PHE-ETHIOPIA CONSORTIUM

A Resource Base and Climate Change Risk Maps for Simien Mountains National Park

Tezera Chernet

ERCAND Consult

2015, Addis Ababa

Financed by the SCIP Fund: the SCIP Fund is financed by the Governments of the United Kingdom (UK), Norway and Denmark.

Table of Contents

List of Tables

List of Figures

List of Plates

List of Annexes

Acronyms

ACCRA	Africa Climate Change Resilience Alliance
ASTER	Advanced Space-borne Thermal Emission and Reflection Radiometer
CSA	Central Statistics Agency
DEM	Digital Elevation Model
EMA	Ethiopian Mapping Agency
EWCA	Ethiopian Wildlife Conservation Authority
FDRE	Federal Democratic Republic of Ethiopia
FIRMS	Fire Information for Resource Management System
GCP	Ground Control Point
GIS	Geographical Information System
GPS	Global Positioning System
HH	House hold
KA	Kebele Administration
LUPRD	Land-use Planning and Regulatory Department
m.a.s.l.	meters above sea level
MoARD	Ministry of Agriculture and Rural Development
MODIS	Moderate Resolution Imaging Spectro-radiometer
MSS	Multi-Spectral Scanner
NMSA	National Meteorological Service Agency
PA	Protected Area
PHE	Population, Health and Environment
SCIP	Strategic Climate Institutions Program
SDPASE	Sustainable development of the protected area system of Ethiopia
SMNP	Simien Mountains National Park
TM	Thematic Mapper
UTM	Universal Transverse Mercator
WBISPP	Woody Biomass Inventory and Strategic Planning Project
WGS	World Geodetic System

Acknowledgments

This study was financed by the SCIP Project and the author would like to thank PHE-Ethiopia Consortium management and staff for providing the opportunities and facilitating the logistic support to conduct the study. The author appreciates and thanks Ato Tadesse Hailu, project coordinator and Mr. Adrian Young, Environmental Program officer at PHE-Ethiopia, for their valuable advice to improve the document. Thanks are also due to EWCA for permission to work and support in acquisition of data on the management plan of the park. Simien Mountains National Park Office and the management were also very supportive in facilitating the field work within the Protected Area; Ato Abebaw Azanaw, Warden of SMNP, has also helped in the acquisition of ground data, provision of valuable description of habitats and wild animals frequenting it and arranging consultative meetings with sector Offices.

Due appreciation also goes to the Department of Hydrology and GIS Section under the Ministry of Water and Energy for their prompt provision of data on discharge and water level and spatial data produced under Tekeze basin study. We acknowledge the use of FIRMS data and imagery from the Land, Atmosphere Near real-time Capability for EOS (LANCE) system operated by the NASA/GSFC/Earth Science Data and Information System (ESDIS) with funding provided by NASA/HQ.

The author is very grateful to Ato Kidane Mengistu, General Manager, ERCAND Consult, Dr. Shiferaw Alem and Yehuala S. for support and providing comments on the draft document. Thanks are also due to Ato Temsgen Yohannes in the vegetation survey and Ato Hailu for assistance during the field work. Special thanks also goes to Ato Getachew Assefa, Officer for Frankfurt Zoological Society at Simien Mountains National Park for information on the park boundary, park scouts for assistance in vegetation survey and providing valuable information on habitats, staff members of Woreda Agricultural Offices in the administration of household level questionnaire and farm households at the KAs who have spent their precious time for providing responses.

Executive Summary

This study presents the terrestrial biological resources of Simien Mountains National Park (SMNP), potential and values and develops resource as well as climate risk maps. Toward these, data that characterize the protected areas and influence the fauna and flora existing within it are acquired and/or generated to form the individual layers for use in Geographical Information System (GIS) analysis. These include raster and vector data, and other available historical (between mid 1970's and 2014) survey and map data from government institutions and on-line databases. Collection of ground data, survey of selected HH, discussion with key informants and direct observation were also made between end of November and December 2014.

ENVI 4.3 was used in the processing, analysis and display of raster data, ArcGIS 9.2 was used to manage and manipulate other geographic data and SPSS was used for the analysis of HH data. Post-classification change detection method was employed to determine magnitude of land cover change. Model was developed to map suitable habitat for selected one endangered species. Derived and acquired data sets were used as input in hazard assessment. Models widely used in the determination of hazards were used to delineate areas susceptible to hazard. Further, based on integration of derived data on hazard and information on the elements at risk, risk assessment was made using weighted overlay. Ranking was made based on relative importance attached and categorized from very high to very low. Available data on previous impacts were also reviewed.

Comparison of time series Landsat image over a period of 40 years on SMNP showed that noticeable changes had occurred in the forest stratum in the early 70s and mid 1980s. Major drivers of change were expansion of cultivated land, extraction of wood and competition for grazing by domestic animals.

Fire and flooding were the types of hazards faced by the protected area and the surrounding communities. An occurrence of fire hazard within the protected area was of anthropogenic origin. Most fire prone areas were also located in or adjoining areas where such activities are permitted. Storm flooding is encountered mainly in the surrounding downstream areas.

Nevertheless, some 36% of SMNP is categorized under different degrees of flood risk. Of these, very high flood risk areas constitute some 5.06%; 29.46% corresponding to grassland, 36.6% to forest and 0.34% to cultivated land. Findings will help strengthen efforts in appraisal of natural resources toward meeting challenges of climate change.

1. Overview of Simien Mountains National Park

1.1 Introduction

Toward meeting the multiple needs of communities while building resilience to future development and climate change, the core interventions of Population, Health and Environment Ethiopia Consortium (PHEEC) programs focus in situation where demographic trends put pressure on the environment and where natural resources degraded threaten human health and livelihoods (PHEEC, 2012).

Ethiopia is known to possess some 284 wild mammal, 861 bird, 201 reptile, 63 amphibian, 188 fish and 1225 arthropod species with about 10, 2, 5, 54, 0.6 and 21 per cent of endemism, respectively (IBC, 2009). Protected areas have significant value in the conservation and development of these resources. The Ethiopian government, in recognition of these, has put in place conservation mechanisms in a bid to protect wild animals from various disasters (FDRE, 2005). The wildlife conservation areas of the country are estimated to cover 158,200 km^2 or about 14% of the country size.

Despite the efforts made to conserve and develop the protected areas, there had been different pressures and mostly were of human origin. Furthermore, these are now exacerbated by climate change; the extent and degree in which climate change affects local level Protected Areas (PAs) are also little known. Simien Mountains National Park (SMNP) was one of the first two national parks gazetted in the country. In the past forty years since establishment, however, there still are a number of constraints that hinder the expected progress.

Accordingly, understanding the nature and characteristics of the existing resources, trends in the past forty years, and the pressures now faced along with its exposure to climate change related stresses, shall help in developing mechanisms to protect and develop the resources.

The first chapter of this paper provides the background and objective of the study and describes the study areas. Chapter two explains the present land cover and examines the historical trends of land use and cover change. Chapter three discusses the habitat type and distribution within the park including habitat fragmentation and make reviews of pressures faced. Chapter four focuses on hazards related with climate change and is followed by the final chapter, which presents the conclusion and recommendations.

1.2 Objective

The general objective of this study was to assess the biological resource potential and values of the Simien Mountains National Park and develop resource as well as climate risk maps.

The specific objectives of this study were:

a. to assess and develop baseline data for the terrestrial biological resources of Simien Mountains National park;
b. to assess the biological resources present in the national park and their location in order to enable them to be conserved appropriately;
c. to provide information for decision makers and justify the conservation and protection of the park ecosystems as a mechanism to eradicate poverty and mitigate and adapt to climate change; and
d. to create climate change risk profiles that cover all the major hazards (floods, droughts, forest fires, landslides etc.) prevailing in and around the Simien Mountains National Park.

1.3. The study areas

1.3.1 Location

Simien Mountains National Park is located between 13^{o}1' to 13^{o}29' North and 37^{o}50' to 38^{o}34' East and some 120 Km NE of *Gonder* town (Figure 1). It is found under North *Gonder* Zonal Administration of *Amhara* Regional State. Some four KAs from *AdiArkay woreda* in the north, seven KAs from *Debarq* woreda in the west, 15 KAs from Beyeda woreda in the Northeast and East, nine KAs from *Janamora* woreda in the south and three KAs from *Tselemt* woreda in the north-east, border the national park.

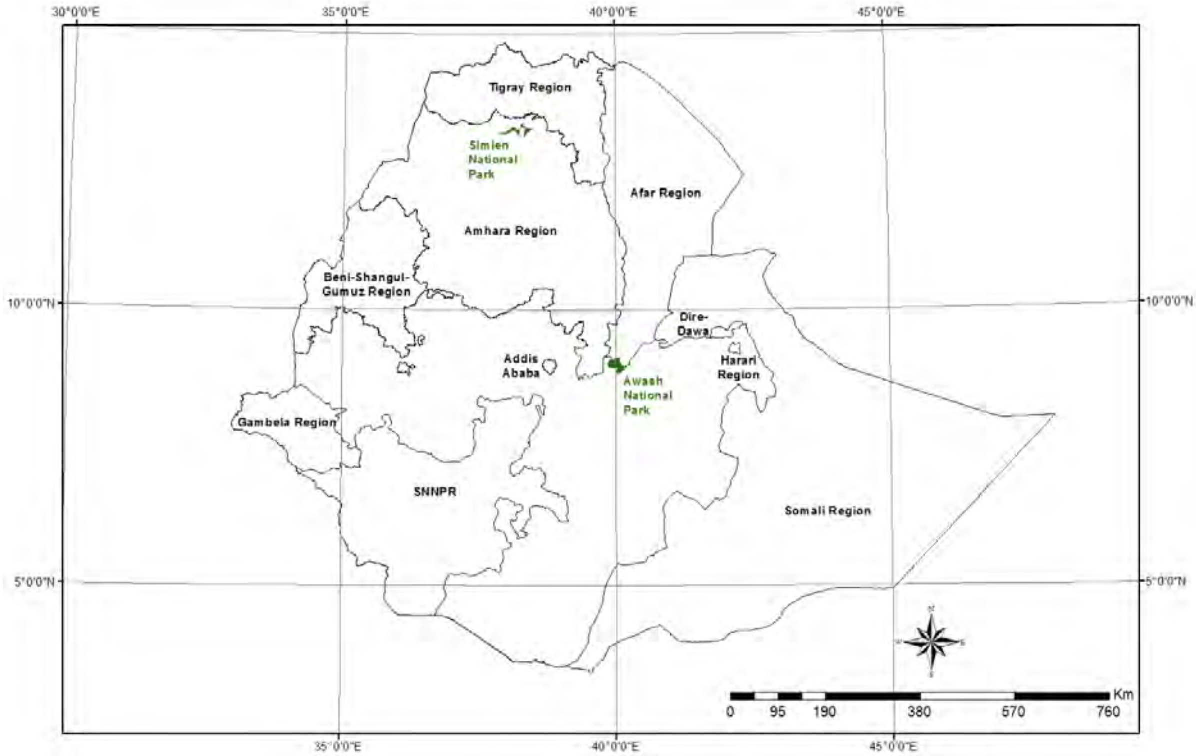


Figure 1: Location map of the study area

1.3.2 Topography

SMNP has an altitudinal range between 1900 at the north eastern part to 4533 meters on Ras Dejen, at far south western part (Figure 2). Most of the northern sides of these areas are precipitously steep in places. The slope classes within the Simien mountains national park had a maximum of 76.83 and a mean of 25.31 degrees with a standard deviation of 13.97.

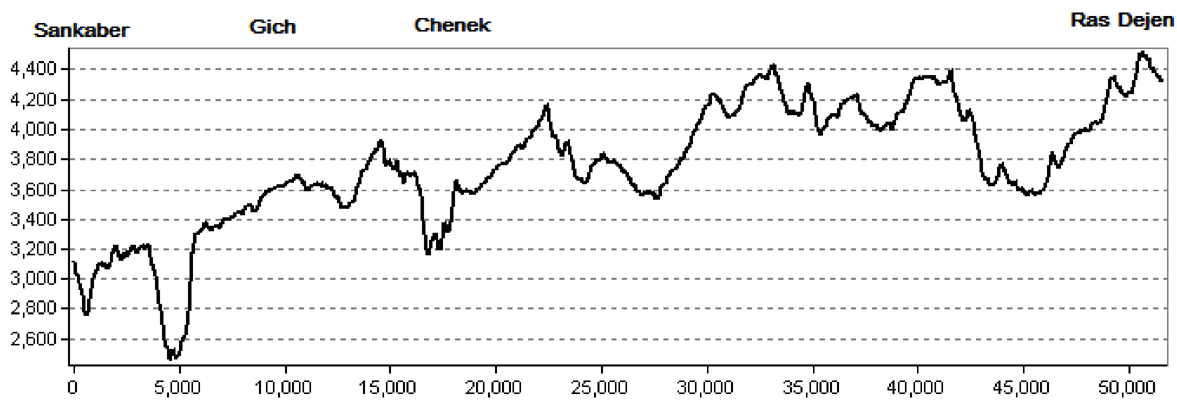


Figure 2: Profile graph: Sankaber-Gich-Chenek-Ras Dejen at SMNP

1.3.3 Soil

Based on the study made by FAO/LUPRD (1982), characteristics soil types of the SMNP are Lithic leptosols (42%), Eutric cambisols (31%) and Dystric podzoluviso (26%) and Humic nitosols (1%).

1.3.4 Water Resources and drainage

More than 12 river and streams rise from the SMNP and drain into the Tekeze river. Water fall, especially during the wet season, is a common phenomenon in most northern parts of the water courses.

1.3.5 Brief History of Simien Mountains National park

Simien Mountains National park was gazetted as a national park in 1969, along with Awash National Park. SMNP was inscribed on the list of World Heritage List in 1978 on the basis of (criterion iv) its importance for biodiversity and (criterion iii) its exceptional natural beauty (WHC-IUCN, 2006).

The park is the refuge for threatened animals such as gelada baboon (*Theropithecus gelada*), Ethiopian Wolf (*Canis simensis)* and Walia ibex (*Capra walie)* (M, U., 2008). In 1996, based on threats of depletion of the Walia ibex population and of other large mammals, encroachment and impacts of road construction, it was included on the list of World Heritage in Danger. Since then, even though substantial progress have been made and recognized, the park is still on the list.

In the late 1960's, the principal surveyors of the then proposed SMNP demarcation lines, had envisaged two park in one, a highland park with an afro-alpine flora and fauna, and a lowland park with more typical African ecology, and two different angles from which to view the escarpment and the animals that lived on it (Nicol, 1972). Even though this was not realized, the size of the park has undergone changes in the past 40 years. It was estimated that the original size of the area was about 136 km^2, in 1997 the figure rose to 236 km^2 and now has an area of 412 km^2. The last demarcation was made to include Lemalimo, Mesarerya, Silki Yared – Kiddis Yared Mountains and the Ras Dejen Mountain. Geech, an area at the center of the park, is still under cultivation and human inhabitation.

In 2013/14 tourists that have visited the SMNP were 260 percent higher than the number visited in 2007/08. Some 85% of these tourists are foreigners and some 12% are local tourists (Figure 3).

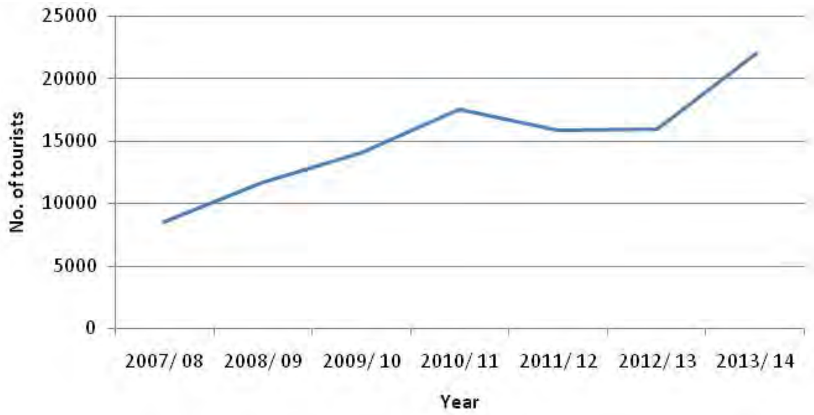
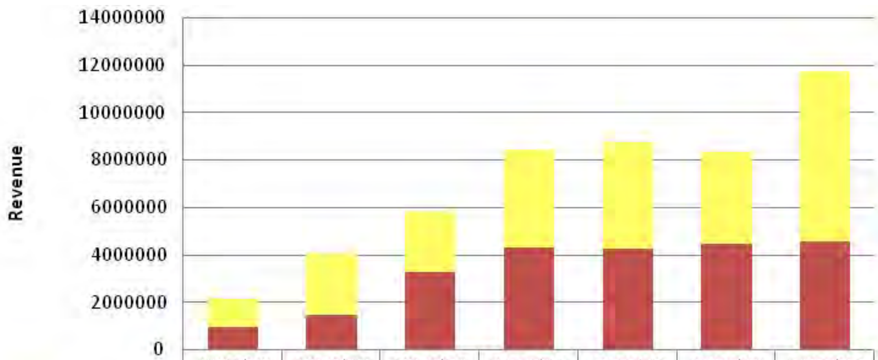


Figure 3: Number of tourists that had visited SMNP between 2007 and 2014

Share of the local community from tourism trade (7,210,810 ETB) has now surpassed that of government revenue (4,544,020 ETB) from same at SMNP (Figure 4).



	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Local Community	1161992	2602000	2523484	4127423	4498875	3910435	7210810
Government	956071	1439790	3281275	4314591	4260510	4441518	4544020

Figure 4: Comparison of government revenue and income to local community at SMNP

2. Land Cover Classification

2.1 Methodology

2.1.1 Data set

Data that characterize the protected areas and influence the fauna and flora existing within it are acquired and/or generated to form the individual layers for use in GIS analysis. These include raster and vector data, and other available historical survey and map data from local institutions and on-line databases.

Landsat images acquired between mid 1970's and 2014 were used to estimate the geographic extent, distribution and types of land cover changes in the national park and its immediate surroundings. Four cloud free scenes, from sensors including L8, TM and MSS, and taken between December and early January were used in the study.

2.1.2 Preprocessing of Images

The image scenes received were geo-referenced using GCP and the required atmospheric corrections were applied. Further, images were stacked, mosaicking and sub-setting to the area of interest done for proper investigation of land cover changes.

2.1.3 Image Classification for land use and land cover mapping

A preliminary land use land cover map (through unsupervised classification) was generated to help guide the field work. Data collection formats were also developed for vegetation survey and the collection of information on wild animals.

The sampling design employed was stratified sampling. Adequate and representative ground data were collected from selected observation plots in December, 2014. At each plot, the species composition, percent cover of the different cover types, life-forms, and other relevant characteristic and information were recorded on prepaed formats along with GPS location data.

Maximum Likelihood classification technique, which assumes that the statistics for each class in each band are normally distributed, was employed to classify the satellite images.

Post-classification change detection method was employed to determine magnitude of change. To validate classification, reference data were collected separately and the associated statistics were generated.

2.1.5 Land cover change detection

Landsat images, acquired between early 1970's and 2014, at an interval of 12 years, were analyzed to estimate the geographic extent, distribution and types of land cover changes in the protected areas. The time span selected between series of layers was determined based on availability of cloud free data and preferred season.

Historical maps and data, depicting vegetation types and distribution, were used to identify cover units. These include studies made by LUPRD, WBISPP, Tekeze Basin study and aerial photographs.

2.1.6 Identification of change drivers

Local level data on proximate factors was collected from sampled households of selected *Kebele* administrations that adjoin the selected national park, through discussions with key informants and on site observations. Questionnaires were administered at household level by individuals who have a good knowledge of the locality and its culture. A total of 13 HH were selected randomly from five KAs to conduct the survey. Furthermore, basic information such as population census, stock density and other available relevant documents and reports were collected from CSA and adjoining woreda administration and reviewed.

2.1.7 Materials and tools

ENVI 4.3 was used in the processing, analysis and display of raster data. Further more, ArcGIS had also been used for manipulation, editing and viewing of geographic and tabular data. SPSS was used for the analysis, conversion and presentation of collected HH data.

Garmin 12 GPS and silva-compass were used for identification of waypoints (locate ground control points), registration of geographical coordinates in the description of land cover units and marking of training areas for signature definition, during the field survey. Furthermore, binoculars were used in habitat assessments, desktop and notebook computers were also used for entry, processing and analysis of different input data.

2.2. Results and Discussion

2.2.1 Present Vegetation types

Four broad land use / cover classes were identified at SMNP (Table 1). These are Montane forest, grassland, woodland and cultivated land.

Table 1: Area size of identified land cover types (Simien Mountains National Park)

Land use / cover type	*mapping unit*	*Area (in ha)*	*Percentage*
Forest	**F1**	12833.28	31.07
Grassland	**F3**	23960.43	58.01
Cultivated land	**C**	4235.76	10.25
Woodland	**F2**	275.31	0.67
Total		41304.78	100.00

Of these, forest land covers an area of 12833 ha (31.07%), grassland 23960 ha (58.01 %), wood land 275 ha (0.67%), and cultivtion 4235 ha (10.25%). Grassland is the predominant land cover type occurring in the study area (Figure 5) and along with the forest land makes up 89.08% of the park area.

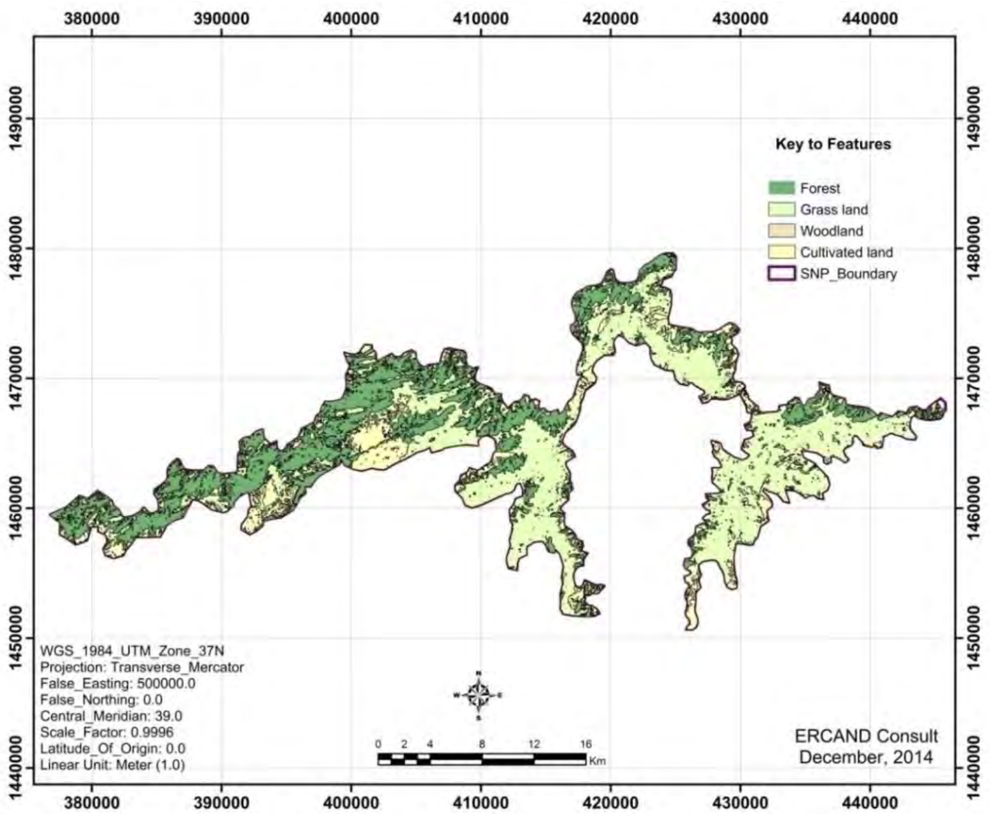


Figure 5: Present land use and land cover map of SMNP

2.2.2. Description of the present land use / cover types

Forest land (F1): Most of the identified forest lands were found on the central and western part of the park; mostly on the side slopes of the gorges (Plate 1). Ericaceous forest is also included in this category.

The unit is characterized by tree species with different type and density. In the mixed forest *Dombia torrida, Shyfleria abysinica, Nuxia congesta, Erica arborea, Allophylus abyssinicus, Galiniera saxifraga, Syzigium giuneensis, Maythenus undata, Euphorbia ampliphyla, Vernonia amigdalina, Olea capensis, Bersama abyssinica, Ekbergia capensis* occur among others. Shrubs like *Myrcene africana* and *Calpurnia aurea* are also present. Otherwise, an ericaceous belt, where the dominant species is *Erica arborea* with the presence of *Hypericum revoltum* constitutes the forest land. Forest land covers an area of 12833 hectare (31%).

Plate 1: Forest land

Grassland (F3), the unit is characterized by an herbaceous layer cover (estimated between 80 to 90%) and is mostly found on the eastern side of the national park (plate 2). Shrubs within the unit cover some 6% and exposed surfaces occupies up to 14%. *Erica arborea, Lobelia rhyncliopetalum, Helichrysum splendidum and Festuca spp.* are some of the shrub and grass species occurring in the unit. The unit covers an area of 23960 hectares (58%).

Plate 2: Grass land

Woodland (F2) covers an area of 275 hectare (0.7%). It is characterized by woody vegetation (15%), shrubs (45-65 %), grasses (20-40%) and bare lands (up to 10%). The unit is dominant in the lower valley that adjoins the park to the western side.

Cultivated land (C) are located at the central part of the park. The unit covers an area of 4235 hectare (10%). Major crops grown include cereals like wheat (*Triticum spp*), barley (*Hordeum vulgare*), and teff (*Eragrostis tef*) as well as pulses like horse bean (*Vicia faba*), lentil (*Lens culinaris*) and chick pea (*Cicer arientinum*).

2.2.3 Land use / cover changes

Between 1972 and 1986 forest has lost 55.55% of its cover. 39% of this change went for grassland while 8.7 % for cultivated land. Similarly, during the same period, 21% of the grassland has been converted to other land uses; the major one (18%) had gone to cultivated land.

From late 1980's up to end of the 1990's, class change was the least in cultivated land and the highest in grassland. Since the late 1990's to 2014, however, the class change in grassland was decreased and in forestland highly reduced while that of cultivation increased (Figure 6).

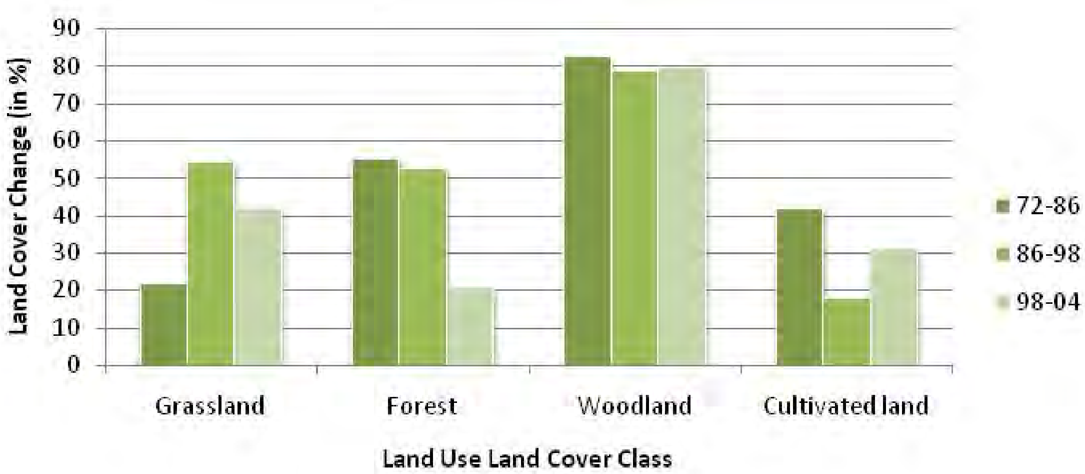


Figure 6: Land use / land cover class change between 1972 and 2014 at SMNP

2.2.4 Drivers of Land cover Change

Between the early 1970's and 1976, deforestation of large areas had taken place mostly by nearby farmers. From 1976 up to mid 1980s most of the park areas were battle ground between the derg regime and opposing fronts. Other notable causes of change were high population growth and the associated demand for agricultural land. Enforcement of law since 1994 had played a major role in the reduction of changes in forest land.

3. Wild Animals Habitat Mapping

3.1 Methodology

3.1.1 Data Set

Input data on environmental variables were obtained from different sources and some are derived from existing data sets. Surface data including DEM from data centers of NASA and USGS and data on infrastructure were collected from local governmental institutions in geo-tiff and shape formats. Further, historical data on recorded wild animal density and other available information were collected from the Park head quarter. Information on habitat requirements for selected species of the area was collected from different documents and in consultation with wild animal experts.

3.1.2 Habitat assessment and mapping

Field work was made between end of November and December 2014. Based on the preliminary land cover map and in consultation with wildlife experts and other key informants, data and information on wild animal habitats within the park were collected. These include data on habitat use, seasonality, and routes frequented. Further, location of animal watering places, frequent wild animal-vehicle collision areas and man-made features were registered. On areas which lacks vegetation information, survey of vegetation classes was also carried out in one transect and nine plots. Information gathered and observations made were registered in formats developed and in reference with registered points (GPS location). Along with the trend analysis, sampled HH were also interviewed in the historic type and abundance of wild-animals along with their personal views for the incline / decline observed. Habitat maps were produced through the analysis of generated and derived data sets in GIS and with the integration of ancillary data and information.

Model was developed to map suitable habitat for selected one endangered species at SMNP. The selected species have a relatively sufficient trait data. Study on Walia ibex (*Capra walie*) made by Dr. Nieverget in the early 1970s was used to determine the suitable ranges of the species in the SMNP. Produced map was also compared with actual and recorded sightings of the species.

ArcGIS 9.2 was used to manage and manipulate geographic data including DEM images. The software was also used to build and run habitat model. Garmin 12 GPS was used to register geographical location during inventory of existing land units and collection of other spatial information. Binoculars and digital cameras were used in the spotting and taking of pictures of wild-animals.

3.2 Results and Discussions

3.2.1 Bio-Diversity of Simien Mountains National Park

The herbaceous and shrub species found in the unit include *Erica arborea, Lobelia rhyncliopetalum, Helichrysum spp. and Festuca spp*. The grasslands and the adjoining cliffs provide habitat for Walia ibex (*Capra walie*), Ethiopian Wolf (*Canis simensis*), klipspringer (*Oreotragus oreotragus*) and Gelada baboon (Plate 3). Gelada baboon (*Theropithecus gelada*) spends the day on the grasslands, on the top and upper slopes but take refugee on the side slopes of the cliffs during the night. Most frequenting visitors include Jackal (*Canis aureus*) and hyena (*Crocuta crocuta*).

Plate 3: Walia ibex at SMNP

Plate 4: Menelik's bushbuck at SMNP

Characteristics tree and shrub species of the montane forest include *Allophylus abyssinicus, Bersama abyssinica, Carisa spp., Calpurinea spp., Cordia spp., Croton spp., Dombia torrida, Ekbergia capensis, Erica arborea, Euphorbia ampliphyla, Galiniera saxifraga, Maythenus undata, Milletia ferrugnea, Nuxia* *congesta, Olea capensis, Rhus natalensis, Shyfleria abysinica, Syzigium giuneensis, and Vernonia amigdalina.* In the ericaceous belt, included in this mapping unit the dominant species was *Erica arborea* with herbs such as *Senecio* spp. Most of the units are located in the side slopes and valley bottoms (plate 4).

These units provide habitat for species like Menelik's bushbuck (*Tragelaphus scriptus meneliki)* and klipspringer (*Oreotragus oreotragus*), the list also include Colobus monkey (*Colobus guereza*), Vervet monkey (*Corcopithecus aethiops*), baboon (*Papio anubis*), Grey duiker (*Sylvicapra grimmia*), Porcupine (*Hystrix spp.)*, Hare (*Lepus capensis*), Rock Hyrax (*Procavia capensis*), Jackal (*Canis aureus)*, Hyena (*Crocuta crocuta*), Serval cat (*Felis serval)* and leopard (*Panthera pardus*).

More than 400 bird species including Lammergeyer (*Gypaetus barbatus*) are found in the SMNP.

3.2.2 Trends in Number of Wild-animal Population

The number of Walia ibex (*Capra walie*) and Ethiopian Wolf (*Canis simensis*), in the SMNP had shown an increase of 26% and 29% respectively between 2008 and 2013 (Figure 7).

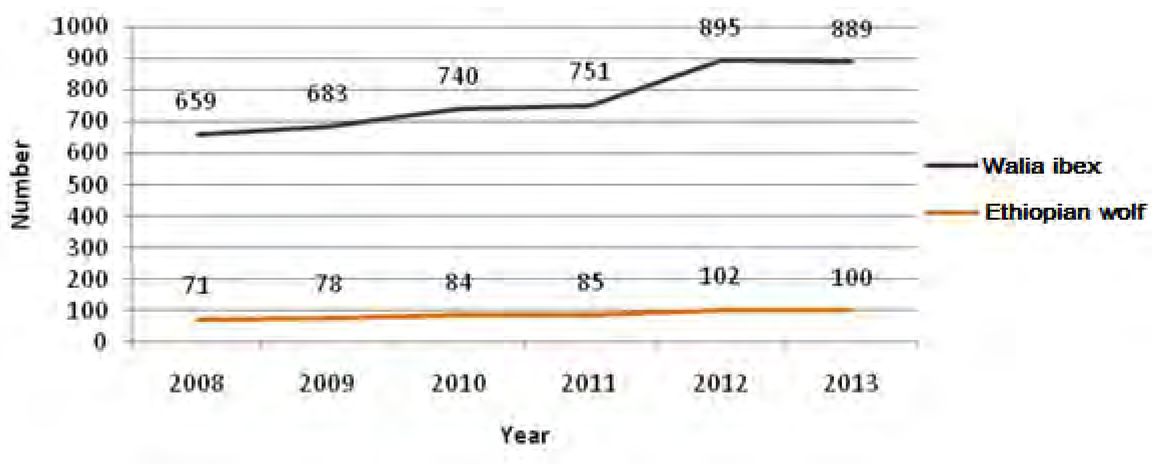


Figure 7: Trend for Walia ibex and Ethiopian Wolf population at SMNP between 2008 and 2013

The present distribution of some wild animals in the national park is shown in Figure 8.

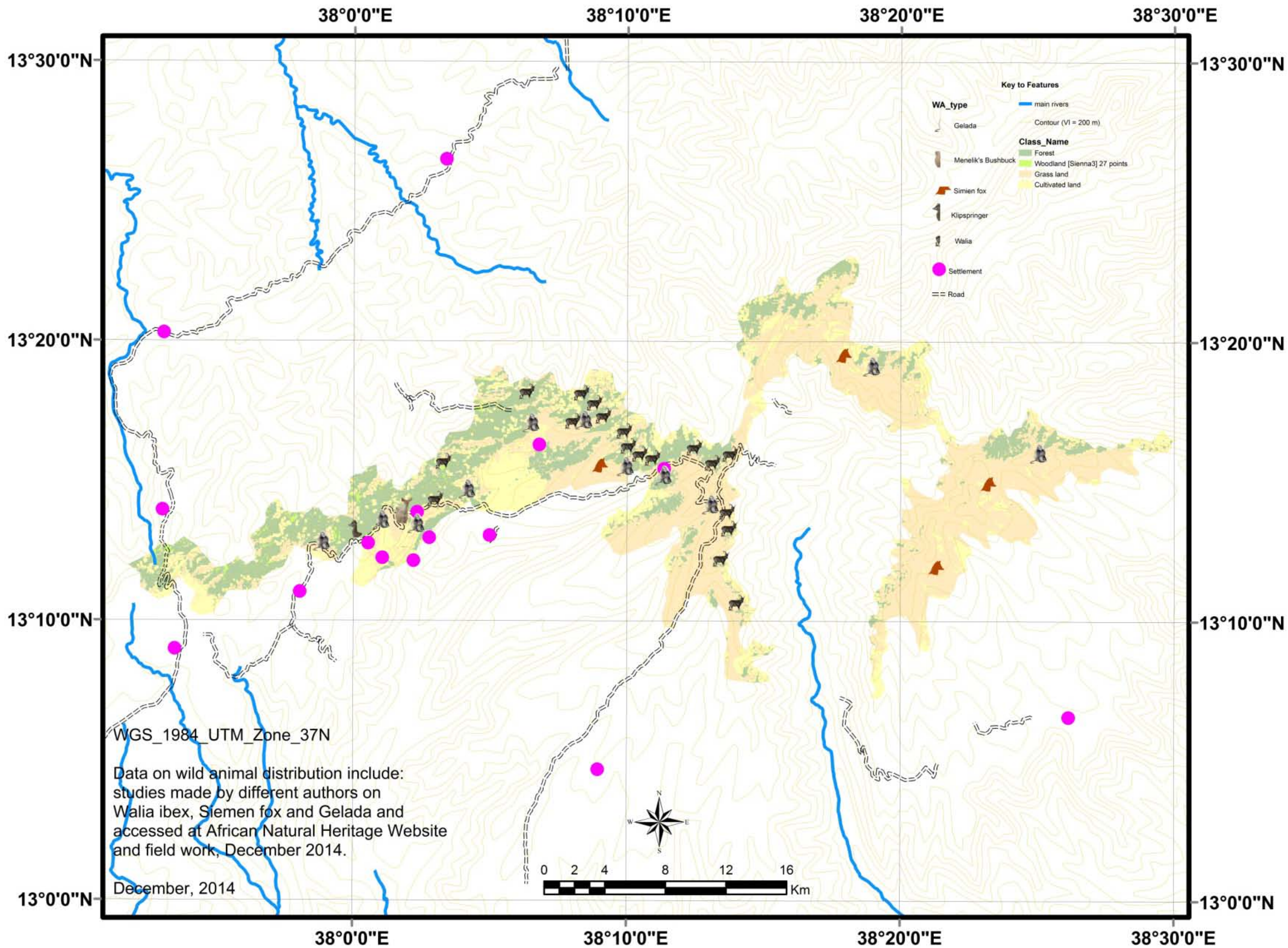


Figure 8: Map depicting the present distributions of some wild animals at SMNP

3.2.3 Habitat Fragmentation

IPCC (2002) had emphasized that changes in ecosystem and attendant loss of biodiversity are caused by land use cover changes and habitat fragmentation, among others. Further, Fischlin *et. al.* (2007) have stated that the present and future land-use change and associated landscape fragmentation are very likely to impede species' migration and thus impair natural adaptation via geographical range shifts. Studies also show that (Barbara et.al, 2009) fragmentation leads some species to become more abundant while make others decline to local or regional extinction.

In the past 40 years, the vegetation units in Simien Mountains National Park have undergone changes in area size and distribution patterns of vegetation unit. The major identified anthropogenic causes of fragmentation are described below.

3.2.3.1 Deforestation and Degradation

Overgrazing by domestic animals, collection of wood and expansion of farmlands were the main factors causing deforestation and degradation in the national park.

3.2.3.1.1 Expansion of Cultivated Land

In mid 2000, it was estimated that some 30,000 resident land users live in the Simen area, of which about 10,000 either live on or use land within the park boundaries of the time (Hurni and Ludi, 2000). A study previously made (Nicol, 1972) also shows that, the total population of Gich (SMNP) in 1969 was about 619 of which 283 were adults. At that time, the total number of cattle was also 1034, and sheep and goat 1937; these can be translated to 15.5 humans, 25.9 cattle, 48.8 sheep and goats per square km.

The total number of population at Gich has now grown to 2776, about 350 people per sq km. Figures can show that the demand for farmland to support families has increased many folds. It is worth noting that almost all household at this specific location are most willing to be relocated to other areas and the local government is trying to allocate funds for its implementation. Nevertheless, there still will remain other pocket cultivated areas elsewhere in the park.

3.2.3.1.2 Competition from Grazing by Domestic Animals

Grünenfelder (2005) has found that the degradation of the natural resources over time and difficulty of alternative due to low residue availability and low stand density has forced some livestock owners to feed their livestock in and around the SMNP.

3.2.3.1.3 Collection of Fuel and construction wood

No data on the amount, season and intensity of collection of fuel and construction wood was available. However, considering that 100% of the surveyed HHs use biomass as the main source of cooking and heating and noting that in the Ethiopian context the average estimated annual consumption is 560kg, it can be inferred that there is high pressure on the national park.

3.2.3.2 Infrastructure development

Debarq – Janamora Road

The road between Debarq and Janmora / Beyeda towns pass through the SMNP, partly through the middle and mostly on the boundary line. However, a new all weather road is currently under construction connecting these towns to Debarq. It is expected that the finalization of the construction of this road shall lift some 24 Km of public road out of the national park.

Settlements

Settlement areas in the peripheries of the Simien Mountains national park, coupled with the location of the only passenger vehicle road, have rendered the park to be a place where more people are observed.

3.2.3.3 Impacts of Fragmentation

Until recently, the population of some wild animals, especially Walia ibex population had declined that the park was registered on the list of World Heritage in Danger. It was noted in the Reactive Monitoring Mission Report (WHC-IUCN, 2006) that the degradation of the resources and its ecological impacts have forced both the Walia ibex and Ethiopian wolf to vacate some of their original ranges and to move further up into the less disturbed highlands.

3.2.3.4 Habitat Suitability Modeling

In order to assist decision makers and park managers with a tool for planning and required conservation actions, there is a need to determine the natural distribution of wild animals and the potential for others in the national park. Accordingly, based on available data, a suitability map has been produced for one endangered species at SMNP.

The habitat suitability model made use of biophysical and environmental variables well described for Walia ibex by Dr. Nievergelt. The present land use and land cover, DEM, aspect, slope, and others data were included in the model to identify and characterize habitats frequented by the species (Figure 9).

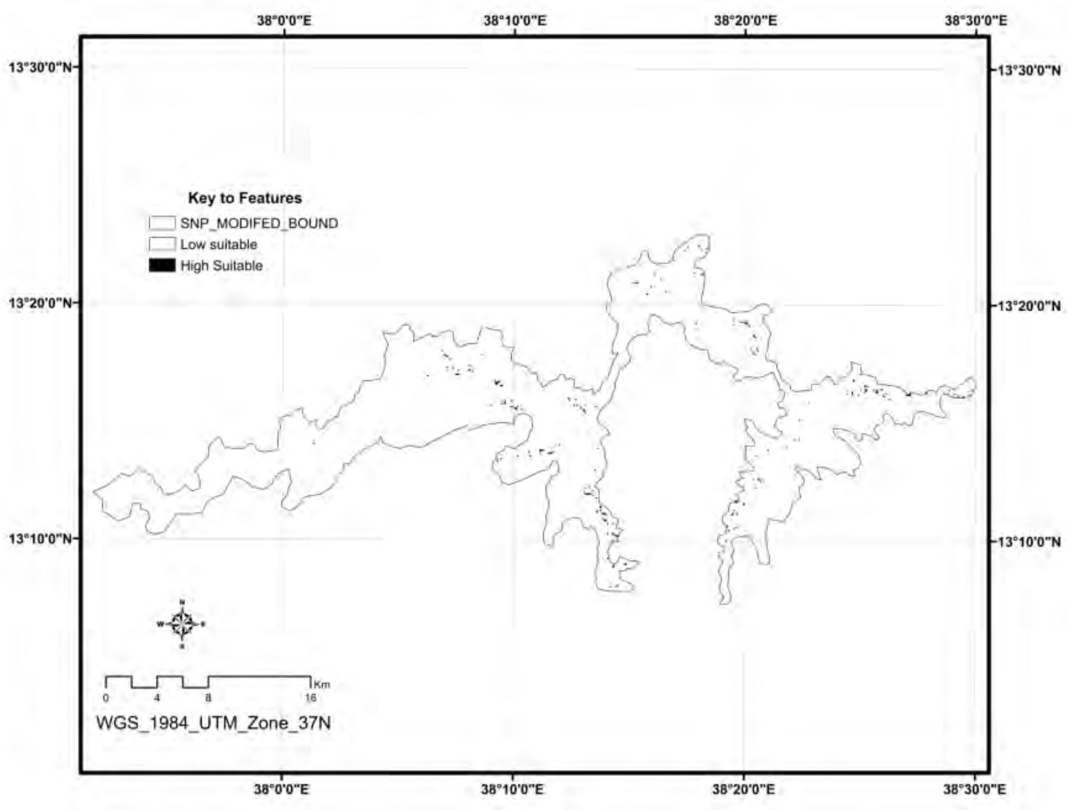


Figure 9: Suitability map: Walia ibex

4. Climate Change Risk Profiles

4.1 Objective

Specific objective of this study was to create climate change risk profiles that cover all the major hazards prevailing in and around the Simien Mountains National Park.

4.2 Methodology

4.2.1 Data Set

Ten years climatic data from meteorological stations at Chenek was collected from the National Meteorological Service Agency (NMSA). The basic parameters that were considered in the analysis are monthly rainfall and monthly temperature.

Surface and atmospheric data files including archive fire from FIRMS[1], surface topography such as digital elevation model (DEM) and vegetation indices are acquired in geo-tiff and shape formats from data centers of NASA and USGS. Climatic data were also acquired from FAO. Classified land use and land cover map and other derived data are also used in the analysis.

Historical data for Tekeze basin were obtained from the Hydrology department of Ministry of Water and Energy. Perennial and intermittent river features and surface water bodies found within the study areas were extracted and digitized from topographic maps.

4.2.2 Hazard Assessment

Data and information on hazards that have occurred in and around the national park and its impact were collected from archived records obtained from Woreda Bureau of Agriculture, in discussion with pertinent officials and key informants, household level survey and direct observation.

[1] **MCD14ML:** This data set was produced by the University of Maryland and provided by NASA FIRMS operated by NASA/GSFC/ESDIS with funding provided by NASA/HQ Available on-line https://earthdata.nasa.gov/active-fire-data#tab-content-6

4.2.2.1 Fire hazard Assessment

Distribution of archived fire data were analyzed and described in terms of spatial distribution and frequency. FIRMS Fire hot-spots are acquired by the MODIS instruments, on board NASA's Terra and Aqua Earth Observing System (EOS) satellites. A MODIS active fire detection represents the center of an approximately 1km pixel flagged as containing one or more actively burning hotspots/fires. Fire detection is performed using a contextual algorithm that exploits the strong emission of mid-infrared radiation from fires. The algorithm examines each pixel of the MODIS swath, and ultimately assigns to each one of the following classes: missing data, cloud, water, non-fire, fire, or unknown (EOS-DIS, 2009).

Input data were used to estimate the fire prone areas at the study sites. The present land use and land cover map, as part of it include the vegetation cover, data on slope, aspect, elevation, proximity to road and to settlements were the variables selected as an input to the model.

Initially, each selected variable were reclassified and categorized between classes. Class categorization of each variable was made between the ranges of very high to very low (Figure 10).

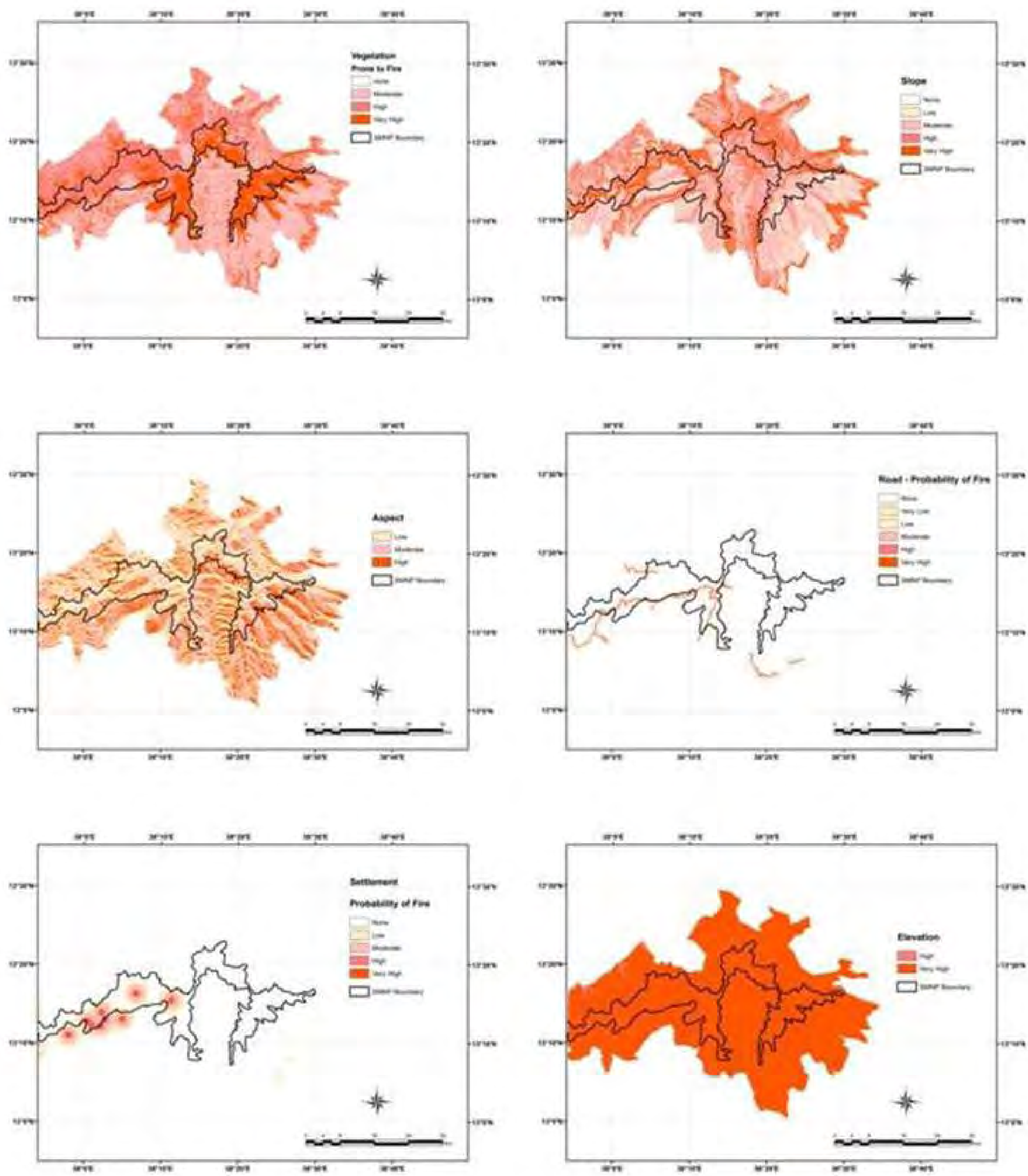


Figure 10: Variables used in the study of fire risk at SMNP

Further, environmental and anthropogenic factors that strongly influence the ignition and spread of fire in the PAs are selected and parameterized with the degree of influence each has on the fire danger (Table 2). Variables weighted include the present land cover classification, slope, aspect, distance from roads, distance from settlements and elevations.

Table 2: Variables and weight factor used in fire hazard mapping

Variable	Assigned weight
Land cover	66
Slope	20
Aspect	7
Distance from Road	3
Distance from Settlements and towns	3
Elevation	1
Total	100

A model widely used in the determination of fire hazard was used to delineate areas susceptible to fire.

4.2.2.3 Flood hazard Assessment

Derived and acquired data sets including slope (derived from digital elevation model), drainage density, soil type, present land use and land cover and elevation data were used as input in flood hazard assessment. The main flooding factors were reclassified into groups and ranked based on significance / influence on the hazard (Table 3).

Table 3: Factors used in Flood Hazard Assessment

Factor	Sub-factor		Description
Slope	43.085-76.830	5	Very high
	31.033-43.085	4	High
	21.091-31.033	3	Moderate
	11.449-21.091	2	Low
	0-11.449	1	Very low
Drainage density	0.371-0.587	5	Very high
	0.251-0.371	4	High
	0.164-0.251	3	Moderate
	0.058-0.164	2	Low
	0-0.058	1	Very low
Soil type	Lithic leptosols	5	V. High
	Humic nitosols	4	High
	Dystric podzoluviso	3	Medium
	Haplic luvisols	3	Medium
	Eutric cambisols	2	Low
	Eutric leptisols	1	Very low
Land use and land cover type	Cultivated land	4	V. High
	Grassland	3	High
	Wood land	2	Moderate
	Forest	1	Low
Elevation	920-1640	5	Very high
	1640-2160	4	High
	2160-2720	3	Moderate
	2720-3360	2	Low
	3360-4520	1	Very low

The standardized map layers were then assigned weights based on their relative importance and normalized by the sum of weights. Accordingly, weights of 33.33, 26.67, 20.00, 13.33 and 6.67 were assigned for slope, drainage density, soil type, land use / cover type and elevation respectively. GIS based weighted linear combination was used to derive flood hazard areas.

4.2.3 Risk Assessment

Based on integration of derived data on hazard and information on the elements at risk, assessment of risk was made using weighted overlay. Ranking was made based on relative importance attached and categorized from very high to very low. Available data on previous impacts were also reviewed.

4.3 Results and Discussions

4.3.1 Climate

4.3.1.1 The Present Climate of SMNP

Chenek, at an elevation of 3626 m.a.s.l in Simien Mountains National Park, receives a total mean annual rainfall of 825.7mm (Figure 11). The rainfall is also uni-modal with peaks in July (287.2mm).

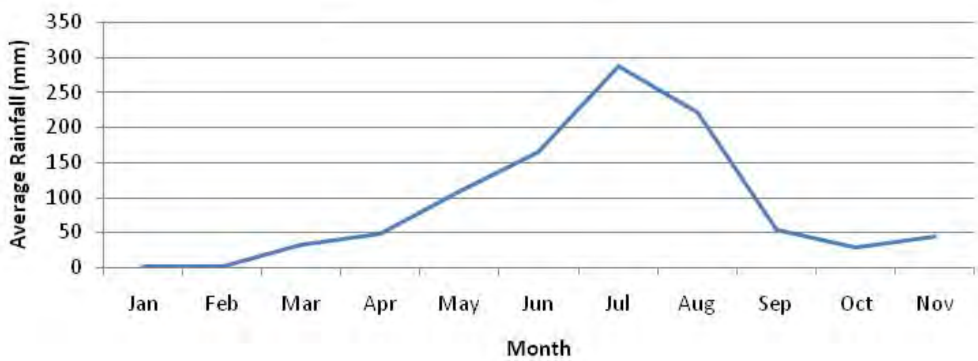


Figure 11: Mean Monthly Rainfall: Chenek.

At Chenek, the monthly mean maximum temperature is the highest in April (14.8°C) and the lowest in July (13.2°C). During December, the mean minimum temperature is at its lowest (2.1°C) and in April at its highest (6.0°C). The Annual mean minimum and maximum temperatures are 4.2°C and 14.8°C respectively (Figure 12).

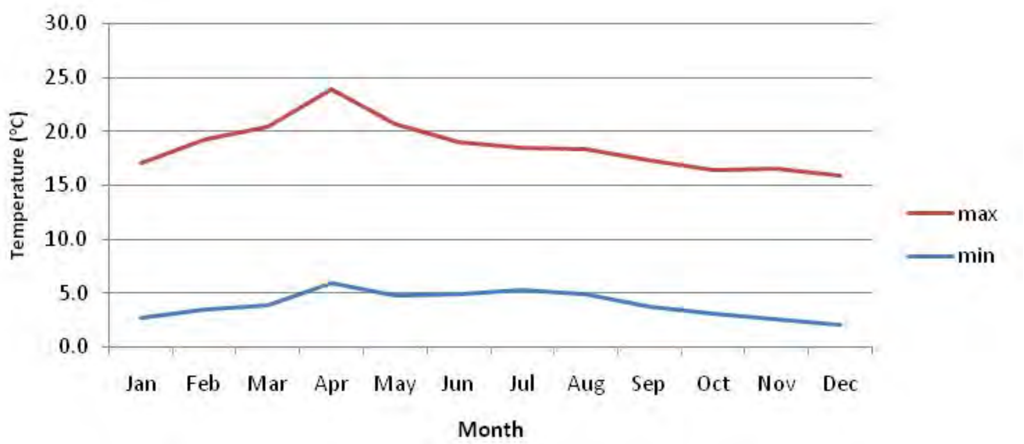


Figure 12: Mean Monthly Temperature: Chenek.

A study made by AACRA (2011) for Debarq show that, both the mean minimum and mean maximum temperatures between 1974-2009 has shown an increase and in particular those observed after 1994. The same study also shows that over the whole period, a small decreasing trend in average annual rainfall can be postulated but no trend can be detected for the period after 1993.

At national level, a similar study (NMSA, 2005) showed that there has been a warming trend in the annual minimum temperature over the past 50 years and an increase by about 0.37^{0}C in every ten years. However, even though there were fluctuations, rainfall for the same period had remained more or less constant when averaged over the whole country.

4.3.1.2 The Future Climate

A study by NMSA (2005) also showed that, for the IPCC mid-range (A1B) emission scenario, the mean annual temperature will increase in the range of 0.9 -1.1°C by 2030, in the range of 1.7 - 2.1°C by 2050 and in the range of 2.7-3.4°C by 2080 over Ethiopia compared to the 1961-1990 normal. A small increase in annual precipitation is also expected over the country.

4.3.2 Hazards Assessment

4.3.2.2 Fire hazard

4.3.2.1.1 Fire Frequency

The total number of hot spots observed at SMNP between 2001 and 2014 were ten. Most of these fires had occurred between March and May, when the temperature of the area is at its peak (Figure 13).

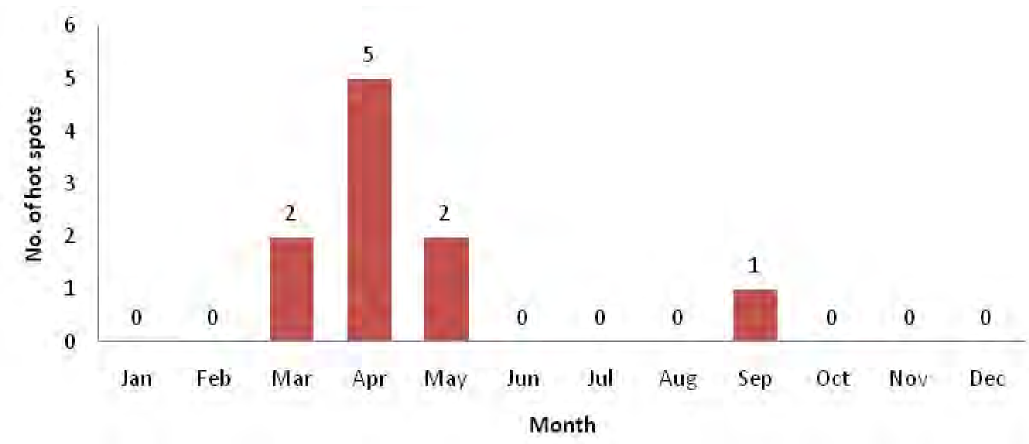


Figure 13: No of hot spots recorded in SMNP between 2001 and 2014

Sixty percent of the hot spots detected at SMNP between 2001 and 2014 had occurred in just two years, that is, in year 2003 and 2004 (Figure 14).

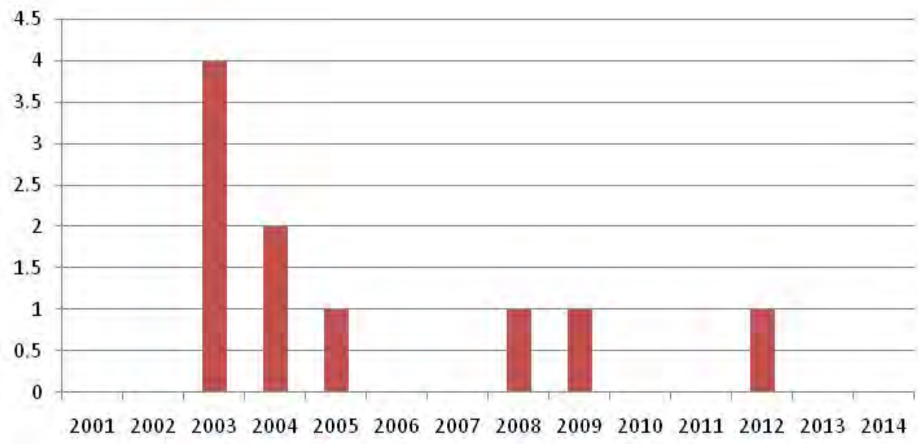


Figure 14: Number of hot spots detected in the SMNP between 2001 and 2014

Considering only the KAs that immediately surround the SMNP, almost all fire hot spots detected had occurred in the north western part of the park. The frequency of hot spots in these areas was much intensive between 2003 and 2010 (Fig. 15).

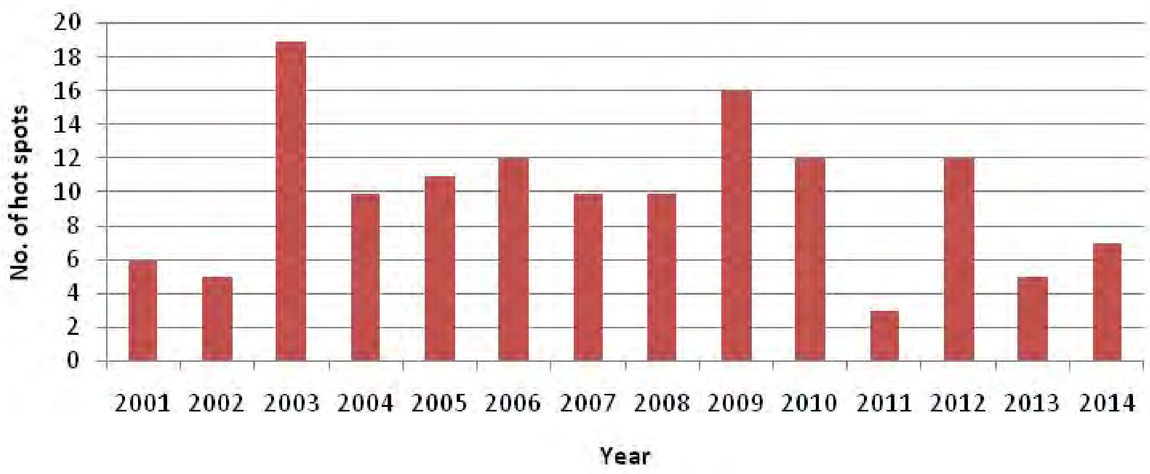


Figure 15: Number Fire hot spots detected in SMNP and surrounding areas between 2001 and 2014

Furthermore, the frequency of hot spots was the highest in between February and April when the temperature is at its maximum and before the onset of the rainfall (Figure 16).

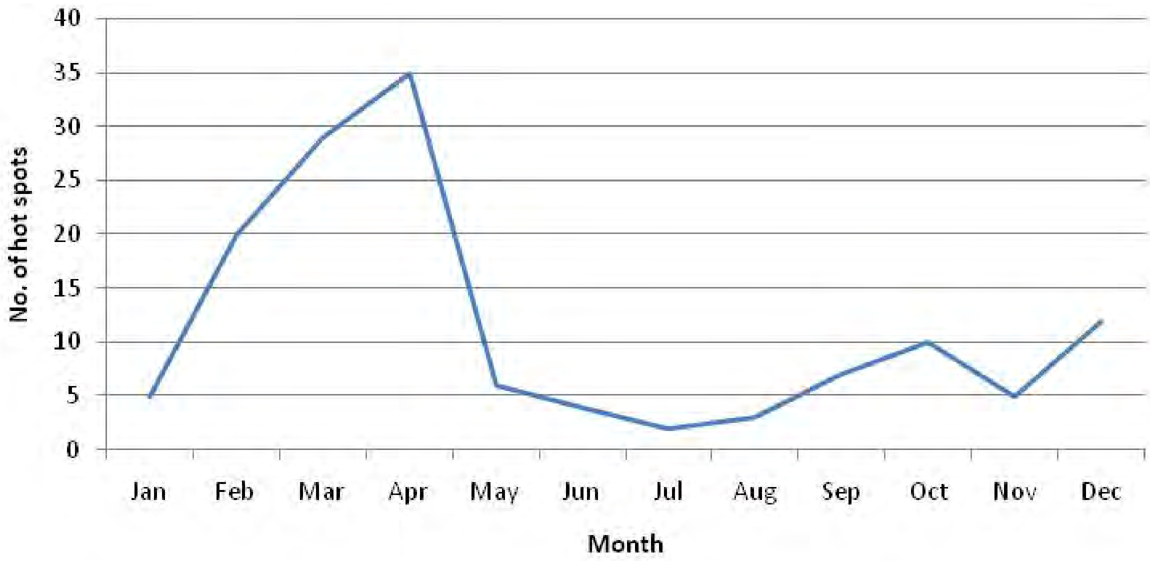


Figure 16: Number Fire hot spots detected by months in SMNP and surrounding areas between 2001 and 2014

Of the total hot spots observed between 2001 and 2014, seventy-seven percent had occurred in *Angewana-keranga* (48%) and *Sera-gudela* (29%) KAs of *Adi-Arqay* woreda. *Dib-*

bahr from *Debarq* woreda (8%) and *Agdamia* KA (3%) from *Adi-Arqay* woreda were some of the other KAs in which hot spots are observed (Figure 17).

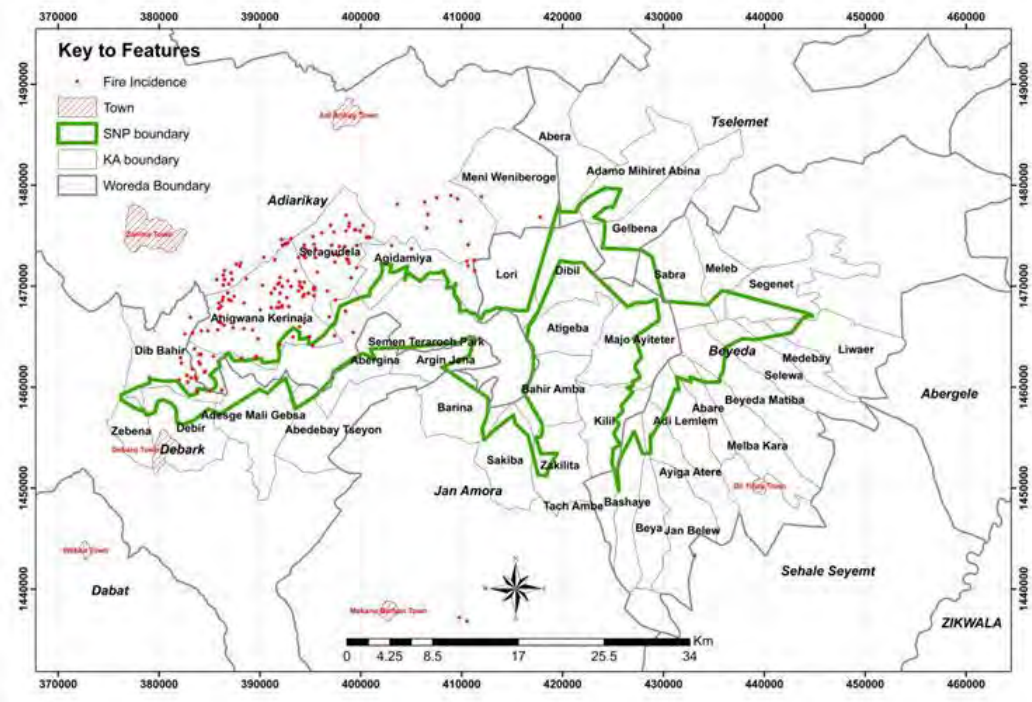


Figure 17: Distribution of hot-spots in and around the SMNP

A close look in the location of hot spots in SMNP, during the studied period, show that most of it had occurred in the lower elevation areas within the forest and peripheries of cultivation lands (Figure 18).

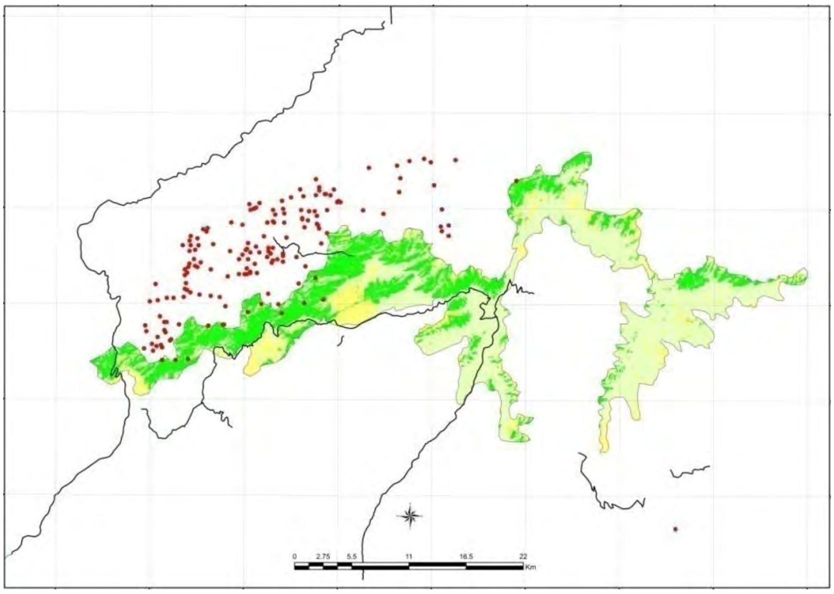


Figure 18: Distribution of hot-spots at SMNP over the present vegetation types

4.3.2.1.2. Fire Prone Areas

Overall, 27.62% of SMNP area is categorized under high hazard area while 39.50% are classified as moderate (Figure 19). Further, 20.22% of SMNP area is under low fire hazard, while 9.93% under very low and a meager 2.73% has none.

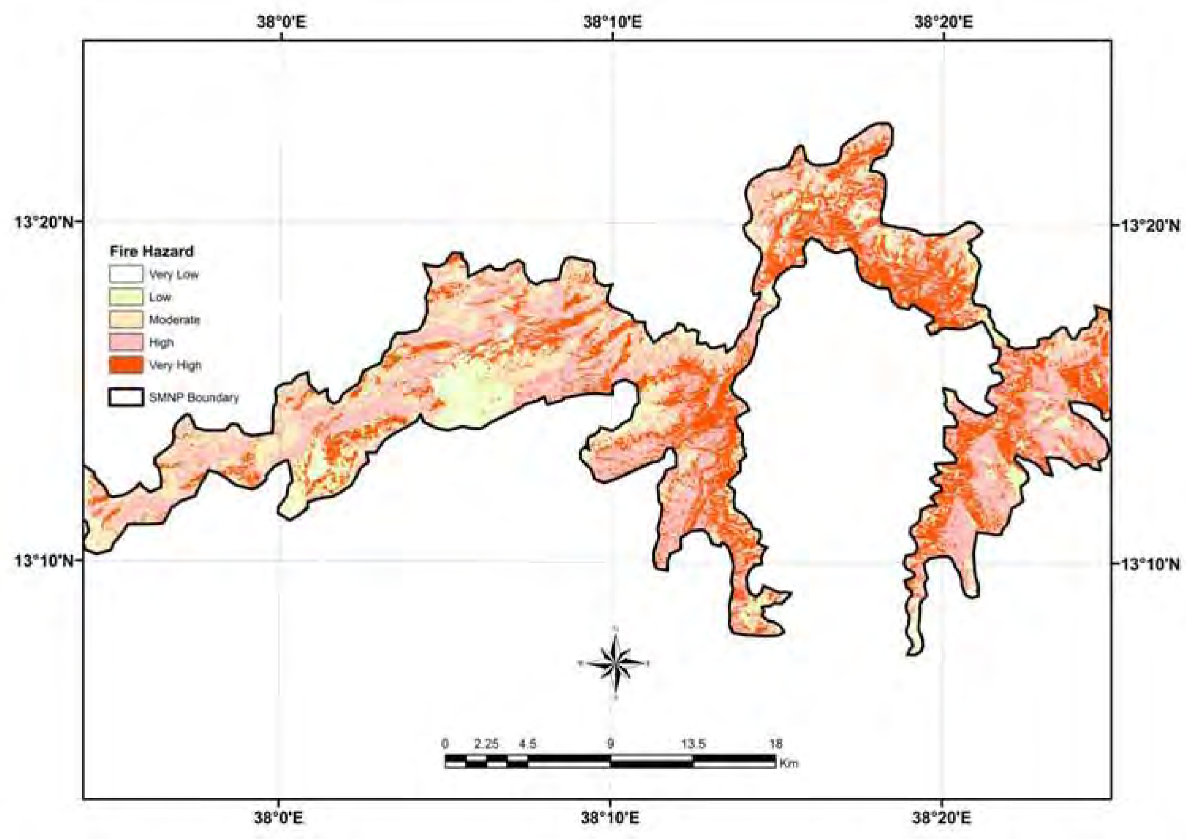


Figure 19: Fire Hazard Map

4.3.2.3 Flood Prone areas

Areas susceptible to very high flooding cover some 5.70 percent and high flood prone areas some 19.16% of the total SMNP and the surrounding KAs area. The corresponding proportion for moderate, low and very low was, 32.98, 30.04 and 12.12% (Figure 20).

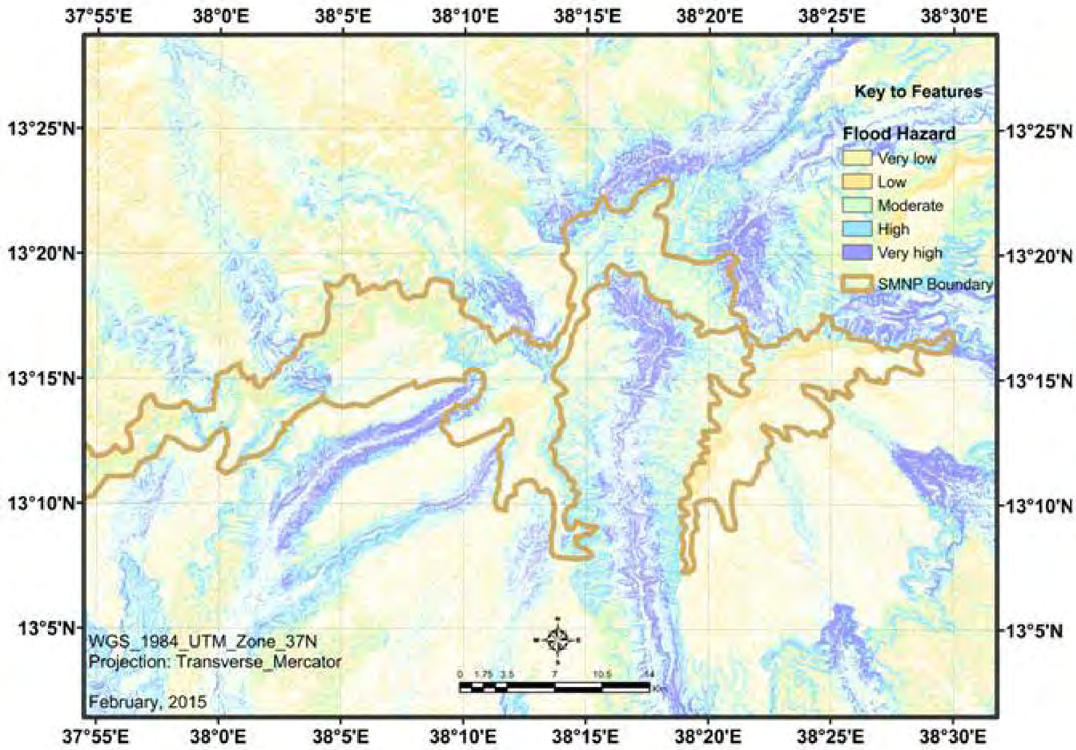


Figure 20: Flood Prone Areas

4.3.3 Vulnerability Assessment

Hazard affects animals mainly through habitat modification (Kennedy and Fontaine, 2009). Even though, the extent, size, life form and combination of vegetation types required by wild animals differ from one species to another, in general, habitat provide shelter, food and water, and space in which the survival and continuity of wild animals depend (Yarrow G., 2009).

The surrounding communities of SMNP mainly depend for their livelihood on crop production and livestock rearing. Number of human and livestock in the adjoining KAs were given in Annex 2 and 3.

4.3.4 Risk Assessment

An occurrence of hazard within the park might potentially affect the size and species composition of habitat and the fauna that depend on it. Resultant fragmentation of habitat might also pave way to other negative impacts. Increased erosion from burnt areas might also lead to high sediment flow with negative impact downstream.

Further, it will also affect the livelihood of local community who mainly depend on agriculture. Disruption of tourism shall also affect government revenue, income derived by the local community from involvement in services such as tourist guides, horse and equipment renting and highly influence jobs and business operating in the area.

4.3.4.1 Fire Risk

Considerable area sizes in the SMNP and the surrounding KAs were categorized under high (44.45%) and very high (28.65%) fire risk, together forming some 72%. Moderate and Low fire risk zones have 7.9 and 19.01 area coverage respectively (Figure 21). 96% of the grassland area and some 0.32% of the forest was highly susceptible to a fire hazard.

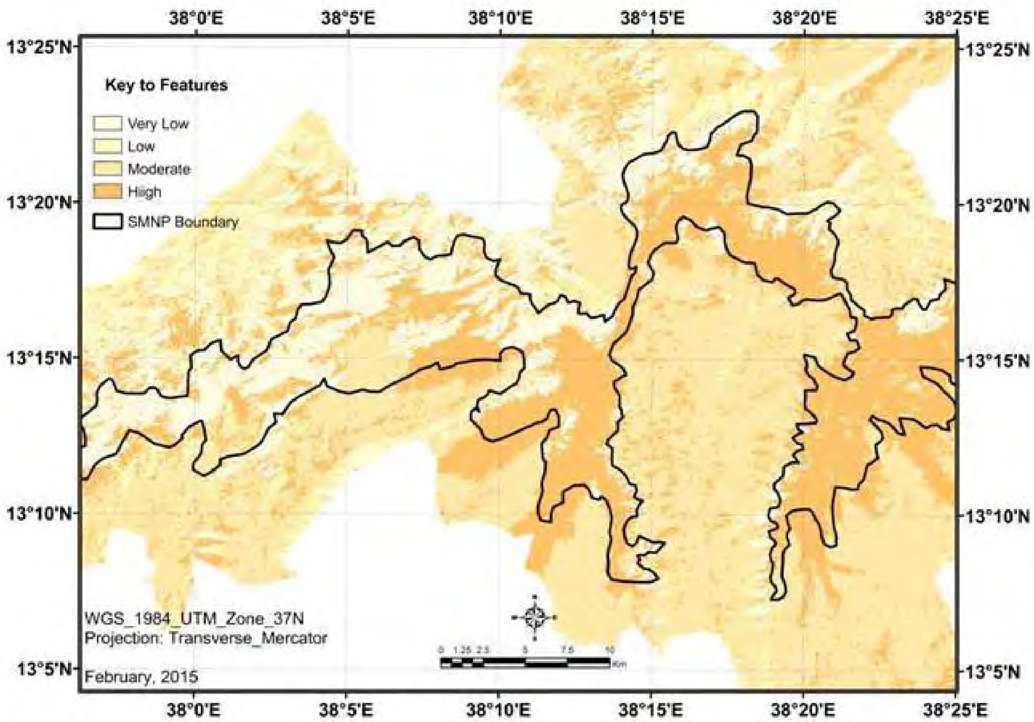


Figure 21: Fire Risk

4.3.4.2 Flood Risk

Some 36% of SMNP was categorized under different degrees of flood risk (Figure 22). Of these, very high flood risk areas constitute some 5.06%; 29.46% corresponding to grassland, 36.6% to forest and 0.34% to cultivated land. High flood risk areas make about 19.69%, moderate some 35% and low to very low together make some 40%.

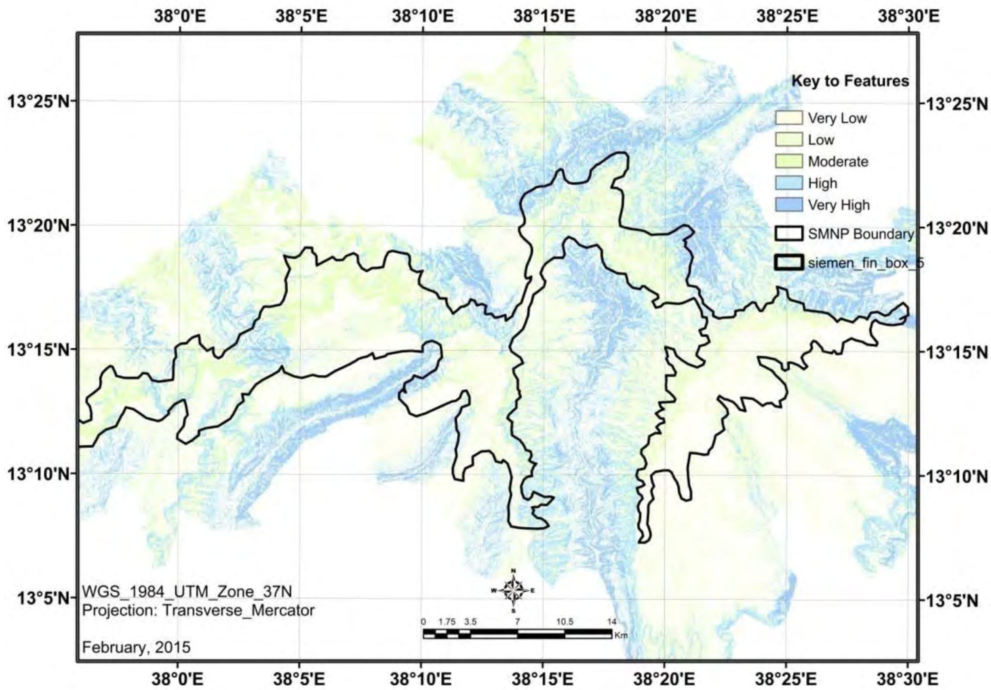


Figure 22: Flood Risk map of SMNP

The forest cover on the side slopes of the mountain at SMNP had been under considerable pressure in the past. Fires were set to on these areas to clear lands for cultivation (Nicol, 1972). The forest areas had also faced high extraction pressure as fuel wood was the main source of energy for household cooking and warming.

Consequently, degradation of the vegetation cover, that once slow the discharge, has made the low land areas more vulnerable to storm flooding. People now living in the park adjoining KAs are facing serious threats from storm flooding, mainly caused by heavy rains in the upper slope areas.

In four Keble administration of Adiarqay woreda, which adjoin the SMNP in the north, for example, storm flood had made a loss of domestic animals, damage to planted crops and other properties. In 2014 alone, a total of 568 HHs with 3154 family members, from four KAs, namely, Meni-wonberge, Sera-gudela, Agdamia and Angua-kerneja are affected by the flood. Consequently, about 301.4 hectare of farm land with staple crops was damaged and some 20 cattle were dead. The KAs actually were found in the high flood hazard zones.

5. Conclusions and Recommendations

5.1. Conclusions

In the SMNP there were land cover changes at different time scales and varied cover classes, notably between the 1970's and 1990's. The major causes for the decline in area size differ in the time period studied. Significant ones include the deforestation and degradation of the vegetation through extraction of wood, overgrazing and expansion of cultivation. Despite these, significant improvements are observed in the maintenance of the forest size since the late 1990s. Furthermore, time-series comparison of census data showed that there were improvements toward the restoration of abundance of selected species, most notably, the relative increase in Walia ibex population. Changes in the observed land use and cover classes, have therefore, significant impact on the composition and abundance of wild animals in the national park.

The national park was exposed to climatic variations, especially related with temperature. Fire risk analysis also shows that the park was exposed to fire hazard of different degrees; some 27.6% and 39.5% of SMNP are classified under high and moderate fire hazard areas, respectively. Consequently, degradation of the vegetation cover, that once slow the discharge, has made the low land areas more vulnerable to storm flooding. People now living in the park adjoining KAs are facing serious threats from storm flooding, mainly caused by heavy rains in the upper slope areas.

The national park possesses significant number of wild animals, including mammals and birds that are endemic to Ethiopia. Beyond the ecosystem goods and services, the parks also have the potential to generate a substantial amount of economic and social benefit from the tourism industry such as livelihood diversification and job creation that will help contribute to the government plan for poverty reduction. Accordingly, some of the successful undertakings to date include the involvement of local communities in the sustainable development of the PA, and plan for the voluntary reallocation of park dwellers and the diversion of public road out of the park boundary.

5.2. Recommendations

The followings are recommended to assist the conservation and development efforts of the protected area particularly toward resilience to climate change:

- Developing monitoring system, deployment of the required material and training of personnel is required to minimize risk and, on the occurrence of one, for an effective response to any identified hazard.
- Collate the existing documents on traits of wild animals found in the country, if not available, conduct brainstorming workshops in which wild animal experts would provide the scientific basis that help determine the interaction in face of climate change.
- Support should be provided to adjoining districts toward re-establishing the original vegetation along with well studied mechanical treatments on selected sites. These can lessen the force of the water flow and minimize the damages.
- One of the major causes of deforestation and degradation is the collection of fuel wood from the forest areas within the PA. Almost all households questioned, at SMNP, use biomass energy and without any improved stove. Use of an improved stove will significantly reduce (at least 20%) the use of wood fuel. Therefore, there is a need to look at the introduction of the stoves to the area and reduce pressure on the forest and woodlands.
- Anthropogenic and now climate change poses difficulties in the management of wild animals found at the national park. However, data to accurately quantify such activities are meager. It would be advisable to collect data on factors such as wild animal dispersal areas, number and distribution of domestic animals and season of use, as well as fuel collections and use of adjoining kebeles.
- There probably exists a wide range of spatial and non-spatial data related to the bio-physical and environmental characteristics of wild animals, park, etc. in the country. However, such data, at least, are not available at park levels. It is therefore, very important and timely to develop a geo-data base and migrate all available maps into this for a better retrieval (can be linked with the existing web page of EWCA and access, if necessary, can be with permission), storage and analysis.

6. References

ACCRA, 2011. Climate trends in Ethiopia: Summary of ACCRA research in three sites. http://community.eldis.org/accra/ Downloaded on 26 January 2015.

Barbara Wilson, Leonie Valentine, Janine Kinloch, Tracy Sonneman, Marnie Swinburn, 2009. Habitat Loss and Fragmentation IN: Biodiversity values and threatening processes of the Gnangara; Editors: Barbara A. Wilson and Leonie E. Valentine

C.W. Nicol, 1972. From the Roof of Africa. Alfred A. Knopf, New York.

Chuvieco, E. and Congalton, R. 1989. Application of Remote Sensing and Geographic Information Systems to Forest Fire Hazard Mapping. Remote Sensing and Environment, 29: 147-159.

Engstrom, R.T. 2010. First-order fire effects on animals: review and recommendations. Fire Ecology 6(1): 115-130. doi: 10.4996/fireecology.0601115

FAO/LUPRD, 1982. Soil association map of Ethiopia, Technical document 6.

FDRE, 2005. wildlife strategy. Addis Abeba

Fischlin, A., G.F. Midgley, J.T. Price, R. Leemans, B. Gopal, C. Turley, M.D.A. Rounsevell, O.P. Dube, J. Tarazona, A.A. Velichko, 2007: Ecosystems, their properties, goods, and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, 211-272.

Greg Yarrow, 2009. Habit Requirements of Wildlife: Food, Water, Cover and Space. Cooperation Extension's Forestry and Natural Resources Team, Clemson University.

Grünenfelder J., 2005. Livestock in the Simen Mountains, Ethiopia. Its role for the livelihoods and land use of local smallholders, Master Thesis, University of Berne

Hürni, H. and Ludi, E., 2000. Reconsidering Conservation and Sustainable Development. A Participatory Study Inside and Around the Simen Mountain National Park, Ethiopia. University of Berne, Switzerland.

Institute of Biodiversity Conservation, 2009. Convention on Biological Diversity, Ethiopia's 4th Country Report, Addis Ababa.

IPCC, 2002. Climate change and biodiversity. Technical paper IV.

MoARD, 2005. Wildlife Development, Protection and Utilization Policy and Strategy, Addis Ababa.

NMSA, 2007. Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia, Editor: Abebe Tadege "Preparation of National Adaptation Programme of Action For Ethiopia", GEF / UNDP. Addis Ababa, Ethiopia.

Nievergelt, B. (1981). Ibexes in an African Environment. Ecology and social system of the Walia Ibex in the Simien Mountains, Ethiopia. Springer Verlag: Berlin and New York. Ecology Studies, Volume 40. 173 pp.

Kennedy P. L. and Fontaine B. J., 2009. Synthesis of Knowledge on the Effects of Fire and Fire Surrogates on Wildlife in U.S. Dry Forests, Special Report 1096. Extension and Experiment Station Communications, Oregon State University.

PHE, 2012. Three years Strategic plan of PHE Ethiopia Consortium, 2011 – 2013. Addis Ababa.

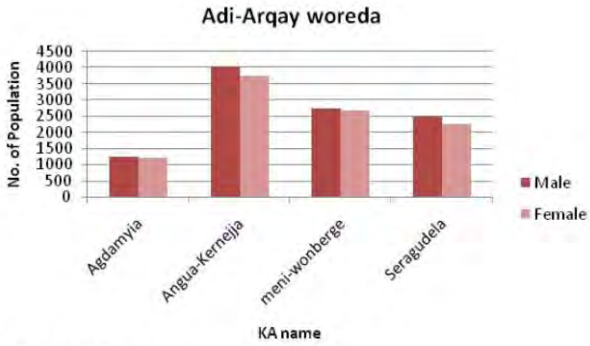
WBISPP, 2002. A strategic plan for the sustainable development, conservation, and management of the woody biomass resources, Volume 5, Methodology: Land Use Systems Analysis.

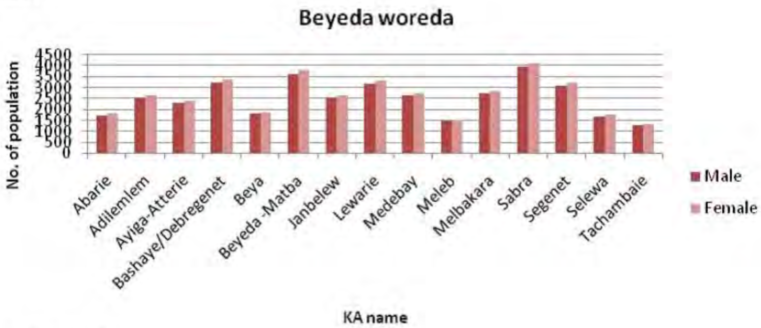
WHC-IUCN, 2006. Joint World Heritage Centre – IUCN: Reactive Monitoring Mission to Simien Mountains National Park World Heritage Property, Mission Report.

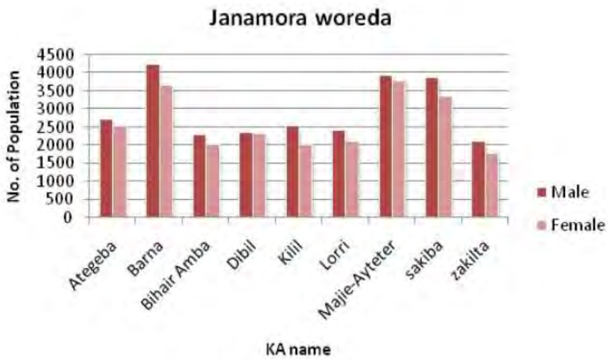
Annex 1: List of wild animals at Awash and Simien Mountains National Park listed in the IUCN Red list

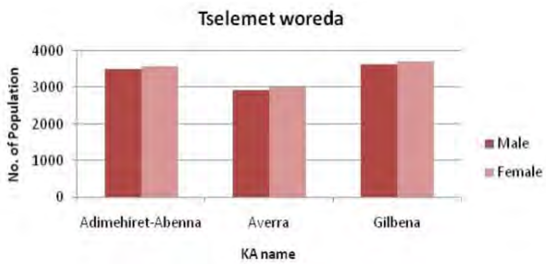
	Common name	Scientific name	IUCN status	Estimated Total no. (2010)	Park
1	Walia ibex	*Capra ibex walie*	Endangered	500	SMNP
2	Ethiopian Wolf	*Canis simensis*	Endangered	78	
3	Gelada Baboon	*Theropithecus gelada*	Least concern	2500	

Annex 2: Number of Human Population in the surrounding KAs of SMNP (data source: Agriculture Office)









Annex 3: Number of domstic animals in the surrounding KAs of SMNP