RESEARCH ARTICLE

Changes in land use land cover and its impact on selected properties of soils in Sdeyni micro-watershed, Northeastern Ethiopia

Worku Teshome, Endalkachew Fekadu*, Haile Getnet

Teshome W, Fekadu E, Getnet H. Changes in land use land cover and its impact on selected properties of soils in Sdeyni micro-watershed, Northeastern Ethiopia. AGBIR.2025;41(6):1-7.

Land use and land cover changes have contributed to land degradation that result from unsustainable agricultural practices. Hence, this assessment was done to evaluate land use land cover changes and their impacts on the properties of soils in the Sdeyni micro-watershed in Northeastern Ethiopia. Satellite images for the periods of 1984, 2000 and 2020 were gathered to evaluate the land use changes. Cultivated land, forest land and grassland were selected to determine their effects on soil properties. Eighteen disturbed composite and 18 undisturbed core soil samples were collected from the selected three land use types at two depths with three replications. The result showed that within 36 years, the overall pattern of forest land declined by 188 ha (1.79%) from 1984-2020 with an annual rate of 0.47% due to the conversion of forest lands to cultivated and grasslands. The forest and grasslands were decreased by 1.8 and 6.7%, respectively, relative to the starting year. Contrary to this, an increase in the size of cultivated and settlement lands were detected by 5.1 and 3.6%, respectively, compared to 1984. In all land uses, bulk density increased with depth, where the highest value was obtained in the cultivated lands. Across land uses, soil pH varied from 5.57 to 6.93 and it was found in a moderately acidic soil reaction. Significantly higher contents of OC, total N and available P were obtained on the surface soil of the forest lands. Exchangeable bases and CEC showed significant differences among land use types and soil depths. All the analyzed bases were more concentrated in the subsoil of the forest lands, whereas the lowest values were observed on the cultivated lands. Therefore, it indicates that the Sdeyni watershed required immediate interventions and sustainable land management to protect the forest lands and improve agricultural productivity. Application of organic materials and chemical fertilizers and amendments should be improved on cultivated lands.

Key Words: *Land cover; Soil properties; Watershed; GIS; Degradation*

INTRODUCTION

Land cover involves the bio-physical cover of the surface of the land, while land use describes the utilization of the diverse activities on land. Land Use Land Cover Change (LULCC) entails reforms of the land surface applied by man for social and economic needs. For instance, forest lands are converted to agricultural lands due to the alarming rate of population growth and increasing human demand. Changing forest lands into cultivated land affects soil aggregate stability, in turn reduces aeration, infiltration, nutrient movement and biological activities. Land cover changes cause physical, chemical and biological degradation of soils, reduced carbon storage, loss of soil flora and fauna and eventual desertification, all of which contribute to the changing climate.

In Ethiopia, land use change mainly comes from the change of lands covered by forest to cultivation and settlement use. These are aggravated by increasing population and other natural and man-made factors that caused the replacement of grasslands and forests by other land uses like farmlands and settlements. Most of the time, soil nutrient depletion and soil degradation contribute to land use changes. Such LULCC and the lack of fallow period on cultivated lands and uncontrolled grazing for long years resulted in a tragic yield decline, mainly in the highlands of Ethiopia, where there has been frequent erosion occurrences.

Increased clearance of forest areas and weak land management plans have significantly contributed to increased runoff, soil loss and nutrient depletion in most highlands of the country. Expansion of lands for farming and settlements on the one hand and shrinking of grass and forest lands on the other are observed in various regions of Ethiopia, mainly due to increased population pressures, livelihood factors and policy implications. The growing size of the population becomes a national challenge to make use of the available land resources for efficient agricultural production. In Ethiopia, the largest segments of the population have based farming as one of the most important economic activities. However, competition for the existing lands for complex and diverse economic, social and environmental functions has limited agricultural development. Natural resource decline and environmental deterioration due to the expansion of farmlands on steep slopes with improper management practices are observed in Ethiopia. Therefore, reversing the situation and improving production will play a vital role in ensuring food security and thereby reducing poverty in tropical Africa. Such recognized LULC changes without a scientific land use plan are typical characteristics of Habru District. The productivity of soils has decreased with the resultant yield decline. Thus, planning of the available land to meet the needs of the people and intervention of management call for identification, evaluation and mapping of the past and the present LULC changes. Analyzing the time and space dynamics in land cover change and its impacts on the properties of soils could provide information for the efficient use of land resources. Thus, this analysis was designed to determine the LULC changes and associated impacts on selected physico-chemical properties of soils in the Sdeyni watershed.

MATERIALS AND METHODS

Description of the study area

Sdeyni micro-watershed, which is found in the Habru District of Northeastern, Ethiopia (Figure 1) lies between 11°45'13" to 11°27'35"North and 39°38'17" to 39°49'22"East covering about 10461ha with an altitude ranging from 1500 to 2400 meters above sea level (masl).

Department of Soil Resource and Watershed Management, Woldia University, Woldia, Ethiopia

Correspondence: *Endalkachew Fekadu, Department of Soil Resource and Watershed Management, Woldia University, Woldia, Ethiopia; E-mail: endalkf@gmail.com*

Received: *09-Apr-2024, Manuscript No. AGBIR-24-131929;* ***Editor assigned:*** *11-Apr-2024, PreQC No. AGBIR-24-131929 (PQ);* ***Reviewed:*** *24-Apr-2025, QC No. AGBIR-24-131929;* ***Revised:*** *03-Nov-2025, Manuscript No. AGBIR-24-131929 (R);* ***Published:*** *10-Nov-2025, DOI: 10.37532/0970-1907.25.41(6):1-7*

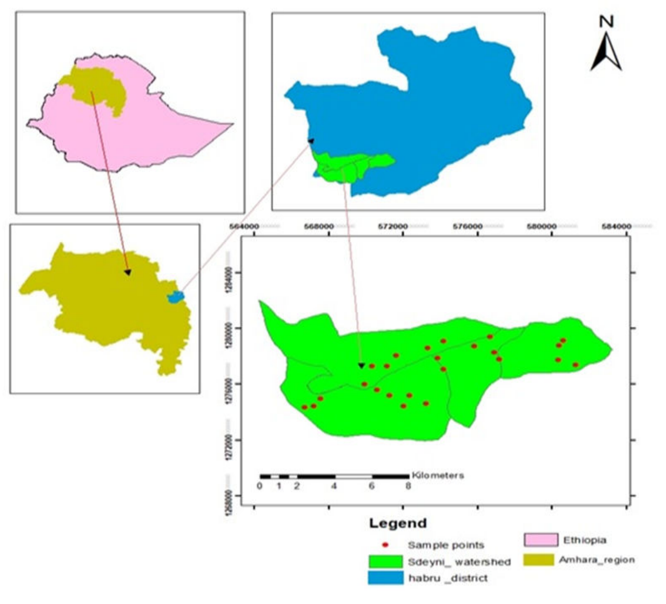

Figure 1) *Location map of Sdeyni micro-watershed*

Mountains (35%), flat (40%), valleys (22%) and others (3%) shared the topographic setting of the area. Based on Habro district agricultural office's (2020) unpublished report, cultivated land (44%), grazing land (20%), forest/ shrub land (23%), settlement (10%) and bare land (3%) shared the district land use pattern. Agro-ecologically, the area is classified into lowland (kolla) (64.7%), midland (woina-dega) (32.3%) and highland (dega) (3%) zones. According to national meteorological service agency, the area receives 700 to 1000 mm average annual rainfall with erratic distribution. The average annual temperature varies from 15°Cto 28°C. October is the coldest month, while May and June are the warmest. Mixed cultivated-livestock farming system, where cultivated production is dependent on using both rain-fed and small-scale irrigation systems. Commonly grown cereal crops include teff, sorghum and maize while different vegetables such as cabbage, pepper, tomato, onion and fruits like orange, mango and lemon are grown by using an irrigation system. The natural vegetation cover comprises some tree species that include forest and shrubs and are mostly found in sloping areas. Most likely, scattered tree species such as *Acacia* spp. and *Zizphus* spp's are practical on the farmlands, while the upper lands of the watershed are predominantly covered with *Olia africana* and *Eucalyptus* species. Soil and water conservation practices such as trenches, hillside terraces with trenches, stone-faced soil bunds, check dams and hillside terraces are commonly found in most of the watershed, although there are technical limitations in design and construction. Diminished crop productivity from time to time is mentioned by farmers in the area because of the observed change in climate and improper land use systems (Table 1).

TABLE 1
Definitions of land use land cover types

Land use/ land cover	Definitions
Cultivated land	Areas under farming by rain fed and irrigation to produce cereals, pulses, vegetables with some trees scattered in some areas of the cultivated fields
Forest land	Areas having closed or nearly closed canopies of trees, could be natural forest or plantation
Grass land	Lands covered by grasses, smaller bush and shrubs are grown, grasses are cut and fed to animals
Settlement	Areas of lands with buildings for commercial, residential or transportation infrastructures
Bare land	Areas having little or devoid of vegetation because of continuous cultivation, overgrazing or erosion

Field survey

A reconnaissance survey was carried out in December 2020 in the watershed to acquire an overview of the land use types, topographic features and aspects and to decide the representative land uses for soil sampling. Five major land uses (bare land, settlement, grassland, cultivated land and forest) were carefully chosen in the watershed following a reconnaissance survey. Land uses with a similar aspect and slope class (5-10%) were purposively selected before starting the soil sampling operation to avoid bias. To validate the processing and classification of images, Ground Control Points (GCPs) sample collection was done by using GPS.

Data acquired and sources

To evaluate land cover changes, the satellite images for the three periods (1984, 2000 and 2020) were obtained from the United States Geological Survey (USGS) earth explorer. Various types of acquired images were considered to cover the study periods. Hence, the Landsat 8 Operational Land Imager (OLI) and Thematic Mapper (TM) were used for the analysis of LULCC of the watershed. All images were obtained from the USGS center and are geo-referenced to ADINDAN UTM zone 37N (Table 2).

TABLE 2
Description of the satellite image multi-spectral sensor for study area

Satellite image	Sensor	Acquisition date	Pixel resolution (m)	No. bands
Land sat 5	TM	21-04-1984	30*30	7
Land sat 5	TM	16-03-2000	30*30	7
Land sat 8	OLI	08-04-2020	30*30	11

Land cover change analysis

The downloaded Landsat images of 1984, 2000 and 2020 were extracted by using WinRAR software into TIFF format. The tiff format is changed to image format by using Envi software by stacking the layers and re-projecting the scenes to UTM Zone 37 North was made using WGS 84. Then, land use/ cover classes were produced by the supervised digital image classification method using exercises taken based on the false color composite (reflectance characteristics) of each land use/cover class). Classification, labeling and calculation of each LULC in the watershed were done using Arc GIS 10.3 software [1]. Five types of LULC types, such as forest land, cultivated land, grassland, bare land and settlement were specified. Finally, maps for these LULC were produced for the three years' study periods and the results were compared.

The accuracy assessment was done by taking 20 Ground Control Points (GCP) from each LULC, to generate 100 reference points for the whole study area. Then the assessment of accuracy for the classification was done following the four common performance criteria: Producer accuracy (column total), user accuracy (row total), overall accuracy and kappa coefficient (K) (row and column) were analyzed from classified images of LULC type. The classification was finally confirmed using GCPs to verify the accuracy of the classified LULC map. All the required corrections were made based on the ground truth to analyze LULC change. The areas were presented in hectares (ha) and percentage (%) changes among the three years 1984, 2000 and 2020 were quantified for LULC changes in the Sdeyni watershed.

Sampling site selection

Among the classified LULC types in the watershed, only three land use types (cultivated land, forest land and grassland) were selected for soil sampling. Composite soil samples from 0-20 cm and 20-40 depths were collected from each land use following the zigzag pattern with three replications [2]. Totally, 18 disturbed soil samples were collected, bagged and labeled. In the same way, 18 undisturbed soil samples were collected using a core. Soil samples were taken to the Sri Lanka Agricultural Research Center (SARC) soil laboratory for the determination of selected physical and chemical soil properties.

Laboratory analysis

Soil particle size proportion was determined using Bouyoucos hydrometer method as developed by day whereas Bulk Density (BD) of soils was calculated from dried soil mass to its bulk volume.

A soil to water (1: 2.5) suspension was prepared and used to determine soil pH and electrical conductivity [3]. Soil OC was determined following the Walkley and Black methods. The organic matter content of the soil was then determined by multiplying the OC percentage by 1.724. Kjeldahl procedures, as described by Walkley and Black were employed to determine the soil total N content of while Olsen, et al., method was served to determine the available P. Cation exchange capacity was determined by ammonium acetate distillation and titration procedures [4]. A flame photometer was employed to read exchangeable Na^+ and K^+ from the leachate whereas an Atomic Absorption Spectrophotometer (AAS) was used to read exchangeable Ca^{2+} and Mg^{2+} as described by Rowell. The percent base saturation of soils was determined by dividing the sum of exchangeable bases by the CEC of the soil sample and multiplying by 100 [5].

Statistical analysis

Variation in soil physical and chemical properties among land use types and soil depths was analyzed by using a two-way Analysis of Variance (ANOVA) applied to factorial experiments using R software. Means for significant values were separated using Tukey's honest test at 5% probability level.

RESULTS AND DISCUSSION

Land use/land cover change for periods (1984, 2000 and 2020

In all the study periods, lands under cultivation have covered the main land use type in the Sdeyni micro-watershed. From the total land area evaluated, cultivated land accounted for about 41.9%, 43.7% and 47% in the periods 1984, 2000 and 2020, respectively (Table 3). This showed that areas under cultivation were constantly increasing in the first sixteen years (1984-2000) with an increment of 193 ha (1.85%) [6]. The analysis LULC also indicated that the area of forest land has covered 997 ha (9.7%), 926 ha (8.9%) and 809 ha (7.7%) in the years 1984, 2000 and 2020, respectively (Table 4). This showed that the area of forest land declined by 71 ha (0.68%) for the first sixteen years and by 117 ha (1.2%) for the second study period. The decrease in forest area for the first and second study periods was due to the deforestation of natural forest and plantation trees by farmers on their communal and farmlands, respectively.

Within 36 years, the overall pattern of forest land declined by 188 ha (1.79%) from 1984 to 2020 with an annual rate of 0.47% (Table 3). This occurred as a result of changing lands covered by vegetation and forest to cultivation and grass. Significantly large areas in the watershed are devoted to cultivation, while the smallest portion is covered by bare land [7]. Relative to the reference year, forest and grasslands were decreased by 1.8 and 6.7%, respectively. On the other hand, compared to the base year of 1984, cultivated land and settlement showed an increase of 5.1 and 3.6%, respectively. The analysis indicated that larger areas in the watershed, which had been previously used for tree and grass production, are now being changed to crop production and settlement (Table 3 and Figure 2) [8]. For instance, 9.5% of the area occupied by forests in 1984 declined to 7.7% in 2020. In comparison, cultivated land expanded from 41.9% in 1984 to 47% in 2020. The LULC analysis showed that the area of grassland decreased by 0.94% during the first period and by 5.71% during the second period. Grassland has decreased by a total of 695 ha over the past thirty-six years. It decreased from 41.1 to 34.4% in area coverage, with 0.45% annual rate in the watershed. This is due to the high population density in rural areas, which depends more on agricultural activities, than other alternative forms of employment [9]. Kindu, et al., reported an increase in cultivated lands from 13,498 ha to 50,317 ha between 1973 and 2012 in Munessa, Shashemene. Similar reports also showed the expansion of cultivated and settlement areas by 20.04 ha (5.19%) from the year 1982-2008 in the Debre-Mewi watershed, Ethiopia. In another landscape of the Ethiopian highlands, Tara Gedam, there was a decline in forest coverage of 71% with 1.54% annual rate of deforestation [10,11]. Such significant forest removal was practiced to search for additional land to grow crops in protected areas. The decline of grassland might be due to the increasing demand for grazing land, cultivated land and settlements. Such LULC changes were common in the Northwestern parts of Ethiopia, where grazing lands were gradually being changed to settlement and cultivated lands due to the ever increasing population density.

TABLE 3
Land use the land cover of the Sdeyni watershed from 1984 to 2020

		Land use land cover (ha)						Rate of changes in LULC classes in ha and % (1984-2020)					
NO	LULCS	1984 (ha)	%	2000 (ha)	%	2020 (ha)	%	1984 To 2000	%	2000 To 2020	%	1984 to 2020	%
1	Bare land	272	2.6	151	1.4	237	2.3	121	1.2	86	0.9	35	0.3
2	Cultivated land	4380	41.9	4573	43.7	4921	47	193	1.8	348	3.3	541	5.1

3	Forest land	997	9.5	926	8.9	809	7.7	188	0.6	117	1.2	188	1.8
4	Grass land	4298	41.1	4200	40.2	3603	34.4	98	0.9	597	5.8	695	6.7
5	Settlement	513	4.9	611	5.8	891	8.5	98	0.9	280	2.7	378	3.6
	Total sum	10461	100	10461	100	10461	100						

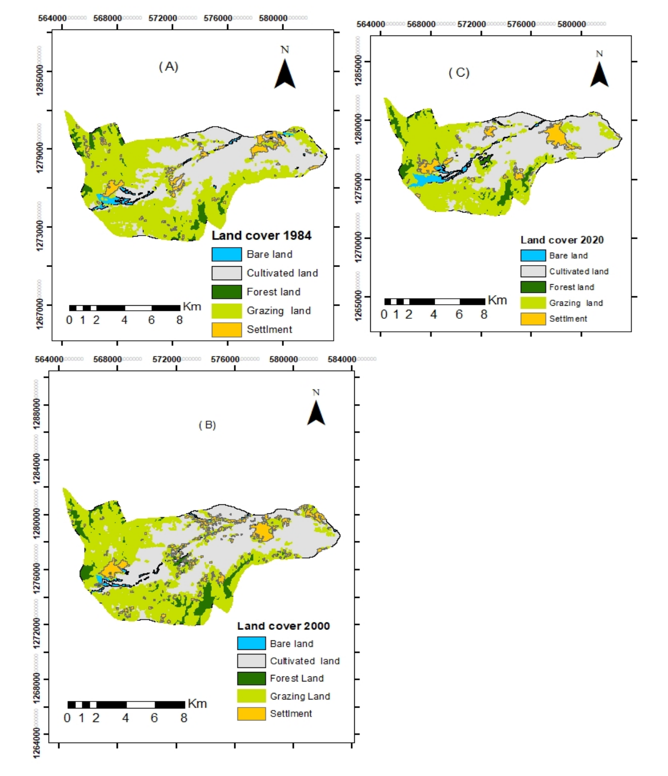

Figure 2) *Land use land cover in (A) 1984 (B) 2000 and (C) 2020*

Accuracy assessment of the classification

An error matrix was employed to compare the classified maps with the referenced data and ground truth. The overall accuracies for 1984, 2000 and 2020 were 92.7%, 95% and 95.6%, with a Kappa coefficient of 0.89, 0.90 and 0.94, respectively (Tables 4-6). The user's accuracy assessment showed that in 1984 the highest class accuracy was obtained for forest land (100%), while the lowest belonged to cultivated land (81.2%). In the year 2000, the maximum class user's accuracy was for grassland (99.63%), with the lowest accuracy for settlement (77.15%) to relatively correctly classified (99.54%) in cultivated land, whereas in the period 2020, the maximum class user's accuracy was for bare land (99.83%) and the minimum was for grassland (83.99%), respectively [12-15]. The producer's accuracy assessment showed that cultivated land, forest land and the correctly classified map had 99.5%, 100% and 99.89% accuracy values in 1984, 2000 and 2020, respectively. The lowest accuracy was grass land (86.02%), cultivated land (93.4%) and settlement area (92.7%) in 1984, 2000 and 2020, respectively.

TABLE 4
LULC change matrix of the Sdeyni watershed 1984

LULC1984	Forest	Bare land	Cultivated land	Settlement	Grass land	Producer accuracy
Forest land	372	0	0	0	0	100
Bare land	0	126	2	0	23	98.44
cultivated land	0	0	846	0	196	99.53
Settlement	0	0	2	186	0	98.41
Grass land user's	0	2	0	3	1348	86.02
accuracy%	100	83.44	81.19	98.4	99.63	

Note: Overall accuracy=92.6%; Kappa coefficient=0.89

TABLE 5
LULC change matrix of the Sdeyni watershed 2000

LULC 2000	Forest	Bare land	Settlement	Cultivated land	Grassland	Producer accuracy
Forest	1065	0	1	0	3	100
Bare land	0	201	2	0	0	97.57
Settlement	0	0	584	171	2	99.15

cultivated land	0	5	0	5836	22	93.41
Grassland	0	0	2	241	911	97.12
User accuracy	99.63	99.01	77.15	99.54	78.94	
Note: Overall accuracy= 95%; Kappa coefficient=0.90						

TABLE 6

LULC change of Sdeyni watershed matrix 2020

LULC 2020	Forest	Cultivated land	Settlement	Bare land	Grass land	Producer accuracy
Forest land	2417	0	0	0	5	99.71
Cultivated land	0	5734	37	0	35	93.6
Settlement	0	21	2020	0	0	92.7
Bare land	0	0	1	584	0	95.89
Grass land	7	371	121	25	2749	98.57
users accuracy	99.79	98.76	98.97	99.83	83.99	
Note: Overall accuracy=95.6%; Kappa coefficient=0.94						

Effects of land use types on soil physical properties

Soil particle size distribution was not affected by land use types, soil depth or their interaction. However, numerical variations existed among the studied land uses. Looking at sand particles on the surface layers of each land use, the highest (25.56%) and the lowest (18.0%) values were obtained on the cultivated and forest lands, respectively. In contrast, the highest (56.57%) and lowest (52.92%) proportions of clay were obtained in the subsoil of the forest and cultivated lands, respectively (Table 7). Generally, the clay content increased with depth in all land use types and the reverse was observed for the silt content.

TABLE 7

Effects of land use types and soil depth on selected soil physical properties

Land use type	Bulk density (g/cm^3)		Clay (%)		Silt (%)		Sand (%)	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20	20-40
Cultivated land	1.05^a (0.02)	1.10^a (0.08)	45.75^a (4.82)	52.92^a (0.57)	28.75^a (5.00)	25.66^a (0.57)	25.5^a (9.26)	21.42^a (0.08)
Grassland	0.84^b (0.05)	0.95^b (0.01)	49.58^a (2.88)	54.24^a (2.64)	27.92^a (3.82)	24.47^a (2.64)	22.5^a (2.64)	20.94^a (0.41)
Forestland	0.79^b (0.03)	0.82^b (0.04)	53.08^a (3.54)	56.57^a (0.28)	28.91^a (2.75)	22.08^a (0.28)	18.0^a (2.64)	21.34^a (0.27)
CV	4.67	5.58	7.75	2.87	13.89	6.57	27.7	1.36

However, the overall mean clay fraction increased numerically with soil depth. The relatively higher proportion of sand particles on the surface layer might be associated to clay movement to the subsoil and its removal from land surface by heavy runoff that led to an increased concentration of sands on the soil surface [16].

Soil bulk density showed a significant difference among land use types and soil depths where higher bulk density was found in the subsurface layer of each land use type. The highest bulk density was measured in the subsurface layer of the cultivated land. Yitbarek, et al., reported highest bulk density value on the surface soil of the cultivated land in comparison with other land uses. According to Hazelton and Murphy, the bulk density values obtained in the watershed are within the agriculturally suitable range of 1.1 gcm^{-3} to 1.4 gcm^{-3}. The higher content of OM accumulated from litter fall and limited livestock movement could contribute to the lower bulk density values in the soils of the forest land whereas, plowing might favor higher bulk density in the soils of cultivated lands because, it tends to hasten the rate of OM decomposition, thereby decreasing aggregations of soil particles. Likewise, Abad, et al. and Takele, et al., indicated higher bulk density on cultivated lands at 0 cm-30 cm depth as compared to forest and grazing lands [17].

Effects of land use types on selected soil chemical properties

Soil reaction (pH): Soil pH varied ($P \leq 0.05$) significantly across land use types and with soil depths. Grassland soils were obtained with the highest pH mean value while cultivated land soils were the lowest (Table 8). The increase in soil pH in the subsoil may be related to the accumulation of basic cations through leaching. As per the rating criteria suggested by Hazelton and Murphy, the soil pH in the watershed ranged from 5.57 to 6.93 and was classified as moderately acid soil. Compared to the other land use types, the lowest soil pH was found in the cultivated land. In agreement with this finding, Mulat, et al., reported that the soil pH was the lowest in the soils of the cultivated land.

Organic matter, total N and available P

Land use types and soil depths caused significant ($P \leq 0.05$) differences in soil OM content (Table 8). Soils in the upper layer of the forest lands were the highest while the subsurface soils of the cultivated lands were the lowest in soil OM content. The highest soil OM found on the surface of the forest land could result from the addition of litter fall and the lower decomposition rate [18]. In the same way, Duguma, et al., explained reduced OM content with going down the soil profile because of reduced root biomass and lower biomass turnover.

TABLE 8
Soil pH, OM, total N, available P and CEC on different land uses and soil depth

Land use Type	pH (H_2O)		OM		Total		Available P		CEC	
			(%)		N (%)		(mg kg^{-1})		(cmol (+) kg^{-1})	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
Cultivated land	5.57^a (0.04)	5.60^a (0.04)	2.98^b (0.28)	2.69^c (0.16)	0.20^c (0.01)	0.18^c (0.01)	12.31^c (1.12)	11.03^c (0.26)	24.26^c (2.44)	26.06^c (2.44)
Grass land	5.84^b (0.10)	5.93^b (0.06)	3.91^b (0.23)	3.69^b (0.27)	0.43^b (0.01)	0.39^b (0.01)	23.85^b (1.58)	20.89^b (0.62)	32.60^b (3.00)	37.4^b (38.8)
Forest land	5.59^a (0.18)	5.62^a (0.05)	6.60^a (0.83)	6.53^a (0.22)	0.54^a (0.03)	0.48^a (0.22)	39.36^a (3.67)	35.48^a (2.74)	40.06^a (2.04)	45.4^a (3.66)
CV	2.16	0.93	11.75	5.19	5.79	5.19	9.53	7.26	7.81	8.37

The total N content of soils was significantly affected ($P \leq 0.05$) by land use types and soil depths (Table 8). The highest soil total N content was found on the surface layer of forest land. In contrast, the lowest was in the subsoil of the cultivated land. Based on the rate suggested in Ethiopian soils, total N content was medium under cultivated lands, while it had a high rating in the soils of grass and forest lands. The total N content of the soil followed a similar pattern with soil OM along depths and land uses. The surface soils of forest lands were rich in total N as compared to other land use types. This could be due to the observed high soil OM content. The removal of crop residues for household fuel consumption and feed for animals might have caused the low total N content of the cultivated lands. Livestock grazing and indiscriminate tree cutting also cause the soil to produce more surface runoff, which may remove residues of plants that in turn expose the soil to total N depletion [19]. Bore and Bedadi reported higher amounts of total N in the forest soils due to the addition of plant residues and the minimum decomposition rate in Loma District, Southern Ethiopia. Soil available P content in the watershed was significantly influenced by land uses and soil depths (Table 8). The highest mean available P content was measured on the surface soils of the forest land, while the lowest was obtained in the subsoil of the cultivated lands.

More than half of the total soil P is derived from soil OM. Hence, forests and grasslands have higher available P due to the decomposition of organic debris as compared to cultivated lands. The noted low available P content in the cultivated land soils may be ascribed to repeated plowing for crop production and biomass removal with little residue left in the soil. Similar studies also noted more available P concentration in soils of cultivated land than in forest and grazing lands. It may be believed that in cultivated and grasslands, the available P taken up by plants would be returned with a very low amount, as most of the residues are removed from the farm system by humans and animals. Moreover, due to many years of cultivation, the observed acidity of the soil might also cause P fixation and low P availability in the cultivated lands.

Cation exchange capacity and exchangeable bases

The cation exchange capacity of soils in the watershed showed significant variation with land use types and depths. Considering the depth of each land use, a higher CEC was observed in the subsoil. Comparing land use types, significantly higher CEC was found in the forest lands. These CEC could be obtained from the presence of higher OM in the soils of natural vegetation land, whereas the cultivated land had low soil OM content. Generally, the forest land was high in CEC, while the cultivated and grasslands were in a medium rating [20].

Exchangeable Ca^{2+} was significantly affected ($P \leq 0.05$) with soil depths; however, it did not vary with land use types. A higher value of exchangeable Ca^{2+} was scored in the subsoil of the forest land. The higher concentration of this ion is associated with leaching by rainfall. Exchangeable Mg^{2+} followed a similar pattern with exchangeable Ca^{2+} and showed significant ($P \leq 0.05$) differences with soil depths and land use types (Table 9). Exchangeable Mg^{2+} was higher in the subsurface soils of the forest land.

The exchangeable K^+ of soils in the studied watershed was significantly affected ($P \leq 0.05$) by land uses and soil depths. The highest exchangeable K^+ content was found in the subsoil of the forest land.

Percent base saturation was significantly affected by land uses and soil depths, in which higher value for each land use was obtained in the subsurface soil. The overall highest PBS was measured in the subsoil of the forest land. The Percent Base Saturation (PBS) is one of the indicators of potential soil fertility; it was obtained at a moderate value for cultivated land, while it was low for other land uses.

TABLE 9
Effects of land use types and soil depth on exchangeable Na^+, K^+, Mg^{2+}, Ca^{2+} and PBS

Land use type	Ca^{2+} ($cmol_c$ kg^{-1})		Mg^{2+} ($cmol_c$ kg^{-1})		K^+ ($cmol_c$ kg^{-1})		Na^+ ($cmol_c$ kg^{-1})		PBS (%)	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20	20-40	0-20	20-40	0-20	20-40
Cultivated land	6.85^a (0.64)	7.27^b (0.31)	2.42^c (0.17)	2.75^b (0.08)	0.68^b (0.03)	0.79^b (0.03)	0.56^c (0.01)	0.64^b (0.03)	43.32^b (0.42)	43.93^b (0.42)
Grassland	7.79^a (1.11)	7.88^a (0.52)	3.02^b (0.04)	3.43^b (0.32)	0.67^b (0.02)	0.84^b (0.04)	0.83^b (0.04)	0.86^a (0.03)	37.76^b (0.69)	34.70^{ab} (1.34)
Forestland	9.02^a (0.79)	9.92^a (0.55)	4.01^a (0.23)	4.26^a (0.34)	0.83^a (0.04)	0.97^a (0.02)	0.92^a (0.04)	0.93^a (0.03)	36.89^a (0.76)	35.41^a (1.01)
CV	11.06	6.8	7.93	5.47	3.84	5.04	4.77	3.77	6.92	4.85

Note: Means with the same letter are not significantly different at $P \leq 0.05$

CONCLUSION

Soil degradation has been increasing due to unplanned land use and is becoming a major challenge to agricultural development and its sustainability. The LULC showed a reduction in the size of forests and grasslands, while there was an expansion of settlements and cultivated lands. These changes have caused significant variations in the physical and chemical soil properties. Most of the chemical properties showed better concentration in the forest lands as compared to the cultivated and grasslands. Relatively higher OM, total N and available P were found in the surface soils as compared to the subsurface soils. Exchangeable bases were higher in the subsoil for all land uses, although forest lands were obtained with relatively higher bases and CEC. The overall finding suggested that land use changes should take into account not only the immediate economic needs of the people in the area but also the sustainability of the land. Cultivated lands should be enriched with OM and chemical fertilizers and amendments to improve productivity.

REFERENCES

1. Abad JRS, Khosravi H, Alamdarlou EH. Assessment the effect of land use changes on soil physicochemical properties in Jafarabad of Golestan province, Iran. Bulletin Environ, Pharmacol Life Sci. 2014;3(3):296-300.
2. Abbasi MK, Zafar M, Khan SR. Influence of different land-cover types on the changes of selected soil properties in the mountain region of Rawalakot Azad Jammu and Kashmir. Nutr Cycl Agroecosystems. 2007;78:97-110.
3. Aytenew M, Kibret K. Assessment of soil fertility status at Dawja watershed in Enebse Sar Midir district, Northwestern Ethiopia. Int J Plant Sci. 2016;11(2):1-3.
4. Bore G, Bedadi B. Impacts of land use types on selected soil physico-chemical properties of Loma Woreda, Dawuro Zone, Southern Ethiopia. Sci Technol Arts Res J. 2015;4(4):40-48.
5. Rhoades JD. Cation exchange capacity. Methods of soil analysis: Part 2 chemical and microbiological properties. 1982;9:149-157.
6. Chemeda M, Kibret K, Fite T. Influence of different land use types and soil depths on selected soil properties related to soil fertility in Warandhab Area, Horo Guduru Wallaga Zone oromiya, Ethiopia. J Environ Sci Nat Resour. 2017;4(2):555634.
7. Day PR. Particle fractionation and particle-size analysis. Methods of soil analysis: Part 1 physical and mineralogical properties, including statistics of measurement and sampling. 1965;9:545-567.
8. Duguma LA, Hager HE, Sieghardt MO. Effects of land use types on soil chemicalproperties in smallholder farmers of central highland Ethiopia. Ekologia (Bratislava. Ekologia). 2010;29(1):1-4.
9. Fekadu E, Kibret K, Bedadi B, et al. Characterization and classification of soils of yikalo subwatershed in lay gayint district, Northwestern highlands of Ethiopia. Eurasian Soil Sci. 2018;7(2): 151-166.
10. Fisseha G, Gebrekidan H, Kibret K, et al. Analysis of land use/land cover changes in the Debre-Mewi watershed at the upper catchment of the Blue Nile Basin, North West Ethiopia. J Biodivers Environ Sci. 2011;1(6):184-198.
11. Gebrelibanos T, Assen M. Effects of slope aspect and vegetation types on selected soil properties in a dryland Hirmi watershed and adjacent agro-ecosystem, Northern highlands of Ethiopia. Afr J Ecol. 2014;52(3):292-299.
12. Hazelton P, Murphy B. Interpreting soil test results: What do all the numbers mean?. CSIRO publishing; 2016.
13. Karltun E, Lemenih M, Tolera M. Comparing farmers' perception of soil fertility change with soil properties and crop performance in Beseku, Ethiopia. Land Degrad Dev. 2013;24(3):228-235.
14. Khresat SE, Al-Bakri J, Al-Tahhan R. Impacts of land use/cover change on soil properties in the Mediterranean region of Northwestern Jordan. Land Degrad Dev. 2008;19(4):397-407.
15. Kindu M, Schneider T, Teketay D, et al. Land use/land cover change analysis using object-based classification approach in Munessa-Shashemene landscape of the Ethiopian highlands. Remote Sens. 2013;5(5):2411-2435.
16. Mekonnen Z, Berie HT, Woldeamanuel T, et al. Land use and land cover changes and the link to land degradation in Arsi Negele district, Central Rift Valley, Ethiopia. Remote Sens Appli: Soc Environ. 2018;12:1-9.
17. Molla E, Gebrekidan H, Mamo T, et al. Patterns of land use/cover dynamics in the mountain landscape of Tara Gedam and adjacent agro-ecosystem, Northwest Ethiopia. SINET: Ethiopian J Sci. 2010;33(2):74-88.
18. Mulat Y, Kibret K, Bedadi B, et al. Soil quality evaluation under different land use types in Kersa sub-watershed, Eastern Ethiopia. Environ Sys Res. 2021;10:1-11.
19. Tufa M, Melese A, Tena W. Effects of land use types on selected soil physical and chemical properties: The case of Kuyu District, Ethiopia. Eurasian J Soil Sci. 2019;8(2):94-109.
20. Olsen SR. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US department of agriculture; 1954.