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Research Article

Land Use Land Cover Change and Its Effect on Selected Soil Physico-Chemical Properties in Southwest Ethiopia

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Abstract

Land cover transformation exerts adverse effects on the environment. This study examined the changes in land cover in the Semen Bench District of southwest Ethiopia from 1986 to 2018, as well as its implications for soil physico-chemical properties. A mixed-method approach was employed, integrating remote sensing (RS) and geospatial data with soil physico-chemical analysis and key informant interviews. Landsat images were processed using ERDAS IMAGINE 2015, and the land use land cover (LU/LC) map was classified using a supervised method employing the maximum likelihood classifier (MLC) algorithm. The classification accuracy was 90%, 87.5%, and 90% for the years 1986, 2001, and 2018, respectively, with corresponding kappa coefficients of 0.87, 0.83, and 0.87. One-way analysis of variance (ANOVA) was conducted to assess differences in soil parameters across various land uses, utilizing SAS software (Version 9.3). The findings indicated that agroforestry and settlements increased by 95% and 428.7%, respectively, while forestland and cropland decreased by 38.6% and 96%, respectively, primarily driven by the expansion of cash crops such as coffee, khat, and eucalyptus, as well as population growth. Significant changes ($P<0.05$) were observed in soil bulk density, soil organic matter, soil pH, available phosphorus, total nitrogen, exchangeable cations, cation exchange capacity, and electrical conductivity, due to land cover change. Conversely, soil texture remained unaffected ($P>0.05$) by these transformations. Consequently, it is essential to develop sustainable natural resource management plans to combat deforestation and the decline in soil fertility.

Keywords

Land Use Land Cover, Landsat, Soil Physic-Chemical Property

1. Introduction

Global environments are subject to continuous dynamics due to both natural and anthropogenic activities. Land use and land cover (LU/LC) changes, primarily induced by human actions, occur in many regions across the globe, raising significant environmental concerns today due to their negative impacts on land resources and ecosystem services [1]. For thousands of years, human actions have significantly modified forest cover to obtain food and other essential goods and

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services, a trend likely to continue in the future [2, 3]. Agriculture is estimated to be the primary driver of deforestation worldwide, accounting for approximately 80% of global deforestation [4]. The FAO [5] reports that agriculture, driven by the growing human population in developing countries, accounts for approximately 73% of deforestation in tropical and subtropical regions.

In addition, the collection of firewood and the production of charcoal are significant contributors to forest cover change in various parts of Africa. The immediate causes of deforestation are shaped by complex interactions multitudes of sociopolitical and cultural processes [4]. Consequently, more than half of the world's forest area was lost between 1990 and 2015, with the highest rates of deforestation occurring in tropical regions, particularly throughout Africa [6]. The effect of LU/LC change is a critical issue in Africa, especially pronounced in the densely populated highlands of East Africa, including Ethiopia [7-11].

Forest cover change in Ethiopia dates back 2,000 to 3,000 years, primarily linked to historical agricultural development and human settlement in the highland regions [8]. Between 1955 and 1979, the country lost approximately 80% of its forest cover due to various factors [12]. By the start of the 20th century, about 40% of Ethiopia's landmass was covered in forest; however, this figure dropped to 2.36% by 2000 due to various direct and indirect drivers of deforestation [11]. These losses of forest and other natural land cover have persisted over the past few decades in different parts of the country [13-15].

The highlands of southwestern Ethiopian, which were once home to dense natural forests at the beginning of the 19th century [16], have experienced significant declines in forest cover over the last five decades [16-19]. For instance, closed Afromontane forests in this area decreased by 24-28% in the Bonga Forest, 23% in the Sheko Forest, and 15% in the Bench, Keffa, and Sheka Forests, while agricultural land increased by 56% in Bonga and by 14% in the Bench, Keffa, and Sheka Forests between 1973 and 2005 [20]. These dynamics of LU/LC change, along with the transition from natural forest to cultivated land, have contributed to land degradation [8, 20, 21].

The conversion of natural forests to cultivated lands has significant consequences for soil properties [22-25], including the reduction of soil organic matter (SOM) due to biomass removal, harvesting, and low input levels [14, 26-29]. Moreover, LU/LC change poses serious threats to soil quality, leading to declines in soil organic carbon, total nitrogen stocks, and other basic cations in various regions of Ethiopia [10, 20, 30-32].

For instance, a study by [33] found that LU/LC change has affected the concentrations of total nitrogen (TN), organic carbon (OC), soil pH, and bulk density (BD) in the Rib watershed of Ethiopia, which can, in turn, impact soil productivity. Additionally, a study conducted by [24] shows that converting natural forests to farmland significantly affects soil physicochemical properties.

The natural forest ecosystem in the southwestern part of Ethiopia supports major vegetation types in the country [34] and is the origin of *Coffea arabica* L. [35]. These forest ecosystems also provide important ecosystem services for the livelihoods of local communities and for the protection of biodiversity in the upper catchment of the White Nile Basin. However, due to human activities, these forest areas have recently undergone extensive changes in forest cover and fragmentation [36, 35].

Despite this, little is known about the conversion of forest cover and its consequences on soil fertility in the Semen Bench district. Therefore, studying LU/LC change dynamics, along with their consequences, is essential for understanding the extent of the problem over time and for supporting decision-making processes. This study aimed to map LU/LC changes between 1986, 2001, and 2018, and to assess the effects of these change on soil physico-chemical properties.

2. Materials and Method

2.1. Description the Study Area

The study was conducted in the Semen Bench district of the Bench-Maji Zone, located in the South Nations, Nationalities, and Peoples' Regional State (SNNPR) of Ethiopia (Figure 1). The altitudes in this area range from 1,153 to 2,696 meters above sea level (m a.s.l.). The average annual rainfall is 1,780 ± 270 mm per year, while the average air temperature ranges from 13 ℃ to 27 ℃ [20].

Leptosols and Nitisols are the predominant soil types found on the crests and hill slopes, respectively, while Fluvisols are situated in the flat valley floor, where meandering rivers can be found [35]. The agroforestry system in this region prominently features *Coffea arabica* as the main cash crop, integrated with food crops such as false banana (Ensete ventricosum), banana (*Musa sapientum*), and taro (*Colocasia esculenta*). Additionally, various spices, including korarima (*Aframomum corrorima*), as well as fruits like mango (*Mangifera indica*), avocado (*Persea americana*), papaya (*Carica papaya*), and orange (*Citrus sinensis*) are also part of the farming system.

Additionally, native tree species such as *Albizia gummifera*, *Cordia africana*, *Millettia ferruginea*, and *Polyscias fulva* are conserved for their various benefits, including offering shade, fodder, firewood, medicinal properties, and enhancing soil fertility. Furthermore, cereal crops like maize (*Zea mays*) and root crops such as enset (*Ensete ventricosum*) and taro (*Colocasia esculenta*) are widely cultivated in the area [20].

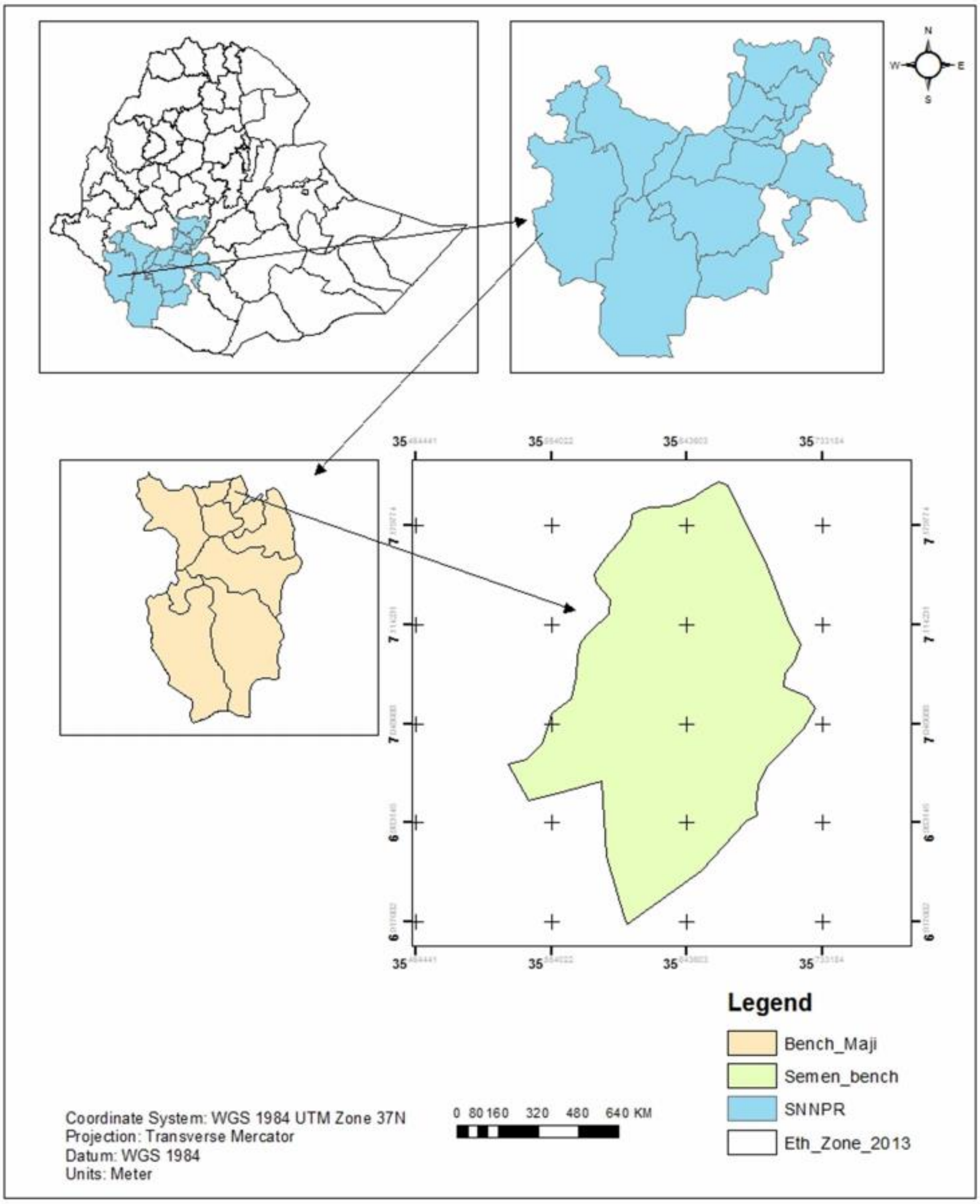


Figure 1. *Map of the study area.*

2.2. Method of Data Collection and Analysis

2.2.1. Acquisition of Satellite Images and Analysis

Cloud-free Landsat satellite images from the dry season for the years 1986, 2001, and 2018 were obtained from the U. S. Geological Survey's Earth Resources Observation and Science (USGS). These specific years were chosen due to the availability of images and the historical context of land use changes, particularly the significant expansion of coffee cultivation, the planting of eucalyptus, and the extensive government-sponsored settlement initiatives in the area following the droughts and famine in northern regions during the 1980s. The technical specifications of the satellite data utilized in this study are presented in Table 1.

Table 1. *Details of satellite data used in the study.*

Satellite	Type of Sensor	Date of Acquisition	Resolution (m)	Path/ and Row	Bands used
Landsat	TM	1986	30 ×30	170/54	6
Landsat	ETM$^+$	2001	30 ×30	170/54	6
Landsat	TM	2018	30 ×30	170/54	6

Pre-processing of the images, including atmospheric correction and geometric rectification, was conducted to eliminate aerosols, noise, and molecular distortions caused by variations in sensor-earth geometry. Image processing and data manipulation were carried out using ERDAS Imagine 2015 software. A total of four land cover classes were identified and verified on the ground: forest, agroforestry, cropland, and settlement (Table 2).

Table 2. *Description of land cover types identified in in Semen-Bench.*

Land cover class	Description
Forest	Natural forestland dominated by dense tree and covered by more than 80% canopy.
Agroforestry	Homegarden and plantation coffee with shade tree aggregated landscape
Cropland	Spatially continuous small household agricultural farms
Settlement	Land dominated with houses, huts and roads they used

Layer staking were involved band from band 1 to 5 and 7 for TM 1986 and ETM+ 2001 and band 2 to 7 for TM 2018. Irrelevant portions of the images were removed to focus on regions of interest. Supervised classification was employed for each year's image, utilizing pixel categorizations based on training areas for each land use/land cover (LU/LC) class. Specific areas in the digital images were marked as signatures for individual identities, and field truth verification was conducted to represent the LU/LC classes accurately. The Maximum Likelihood Classification (MLC) algorithm was applied using ERDAS Imagine 2015 software.

An accuracy assessment was performed using data collected from each of the four land cover classes in the field, comparing this data with the classified images. Random sample points were established for each classified cover type prior to field visits, where the actual cover types were confirmed and recorded as reference data using a handheld Global Positioning System (GPS). Fifty ground control points (GCPs) were identified for each land cover class. Additionally, Google Earth was utilized to validate the LU/LC classification accuracy. The final classification accuracy results were calculated for the land use and land cover maps of 1986, 2001, and 2018.

Change detection analysis was conducted by comparing two successive image periods. Both post-classification comparison and multi-date composite image change detection methods were used to analyze changes. The analysis focused on the periods of 1986 to 2001, 2001 to 2018, and 1986 to 2018 to gather information about changes in land use and land cover, particularly regarding the rates of settlement, cropland, forest land, and agroforestry coverage in the study area. Change statistics were computed by comparing the area values of one dataset with the corresponding values of the other dataset for each period, expressed in square kilometers (km^2) and percentages. The percentage of LU/LC changes was calculated using the following equation [35].

$$\text{LU/LC change (\%)} = \frac{\text{Area}_{\text{final year}} - \text{Area}_{\text{initial year}}}{\text{Area}_{\text{initial year}}} \times 100$$

Where: Area is the extent of each LU/LC type. Positive values suggest an increase whereas negative values imply a decrease in extent.

The relationship between LU/LC distribution and changes in each category was analyzed in ArcGIS 10.4.1 by combining images. Cross-tabulation was utilized to quantify the conversions from one land cover category to another over time. Three focused group discussions (FGDs) were conducted with 6-8 key informants, totaling 21 purposively selected farmers aged over 50 who have lived in the selected village for more than 35 years. The discussions centered on historical changes in land use and land cover, major drivers of deforestation, and the condition of soil following deforestation and forest conversion.

2.2.2. Soil Sampling and Analysis

Soil samples were purposefully collected from three different land uses: cropland, forestland, and agroforestry, to evaluate the impact of these land use types on soil physicochemical properties. Each land use was sampled six times from a depth of 0-30 cm, reflecting the typical plowing depth in the study area [10]. Forestlands were used as a reference point to compare how other land uses have affected soil properties. Before soil sampling, FGDs were conducted to ascertain the extent of conversion and the history of agroforestry and cropland, which informed the selection of soil sampling points in these areas.

A total of eighteen samples (3 land uses × 6 replications) were collected from five locations and composited into one sample after removing surface vegetation and litter. All sampling sites in agroforestry and cropland areas were previously forested before 2001 to minimize any temporal differences in soil properties, based on discussions with key informants. Environmental factors such as slope, elevation, and management practices were kept consistent. Disturbed soil samples were collected using an auger, while undisturbed soil samples were taken with a core sampler (100 cm^3) for bulk density analysis.

Particle size distribution was measured using the hydrometer method after the organic matter was destroyed and the soil was dispersed [37]. Soil bulk density was assessed using the core method [38], in which soil cores were taken and dried to a constant weight in an oven at 105 ℃ for 24 hours. Soil pH was determined in a 1: 2.5 soil-distilled water ratio using a glass-calomel electrode, while electrical conductivity (EC) was measured with a conductivity meter using a 1: 2.5 soil-to-water suspension. Organic carbon (OC) content was analyzed using the wet digestion method described by Walkley-Black [39]. Total nitrogen (%TN) was quantified using the Kjeldahl method [40], and available phosphorus (Pav) was determined using the Bray method [41]. Cation exchange capacity (CEC) was assessed from ammonium-saturated samples, which were partially replaced by sodium ions (Na+) through a percolating sodium chloride solution. The excess salt was removed by washing, and the ammonium displaced by sodium was measured using the Kjeldahl method [42]. Exchangeable magnesium (Mg^{2+}) and calcium (Ca^{2+}) in the extracts were measured using an atomic absorption spectrophotometer (AAS), while potassium (K^+) and sodium (Na^+) were analyzed using a flame photometer.

2.2.3. Statistical Analysis

Soil physicochemical data collected from the three land use types were analyzed using SAS software (Version 9.3). A one-way analysis of variance (ANOVA) was conducted to determine whether significant differences existed among soil properties across the three land use types. The effects of land use and their interactions were evaluated at $\alpha = 0.05$. For those soil properties significantly affected by LU/LC changes, the Least Significant Difference (LSD) test for multiple comparisons at a 95% confidence level was employed to compare average differences between land use types. Data collected from FGDs were presented in the form of narrative information.

3. Result and Discussion

3.1. Accuracy Assessment and Land Use Land Cover Change Detection

The overall map classification accuracy was 90%, 83%, and 90% for 1986, 2001, and 2018, respectively, accompanied by Kappa coefficient values of 0.87, 0.83, and 0.87 (Table 3). According to [43], the overall accuracy is considered acceptable, as it exceeds 80%. Similar results with relatively high accuracies (86–93%) have been reported for land cover classifications in various regions of Ethiopia [44-46].

Table 3. *Classification confusion matrix (1986–2018).*

Land use category	1986		2001		2018	
	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)
Forest	90.0	90.0	88.9	90.0	90	90
Agro forestry	90.0	90.0	90.0	90.0	90	90
Crop Land	90.0	90.0	90.0	90.0	90	90
Settlement	90.0	90.0	81.8	80.0	90	90
Over all accuracy (%)	90		87.5		90	
Kappa coefficient	0.87		0.83		0.87	

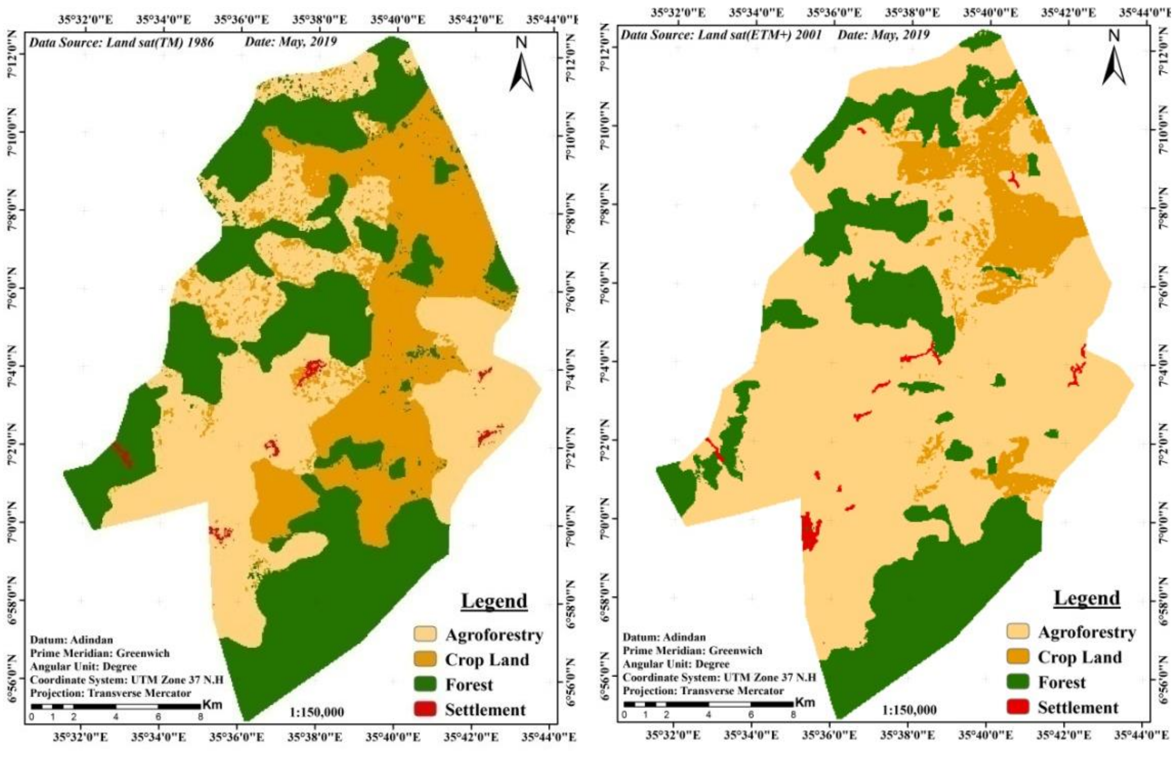
Note: UA= User Accuracy, PA= Producer Accuracy

The results presented in Table 4 reveal that LU/LC of Semen Bench district has changed significantly since 1986. At the beginning of the study period (1986) the forestland was the dominant land use constitute 37.84% followed by agroforestry (35.89%) and cropland (25.79%). In 2001, agroforestry was the dominant land use constitutes 64.9% followed by forestland (25.1%) and cropland (9.29%). Agroforestry continue to be the dominant in 2018 followed by forestland and cropland and settlements.

Table 4. *Areal extent of LU/LC in Semen Bench district from 1986–2018.*

Land use category	Land cover distribution						Land cover changes (%)		
	1986		2001		2018		1986-2001	2001-2018	1986-2018
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%			
Agroforestry	138.39	35.89	250.31	64.9	271.00	70.26	80.87	8.27	95.1
Cropland	99.44	25.79	35.82	9.29	15.08	3.91	-63.98	-57.9	-96.07
Forestland	145.90	37.84	96.74	25.1	89.6	23.25	-33.69	-7.38	-38.59
Settlement	1.88	0.49	2.74	0.71	9.94	2.58	45.75	262.77	428.72
	385.62	100	385.62	100	385.62	100			

The 32 year time span for change analysis of three periods (1986 to 2001, 2001 to 2018 and 1986 to 2018) is moderately enough to detect the long history of LU/LCC. Between 1986 and 2001, an increase in agroforestry (80.87%) and settlement (45.75%) and a reduction in forestland (33.69%) and cropland (63.98%) were observed (Table 4; Figure 2). This trend was continuing between 2001 and 2018 with slight increase of agroforestry (8.3%) and significant increase in settlement (262.8%). The result therefore revealed there was significant land use change between 1986 and 2018 with huge loss of forestlands and croplands and huge gain of agroforestry and settlements.



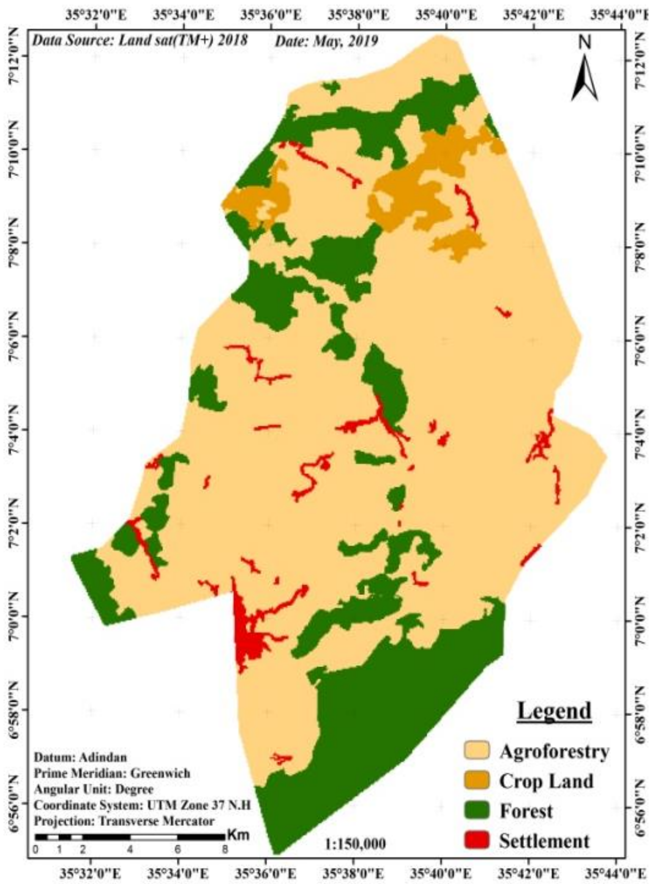


Figure 2. *Land cover maps based on the image classification of Semen Bench District for the years 1986, 2001 and 2018.*

The result (Table 5) also revealed the reduction in forestland and cropland can be attributed to expansion of cash crops in the area such as small scale coffee (*Coffea arabica*) and khat (*Catha edulis*) and expansion of eucalyptus (*Eucalyptus* spp.) tree following increasing demands of khat and eucalyptus, which were largely transported to central and eastern part of the country. Coffee specialization strategies of the government in one hand and reduction in soil fertility of cropland other hand forced farmer to encroach forestland for coffee agroforestry and converted their croplands to agroforestry especially to *khat* and *eucalyptus* tree.

Additionally, the key informant noted that population growth is a significant factor contributing to the reduction of remaining forest cover in the area. As a result, forestlands and croplands have been converted into agroforestry and settlement spaces. While the conversion of forestland negatively impacts the ecological functions of the landscape, it increases vegetation cover through the transformation of cropland into agroforestry. This shift can play a positive role in conserving native species, particularly in coffee agroforestry, and in soil conservation. Research in southwest Ethiopia has shown that the transition from forests to wild and semi-wild shade coffee systems has preserved over 60% of native woody biodiversity [19, 47, 48]. Similarly, [45] reported the expansion of woodlots of *Acacia decurrens*, which are being established as part of a sustainable livelihoods initiative and land revitalization strategy, at the expense of cultivated lands in the Fagita Lekoma District of northern Ethiopia. Tadesse [19] also indicated that the conversion of native forests to coffee farms, Eucalyptus, and tea plantations over the past 40 years in the Shaka and Keffa zones of the SNNPRS has been a major contributor to more than 50% of forest cover loss. This contrast with the findings of [46], which showed that coffee agroforestry in the Abaya-Chamo Basin of southern Ethiopia, was being converted into heterogeneous agricultural areas. The increasing demands for housing, food, and firewood driven by population growth were identified as the primary causes of forest degradation around Arba Minch, Southern Ethiopia [49].

Table 5. *Change matrix of Land cover change (LCC) types (km^2) between 1986 and 2018.*

	Land Cover Categories	Initial area (km^2) (1986)				
		Agroforestry	**Cropland**	**Forestland**	**Settlement**	**Total**
Final state (2018)	Agroforestry	122.48	84.33	63.18	0.98	271.00
	Cropland	1.88	8.74	4.44	0.00	15.08
	Forestland	7.87	4.32	77.38	0.06.	89.6
	Settlement	6.16	2.05	0.90	0.84	9.94
	Class Total	138.39	99.44	145.90	1.88	385.62
	Class changes	15.91	15.11	82.72	0.90	
	Image difference	132.61.	-84.36	-56.31	8.05	

3.2. Soil Physicochemical Properties

3.2.1. Soil Physical Properties

The conversion of forestland to other managed land uses can significantly alter the physicochemical properties of the soil. Globally, the transition from natural forestland to agricultural land is a major concern, as it often leads to soil degradation and disrupts nutrient cycles [25, 50]. Soil texture is a critical characteristic, as approximately 70% of soil organic matter (SOM) is associated with the fine earth fraction [27]. Our results indicated that the three land uses exhibited similar texture classes, specifically sandy loam. The particle size distribution (sand, clay, and silt) did not significantly differ across the various land uses ($P > 0.05$) (Table 6). This stability in soil texture and its inherent characteristics may suggest that they are not significantly impacted over a short period following land use change [51], especially given the less destructive nature of farming systems in the area. Similar findings were reported by [41] in the Abobo area of western Ethiopia. However, [52] noted variations in sand and clay content, with forest land showing the highest sand and lowest clay content, while cultivated land showed the opposite. The discrepancies between the two study areas may be attributable to differences in parent material and farming practices such as plowing, clearing, and leveling of agricultural fields. Conventionally, the conversion of forests into other land uses, such as cropland, is known to deteriorate soil physical properties, making the land more susceptible to erosion, disturbing soil structure (particularly macro-aggregates), and altering soil texture [53].

Table 6. *Mean value of particle size distribution and bulk density of the study land uses.*

Land use	sand	Silt	Clay	BD (g/cm^3)
Agro-forestry	60.83^a	23.67^a	15.5^a	0.96^b
Cropland	55.17^a	28.33^a	16.5^a	1.03^a
Forestland	57.33^a	30.67^a	14.33^a	0.78^c
LSD	NS	NS	NS	0.07
CV%)	6.9	22.04	15.66	6.37

Means within column followed by the same letter are not statistically different from each other at $P > 0.05$; LSD = least significant difference; NS= non- significant; CV = coefficient of variation; Agro forestry; cropland; 3=forest land. BD = bulk density

Soil bulk density showed a highly significant difference ($P < 0.0001$) among the three land uses. The highest bulk density measured was 1.03 g/cm^3 in the cropland, while the lowest was 0.78 g/cm^3 in the forestland (Table 6). This finding is consistent with previous studies [54, 55, 24]. The elevated bulk density in croplands may be attributed to a reduced pore space resulting from trampling effects caused by repeated tillage practices and soil compaction, as well as low organic matter content in croplands and the continuous exposure of bare soil to the direct impact of raindrops. Furthermore, the ongoing removal and burning of crops and cut plants negatively affect soil bulk density by decreasing the amount of soil organic matter (SOM) returned to the soil system, reducing structural stability, and subsequently increasing soil bulk density [10, 54].

3.2.2. Soil Chemical Properties

Soil pH is an important indicator of soil quality across different land uses [56]. However, no significant difference ($P > 0.05$) was observed between forestland and agroforestry. Similar findings were reported in previous studies conducted in the Gacheb catchment in southwest Ethiopia [16, 57]. In contrast, the pH levels of both forestland and agroforestry were found to be significantly higher than those of cropland ($P < 0.001$) (Table 7). The lowest mean soil pH observed in cropland may be attributed to the depletion of basic cations caused by crop harvesting [58] and the leaching of these cations, along with their removal due to soil erosion resulting from high rainfall [52]. Previous studies in Ethiopia [16, 52, 57, 59] (have also reported lower soil pH in cropland compared to adjacent forestland.

Table 7. *Mean values of soil chemical properties of the study land uses.*

Land use	pH	SOC%	TN%	AVP (ppm)	EC mS/cm	CEC	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}
Agroforestry	6.11^{a}	3.37^{b}	0.22^{b}	14.31b	73^{b}	20.19^{b}	11.95^{b}	1.58^{b}	11.35^{b}	0.0146^{a}
Cropland	5.49^{b}	1.86^{c}	0.09^{c}	9.32c	44.53^{a}	13.91^{c}	8.06^{c}	1.12^{c}	6.96^{c}	0.00890^{b}
Forestland	6.36^{a}	4.82^{a}	0.38^{a}	19.45a	47.16^{a}	25.40^{a}	15.82^{a}	1.95^{a}	14.73^{a}	0.0094^{b}
LSD	0.25	0.52	0.08	2.62	16.73	1.93	2.61	0.26	1.83	0.003
SEM	0.08	0.16	0.028	0.83	5.31	0.73	0.94	0.09	0.61	0.00098
CV	3.32	12.24	29.57	14.19	23.70	7.58	17.01	13.26	12.93	23.69

Means with in column followed by the same letter are not statistically significant from each other at $P > 0.05$. LSD = Least significant difference, SEM=Standard error means, CV = coefficient of variation.

Soil organic carbon (SOC) exhibited highly significant differences among the three land uses ($P < 0.0001$). The mean differences between forestland and cropland, as well as between forestland and agroforestry, were statistically significant ($P < 0.05$), while the mean difference between forestland and cropland was highly significant ($P < 0.01$) (Table 7). This study aligns with various previous findings [16, 23, 24, 57]. Continuous supply of litter and decaying woody parts from the forest, along with a reduced decomposition rate due to low aeration and soil temperature, likely resulted in high SOC levels in both forestland and agroforestry. In contrast, the low SOC in cropland can be attributed to limited inputs from removed crop residues, the burning of slashed plant material during tillage, and increased decomposition rates associated with higher soil temperatures and improved aeration following tillage. Other studies confirm that the amount of soil organic matter (SOM) in arable land is typically lower than in forests, primarily because harvesting reduces organic matter inputs to the soil [26, 27, 29] and due to the removal of biomass during harvest, accelerated mineralization rates due to tillage-induced aeration, and SOM loss through erosion [26, 60].

Soil total nitrogen (TN) is commonly used as an important index for evaluating soil quality, as it reflects the nitrogen status of the soil [61]. The total nitrogen content among the study's land uses was very highly significantly affected by land use change ($P < 0.0001$) (Table 7). Cropland exhibited the lowest TN (0.09%) compared to agroforestry (0.20%) and forestland (0.38%). A strong and significant correlation was observed between total nitrogen content and organic matter content ($r = 0.796^{**}$) (Table 8). According to earlier studies, the processes that deplete SOC in cropland also affect total nitrogen content, as organic matter serves as a source for both [62] (Brady and Weil, 2001). The study by [10, 58] also demonstrated the parallel variations of total nitrogen content with organic matter content. Various studies have reported higher amounts of TN in agroforestry and forestry compared to cropland [10, 16, 50, 57]. The removal of biomass during harvest, increased mineralization rates due to tillage-induced aeration, and losses due to erosion are likely reasons for the low TN levels in cropland. Additionally, the mineralization of accumulated SOM to ammonia and the activity of nitrogen-fixing bacteria in cropland may contribute to low TN levels in these areas.

The results indicated that available phosphorus (AvP) content was very highly significantly affected by land uses ($P < 0.0001$). The highest mean value of AvP was recorded in forestland (19.458 ppm), followed by agroforestry (14.31 ppm) and cropland (9.32 ppm) (Table 7). The lower concentration of phosphorus in cropland may result from the continuous loss of phosphorus due to crop harvesting and the removal of plant residues. Furthermore, the continuous application of organic matter (OM) through litter fall and decaying plants in forest and agroforestry areas can increase soil phosphorus availability through the decomposition and mineralization of organic phosphorus (OP), thus reducing phosphate adsorption in the soil colloids [63]. There is a strong and significant correlation between phosphorus levels and soil organic matter (r = 0.73**) (Table 8). The relatively higher moisture levels in forestland, due to a substantial ground cover from litter as well as above-ground vegetation, enhance phosphorus solubility [64]. Additionally, erosion may contribute to lower phosphorus levels in cropland. This study also agrees with various previous findings [16, 57, 58, 65, 66].

The electrical conductivity (EC) values were significantly affected by land use ($P < 0.05$). The highest mean EC value was recorded in agroforestry (73 mS/cm), while the lowest was in cropland (44.53 mS/cm), with a significant difference between them (Table 7). Conversely, the mean EC values for forestland and cropland were not significantly different ($P > 0.05$). The higher EC in agroforestry may be attributed to increased levels of basic cations, whereas the lower EC in cropland could be linked to leaching of basic cations caused by crop residue removal and harvesting, as well as soil erosion resulting from high rainfall in the area. These findings are consistent with those reported by [67]. According to [68], the EC levels of all land uses fall under non-saline conditions (EC < 2 dS/m).

Table 8. *Pearson's correlations of measured soil properties.*

	pH	SOC	TN	AP	EC	Sand	Clay	silt	CEC	Ca2+	Mg2+	K+	Na+	BD
pH	1													
SOC	0.46ns	0.796**												
TN	0.46ns	0.796**	1											
AP	0.49*	0.73**	0.84**	1										
EC	0.44ns	0.83**	0.80**	0.63**	1									
sand	-0.64**	0.18ns	0.018ns	0.15ns	-0.088ns	1								
clay	-0.33s	0.23ns	0.2s	0.14ns	0.15ns	0.56*	1							
Silt	-0.198ns	-0.31ns	-0.39ns	-0.08ns	-0.40ns	0.07ns	-0.24ns	1						
CEC	0.43ns	0.54*	0.11ns	-0.06ns	0.17ns	-0.54*	-0.68**	-0.54*	1					
Ca^{2+}	0.46ns	0.83**	0.79**	0.84**	0.78**	0.14ns	0.14ns	-0.103ns	-0.04ns	1				
Mg2+	0.42ns	0.79**	0.71**	0.78**	0.73**	0.072ns	0.031ns	-0.102ns	0.05ns	0.87**	1			
K+	0.38ns	0.81**	0.72**	0.73**	0.77**	0.013ns	0.08ns	-0.04ns	-0.03ns	0.89**	0.88**	1		
Na+	0.38ns	0.88**	0.81**	0.67**	0.96**	0.018ns	0.15ns	-0.44ns	0.20ns	0.80**	0.77**	0.81**	1	
BD	-0.64**	0.17ns	0.018ns	0.15ns	-0.09ns	0.99**	0.56**	0.071ns	-0.53*	0.14ns	0.07ns	0.012 ns	0.016 ns	11

ns. Correlation is non-significant; *. Correlation is significant at the 0.05 level (two tailed); **. Correlation is significant at the 0.01level (two tailed).

The cation exchange capacity (CEC) values of the soils in the study area were highly significantly affected by land use change ($P < 0.0001$). The highest CEC value, 25.4 cmol (+)/kg, was observed in forestland, while the lowest, 13.91 cmol (+)/kg, was recorded in cropland. According to Landon (1991), the CEC classifications for topsoils categorize forest, agroforestry, and cropland as having high CEC (> 25 cmol (+)/kg), medium CEC (15-25 cmol (+)/kg), and low CEC (5-15 cmol (+)/kg), respectively. The low CEC in cropland may be attributed to soil erosion and the reduction of soil organic matter (SOM) [69, 29]. Other studies have reported similar results, indicating that lower CEC in cropland is related to lower SOC levels [70, 65, 10, 58]. The results also revealed a significant correlation between SOC and CEC (r = 0.54*).

The results indicated that the content of exchangeable cations such as Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+} was highly significantly affected by land use change ($P < 0.001$). The mean values of Ca^{2+}, Mg^{2+}, and K^{+} were highest in forestland, followed by agroforestry and cropland (Table 7). However, for Na^+, agroforestry exhibited higher levels than the other land uses, while the soils under cropland and forest showed slight differences, with their mean values being non-significant ($P > 0.05$). The probable reasons for lower levels of Ca^{2+}, Mg^{2+}, and K^+ in cropland could include their removal through various processes such as erosion, crop harvesting, removal and burning of crop residues and slashed plants, and leaching. These results are consistent with previous studies conducted in Ethiopia [10, 58, 69, 71, 72], which also reported lower levels of Mg^{2+}, Ca^{2+}, and K^+. Furthermore, studies by [24] and [58] reported non-significant differences ($P > 0.05$) in Na^+ content among various land use types, which supports the findings of this study.

4. Conclusion

LU/LC change analysis is a valuable tool for understanding the dynamics land cover including their patterns and consequences. The LU/LCC analysis revealed considerable changes in land cover over the past three decades. There was a reduction in both forestland and cropland, along with a significant increase in agroforestry and settlement during the study period. Over the last 32 years, agroforestry and settlement increased by 95% and 428.7%, respectively, while forestland and cropland decreased by 38.6% and 96%, primarily due to the expansion of cash crops such as coffee and khat, as well as the planting of eucalyptus trees and population growth. Significant land cover changes in forestland, cropland, and agroforestry occurred between 1986 and 2001, whereas settlement increased significantly from 2001 to 2018.

The study also highlighted the detrimental effects of LU/LCC on soil resources. Soil physical properties, such as bulk density, and chemical properties, including soil organic matter (SOM), total nitrogen (TN), available phosphorus (AvP), pH, Ca^{2+}, Mg^{2+}, K^+, Na^+, electrical conductivity (EC), and cation exchange capacity (CEC), were significantly altered over the past 32 years, while soil texture was not significantly affected.

Therefore, it can be concluded that the LU/LC change experienced over the last three decades is significant and has led to adverse impacts on soil quality and the sustainability of agriculture in the area. As a result, the reduction of forest cover and soil fertility highlights the need for a sustainable natural resource management plan. Further studies are essential to assess the impact of LU/LC change on plant and animal biodiversity, ecosystem services, and the livelihoods of the community.

Abbreviations

AAS	Atomic Absorption Spectrophotometer
ANOVA	Analysis of Variance
BD	Bulk Density
CEC	Cation Exchange Capacity
EC	Electrical Conductivity
ERDAS	Earth Resources Data Analysis System
FAO	Food and Agriculture Organization
FGD	Focused Group Discussions
GCP	Ground Control Points
GPS	Global Positioning System
LU/LC	Land Use Land Cover
MLC	Maximum Likelihood Classification
OC	Organic Carbon
SOM	Soil Organic Matter
TN	Total Nitrogen

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Author Contributions

Mesfin Gubila: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Writing – original draft, Writing – review & editing

Alemayehu Regassa: Conceptualization, Data curation, Formal Analysis, Methodology, Supervision, Validation, Writing – review & editing

Gudina Legess: Methodology, Supervision, Validation, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

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Research Field

Mesfin Gubila: Land use land cover change analysis, Integrated watershed management and landscape response

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Kassahun Mulatu: Land Use Land Cover Change Analysis, Wetland Resource Management and research, Watershed management and landscape ecology, Agroforestry and biodiversity research, Forest resource and its biodiversity research