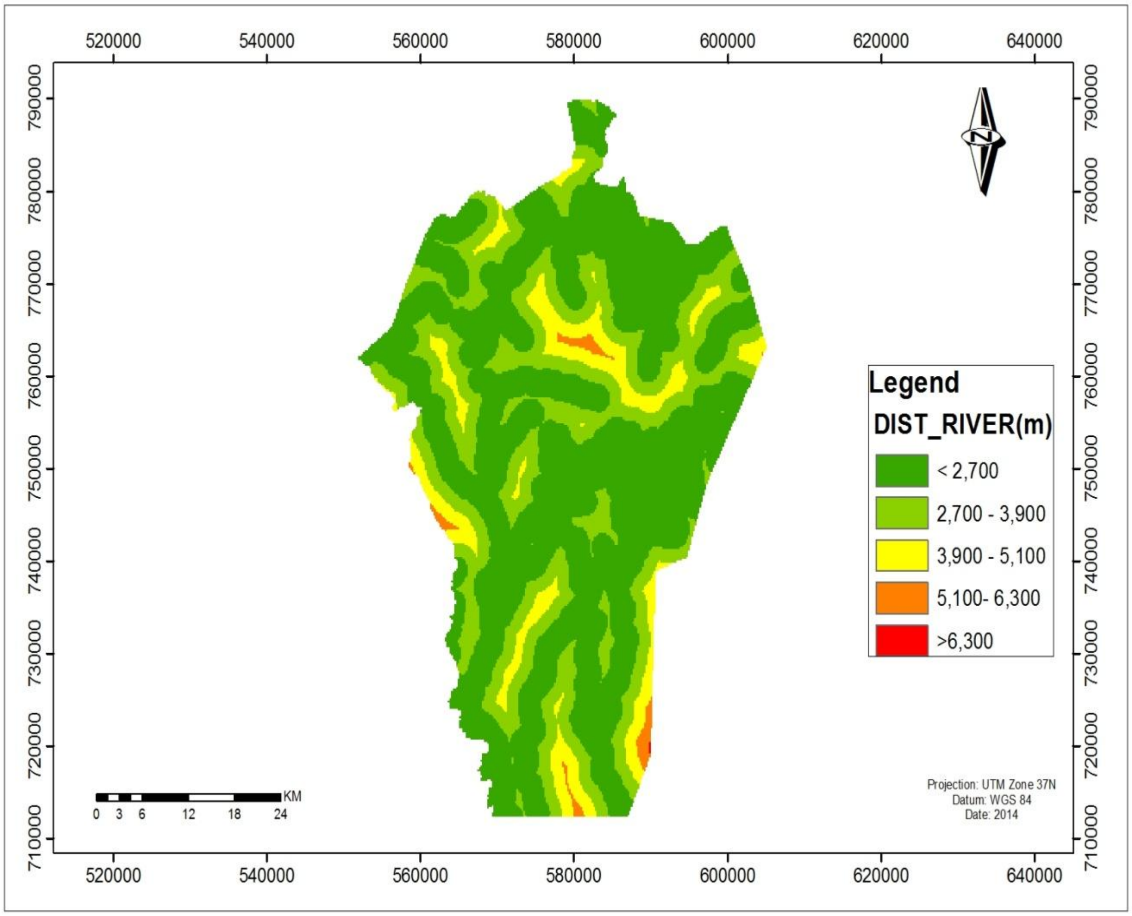


Fig 4.15: Distance to Rivers map

Reclassification of the distance to Main River was done on model builder using GIS spatial analyst tool. The nearest distance to Main River, the highly suitable and the fairest distance to the main river, the permanently not suitable for mountain Nyala species. The reclassified map of the distance to main rivers was generated as follows (Figure: 4.16).

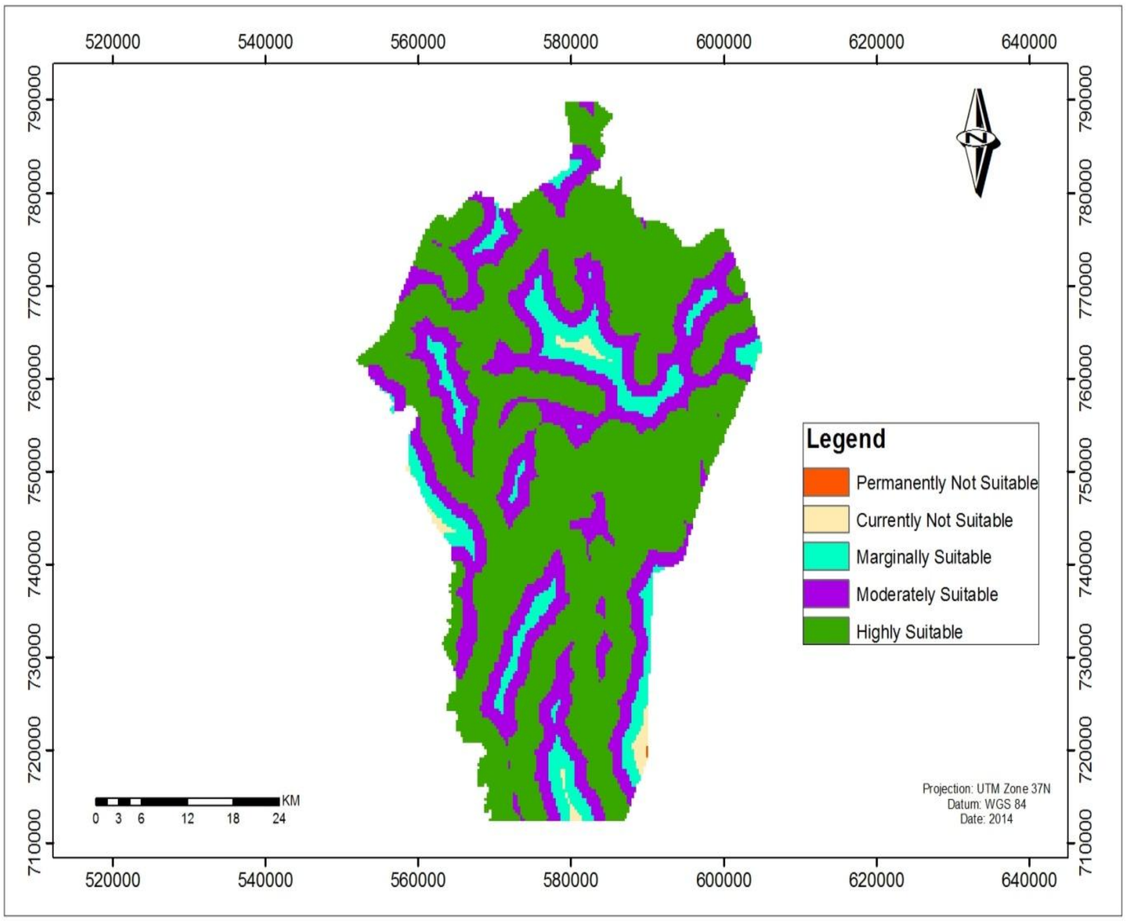


Fig 4.16: Reclassified Distance to Rivers Map

The area suitability level of distance to main rivers of the park after reclassification has been done was generated through dissolving the features of layer as follow table 4.11.

Table 4.11: Area of suitability level in terms of proximity to main rivers (BMNP)

No	Suitability Class	Area (Km^2)	Area (%)
1	Permanently not suitable	0.39	0.02
2	Currently not suitable	21.65	0.94
3	Marginally suitable	207.82	8.98
4	Moderately suitable	651.07	28.12
5	Highly suitable	1434.53	61.95
	Grand total	**2315.46**	**100.00**

Source: Own computation, 2014

4.2. Determining factors weight

The study has employed MCE to establish a set of weights for each of the factors. The technique described here and implemented in IDRISI32 is that of Pair-wise comparisons developed by Saaty (1990) 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 4.4). 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.

Accordingly, all the eight factors, which were selected for the evaluation of Land suitability in the study area, were weighted using pair-wise comparison in (Table 4.12). After the Pair-wise comparison matrices were filled based on expert's judgments, observational fields, reviewed literatures, and various visitors' reports, the weight module was used to identify consistency ratio and develop the best-fit weights.

Table 4.12: Nine point importance scale

WEIGHT - AHP weight derivation

Pairwise Comparison 9 Point Continuous Rating 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
Less Important					More Important			

Pairwise comparison file to be saved : ... Calculate weights

Factors	*Road*	*River*	*Town*	*Slope*	*Soil*	*Elevation*	*Temperature*	*Vegetation*
Dist_Road	1							
Dist_River	3	1						
Dist_Town	3	1/3	1					
Slope	3	3	3	1				
Soil	3	3	3	1/3	1			
Elevation	5	5	5	1	3	1		
Temperature	7	5	5	3	3	3	1	
Vegetation	7	7	7	5	5	3	3	1

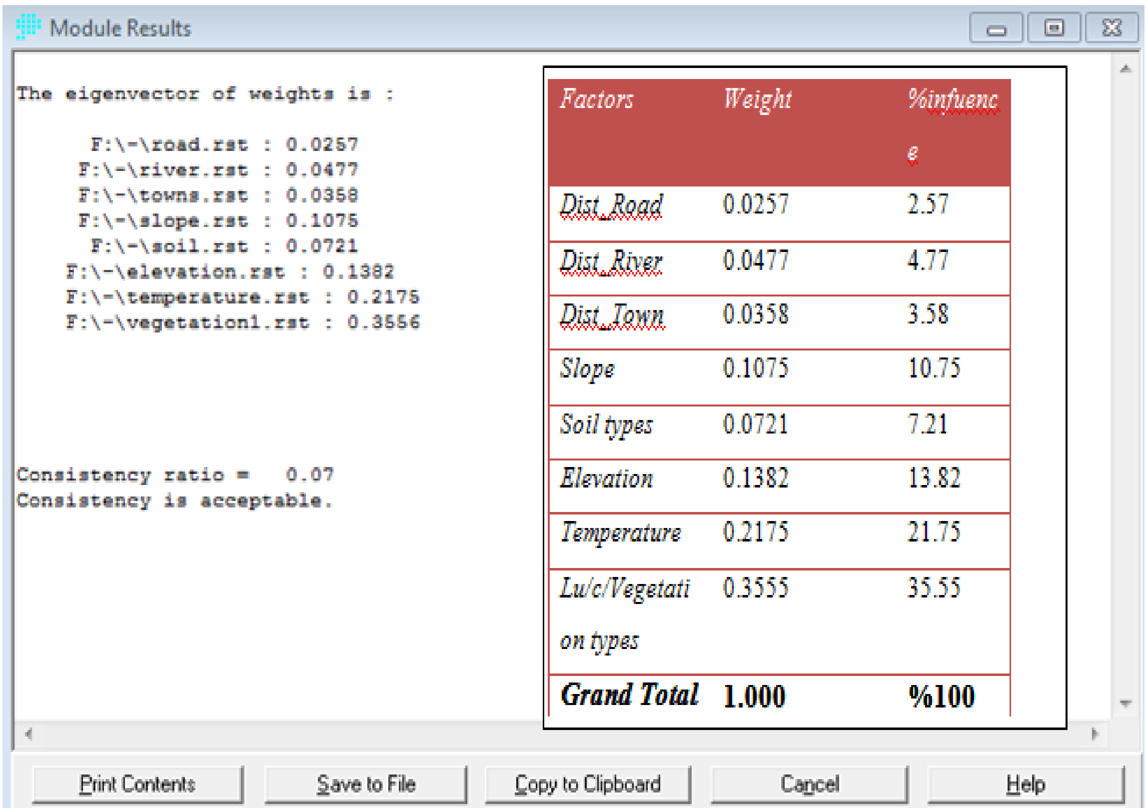
Compare the relative importance of F:\-\vegetation1.rst to F:\-\temperature.rst

OK Cancel Help

Source: Own computation, 2014

To produce the best set of weights, the principal eigenvector of the above pair wise comparison matrix was computed in IDRSI 32 software by a special module named Decision Support and Weight.

Table 4.13: Principal Eigenvector of the pair wise comparison matrix



Factors	*Weight*	*%infuence*
Dist_Road	0.0257	2.57
Dist_River	0.0477	4.77
Dist_Town	0.0358	3.58
Slope	0.1075	10.75
Soil types	0.0721	7.21
Elevation	0.1382	13.82
Temperature	0.2175	21.75
Lu/c/Vegetation types	0.3555	35.55
Grand Total	**1.000**	**%100**

Source: Own computation, 2014

Consistency ratio = 0.07

The consistency ratio (CR) was 0.07, which was acceptable for weighting the factors to evaluate the physical land suitability of the area (Table 4.13).

4.2.1. Weighted overlay analysis and Combining datasets

Weighting was used to develop a set of relative weights for a group of factors in a multi-criteria 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 or 100%. The factors and their resulting weights can be used as input for the MCE module for weighted linear combination.

Reclassification of each factor had been conducted and their respective map was generated by reclassify technique in spatial analyst tool. Then, in order to combining datasets weighted overlay in overlay spatial analyst tool was used; aggregation stage was undertaken to combine datasets. The weight of each factor was obtained through employing AHP Pair wise Comparison matrix of the eight parameters in the module Multi-Criteria Evaluation-Decision Support (MCE-DS). Then, using the following simple raster equation the weight or percentage influence of each factor has been multiplied and finally combined to select Nyalas suitable area.

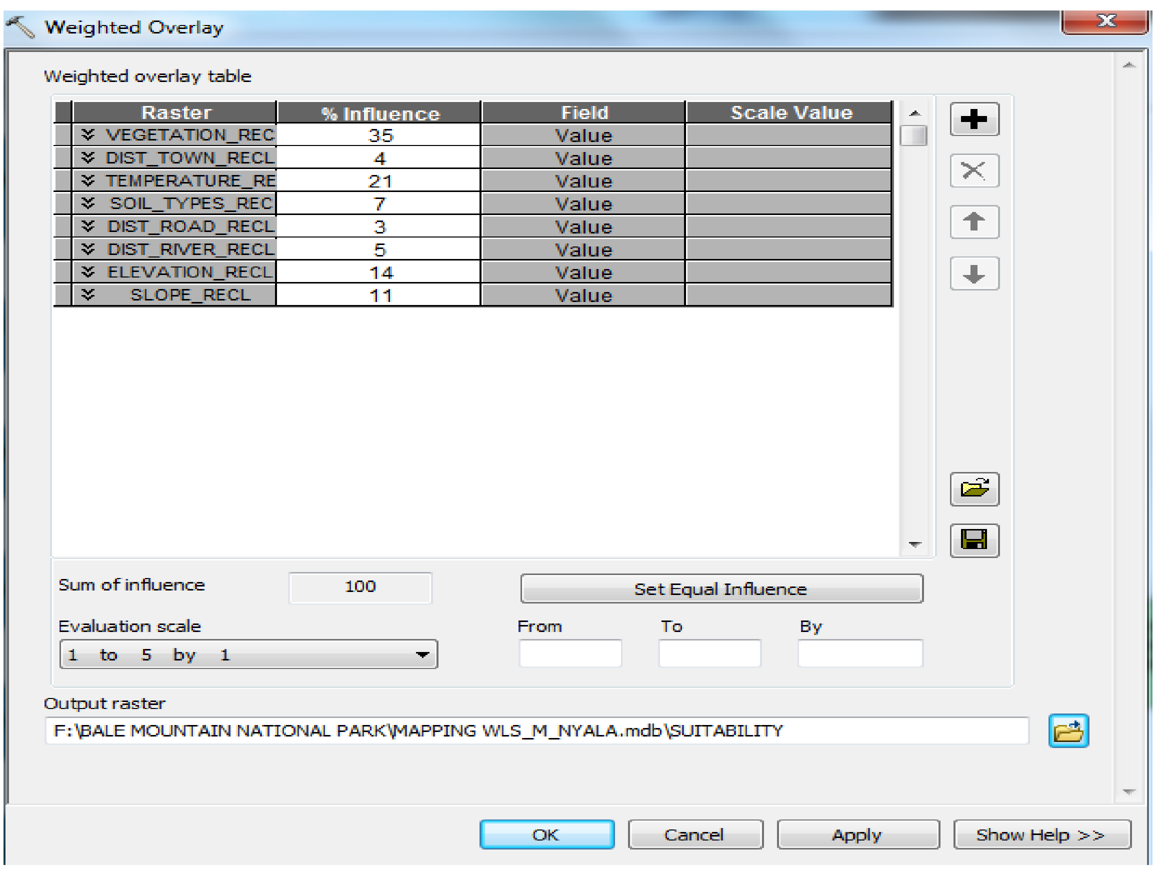
$S = \Sigma_{Fnwi}$, Where:

- **S** = Suitable Wildlife Corridor for Mountain Nyala species
- **Wi** = The weight of each factors
- **Fn** = The reclassified each factors

Σ **FnWi** = Sum of the multiplied Weights of each by reclassified factors

The reclassified raster layers were prioritized according to their importance obtained from matrix. Here raster calculator was conducted and weighted overlay in the Spatial Analyst Tool on Model builder the reclassified raster layers have been multiplied by their weight/percentage influence. After summed and evaluated, the suitability map was generated. Then to generate the suitable area only which is assigned greater than and equal to the value of three (3) from the total suitable area a conditional tool called con was used. Hence, the dialog box of Sum of the multiplied Weights to each reclassified factors and the model developed for Mountain Nyala species suitable corridor selection is displayed as follow (Table 4.14).

Table 4.14: Comparison Weighed percentage influence and raster calculator



Raster	% Influence	Field	Scale Value
VEGETATION_REC	35	Value	
DIST_TOWN_RECL	4	Value	
TEMPERATURE_RE	21	Value	
SOIL_TYPES_REC	7	Value	
DIST_ROAD_RECL	3	Value	
DIST_RIVER_RECL	5	Value	
ELEVATION_RECL	14	Value	
SLOPE_RECL	11	Value	

Source: Own computation, 2014

[("VEGETATION_RECL_LAST" * 0.3555) + ("TEMPERATURE_RECL" * 0.2105) + ("ELEVATION" * 0.1382) + ("SLOPE_RECL" * 0.1075) + ("SOIL_TYPES_RECL" * 0.0721) + ("DIST_RIVER_RECL" * 0.0477) + ("DIST_TOWN_RECL" * 0.0358) + ("DIST_ROAD_RECL" * 0.0257)] = Suitable Wildlife Corridor for Mountain Nyala Species

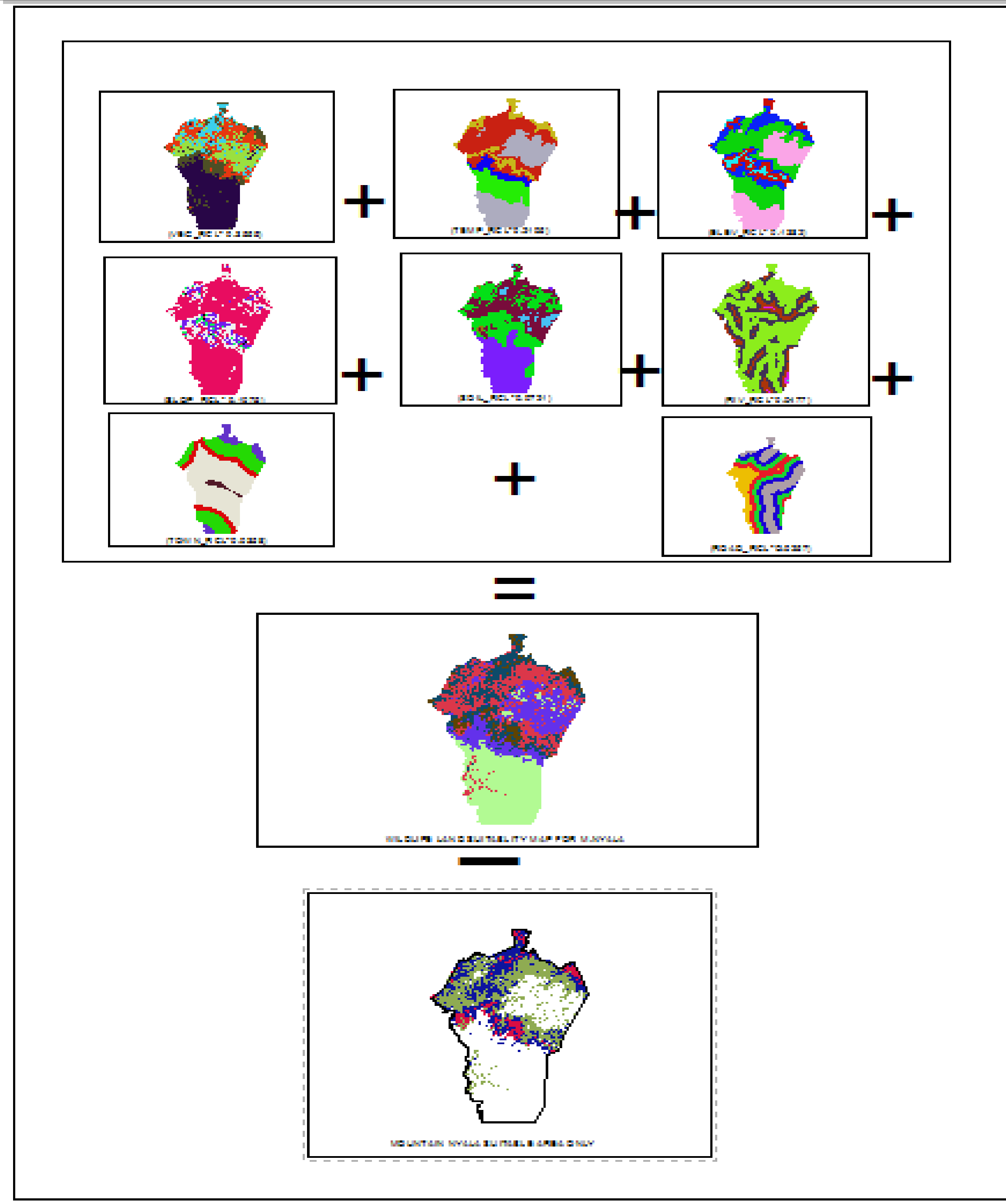


Fig 4.17: Diagram of sum all layers to generate wildlife land suitability map

4.3. Result and Discussion

4.3.1. Results

Based on the GIS overlay analysis result showed, five suitability classes of wildlife corridors have been identified for selected species. These classes are highly suitable, moderately suitable, marginally/less suitable, currently not suitable and permanently not suitable areas. The majority of suitable habitat lies around the northern part of the park, western periphery and along the peak of the so-called Harrena forest.

From the total land of the study area 137.5 km^2 (% 5.96) was highly suitable, 395.6 km^2 (% 17.14) was moderately suitable, 561.8 km^2 (% 24.34) was marginally suitable, 501.6 km^2 (% 21.73) was currently not suitable, and 711.5km^2(% 30.83) was permanently not suitable areas. Wood land vegetation type along with elevation range between 2632-2950 m.a.s.l, temperature ranges between 10-12.5°C, slope ranges 0-12.5% and soil types of chromic luvisols found to be the highly suitable habitat for Mountain Nyala. The proximity of highly suitable area to main rivers was about 2700m, distance from Road was greater than 12100m and settlement was greater than 15000m (Figure.4.18).

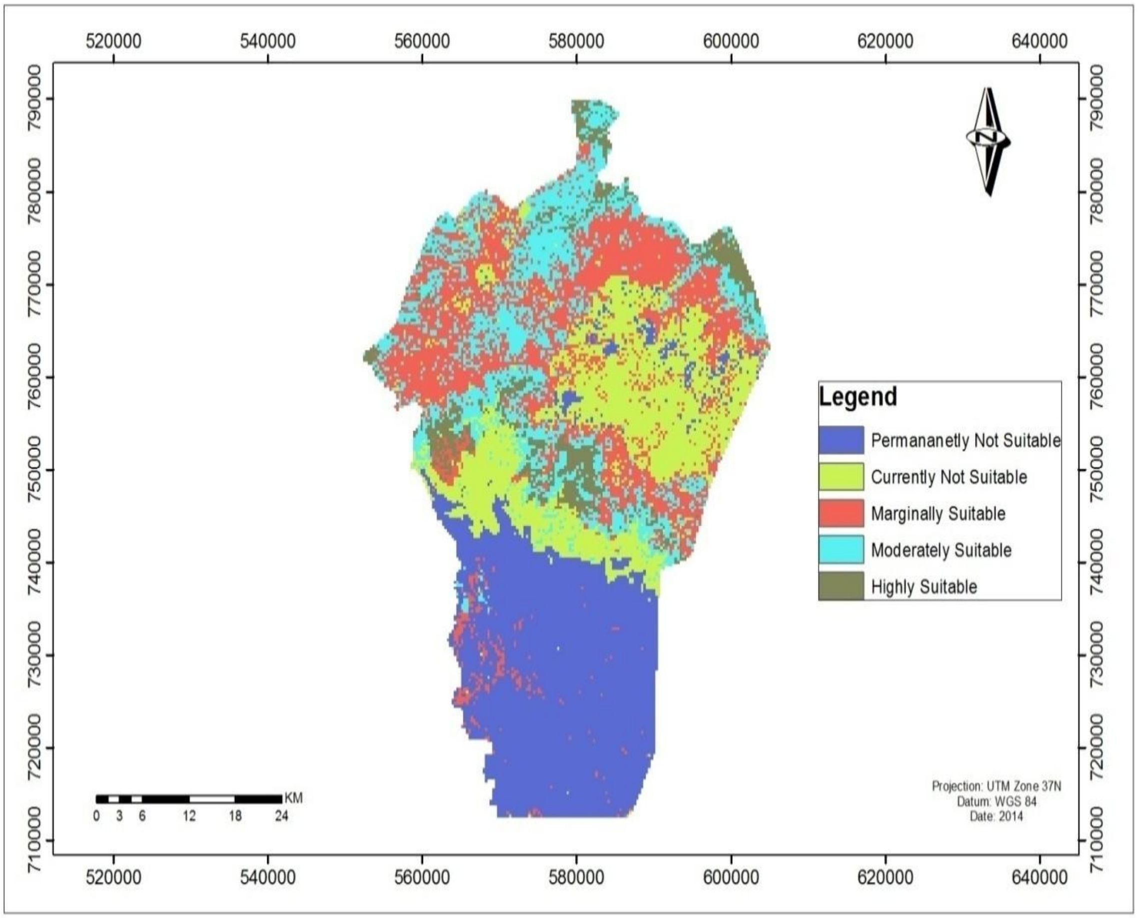


Fig 4.18: Mountain Nyala Wildlife Land Suitability Map

From the map the dark green, apatite blue and red are the highly, moderately and marginally/less suitable areas for wildlife corridor for Mountain Nyala species respectively but the dark yellowish color indicate currently not suitable area; where scattered farm plots and barren land cover as well as along the elevation ranges between 3585-3902m and 1679-1996m. This implies that, since the land use land cover/ vegetation types is very determining factor for Nyala habitat, there would be the probabilities that scattered farm plots and barren land will rehabilitated and treated.

As a result of this, barren land and scattered farm plot with homesteads are currently not suitable areas for Mountain Nyala, but dense moist montane forest represented in blue color indicates that permanently not suitable areas; this area is of the low-lying plain and there is no open space even that makes the area not suitable as follow table 4.15.

Table 4.15: Area of suitable Wildlife corridors

No	Suitability rank	Area(Ha)	Area (km^2)	(%)Area
1	Permanently Not Suitable	71151.6	711.5	30.83
	Currently Not Suitable	50159.4	501.6	21.73
3	Marginally Suitable	56177.1	561.8	24.34
4	Moderately Suitable	39559.0	395.6	17.14
5	Highly Suitable	13754.6	137.5	5.96
Grand Total		**230801.72**	**2308.02**	**100**

Source: Own computation, 2014

From the suitable area model, the study has also generated areas which were suitable only. Suitable area only was develop using GIS conditional tool called 'Con' through providing the suitability rank/value greater than or equal to three (3) i.e. suitable area only was about 1091.5km^2(47.5%) from the total suitability area of the study area; (Table 4.15). However, this area is very susceptible for factors i.e. encroachment of livestock, scattered farm plots and homestead settlements inside and outside the park impeding wildlife corridor (Annex 2). The suitable area only map was produced by overlaying the boundary of the study area (Figure: 4.19).

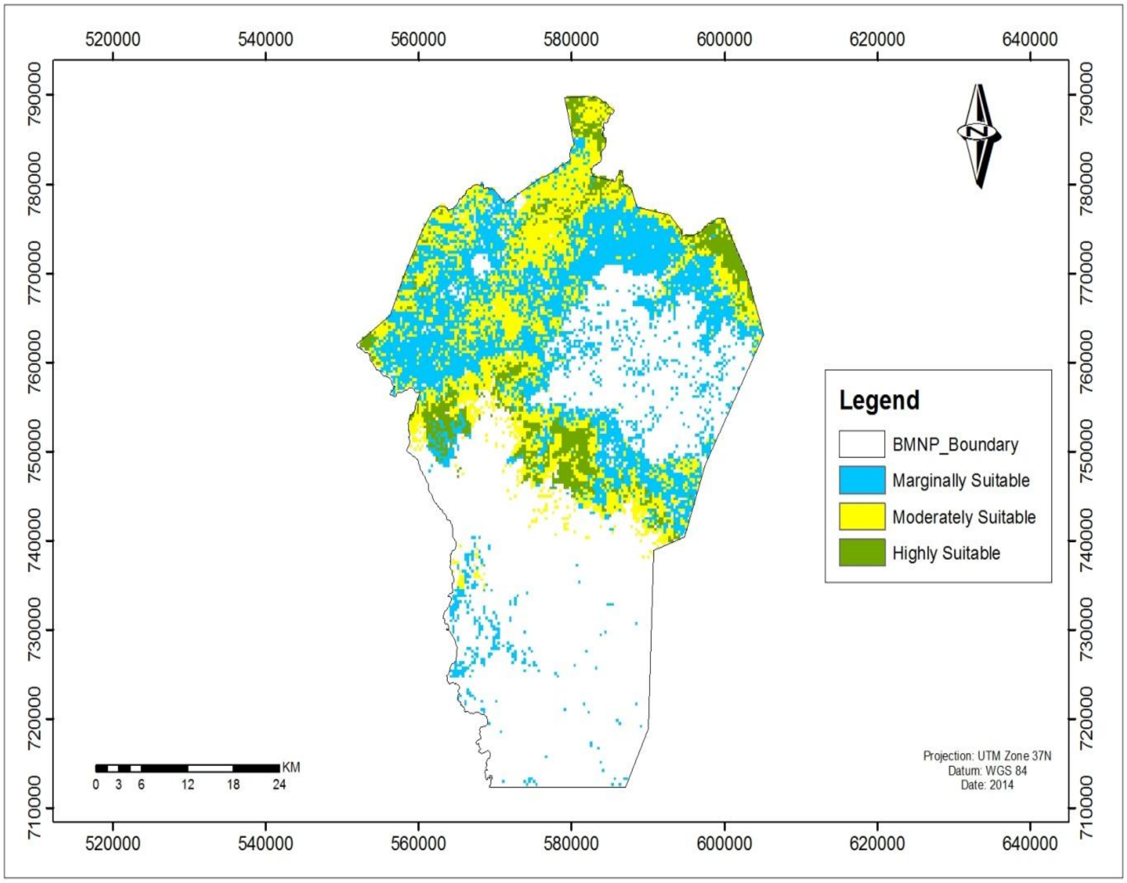


Fig 4.19: Suitable area only map

4.3.2. Discussion

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 northern, central and northeast periphery part of the study area is highly suitable for the Nyala species. Along the northern central part and northwestern part of the study area the land are moderately and marginally suitable for wildlife corridor. The southern and eastern part of the study area is not currently and permanently used/ suitable for wild life corridors because of the sum of the reclassified factors in respective to their weights.

However, this unsuitability is not entirely based on their proximity factors mainly but because of another parameters, for example, the vegetation types/land use functionality, elevation and temperature entirely, as well as slope and soil as it relies on the weight of respective parameters. Even though the objective of this study was not aimed to study the land characteristic which is more influencing the selected species habitat directly but based on the various reviews of literature and visitors reports which had been conducted on Mt. Nyala habitat as well as based on the weight influences of multi-criteria; vegetation types in a sense land use functionality of the park takes a lion share influencing the species habitat, of course the theories still revealed that this vegetation types relies on topographic and climate factors.

Hence, understanding the specific needs of wildlife populations is a key to preventing local or global extinctions, rehabilitating populations, and restoring habitat.

Researches shows, that 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 data are being used in combination for the input, storage, manipulation, analysis, and display of geographic information and its associated attribute data (Anderson 1996).

These spatial techniques provide an effective and efficient means of generating habitat spatial information as well as more accurate measures of damage as far as this study aimed to assess potential habitat of endangered Mt.Nyala species and finally come across the species habitat model that enables to produce the thematic map of wildlife corridors.

The application of GIS integrating with remotely sensed data enables to map out wildlife corridor for Mt.Nyala which helps to develop the sites for economic purposes, to protect them from human threats and therefore to conserve them. The suitability model shows that 47.5% of the study area is suitable for wildlife corridor for selected species. This implies that the area is very significantly important for conservation, maintaining equitable environment and environmental sustainability. Wildlife corridor which has been identified as a potential habitat for Nyala species are very susceptible to human inducing factors due to the plainly of landscape. Even though the park is in the high risk level, if effective protection and management system would be established, this study suggests I that would contribute to as world heritage site.

For instance, the survey of 2012 that has been conducted by Frankfurt Zoological Society to Bale Mountains National Park Conservation Project indicates; the distribution of permanent homesteads of about 2912 which own farm plot are found within the park. In addition to this, the steady expansion of towns/settlements and the main road are entirely found at the northern part of the park. This interns leads to encroachment of livestock's, overgrazing, and expansion of farm plots and loss of natural recourses at large. When these homesteads are overlaid with the wildlife corridor identified in this study, it reveals that the habitat potential of the Nyala species is very vulnerable to deterioration (Figure 4:20).

In general, the Mt.Nyala model built also reveals that 21.7% and 30.8% of the study area is currently not suitable and permanently not suitable areas respectively. This indicates the area is not important for the survival of the wildlife species mentioned. Area which is not suitable currently needs some rehabilitations and or improvements through conducting farther investigations as well as impact assessment and environmental management in order to mitigate the areas specially degraded due to human activities. Thus, understanding of the environmental conditions and factors involved in the deterioration of the eco-systems found inside the park are fundamental for appropriate management.

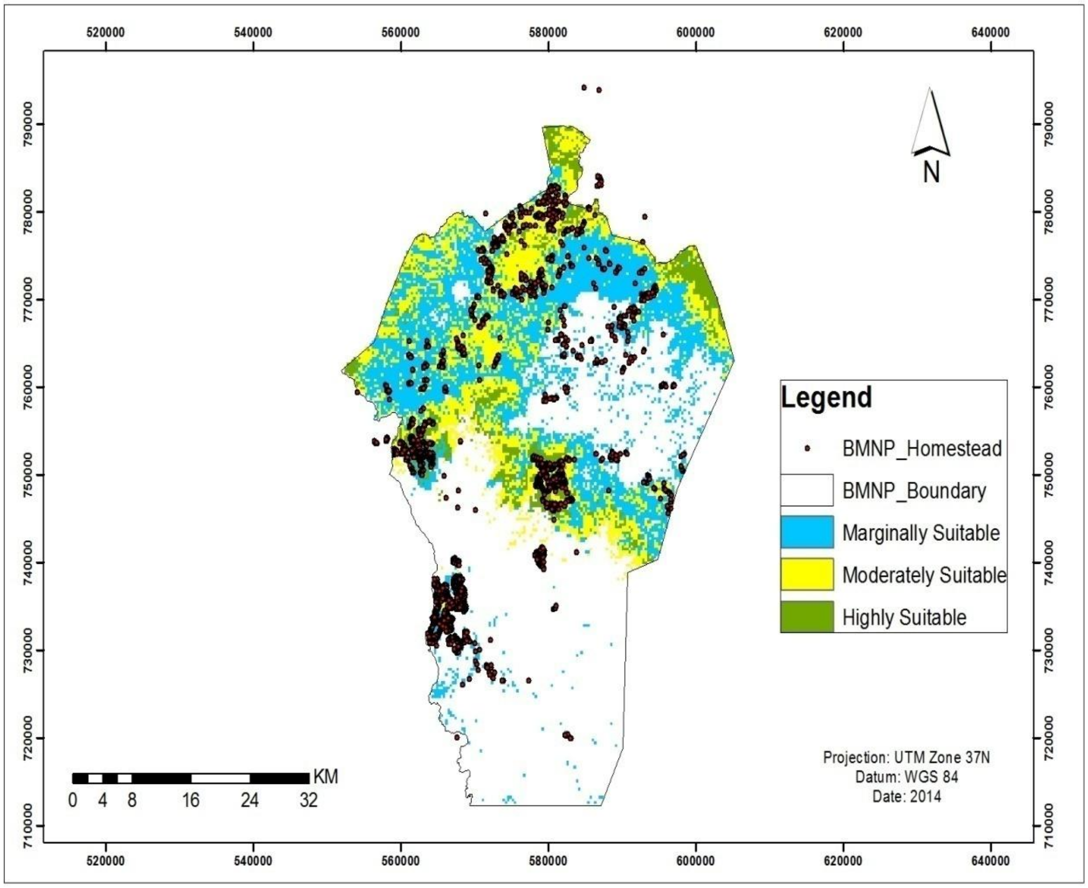


Fig 20: Susceptible wildlife corridor

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This paper addressed to produce potential wildlife corridors for Mountain Nyala (Tragelaphus buxtoni) in the Bale Mountains national Park. The study area covers an approximate area of 2316km^2. Bale Mountains National Park is found at southeast of Addis Ababa in Oromia Region in southeastern part of the country. Mountain Nyala species are one of the endangered wildlife, and the number of species decreasing. One of the conservation mechanisms of Mountain Nyala species is identifying a good wildlife corridor area so that the species is kept and conserved properly. GIS and remote sensing techniques are widely employed towards assessing habitat potential and modeling suitable areas through evaluating multi-criteria for wildlife corridors.

The result of the suitability analysis shows that 1091.5km^2(47.5%) of the study area is suitable area only for wildlife corridor for Mountain Nyala species. This implies that the area is very significantly important for conservation, maintaining equitable environment and environmental sustainability. Alternative wildlife corridors are not proposed as mitigation for loss of core habitat in this study. 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. The identified suitable habitat appear fragmented in a sense which was diminished and deteriorated physically as well as lack contiguity, which may be disadvantage.

According to the present Nyala habitat suitability model, potential habitats have been identified through GIS analysis of eight factors. Woodland, Grass land and dry ever green forest and alpine bush lands vegetation type along with the elevation range between 2500-3500 m.a.s.l found to be the suitable habitat for Mountain Nyala. Application of the habitat models in this specific area demonstrated that it satisfactorily mapped out habitat suitability. In light of this, it can be conclude that, Geographic Information Systems (GIS) along with remote sensing technology could provide new opportunities to model and evaluate wildlife habitat suitability.

In general, the result from this study appears practically useful for natural resources management in Bale Mountains National Park. Especially with the availability of low cost and timely satellite images as well as recent advances in GIS and remote sensing technology, the use of remotely sensed data for natural resource management becomes more feasible and efficient.

5.2. Recommendations

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

- ❖ Creating awareness among the society concerning the economic benefit of endemic Mt.Nyala species so as to restrict their livestock's and prevents from degradation of wildlife corroder and natural recourses at large.
- ❖ The wildlife corridor/ core areas identified should be protected with special management emphasis.
- ❖ NGOs could play significant role in developing a program to help homestead societies in the park not to pressure the corridor.
- ❖ Settlement in the park should be reduced to tolerable size and distribution.
- ❖ This study has touched single wildlife habitat suitability modeling with limited parameters; the future research should explore the application of integrated and advanced geospatial technologies to assess wildlife habitat and environmental as well as social pressures to endemic Mountains Nyala and other species in the National Park.

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Annexes

Annex-1: Photo: Mountain Nyalas while feeding around Dinsho (HQ)

Source: photo by researcher, 2014

Annex-2: Photo: One of the magnificent area while livestock's grazing in BMNP

Source: photo by researcher, 2014

Annex 3: Table of Classification Accuracy Assessment Report

Land Use Classes Of Landsat8 2014	Moist Montane Forest	Alpine Bush Land	Wood Land	Barren Land	Scattered Farm plots	Ever Green Forest	Water resources	Montane Grass Land	Total Reference	User Accuracy (%)
Moist Montane F	25	5	1	1	1	0	0	1	34	73.53
Alpine Bush Land	0	16	0	0	0	0	2	0	18	88.89
Wood Land1	1	0	8	0	0	0	0	0	9	88.89
Barren Land	0	0	0	2	0	0	0	0	2	100
Scattered Farm	1	0	0	0	6	0	0	0	7	85.71
Ever Green Forest	0	0	0	0	0	1	0	0	1	100
Water resources	0	0	0	0	0	0	1	0	1	100
Montane Grass land	1	0	0	0	0	0	0	7	8	87.5
Total	28	21	9	3	7	1	3	8	80	
Procedure Accuracy %	89.3	76.2	88.89	67.1	68.00	100	34.1	87.5		

Source: Own computation, 2014

- *Total Reference = 80*
- *Number of correct = 66*
- *Overall classification accuracy =82.50%*
- *Overall kappa Statistics = 0. 7698*