ORIGINAL ARITICLE

Land Use/Land Cover Dynamics and Driving Forces in Simien Mountains National Park, Amhara Region, Ethiopia

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Abstract

The Simien Mountains National Park (SMNP) was inscribed by UNESCO as world heritage site in 1978 due to its unique landscapes and rich biodiversity resources. However, many parts of the park have been farmed for more than 2,000 years and is seriously degraded due to unsustainable land utilization. The main purpose of this study is to quantify the magnitude and rate of change of major land use/land cover (LULC) types by identifying the major drivers of change in SMNP using GIS and remote sensing techniques. Three Landsat images of the periods between 1985 and 2015 were classified and analyzed using Erdas Emagine 13 and ArcGIS 10.1. The results of LULC analysis indicated that a remarkable expansion was observed in shrubs cover by 110.8% (79 ha/y) followed by farmland and settlements by 53.7% (81 ha/y) between 1985 and 2015 although some portions of their original extent were converted into other LULC classes. The results also indicated that the reduction of areas under forests and grassland covers by about 56.4% (98 ha/y) and 49% (142 ha/y) were evident. The major institutional and policy factors identified in the study area were civil war between 1976 and 1991, changes in political structure and land reform of 1997. However, population pressure in the park was the most important human factor of land use and land cover change. Therefore, sustainable management in the park is vital to curb the biodiversity depletion and loss of tourist attractions in the area.

***Keywords**: land use/land cover change, driving forces, GIS, remote sensing, population pressure Simien Mountain National Park*

Introduction

Local changes in land use and land cover (LULC) affect life support functions and human livelihoods (Lambin et al., 2001; Lambin and Giest, 2006). Both LU and LC have diverse environmental impacts, negatively affecting water supply, reservoir storage capacity, agricultural productivity and ecology of a region (Sharma et al., 2011). In most developing countries, the demands for meeting local food production caused expansion of agricultural lands at the expense of forests and grasslands (Lambin et al., 2003). Local level studies undertaken in Ethiopia suggest a presence of significant LULC changes caused by a combination of varying factors depending on local conditions (Hassen et al., 2015; Eyayu et al., 2009; Weldeamlak and Sterk, 2005; Eleni et al., 2013; Mohammed, 2011; Weldeamlak, 2002).

Increased deforestation and poor farm management practices have led to accelerated soil erosion and land degradation in the Ethiopian highlands (Mohammed et al., 2005; Hurni et al., 2005; Hassen et al., 2015). These are common in areas where high population pressure exists and people's livelihoods directly depend on the exploitation of natural resources (Weldeamlak and Sterk, 2005). Farmland/settlements and bush-lands/degraded lands were expanding appreciably while grasslands and forest areas have been diminished largely by population pressures, economic factors and policy issues (Weldeamlak, 2002; Getachew et al., 2011; Tsehaye and Mohammed, 2013; Eleni et al., 2015; Hassen et al., 2015). Similarly, significant expansions of urban built-up were accompanied by substantial decline in forest, grass and shrub lands (Mohammed, 2011). These studies

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supported that LULC changes have implications for environmental degradation such as soil erosion, soil quality deterioration, decreasing available water and the subsequent drying-out of water reservoirs.

The SMNP was inscribed by UNESCO as world heritage site in 1978 due to its unique landscapes and rich biodiversity resources. The varied topography of the park offers a habitat to a wide range of flora and fauna with complex endemism (Mulugeta, 2015). On the basis of linguistic, historic, geographic and botanical studies, the park has been farmed for more than two millennia and it has been seriously degraded due to unsustainable land utilization (UNDP, 2012). The oldest C14 (carbon 14 isotope for radio-active dating) sample dates back to 540 years Before Present for Gich Village, in the centre of the Park, indicated the evidences of farming system (Hurni, 2005; Debonnet et al., 2006). These mounting pressures on the natural forest, shrubs and grasslands in the park by the local community have witnessed spatiotemporal changes in LULC patterns (Hurni and Ludi, 2000). Nevertheless, field observation in the park indicated that there is still limited human encroachment in some of the steepest and coldest parts of these mountains and thus maintained a highly diverse fauna and flora. In the context of sustainable tourism development, empirical evidences on the rate and patterns of change and major driving forces of LULC dynamics in northwest highlands of Ethiopia where the park is located can contribute to effective land management options for sustainable agriculture.

Besides providing financial incentives to protect the natural environment and improve livelihoods of the local communities at destination, tourism can actually be the very reason for protecting environmental and natural resources (Mulugeta, 2015). This is essential to ensure sustainable tourism that takes full account of its current and future economic, social and environmental impacts by addressing the needs of the visitors, the industry, the environment and host communities (UNWTO and UNEP, 2005). However, despite the importance of sustainable park management to the socio-economic development and environmental conservation, it is difficult to reconcile biodiversity conservation and livelihood needs from the local communities in the park. In addition, trends of LULC change driven by population pressure, institutional and policy factors for the past 30 years can assist decision makers in curbing the challenges and implement integrated park management. As a result, this study provides insights into the rate of LULC dynamics and major contributors to sustainable park management. Therefore, the main purpose of this analysis is to quantify the magnitude and rate of change of major LULC classes, and identify the major drivers of change of LULC dynamics in SMNP.

Materials and Methods

Study area description

Location and physiographic setting

The park is located in northern Ethiopia, and it is 120 km Northeast of Gondar City — bordered by the town of Adiark'ay in the North, Debark in the south, Beyeda and Jan Amora in the east. It lies between 13008'58" to 13018'53" N latitudes and 37051'24" to 38014'53" East longitude. The park constituted rural kebeles/ communities, namely, Mindigebsa and Adisge, Abergina, Ambaras/Jona & Argin, Lori in the highlands, and Adebabay, Agidamiya, Kabena and Sera Gudela, and Angwa and Kernejan belonging to three different Woreda (Adi Arkay, Janamora and Debark). According to SMNP and the EWCA (Ethiopian Wildlife Conservation Authority) report on 2013, re-demarcation of the park's boundary was carried out in 2003 when the Amhara Government and communities agreed to exclude villages along the park boundary and some areas under cultivation after the first establishment in 1966. According to North Gondar Culture and Tourism Department NGCTD, 2009, the Park was extended recently to include much more area to the South and East, including Mesarerya, as well as Silki/Abba Yared/ Kidus Yared, and the Ras Dejen escarpment ranges found in Tselemt and Beyeda Wered.

The Simien Mountain System area was built up by plateau basalt (Trapp series) of tertiary period constituting about 3,000–3,500 m thick sequence of basaltic volcanic layers composed of numerous 5 to 50 m thick olivine-basalt lava flows, inter-bedded with tuff layers (Hurni and Ludi, 2000). It extends from its lowest point at 1871 m a.s.l in the north-west to 4,437 m a.s.l at the Peak of Bwahit Mountain. As a result, high relief is an important characteristic of the park comprising 2555m altitudinal differences in 23,262.4ha area. The Ras Degen Mountain Ranges, the second highest mountain in Africa, is found in the vicinity of the park, and it provides uniquely attractive park. scenery.

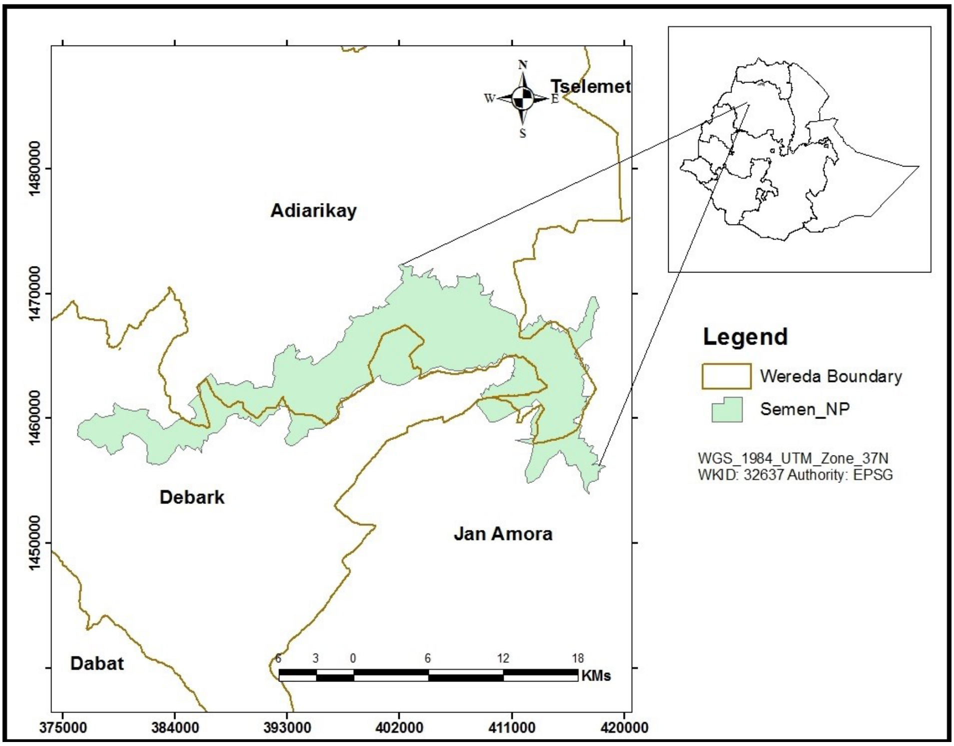

Figure 1: Location Map of Simien Mountains National Park (CSA, 2007)

Note: National Park boundary is based on ground control points (GCPs) collected by the Park administration (2005) and it does not incorporate park areas that were obtained after the demarcation of 2009.

Climate and agroecology

Based on the long-term weather variable records from National Meteorological Service Agency Bahir Dar Branch Office (NMSA) for Debark meteorological station, the mean annual rainfall is 1,550 mm in two wet seasons, from February to March, and July to September that have become much lower since the 1960s. The temperatures range from a minimum of -2.5°C to 4°C to a maximum of 11°C to 18°C. There are often drying winds during the day; frosts may occur at night, and snow sometimes drops on the summit of Ras Dejen (NMA, 2015). Based on altitudinal information obtained from 30 m×30 m SRTM (shuttle Radar Topographic Mission) image, Elevation ranges from 1871 m to 4437 m a.s.l with a relief of 2,555 meters. According to Hurni, 1998 the park falls under four agroecological conditions, namely high Wurch (>3700 m), wet Wurch (3200-3700 m), wet Dega (2300-3200 m) and wet Weynadega (1871-2300 m) above sea level.

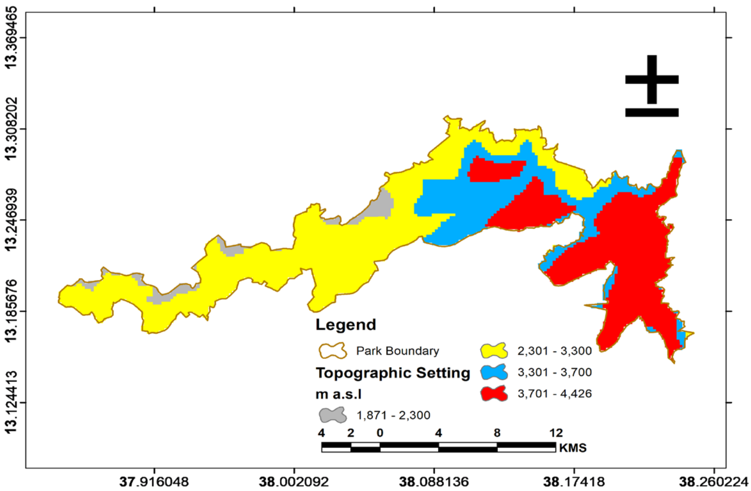

Figure 2: Physiographic setting derived from SRTM image (60m×60m) based on local agroecological classification (Hurni, 1998)

Table 1: Elevation categories and local agroecological zones adapted from Hurni, 1998.

No	**Elevation categories (m.a.s.l)**	**Area coverage (ha)**	**% coverage**	**Local agroecological zones**
1	1871-2300	897.17	3.86	Wet Weynadega
2	2300-3200	9478.39	40.78	Wet Dega
3	3200-3700	5691.82	24.49	High Dega
4	≥3700	7175.71	30.87	Wet Wurch

Vegetations and wildlife

The presence of large number of endemic species, unique bio-physical features, and its international significance made SMNP a World Heritage Site in 1978 (Mesele et al., 2008). The park is known for endemic wildlife species, such as the Walya Ibex and the Simien fox (Ethiopian wolf). The natural vegetation belts are typical to Ethiopia where most extended vegetation sequences are seen in their altitudinal range (Hurni, 1998). As a result, it forms part of the Afroalpine center of plant diversity and the eastern Afromontane biodiversity hotspot; however, most of its natural vegetation has been lost like the rest of the highlands of Ethiopia. (Minale et al., 2012). In 1996, the park was inscribed in the List of World Heritage in Danger due to the deterioration of the population of Walia Ibex, agricultural encroachment from nearby weredas, and the impacts of road construction (MNRDEP, 1996).

According to Ethiopian Wildlife Conservation Authority (EWCA), 2014 report, the park is endowed with floristically rich vegetation growing in four belts related to altitude: Afromontane forest, Hypericum woodland, Afromontane grassland and Afro-alpine moorland. These include species in the latter two biomes showing adaptations to extreme high-altitude conditions, and much speciation. However, the heavy overgrazing has eroded and degraded the grassland. Now SMNP is a mountainous area endowed with unique botanical and zoological combinations that have been able to resist human interference because of the extreme topography and altitudinal range of the landscape (Hurni and Ludi, 2000).

Methodology

Satellite images (Landsat TM 1985, ETM 2000 and OLI 2015) between December 30 and January 30 were the main sources of input data for the analysis because cloud cover is considered minimum and spectral discrimination is easier among different LULC classes. These were obtained and downloaded from Global Land Cover Facility (GLCF) and from the USGS archives. In addition, 1:50,000 topographic map as a base map for the national park delineation has been digitized. A time span of about 30 years in LULC change detection as well as analysis of the associated implications on biodiversity and socioeconomic conditions is quite adequate. This is representative of two modes of governance with their own land use and tenure policies in Ethiopia which was considered as sufficient to see the drivers of change and associated implication of LULC change. The selection of three time series images such as 1985, 2000 and 2015 was aimed at analyzing the rate of change of LULC in periods at fifteen years interval, i.e., between 1985 – 2000 and 2000 – 2015 where clear changes in LULC classes can be discerned. About 100 Ground control points (GCP), representative of the major five land use and cover classes of the study area, using historical imagery of 1984, 2000 and 2016 in Google Earth Pro Landsat images, were collected and used to improve the accuracy of supervised classification (see Table 3).

Table 3: Description of the land use and cover classes identified in SMNP, Ethiopia (Weldeamlak, 2002; Menale et al., 2011; Menale et al., 2012).

Land use and cover types	**Descriptions**
Shrubs	These include shrubs, bushes and young tree species.
Grassland	It is also called afro-alpine grassland "Guassa" representing land predominately covered with grassland mixed with Lobelia species used for wildlife grazing and habitat.

Forests	These are Afromonane forests comprising natural forests and woodlands with a composition of different tree species and one dominating species (Ericaceous species, >95% of the mix).
Farm land and Settlement	Areas used for crop cultivation, both annuals and perennials, and the scattered rural settlements that are closely associated with the cultivated fields. These were combined into one category as it was difficult to identify the dispersed rural settlements and a small town as a separated LULC type where fragmented cultivated land exists around homesteads.
Exposed volcanic rocks & Bare ground	It consists of dark Trapp basalt and bright, soft turf with a massive complex that is more than 3000 m thick. It is largely characterized as very little or no grass cover.

LULC classification is based on quantitative method that requires an independent classification of individual images of different dates for the same geographic location. It is usually followed by a comparison of the corresponding pixels to identify and quantify areas of change (Lillesand and Kiefer, 1994). However, because of low resolution of images, only major land cover types were considered. The farm and settlement areas were included in the same land cover as it was difficult to separate these two on the employed images. Thus, five LULC classes are considered in the classification process (see Table 3). Supervised classification using training areas obtained from classes ground truth data combined with spectral signatures in false color composite images by maximum likelihood classifier, the accuracy assessment was conducted for all the classified imageries (maps) using accuracy assessment tool in ERDAS imagine environment to evaluate the user's and the producer's accuracy.

Therefore, LULC classification method using ERDAS IMAGINE 9.2 software involved the following key steps in the flowchart (figure 3). This software consists of accuracy assessment tool. The land use land cover map should be in raster format to run this tool. By applying random points in accuracy assessment window, we got accuracy report which contains overall classification accuracy and Kappa Coefficient. In this land use land cover classification, overall classification accuracy for three LULC maps is more than 80% indicating a strong agreement or accuracy between the classification map and the ground reference information (see Table 4).

Table 4. Accuracy assessment for the classified images

Reference Year	**Classified image**	**Overall classification accuracy (%)**	**Overall Kappa coefficient**
1985	Landsat TM	86.7	0.75
2000	Landsat ETM+	82.4	0.69
2015	Landsat OLI	88.0	0.86

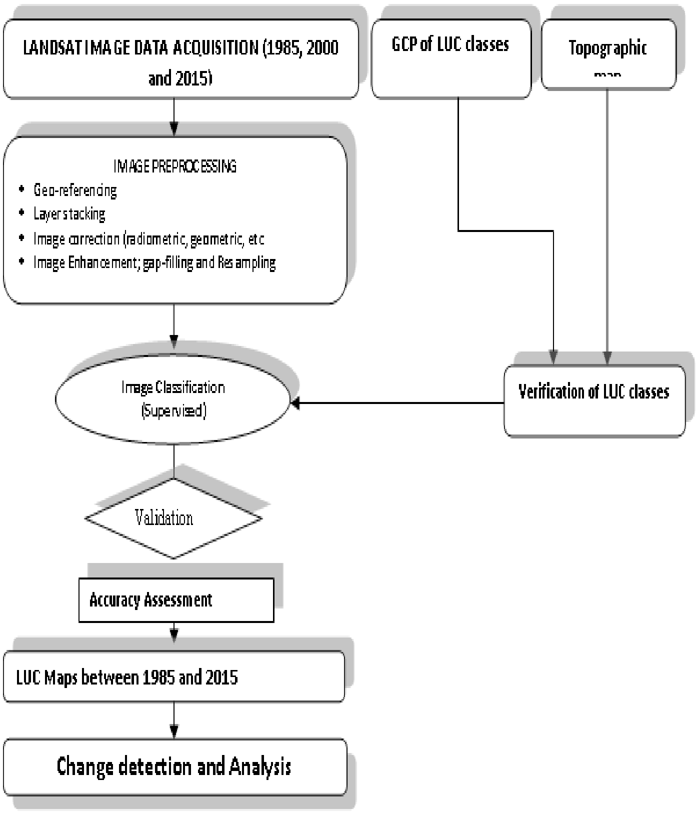

Figure 3. Schematic representations of LULC detection and analysis process (own work, 2013)

Results and Discussion

LULC dynamics in SMNP from 1985 to 2015

Analysis of the 1985 and 2000, and 2015 Landsat images confirmed the existence of five major LULC types, such as natural forest, shrub and bush land, grassland, cultivated and settlement land, and rock outcrop in SMNP. The land cover maps of the park for the 3 reference years and statistical summaries of the different land cover types indicated that LULC patterns of the study area have shown spatiotemporal variations over the entire study period (see Figure 4, 5 and 6).

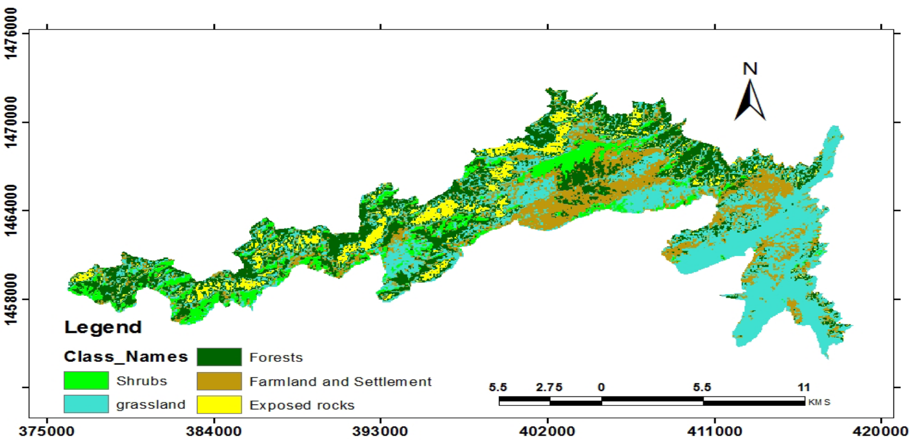

Figure 4: Land use –land cover Map of the study area (1985)

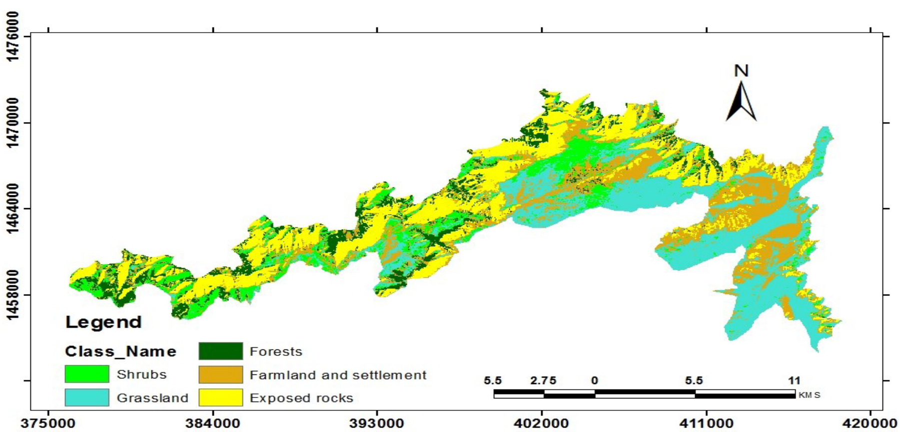

Figure 5: Land use –land cover Map of the study area (2000)

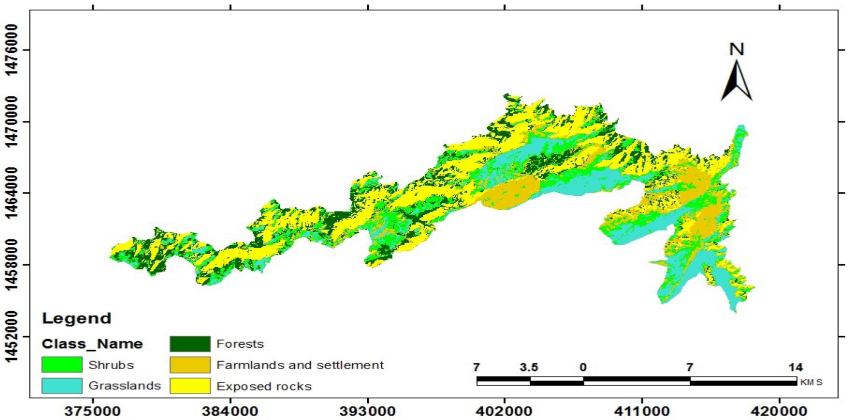

Figure 6: Land use –land cover map of the study area (2015)

Table 5: Area coverage of LULC classes in the study area between 1985 and 2015

Land use and cover types	1985		2000		2015	
	hectares	**%**	**hectares**	**%**	**hectares**	**%**
Shrubs	2150.4	9.2	2870.5	12.2	4527.6	19.3
Grassland	8330.2	35.4	6450.3	27.4	4081.7	17.4
Forests	6772.8	28.8	2281.6	9.7	3816.8	16.2
Farm land and Settlement	4508.1	19.2	5949.6	25.3	6928.6	29.5
Exposed volcanic rocks and Bare ground	1738.3	7.4	5947.6	25.3	4144.9	17.6

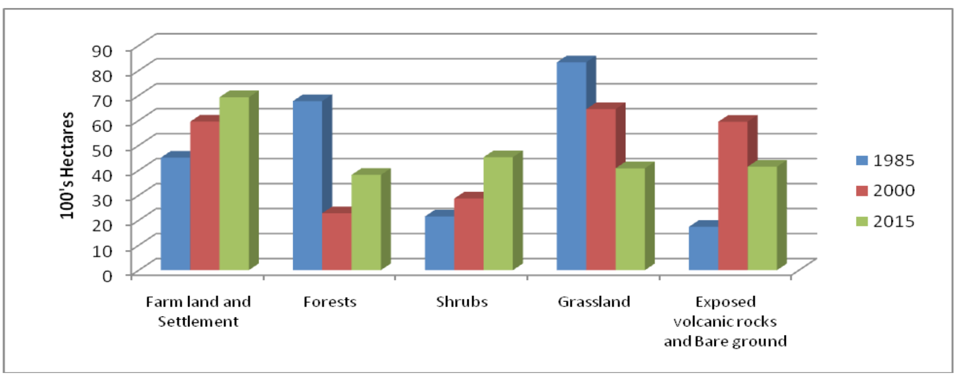

Figure 7: Graph showing LULC patterns of the study area between 1985 and 2015

Table 6: Rate of change of LULC classes in the study area between 1985 and 2015

Land use and cover types	1985-2000		2000-15	
	hectares	%	hectares	%
Farm land and Settlement	1441.5	32	979	16.4
Forests	-4491.2	66.3	1535.2	67.3
Shrubs	720.1	33.5	1657.1	57.7
Grassland	-1879.9	22.6	-2368.6	36.7
Exposed volcanic rocks & Bare ground	4209.3	242.2	-1802.7	30.3

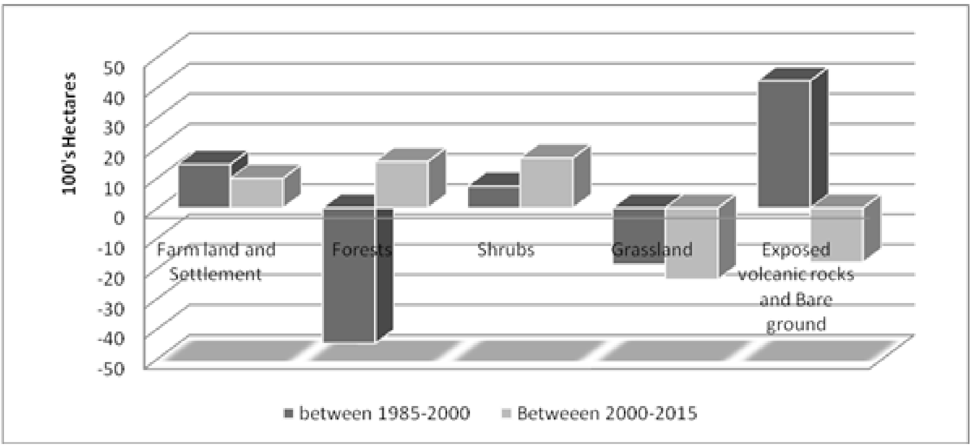

Figure 8: Graph showing the patterns of LULC change in the study area (1985 – 2015)

Shrubs

The pattern of change in shrubs generally revealed an expansion of its spatial coverage over the entire study period. It has expanded by about 34% (48 ha/y) in the first study period and by about 58% (110 ha/y) in the second study period as shown in Table 5, and Figure 7 and 8. The change detection matrix results indicated that expansion was observed in shrubs cover despite some losses from the initial coverage over the entire 30 years time. The dominant contributor of the existing expansions in shrubs was largely attributed to area gains from farmlands and settlements (1223 ha) and grasslands (1464 ha) as shown in Table 7.

Grassland

The grassland largely constituted by Guassa (see Table 3), comprised around 8330 ha (35%), 6450 ha (27) and 4082 ha (17%) of the total area of the study area in 1985, 2000 and 2015, respectively (Table 5). An important LULC class was reduced by 23% (125 ha/y) in the first period of analysis and by 37% (158 ha/yr) in the second period of analysis largely due to overgrazing by cattle (Table 5, and Figure 7 and 8). Also, the decrease in the area extent of grassland was largely caused by population pressure, which caused much of the open grazing land to be transformed into cropland and badlands.

The dominant contributor of the existing decline in grassland was associated with the conversions of its initial extent into exposed volcanic rocks and bare ground (2088 ha) followed by farmland and settlement (1715 ha) and shrubs (1464 ha) between 1985 and 2015 (Table 7). This is possibly attributed to the existence of settlements in the park which required additional lands for farming and livestock breeding. This caused the disappearance of some portions of grasslands as a response to the conversion of some of the areas that were previously grasslands largely into farmlands and settlement units. The other possible impact of population pressure on the park was increasing demand for cultivated lands, settlement units and areas for cattle grazing at the expense of other LULC classes that are habitats for precious wildlife species. The settlers also used to keep dogs which can transmit diseases like rabbis that ultimately caused species damage to the endemic Simien Fox (Canid Specialist Group and IUCN SSC, 2011; Sillero-Zubiri et al. (eds), 2004).

Forests

The area under forest cover, which largely includes afro-montane forests constituted only 6773 ha (29%) of the total area of the park in 1985 and showed variability but general decline over the entire study period (Figure 7 and 8). The area under forests declined by about 66% (299ha/y) between 1985 and 2000 and later expanded by 67% (102 ha/y) between 2000 and 2015 (Table 6 and Figure 8).

Despite some area gained from LULC classes, shrinkage was observed in forest covers over the entire study period. The dominant contributors of shrinkages in forest cover were largely attributed to conversions of the original cover into exposed rocks and bare grounds (2687 ha) and shrubs (996 ha) as shown in Table 7. These possibly attributed to unsustainable utilization of forests during the civil war period between 1984 and 1991, the agricultural exploitation; deforestation and illegal wildlife hunting. These were intensified largely due to population pressure caused by a strong influx of settlers for the last decade.

Farmland and settlements

This category merged farmland and settlements into one LULC group. They were combined into one category because it was difficult to identify the dispersed rural settlements as a separate land cover type and the existence of cultivated land around homesteads (Weldeamlak, 2002). Table 5 indicated that farmland and settlements constituted about 4508 ha (19%), 5950 ha (25%), 6929 ha (29%) of the total area of the park in 1985, 2000 and 2015, respectively (Table 6 and Figure 8). Table 6 and Figure 8 also revealed that the area under this category was expanded considerably by about 32% (96 ha/y) in the first studied period (1985-2000). This was possibly related to land encroachment by local community into the park driven by population pressure. However, it has also shown a slight expansion by about 16% (53 ha/y) in the second studied period between 2000 and 2015 (Table 6 and Figure 8). The low rate of expansion in the latter 15-years was attributable to recent park conservation and management effort to implement park regulation focusing on segregation of local communities from the conservation area.

Although some portions of the original extent of farmland and settlement was simultaneously lost into other LULC classes, it has been expanded mainly due to area gains from grassland (1715 ha) as shown in Table 7. This is largely associated with encroachment of farmlands and settlements into grasslands and original natural forest cover as a result of population pressure. Population pressure through settlement and cultivation in the form of intensive cutting of trees for local energy consumption, and cutting of long grass for the construction of houses have changed the traditional *Walya Ibex* habitats into intensive man-used zone.

Table 7: Land use and cover change analysis results of the study area (1985-2015)

	Change to LULC 2015 (ha)						
	LUT	Farmland and settlement	Grassland	Exposed volcanic rocks & Bare ground	Shrubs	Forest cover	Total
Change from LULC 1985 (ha)	Farmland and settlement	1815.8	380.6	531	1223.3	630.5	4581.1
	Grassland	1714.7	2550	2088	1463.8	512.8	8330
	Exposed volcanic rocks & Bare ground	31.3	3.3	1670.3	13.6	86	1738.3
	Shrubs	118.1	940	42.8	836.2	213.4	2150.4
	Forest cover	494.5	193.6	2687	995.6	6721	6772
	Total	4174.4	4067.5	7019.1	4532.5	8163.7	

Major drivers of land use and cover dynamics

Despite the efforts made to conserve and develop the protected areas in Ethiopia, there had been different pressures largely from human factors (Tezera, 2015). Thus, LULC dynamics in the study area largely depends on dynamic relationships among population and policy/institutional factors, but the effect of natural factors such as climate over a small area and short periods of time may not be felt as such.

Population pressure

Population pressure has been the largest human factor causing LULC changes in the highlands of Ethiopia (Weldeamlak, 2002; Wubalem, 2012; Hurni 1988; Mekuria, 2005; Tsehaye and Mohamed, 2015; Hassen, et al., 2015). Although the overall demographic data for the study area were not possible to obtain due to the national park boundaries, the data were compiled according to administrative structure where the park is located. Between the early 1970's and 1976, deforestation of large areas had taken place mostly by nearby farmers (Tezera, 2015). The encroachments of inhabitants from the nearby woreda to the park had also occurred, particularly during the political instability of the late 1980s and early 1990s in the country. The inhabitants found within the park vicinity are households largely depending on land resources as means of livelihood, which caused expansion of farmlands into shrubs, forests and grasslands. These caused overgrazing; deforestation for household energy consumption and income; and declined arable land per capita (i.e., share of farm lots by farming households declined due to increased population pressure) in the park. These suggest that population growth is a major driving force in LULC dynamics of SMNP.

Institutional and policy factors

Ethiopia has undertaken many institutional and policy changes regarding land resources management following major changes in government structures. The agricultural policies practiced by succeeding governments in Ethiopia have been among the major contributing factors for LULC dynamics (Hassen et al., 2015; Alemu et al., 2015). The downfall of the imperial regime followed by land reform of 1975 where farmlands were given to landless tenants confiscated from landlords, and clearing of forest and shrubs contributed to LULC change. Sociopolitical influences, especially inse¬curity of land tenure and disincentives among farmers for conservation programs have discouraged farmers from investing in soil conservation practices in Ethiopia (Hurni, 1988). From 1976 up to mid-1980s most of the park areas were ground for battle between the Derg regime and opposing fronts (Tezera, 2015).

The resettlement program between 1987 and 1990, civil war between 1990 and 1991, downfall of the socialist regime, and the resulting legal vacuum in natural resource conservation attributed to the clearance of shrubs and forest cover. The 1997 land redistribution in Amhara region that aimed at ensuring social justice and responding to population change was another factor despite its failure to fully satisfy the ever-increasing demand for farmlands and settlement. However, enforcement of law since 1994 had played a major role in the reduction of forest land of the park (Tezera, 2015).

Conclusion

There have been substantial LULC changes in SMNP driven mainly by population pressure. The existing expansions of traditional farming practices on grasslands, natural vegetation and marginal lands eventually led to loss of habitat. The increase in the number of population and their cattle in the park forced the local community to keep their cattle in the critical zone of wildlife habitat and, thereby causing habitat fragmentation. The institutional and policy reforms over the entire study period have contributed to changes in the legal and policy frameworks of nature conservation management and local land ownerships. These changes could have negative implications for sustainable tourism management and the livelihood of the local community. As a result, reconciling biodiversity conservation and rural development in the study area are critical to make the trade-offs between the diverse interests through adequate stakeholder involvement and negotiations. This can result in the participation of local populations towards the benefits of conservation through awareness raising on the coexistence between nature conservation and livelihood.

Conflict of interest

There is no conflict of interests

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