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Land use land cover changes along topographic gradients in Hugumburda national forest priority area, Northern Ethiopia

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ABSTRACT

This study investigated the influence of topographic variability on land use land cover (LULC) change in Hugumburda national forest priority area. The study was based on three periods of LULC maps derived from satellite imageries: Landsat TM for 1985, Landsat ETM+ for 2000 and Landsat OLI for 2015, and topographic attributes derived from ASTER digital elevation model. Supervised image classification was carried out using Maximum Likelihood classifier algorithm. Changes in LULC vis-a-vis topographic variability (altitude, slope and aspect) were assessed based on overlay analysis in a GIS environment. Six LULC classes were identified with an overall accuracy of 93% and Kappa statistics of 0.90. Shrubland and forest land were the dominant LULC types which respectively accounted for about 36% and 26% in 1985 and 39% and 33% in 2000. Forest land (35%) followed by shrubland (30%) continued to be the dominant LULC types in 2015. Between 1985 and 2015, about 23% of the study area showed changes in LULC which constitute increase in forest cover by about 715 ha mainly at the expense of shrubland. Steep slopes, higher altitudes and Northeast aspect were important topographic attributes where marked increased in forest cover was observed. The increase in forest cover along steep slopes, higher altitudes and Northeast aspect can be used to stimulate further expansion of forest cover along similar topographic conditions. This study demonstrated that topographic variability plays an important role in controlling LULC changes. Detailed investigation of drivers of the increased in forest cover is required to scale up the success in other regions with similar climatic and topographic settings.

1. Introduction

Land and its resources have been used to meet the material, social, cultural and spiritual needs of human beings. In the process, human beings modified land uses for various habits and intensities. Conversion of natural forests and grasslands into farming and crop areas to meet the food demand of the ever increasing world population are among the examples (FAO, 2011).

The Ethiopian highlands constitute large parts of the Afromontane regions of Africa which stretch from Cameroon to eastern Africa (White, 1983; Friis, 1992). The Afromontane ecosystem is one of the biodiversity hotspot areas in Africa (Friis, 1992). Ethiopia has 58 national priority forest areas, two of which are located in Tigray region, Hugumburda and Desa'a (Friis, 1992; Aerts et al., 2006; Aynekulu, 2011). As in many tropical forests; disturbance due to natural and anthropogenic factors has changed the structure and floristic composition of forests in northern Ethiopia for millennia (Darbyshire et al., 2003). Currently, only a few natural forest remnants are left as islands in landscapes dominated by agriculture (Aerts et al., 2006).

Land use and land cover (LULC) change results from a complex interaction of social and ecological factors (Lakew, 2000). Consequently, LULC changes could lead to a shift of products and environmental services for humans, livestock, agricultural production and damage to the environment as well in type and amount of environmental services (Foody, 2002). Due to this fact, the world is experiencing rapid land use changes, mainly the conversion of forests and scrublands to agricultural and grazing lands (Gibbs et al., 2007; FAO, 2011).

Ethiopia is experiencing huge LULC dynamics mainly from natural vegetation to farming practices and human settlement (Kindu et al., 2013). The land cover dynamics is more severe in the highlands

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because of higher population density and persistent agricultural activities for millennia compared to lowlands (Wondie et al., 2012). Zeleke and Hurni (2001) reported a sharp decrease of forest cover in the Ethiopian highlands. Contrarily, Bewket (2002) documented a sharp increase of forest cover in Chemoga watershed, Blue Nile Basin, Ethiopia.

Land cover depends on both environmental variables and anthropogenic influence leading to specific land use (Wang et al., 2008; Hishe et al., 2015a). Physical factors such as elevation, slope, and aspect are among many that have a significant influence on LULC distribution and mainly on the deforestation process (Saadi and Abolfazl, 2000; Hishe et al., 2015a). The pattern of altitude, slope, and aspect determines heterogeneity and the complexity of climate, fauna, and land cover (soil type and vegetation cover for example) in relation to socio-economic interactions (Wang et al., 2008). In Ethiopia, several studies have been conducted to estimate LULC change (Kindu et al., 2013; Demissie et al., 2017; Solomon et al., 2018; WoldeYohannes et al., 2018). However, little is known about the effects of topography on LULC change in the dry Afromontane forests of Ethiopia. Understanding of the historic relationship between topographic variability and land cover change needs to be greatly improved with systematic methods (Verheye and Unesco, 2009). To understand the factors of changes, it is necessary to conduct studies that clearly reveal the variation in changing characteristics for proper mitigation measures (Strahler et al., 2006). Therefore, this study was conducted (i) to determine the percentage change of land cover types for the last 30 years; and (ii) to analyze the effect of topography (altitude, slope and aspect) on LULC change. We expect that the results of this study can provide useful information to policy makers and land managers to ensure sustainable environmental restoration and management of resources.

2. Materials and methods

2.1. Study area

Hugumburda forest is located at 12°33' and 12°42' N latitude and 39°30' and 39°39' E longitude (Fig. 1). The study area covers about 8110 ha (Aynekulu, 2011). Hugumburda forest is one of the dry Afromontane forests of Ethiopia. It is composed of different trees, shrubland and liana species dominated by *Juniperus procera*, *Olea europaea sub* spp. cuspidata and *Afrocarpus falcatus* (Friis, 1992; Aynekulu, 2011). The study area is characterized by plain to steep slopes. It lays in an elevation range between 1574 m and 2822 m above sea level. The elevation increases from north-east to south-west direction. The rainfall season is between June and September, while the remaining months are more or less dry. The annual mean minimum and mean maximum rainfall are 609.6 and 1128.4 mm, respectively. The study area has a mean minimum temperature between 6.5 °C and 8.5 °C in the months of December and October and mean maximum temperatures of 27.9 °C and 24.5 °C in February and June, respectively (Aynekulu, 2011).

2.2. Methods

2.2.1. Data types and sources

Landsat Thematic Mapper (TM) for 1985, Enhanced Thematic Mapper Plus (ETM^+) for 2000 and Landsat Operational Land Imager (OLI) for 2015 were downloaded free of charge from the United States Geological Survey (USGS) via http://earthexplorer.usgs.gov/. The study area was entirely contained within a single Landsat scene (path 168, row 51). Three Landsat scenes for the three acquisition years were acquired for the months of December and January. Selection of appropriate image acquisition dates is a precondition for clear identification of the LULC types from satellite imageries (Fenta et al., 2017; WoldeYohannes et al., 2018). As such, in this study, image acquisition dates were selected based on availability of cloud free images in the months of the dry season. The detailed properties of Landsat data used

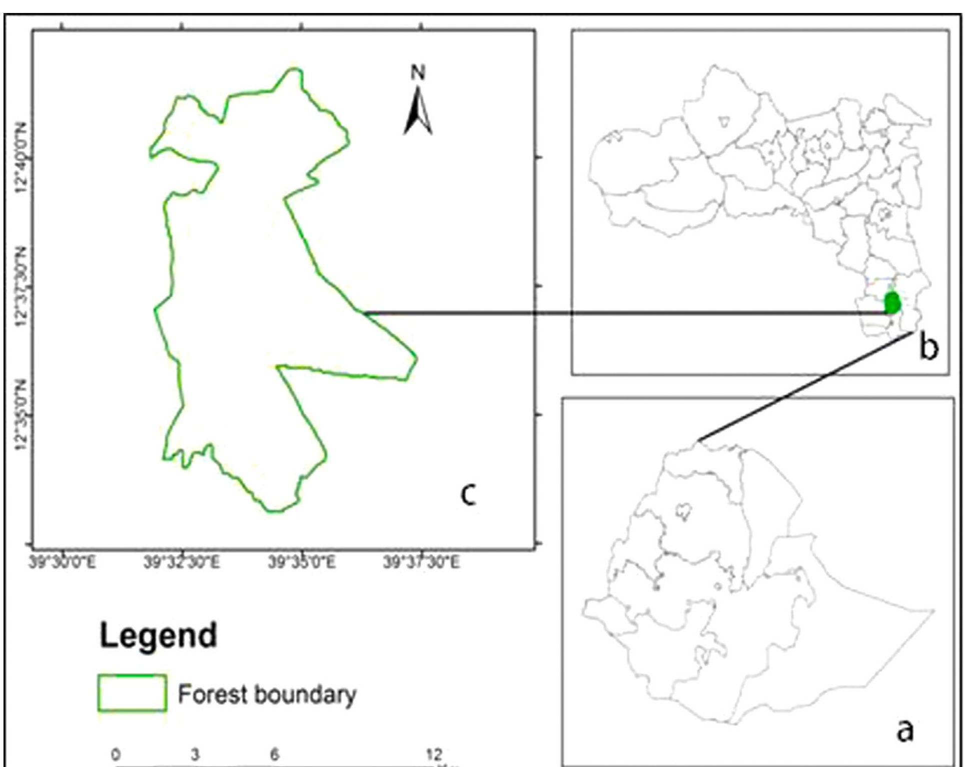

Fig. 1. a) Map of Ethiopia regions, b) Districts of Tigray region, and c) Study area in Hugumburda forest.

Table 1
Detailed properties of Landsat data used.

No	Landsat data	Acquisition date	Spatial resolution (m)	Band combinations
1	TM	Jan 18, 1985	30	4–3–2 (near-infrared red–green)
2	ETM+	Dec 03, 2000	30	4–3–2 (near-infrared red–green)
3	OLI	Jan 01, 2015	30	5–4–3 (near-infrared red–green)

in this study are presented in Table 1. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) digital elevation model (DEM) with 30-m resolution was used to derive topographic attributes of elevation, slope and aspect variables. Moreover, aerial photographs (scale 1:50,000) collected from the Ethiopian Mapping Agency (EMA) and historical high resolution Google Earth images were used during image classification and accuracy assessment. Field observation was also carried out in 2015 to assess the land cover types existed in the study area. The aerial photograph of 1985 and Google earth images of 2000 were used to help classification and verification results specifically for 1985 and 2000, respectively. A total of 360 sample points were collected from which half were used for training and the other half for accuracy assessment.

2.2.2. *Digital image processing*

This study used Landsat Level-1 products which are geometrically corrected, radiometrically calibrated and orthorectified using ground control points, and a digital elevation model by the data provider (Tucker et al., 2004; USGS, 2017). However, pre-processing operations like image enhancement and normalization were applied to multi-date satellite images in order to increase visual discrimination between features and to improve interpretability. Based on the spectral responses of features on the Landsat images and field observation in 2015, six LULC types were identified; namely, forest, agricultural, grazing, shrubland, bare lands, and settlement. The description used for the land cover types identified is provided in Table 2. Supervised image classification was run using the Maximum Likelihood classifier algorithm which is one of the most popular and widely used types of image classification techniques (Chen and Stow, 2002). Classifications were performed using signatures developed from 180 training sample points collected for each of the identified land cover classes from secondary data sources and field survey. Accuracy assessment was done using the remaining 180 sample points which were not used for signature development. Confusion matrix was retrieved and producers and users accuracies and Kappa statistic were calculated from the error matrix.

Change analysis was conducted using post-classification change detection technique following the classification of the imageries. Change statistics were computed by comparing image values of one dataset with the corresponding value of the second data set in each period.

2.2.3. *Derivation of topographic attributes*

Topographic attributes of elevation, slope and aspect were derived from ASTER DEM in Arc GIS environment. Following the classification system suggested by Wondie et al. (2012), the slopes in the study area were reclassified into five categories, i.e., gentle slope (0–5°), moderate slopes (6–10°), steep slopes (11–20°), very steep slopes (21–30°), and extremely steep slopes (31–43.5°). The elevation range was categorized into five classes with an interval of 250 m. Aspect categories distinguished Flat areas (−1), North (337.5–22.50), Northeast (22.5–67.50), East (67.5–112.50), Southeast (112.5–157.50), South (157.5–202.50), Southwest (202.5–247.50), West (247.5–292.50) and Northwest (292.5–337.50) exposed slopes. By overlaying the classified maps of each reference year (1985, 2000 and 2015) on the slope, elevation and aspect maps, thematic information showing the relationship between land cover distribution and changes in each category of topographic variables were extracted in a ArcGIS environment.

3. Results and discussion

3.1. *Accuracy classification*

The overall accuracies of the classified images ranged from 89% to 93% with the Kappa coefficient ranging from 0.86 to 0.90 (Table 3). The kappa value results showed a high level of agreement for the classified image. The accuracy of our result is reasonably high falling within the range of land cover classification accuracies in similar regions (Kindu et al., 2013; Solomon et al., 2018).

3.2. *LULC status and change*

The dominant LULC types extracted from 1985, 2000, and 2015 images were cultivated land, grassland, forest land, settlements, shrubland and bare land. In 1985, the highest portion (35.49%) of the total area was covered by shrubland followed by forest land (26.27%) (Fig. 2 and Table 4). Settlement, farmland, bare land and grassland shared 19.6%, 16.12%, 2.47% and 0.04% of the total area respectively. Shrubland continued to be the dominant land cover type covering 38.68% of the total area in 2000 followed by forest land (33.15%). Settlement, grassland and farmland covered 11%, 3.4% and 11.4% of the total area, respectively (Table 4 and Fig. 2). In 2015, the largest portion of the land was covered by forest (35.08%), followed by shrubland (30.14%), and farmland (15.9%). Settlements, bare land and grasslands accounted for 15.48%, 2.43% and 0.97% respectively to form the three from the bottom lists.

Forest land showed an increasing trend throughout the study period. While shrubland and grassland increased between 1985 and 2000, they decreased from 2000 to 2015 (Table 4). Though decrement was recorded in farmland, bare land and settlement between 1985 and 2000, they increased between 2000 and 2015 by 367 ha, 21 ha and 347 ha, respectively (Table 4). Overall, between 1985 and 2015, while forest cover and grassland increased by 714 ha and 75 ha respectively;

Table 2
LULC types identified in the study area.

Land cover classes	Characterization features
Forest land	Areas dominated by forest composed of broadleaved and coniferous/ deciduous tree species
Agricultural land	Areas of land prepared for growing agricultural crops which include areas currently under crop, and land under preparation.
Grassland	An area covered by herbaceous plants and includes small shrubs.
shrub/bushland	Common in the escarpments and lowland plains especially near the lake. Typically dominated by several Acacia and Commiphora species with little or no undergrowth.
Bare lands	Areas of land that already gets bare either due to erosion or misuses especially overgrazing and crop cultivation.
Settlement	Build-ups (houses) in both urban and rural parts.

Table 3
Accuracy assessment of classified images.

LULC types	Accuracy (%)					
	1985		2000		2015	
	Producer's	User's	Producer's	User's	Producer's	User's
Settlement	81	93	81	93	75	92
Bare land	93	88	92	86	100	100
Forest land	91	87	90	82	100	82
Shrubland	95	93	91	91	95	98
Grassland	92	92	87	95	100	100
Farm land	92	96	91	88	95	95
Overall Accuracy	92		89		93	
Kappa Coefficient	0.90		0.86		0.90	

settlement and shrublands decreased significantly (Table 4). The reduction in settlement and farmland between 1985 and 2000 might be due to the restoration programs taken place in 1990s. The increase in forest cover in the present study might be due to some interventions including soil and water conservation, exclosure establishment and enrichment planting which have been carried out since 1980s. Exclosure is practiced in the forest area since 1980s. This is a common pool natural resource management system in the study area with a well-established set of rules (Kidane et al., 2018).

Findings from elsewhere with similar setting also showed improvements in forest cover. For example, a study by Bewket (2002) revealed a sharp increase in forest lands in Chemoga Watershed, Blue Nile Basin, Ethiopia. Similarly, Gebrehiwot et al. (2014) reported that total forest cover increased from 10% to 22% cover between 1957 and 2001 in Gilgel Abbay watershed in the Blue Nile Basin, Ethiopia. The reason for the forest cover improvement in Gilgel Abbay was primarily due to the expansion of Eucalyptus plantations. However, the present study result is in contrary with the result of Kindu et al. (2013) and Girmay et al. (2010) who reported a fast decline of vegetation cover and increment of other land covers in Munessa-Shashemene and Gum Selassa, respectively. Hailemariam et al. (2016) also found a forest cover loss of 123,751 ha due to farmland and urban settlement expansion from 1985 to 2015 in Bale Mountain Eco-Region of Ethiopia. Farmland and urban settlement expansion were found to be major drivers of LULC change.

The change matrix analysis (Table 5) shows that, shrubland, the main conversion hotspot, has been largely converted to forest land (591 ha) and farmland (105 ha). Afforestation, natural tree growth and establishment of exclosures which inhibits the interference of human and animal might be the cause of the replacement of shrubland to forest land. Similarly, Asmamaw et al. (2011) found that, forest land expanded at the expense of shrublands between 1985 and 2006 in the Gerado catchment, northeastern Ethiopia. Such changes of shrubland to forest land are also evident in different parts of the world. For instance, Wu et al. (2007) reported that shrublands were converted into forest land due to afforestation in Beijing, China. Li et al. (2017) also indicated that forest land appears to be increasing by encroaching upon shrubland, grassland and arable land between 1986 and 2010 in the Koshi Hills, Eastern Nepal. On the other hand, the change from shrubland to farmland might be due to the expansion of cultivated land in the recent times. In agreement with this study, Hailemariam et al. (2016) indicated that, 92,577 ha of shrubland converted into farmland between 1985 and 2016 in the Bale Mountain Eco-Region of Ethiopia. WoldeYohannes et al. (2018) also revealed that 6.18% of shrubland replaced by arable land between 1985 and 2010 in Abaya-Chamo Basin, Southern Ethiopia.

In Ethiopia, and particularly in Tigray, agriculture has a long history of being the backbone of the economy where more than 85% of the population is engaged in. For this reason, with the increase of population and, therefore, high demand of agricultural production forest and shrubland clearance and conversion to arable land is common in many parts of the country (Girmay et al., 2010; Asmamaw et al., 2011). However, such trend of forest and shrubland loss is not uniform throughout the country indicating land use land cover dynamics are socioeconomic, culture and site dependent (Girmay et al., 2010). There are localities where forest and shrubland are well protected and increased over time similar to this area (Teferi et al., 2010; Asmamaw et al., 2011). Within the same region, Tigray, the condition of the two big national priority forest areas is very different. While Desa'a is reported to be highly degraded due to dieback of prominent species (Aynekulu et al., 2012; Mokria et al., 2015) and high dependency of the community for household and commercial consumption of fuelwood (Gebreegziabher, 1999; Hishe et al., 2015b), this paper has confirmed, however, continued increment of forest over the past three decades.

3.3. LULC distributions and changes along slopes

The area coverage of six LULC types across five slope classes in three different periods was presented in Fig. 3. Almost all of the LULC types were found in the five slope gradients of the study landscape with different proportions. In the slope range of 0–5 degrees, shrubland was the dominant land cover type followed by forestland. Grassland recorded the lowest area in this slope range. Similarly, in the slope range of 6–10 degrees, shrubland and forest land were the dominant land cover types. In this slope class, grassland and bare land recorded the lowest area. In the slope range of 11–20 and 31–43.5 degrees, forest land was the dominant land cover type followed by shrubland. It was observed that grassland and bare land recorded the lowest value in this slope class. In the slope class of 21–30 degrees, in 1985, shrubland was the dominant land cover type, while forestland dominated in the years of 2000 and 2015. Highest farmland ratios were recorded in the slope class of 6–10° as compared to the other slope classes throughout the reference years. On the other hand, in 1985, higher forest cover was found in the 6–10 degrees. However, in 2000 and 2015, higher forest cover was observed in slope class of 21–30 degrees. In all slope classes forest land showed an increasing pattern, while shrubland decreased.

Similar to distribution of LULC, percentages of changes were different along the slope classes (Table 5). The steepest slope category was the most dynamic in terms of overall LULC change. A total of 530 ha

Table 4
Area coverage and changes in the area of LULCs of the study area for the years 1985, 2000 and 2015.

	1985		2000		2015		LULC change (ha)		
LULC types	(ha)	(%)	(ha)	(%)	(ha)	(%)	1985–2000	2000–2015	1985–2015
Forest land	2131	26	2688	33	2845	35	557	157	714
Farm land	1308	16	922	11	1289	16	− 386	367	− 19
Bare land	200	2	176	2	197	2	− 25	21	− 3
Settlement	1590	20	908	11	1256	15	− 682	347	− 334
Shrubland	2878	35	3137	39	2444	30	260	− 693	− 434
Grassland	3	0	278	3	78	1	275	− 200	75
Total	8110	100	8110	100	8110	100			

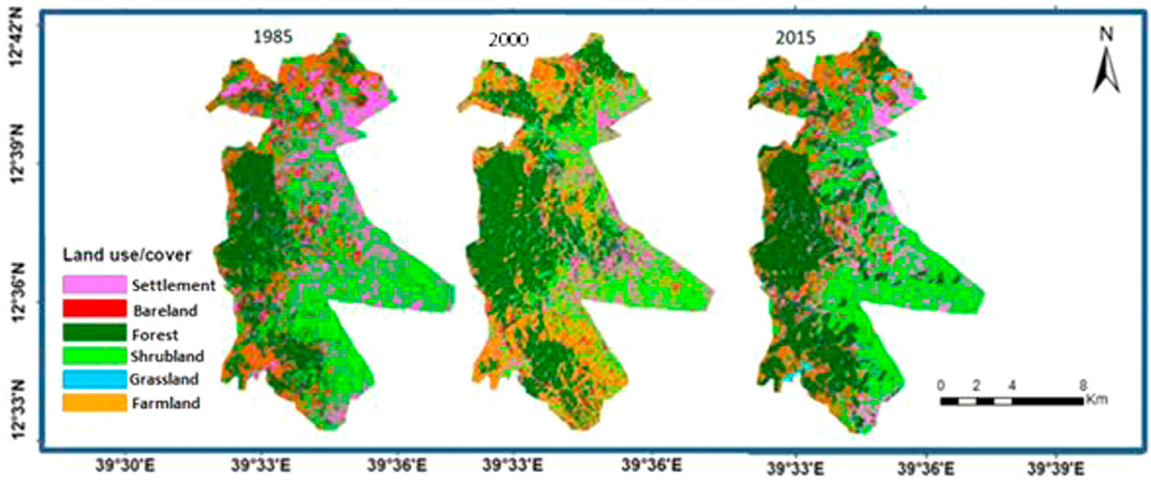

Fig. 2. Land use land cover maps of 1985, 2000 and 2015.

Table 5
LULC change matrix (ha) from 1985 to 2015.

To	From						
	Bare land	Forest	Shrub land	Farm land	Grassland	Settlements	Total (2015)
Bare land	**196.83**	3.51	0	15.48	0	0	215.82
Forest land	71.64	**1991.7**	0	64.71	2.61	71.64	2202.3
Shrubland	85.05	591.48	**2078.91**	105.12	17.19	0	2877.75
Farm land	77.76	0	0	**1104.12**	11.16	114.66	1307.7
Grassland	0	0	0	0	**3.42**	0	3.42
Settlements	0.27	180.63	365.13	15.48	44.1	**984.24**	1589.85
Total(1985)	431.55	2767.32	2444.04	1304.91	78.48	1170.54	8196.84

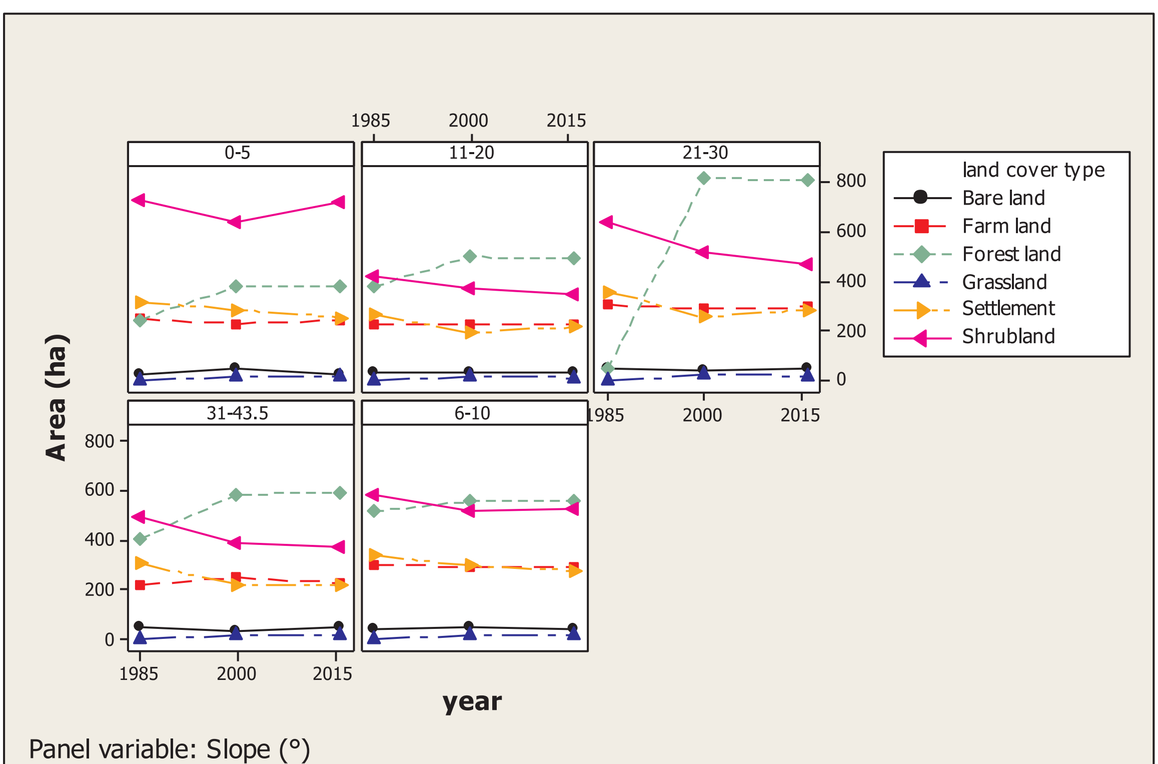

Fig. 3. Spatial distribution of land use land cover (%) across slopes categories in 1985, 2000 and 2015.

Table 6
LULC change across slope categories between 1985 and 2015 in ha.

Land cover class	Slope (°)				
	0–5	6–10	11–20	21–30	31–43.5
Bare land	− 0.24	**− 0.78**	**− 0.78**	− 0.23	− 1.22
Forest land	134.99	45.2	113.52	**760.7**	189.5
Shrubland	− 10.5	− 56.61	− 73.02	**− 170.36**	− 123.22
Farm land	**− 7.57**	**− 8.01**	− 1.16	− 7.07	5.54
Grassland	14.91	12.75	11.27	**19.67**	16.45
Settlement	− 60.6	− 62.69	− 49.78	**− 73.23**	− 87.93

have undergone change. This was due to the large increment of forest cover (761 ha) and decrement of shrubland (170 ha). Bare land, shrubland, farmland and settlement have decreased in all slope categories (Table 6). Contrarily, forest and grassland have increased in all slope categories. Comparably, decrement was mainly observed in 6–10 and 11–20 degrees for bare land, 21–30 degrees for shrubland and settlement; and increment was observed in 21–30 degrees for forest and grassland (Table 4). Farm land decreased in most of the slope classes except for the slope class of 31–43.5 where expansion of farm land was observed.

This study confirmed that LULC change was greatly affected by slope inclination. In agreement with this study, Shiferaw and Singh (2011) noted slope inclination as a major driving forces among others for LULC changes in Borena woreda South Wollo highlands, Ethiopia. The increment of forests is more in steep slopes which can be due to the fact that these areas are inaccessible to human activities unlike the moderate and gentle slopes. Additionally, steeper slopes are not favourable for farmland and grassland due to the inaccessibility and fragility of the land hinder from depleting the forests (Girmay et al., 2010; Asmamaw et al., 2011; Gala et al., 2011; Wondie et al., 2012; Hishe et al., 2015a). Contrarily, Kindu et al. (2013) indicated that forest declined by half from about 63% in 1973 to 32% in 2012 on steep slopes, in Munessa-Shashemene landscape of the Ethiopian highlands. In the present study the expansion of farm land was observed on steep slopes. This is in agreement with the results of Kindu et al. (2013) who reported expansion of croplands from gentle and moderate slopes to steep and very steep slopes in Munessa-Shashemene landscape of the Ethiopian highlands.

3.4. LULC distributions and changes along aspects

In all aspect classes and periods shrubland and forest land were the dominant land cover types (Fig. 4). For example, in the flat, East, South and Southeast aspect shrubland was the dominant land cover type across all reference years. In the North aspect, in 1985, shrubland was the dominant land cover type, while forest land dominated in 2000 and 2015. In the Northeast, Northwest and Southwest aspect, shrubland dominated in 1985 and 2000. In the aforementioned aspects forest land was dominant in 2015. In the West aspect forest land was the dominant land cover types across all the reference years. In all aspect classes and periods, grassland and bare land was the least recoded. In most aspects, shrubland decreased, while forest land increased.

Forest land and shrubland are found dominantly in the Northeast directions (Table 7). While forests have increased by 169 ha, shrubs have decreased by 256 ha. The decrement of the shrubland might be explained by the transformation of these shrubland to forest due to succession. Such positive changes could be caused by appropriate environmental conditions in this aspect such as exposure to sunlight and moisture assisted by low evapotranspiration of the vegetation (Van de Water et al., 2002; Jin et al., 2008; Hishe et al., 2015a).

3.5. LULC distributions and changes along altitudinal gradient

Furthermore, Fig. 5 indicates the area coverage of the six LULC types in five different elevation ranges across three different periods. Shrubland was dominant in the elevation range of 1574–1824 m and 1824–2074 m across all the reference years. In those two elevation ranges settlement was the second dominant land cover type. In the

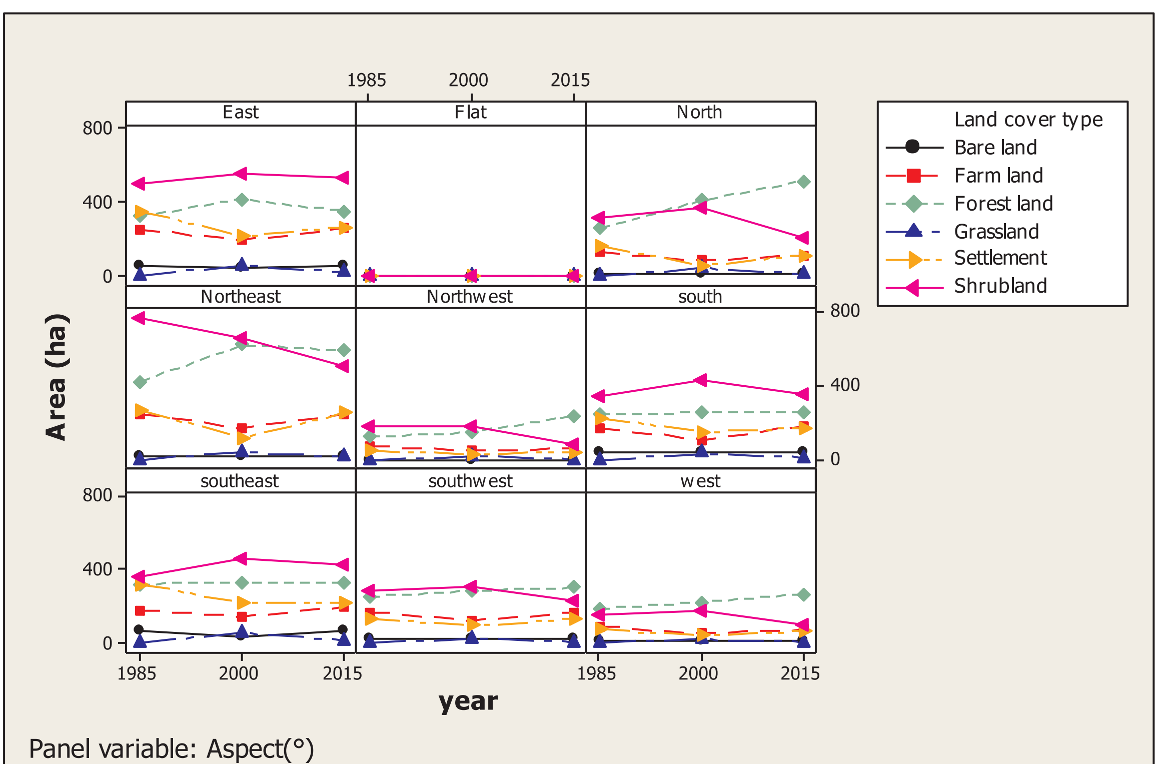

Fig. 4. Spatial distribution of land use land cover (%) across aspect categories in 1985, 2000 and 2015.

Table 7
LULC change across aspect categories between 1985 and 2015 in ha.

Land Cover Class	Aspect (°)								
	Flat	North	Northeast	East	Southeast	South	Southwest	West	Northwest
Bare land	0	1	0.6	0.2	1.3	− 0.5	0.7	0.5	− 0.3
Forest land	0	− 255.4	− **169.1**	− 28.0	− 3.4	− 15.1	− 51.1	− 80.3	− 112.1
Shrubland	− 0.2	105.7	**256.4**	− 36.5	− 71.4	− 17.3	45.3	60.6	91.1
Farm land	− 0.04	16.0	3.8	− 6.6	− 14.3	− 13.1	4.1	16.0	12.4
Grassland	0	− 10.3	− 15.8	− 17.8	− 11.2	− 11.1	− 3.2	− 3.3	− 2.4
Settlement	0.3	50.2	18.7	86.61	99.7	58.0	2.6	6.4	11.8

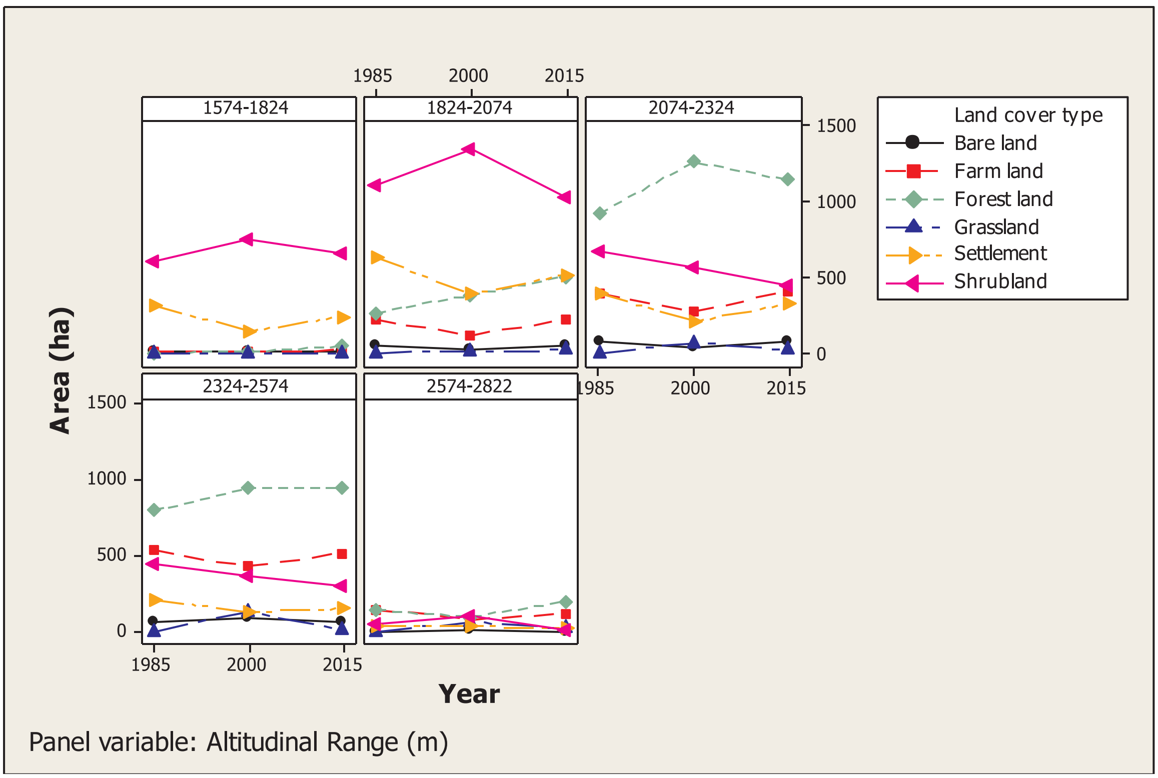

Fig. 5. Spatial distribution of land use land cover (%) across elevation categories in 1985, 2000 and 2015.

Table 8
LULC change along an altitudinal gradient between 1985 and 2015 in ha.

Land cover class	Altitudinal range (m)				
	1574–1824	1824–2074	2074–2324	2324–2574	2574–2822
Bare land	− 0.4	1.4	0.73	1.53	0.06
Forest land	− 44.04	− 236.29	− 222.58	− 156.03	− 55.5
Shrubland	− 52.6	80.98	229.89	140.76	34.64
Farm land	− 1.98	− 3.9	− 17.06	14.54	26.67
Grassland	− 0.15	− 19.2	− 22.93	− 13.46	− 19.32
Settlement	75.73	112.09	66.51	59.07	20.84

2074–2324, 2324–2574 and 2574–2822 m elevation range, forest land was the dominant land cover type. In the 2074–2324 m elevation range, shrubland was the second dominant land cover type, while farmland was the second dominant land cover type in the elevation range of 2324–2574 m covering 40.81% of the total farmland within the study area. In all elevation ranges, grassland and bare land recorded the lowest area.

Over the last 30 years, the study area had shown increment on forest distribution in an altitude range of 2074–2324 m (Table 8). Similarly, increment was observed in shrublands in the elevation of 1824–2074 m. However, in the lowest altitude, the area coverage of forests was drastically decreased as compared to shrublands. The reduced amount of forest land in the lower elevation might be due to socioeconomic activities such as agricultural expansion to marginal lands for cultivation, mainly due to population pressure, introduction of sawmills, civil war, production of charcoal for sale and cutting tree/shrubs for firewood both for the market and home consumption (Kidane et al., 2018). This was in agreement with the results of Wu et al. (2007) and Sun et al. (2014) who reported lower altitude areas were covered by farmland and built up areas. The highest shrubland coverage was located in an elevation of 1824–2074 m that could be due to logging of big size trees for different purposes. Consistently, forest and shrubland increment was reported within 2500–3000 m of elevation in Simen Mountains (Wondie et al., 2012).

4. Conclusions

Land use and land cover estimates are among the most essential information in any forest management practice. In the study area, a significant increase in forest cover was observed, while farmland, settlement, and grassland showed fluctuating trends. Forest cover significantly increased on steep slope areas (21–30°), moderate altitudes and Northeast aspects. Farmland increased on gentle and moderate slopes, elevation range of 1824–2074 m and in East and Northeast aspects in the reference periods. Lower proportions of shrubland, settlement, and farmlands were located in steep slopes in high elevation and west directions of the study area. Over all elevation, slope and aspects have an impact on land cover distribution and change. The topographic gradient effect of land use change might be the result of an interaction of natural and socio-economic effects. This research is important to inform policy makers on the status and change of land use land cover for further planning and intervention. Furthermore, the forest cover showed improvement, thus the forest management in the study area can be scaled up to other forest areas in a similar setting.

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Author contributions

H.A. and E.B. conceived and designed the study; H.A. collected and analyzed the data; H.A. and E.B. wrote the paper; E.B., A.A., H.H., H.G. and N.S. critically reviewed the paper and provided comments on the contents and structure of the paper.

Conflicts of interest

The authors declare no conflict of interest.

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