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# STUDY ON TEMPORAL ALTERATIONS IN LAND COVER TYPES IN SIMIEN MOUNTAIN NATIONAL PARK, NORTHWEST ETHIOPIA

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## *ABSTRACT*

This study was carried out in Simien Mountain National Park (SMNP) of Ethiopia to trace the temporal dynamics in land use types from the information generated through the analysis of land sat images. Results revealed that throughout the study period, variable extent of changes was observed in land use classes. In the first reference period (1972 - 1994), agricultural (9945.56 ha) and barren land (3066.6 ha) showed a remarkable increment whereas other land use types were decreased. In the second reference period (1994 - 2017), montane forest, grassland and shadow showed increasing trend with the dramatic change in grassland. In the first reference period (1972 - 1994), maximum negative rate of change was observed for Erica forest with deceleration rate of 83 ha/year which continued in the 2nd reference period (1994 - 2017) with the change decreasing rate of 16.6 ha/year. Maximum positive rate of change (74.6 ha/year) was observed for agricultural land followed by barren land (68.6 ha/year). In the second reference period maximum positive rate of change was observed for grassland with accelerated rate of change 260.5 ha/year whereas maximum deceleration rate (272.8 ha/year) was observed for agricultural land. At present, montane forest cover is increasing whereas agricultural land is decreasing dramatically contributing for the restoration of the ecosystem. However, intensified grazing was identified as a principal driver affecting ecological process in the Park; therefore, a long term strategy should be designed to meet the sustainable utilization of natural resources in the Park.

**Contribution/Originality:** This study contributes to the existing literature by providing basic information for other researchers regarding land use change in Simien Mountains National Park, Ethiopia. In addition, this study documents the current trends land use dynamics in the Park.

## 1. INTRODUCTION

Land cover is usually defined as cover of the earths' surface by natural vegetation that characterize a particular land area whereas land use is to mean human uses of land through modification or change of the natural vegetation cover (Sherbinin, 2002). Land cover change would mean the modification (increase or decrease) in the vegetation cover of an area when compared at different times (Lemlem, 2007).

Major driving force for land cover changes is human induced (Allen and Barnes, 1985) which is critical and currently increasing in alarming rate resulting immeasurable impact on the globe (FAO, 1983). The recent increase of human impact on land is due to alarming population growth, advances in technology and the demand following these events, changing entire earths' surface, and ultimately affecting the entire ecological processes. Consequences of such alterations could bring deforestation and biodiversity loss (Skole *et al*., 1994) land degradation following soil erosion, decline in wetlands (Detenbeck *et al*., 1993) reductions in natural recharge and reduction in carbon dioxide sequestration (Kates *et al*., 1990). Understanding the driving forces and the associated consequences of land cover change can be used as a road map that can lead to the appropriate solution of the problem (Ehrlick, 1998).

Anthropogenic disturbances have impacted the ecosystem function and structure of SMNP. Except its inaccessible cliffs and highest peaks, the park is highly disturbed by grazing (specially the afroalpine plateau) (Ludi, 2005; PADPA, 2006). Barley cultivation accounts for about eight percent of the park (ANRS, 2009). These land uses have affected the ecosystem functions and natural processes of the area resulting loss of homes and key habitats of organisms (Ludi, 2005). Inhabitants of the surrounding Kebeles grazed the park over the sustainable rate (Hurni and Ludi, 2000). As a result grassland quality is reduced, leading to the boosting of unpalatable grasses (e.g. *Festuca* species), and species richness is dropping in the park.

Assessment of land cover changes at intervals is a central element to understand the causes and associated environmental changes (Meyer, 1995) up on which decision makers enabled to take appropriate actions by allocating optimum resource for the prevention of the causative factors and mitigation of impacts. For this, satellite imagery techniques are found to be appropriate to capture and prepare precise land use maps and analyze changes at intervals (Harris and Ventura, 1995). To collect data in a cost and time efficient manner, this method is the most appropriate for SMNP where most of the areas are inaccessible by the usual data collection techniques. In addition, satellite imagery techniques allow long term follow up (mentoring) of the change.

Detection of changes is used to analyze what land use category is changing to what other type(s) which could be used as a baseline information for managerial intervention. Overlay analysis using pixel to pixel comparison of the study year images is used to detect dynamics including the direction of change(s).

## 2. MATERIAL AND METHODS

### *2.1. Study Area*

SMNP is found in North Gondar Administrative Zone, Amhara National Regional State, northwest Ethiopia. Its location extends from 13°06'44.09 " N to 13°23'07.85" N latitude and 37°51'26.36"E to 38° 29'27.59"E longitude. It covers a total area of 412 $km^2$ and bordered by 5 districts of the Zone (Debark, Janamora, Adarkay, Beyeda, and Telemit). It is situated 120 km northeast of Gondar town and 860 km away from Addis Ababa with altitudinal range from 2000 to 4530 m a.s.l. The temperature ranges from 2°C to 18°C and average annual rainfall is about 1450 mm.

### *2.2. Data Acquisition Methodology*

Data for past and present land use change were generated by satellite remote sensing techniques. Images from satellite were obtained through the Global Land Cover Facility (www.glcf.org). Landsat images from Multi-Spectral Scanner (MSS) for 1972, *Thematic Mapper (TM)* for 1994 and Operational land Image (OLI) for 2017 were used Table 1. These data were used to create False Color Composite (FCC) which was used to develop the land use maps for time intervals of 1972, 1994 and 2017.

**Table-1.** Materials and their Sources.

| No. | Land sat Image | Sensor | Resolution | Acquisition date | Source |
|---|---|---|---|---|---|
| 1 | Landsat3/4 | MSS | 60 m | 1972 | USGS |
| 2 | Landsat5 | TM | 30 m | 1994 | USGS |
| 3 | Landsat8 | OLI | 30 m | 2017 | USGS |
| 4 | SPOT5 | Spot | 5 m | 2007 | EMA |
| 5 | SRTM | SRTM | 90 m | 2000 | USGS |
| 6 | Map | | 1:100,000 | | |

**Source:** Georeferenced Satellite Data.

Digitized and geo-referenced topographic maps of SMNP and ground truthing information were used. Samples (GIS reading data) were collected from each land use types to obtain representative Ground Control Points which were used for georeferencing the images, understanding the features of the different land cover classes, support visual interpretation of the image, select reference and test areas (for accuracy assessment). With some modification, Tso and Mather (2007) and Amsalu *et al.* (2007) land cover categorization were used to classify the land use types Table 2.

**Table-2.** Description of LULC classes used for analyses of changes.

| Class name | Description |
|---|---|
| Agriculture | Land used for subsistence crop production and the associated rural settlements |
| Barren land | Surface of the earth largely enveloped by exposed rock and stones. |
| Erica forest | Vegetation cover dominated by Ericaceous species having similar reflectance to the natural forest but largely distributed in elevation higher than 3200 m a.s.l. |
| Forest | Natural vegetation with different tree species forming closed or nearly closed canopies |
| Grassland | Surface of the earth covered by grasses mixed predominantly with Kniphofia, *Helicrysum* and *Lobelia* species. Grasses are the dominant natural vegetation. |
| Shadow | Area with unidentifiable cover as a result of shading consequence of the escarpment |

**Source:** Georeferenced Satellite Data.

### *2.3. Data Analyses for Land Use Changes*

Combination of procedures and steps were employed to evaluate, map out, interpret and quantify the collected data sets. Ground control points were used for georeferencing images with a root mean square error of less than one cell (pixel). To geo-reference the images, the Universal Transverse Mercator (UTM) geographic projection system, WGS-1984-UTM and Adindan (Ethiopia) zone 37 North datum were used. Supervised classification were used to classify the Landsat images using image processing software ERDAS (Imagine 9.1). Training areas were recognized and examined based on ground truth information collected from the study area and cross-compared with those from SPOT, 2006. Maximum likelihood classifier algorithm decision rule were used in this supervised classification.

Error matrix techniques were employed to control accuracy assessment of the classification output, which compare field data with the equivalent outputs of the automated classification (Lillesand and Kiefer, 2000). From the error matrix classification overall accuracy, accuracy producer's and user's and Kappa Coefficient were calculated. Pixel-based statistical analysis, proven technique for change detection, was used to post classification comparison of the three independent images (Shalaby and Tateishi, 2007). This approach detects the change in each cell for all land use classes; class to class changes dynamics and total gains and losses of a given land use types. A requirement for the application of change detection matrices is a similar spatial resolution of geoinformation when comparing one time step with the next (Alphan *et al.*, 2009). Thus, the Landsat ETM+ 30 m image of 1994, the Landsat OIL 30 m image of 2017 and the SPOT images of 5 m 2006 were resampled to 60 m resolution in order to match the pixel size to the Landsat MSS of 1972 image. A conversion matrix between the maps was compiled in the form of a contingency.

Rate of change was obtained using the formula: $Rate of change = \frac{A-B}{C}$, where A = recent areas of land use in ha, B = previous area of land use in ha and C = time difference between A and B in years.

## 3. RESULTS

The land use types of SMNP derived from the maps of 1972, 1994 and 2017 were described as montane forest, *Erica* forest, grassland, agriculture, barren land and shadow. Based on their increasing order of percent coverage, the land use types for the year 1972 were barren land, shadow, *Erica* forest, agricultural land, montane forest, and grassland.

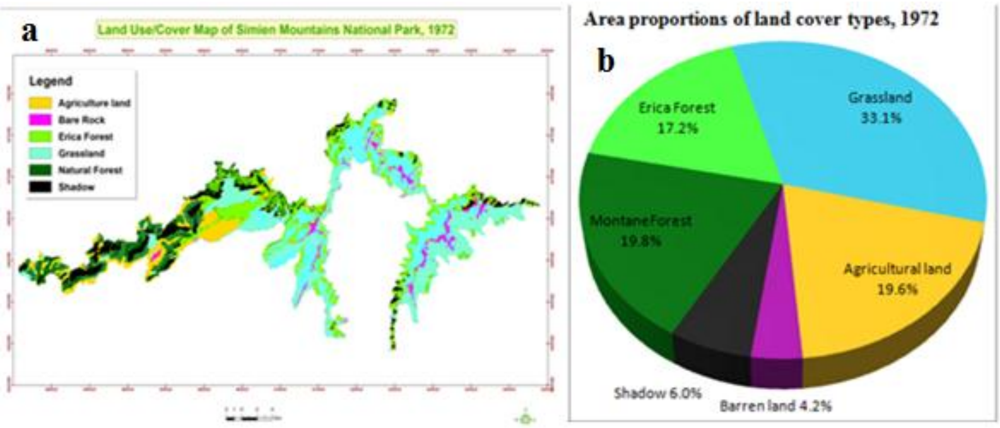


**Figure-1.** Land - use (a) map and (b) proportion of SMNP in 1972.
**Source:** Georeferenced Satellite Data.

As shown in Figure 1, grassland, ranked first in cove (33.1%) followed by Montane forest (19.8%) and *Erica* forest (17.2%) respectively. Agriculture, shadow and barren land covered 19.6%, 6% and 4.2% of the study area respectively. The land use map also revealed that montane forest, *Erica* forest and grassland accounted for 70.1% of the total area of SMNP whereas the remaining 29.9% was accounted for agricultural, shadow and barren land.

The sequence of percent coverage for the land classification of the 1994 was shadow, barren land, *Erica* forest, montane forest, agricultural land and grassland. Figure 2, shows that grassland accounted for the maximum share (32.6%) from the total area. Montane forest and *Erica* forest covered 19.2% and 12.9% respectively. Agriculture, barren land and shadow shared 23.7%, 7.3% and 4.3% coverage from SMNP respectively. Green vegetation (grassland, montane forest and *Erica* forest) covered larger area (64.7%) in SMNP than the remaining land use-land cover types (Agriculture, barren land and shadow) which, in total, accounted for 35.3%.

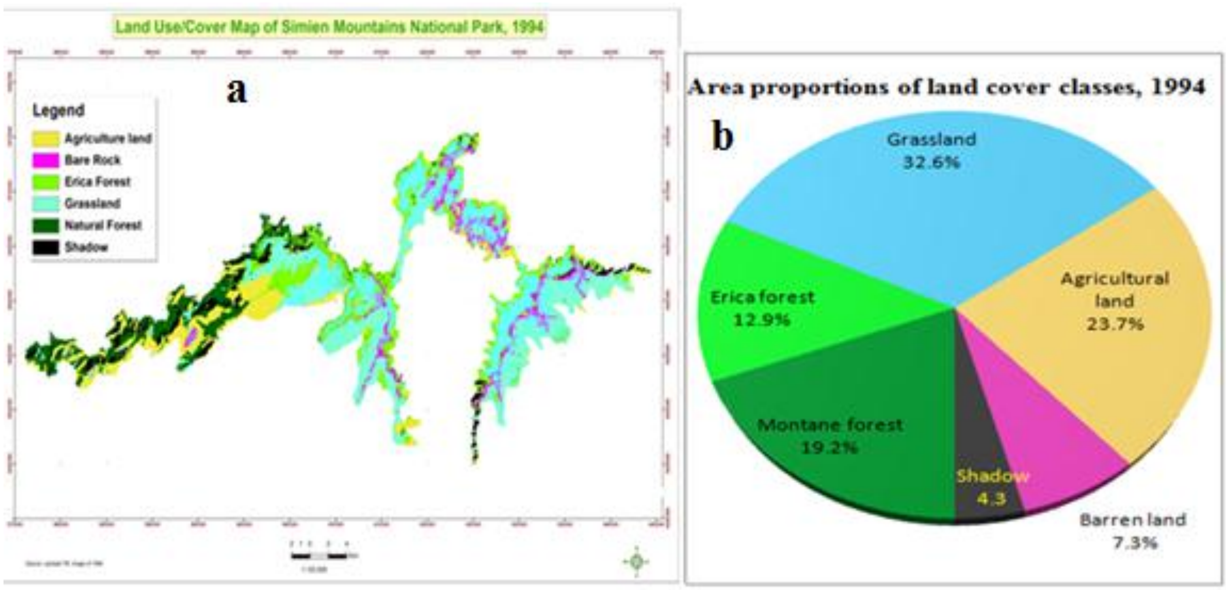


**Figure-2.** Land use (a) map and (b) proportion of SMNP in 1994.
**Source:** Georeferenced Satellite Data.

Based on their increasing order of percent coverage for the year 2017 land classification, barren land took the first rank followed by shadow, *Erica* forest, agricultural land, montane forest and grassland respectively. For the year 2017, the land use distribution map and the percent area cover for each land use are presented in Figure 3a and b respectively.

As shown in Figure 3, grassland accounted for the greatest area coverage (44.4%) whereas montane forest and *Erica* forest contributed 20.2% and 11.7% of the total area respectively. Agricultural land, barren land and shadow shared 11.3%, 7.29% and 5.08% from SMNP respectively. In 2017, green vegetation (grassland, montane forest and *Erica* forest) covered larger area (76.3%) in SMNP than the remaining land use-land cover types (Agriculture, barren land and shadow) which, in total, accounted for 23.7%. The vegetation cover showed considerable increase compared to the previous years. In most land use types the alteration did not show predictable trends. For instance, coverage of agricultural land increased in 1994 but decreased in 2017 whereas grassland showed the reverse pattern. It can also be observed that *Erica* forest had lost considerable amount of coverage during the study years (1972, 1994 and 2017).

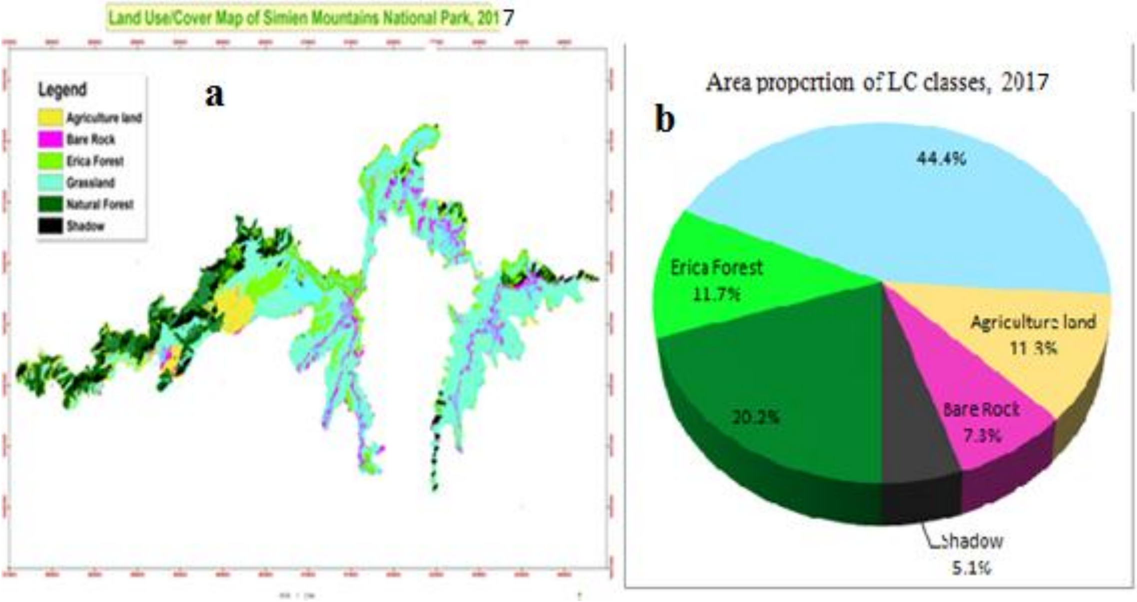


**Figure-3.** Land use (a) map and (b) proportion of SMNP in 2017.

**Source:** Georeferenced Satellite Data.

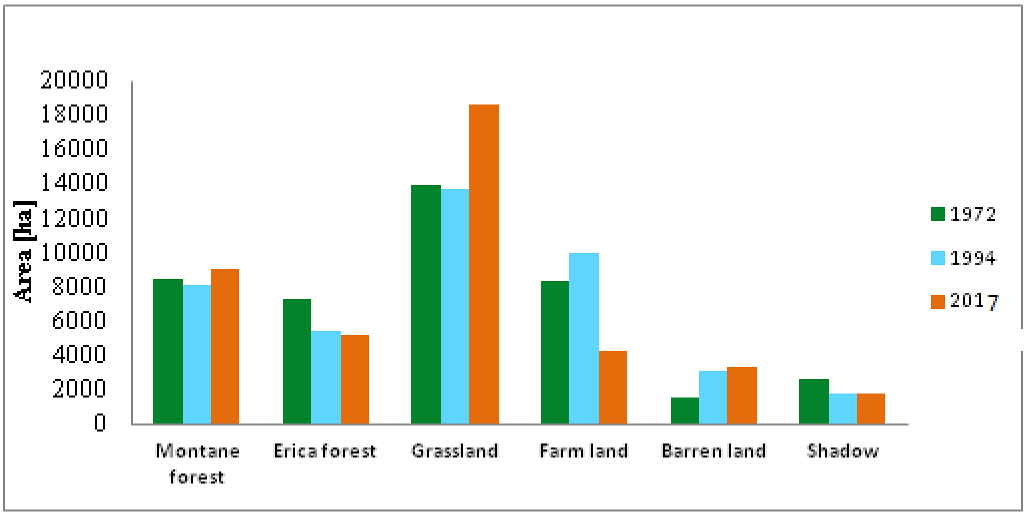


**Figure-4.** Patterns of land use during the reference periods (1972→1994→2017).

**Source:** Georeferenced Satellite Data.

### *3.1. Land Use Dynamics*

Land use classes showed variable extent of changes throughout the study period Figure 4. In the 1st reference period (1972 - 1994), agricultural (9945.56 ha) and barren land (3066.6 ha) showed a remarkable increase whereas montane forest (8040.69 ha), *Erica* forest (5446.3 ha), grassland (13693 ha) and shadow (1792.5 ha) showed shrinkage. In the second reference period (1994 - 2017), montane forest, grassland and shadow showed increasing trend with the dramatic increase in grassland at the cost of farm lands. *Erica* forest and farmlands land showed a decreasing tendency with a dramatic shrinkage in agricultural land.

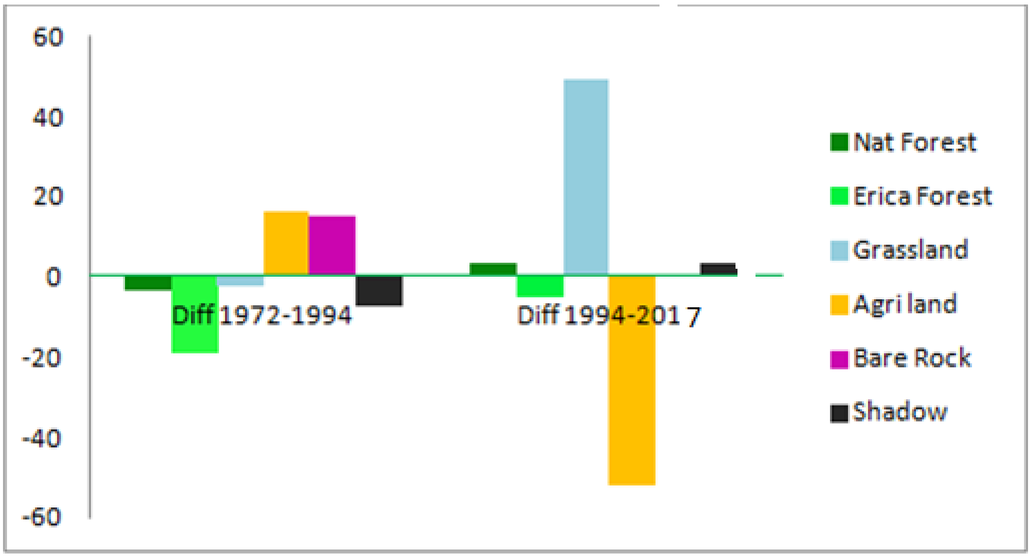


**Figure-5.** Temporal gain or loss for each land use type (between 1972 - 1994 and 1994 - 2017).
**Source:** Georeferenced Satellite Data.

### *3.2. Speed of Land Use Change*

Speed (rate) of land use change is indicated in Table 3. In the first reference period (1972 - 1994), maximum negative speed of change was observed for *Erica* forest which decelerated with a speed of 83 ha/year and further decreased in the 2nd reference time (period) (1994 - 2017) with dwindling speed of change 16.6 ha/year. Maximum positive rate of change (74.6 ha/year) was observed for agricultural land followed by barren land (68.6 ha/year). In the 2nd reference period maximum positive rate of change was observed for grassland with accelerated rate of change 260.5 ha/year whereas maximum deceleration rate (272.8 ha/year) was observed for agricultural land.

**Table-3.** Speed of change in land use types.

| Class Name | 1972 | 1994 | 2017 | Speed of change | |
|---|---|---|---|---|---|
| | | | | From 1972-1994 | From 1994-2017 |
| Montane forest | 8385.4 | 8040.7 | 8407.1 | -15.7 | 19.3 |
| *Erica* forest | 7272.8 | 5446.3 | 4930 | -83.0 | -27.2 |
| Grassland | 13923.6 | 13693.0 | 18641.8 | -10.5 | 260.5 |
| Farm land | 8304.0 | 9945.6 | 4761.9 | 74.6 | -272.8 |
| Barren land | 1558.2 | 3066.6 | 3080.3 | 68.6 | 0.7 |
| Shadow | 2540.8 | 1792.5 | 2153.4 | -34.0 | 19.0 |
| Total | 41984.8 | 41984.8 | 41984.8 | | |

**Source:** Georeferenced Satellite Data.

### *3.3. Change Detection*

Detection of change was accomplished using the classified maps of 1972 and 1994, and 1994 and 2017 Tables 4 and 5 respectively. Land cover types that did not show change during the time period are shown by the diagonal values. In addition, image differences were observed for all land use types with different extent throughout the study period. Comparison between 1972 and 1994 land use types showed that higher class change were observed for grassland, agricultural land, *Erica* forest, montane forest and barren land, among which positive changes were observed for agricultural land and barren land whereas negative changes were observed for the remaining land use types.

During the first reference period (1972-1994) 12.4 km² montane forest, 15 km² *Erica* forest and 24.5 km² grassland were converted to agricultural land contributing to its dramatic expansion. Considerable area of *Erica* forest (8.6 km²), agricultural land (9.5 km²) and shadow (8.9 km²) were converted to grassland Tables 4.

**Table-4.** Change detection matrix between 1972 and 1994 (km²).

| Final year (1994) | Initial year (1972) | | | | | | |
|---|---|---|---|---|---|---|---|
| Class Type | Montane Forest | *Erica* Forest | Grassland | Farm Land | Barren Land | Shadow | Class total |
| Montane forest | **57.1** | 1.4 | 6.4 | 8.9 | 1.4 | 5.2 | 80.4 |
| *Erica* Forest | 1.8 | **42.3** | 4.5 | 5.0 | 1.0 | 0.0 | 54.5 |
| Grassland | 6.7 | 8.6 | **96.2** | 9.5 | 7.0 | 8.9 | 136.9 |
| Farm land | 12.4 | 15.0 | 24.5 | **44.6** | 0.0 | 3.0 | 99.5 |
| Barren land | 5.5 | 3.7 | 5.5 | 8.6 | **5.8** | 1.6 | 30.7 |
| Shadow | 0.4 | 1.7 | 2.2 | 6.5 | 0.4 | **6.8** | 17.9 |
| Class total | 83.9 | 72.7 | 139.2 | 83.0 | 15.6 | 25.4 | 0.0 |
| Class change | 29.8 | 31.0 | 43.0 | 38.8 | 25.4 | 18.6 | 0.0 |
| Image difference | -3.4 | -18.3 | -2.3 | 16.4 | 15.1 | -7.5 | 0.0 |

**Source:** Georeferenced Satellite Data.

Comparison of 1994 and 2017 land classification revealed grassland and montane forest showed higher positive changes whereas agricultural land showed the highest negative change. Thus, large amount of agricultural land (35.3 km²) were converted to grassland. In addition, substantial amount of montane forest (10.7 km²), *Erica* forest (10.7 km²), barren land (12.3 km²) and shadow (9.5 km²) were converted to grassland contributing for its remarkable increment in the period Table 5.

**Table-5.** Change detection matrix between 1994 and 2017 (km²).

| Final year (2017) | Initial year (1994) | | | | | | |
|---|---|---|---|---|---|---|---|
| Class type | Montane Forest | *Erica* Forest | Grassland | Farm Land | Barren Land | Shadow | Class total |
| Montane forest | **62.4** | 0.5 | 7.4 | 9.8 | 3.4 | 0.5 | 84.0 |
| *Erica* Forest | 1.0 | **35.2** | 2.5 | 9.1 | 0.9 | 0.7 | 49.4 |
| Grassland | 10.7 | 10.7 | **107.9** | 35.3 | 12.3 | 9.5 | 186.5 |
| Farm land | 0.8 | 1.5 | 6.4 | **37.8** | 0.8 | 0.3 | 47.6 |
| Barren land | 1.5 | 4.5 | 7.7 | 3.4 | **12.9** | 0.8 | 30.8 |
| Shadow | 4.0 | 2.1 | 5.0 | 4.0 | 0.3 | **6.1** | 21.5 |
| Class total | 80.4 | 54.5 | 136.9 | 99.4 | 30.6 | 17.9 | 0.0 |
| Class change | 18.0 | 19.3 | 29.0 | 61.6 | 17.7 | 11.8 | 0.0 |
| Image difference | 3.6 | -5.1 | 49.5 | -51.8 | 0.2 | 3.6 | 0.0 |

**Source:** Georeferenced Satellite Data.

## 4. DISCUSSION

### *4.1. Land Use Dynamics*

For appropriate decision, managers of natural resources need accurate timely information. Results generated from this work provide basic information for appropriate managerial intervention in SMNP. SMNP major land use types, over the past 42 years, have been identified and quantified using satellite imagery and GIS mapping techniques.

The accuracy level is well over the minimum prerequisite (85%) (Anderson *et al.*, 1976) showing the land classification of SMNP is valued. Classification accuracy assessment results of the year 1972, 1994 and 2017 are indicated in Tables 4 and 5 respectively. Kappa coefficient was highest (92% or 0.92) for 1994 and the lowest (84%

or 0.84) for 1972. Kappa values greater than 80% illustrate strong agreement, a value between 40 to 80%) indicate moderate agreement, and a value below 40% show poor agreement (Viera and Garrett, 2005). Thus, the result revealed strong agreement (higher Kappa statistics) of the classification map with the ground reference information proving that the classified land use types are actually found on SMNP. Therefore, 6 land use classes were truly recognized from supervised classification of 1972, 1994 and 2017 images, namely, natural forest, *Erica* forest, grassland, agricultural land, barren land and shadow.

Accurate automated classification was carried out for most land cover types. However, the least classification accuracy was observed for *Erica* forest, which might be due to the similarity of *Erica* forest to montane forest towards their junction (lower elevation) and *Lobelia* mixed grassland towards the higher elevation that would make unable to identify. .

Since ecosystems are disturbed by anthropogenic and natural factors, it is always in dynamic state resulting temporal changes. The consequence of this change may affect ecosystem structure and function including species distribution, species composition and diversity (Jentsch *et al*., 2002). Increase in disturbance frequency and magnitude pronounce responses of the ecosystem to change. In this study, sequence of categorization of the land classification changed through the studied periods. The change in result is due to shift of one class (category) to other class that explained the dynamicity of land classification over the study period.

In the study area, as revealed from matrix of change detection, strong transformations of land use types were observed with variable extents in the reference periods. In the first reference period, 60.2% of the total area of SMNP (41 thousand hectares) left unchanged and the remaining, 39.8% were changed from one class to other class (category). In the second reference period 62.5% of the total coverage of SMNP remained the same and 37.5% coverage underwent change from one class to other class (category).

In the 1st reference period (1972 to 1994), a noticeable transformation was made from grassland to agricultural land. In this period there were farmland expansion, sever forest removal and habitat loss because, in Ethiopia, this was the time characterized by resettlement, a shift in tenure policy, and climate instability (unpredictable climate) (Hillmann, 1990). The 2nd period (1994 to 2017) was featured by fast decline of farmland. Agriculture and livestock raring are the major income sources of the local community found in the vicinity of SMNP. Farmland and grassland were the two top land use classes of the SMNP both in 1972 and in 1994. The result is in line with the similar previous study by Menale *et al.* (2011). These two categories, in combination, accounted for about 50% coverage of SMNP total area throughout the study period.

### *4.2. Land Use Trends during the Reference Periods*

The total area covered by green vegetation (montane forest, *Erica* forest and grassland) in each of the study year (1972, 1994 and 2017) was greater than the total area covered by the remaining land uses types (agriculture, barren land and shadow) which was the highest in 2017 (76.2%) and the least in 1994 (64.7%). However, considerable amount of one land use type was transformed to other type.

In the 1st reference period (1972 - 1994) pronounced increase in farmland coverage was observed. In 1972 land classification map, farmland accounted for 8,304 ha which means 19.6% of SMNP total area. However, this land category increased to 9,945.6 ha (23.7%) in 1994 land - use and land - cover classification with high average positive rate of change (74.6 ha/year). As it was revealed from the change detection matrix, 12.4 km$^2$ of montane forest, 15 km$^2$ of *Erica* forest and 19.5 of km$^2$ grassland were transformed to agricultural land with higher average negative rate of change (15, 83 and 10.3 ha/year respectively). Transformation of such large area of land into farmland was largely due to population expansion. Population expansion resulted in scarcity of land and infertility of soil which compelled farmers to use all available and marginal lands. This led to the rapid increase and large share of farmland coverage.

In the 2nd reference time (period) farmland showed remarkable decrease from 9,945.6 ha (23.7%) in 1994 to 4,761.9 ha (11.3%) in 2017. As revealed from matrix of change detection, large amount of farmland was transformed to grassland (35.3 $km^2$) with the highest average negative rate of change (272.8 ha/year). Moreover, montane forest (10.7 $km^2$), *Erica* forest (10.7 $km^2$), barren land (12.3 $km^2$) and shadow (9.5 $km^2$) were transformed into grassland. Dramatic decrease in agricultural land and its large contribution to the increase of other land cover types was also reported by Menale *et al.* (2011). The noticeable increase in grassland and montane forest may be due to the government intervention to abandon farming in the area in recent times. Throughout the study period, grassland was the most dominant land cover type since afroalpine belt dominates the study area.

In the first reference period, grassland showed slight decrease from 13,923.6 to 13,693 ha due to comparable loss and gain. Transformation of grassland into agricultural land was almost compensated by the gain from the other land cover types. In the second reference period, grassland showed noticeable increase from 13,693 to 18,641.8 ha with the highest average positive rate of change (261 ha/year). Agricultural land contributed the largest share (35.3 $km^2$) for the increase of grassland.

Based on their coverage, the major vegetation types in SMNP are grassland and montane forest (Puff and Sileshi, 2001;2005; Menale *et al.*, 2011) which are also confirmed in the present study. Grassland, the most dominant land cover type in SMNP, is largely found in the afroalpine belt where disturbance in the form of agriculture is relatively reduced due to unfavourable environmental conditions. This doesn't mean that the quality and delicacy of afroalpine vegetation in SMNP is maintained but rather highly disturbed through intensive grazing to the extent of losing its natural biodiversity combination.

Due to unpredictability of rainfall pattern and frequent reoccurrence of drought, rain-fed farming does not give guarantee for Ethiopian farmers (Girma, 2001) which imposed them to shift or diversify their land use patterns. Therefore, livestock raring is considered as a means of livelihood diversification option to compensate unsatisfaction from the agriculture sector. These resulted overgrazing of the fragile afroalpine ecosystems that are easily damaged by the grazing pressure (Buytaert *et al.*, 2010). Local community used to graze the delicate vegetation of the afroalpine area (Hillmann, 1990) throughout the year which might lead to the local extinction of palatable endemic plant species (Uhlig, 1990). These susceptible ecosystems are the habitat of various endemic organisms (plants and animals), therefore, are gravely vital with respect to afroalpine biodiversity conservation.

Trend in the coverage of *Erica* forest showed noticeable decrease in the first reference period followed by slight shrinkage in the second reference period. This may be due to removal of *Erica* species for various purposes as it is the only major woody species at ericaceous belt altitudinal range. In the second reference period, better management practices in the Park reduced the destruction of the *Erica* forest. This result does not agree with the previous work by Menale *et al.* (2011) who reported that *Erica* dominated forest showed better improvement especially at the "Gich". A study conducted in Bale Mountains National Park vegetation by Kidane *et al.* (2012) reported that temporal coverage of *Erica* forest did not follow regular trend. Montane forest did not show significant change throughout the study period. The extent of forest showed little decline in the 1st reference period (time) followed by minor increment during the 2nd reference period (time). The relatively constant trend in montane forest is the fact that forests are found in scattered patches restricted largely in almost inaccessible gorges and valleys of SMNP (Puff and Sileshi, 2005). This land cover type is, therefore, largely self protected irrespective of the degree disturbances.

The result with regard to land use dynamics revealed increase of forest cover in the 2nd reference period. However, farmland and grassland showed reciprocal trend in the 2nd reference period where farmland showed a dramatic decline. Such trend of agricultural land and montane forest in the second period was also reported in the previous study by Menale *et al.* (2011).

### *4.3. Motive Forces to Land Use Dynamics*

In northern Ethiopia including SMNP, long history of occupation (Darbyshire *et al*., 2003) led to population growth. Little attention is given to adjust family size because large family size is believed to be an advantage or asset to confront ups and downs of life. Thus, unplanned growth of population was the main motive factor in the observed land use change. Pahari and Murai (1999) reported similar result stating that pressure from population growth is the main driving force of deforestation due to the associated demand of land for various purposes. Population pressure, thus, resulted farming of marginal lands, soil degradation, continuous ploughing of the same land and unwise use of forest resources (Abate, 2011).

Lack of consistency in land tenure system during the different government regimes of Ethiopia made farmers lose their confidence in the security of their rights to the land. This led farmers to seek short-term needs rather than long-term conservation for sustainable utilization of the land resources (Badege, 2001) which resulted in ecological damage.

In SMNP, overstocking of livestock was another motive factor for land use dynamics. As result of massive food shortages associated with uncertainty of rainfall and increased intensity of droughts, overstocking of livestock is becoming the main livelihood option (Girma, 2001). In Ethiopian highlands like SMNP, animal husbandry is becoming the main strategy to assure food security of the inhabitants (Galvin *et al*., 2001). Thus, the sizes (number) of domestic animals in SMNP were greater than wild animals (personal observation). Grazing intensity depends on the season which is higher during the rainy season where private lands outside the Park are covered by crops. During crop growing period, moorlands of the SMNP are land of common use (to graze livestock). Overgrazing may result change in floristic composition, biodiversity decline, affect soil structure (soil compaction), and even it can totally remove the vegetation (if extreme) (White *et al*., 2002).

## 5. CONCLUSION AND RECOMMENDATIONS

The present results reveal that the agricultural land has decreased recently to the extent that it would not be a major threat for the future existence of the Park, if the present management practices are continued and strengthened. On the other hand, livestock grazing is still threatening the Park especially the afroalpine zone and is identified as the paramount driver of ecological instability in the Park that disrupts the ecological processes. Thus, the study recommends that responsible bodies shall develop a long term plan and strategy for the gradual reduction (especially in wildlife habitats) of grazing so as to meet sustainable utilization of natural resources in the Park.

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## REFERENCES

Abate, S., 2011. Evaluating the land use and land cover dynamics in Borena Woreda of South Wollo Highlands, Ethiopia. Journal of Sustainable Development in Africa, 13(1): 87-107.

Allen, J.C. and D.F. Barnes, 1985. The causes of deforestation in developing countries. Annals of the Association of American Geographers, 75(2): 163-184.Available at: https://doi.org/10.1111/j.1467-8306.1985.tb00079.x.

Alphan, H., H. Doygun and Y.I. Unlukaplan, 2009. Post-classification comparison of land cover using multitemporal Landsat and ASTER imagery: The case of Kahramanmaraş, Turkey. Environmental Monitoring and Assessment, 151(1-4): 327-336.Available at: https://doi.org/10.1007/s10661-008-0274-x.

Amsalu, A., L. Stroosnijder and J. de Graaff, 2007. Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. Journal of Environmental Management, 83(4): 448-459.Available at: https://doi.org/10.1016/j.jenvman.2006.04.010.

Anderson, J.R., E.E. Hardy, J.T. Roach and W.E. Witmer, 1976. A land use land cover classification system for use with remote sensing data. United States Geological Survey Professional Paper 964, Reston, Virginia, U.S. pp: 45.

ANRS, 2009. Simien Mountains National Park general management plan. Bahir Dar: Amhara National Regional State Parks Development and Protection Authority.

Badege, B., 2001. Deforestation and land degradation in the Ethiopian highlands: A strategy for physical recovery. Northeast African Studies, 8(1): 7-26.Available at: https://doi.org/10.1353/nas.2005.0014.

Buytaert, W., F. Cuesta-Camacho and C. Tobón, 2010. Potential impacts of climate change on the environmental services of humid tropical alpine regions. Global Ecology and Biogeography, 20(1): 19-33.

Darbyshire, I., H. Lamb and M. Umer, 2003. Forest clearance and regrowth in northern Ethiopia during the last 3000 years. The Holocene, 13(4): 537-546.Available at: https://doi.org/10.1191/0959683603hl644rp.

Detenbeck, N.E., C.A. Johnston and G.J. Niemi, 1993. Wetland effects on lake water quality in the Minneapolis/St. Paul metropolitan area. Landscape Ecology, 8(1): 39-61.Available at: https://doi.org/10.1007/bf00129866.

Ehrlick, P., 1998. The loss of diversity: Cause and consequence. In: Wilson, E.O. (Ed.). Biodiversity. Washington DC: National Academic Press.

FAO, 1983. Guidelines: Land evaluation for rainfed agriculture. FAO Soils Bulletin 52, Rome. pp: 237.

Galvin, K.A., R.B. Boone, N.M. Smith and S.J. Lynn, 2001. Impacts of climate variability on East African pastoralists: Linking social science and remote sensing. Climate Research, 19(2): 161-172.Available at: https://doi.org/10.3354/cr019161.

Girma, T., 2001. Land degradation: A challenge to Ethiopia. Environmental Management, 27(6): 815-824.Available at: https://doi.org/10.1007/s002670010190.

Harris, P.M. and S.J. Ventura, 1995. The integration of geographic data with remotely sensed imagery to improve classification in an urban area. Photogrammetric Engineering and Remote sensing, 61(8): 993-998.

Hillmann, J.C., 1990. The Bale Mountains National Park area, South Rastern Ethiopia, and its management. In: African Mountains and Highlands: Problems and perspectives. Messerli and H. Hurni (Eds.). Missouri: Walsworth Press. pp: 277-286.

Hurni, H. and E. Ludi, 2000. Reconciling conservation with sustainable development. A participatory study inside and around the Simien Mountains National Park. Centre for Development and Environment, University of Bern, Switzerland. pp: 476.

Jentsch, A., C. Beierkuhnlein and P.S. White, 2002. Scale, the dynamic stability of forest ecosystems, and the persistence of biodiversity. Silva Fennica, 36(1): 393-400.Available at: https://doi.org/10.14214/sf.570.

Kates, R.W., B.L. Turner and W.C. Clark, 1990. The great transformation. In: Turner, B.L., Clark, W.C., Kates, R.W., Richards, J.F., Mathews, J.T. and Meyer, W.B. (Eds.), The Earth as Transformed by Human. Cambridge: Cambridge University Press. pp: 1-17.

Kidane, Y., R. Stahlmann and C. Beierkuhnlein, 2012. Vegetation dynamics, and land use and land cover change in the Bale Mountains, Ethiopia. Environmental Monitoring and Assessment, 184(12): 7473-7489.Available at: https://doi.org/10.1007/s10661-011-2514-8.

Lemlem, A., 2007. Assessing the impact of land use and land cover change on groundwater recharge using Rs and Gis; a case of Awassa catchement, Southern Ethiopia. M. Sc. Thesis. Addis Ababa University, Ethiopia.

Lillesand, T.M. and R.W. Kiefer, 2000. Remote sensing and image interpretation. New York: John Wiley and Sons. pp: 724.

Ludi, E., 2005. Simien mountains study 2004. International Report on the 2004 Field Expedition to the Simien Mountains in Northern Ethiopia. Dialogue Series. NCCR North -South Brene.

Menale, W., W. Schneider, A.M. Melesse and D. Teketay, 2011. Spatial and temporal land cover changes in the Simen Mountains National Park, a world heritage site in Northwestern Ethiopia. Remote Sensing, 3(4): 752-766.Available at: https://doi.org/10.3390/rs3040752.

Meyer, W.B., 1995. Past and present land use and land cover in the USA. Consequences, 1(1): 25-33.

PADPA, 2006. Priority research areas in Simen Mountains National Park (SMNP). Bahir Dar: ANRS Parks Development and Protection Authority.

Pahari, K. and S. Murai, 1999. Modelling for prediction of global deforestation based on the growth of human population. ISPRS Journal of Photogrammetry and Remote Sensing, 54(5-6): 317-324.Available at: https://doi.org/10.1016/s0924-2716(99)00032-5.

Puff, C. and N. Sileshi, 2001. The Simien Mountains (Ethiopia): Comments on plant biodiversity, endemism, phytogeographical affinities and historical aspects. Systematics and Geography of Plants, 71(2): 975-991.Available at: https://doi.org/10.2307/3668732.

Puff, C. and N. Sileshi, 2005. PIants of Simien. A Flora of the Simien Mountains and Surroundings, Northern Ethiopia. Brussels: Meise, National Botanic Garden of Belgium. pp: 258.

Shalaby, A. and R. Tateishi, 2007. Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt. Applied Geography, 27(1): 28-41.Available at: https://doi.org/10.1016/j.apgeog.2006.09.004.

Sherbinin, A., 2002. Land-use and land-cover change, A CIESIN thematic guide. Palisades, NY, USA: Center for International Earth Science Information Network (CIESIN) of Columbia University.

Skole, D.L., W.H. Chomentowski, W.A. Salas and A.D. Nobre, 1994. Physical and human dimensions of deforestation in Amazonia. BioScience, 44(5): 314-322.Available at: https://doi.org/10.2307/1312381.

Tso, B. and P. Mather, 2007. Classification methods for remotely sensed data. Boca Raton, USA: CRC Press.

Uhlig, S.K., 1990. Mountain forests and the upper tree limit on the southeastern plateau of Ethiopia. In: Messerli & H. Hurni (Eds.), African Mountains and Highlands: Problems and perspectives. Missouri: Walsworth Press. pp: 237-248.

Viera, A.J. and J.M. Garrett, 2005. Understanding interobserver agreement: The kappa statistic. Fam Med, 37(5): 360-363.

White, R.P., P. Tunstall and N. Henniger, 2002. An ecosystem approach to drylands: Building support for new development policies. Washington, DC, USA: Information Policy Brief, World Resources Institute.