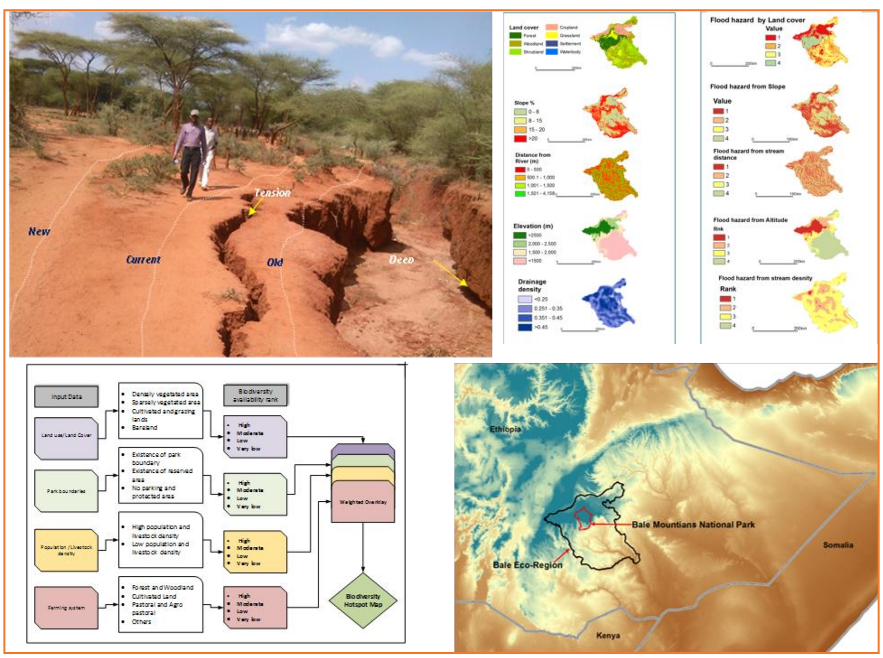
Hotspots of Environmental Degradation in the Bale Eco-Region

SHARE Bale Eco-Region Research Report Series no. 6



END HUNGER >>> GROW FARMING
FARM AFRICA

SOS SAHEL ETHIOPIA

IWMI International Water Management Institute

FRANKFURT ZOOLOGICAL SOCIETY

PHE Ethiopia Consortium "Healthy Families - Healthy Environment"

ABOUT THE SHARE BALE ECO-REGION PROJECT

Conservation of Biodiversity and Ecosystems Functions and Improved Well-being of Highland and Lowland Communities within the Bale Eco-Region (BER) is one of the European Union (EU) funded projects that stands for Supporting Horn of Africa Resilience (SHARE). In Ethiopia, the project covers 16 districts (Districts) in West Arsi and Bale Zones of Oromia Regional State, around 22,000 km^2, with a population of about 3.3 million. The project life span is 42 months starting July 2014 and ending in November 2017. Five partners are implementing the project: Farm Africa, SOS Sahel, International Water Management Institute (IWMI), Frankfurt Zoological Society (FZS) and Population Health and Environment (PHE).

Location of the Bale Eco Region (BER) in Ethiopia

Acknowledgements

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Acronyms

BER	Bale Eco-Region
BERSMP	Bale Eco-Region Sustainable Management Program
BMNP	Bale Mountains National Park
CL	Cropland
CSA	Central Statistical Agency
EWCA	Ethiopian Wildlife Conservation Authority
F- CL	Forest to Cropland
F	Forest
FDL	Forest Dominating Landscape
FZS	Frankfurt Zoological Society
GL	Grassland
IWMI	International Water Management Institute
LULC	Land Use Land Cover
NGO	Non-Governmental Organizations
OFWE	Oromia Forest and Wildlife Enterprise
PFM	Participatory Forest Management
PHEEC	Population Health and Environment Ethiopia Consortium
SBL	Shrub/Bushland
SHARE	Supporting Horn of Africa Resilience
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WL	Woodland
WLRC	Water and Land Resource Centre

Executive summary

The Bale Eco-Region (BER) in the south eastern part of Ethiopia, is well known for its unique biodiversity and immense natural resources. Having BMNP at its center, the BER provides habitat to globally unique and diverse fauna and flora including a significant number of rare and endemic species (e.g. Ethiopian Wolf and Mountain Nyala). The BER comprises the largest afro-alpine environment in Africa. The Harena Forest and adjacent Mena-Angetu forest form the second largest moist tropical forest remaining in Ethiopia (BERSMP 2006). Furthermore, the mountainous highland part of the Bale Eco-Region is a water tower for the surrounding drought prone and arid lowlands of south east Ethiopia, northern Kenya and Somalia.

However, anthropogenic threats are increasing in the BER and include the rapid expansion of agricultural land as well as rural and urban settlement growth, which is occurring at the expense of forests, woodlands and natural vegetation.

Responding to these problems, SHARE Bale Eco-Region project was designed comprising five implementing partners. The five implementing partners are Farm Africa, IWMI, SOS Sahel Ethiopia, FZS and PHEEC. The project is supported by the European Union's SHARE. IMWI is leading the research component of the project. WLRC entered agreement with IMWI to conduct this research.

Therefore, this research was conducted by WLRC commissioned by SHARE Bale Eco-Region project through IMWI. The objective of this study was to identify and map different land degradation and map hotspot areas to address pressures and drivers of the eco-region degradation and its implications on biodiversity and hydrological systems of the Bale Eco-Region (BER).

To meet this objective LULC maps of the BER were developed for the years 1973, 1986, 2010 and 2015 from Landsat satellite images. Seven LULC class such as forest, woodland, shrub/bushland, grassland cropland, settlement and water body were identified. Using the LULC maps as input the change detection was carried out using post-classification comparison method. The changes were calculated and presented at two levels. The first level detected the overall change by considering the entire ecoregion and the second level detected change at landscape level by sub dividing the ecoregion into four dominant landscape zones. The landscape zones are namely; forest, cropland, woodland, and afro-alpine dominating landscapes.

In order to identify soil degradation by erosion hotspot areas, USPED model was employed. The model uses land use land cover map estimate the cover 'C' factor, field observation to estimate the management 'P' factor; soil texture estimate the soil erodibility 'K' factor, rainfall data to estimate the 'R' factor STRM data to estimate the slope length 'LS' factor. Moreover, different layers of spatial data were used to map vegetation change, bio-diversity, flood risk maps.

The overall change showed that area of cropland increased from 6.73% in 1973 to 9.22% in 1986, then to about 16% in 2010, and to 21% in 2015. Forest which was 24.56% in 1973 decreased to 17.35% in 2015.The area increase in cropland is majorly at the expense of forest, woodland grassland and shrub/bushland. Out of the total LULC type converted to cropland between 1973 and 1986 about 73.85% was grassland. In the period 1986-2010, out of the total LULC type converted to cropland, 48.27% was grassland, 16.49% was forest, 22.51% was woodland and 12.73% was shrub/bushland. Out

of the total LULC type converted to cropland in the period 2010-2015, grassland constitute about 44.64%, woodland constitute 42.98% and forest constitute 10.68%.

LULC modification (example, forest to woodland, shrub/bushland to woodland) was also observed in the BER over the last four decades. Such change in the BER is majorly related to recurrent fire, wood harvesting and over grazing by livestock.

The landscape level change detection result showed that 16.7% of Forest Dominating Landscape, 22.4% of Cropland Dominating Landscape, 22.18% Woodland Dominating Landscape and 19% the Afro-alpine Dominating Landscape has changed over the last four decades.

The change hotspot areas are categorized into three zones: High, moderate, and slightly changed hotspot areas. The high change hotspot areas consist of 31 % and characterized majorly by conversion of LULC such as conversion of forest, woodland, shrub bush to crop. The moderate change hotspot area covers about 35 % and majorly characterized by LULC modification than conversion (example woodland to forest) and minor conversions are also present. The slightly changed hotspot areas covers 34% of the hotspot areas and mainly characterized by minor changes and in some cases no change.

The most vulnerable land degradation by soil erosion areas are crops and shrub lands. About --- % of the crop land is high erosion risk (> 20 ton/ha/yr) ------ % is medium erosion risk (10-20 ton/ha/yr). Estimates of soil erosion in the shrub land showed ---- % is high and -----% is low. Acidity is a chemical degradation prevalent in the high rainfall plateaus. About 26% of the Bale-ecoregion is highly acidic while 25.6 % is moderately acidic.

Land degradation in the BER is mainly due to population increase including migration from drought prone and agricultural land scare areas namely West and East Hararghe zones, Arsi zone and Sidama zone of SNNPR. But majorly, migrants are coming from Hararghe zone. For example, between 1986/7 and 2002 about 20,093 migrants were settled in the BER out of which 95% were from Haraghe. Majority of these migrants settled in forested kebeles including kebeles which were part of BMNP gradually giving way to modification of the boundary of BMNP in 2014. Other causes of changes in the BER are cropland expansion, fire, wood extraction, over grazing, institutional instability and week policy enforcement.

This removal of vegetation in the upper part of BER due the above mentioned reasons may affect the water production capacity of the BER which is critical for the inhabitants of the BER as well as the downstream arid areas of Ethiopia, Kenya and Somalia. On the other hand the removal of vegetation in the BER will affect the vegetation structure which in turn affects unique biodiversity of the BER. Reversing land degradation on cultivated and shrub lands to improve the crop productivity of the agricultural land and off-site impacts soil erosion also requires immediate intervention. These includes integrated watershed development, prevention of gully formation and rehabilitation of degraded lands; management of extensive acidic soil in upland.

Finally managing the eco-system degradation is an urgent task the need to be pursued at all levels. These include implementation of existing land policy, awareness creation, and enhancing livelihood options in the BER. In addition, a way should be devised at least to minimize number of migrants coming to BER from the two Hararghe zones, Arsi zone as well as Sidama zone of SNNPR. One way to stop such migrants could be possible through political dialogs and developing livelihood options in their home

District (districts). Farther more, development actors operating in the BER should strongly collaborate with the local government in finding alterative livelihood for people dependent on the BER, implement land policy and low enforcement. Fire in the BER particularly in the Afro-alpine environment, and the lowland woodland is a means of pasture management system by the local people. Such pasture management system by the local people should be either replaced by other means of management or mechanism should be devised to regulate such pasture management system.

1 INTRODUCTION

The Bale Eco-Region (BER), located in south eastern part of Ethiopia, is well known for its unique biodiversity and immense natural resources. It encompasses wide range of ecosystems (from an Afro-alpine landscape to very dry lowland landscape). The upland part of the BER has become one of the 34 World Biodiversity hotspots(BMNP 2007) and provide habitat to globally unique and diverse fauna and flora including a significant number of rare and endemic species (e.g. Ethiopian Wolf and Mountain Nyala). The BER comprises the largest afro-alpine environment in Africa. The Harena Forest and adjacent Mena-Angetu forest form the second largest moist tropical forest remaining in Ethiopia and being one of the genetic hot spots of wild Coffee Arabica (BERSMP 2006). Furthermore, the mountainous highland part of the eco-region is a water pool for the surrounding drought prone and arid lowlands of south east Ethiopia, northern Kenya and Somalia. The topographic setting of the BER makes an important ecoregion where strong highland-lowland ecosystem interaction exists. The topographic setting favored the area to get prolonged and high amount of rainfall and some areas receive a bimodal rainfall pattern. Besides to a high rainfall the region it receives, the mountain grasslands, lakes, wetlands and forests located in the higher altitude of BER catchment are also sources of cloud and mist formations that determine local climate at eco-regional scale (BMNP 2007; BERSMP 2006). Over 40 streams flow down from Bale Mountains and join major two transboundary rivers: namely Wabe Shebelle and Genale. The hydrologic system linked the livelihoods of an estimated 12 million people located in the upstream and downstream areas of the BER.

In spite of all the resources and ecosystem services potential, the BER is suffering from detrimental anthropogenic threats in every direction and aspect. Among others, rapid expansion of agricultural land, over grazing by livestock, unsustainable fuel wood and timber extraction as well as unregulated rural and urban settlement expansion destruct the BER. Such anthropogenic pressures are mainly driven by population growth, poverty, weak policy implementation arrangements, lack of cross-sector integration of actors responsible for sustainable NRM. These pressures are recently triggering flood hazard, soil erosion, water shortage and drought in the lower altitudes. As a result, drought prone areas especially those located in the lower riparian region of BER are recurrently experiencing chronic food and water shortage. In the higher altitude also the expansion of cropland pushes the Afro-alpine region boundary and damage the ecosystem important for ecotourism.

In response to this, over the last two decades' various programs and projects have been underway. However, effective implementation of the programs requires concert evidences on the causes and implications of anthropogenic activities happing at a varying time and space. In many of the circumstance, projects ignore to understand the Land Use and Land Cover (LULC) dynamics of the entire eco-region. Lack of information and poor understanding on the spatio-temporal dynamics of the LULC hindered effective implementation of sustainable land management programs and makes difficult to monitor their impact at the end. Previous experiences show that in many of the initiatives, the need to have baseline information on the LULC were ignored, if exist, are incomplete and incomprehensive. The good knowledge base, experience and data collected by many of the initiatives are site specific and focused on few ecosystems localities. For example, the fundamental drivers of landscape change such as human population growth, and its present and future effect on sustainable management of NRM (demography-environment nexus) is not well documented at a required level. As a result, the overall spatial-temporal state of the BER landscape remain unknown and impact of all successive sustainable resources management initiatives will remain unjustified.

Cognizant to these gaps, SHARE project was conceptualized with the objective of "Conservation of Biodiversity and Ecosystems Functions and Improved well-being of Highland and Lowland Communities within BER". The project comprises five implementing partners: Farm Africa, International Water Management Institute (IWMI), SOS Sahel Ethiopia, Frankfurt Zoological Society (FZS) and Population Health and Environment Ethiopia Consortium (PHEEC) supported by the European Union's SHARE (Supporting Horn of Africa Resilience). IWMI leads the research component of the project with a major focus on building capacity, knowledge and understanding of biophysical and socio-economic dynamics in relation to natural resource use. Water and Land Resource (WLRC) of Ethiopia entered into an agreement with IWMI to play role in generating and documenting important knowledge on BER sustainable resource management. One of the activities of WLRC is to generate the LULC dynamics of the entire BER, the fundamental drivers of the change, how these drivers affect sustainable natural resources management in BER.

Therefore, this technical report presents;

- LULC dynamics, drivers of change, and hotspots areas over the last four decades as primary indicator the eco-region degradation.
- Risks areas associated to land degradation primarily related to soil erosion, soil acidity, flood, vegetation, and bio-diversity.

2 DESCRIPTION OF BALE ECO REGION

1.1 Location of the study area

The Bale Eco-region (BER) is located in the south eastern part of Ethiopia (Figure 1). It covers approximately an area of 39,765,000 km^2. The BER defined with its Centre at the plateau around Tulu Dimtu and extending to the south up to the boundary of Mena Angetu district including part of the Combretum-Terminalia woodland zone, to the north by the Wabi Shebelle river, to the east by river Web (Sofomor valley), and to the west by the agricultural plains of the Arsi-Bale plains in Dodolla and Adaba districts. It comprises about 16 districts in West Arsi and Bale zones of Oromia National Regional State. Adaba, Dodola,Kokosa and Nensebo are part of West Arsi zone where as Goba, Dinsho, Berbere, Sinana, Harena Bulq, Dollo mana, Gurra Damole, Badda Walabu, Agrfa, Gasera. Gololcha and Goro are in Bale Zone.

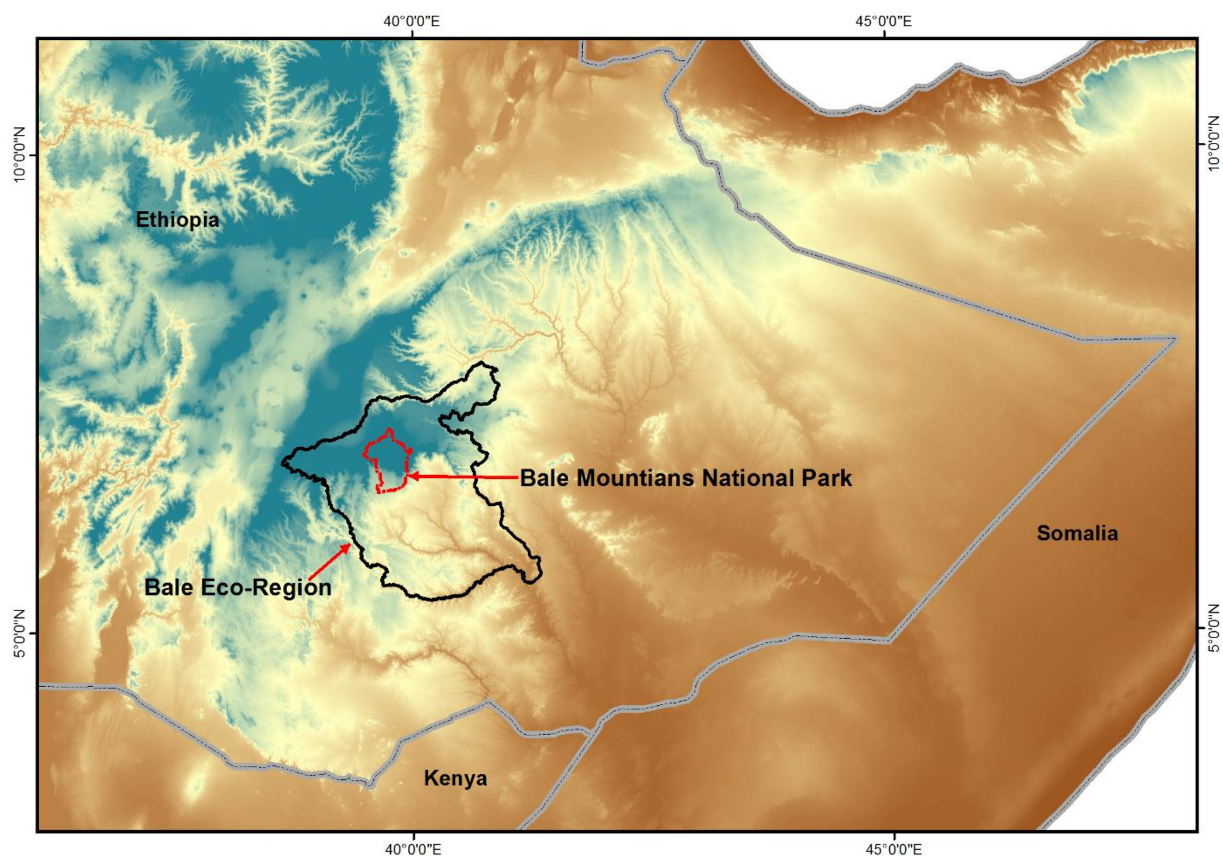

Figure 1. Location of the BER

1.2 Climate

The vast highland plateau and associated mountains of the BER is characterized by a cool temperature and high rainfall, and the high peaks like the Sanetti plateau and Tullu Dimtu could experience snowfalls in winter. Further south of the mountains and down in the lowlands a tropical warm and dry climate prevails. A bimodal local climate with two wet seasons that have heavy and small rains is characteristic in the eastern part of the project area, while the western part is characterized by a monomodal rainfall pattern. In the part with a bimodal rainfall pattern, heavy rain occurs from July to October, with the highest peak in August and the small rains from March to June, with a peak in April. There are typically eight rainy months (March-October) and four dry months (November-February) in a given year in the part with monomodal pattern. The far south and lower altitudinal areas experience a shorter, four-month rainy season usually from February to June. This lower altitude area receives between 600-1,000 mm of rainfall annually, whereas the higher altitudinal areas receive between 1,000-1,400mm. The rainfall source of the BER are two the equatorial westerlies and the Indian Ocean air streams. The daily temperatures during the dry season show high fluctuation. The lowest temperature that has been recorded in the mountains is -15^{O}C at night, with the highest recorded temperature the next day of +26^{O}C; thus a range of 40^{O}C within a 24-hour period. In contrast, in the rainy season temperature is mild, shows much less daily fluctuation. It rarely freezes during the rainy season but also the temperature rarely climbs over 20^{O}C.The mean annual maximum temperature is 18.4^{o}C, while the mean annual minimum is 1.4^{o}C

1.3 Hydrology

The hydrological resource of the BER has local and regional significance. The upper catchment of the BER is the source of over 40 streams that feed five major rivers: Web, Wabe Shebelle, Welmel, Dumal and Ganale. These rivers are the major sources of perennial water for approximately 12 million people downstream in the Ogden, Somalia, lowlands of Ethiopia and northern Kenya.

1.4 Geology

The Bale Mountains form part of the Ethiopian highlands system was formed during the Oligocene and Miocene geological periods, between 38 - 7 million years ago (Miehe and Miehe, 1994). The rocks of the volcanic outpourings are pre-dominantly trachytes but also include rhyolites, basalts and associated agglomerates, and tuffs. The area consists of a vast lava plateau with at least six volcanic cones, each more than 4,200 meters high, which have been considerably flattened by repeated glaciations.

1.5 Biodiversity

The BER is home for diverse and unique biodiversity resources. It is endowed with unique topographic and landscape diversity and makes unique habitat for numerous flora and fauna of some are endemic to Ethiopia. The BER is the largest Afro-alpine habitat (1,000 km2 equivalent of 17% of the continental total. More specifically the Harena Forest and adjacent Mena-Angetu forest form the second largest moist tropical forest remaining in Ethiopia and being one of the genetic hotspots of wild Coffee Arabica and was recognized as one of the 34 world Biodiversity hotspots. It is habitat for over half the global population of Ethiopian wolves (Canis simensis), the rarest canid in the world, which is also listed as endangered species by the World Conservation Union (IUCN). It hosts the largest population of the endemic Mountain Nyala (Tragelaphus buxtoni), estimated to be about two-thirds of the global population. In general, the upland area of the eco-region hosts 26% of Ethiopia's endemic species (1 primate, 1 bovid, 1 hare and 8 species of rodent). Of the area's recorded birds, 6.1% are Ethiopian endemics. In addition, there are several rare and endemic amphibian species.

1.6 Farming and livelihood system

In the BER, three major farming systems can be identified; agro-pastoralist (mixed agro-pastoralist), silvo-cultural and pure pastoralist. These farming systems form distinct spatial boundary. The mixed agro-pastoralist zone found in the northern and north eastern and north western sides of the BER and dominated by smallholder subsistent farmers. Though it is small in area large scale commercial farming in the north and north eastern part of the BER. Smallholder based subsistent farming system in the eco-region is similar to farming system commonly exist in the most highland areas of Ethiopia; combines crop and livestock. The exact combination of crop and livestock may vary depending on altitude. In the lower altitude areas, bordering the project area, typically below 500 masl in the southern fringe of the eco-region pastoralism and agro-pastoralism is dominant system. The highland farming system may comprise at least three sub-types depending on crop livestock combinations that are further influenced by altitude. These are: i) livestock-barley subsystem; ii) livestock – wheat/pulse mixed system; iii) livestock- maize/teff subsystem m. The livestock- barley sub-system is typical of the cool and humid high altitude areas above 3000 masl with a mean temperature of about 14 ^{o}C. Barley, horse, sheep and cattle were the major component of the farming system. In recent year potato is also emerging as important crop in this part. Wheat can also be grown mixed with barley in this farming system. Diversity of crop is very restricted in this farming system due to low temperature. The livestock- maize/teff sub-system is typical of the warm and humid lower altitude area near transition to the hot arid and semiarid lowlands. It is typically practiced in the altitude range between 2,000-1,500 masl.

The livestock-wheat/pulse occupies intermediate altitude range (2,000-3,000 masl) between the above two sub-systems. There is a strong interaction between the crop and livestock components of these farming systems. The livestock component provides draught power for ploughing and transport, manure for soil fertilizing, as well as additional income to purchase chemical fertilizers and other inputs. Cultivation is done with oxen that pull locally made plough called 'maresha'. The crop system in turn provides the major supply of feed. Owing to declining grazing land, in most part of the northern section of the eco-region crop residues supply at least 50 % of the annual feed requirements. The farming system in general is characterized by traditional Ethiopian highland practices that involves oxen ploughing, hand weeding, broadcasting and manual harvesting and threshing. Livestock grazing system is also a free roaming. Community focuses on number rather than productivity as having large herd offers culturally a social pride.

The farming system is characterized by low input and low output system. Use of chemical fertilizer is restricted mainly due to timely supply and economic constraints. Market access and agro-industries are yet to be developed.

In the South and South Western parts of the eco-region, coffee production is one of the major land use system with increasing importance in terms of contributing to household livelihoods. Coffee is produced in the form of small scale garden production system as well as production from natural stands – forest coffee. In this part of the eco-region Enset (Mussa ventricossa) or false banana cultivation is also observed. As a result, agro-silvo-pastoral farming system is also practiced in the forest dominating landscape of the BER. The natural forests are widely used as forest grazing areas to supplement annual feed requirement for the livestock enterprise supplementing the feed from crop residue and forage from the small grazing land reserves. In addition, the forest system supplies products that generate considerable household income. In fact, such livelihood activities in the eco-region can better be described as crop-livestock-forest mixed production system. Forestry provides up to 1/3 of annual household income (Tesfaye et al. 2010).

For the pastoral and agro-pastoral communities in the lower altitude areas in the southern part of the eco-region, the high forests (dry and moist) serve as a dry season grazing fallbacks. There is a traditional grazing system called 'Godantu' meaning seasonal migration with livestock, which is a system of moving with livestock particularly during dry season to areas with sufficient feed and water.

3 HOTSPOT ASSESSMENT APPROACH

3.1 LULC Dynamics

3.1.1 Satellite Images used

Landsat archive images were used to produce accurate Land Use and Land Cover (LULC) maps for four periods (1973, 1986, 2010 and 2015). About 15 radometrically and geometrically corrected Landsat images (for years 1973,186 and 2015) were downloaded from official website of USGS and Land Use/Cover data for the year 2010 was obtained from WLRC of Ethiopia. Each of the images were georeferenced to WGS1984 UTM zone 37 North. All the images were cloud free. Detail description of the satellite images is given in Table 1.

Table 1. Satellite Images captured for LLULC analysis

Spacecraft id	Sensor id	Path/Row	Pixel size	Date acquired	Image ID
Landsat_1	MSS	178/056	60m	1973-01-28	LM11780561973028AAA05
Landsat_1	MSS	179/055	60m	1973-03-06	LM11790551973065AAA04
Landsat_1	MSS	179/056	60m	1973-03-06	LM11790561973065AAA04
Landsat_1	MSS	180/055	60m	1973-01-30	LM11800551973030AAA04
Landsat_1	MSS	180/056	60m	1973-01-30	LM11800561973030AAA05
Landsat_5	TM	166/056	30m	1986-01-23	LT51660561986023XXX06
Landsat_5	TM	167/055	30m	1986-01-14	LT51670551986014XXX04
Landsat_5	TM	167/056	30m	1986-01-14	LT51670561986014XXX03
Landsat_5	TM	168/055	30m	1986-12-23	LT51680551986357XXX10
Landsat_5	TM	168/056	30m	1986-01-05	LT51680561986005XXX11
Landsat_8	OLI_TIRS	168/55	30m	2015-03-10	LC81680552015069LGN00
Landsat_8	OLI_TIRS	168/56	30m	2015-03-10	LC81680562015069LGN00
Landsat_8	OLI_TIRS	167/55	30m	2015-03-03	LO81670552015062LGN00
Landsat_8	OLI_TIRS	167/56	30m	2015-03-03	LO81670562015062LGN00
Landsat_8	OLI_TIRS	166/56	30m	2015-03-12	LC81660562015071LGN00

3.1.2 Image classification

Seven important land cover class were defined through visual assessment of the satellite images and field visit. These LULC class, as described in Table 2 includes forest, woodland, shrub/bushland, grassland, cropland, water body and settlements.

Complex bio-physical and socio-cultural settings of the BER makes the LULC mapping very challenging. To tackle these major mapping challenges, the present study adapted a mapping classification method proposed by Kassawamr et al., 2016. In areas where the topography is rugged and the farming system forms distinct zones stratifying the landscape according to similar spectral properties of land features is highly acknowledged by several researchers.

Table 2. Description of dominant LULC classes of the study area

SN	Classes	Description
1	Forest	Dense high forest with canopy cover of more than 70% and plantation forest
2	Woodland	Forest with less than 70% of canopy cover. It can have shrub/bush and tall grass.
3	Shrub/Bushland	Includes shrub, bush with grass under growth and in some cases scattered wood trees are present.
4	Cropland	Annual crop (e.g. barely and sorghum) and perennial crops such as Enset, home yard bamboo and coffee
5	Grassland	Open grass cover fields and grass with scattered shrub trees in some places.
6	Settlement	Urban areas and clustered large rural settlement.
7	Water body	This refers to manmade lakes (Lake Malka Wakene)

Hence, the present study employed a mapping approach that divides the full-scene of the satellite image into a number of sub-scenes that follows the bio-physical and socio-cultural situation of the BER. Land features occurrence vary significantly over the wider landscapes. For instance, a land feature may be dominant in a particular area and appear very rarely in the other regions. The presence of varying composition and frequency of the different LULC classes in each zone makes classifying the entire region together very challenging. Cognizant to challenges of LULC mapping in complex landscapes, therefore, in the present study we applied homogenization concept of LULC mapping (Kassawmar et al., 2016). Following Kassawmar et al., (2016) method we divided the BER into 24 homogenous units based on spectral character of the land features, topography and socio-cultural settings of BER. This approach makes easy to classify the LULC of the complex BER.

After sub setting the images into homogenous units, unsupervised classification was applied on each sub images. The reason why we did not use supervised classification is mainly because the collection of training samples to run supervised classification makes the whole mapping process very lengthy as such technique requires to collect pure pixels to train the classification, which is very difficult on such heterogeneous and large areas (Kassawmar et al., 2016). Therefore, the present LULC mapping was performed using unsupervised classification technique taking the ISODAT algorithms. The unsupervised classification was performed after sub-setting each footprints of the Landsat scenes by the identified landscape zones. The final class labelling was done by displaying each piece of unsupervised images over original false color composite Landsat images. Each adjoining classified Landsat subsets were checked for consistency, and inconsistence were corrected. This makes the classification approach accurate and faster. Finally, after each sub-sets of Landsat scenes were labelled properly with better accuracy, all the sub-sets were merged and used for change analysis.

Field visit was carried out two times: before and after satellite image classification activities were performed. The objective of the first visit was to understand the bio-physical settings of the study area and important spots were photographed and GPS readings were also collected. The second visit was to check the classification on the ground and to understand the socio-economic dynamics complemented with interviewing of local elders, Government offices and NGOs on how the socio-economic situation of BER has been changing and affect the ecosystem.

3.1.3 Change detection

After classifying the four satellite images independently, LULC change was calculated using post classification change detection method. Post classification change detection method is the most commonly used quantitative method of change detection (Chen 2002). It operates on two or more independently classified images minimizing the atmospheric and sensor differences between the two dates. The post-classification approach provides ‘‘from–to’’ change information and the kind of landscape transformations that have occurred can easily be calculated and mapped (Bauer et al., 2005). Food and Agriculture Organization of the United Nations successfully applied post classification change detection technique in a survey of forest cover and change process in 1990 (FAO, 1996). Similarly in Ethiopia, different researchers like (Solomon 1994) in Metu area, (Gete and Hurni 2001) in Dembecha area, and (Woldamlak, 2002) in Chemoga area successfully applied post-classification comparison method to quantify land use cover changes. This study utilizes post-classification method by acknowledging its importance.

In this study using post-classification comparison method, the change detection statistics was generated in two ways: Overall change detection for the entire BER and landscape level change detection. The overall change detection considers the entire BER to calculate the change statistics. In the landscape level change detection, we divided the BER in to four categories depending on landscape dominance (Table 3 and Figure 2). The zonation was done by using Land use Land Cover (LULC) data of 1973 and elevation data. Generating change statistics at landscape level enable us to properly understand local level changes. Table 3 provides the identified landscape zones and their proportional area coverage in the BER.

Table 3. Description of landscape zones of BER

No.	Landscape Type	Code	%
1	Forest Dominating Landscape	FDL	20
2	The Cropland Dominating Landscape	CDL	13
3	The Woodland Dominating Landscape	WLDL	62
4	The Afro-alpine Dominating Landscape	ADL	5

	Total		100

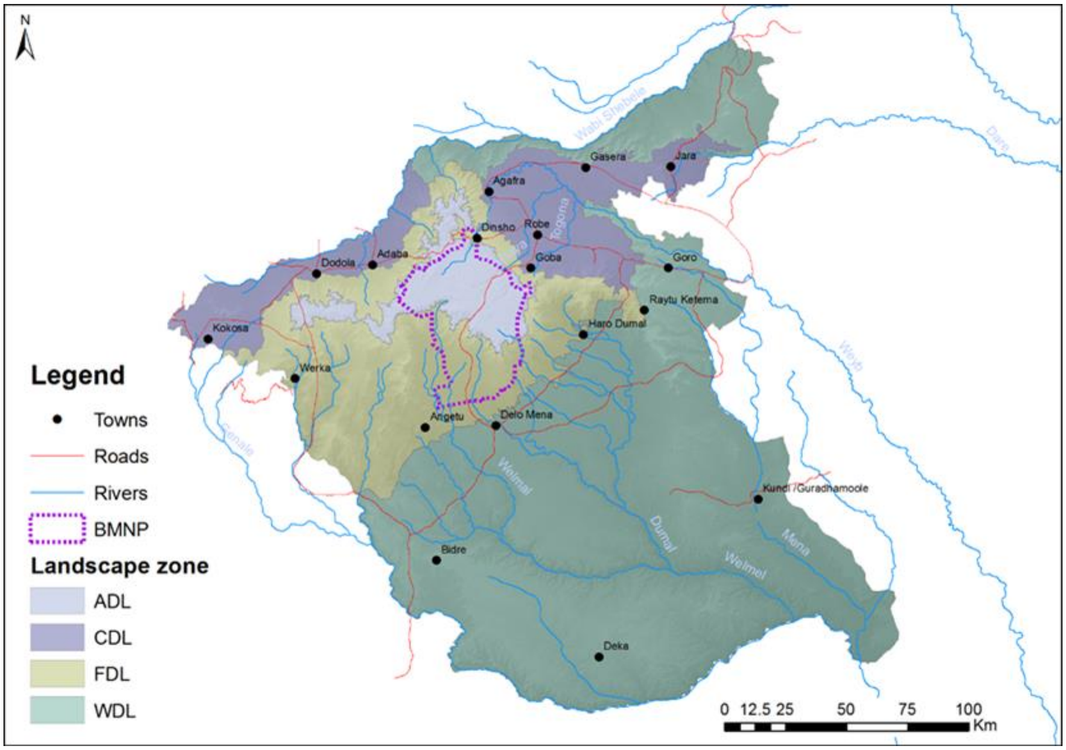

Figure 1. Landscape zones of the BER

3.1.4 *LULC change hotspot mapping*

The change hotspot areas are analyzed based on land use and land cover change results. The hotspot areas are reclassified into high, moderate and no change/slightly changed areas based on change intensity. Areas characterized dominantly by conversion (for example, conversion of forest to cropland, grassland to cropland) are classified as high change hot spot areas. Moderately changed areas are dominantly characterized by modification than conversion (example woodland to bush/shrub land). They are mainly affected by fire, overgrazing, and wood extraction but affected by minimum agricultural and settlement expansion. No change/slightly changed areas are areas where change is not detected or minor changes are observed.

3.2 Land Degradation Assessment approach

The data used for the analysis of land degradation analysis; i.e., soil erosion (sheet, rill and gully erosion), soil acidity, flood risk, vegetation and biodiversity assessment are shown **Error! Reference source not found.**.

Table 4. Data sources, methods and type of data used for the present assessment

	Components	Data sources	Methods	Source type
I	Soil erosion (Sheet and rill erosion, gully erosion) Vegetation degradation (LULC change)	Landsat TM (30 m resolution)	Unsupervised classification and post-classification change detection	Primary (produced for this purpose)
II				
Physical degradation	Sheet and rill erosion	Economics of Land degradation database	USPED model	Secondary
	Gully erosion	LULC map from Landsat, Soil data (FAO), RF	Multi-criteria analysis supported by field observation and expert knowledge	Primary (produced for this purpose) and physical observation
Chemical degradation	Soil Acidy/alkalinity	LULC map from Landsat, Soil data (FAO), RF	Multi-criteria analysis supported by field observation and expert knowledge	Primary (produced for this purpose)
II	Biodiversity	LULC map from Landsat, and other secondary data	Multi-criteria analysis supported by field observation and expert knowledge	Both primary and secondary data were used
III	Flood risk	LULC map from Landsat, DEM, RF, Runoff	Multi-criteria analysis supported by field observation and expert knowledge	Both primary and secondary data were used

Overlay analysis technique with different multi criteria evaluation methods have been implemented in the GIS environment. The weighted linear combination or rating method was used to produce hotspot maps of environmental degradation Feature layer attributes data were normalized as follows: '1' for high risk of degradation; '2' for the moderate risk of degradation; '3' for the low risk of degradation; and '4' for the no or very risk of degradation.

3.2.1 Soil degradation

In assessing physical soil degradation, sheet, rill and gully erosion process were considered for analysis.

i) Sheet and rill erosion: The Stream Power Erosion Deposition (USPED) approach described in Hurni et al., (2015) was used to produce soil erosion risk map at a pixel level. USPED model algorithm of soil erosion simulation is similar to that of the USLE (Universal Soil Loss Equation) or Revised Universal Soil Loss Equation (RUSLE) except that the former consider the sediment transporting capacity of surface runoff (Liu et al, 2007). Figure 1 shows the detail algorithm followed in the hotspot analysis.

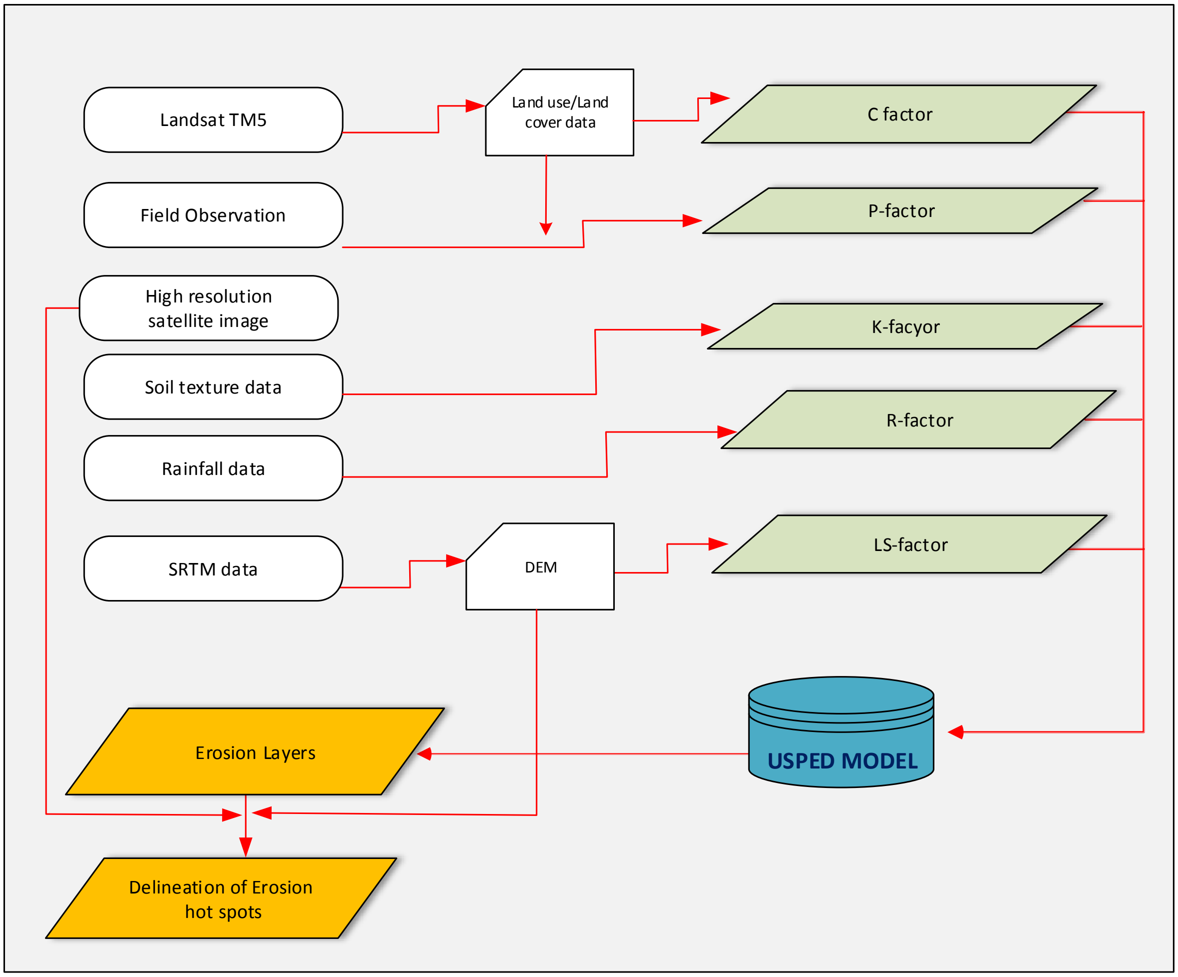

Figure 1. Schematic work workflow for soil erosion estimation using USPED

ii) Gully erosion:

In order to map gully erosion risk areas, various secondary geospatial data such as agro-ecology, farming systems, soil, geology, and topographic conditions and a multi-criteria overlay analysis technique was employed. For multi criteria evaluation, thematic maps of causative factor on terrain roughness, LULC, rainfall, slope were used (**Error! Reference source not found.**). Google Earth was employed to verify the overlay analysis. It was observed that gully formation was prevalent in woodland dominating landscape (**Error! Reference source not found.**).

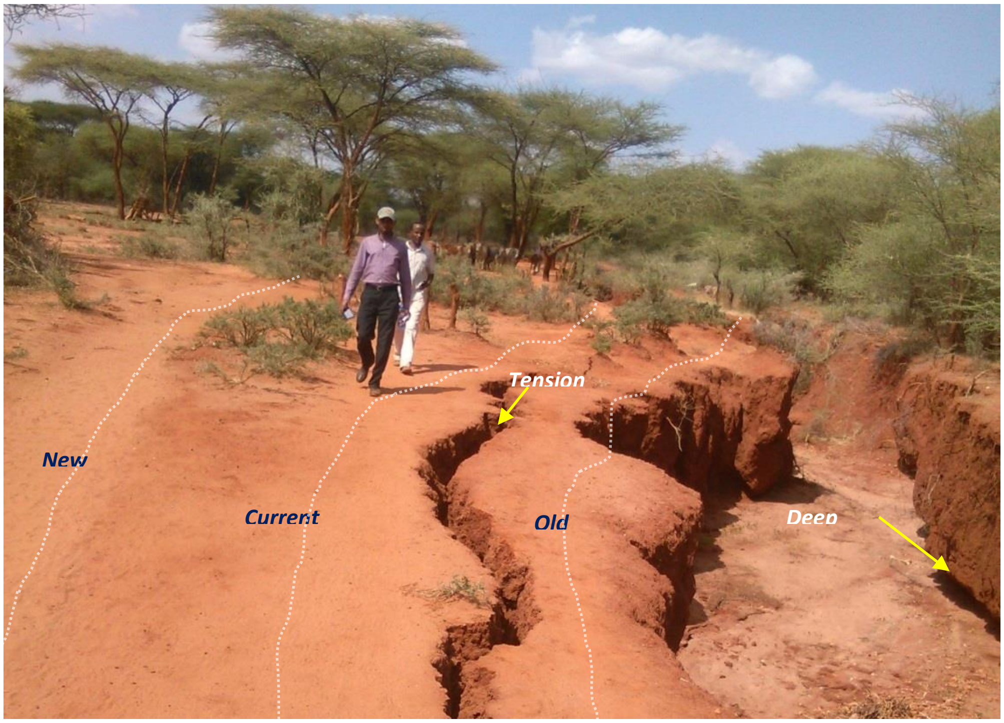

Figure 2. Permanent gully formation in the lowland area of the Delo Mena District, Bale Eco-Region March 2016).

iii) Soil acidity

Risk to soil acidity, which is dominant form of chemical land degradation in the uplands of BER, was generated using multi-criteria analysis that employs chemical property obtained from Genale Dawa Master Plan (MoWE, 2007), long years of rainfall data (Ethio GIS III from WLRC), and LULC map expert judgement and local area knowledge (**Error! Reference source not found.**).

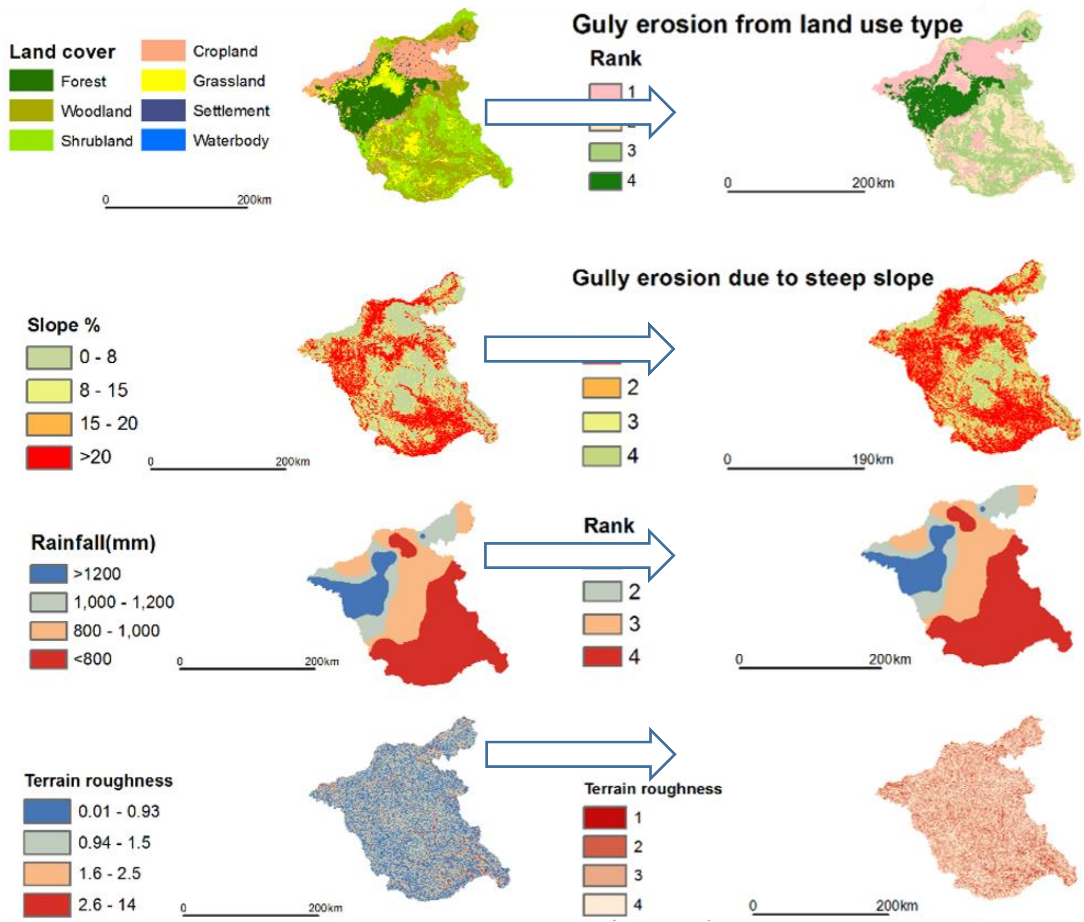

Figure 3. Geospatial data used and workflow for gully erosion risk mapping

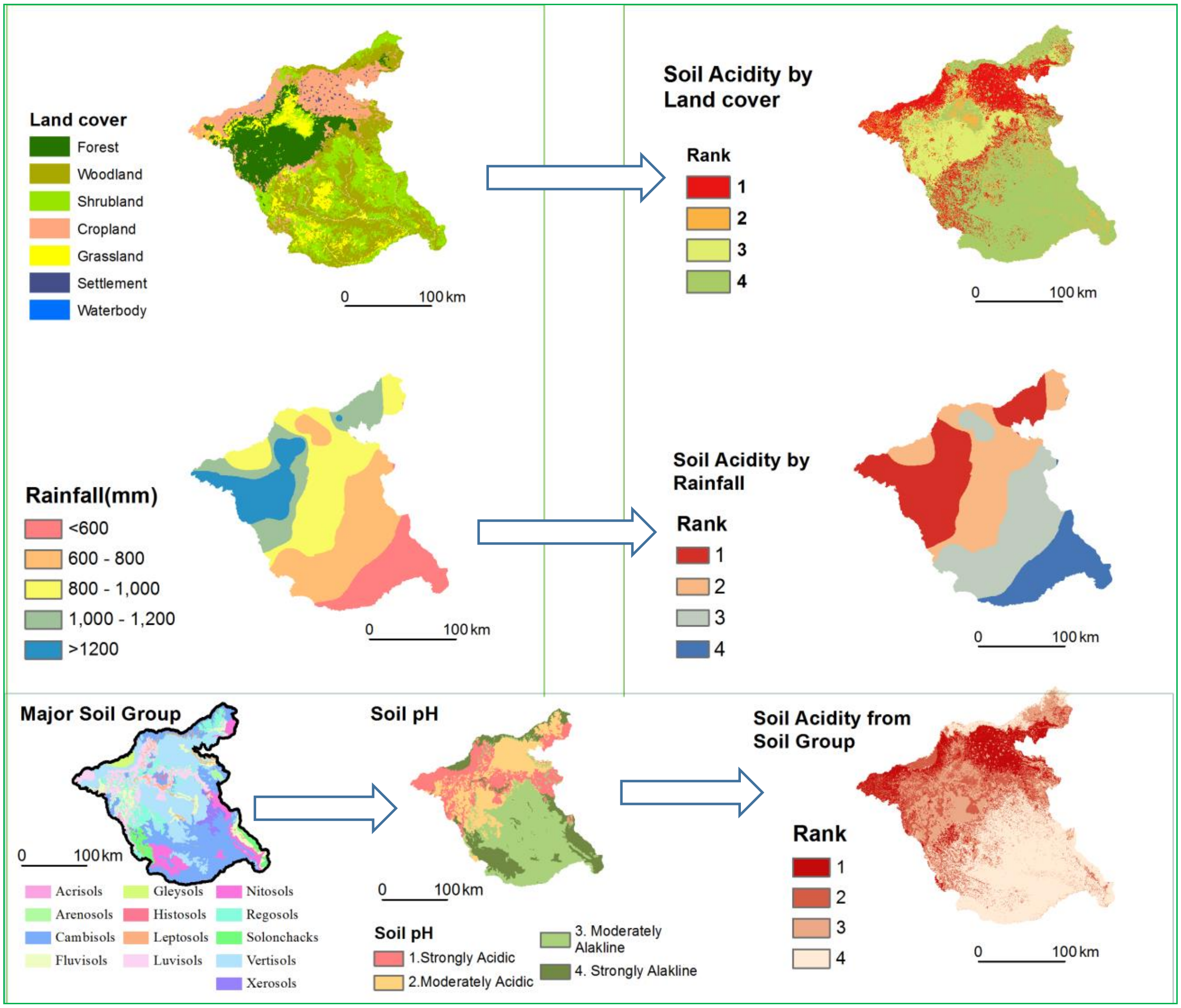

Figure 4. Geospatial data used and workflow for soil acidity hotspot identification

3.2.2 Vegetation degradation risk mapping

Vegetation degradation hotspots were identified following steps shown in **Error! Reference source not found.**. Two approaches were followed: first all classes of the two (1970 and 2016) LULC maps were regrouped into two major categories, i.e. vegetated and non-vegetated. An image differencing was made and areas where vegetation cover change happened over the considered period were identified. Second, taking the two periods of LULC maps, image differencing was performed using a combine tool. The tool produces a new raster with all possible combination of change transitions from which vegetation degradation were identified. Then, vegetation degradation indicating transitions were regrouped and ranked into four levels of vegetation degradation. Combining the

1973 and 2016 images, vegetation degradation hotspots were identified using differencing technique (**Error! Reference source not found.**)

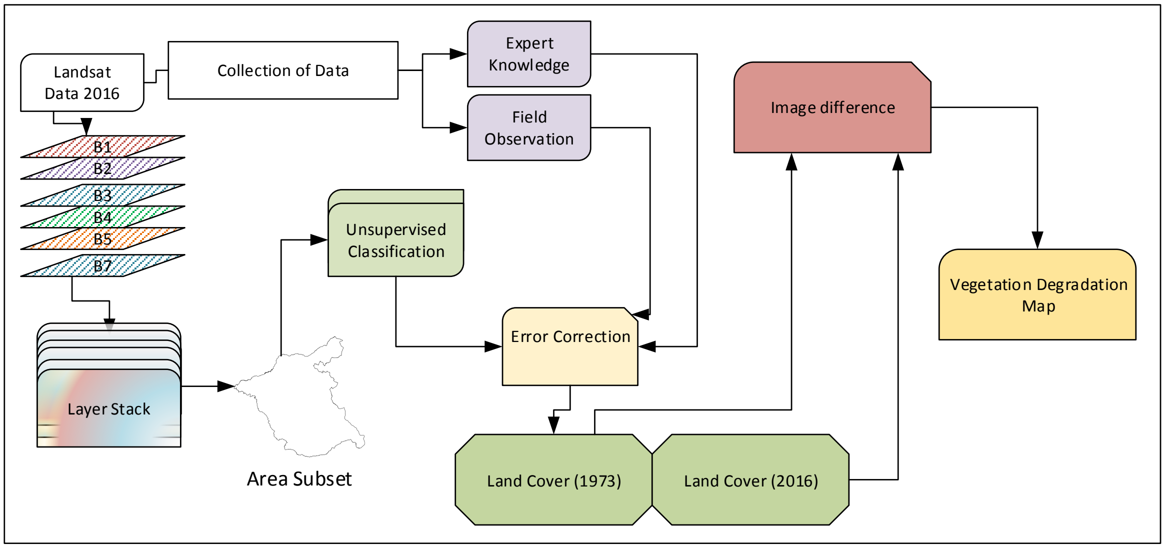

Figure 5. Image classification and hotspot detection work flow for vegetation degradation analysis

3.2.3 Biodiversity hotspots

Biodiversity risk maps were mapped following the recommendations in (Bugalho et al., 2016). The biodiversity destruction (loss) can also be directly linked with the land use/management. The workflow employed to identify Biodiversity hot spot is shown in **Error! Reference source not found.**.

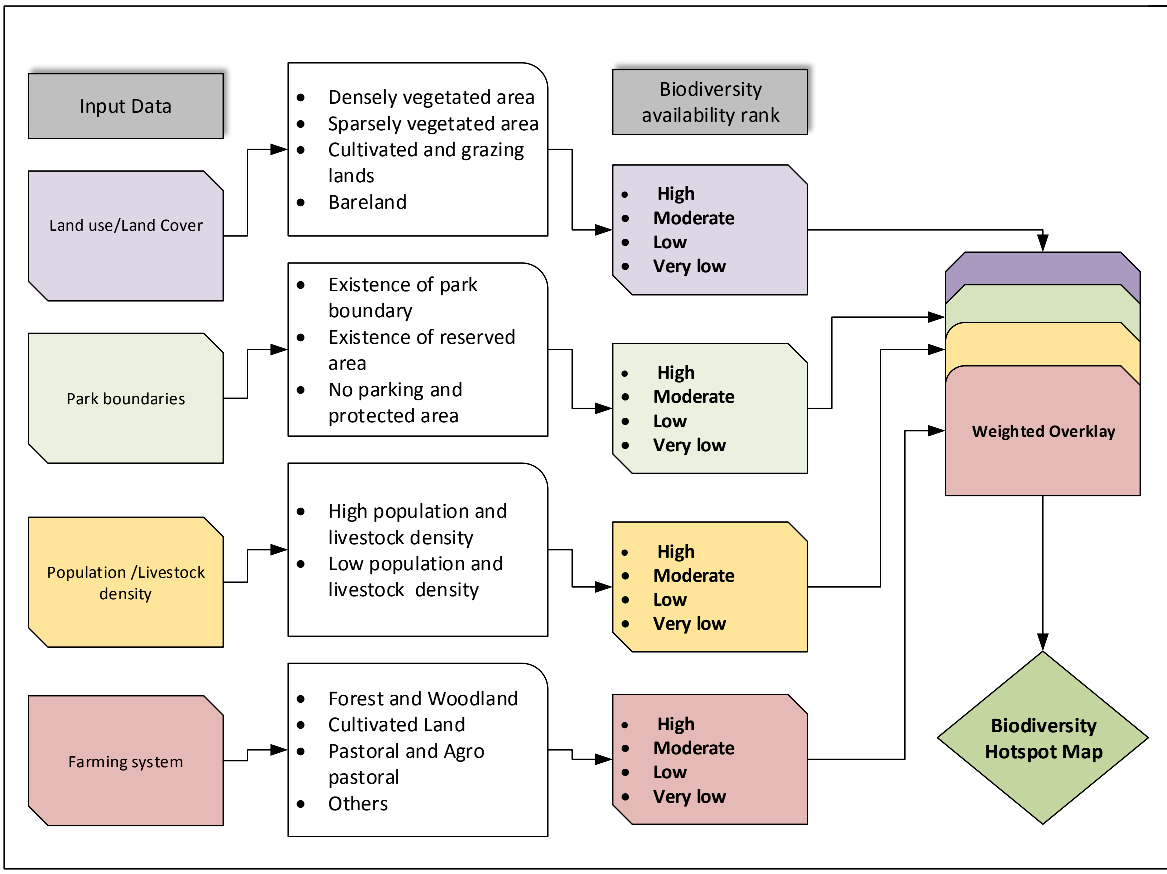

Figure 6. Geospatial data and work flow for biodiversity mapping

i) Flood risk areas

Flood hazard analysis was made using slope, elevation, drainage density, distance from streams and land use as predictors: (i) Slope layer was generated from SRTM 30 m DEM, (ii) Distance from streams layer was generated using line distance tool, (iii) Drainage density, the length of rivers per unit area was calculated from the Line Density function using a 2 km radius, (iv) LULC map generated earlier was used; (v) DEM from the STRM was used to generate altitude. The work flow is shown in **Error! Reference source not found.**

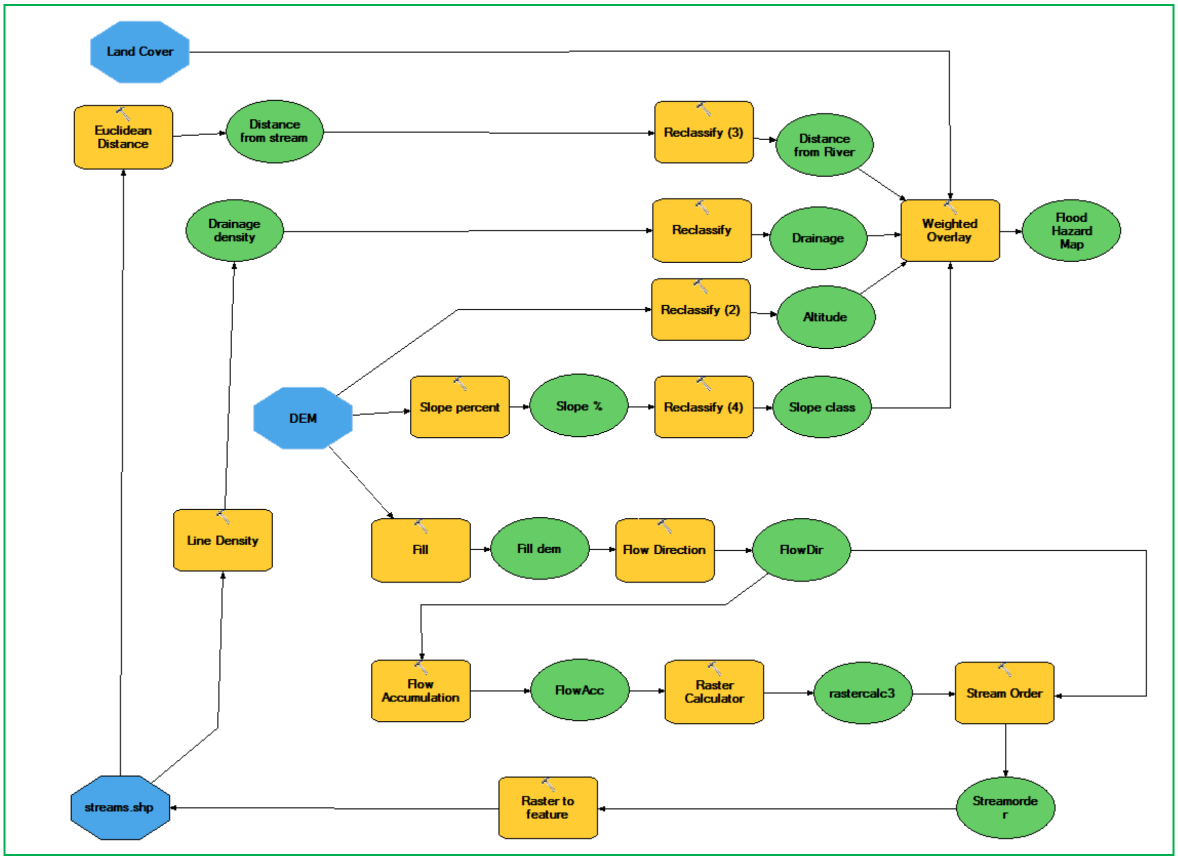

Figure 7. Model for flood risk map generation

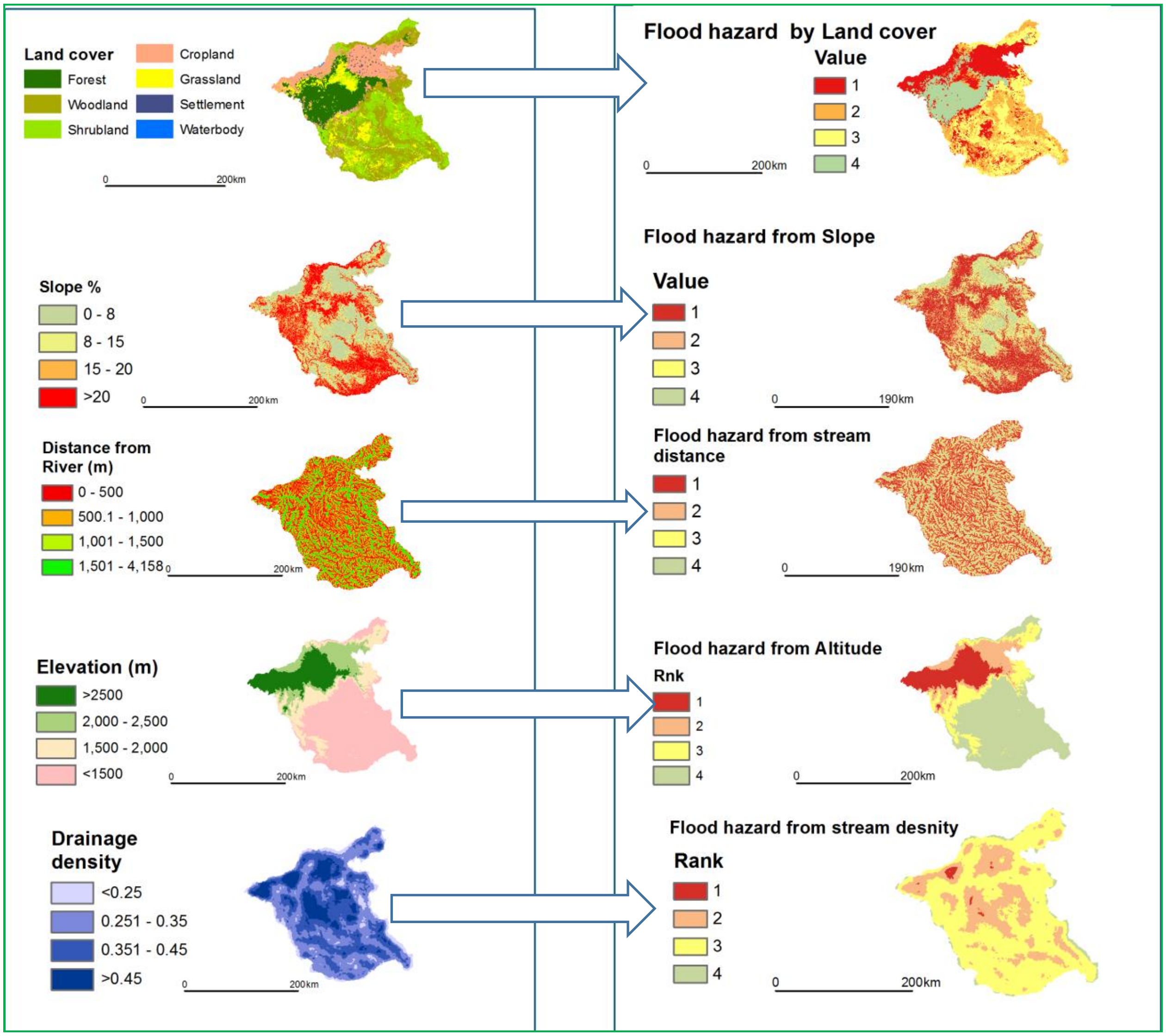

Figure 8. Spatial layer/data used to map flood risk map

Validation of the MCE output was made using secondary data on the occurrence of flood and its effect.

4 MAJOR FINDINGS AND DISCUSSION

4.1 Overall Land Use Land Cover Change

This subsection highlights the Land Use/Land Cover (LULC) of BER for four periods that have socio-political denotation and characterizes the spatio-temporal dynamics over the last four decades. The LULC statistics and maps of the four considered periods are presented in **Error! Reference source not found.** and **Error! Reference source not found.**, respectively. The result shows that currently about 70% of the BER is dominantly covered by woody vegetation that includes forest, woodland and shrub/Bushland) and the rest 30% of the BER is covered by cropland, grassland water body and settlement. Among the seven LULC classes considered for the present assessment, waterbody and settlement covers a very small portion of the BER. Large water body appeared after 1986 following the construction of Melka Wakene hydropower dam on Wabi Shebelle River. Only a small portion of this water body is included in the BER (**Error! Reference source not found.**).

Table 5. Land use land cover of statistics of the BER for four periods

	LULC class	1973		1986		2010		2015	
No		Area (km^2)	(%)	Area (km^2)	(%)	Area (km^2)	(%)	Area (km^2)	(%)
1	Forest	9766.2	24.6	9068.2	22.8	7683.2	19.3	6899.6	17.4
2	Cropland	2674.5	6.7	3666.9	9.2	6324.2	15.9	8326.1	20.9
3	Woodland	19656.3	49.4	19344.5	48.7	19747.5	49.7	18611.7	46.8
4	Grassland	4283.6	10.8	4216.2	10.6	3231.3	8.1	3195.8	8.0
5	Shrub/Bushland	3384.2	8.5	3413.2	8.6	2540.3	6.4	2493.2	6.3
6	Settlement	0.0	0.0	55.7	0.1	218.6	0.6	218.6	0.6
7	Water body	0.0	0.0	0.0	0.0	19.7	0.1	19.7	0.1
	Total	39764.7	100.0	39764.7	100.0	39764.7	100.0	39764.7	100.0

The change statistics depicted in **Error! Reference source not found.** show that the area of cropland has been increased in the last four decades. But the other LULC class such as forest, woodland, shrub/bushland and grasslands has been decreased. Similarly, even though the proportional coverage is relatively low waterbody and settlements also revealed a positive higher percentage of change. Out of the considered LULC classes a higher percentage of change was observed in croplands. This is majorly due to conversion of grassland, forest and woodland to cropland over the last four decades and the conversion of grassland to cropland is considerable than the other LULC class conversion to cropland as indicated in **Error! Reference source not found.**. Out of the total changed LULC in BER, 15.20%, 14.45% and 26.93% is grassland that has been converted to cropland between 1973-1986, 1986-2010 and 2010-2015 respectively.

Table 6. Net change by LULC types of BER

		Change (1973-1986)		Change (1986-2010)		Change (2010-2015)	
No	LULC class	Area (km²)	%	Area (km²)	%	Area (km²)	%
1	Forest	-698	-7.2	-1,385	-15.3	-784	-10.2
2	Cropland	992	37.1	2657	72.5	2,002	31.7
3	Woodland	-312	-1.6	403	2.1	-1,136	-5.8
4	Grassland	-67	-1.6	-985	-23.4	-36	-1.1
5	Shrub/Bushland	29	0.9	-873	-25.6	-47	-1.9

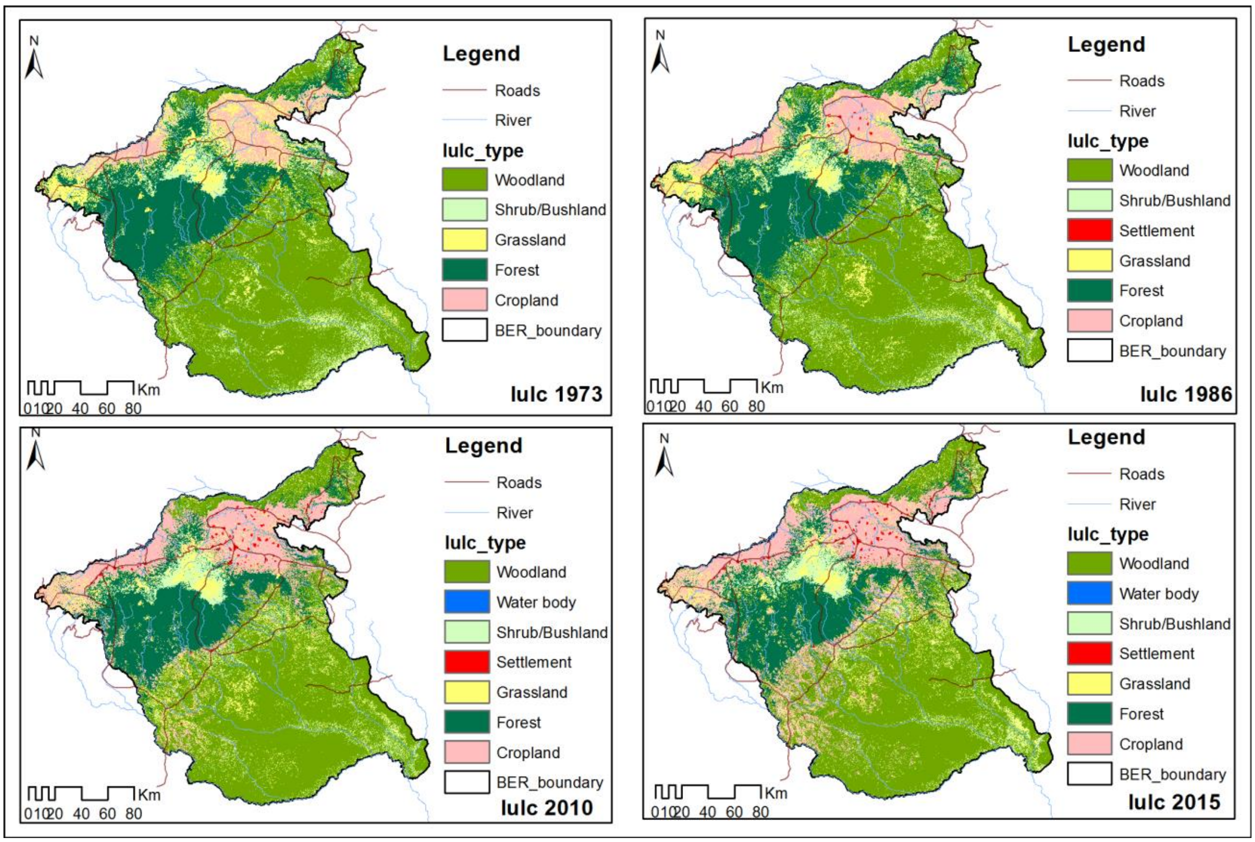

Figure 9. LULC maps of BER for the considered periods (1973, 1986, 2010 and 2015)

When we look at transitions of LULC of the BER in the last four decades, 25 transition types are observed and about 20 considerable transitions are provided using (**Error! Reference source not found.**). Between 1973 and 1986 major changes (bold) are seen in F-CL, WL-SBL, WL-GL and GL-Cl. The change in F-CL and GL-CL may be related to the intensification of mechanized state farms by the Socialist-military government (1974-1991) which pushed pastoralist to the high altitude areas

(Stephens et al 2001: 308). Transitions in WL-SBL and WL-GL could be related to recurrent of fire in the BER and in some cases such changes can be introduced due to classification errors.

Table 7. LULC transitions in BER

Transition types	Period					
	1973-1986		1986-2010		2010-2015	
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
F-WL	344.38	4.23	1036.44	9.39	273.57	5.80
F-SBL	0.00	0.00	400.46	3.63	0.00	0.00
F-GL	230.25	2.83	231.53	2.10	259.36	5.50
F-CL	121.12	1.49	544.83	4.94	303.74	6.44
WL-F	0.00	0.00	436.48	3.96	24.71	0.52
WL-SBL	1489.11	18.29	829.31	7.51	0.00	0.00
WL-CL	110.90	1.36	743.80	6.74	1222.13	25.90
WL-GL	821.23	10.09	925.68	8.39	417.38	8.85
SBL-F	0.00	0.00	134.94	1.22	0.00	0.00
SBL-WL	1309.30	16.08	1556.74	14.11	0.59	0.01
SBL-GL	615.07	7.55	458.93	4.16	0.31	0.01
SBL-CL	206.20	2.53	420.58	3.81	46.91	0.99
CL-F	0.00	0.00	89.99	0.82	19.74	0.42
CL-WL	33.11	0.41	142.51	1.29	205.55	4.36
CL-SBL	94.64	1.16	36.16	0.33	0.64	0.01
CL-GL	524.94	6.45	243.31	2.20	615.31	13.04
GL-F	0.00	0.00	168.34	1.53	8.63	0.18
GL-WL	424.79	5.22	604.43	5.48	48.74	1.03
GL-SBL	578.66	7.11	436.60	3.96	0.15	0.00
GL-CL	1237.80	15.20	1594.64	14.45	1270.41	26.93
Percent of total change	20.61% of the BER	100 of the total changed pixels from the	28.21% of the total BER	100 of the total changed pixels from the	11.91% of the BER	100 of the total changed pixels from the

In the period 1986-2010 five major transitions such as F-WL, F-CL, WL-GL, SBL-WL and GL-CL are observed. In the period 2010-2015 major transitions are seen in F-CL, WL-CL, CL-GL and GL-CL. Transitions in both periods (1986-2010 and 2010-2015) mainly related to population growth due to a higher birth rate of the inhabitants and a higher migration rate from drought prone, highly populated and agricultural land scarce areas. Migrants are mainly coming from Hararghe, Arsi zone, and Sidama zone of SNNPR. Between 1996-1997 and 2002 only the BER received 20,093 migrants from above mentioned areas out of which 85% of them settled in ten Kebeles of Mena-Angetu (currently Delo Mena and Harena Buluq Districts) Kebeles which are mainly covered by forest (Lemessa, 2002). Both the local inhabitants and migrants are expanding agriculture and settlement in forest and environmentally sensitive areas to secure their livelihood.

The above table presents transition of major LULC for the entire BER. In the following sub-sections, the type of change and magnitude of change at landscape level will be presented separately to understand local changes properly as mentioned in the methodology section.

4.2 Land Use/Cover change analysis based on dominant landscapes

4.2.1 Forest dominating landscape of BER

Forest dominating landscape (FDL) was delineated taking the spectral behavior of the forest landscape into consideration. The FDL covers about 7,823 km^2 which accounts for about 20% of the total BER. **Error! Reference source not found.** presents changes happened in FDL part of the BER in the last four decades.

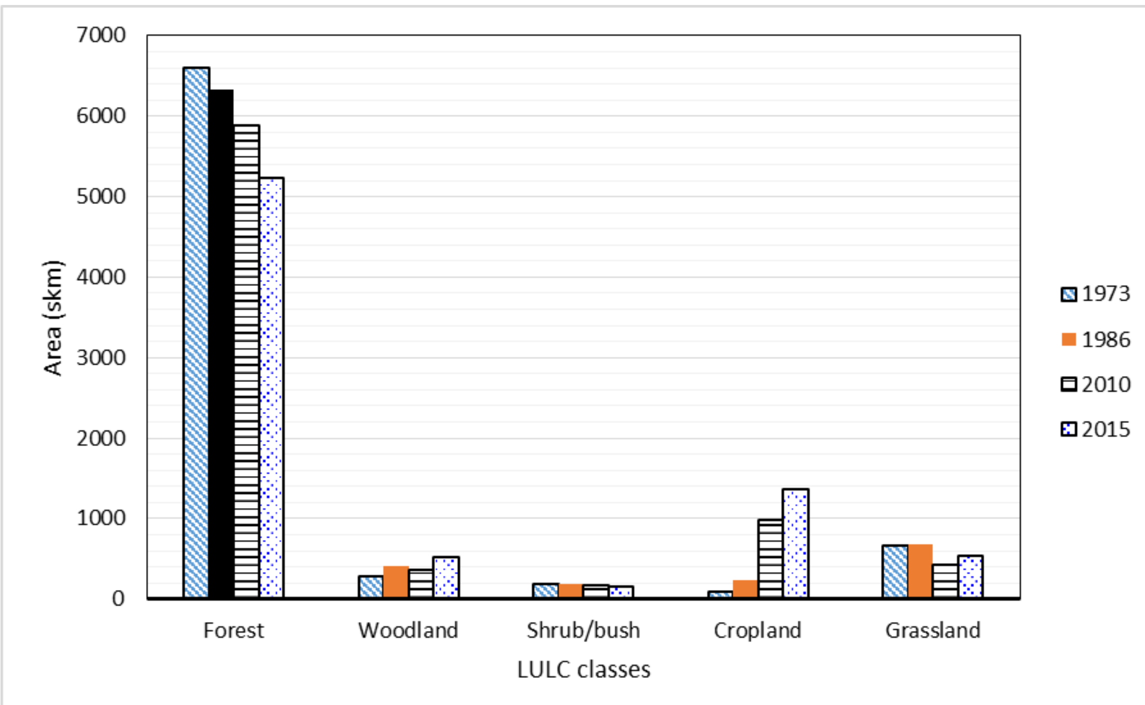

Figure 10. Gross change measured for major LULC types exist in the forest dominating landscape

As depicted in **Error! Reference source not found.**, the five LULC classes exist within the FDL revealed a different proportion of change over the considered periods. Area of change for each transition is presented in **Error! Reference source not found.**. Over the last four decades, in the FDL of BER only 11-17% of the landscape revealed change and the rest (83%) of the landscape remained unchanged.

Among those changes, major change is observed in F-WL, F-CL, F-GL, WL-CL and GL-CL. Changes such as F-CL, GL-CL and F-GL indicates complete conversion whereas changes such as F-WL, F-SB, WL-F and F-WL indicate modification that certainly led to conversion unless certain measure is taken.

Generally, a relatively high change is measured in the recent two periods (1986 – 2010) and (2010 – 2015) compared with the period between 1973 and 1986 but when we compare the two periods, high change is measured in the period (2010 – 2015) than that of (1986 – 2010). In addition, the conversion of forest to cropland (FL-CL) by 16.37% between 2010 and 2015(in 5 years) is more significant than the change that occurred between 1986-2010 (in 24 years) by 18.49% in terms of amount and rate of change. F-WL change has been found very high in the period between 2010 and 2015 (~19%) than the change that happened between 1986 and 2010(12.46%).The change WL-CL also increased from nearly 7% in the period 1986-2010 to nearly 12% in the period 2010-2015 in the FDL of BER.

When we see the locations where changes occurred within the FDL, high intensity of change is observed in the periphery of the forest than the inside part of the FDL. Changes observed in the middle of the forest looks insignificant but the way the change happens is very alarming. The changes in the FDL is related to expansion of cropland, illegal settlement and wood extraction. Livestock grazing also observed in the FDL affecting forest undergrowth. As informants mentioned expansion of coffee forest also affected the forest ecosystem.

Table 8. Major LULC transitions identified in FDL of the BER

Transition types	Period					
	1973-1986		1986-2010		2010-2015	
	Area(Km^2)	%	Area(Km^2)	%	Area(Km^2)	%
F-WL	**125.41**	**14.57**	**217.19**	**12.46**	**246.24**	**18.68**
F-SBL	0.00	0.00	96.36	5.53	0.00	0.00
F-GL	**105.57**	**12.27**	**109.49**	**6.28**	**194.75**	**14.77**
F-CL	**49.58**	**5.76**	**322.31**	**18.49**	**215.83**	**16.37**
WL-F	0.00	0.00	**129.59**	**7.43**	4.74	0.36
WL-SBL	46.71	5.43	18.38	1.05	0.00	0.00
WL-CL	**24.86**	**2.89**	**121.32**	**6.96**	**154.60**	**11.73**
WL-GL	**62.19**	**7.23**	38.25	2.19	25.50	1.93
SBL-F	0.00	0.00	34.06	1.95	0.00	0.00
SBL-WL	43.94	5.11	16.01	0.92	0.01	0.00
SBL-GL	**70.30**	**8.17**	31.59	1.81	0.00	0.00
SBL-CL	17.05	1.98	83.30	4.78	9.66	0.73
CL-F	0.00	0.00	37.84	2.17	4.60	0.35
CL-WL	7.78	0.90	13.65	0.78	80.62	6.11
CL-SBL	8.40	0.98	4.05	0.23	0.00	0.00
CL-GL	39.52	4.59	22.49	1.29	131.70	9.99
GL-F	0.00	0.00	95.70	5.49	2.35	0.18
GL-WL	**82.06**	**9.54**	22.67	1.30	19.35	1.47
GL-SBL	**79.13**	**9.20**	27.09	1.55	0.00	0.00
GL-CL	**97.94**	**11.38**	**301.72**	**17.31**	**228.50**	**17.33**
Percent of total change	11% of the total FDL	100 of the total changed pixels from the	13.39% of the total FDL	100 of the total changed pixels from the	16.8% of the total FDL	100 of the total changed pixels from the

4.2.2 *The cropland dominating landscape of BER*

The land used for annual crop production and perineal crops (Enset, coffee) is represented as Cropland Dominating Landscapes (CDL). The boundary of CDL is delineated based on the LULC data of 1973 taking the pixels that represent cropland. One of the very peculiar character of the CDL of BER is its conducive soil and slope to implement mechanized farming. Crops commonly grow in the area are wheat and barley. Currently crop is pushing to higher altitude and encroaching forest land and afro-alpine areas of BER. **Error! Reference source not found.** presents the LULC change over the considered periods within the CDL of the BER.

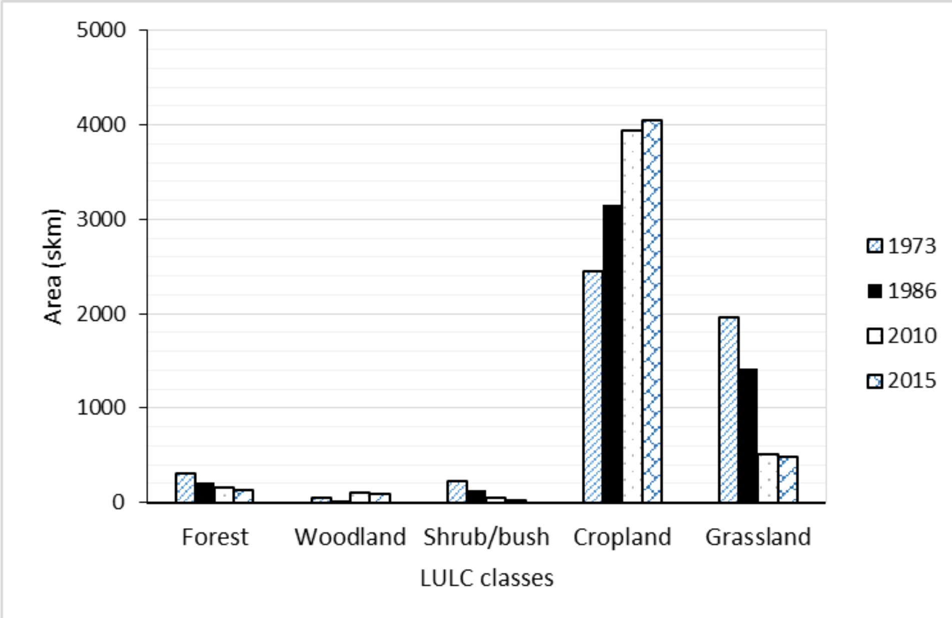

Figure 11. Gross change measured for major LULC types exist in the crop dominating landscape

The CDL covers about 4999.51km^2 and accounts about 12.57% of BER. Open cropland fields, patches of forest (plantation in some localities), settlements, and grasslands are important LULC class in the CDL. Very small proportion of the area is also covered by woodland and shrub/bushlands. Area coverage of these classes for each analysis period is depicted in **Error! Reference source not found.**. The overall change of CDL over the considered period ranges between 15% and 33%. The overall change between 1973 and 1986 was estimated to be 20%. Between 1986 and 2010, the change increased to 33%. But in the recent period between 2010 and 2015(in five years only) the CDL increased by 15% which is more considerable increase than the two previous periods. Over the considered periods, grassland is considerably converted to cropland.

Among the measured transition types in CDL as depicted in Table 8, F-GL, F-Cl, SBL-GL, SBL-CL, GL-CL and CL-GL account more than 90% of the change. The transition between grassland and cropland (GR-CL and CL-GL) has been found an important transition in the CDL for all the periods of analysis consisting 50% of the change occurred in the CDL.

Table 9. Major LULC transitions identified in CDL the BER

Transition types	period					
	1973-86		1986-2010		2010-2015	
	Area(Km2)	%	Area(Km2)	%	Area(Km2)	%
F-WL	0.54	0.03	21.27	1.27	1.90	0.26
F-SBL	0.00	0.00	5.90	0.35	0.00	0.00
F-GL	66.60	**3.33**	8.68	0.52	4.94	0.68
F-CL	27.01	**1.35**	**98.47**	**5.87**	34.86	**4.78**
WL-F	0.00	0.00	3.08	0.18	0.07	0.01
WL-SBL	2.26	0.11	1.48	0.09	0.00	0.00
WL-CL	21.25	1.06	9.86	0.59	51.28	**7.03**
WL-GL	17.98	0.90	1.15	0.07	0.48	0.07
SBL-F	0.00	0.00	10.28	0.61	0.00	0.00
SBL-WL	6.71	0.34	13.10	0.78	0.58	0.08
SBL-GL	59.04	**2.95**	6.49	0.39	0.31	0.04
SBL-CL	135.24	**6.76**	95.31	5.68	23.97	**3.28**
CL-F	0.00	0.00	34.27	2.04	13.46	**1.85**
CL-WL	0.70	0.04	46.98	2.80	31.73	**4.35**
CL-SBL	59.03	2.95	21.86	1.30	0.64	0.09
CL-GL	466.59	**23.31**	203.87	**12.16**	265.06	**36.33**
GL-F	0.00	0.00	33.21	1.98	1.54	0.21
GL-WL	7.45	0.37	16.99	1.01	1.28	0.18
GL-SBL	55.92	2.79	17.72	1.06	0.14	0.02
GL-CL	1074.93	**53.71**	1026.95	**61.24**	297.44	**40.77**
Percent of total change	19.9% of the total CDL	100 of the total changed pixels from the CDL	32.93% of the total CDL	100 of the total changed pixels from the CDL	14.59% of the total CDL	100 of the total changed pixels from the CDL

The statistics shows that there is a back and forth change between grassland and cropland but the change from cropland to grassland could be attributed to a couple of reasons; cropland abandoning, fallowing, and it could be also attributed to classification error for there is always spectral confusion between cropland and grassland in some areas. Cropland abandoning was physically observed in the western part of the BER where extensive area of the land is left as grassland which has been under cultivation in the earlier period. The conversion of cropland to grassland due to any reason mentioned above accounts 23% between 1973 and 1986, 12% in the period between 1986-2010 and increased to (36%) in the period between 2010-2015. On the other hand, between 1973-1986 conversions of grassland to cropland was 53%, between 1986 and 2010 the conversion increased to 61%and recently in five years only between 2010 and 2015 the conversion of grassland to cropland become 41%. These conversion of grassland to cropland (GL-CL) created shortage of grazing land and partly pushed livestock grazing in forest and afro-alpine areas including in BMNP. The other important conversion in CDL is forest to cropland conversion which accounts 1.3% between 1973 and 1986, and diminished to 0.33% in the period1986-2010. In many of the literatures, it appeared that the cropland landscape is pushing the boundary of the forest. Spatial distribution of measured changes reveals this fact as the intensity of change in the cropland landscape is strenuous in the interface between forest and cropland landscapes. Such change in the CLDL is may be related to population increase and high investment in mechanized state farms by government.

4.2.3 The woodland dominating landscape of BER

In the BER, the FDL and WLDL revealed distinct spectral properties which is related to rainfall, temperature, anatomy and physiology of the species, and other economic activities. Distinct spectral behavior of the lowland woody vegetation was observed below 1600 masl. Thus, the WLDL of the BER was delineated considering 1500 masl as the upper limit of the boundary.

The WLDL covers about 24838.84 km^2 and accounts about 62.46% of BER. Area coverage of these classes over the considered period is depicted in **Error! Reference source not found.** and the most important transition types are presented in **Error! Reference source not found.**. Overall, within the considered period, the WLDL change ranges between 10-27%. In the period 1973-1986 the overall change was 20%. Between 1986 and 2015, the change has become significant (27%) and in the period 2010-2015 (in five years only) the changes in the WLDL become 10%. Recently, in five years only (between 2010 and 2015), 40% of woodland converted to cropland which was very small in the previous periods. Similarly, the conversion of grassland to cropland between 2010 and 2015 (GL-CL) is more prominent (28%) than the previous periods, for example, GL-CL accounts only 1.5% in the period 1986-2010.

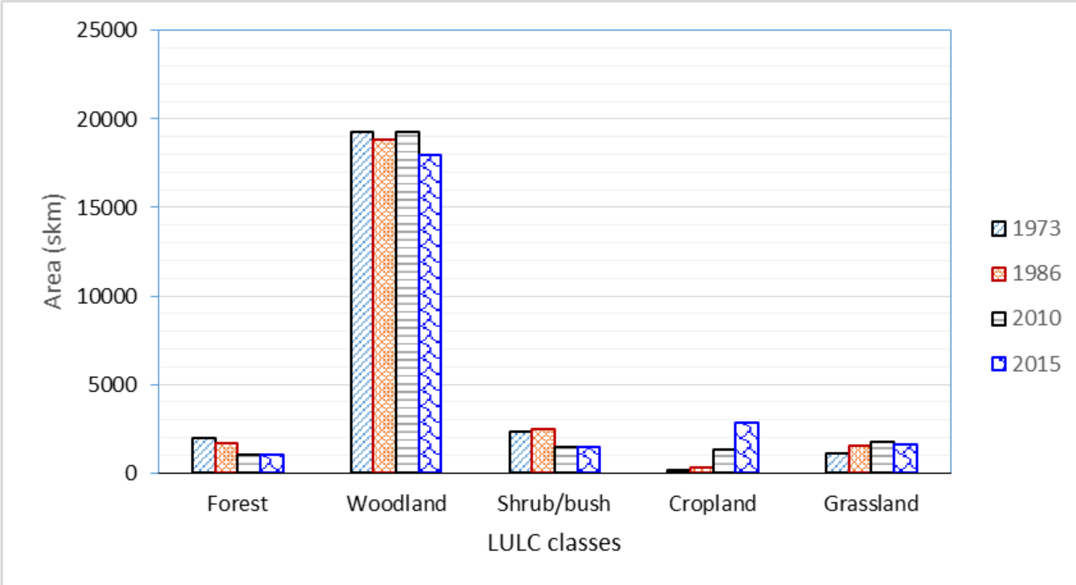

Figure 12. Coverage of major LULC types in the woodland dominated landscape

Thus, the recent change in the WLDL indicates that the expansion of cropland and settlement to the lower altitude woody vegetation landscape.

Among the identified transitions, back-and forth change between woodland and shrub/bushland accounts the largest change percent (25%). In the period1973-1986, change from woodland to shrub/bushland was 30% but in the period 1986-2010 it was dropped to 11%. On the other hand, the change of woodland to shrub/bushland was 25% in the period 1973-1986 and in the period 1986-2010 it became 22%. Such a back-and forth change between woodland and shrub/bushland could be due to classification error that may be resulted from spectral similarity between woodland and shrub/bushland in the BER.

4.2.4 The afro-alpine dominating landscape of BER

Afro-alpine Dominating Landscape (ADL) of the BER, is delineated based on SRTM 90m DEM data in reference with existence of afro-alpine vegetation species and was verified using ground truth. Accordingly, areas above 3200 masl are considered as ADL. LULC composition and their area coverage in the ADL for the considered periods is depicted in **Error! Reference source not found.**.

Table 10. Major LULC transitions identified in WLDL of the BER.

Transition types	period					
	1973-86		1986-2010		2010-2015	
	Area(Km2)	%	Area(Km2)	%	Area(Km2)	%
F-WL	201.80	4.17	**789.54**	**11.63**	7.93	0.31
F-SBL	0.00	0.00	38.09	0.56	0.00	0.00
F-GL	29.16	0.60	57.18	0.84	18.96	0.75
F-CL	40.51	0.84	112.07	1.65	39.52	1.56
WL-F	0.00	0.00	283.74	4.18	19.29	0.76
WL-SBL	**1418.09**	**29.30**	**803.43**	**11.83**	0.00	0.00
WL-CL	63.17	1.31	607.81	8.95	**1011.09**	**39.88**
WL-GL	**730.70**	**15.10**	**871.59**	**12.84**	**390.08**	**15.39**
SBL-F	0.00	0.00	33.87	0.50	0.00	0.00
SBL-WL	**1247.95**	**25.79**	**1524.15**	**22.45**	0.00	0.00
SBL-GL	**316.83**	**6.55**	**275.37**	**4.06**	0.00	0.00
SBL-CL	52.53	1.09	233.51	3.44	12.70	0.50
CL-F	0.00	0.00	14.74	0.22	1.52	0.06
CL-WL	24.57	0.51	81.77	1.20	91.63	3.61
CL-SBL	26.96	0.56	9.26	0.14	0.00	0.00
CL-GL	18.03	0.37	11.02	0.16	**202.96**	**8.01**
GL-F	0.00	0.00	22.20	0.33	3.10	0.12
GL-WL	**325.65**	**6.73**	**563.09**	**8.29**	18.01	0.71
GL-SBL	286.62	5.92	212.12	3.12	0.00	0.00
GL-CL	56.85	1.17	**245.16**	**3.61**	**718.44**	**28.34**
Percent of total change	20% of the total WLDL	100 of the total changed pixels from the WLDL	27.2% of the total WLDL	100 of the total changed pixels from the WLDL	10.2% of the total ADL	100 of the total changed pixels from the WLDL

The ADL covers ~2,099 km2 and accounts about 5% of BER. The overall change in the ALD is estimated to be 20% in the period 1973-1986. In the period 1986-2010, the change increased to 40%, and in the year between 2010 and 2015 (in five years) it has become 6.7%. Detailed change with type of transitions is presented using Table 10. Among the identified transitions, back-and forth change between grassland and shrub/bush constitute the larger percentage of change measured in the ADL of the BER in the period 1973- 1986 and 1986-2010. This change is directly related to recurrence of fire in the ADL of the BER. Burned areas with small regeneration looks grass on satellite images everywhere in the ADL of BER. Utilization of the ADL for crop cultivation through conversion of afro-alpine grassland (~2%) and Afro-alpine forest (1%) was insignificant in the period 1973-1986. In the recent period (2010-2015) the conversion of afro-alpine grass to cropland (GL-CL) increased to 20% and conversion of afro-alpine forest to cropland increased to 10%.

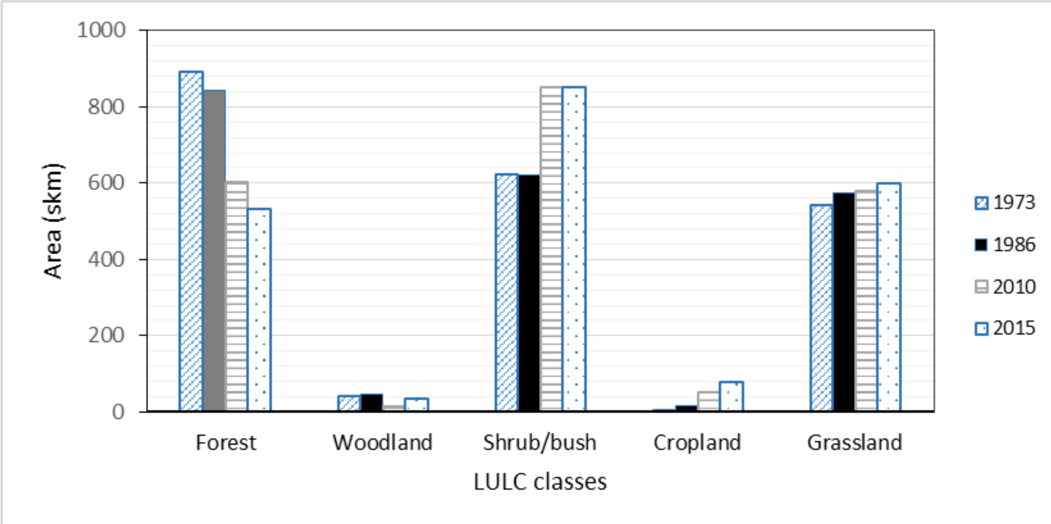

Figure 13. Coverage of major LULC types in the afro-alpine dominating landscape

The conversion of Forest (dominantly Erica forest) to grassland (F-GL) accounts about 7% in the period 1970-1986 and 30% in the period 2010-2016 and this change may be due to the recurrence of Forest fire the ADL. The spatial occurrence of measured changes in the Afro-alpine zone is dominantly occurred in the periphery than in the center of the Afro-alpine zone.

In summary, over the considered period, about 20% of the entire BER underwent a considerable transformation. From a LULC perspective, the remaining 80% of the region remained stable. Overall change measured for each landscape is presented in **Error! Reference source not found.**.

From the summary **Error! Reference source not found.**, the change estimated in the period between 1986 and 2010 are larger than changes estimated in the other periods but it is measured over 24 years which is nearly twofold of the initial period (1973-1986) and nearly fivefold of the recent period (2010-2015).Thus, when we compare the change between 1986-2010(24 years) and 2010-2015(5 years) by taking number of years in each periods, the change that happened between 2010 and 2015 is more significant than changes measured between 1986 and 2010. The change could be associated with various socio-economic and institutional dynamics happening at local, regional and national scale.

Table 11. Major LULC transitions identified in ADL of the BER

Transition types	Period					
	1973-86		1986-2010		2010-2015	
	Area(Km²)	%	Area (Km²)	%	Area(Km²)	%
F-WL	16.59	3.78	7.94	0.96	**17.47**	**13.06**
F-SBL	0.00	0.00	**260.10**	**31.56**	0.00	0.00
F-GL	**28.82**	**6.56**	**56.16**	**6.81**	**40.61**	**30.36**
F-CL	4.00	0.91	11.82	1.43	**13.36**	**9.99**
WL-F	0.00	0.00	19.85	2.41	0.59	0.44
WL-SBL	21.86	4.98	5.97	0.72	0.00	0.00
WL-CL	1.59	0.36	4.77	0.58	**5.03**	**3.76**
WL-GL	10.29	2.34	14.66	1.78	1.29	0.96
SBL-F	0.00	0.00	**56.65**	**6.87**	0.00	0.00
SBL-WL	10.60	2.41	3.25	0.39	0.00	0.00
SBL-GL	**168.80**	**38.43**	**145.46**	**17.65**	0.00	0.00
SBL-CL	1.32	0.30	8.42	1.02	0.58	0.43
CL-F	0.00	0.00	3.12	0.38	0.14	0.11
CL-WL	0.04	0.01	0.10	0.01	1.53	1.15
CL-SBL	0.25	0.06	0.98	0.12	0.00	0.00
CL-GL	0.72	0.16	5.88	0.71	**25.91**	**19.37**
GL-F	0.00	0.00	17.18	2.08	1.63	1.22
GL-WL	9.59	2.18	1.62	0.20	**10.10**	**7.55**
GL-SBL	**156.90**	**35.72**	**179.65**	**21.80**	0.00	0.00
GL-CL	**7.90**	**1.80**	**20.46**	**2.48**	**25.91**	**19.37**
Percent of total change	20.9% of the total ADL	100 of the total changed pixels from the ADL	39.26% of the total ADL	100 of the total changed pixels from the ADL	6.37% of the total ADL	100 of the total changed pixels from the ADL

Table 12. Landscape change summary (%)

Landscape type	1973-1986		1986-2010		2010-2015		Overall	
	Unchanged	Changed	Unchanged	Changed	Unchanged	Changed	Unchanged	Changed
	area					area		%
Forest	89.00	**11.00**	77.61	**22.39**	83.15	**16.85**		16.7
Cropland	80.10	**19.9**	63.07	**32.93**	85.41	**14.59**		22.4
Woodland	80.5	19.5	72.62	27.38	89.79	10.21		19.01
Afro-alpine	79.07	**20.93**	60.74	**39.26**	93.63	**6.37**		22.18
Total (BER)		**17.8**		**30.5**		**12.0**		20.11

The FDL of the BER covers the largest portion of the BER next to the WLDL. Nevertheless, in terms of area changed it is the least as only 16% of the FDL has been changed. However, in terms of the significance of the change, as the FDL is found at the interface between the two dominant farming systems where competition between users is very common, future conversion and modifications are expected to be high.

The WLDL of the BER covers the largest portion of the BER. Comparing the percent of change in each landscape zones, a smaller change is observed in the WLDL. However, in terms of area changed, as it covers large area, a larger portion of changed area has been measured in the WLDL than the others. When the type of change is considered, change transitions between woodland and shrub and bushlands account the largest percentage of the change in this particular landscape zone. This makes the WLDL of the BER the least transformed in terms of conversion. In other words, the majority of changes measured in the woodland dominating landscapes depict modification than conversion.

Generally, in terms of the amount of change measured, as the ADL covers smaller portion of the BER next to cropland, a relatively small proportion of change is measured in this part of the BER. However, compared to other zones, biodiversity sensitivity change transitions have occurred in this part of the BER and the anthropogenic activities that drove these changes are too dangerous. This implies that change drivers observed in the ADL have significant negative impact on ecosystem service and function. Thus, the process of the change is more important than measured changes. If change assessment was done from a biodiversity degradation perspective, the revers would be true.

4.2.5 LULC change hot spot areas

The change hotspot areas are mapped based on LULC change data as mentioned in the methodology part. The change hot spot areas are categorized into three zones: High, moderate, and slightly changed hotspot areas (Figure 8). The high change hotspot areas consist of 31 % and characterized majorly by conversion of LULC such as conversion of forest, woodland, shrub/bushland, grassland to cropland. The moderate change hotspot area covers about 35 % and majorly characterized by LULC modification than conversion (example woodland to forest) and minor conversions are also present. The slightly changed hotspot area covers 34% of the hotspot areas and mainly characterized by minor changes and in some cases no change.

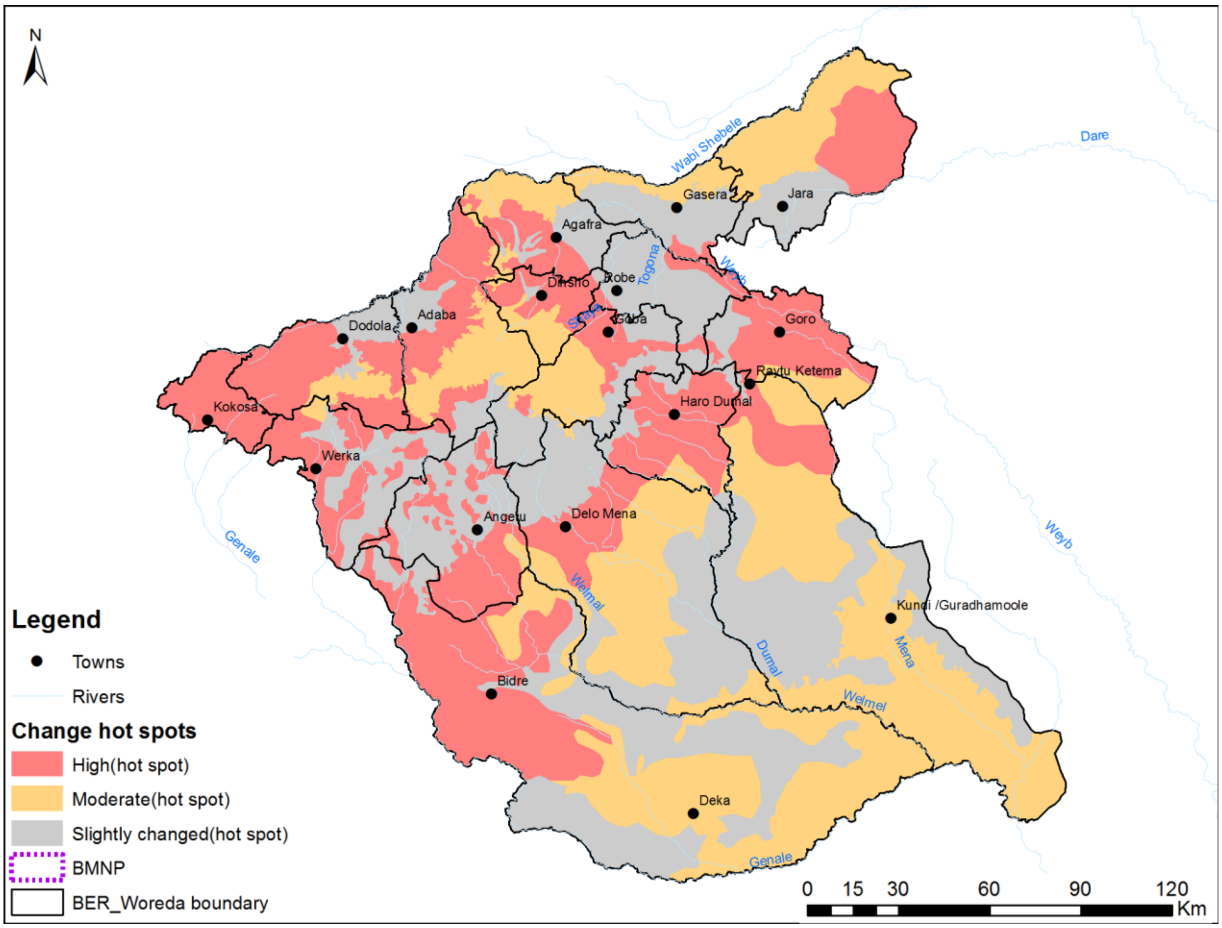

Figure 14. LULC change hot spots in the BER

4.3 Land degradation hotspots

4.3.1 Soil Erosion Hotspots

Error! Reference source not found. presents soil erosion risk map due to sheet and rill erosion in the BER. Erosion risks significantly vary with land use, slope and rainfall. Higher risk of erosion is occurring in the interface between agricultural and vegetated landscape where the forest cover is currently converted to cropland and settlement. In these landscapes, the canopy is has started to open, the slopes are steep, and rainfall intensity is high. Consequently, these areas are prone to soil erosion. On the other hand, farmland in BER are flat lands and erosion rates there is modest.

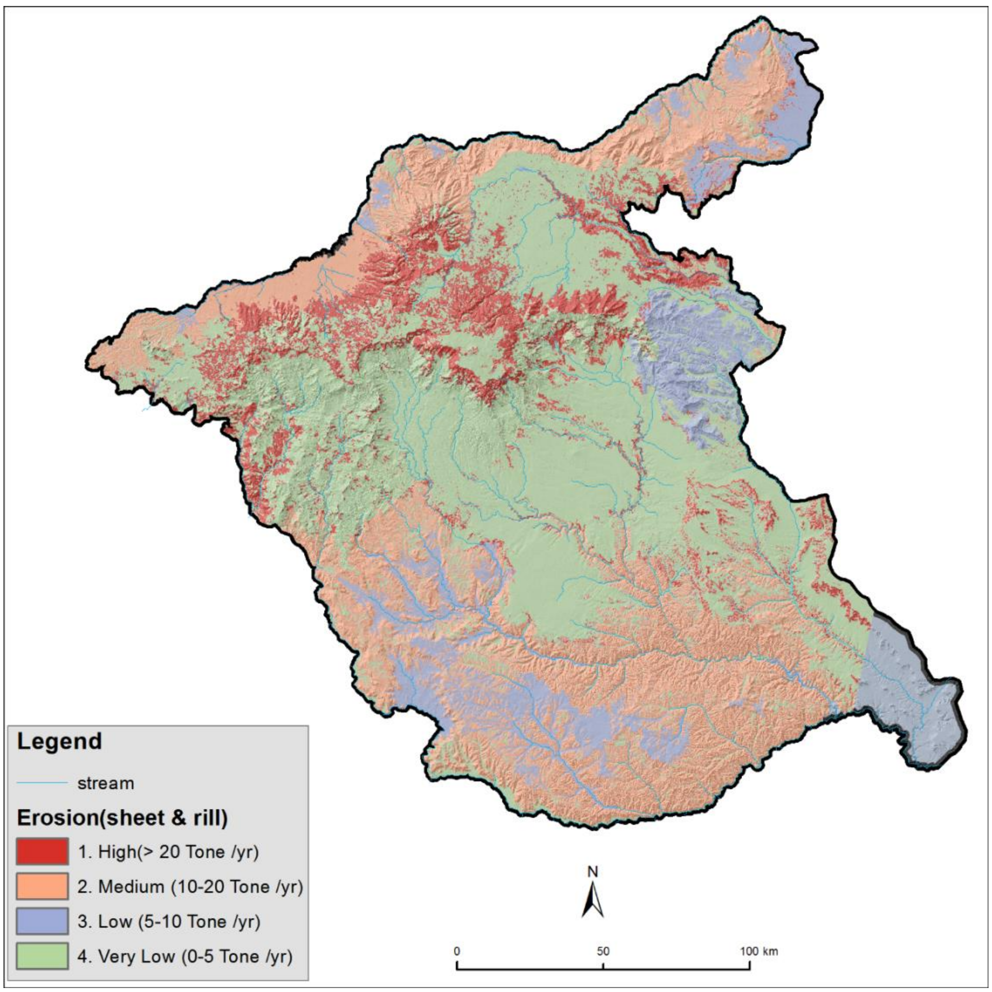

Figure 15. Sheet and rill erosion hotspot map of the BER

Table 13. Risk of sheet and rill erosion by different land use/cover types

Land Cover		Erosion Hazard in %			
	No erosion hazard	Low	Medium	High	Very High
Cropland	15.6	15.3	18.2	21.5	19.7
Forest	9.1	19.1	17.6	15.0	24.1
Grassland	9.2	9.0	10.1	11.0	12.2
Riverine Forest	0.0	0.2	1.1	1.6	0.8
Settlement	1.6	0.4	0.4	0.2	0.1
Shrub Land	33.6	22.2	21.1	21.7	18.2
Waterbody	0.2	0.0	0.1	0.0	0.0
Woodland	30.8	33.8	31.5	29.0	24.9

The majority of cultivated landscapes of the BER are located in a very flat to gentle slope areas. As a result, they are not affected by sheet and rill erosion. Nevertheless, croplands located in the interface between the extensive cultivated and vegetated landscape (mainly in the northern part of the BER) is highly affected by sheet and rill erosion. This is another area that requires immediate intervention. In sum, the very high soil erosion risk areas are ranked as 1 and are hotspots of environmental degradation. These are required a priority in terms of soil and water conservation

Gully erosion hotspots

Figure 18 depicts the probability of gully manifestation in the BER. Alike the sheet and rill erosion, a higher risk of gully erosion in the BER follows, the land cover, land use/ management, rainfall and slope. Higher risk of gully erosion is observed where vegetation cover is currently converted to cropland and settlement. Vegetation degradation is currently happening in the interface between agricultural and vegetated landscape (in the northern part of the BER) as well as in the interface between the tick high forest and the woodland (in the southern part of the BER). Relatively higher risk to gully is common in these parts of the BER. As depicted in the above section, the majority of the BER cultivated lands are not vulnerable for sheet and rill erosion. Nevertheless, they are moderately vulnerable to gully erosion especially in pelic vertisols landscapes. Further high risk of gully manifestation areas are located in the degraded woodland and forests, rangelands and croplands.

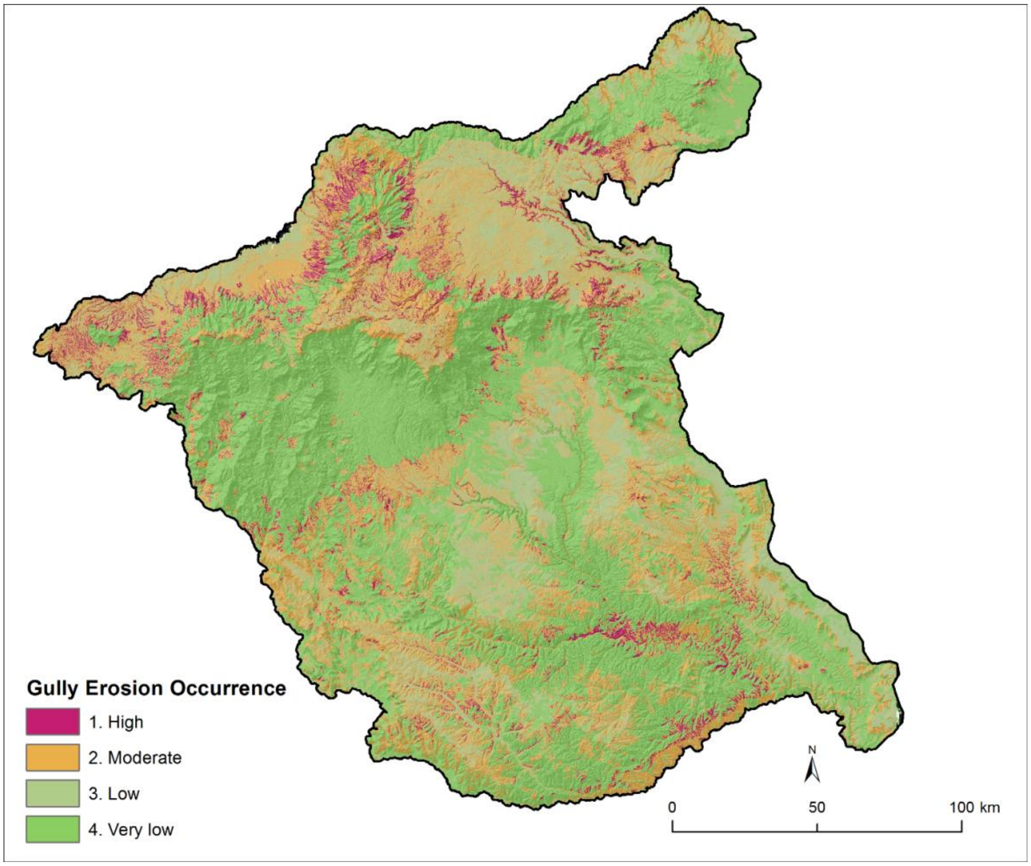

Figure 2. Gully erosion manifestation areas of the BER

3.2.3 Soil acidity hotspot

Figure 19 shows areas potently affected by soil acidity and alkalinity. Rank 1 represents severely affected areas by acidity with pH values less than 5.5 (leveled as 1 strongly acid), strongly basic (leveled as 4) for those with pH value higher than 8.4. This was also confirmed by physical observation and discussion made with local people, the soil of the north western part of the BER is highly affected by acidity. As a result, a considerable arable land has been abandoned from crop cultivation for several years (Figure 20).

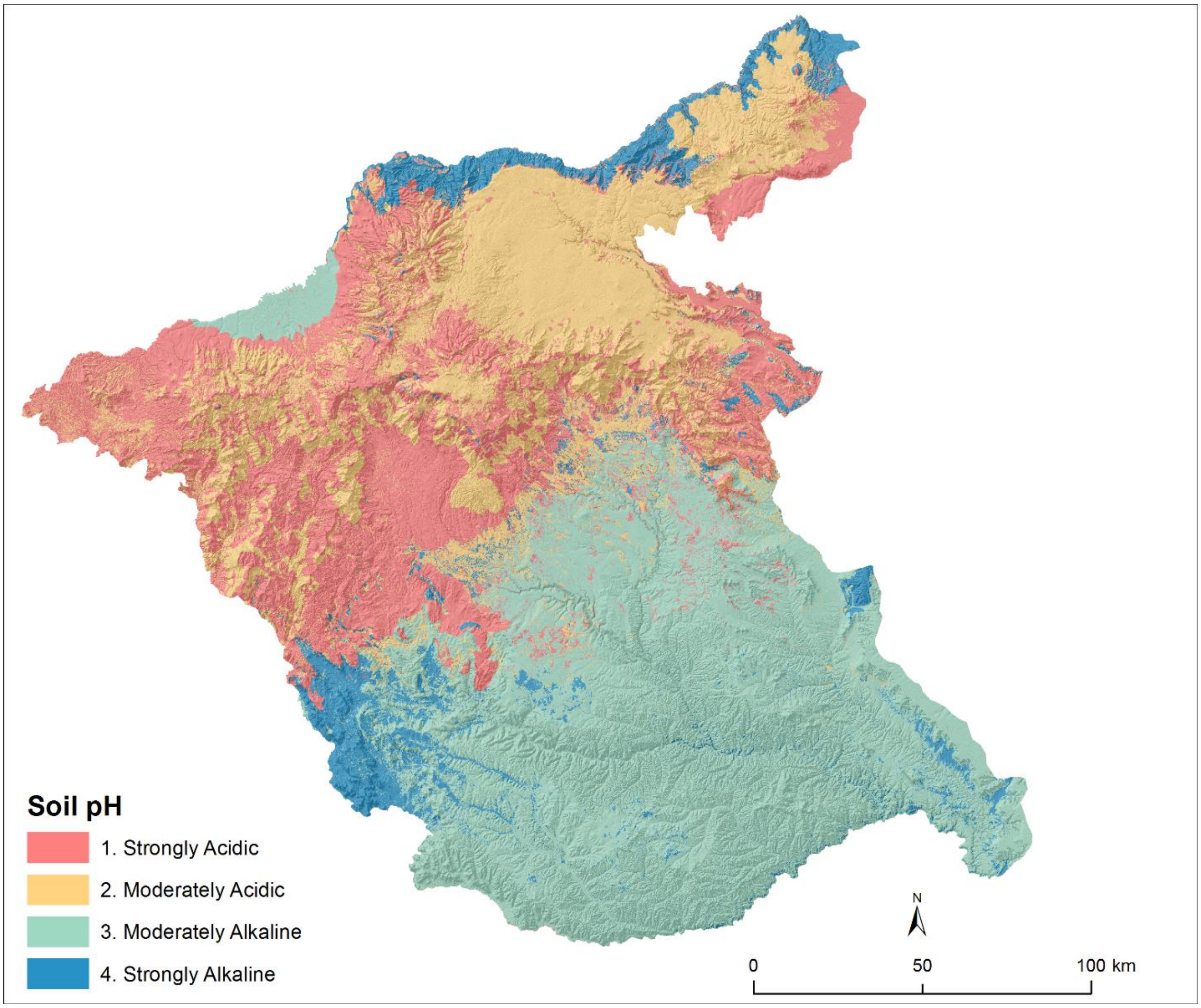

Figure 2. Soil chemical degradation hotspot map of the BER

Table 14. Statistics on soil acidity /alkalinity in Bale ecoregion

Code	pH category	Area (ha)	Percent (%)
1	Strongly Acidic	1,013,300	26.2
2	Moderately Acidic	1,010,277	25.6
3	Moderately Alkaline	1,631,572	41.0
4	Strongly Alkaline	320,846	8.1

Figure 16. Acidic soil that cannot grow crop any more (area on the way from Dodola to Kokosa)

At present, landscapes extremely affected by soil acidity are only used for forage production and grazing area. The landscape shown in Figure 20 shows no single plot is currently used to grow field crops. It was observed that farmers grow only false banana and other root crops around their homestead. Much of the acid soil in the area may need reclamation or other management options.

4.3.2 Vegetation degradation hotspot

The extent and severity of vegetation degradation in the BER considerably vary with altitude, land use/land cover and population distribution. The vegetation degradation compared to the base year 1973 is presented as shown in Figure 22. Areas labeled as 1 represent high vegetation degradation and labeled as hotspots while those labeled as 4 experiences very little or no vegetation degradation over the last four decades.

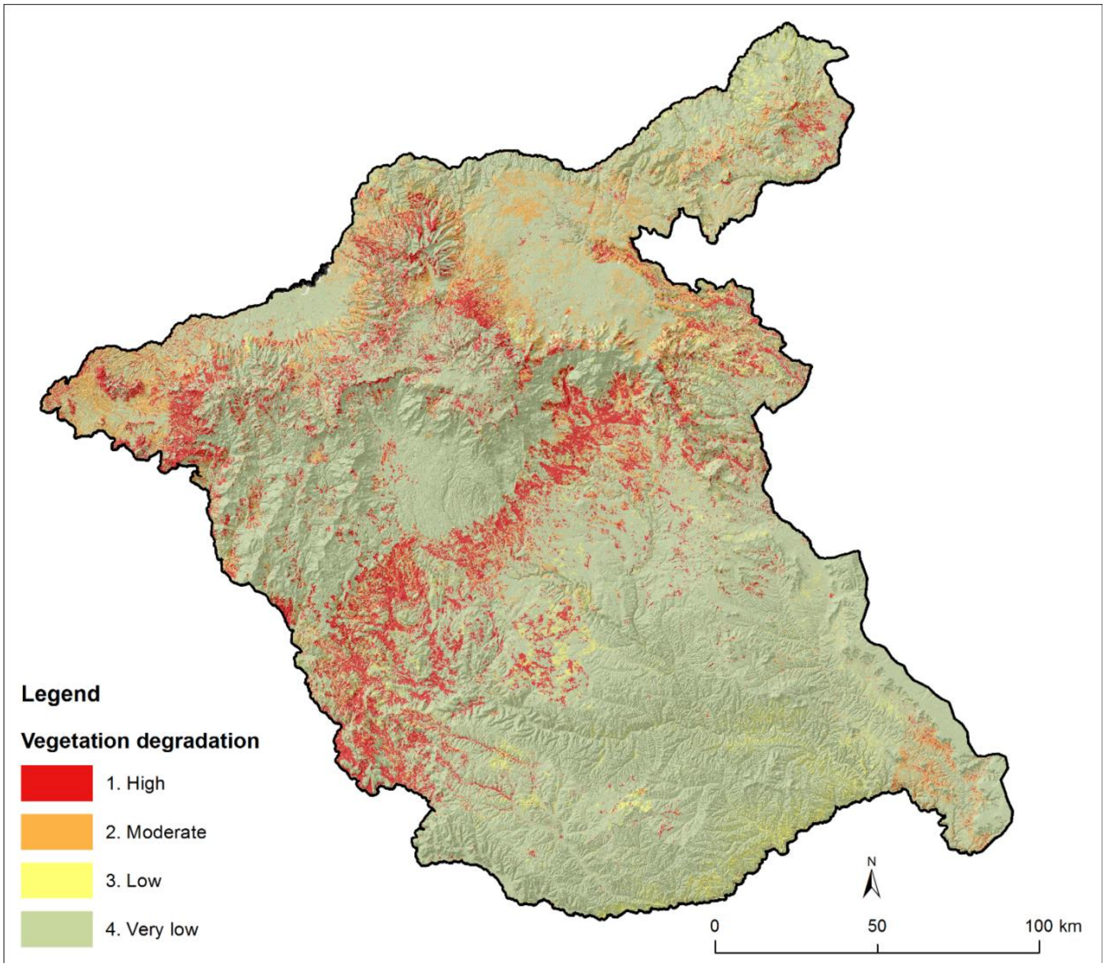

Figure 17. Vegetation degradation (hotspot) map of the BER

Table 15. Vegetation degradation across slope gradient

Vegetation Degradation	Slope gradient % and area coverage (hectare)											
	0-3		3-8		8-15		15-30		30-50		>50	
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
High	12,254	8.0	154,687	13.6	120,716	15.7	110,781	10.5	33,535	5.2	7,252	3.4
Moderate	15,383	10.1	146,636	12.9	86,854	11.3	81,611	7.7	24,686	3.8	9,911	4.7
Low	6,677	4.4	50,547	4.4	35,082	4.6	39,803	3.8	42,747	6.6	18,067	8.5
Very Low	118,625	77.6	784,824	69.0	526,126	68.4	822,605	78.0	547,182	84.4	176,563	83.4

The proportional percentage of degree of vegetation degradation hotspots is presented in **Error! Reference source not found.**. Over the last four decades, the largest vegetation degradation process has occurred on landscapes with slopes ranging between 8-15 and 15-30%. This clearly exhibits the fact that slopes are converted to cultivated land.

4.3.3 Biodiversity hotspot

Biodiversity considered in this analysis refers to vegetation biodiversity. In general, the risk to biodiversity loss in the region is very high, but there is a considerable spatial variation associated to the prevailing land use/cover type and other driving forces such as biodiversity loss, mainly human settlement and agricultural activities. The majority of the BER is covered by woody vegetation – about 17% is considered as high forest and 53% as dryland woody/shrubby land. The availability of extensive vegetated landscape with rich biodiversity makes the area vulnerable for conversion and modification and in turn affects the biodiversity of the region. Figure 23 identifies biodiversity hotspot areas of the BER mapped based on richness in flora and the prevailing human pressures to the loss of biodiversity.

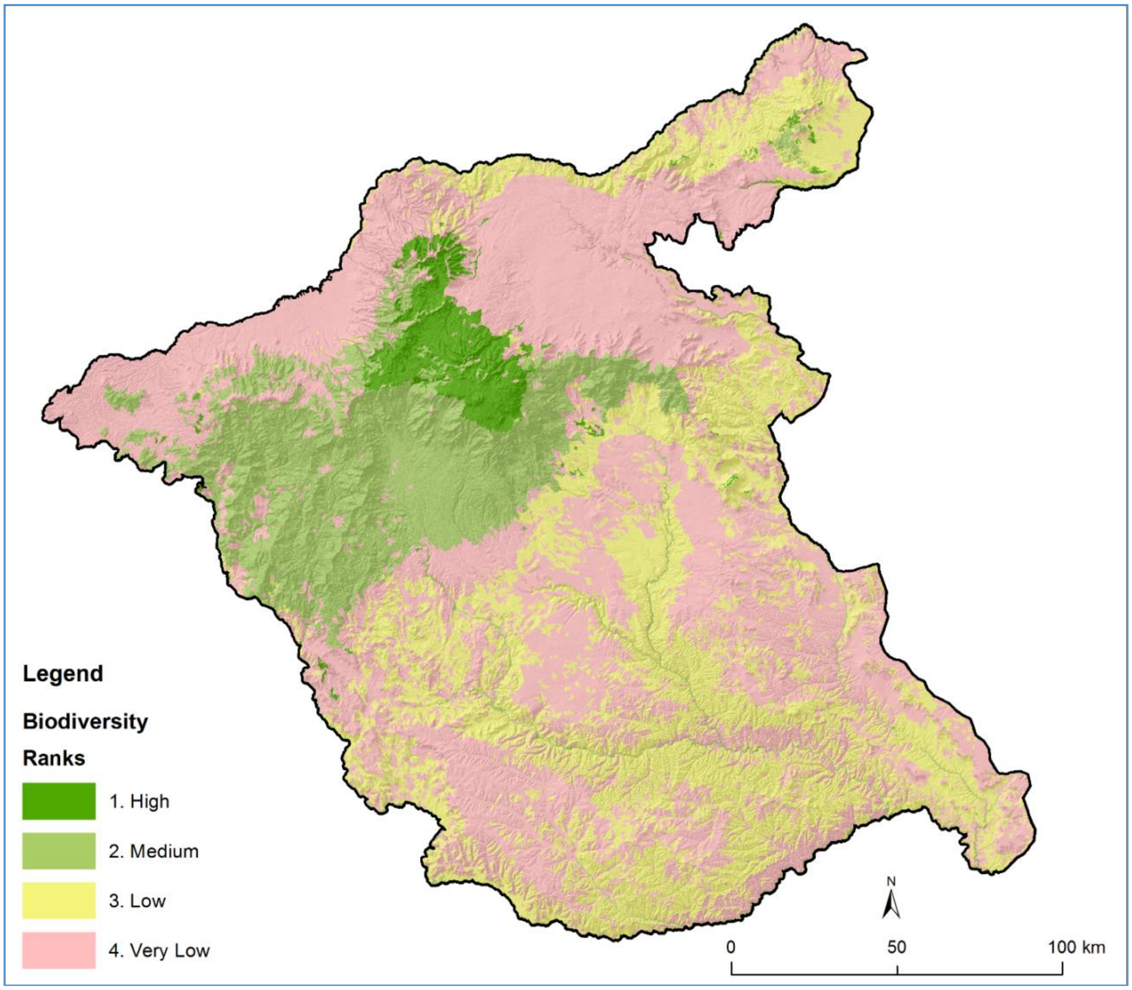

Figure 18. Biodiversity hotspot map of the BER

Table 16. Statistical summary of proportional coverage of biodiversity host spots areas by altitude

	Biodiversity distribution by altitude							
Altitude (masl)	**High**		**Medium**		**Low**		**Very Low**	
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area(ha)**	**%**
<1000	620	0.4	21,676	3.2	365,174	29.7	226,938	11.8

1000-1500	2,235	1.6	34,046	5.1	654,559	53.1	815,953	42.3
1500-2000	5,941	4.1	226,760	33.6	186,964	15.2	226,004	11.7
2000-2500	1,363	0.9	155,259	23.0	17,420	1.4	378,510	19.6
2500-3000	7,508	5.2	129,140	19.2	5,620	0.5	228,391	11.9
>3000	125,981	87.7	107,092	15.9	1,835	0.1	51,203	2.7

4.3.4 Flood hazard areas of the BER

The BER is one of the areas where damage due to excess runoff is very common. Figure 23 depicts the potential risk where excess run-off creates potential danger such as gully and rill formation, possible impacts agricultural human activities.

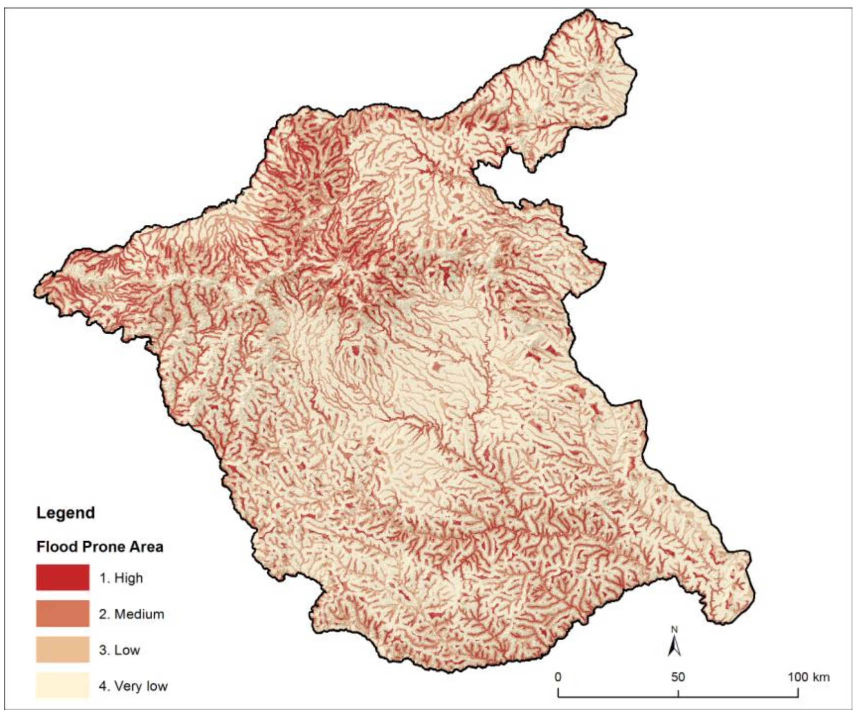

Figure 19. Map showing potential vulnerable areas for damage by excess run-off

4.3.5 Drivers and pressures of LULC and Land Degradation

A) Population pressure

The most important driving factor for Land Use and Land Cover (LULC) change to happen in Ethiopia is human population growth (Hurni 1993). Ethiopia is the second most populous country in Africa with estimated total population size of 90.1 million in July 2015 and a project growth rate of 2.39 percent between 2012 and 2017, resulting a doubling time of 29 years (CSA, 2013). Population increase is often considered as the most important factors affecting land use distribution and change (Turner and Meyer 1994). Undoubtedly LULC change in the BER is mainly driven by human population increase (BERSMP 2006) as it can be proved by the alarming population rise. The alarming population growth of the BER is persuaded due to two main reason; a higher birth rate and high migration of the inhabitants and a higher migration rate from drought prone, highly populated and agricultural land scarce areas. According to the 1994 population, the total inhabitants of the BER was 1,015,248 (CSA, 1994). The figure increased to 1,619,066, in 2007 censuses (CSA 2007). According to the official population projection, it reached to 2,019,160 in the 2015 (CSA 2015). This implies that the population of the BER doubles in two decades times and compared to the national population which took three decades for doubling, the population growth is very fast. According to CSA 1994, out of the total population of the BER, 5% (52,902) were immigrants. In 2007 the number of migrants increased to 303,186 (19 %) of the total population (CSA 2007) which is more than fivefold of the 1994 number of migrants. Most of the migrants are coming from East Hararghe Zone, West Hararghe zone, West Arsi and Sidama Zone of SNNPR. For example, starting from 1996/7 until end of October 2002 about 20,093 people settled in Mena Angetu, Berbere and Gololcha districts of the BER from above mentioned areas out of which 19159(95%) are from west and east Hararghe. Out of the 20,093 migrants 85% of them settled in ten kebeles of Mena Angetu District. Some of these kebeles such as Sodu Welmal, Hawo and Kumbi are part of BMNP (Lemessa 2002). The major driving factor of this migration was resource degradation and population pressure driven land shortage in their respective place of origin and recurrent drought (Lemessa 2002). Based on information obtained from community elders and government offices (Bale zone environment and Land administration and OFWE) still people are coming from aforementioned areas. Migrants coming from Hararghe are very large in number and considered as a serious threat to the environment of the BER.

Responding to this issue, the local government caught migrants while they are coming to the BER by using different means such as establishing check points, police and community members. Then the local government in collaboration with other government agencies (eg.OFWE) drive migrants back to their original places by facilitating transportation. But the transportation facility is upto nearby towns such as Adama, Sheshemene, Hawassa and even some times up to Goba and Robe towns. As a result, some migrants return back to BER as it is easy for them to go back to BER than traveling back to their place of origin. It is also noticed that the reasons of some migrants is not only related to land degradation and drought reoccurrence in their home district but they are looking for wide and open agricultural land while, the expansion of the local people to forest and environmentally sensitive area is due to lack of farmland caused by population increase and lack of livelihood options. Some of the migrants easily get Kebele ID of Bale zone before they reach the Kebele of their destination in the BER illegally. Once the migrants reach Kebele of their destination, the Kebele and District officials guide them where to settle in the forest. Most of the time migrants settle in the middle of the forest where nobody can identify them easily. Such hidden settlements arranged illegally by some government officials are commonly recognized after immigrants' caused lot of damage and destruction in the ecosystem. The common activities are expansion of agriculture by deforestation, cut trees for construction and energy to cook and heating.

Because of such population growth and uncontrolled migration, existing settlements are growing, and new settlements are appearing in previously unsettled and environmentally sensitive areas. For example, study conducted by IRIS consult commissioned by BERSMP on community profile and settlement dynamics of BER revealed that in Delo Mena District only villages such as Hiliye, Malka Funani, Qorke Harawa and Qorke Beelbaa emerged after 1998 (IRIS Consult 2008). Such human settlement and population increase in the study area induced huge conversion of forest land and grass land into farm land and built up areas that negatively affect the biodiversity and the hydrological systems of BER.

When we see population dynamics within the Bale Mountains National Park (BMNP) which is central part of the BER, there were only 2500 inhabitants in the BMNP in 1986 (Hillman 1986) which increased to 40,000 in 2003 (BMNP 2004). In 2007 about 3088 households were recorded in the BMNP out of which 1920 (62%) are permanent settlers, 702 (23%) are seasonal settlers and 466 (15%) are not identified as seasonal or permanent settlers (BMNP 2007). The distribution of these household/settlement locations in BMNP is shown in Figure 9. In response to the ever rising settlement and population within the BMNP, the government adjusted partly the park boundary in 2014.On Figure 9, at locations A, B and C the shrink in the Park boundary seems due to settlement expansion in this particular areas. According to the population growth of BER the people living in the national park is expected to be 80,000 in 2023. Such settlement expansion and population growth will undoubtedly make the park a permeant settlement area and induce huge destruction of the natural landscape unless some measures are taken by government. This will eventually wide up with complete transformation of the natural landscape to a human dominating landscape.

B) Expansion of cultivated land and increment of livestock

Livestock overgrazing: Livestock over grazing in forest and Afro-alpine environment is another threat to BER. (Figure 10). There are seasonal and permanent grazers in the upper catchment of the BER. The seasonal grazers are called 'Godantu' meaning seasonal migration with livestock, which is a system of moving with livestock particularly during dry season to areas having sufficient water and forage sources. The movement of livestock from the lowland to the high altitude is related to lack of grazing land and water in the lowland and also pushed by presence of livestock disease commonly manifested during dry season (Ayele 1976). Hence, during wet season, pastoralists commonly move with their livestock to the high altitude forest areas where they easily get water and forage for their livestock (Girma 2005).

"Under the Godantu system, peak livestock numbers occur in the Afro-alpine in the wetter months, from April to August, when livestock are moved from lower pastures where agricultural crops are being grown. In the Harenna forest, influxes of pastoralists from the surrounding lowland areas stayed for 3-4 months (December-March) in the dry season" (BMNP 2007: 58). The permanent grazers are people who are permanently living on the mountain.

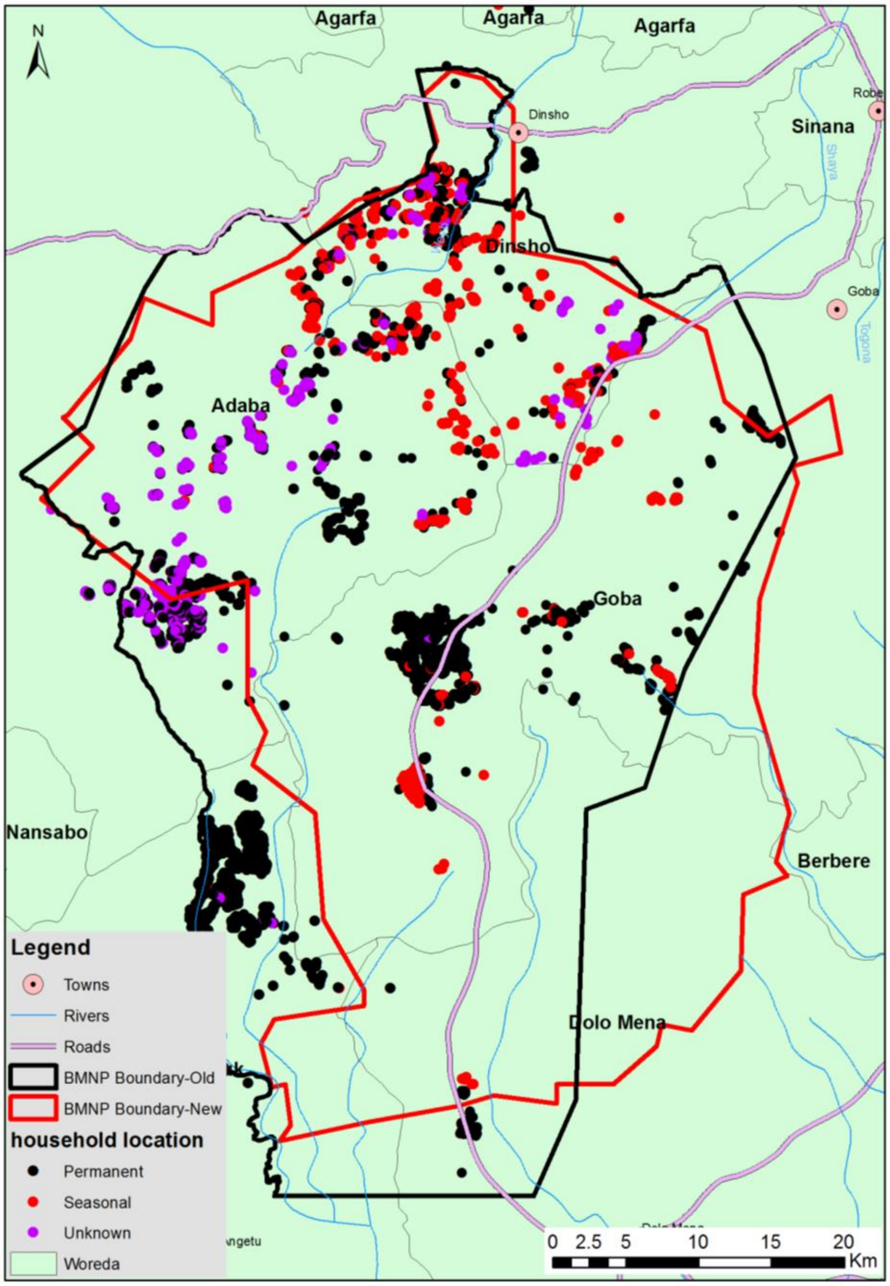

Figure 3. Settlement distribution in BMNP (the raw data was collected by FZS in 2007)

Figure 4. Illegal grazing inside the BMNP (a herd from the permanent residents)

Cropland expansion: As clearly indicated in section 3.2.2, the current study showed that significant increase in cultivated land that consumed forest land, grassland, shrub/bushland, woodland and the afro-alpine landscape in the BER. Farmlands are observed in the middle of Harena forest and in the BMNP which are environmentally sensitive. As indicated on Figure 11, cropland is expanding on forest land and the afro-alpine environment. The net gain by cropland from other LULC in the BER was 37.11% in the period 1973-1986 which increased to 72.47% in the period 1986-2010. Then in five years only, it gained 31.66% between 2010 and 2015 as presented using Table 5. This gain by cropland was majorly due to expansion of cropland at the expense of forest, woodland, shrub/bushland and grassland as indicated using Table 12.

Out of the total LULC type converted to cropland between 1973 and 1986 about about 73.85% was

Figure 5. Cropland and settlement expansion in the periphery of the BMNP

grassland. This is mainly related to expansion of state farms on pastur lands duduring (1974-191) by the military socialist government of Ethiopia pushing pasturalists to the upland of BER. In the priod 1986-2010, out of the total LULC type converted to cropland 48.27% was grassland, 16.49% was forest, 22.51% was woodland and 12.73% was shrub/bushland. In the period 2010-2015, grassland consititute about 44.64%, woodland constitute 42.98% and forest consititute 10.68% out of the total LULC type converted to cropland. This is mainly related to population increase becose of high fertility rate and migration from the sorounding drought prone and agricultural land scarse areas.

Table 17. Description of LULC types converted to Cropland

Transition types	Period					
	1973-1986		1986-2010		2010-2015	
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
F-CL	121	7	545	17	304	11
WL-CL	111	7	744	23	1,222	43
SBL-CL	206	12	421	13	47	2
GL-CL	1,238	74	1,595	48	1,270	45
Total	1,676	100	3,304	100	2,843	100

C) Fire

Fire in the Bale Mountains area is a historical phenomenon but increased in recent years. Researchers claim that people have been burning Erica forest and Hagenia/Juniper woodland since many years ago. Erica fire which is the most affected part of BER being part of BMNP is started by local people to stimulate new Erica bush regeneration for cattle feeding (Figure 12) and to increase accessibility for livestock movement and also to reduce predation risk for livestock. Among the recurrent fires in the Bale Mountains massif, the one that occurred between February and April 2000 was the worst of the last one hundred years, and damaged more than 90 thousand hectares of the moist evergreen forest in BER. The loss of biomass was estimated at 18 million tons worth of an estimated 331 million Eth Birr (19.4 million USD) that resulted a direct and indirect loss of local and national economy (Wolde-Selassie, 2004). Most recently, in 2008 forest fire occurred in about nine Districts of Bale Zone, and recorded as the second severe fire next to the 2000 forest fire. It is reported that the recent burned even the below ground biomass of Erica that burned the soil up to 15 cm depth and damage the soil biota (Anteneh et. al., 2013)

Figure 6. Traditional firing of the Afro-alpine species to get fresh growth

D) Wood harvesting

Majority of the households found in the ecoregion harvest wood for cooking, heating and construction. People also sale fire wood and timber to the nearby towns (example Goba) to generate additional income. Charcoal production and selling to the nearby towns and the passing trucks are also common in the BER. Timber production in Dodola, Adaba, Agarfa following the Junnipurus procera (locally called Tid) belt become very high. This is mainly because timber from Tid is expensive and the most wanted wood for construction.

Figure 7. Wood harvesting in the BER

Note: photo by Maria Johansson in 2016.Woman on the way to the weekly market, cutting and bringing some Juniperus light poles (probably illegal, in part of Dodola District) to sell and get additional income.

E) Institutional instability and weak policy enforcement.

The dynamic nature of institutions in the BER have played pivotal role in changing the landscape of the BER. During the socialist-military government (1974-1991), high investment in mechanized state farms pushed pastoralists to higher altitudes of BER which was main driver for change in the BMNP (Stephens et al 2001: 308). During Dergue regime the state authority over the Park was strong, people were evacuated by force from the Park and mountain landscape. But following the fall of Dergue in 1991 the local people moved back to the park and destroyed all the outposts of the park, converted areas like Tamsa'a into farmland for the local people had no good feelings towards the park (B & M Consultants 2004: 28). Since the inception of the current Government, the park management and the surrounding priority forest areas became under the care of the regional government. But very recently the park is given to federal government to be managed by Ethiopian Wildlife Conservation Authority (EWCA) whereas the forest priority areas which was under Agricultural and Rural Land Management Bureau of Oromia become under Oromia Forest and wild life Enterprise (OFWE). Furthermore, land other than the BMNP and forest out of the concession of OFWE is under environment and land administration department of the Bale zone. Such political system and institutional instability unquestionably create gap on the management of the natural resource of the BER. On top of that this institutions have no as such strong integration to protect the resource. Moreover currently the forest landscape of BER is partly managed by community through Participatory Forest Management (PFM). PFM is considered as a solution to the destruction of the natural resource of BER. But the joint management of forest by OFWE and community has its own drawbacks particularly on the monitoring aspect as there is very weak law enforcement.

4.3.6 Implication of ULC change and Land Degradation.

The impact of LULC change process is a very difficult aspect in land change assessment. Change is inevitable but what makes LULC change very sensitive issue is the intricate and interlinked undesirable changes on the ecology, social, and economic dimension of the larger ecosystem. Real impacts of LULC changes are so very complex to verify and provide concrete evidences. However, from a remote sensing based assessment, only very obvious implications of LULC changes such as biodiversity, erosion and sediment related implications can be discerned qualitatively.

A) Implication on biodiversity

The BER is rich in biodiversity (Figure 12). One of the direct impact of change in the use and cover in all zones of the BER is loss of flora and fauna species which are ecologically very significant in many aspects. In the Afro-alpine region, the intricate detrimental human-nature interaction affects the biodiversity of the afro-alpine zone. In the afro-alpine landscape, Erica bush fire, extraction of wood and over grazing are altering vegetation structure and composition. In the woodland and forest landscape, the conversion of vegetation cover become sever and harmfully affecting the biodiversity of the eco-region. LULC change transitions such as conversion of natural vegetation (forest woodland, shrub and grass) into agricultural land and settlement due to human pressure can bring a considerable negative effect on biodiversity and ecology while it may have an economic benefit in the short run for the society by increasing overall grain production. The Harena forest and the Erica bush, Afro alpine grass are home for globally unique biodiversity (e.g. Mountian Nyala and the Ethiopian wolf) and different plant species. Conversion of this unique habitat to another land use type definitely led to reduction of biodiversity which in turn affects tourism and associated economic services. On the other hand, the increase in dogs associated with settlement also affecting Ethiopian wolves through predation and transmission of rabies and other canine diseases to Ethiopian wolves.

B) Implication on hydrological system

When the natural LULC is changed, all the ecosystems function and services got disrupted. Conversion and modification of LULC of a given ecosystem disorder the hydrological cycles by increasing surface runoff and decreasing infiltration (Sahin and Hall 1996). Such phenomenon makes the environment vulnerable for flooding, shortage of water during the dry season, etc. These effects are dependent on slope, land use, soil and rainfall. When we see the BER, the boundary between the afro-alpine region and crop dominating landscape, tick forest and grasslands are serving as natural buffer to control water flow and protect the lower slope from flood damage. On the other hand, it also preserves water in the plateau part of the mountain where numerous afro-alpine lakes are found (Figure 11) which release water steadily and supply water to the lower areas of the BER. Such interlinked ecosystem functions balance are being damaged due to massive destruction of the vegetation cover and the land use change. The protective function naturally provided by the forest belt has been broken and flooding and water shortage have become a challenge for the up and downstream societies. Undoubtedly the removal of vegetation through the conversion of forest to grassland, and bush and woodland into farm land, over grazing and forest fire on the mountainous highland part of the BER is affecting the water production and regulating capacity of the Bale Mountains. The effect has been pronounced on a recurrent flooding, lower water table and short-lived river flow phenomenon and shortage of water in drought prone and arid lowlands of the BER. Consequent to the interlinked livelihood system of community who largely depend on the BER resources, the improper resource utilization ends up with conflicts.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Given the land capability and suitability view point and experiences from other highlands in the country, the BER would have been converted to grain production landscape. Yet, much of land scape is the Region is covered by woody vegetation (>71%). Compared to the current population inhibiting in the BER, still the grain production landscape is relatively small. The spatial distribution of BER

Figure 3 Afro-alpine lakes and their biodiversity

major farming systems well fit with the carrying capacity and quality and capability of the land. Nevertheless, unless concerted effort is made in promoting sustainable utilization of land resources, the LULC would change adversely and the entire BER ecosystem function will disrupt in short time. This LULC and land degradation hotspot assessment identified major threats that could potentially disrupt the ecosystem of BER and unless interventions are immediately. Important findings, conclusions and recommendations come out from the present assessment are:

- The intensity of change and land degradation observed in the larger BER varies depending on the dominant LULC type and drivers acting in each zone.

- From the statistics, it is possible to conclude that the majority of measured changes over the last four decades have modification character than conversion. But the way the conversion is going on is very serious. Settlement and farm land expansion are happing in environmentally sensitive areas such as in the middle of Afro-mountain wet and dry forest, afro alpine landscape affecting the BMNP which is established to conserve the unique biodiversity of BER.
- Migration to forest land and high altitude areas as well as to the lowland woody vegetation by local people due to shortage of land and lack of livelihood option and migrants from Hararghe and other places, pushed by recurrent drought and land degradation are major threats to the BER.

5.2 Recommendations

- There should be a political dialog between Bale zone and West and east Hararghe zone, Arsi zone of Oromia as well as Sidama zone of SNNPR to manage migration and new encroachment into BER. At the same time, livelihood options should be developed in these localities.
- Existing land policy should be implemented properly supported by effective law enforcement.
- Development actors operating in the BER should strongly collaborate with the local government in finding alterative livelihood for local people before they move to forest land and destruct it to generate their livelihood
- There should be an appropriate integration among development actors in the BER particularly EWCA, OFWE and zonal Land administration to implement policy and low enforcement.
- For seasonal migrants, it is better develop water points and animal feed for their livestock to stop them from coming to the high altitude forest (Harena and Mana Angetu forest).
- Erica fire in the BER that escape to forest sometimes is a serious problem but should be carefully seen since this is pasture management system by the local people. Other mechanism should by devised to regulate such pasture management system.
- Land degradation due to erosion is threating newly cultivated lands on high slops effort should be made such that these lands are used with appropriate sustainable land management interventions.

- Acid soils in uplands are limiting agricultural productivity. Appropriate agronomic or land management initiative should be promoted where acidity is threat.
- Bale eco-region diversity in terms of water available is extreme. Hence appropriate water conservation for rainfed agriculture should be considered in areas where rainfall variability is threating agricultural productivity.

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