Journal of Agriculture and Environmental Sciences

**Research Article**

# Changes in land use and land cover: effects on selected soil properties in Sdeyni Sub-watershed, Northeastern Ethiopia

***Endalkachew Fekadu*** [1*]***, Worku Teshome*** [1]***, Haile Getnet*** [1]***, Wondim Alemu*** [2]

[1]Department of Soil Resource and Watershed Management, Woldia University, Woldia, Ethiopia
[2]Department of Land Administration and Surveying, Woldia University, Woldia, Ethiopia
***Corresponding author:** endalkf@gmail.com

Received: December 16, 2023; Received in revised form: June 21, 2024; Accepted: November 12, 2024

**Abstract:** *Land use and land cover changes coupled with unplanned agricultural activities have contributed to land degradation. Hence, this study evaluated land use land cover changes, and effects on properties of soils in the Sdeyni sub-watershed in Northeastern Ethiopia. Satellite images for the periods of 1984, 2000, and 2020 were gathered to analyze the land use changes. Crop land, forest land, and bush-land 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 replicated three times. The results showed that within 36 years, the overall pattern of forest land declined by 1080.49 ha (10.34%) with an annual rate of 0.028%. The LULC analysis showed that the area of bush-land decreased by 4.27% during the first period (1984-2000), and by 0.91 % during the second period (2000-2020). Significantly large areas in the watershed are devoted for crop category while the smallest portion is covered by settlement part. 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 croplands. 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 organic matter, total Nitrogen, and available Phosphorus were obtained on the surface soil of the forest lands. Exchangeable bases and cation exchange capacity 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 lowest values were observed on the crop lands. Generally, forest land declined, while an increase in the cultivated and settlement lands was the major land use land cover change. Croplands in the watershed were found poor in soil nutrient content. Therefore, immediate policy interventions are required to protect the forest lands and improve sustainable agricultural productivity.*

**Keywords:** Image classification; Land use land cover, Soil properties, Sub-watershed
**Citation:** Fekadu, E., Teshome, W., Getnet, H., Alemu, W. (2024). Changes in land use and land cover: effects on selected soil properties in Sdeyni Sub-watershed, Northeastern Ethiopia. J. Agric. Environ. Sci. 9(2): 18-32. DOI: https://doi.org/10.20372/jaes.v9i2.9330



## 1. Introduction

Land cover involves that the bio-physical cover of the surface of the land, while land use describes 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 (Yu et al., 2019). For instance, forest lands are converted to agricultural lands due to the alarming rate of population growth and increasing of human demand (Abad et al., 2014). Expansion of lands for farming, and settlements on one hand, and shrinking of bush and forest lands on the other are observed in various regions of Ethiopia (Fisseha et al., 2011; Gebrelibanos and Assen, 2014) mainly by increased population pressures demanding more land for cultivation, and more trees for domestic fuelwood consumption (Meshesha et al., 2016; Molla et al., 2022).

In tropical highlands, indiscriminate cutting of trees for firewood, charcoal production, and construction purposes caused accelerated soil degradation (Chidumayo and Gumbo, 2013). Changing forest lands into cropland affects soil aggregate stability and that in turn reduces aeration, infiltration, nutrient movement and biological activities (Rasiah et al., 2004). Land cover changes cause physical, chemical and biological degradations of soils, reduced carbon storage, loss of soil flora and fauna, and eventual desertification contributing to changing climate (Mekonnen et al., 2018). 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 (Abbasi et al., 2007). Bulk density, hydraulic conductivity, water-stable aggregates, SOM and total N decreased when forest land was changed into cropland (Göl et al., 2010). Many authors agree deforestation and subsequent cultivation adversely affect soil quality indicators (Haghighi et al., 2010; Tellen and Yerima, 2018). In contrast, the replacement of natural forests with the plantation of various species such as *Cupressus sempervirens, and Alnus subcordata* increased SOC and soil microbial biomass (Soleimani et al., 2019). In the same way, SOC, available P, and total N were improved when the land use was changed from natural forest to tea plantation (Majaliwa et al., 2010). In general, reviewed reports suggested that the chemical and physical properties of soils are the functions of land management.

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 people have based on farming as one of the most important economic activities. However, competition of the existing lands for complex and diverse economic, social and environmental functions has limited agricultural development. Natural resource decline, soil nutrient depletion, and environmental deterioration due to the expansion of farmlands on steep slope areas with improper management practices are observed in Ethiopia (Aytenew and Kibret, 2016). Therefore, reversing the situation and improving production will play a vital role in ensuring food security, and thereby reducing poverty in tropical Africa (Qadir et al., 2014). Such recognized LULC changes without a scientific land use plan are typical characteristics of Habru District. Although several pieces of research have been reported on LULC changes, the available information on soil properties in relation to land cover changes is very limited in Habru District. 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 resultant effects on properties of soils could provide input for efficient land resource management. Thus, this analysis was designed to determine the LULC changes for the years 1984, 2000, and 2020, and the associated effects on selected physico-chemical properties of soils in the Sdeyni watershed.

## 2. Materials and Methods

### 2.1. Description of the study area

The study area, the Sdeyni sub-watershed is found in Harbru District, North Wollo Zone of Eastern Amhara Region (Figure 1). It lies between 11˚45'13" to 11˚27'35''North and 39˚38'17" to 39˚49'22''East covering about 10450.59 ha with an altitude ranging from 1347 to 2780 meters above sea level (masl).

Physically, the watershed has mountains (35%), flats (40%), valleys (22%), and others (3%) shared the topographic setting of the area. Agro-ecologically, the area is classified into lowland (*kolla*) (64.7%), midland (*woina-dega*) (32.3%), and highland (*dega*) (3%) zones. According to the National Meteorological Service Agency (2019), the area receives 700 to 1000 mm of average annual rainfall with an erratic distribution. The average annual temperature varies from 15$^{o}$C to 28$^{o}$C. October is the coldest month while May and June are the warmest. Mixed crop-livestock farming system, where crop production is dependent on using both rain-fed and small-scale irrigation is the farming system in the community. Commonly grown cereals 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 slopping areas. Most likely, scattered tree species such as *Acacia spp*, and *Zizphus spps* are practical on the farmlands, while the upper lands of the watershed are dominantly covered with *Olia Africana* and Eucalyptus species. Soil and water conservation practices such as trenches, hillside terraces with trenches, stone-faced soil bunds, and check dams are commonly found in most parts of the watershed although there are technical limitations in design and construction. Diminished productivity from time to time is mentioned by farmers in the area because of the observed improper land use systems.

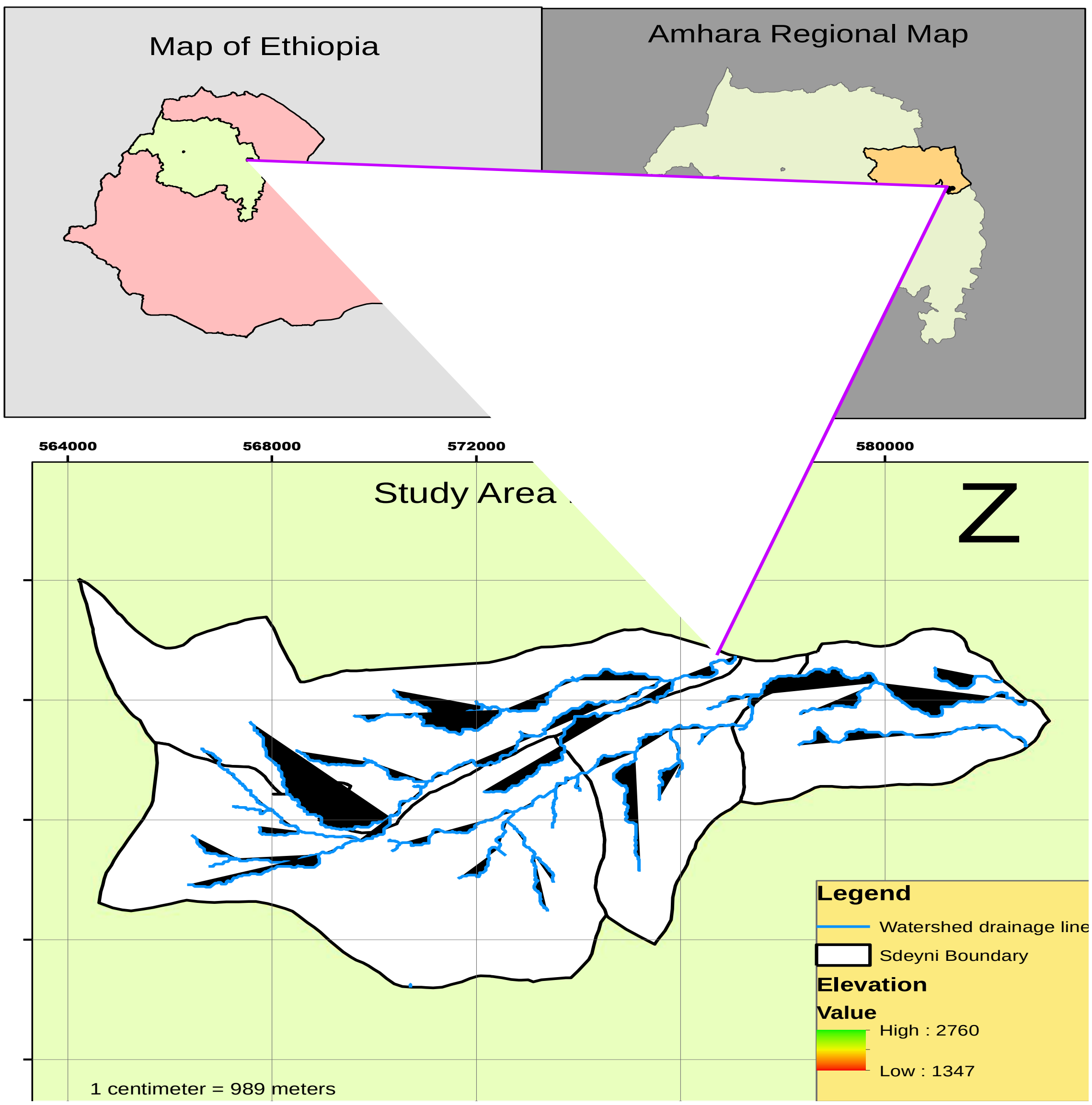


**Figure 1: Location map of Sdeyni sub-watershed**

**2.2. 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 (Figure 3). Four major land uses (cropland, bushland, forestland, and settlement) were carefully chosen in the watershed following a reconnaissance survey to evaluate LULC changes (Table 1). Land uses with a similar aspect and slope class (5-10%) were purposively selected before starting the soil sampling operation to avoid variability due to topographic factors. To validate the processing and classification of images, Ground Control Points (GCPs) sample collection was done by using GPS.

**Table 1: Definitions of land use land cover types**

| Land use/ land cover | Definitions |
|---|---|
| Cropland | Areas under farming by rainfed and irrigation to produce cereals, pulses, and 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 forests or plantations. |
| Settlement | Areas of land used for human settlement, commercial, etc either in Urban and /or rural areas which have different construction modalities. |
| Bush land | Areas having dense and moderate shrubs of vegetation characterized by branches of a canopy. |

**Table 2: Satellite images and their characteristics used in the study**

| No | Image type | Sensor | Path/row | Spatial Resolution | Number of Bands | Sources |
|---|---|---|---|---|---|---|
| 1 | Land sat5 | TM | 168/52 | 30m | 7 | USGS |
| 2 | Landsat7 | ETM+ | 168/52 | 30m | 7 | USGS |
| 3 | Sentinel | Sentinel-2A | 168/52 | 10m | 13 | ESA |

**2.3. Land cover change analysis**

The land use and land cover changes have a significant impact on deteriorating the physical and chemical properties as well as the biological activity of the soil (Sebhatleab, 2014). Spatial heterogeneity in soil properties is closely associated with the LULC changes and their management practices (Nguyen et al., 2024). Land use and land cover maps of the area were generated from satellite image data from 1984, 2000, and 2020. The satellite images were originally ortho-rectified and therefore did not require geo-referencing. However, UTM projection and Adindan datum was used in Ethiopia images with WGS84 re-projection. This is important because datum and projection conflict would certainly hinder the use of various layers. In this study, Landsat TM (path 168 row 52) from the year 1984 and Landsat ETM + (path 168 row 52) from the year 2020, and Sentinel-2A (Table 2) were used for the analysis.

Pre-processing image enhancement was done on the ortho-rectified images. The purpose of this technique was to increase the visual distinction between features and extract information. After different image enhancement schemes were performed, the remotely sensed data was trained by taking GPS points and a previous map of the area as primary datasets and elders' prior knowledge as ancillary data. A supervised image classification scheme with the maximum likelihood classifier algorithm module of ERDAS 2015 which leads to high classification accuracy (Ahmad and Quegan, 2012) and ArcGIS 10.8 for mapping and measurements were used. Thus, the scenes for each year's data (1984 of TM, 2000 ETM+) and 2020 sentinel-2A of the image were categorized into different land use and land covers. The major land use and land cover (LULC) types found in the sub-watershed area were forest, bushland, cropland and settlement part and they are defined in Table 1.

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 (Figure 2) to verify the accuracy of the classified LULC map (Biro et al., 2013; Sabiela et al., 2020). The accuracy assessment data of ground truth points were collected from the watershed boundary extent using handheld GPS. There were 199 ground truth points collected for the study classification accuracy assessment based on the land use type area coverage. 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.

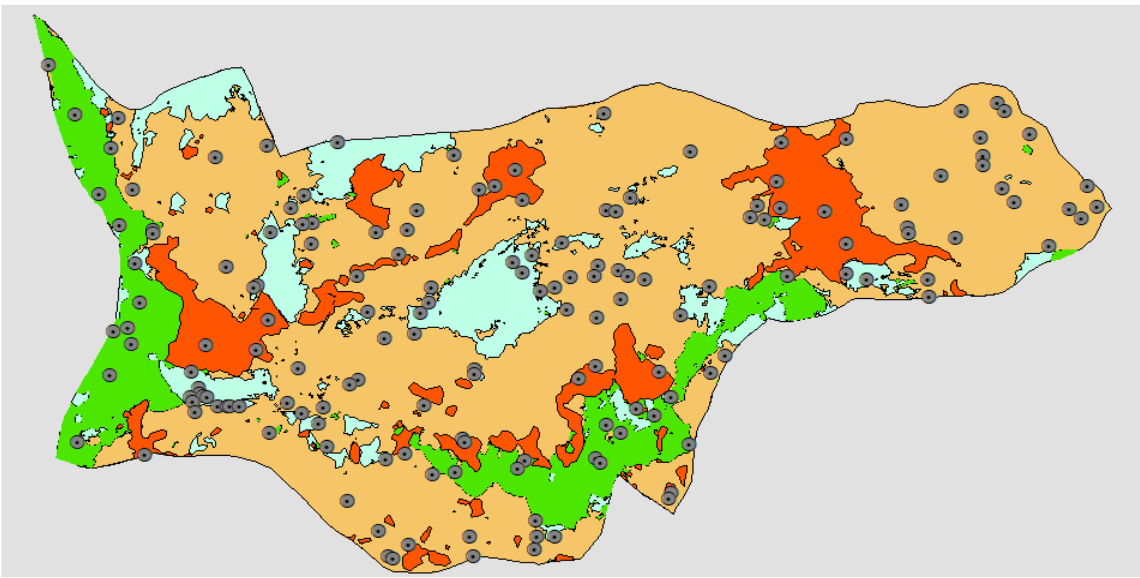

**Figure 2: The reference ground control points for accuracy assessment checking (2020)**

### 2.4. Sampling site selection

Among the classified LULC types in the watershed, only the three main land use types (cropland, forestland and bushland) were selected for soil sampling (Assefa et al, 2020). Composite soil samples from 0-20 cm and 20-40 depths were collected from each land use following a zigzag pattern with three replications. In total, 18 disturbed soil samples were collected, bagged and labeled. In the same way, 18 undisturbed soil samples were collected using a core to analyze soil bulk density of soils. Soil samples were taken to Srinka agricultural research centre soil laboratory for the determination of texture, bulk density, pH, OC, total N, available P, exchangeable bases ($Ca^{2+}$, $Mg^{2+}$, $K^+$, $Na^+$), PBS, and CEC.

### 2.5. Laboratory analysis

Soil particle size proportion was determined using Bouyoucos hydrometer method as developed by Day (1965) whereas bulk density (BD) of soils was calculated from dried soil mass to its bulk volume. Soil to water (1: 2.5) suspension was prepared and used to determine soil pH and electrical conductivity (Van Reewijk, 1992). Soil OC was determined following the Walkley and Black (1934) methods. The organic matter content of the soil was then determined by multiplying the OC percentage by 1.724. Kjeldahl procedures as described by Black (1965) were employed to determine soil total N content while Olsen et al. (1954) method was served to determine available P. Cation exchange capacity was determined by ammonium acetate distillation and titration procedures (Chapman, 1965). A flame photometer was employed to read exchangeable $Na^+$ and $K^+$ from the leachate whereas atomic absorption spectrophotometer (AAS) was used to read exchangeable $Ca^{2+}$ and $Mg^{2+}$ as described by Rowell (1994). 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.

### 2.6. 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.

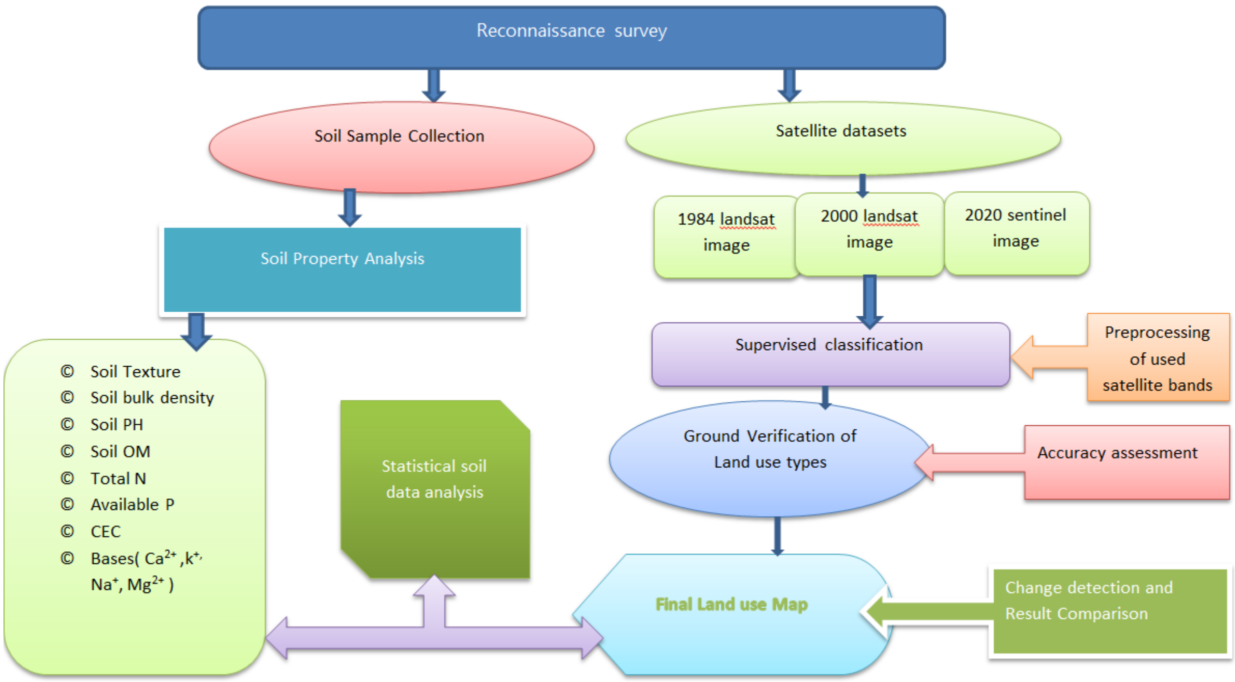


**Figure 3: Workflow of the LULC, and soil analysis**

## 3. Results and Discussion

### 3.1. Land use/land cover change for periods (1984, 2000 and 2020)

In all the study periods, lands under the cropland category have been covering the main land use type in Sdeyni sub-watershed. From the total land area classified, cropland accounted for 60.37%, 61.30%, and 63.82% in the periods 1984, 2000, and 2020, respectively (Table 3). This showed that areas under the cropland category were constantly increasing in the first sixteen years (1984-2000) with an increment of 96.95 ha (0.93%).

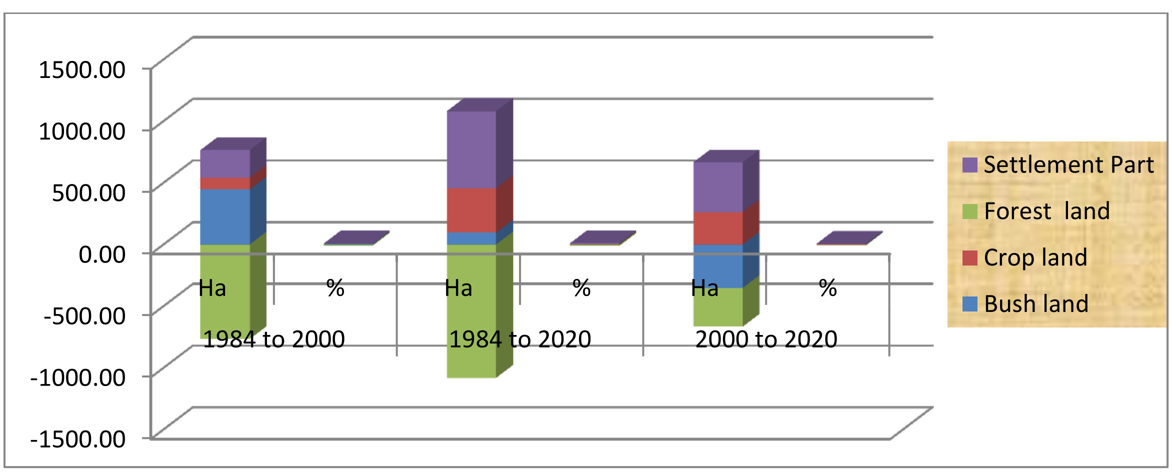


**Figure 4: Land use land cover change analysis in the study periods**

The analysis LULC also indicated that the area of forest land has covered 2349.95 ha (22.49%), 1584.19 ha (15.16%), and 1269.47 ha (12.15%) in the year 1984, 2000, and 2020, respectively (Table 3 and Figure 4). This showed that the area of forest land declined by 765.76 ha (07.33%) for the first sixteen years (1984-2000) and by 314.73 ha (3.01%) for the second study period (2000- 2020).

Within 36 years, the overall pattern of forest land declined by 1080.49ha (10.34%) from 1984 to 2020 with an annual rate of 0.028% (Table 3). This occurred as a result of changing lands covered by vegetation and forest to cultivation and settlement. Significantly large areas in the watershed are devoted for crop category while the smallest portion is covered by settlement part. On the other hand, compared to the base year of 1984, cropland, and settlement parts showed an increase of 0.93 and 2.13%, respectively (Tables 3, 4, and Figure 5). For instance, 22.49% of the area occupied by forest in 1984 declined to 12.15% in 2020. In comparison, cropland expanded from 60.37% in 1984 to 63.82% in 2020. The LULC analysis showed that the area of bushland decreased by 4.27% during the first period (1984-2000), and by 0.91 % during the second period (2000-2020). This is due to the high population density in the rural areas which depends more on agricultural activities, than other alternative forms of employment. Kindu et al. (2013) reported an increase in croplands from 13,498 ha to 50,317 ha between 1973 and 2012 in Munessa, Shashemene. Similar reports (Fisseha et al., 2011) 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 observed a decline in forest coverage by 71% with a 1.54% annual rate of deforestation (Molla et al., 2010). Such significant forest removal was practiced to search for additional land to grow crops in protected areas. The decline of bushland might be due to the result of increasing demand for animal feeds, crop land and settlements. Such LULC changes were common in the Northwestern parts of Ethiopia where bushlands are gradually being changed to settlement and croplands due to the ever-increasing population.

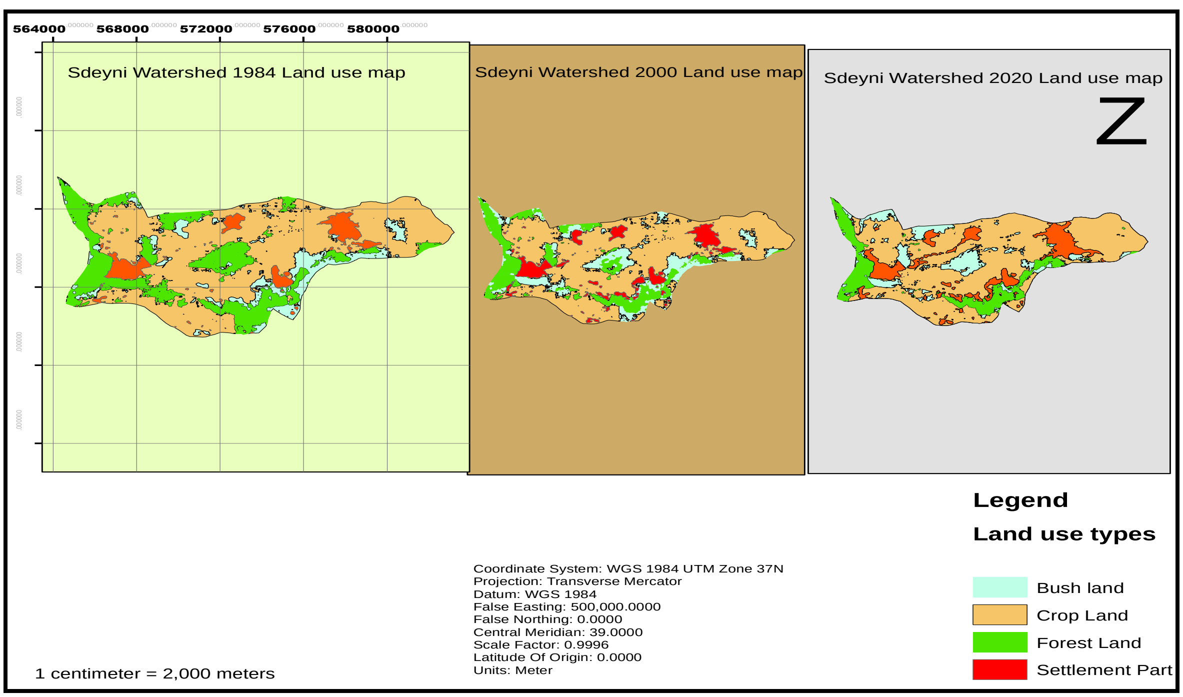


**Figure 5: Land use land cover change map in the study periods**

**Table 3: Land use land cover of the Sdeyni watershed from 1984 to 2020**

| | | 1984 | | 2000 | | 2020 | | 1984 to 2000 | | 1984 to 2020 | | 2000 to 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | Land use type | Ha | % | Ha | % | Ha | % | Ha | % | Ha | % | Ha | % |
| 1 | Bushland | 1118.08 | 10.70 | 1564.58 | 14.97 | 1213.40 | 11.61 | 446.50 | 4.27 | 95.32 | 0.91 | -351.18 | -3.36 |
| 2 | Cropland | 6309.38 | 60.37 | 6406.33 | 61.30 | 6670.38 | 63.82 | 96.95 | 0.93 | 361.00 | 3.45 | 264.05 | 2.53 |
| 3 | Forest land | 2349.95 | 22.49 | 1584.19 | 15.16 | 1269.47 | 12.15 | -765.76 | -7.33 | -1080.49 | -10.34 | -314.73 | -3.01 |
| 4 | Settlement Part | 673.37 | 6.44 | 895.68 | 8.57 | 1297.90 | 12.42 | 222.31 | 2.13 | 624.53 | 5.98 | 402.22 | 3.85 |
| Total | | 10450.79 | 100.00 | 10450.79 | 100.00 | 10451.14 | 100.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 4: Summary land use land covers change detection (1984, 2000, and 2020)**

| No | Change land use type ( 1984 to 2000) | Change area-Ha | No | Change land use type ( 1984 to 2020) | Change area-Ha |
|---|---|---|---|---|---|
| 1 | Bush land - Bush land | 642.10 | 1 | Bush land - Bush land | 242.67 |
| 2 | Crop land - Bush land | 142.21 | 2 | Bush land - Crop land | 503.31 |
| 3 | Forest land - Bush land | 427.57 | 3 | Bush land - Forest land | 131.01 |
| 4 | Settlement part - Bush land | 1.18 | 4 | Bush land - Settlement part | 240.59 |
| 5 | Bush land - Crop land | 724.30 | 5 | Crop land - Bush land | 141.29 |
| 6 | Crop land - Crop land | 5868.34 | 6 | Crop land - Crop land | 5760.11 |
| 7 | Forest land - Crop land | 64.55 | 7 | Crop land - Forest land | 37.20 |
| 8 | Settlement part - Crop land | 12.37 | 8 | Crop land - Settlement part | 370.45 |
| 9 | Bush land - Forest land | 146.08 | 9 | Forest land - Bush land | 827.97 |
| 10 | Crop land - Forest land | 34.22 | 10 | Forest land - Crop land | 398.16 |
| 11 | Forest land - Forest land | 1079.88 | 11 | Forest land - Forest land | 1097.19 |
| 12 | Settlement part - Forest land | 9.00 | 12 | Forest land - Settlement part | 26.21 |
| 13 | Bush land - Settlement part | 51.53 | 13 | Settlement Part - Bush land | 1.14 |
| 14 | Crop land - Settlement part | 361.16 | 14 | Settlement Part - Crop land | 7.98 |
| 15 | Forest land - Settlement part | 11.91 | 15 | Settlement Part - Forest land | 3.78 |
| 16 | Settlement part - Settlement part | 873.09 | 16 | Settlement Part - Settlement part | 660.44 |
| Sum | | 10450.79 | Sum | | 10450.79 |

**Table 5: Land use change between 2000 and 2020**

| No | Change land use type ( 2000 to 2020) | Change area-Ha | No | Change land use type ( 2020 to 2020) | Change area-Ha |
|---|---|---|---|---|---|
| 1 | Bush land - Bush land | 798.82 | 6 | Forest land - Bush land | 765.76 |
| 2 | Bush land - Crop land | 112.61 | 7 | Forest land - Forest land | 1584.19 |
| 3 | Bush land - Settlement part | 206.65 | 8 | Settlement Part - Settlement part | 673.37 |
| 4 | Crop land - Crop land | 6293.72 | | | |
| 5 | Crop land - Settlement part | 15.66 | | Sum | 10450.79 |

### 3.2. Accuracy assessment of the classification

Accuracy assessment determines the quality of the information derived from the remotely sensed data. It is most reliable when used along with ground reference data or data derived from aerial photographs at or near the time of satellite overpass (Biro et al., 2013). An error matrix was employed to compare the classified maps with the referenced data and ground truth. The overall accuracies for 2020 image classification were 83.25%, with the Kappa coefficient of 79.54% respectively (Table 6). The user's accuracy assessment showed that in 2020 the highest class accuracy was obtained settlement part (87.8%) while the lowest belonged to bushland (79.55%). The producer's accuracy assessment showed that forest land, and cropland settlement part have correctly classified map value of 88.37%, 86.96% and 81.82% accuracy values in 2020 supervised classification results respectively. The lowest accuracy was bushland (81.40%).

**Table 6: Digital Image classification confusion matrix (2020)**

| | Reference field GCP points | | | | | | |
|---|---|---|---|---|---|---|---|
| | Land use type | Bush land | Crop land | Forest land | Settlement part | Row total | User accuracy (%) |
| Classified value | Bush land | 35 | 4 | 3 | 2 | 44 | 79.55 |
| | Crop land | 3 | 60 | 2 | 5 | 70 | 85.71 |
| | Forest land | 2 | 3 | 38 | 1 | 44 | 86.36 |
| | Settlement part | 3 | 2 | 0 | 36 | 41 | 87.80 |
| | Column total | 43 | 69 | 43 | 44 | | |
| | Producer accuracy | 81.40 | 86.96 | 88.37 | 81.82 | 199 | |
| | Overall accuracy | 83.25% | | | | | |
| | Kappa coefficient | 79.54% | | | | | |

### 3.3. 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 (Table 7). 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 crop, and forest lands, respectively. In contrast, the highest (56.57%) and lowest (52.92%) proportion clay were obtained in the subsoil of the forest, and croplands, respectively (Table 7). Generally, the clay content increased with depth in all land use types, and the reverse was observed in the silt content

The relatively higher proportion of sand particles on the surface layer might be associated with clay movement to the subsoil, and its removal from the land surface by heavy runoff that led to an increased concentration of sand on the soil surface (Fekadu et al., 2018). Similarly, non-significant results of particle size distribution were reported for LULC types (Biro et al., 2013).

Soil bulk density showed significant differences among land use types, and soil depths (Table 7) 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 cropland. Tufa et al. (2019) reported the highest bulk density value on the surface soil of the cropland in comparison with other land uses. According to Kolay (2000), the values of bulk density obtained in the watershed are in the suitable ranges for agricultural activities (1.1 to 1.5 g $cm^{-3}$). The higher content of OM accumulated from litterfall and limited livestock movement could contribute to the lower bulk density values in the soils of the forest land. The same findings were also reported in various areas (Abate and Kibret, 2016; Molla et al., 2022). In contrast, ploughing might favour higher bulk density in the soils of croplands. It tends to hasten the rate of

OM decomposition thereby decreasing aggregations of soil particles. Likewise, Abad et al. (2014) and Lechisa et al. (2014) indicated higher bulk density on croplands at 0-30 cm depth as compared to forest and grazing lands.

### 3.4. Effects of land use types on selected soil chemical properties

#### *3.4.1. Soil reaction (pH)*

Soil pH varied ($P \leq 0.05$) significantly across land use types and with soil depths. Bushland soils were obtained with a slightly higher pH mean value while cropland soils were the lowest (Table 8). The increase in soil pH in the subsoil may be related to an accumulation of basic cations through leaching. As per the rating criteria suggested by Hazelton and Murphy (2016), the soil pH in the watershed ranged from 5.57 to 6.93 and was classified as moderately acid soils. Compared to the other land use types, the lowest soil pH was found in the cropland. In agreement with this finding, Mulat et al. (2021) reported the soil pH was the lowest in the soils of the cropland.

#### *3.4.2. 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 croplands 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 litterfall and the lower decomposition rate (Khresat et al., 2008). In the same way, different researchers (Duguma et al., 2010; Mengistu and Dereje, 2020) explained reduced OM content with soil depth in different land use systems because of reduced root biomass, and lower biomass turnover.

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 cropland. Based on the rate suggested in Ethiopian soils (Tadesse et al., 1991), total N content was medium under croplands while it was in a high rating in the soils of bush 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 residues for household fuel consumption, intensive tillage, and lack of optimal fertilizer use and feed for animals might have caused the low total N content of the croplands (Getahun et al., 2022). 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 (Tufa et al., 2019). Bore and Bedadi (2015) reported higher amounts of total N in the forest soils due to the addition of plant residues and 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 croplands.

More than half of the total soil P is derived from soil OM. Hence, forests and bushlands have got higher available P due to the decomposition of organic debris as compared to the croplands. The noted low available P content in the cropland soils may be ascribed to repeated ploughing for production, and biomass removal with little residue left in the soil. Similar studies (Mengistu et al., 2017; Tufa et al., 2019) also noted more available P concentration in soils of cropland than in forest and grazing lands. It may be believed that in crops and bushlands, 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 man 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 croplands

**Table 7: Effects of land use types and soil depth on selected soil physical properties**

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

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

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

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

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

| Soil property | Soil depth (cm) | Land use types | | | CV (%) |
|---|---|---|---|---|---|
| | | Crop land | Bush land | Forest land | |
| $Ca^{2+}$ ($cmol_c$ $kg^{-1}$) | 0-20 | $6.85^a$(0.64) | $7.79^a$(1.11 | $9.02^a$(0.79) | 11.06 |
| | 20-40 | $7.27^b$(0.31) | $7.88^a$(0.52) | $9.92^a$(0.55) | 6.80 |
| $Mg^{2+}$ ($cmol_c$ $kg^{-1}$) | 0-20 | $2.42^c$(0.17) | $3.02^b$(0.04) | $4.01^a$(0.23) | 7.93 |
| | 20-40 | $2.75^b$(0.08) | $3.43^b$(0.32) | $4.26^a$(0.34) | 5.47 |
| $K^+$ ($cmol_c$ $kg^{-1}$) | 0-20 | $0.68^b$(0.03) | $0.67^b$(0.02) | $0.83^a$(0.04) | 3.84 |
| | 20-40 | $0.79^b$(0.03) | $0.84^b$(0.04)) | $0.97^a$(0.02) | 5.04 |
| $Na^+$ ($cmol_c$ $kg^{-1}$) | 0-20 | $0.56^c$(0.01) | $0.83^b$(0.04) | $0.92^a$(0.04) | 4.77 |
| | 20-40 | $0.64^b$(0.03) | $0.86^a$(0.03) | $0.93^a$(0.03) | 3.77 |
| PBS (%) | 0-20 | $43.32^b$(0.42) | $37.76^b$(0.07) | $36.89^a$(0.76) | 6.92 |
| | 20-40 | 43.93b(0.42) | $34.70^{ab}$(1.34) | $35.41^a$(1.01) | 4.85 |

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

### *3.4.3. Cation exchange capacity and exchangeable bases*

The cation exchange capacity of soils in the watershed showed significant variation with land use types and depths (Table 8). Considering the depth of each land use, higher CEC was observed in the subsoil. Such an increase in CEC with depth could be associated with an increase in clay content (Abate and Kibret, 2016). Comparing land use types, significantly higher CEC was found in the forest lands. These CECs could be obtained from the presence of higher OM in the soils of natural vegetation land whereas the cropland had low soil OM content. Similar results were reported by Sabiela et al. (2020). Generally, the forest land was high in CEC while the crop and bush lands were in a medium rating (Hazelton and Murphy, 2016).

Exchangeable $Ca^{2+}$ was significantly affected ($P \leq 0.05$) with soil depths; however, it did not vary with land use types (Table 9). 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 ($P \leq 0.05$) difference 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 affected ($P \leq 0.05$) significantly by land uses and soil depths (Table 9). The highest exchangeable $K^{+}$ content was found in the subsoil of the forest land. Percent base saturation was affected significantly by land uses and soil depths in which a 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 in moderate value for cropland while it was low for other land uses.

## 4. Conclusion

Soil degradation has been increasing due to unplanned land use, and becoming a major challenge of agricultural development and its sustainability. The LULC showed a decline in the size of forests and bushlands, with the expansion of settlement and croplands. The present land use showed significant variation in the physical and chemical soil properties. Most of the chemical properties were better in the forest lands as compared to the crop, and bushlands. 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 in all land uses although the forest lands were obtained with relatively higher bases and CEC. The overall finding indicated significant replacement of forest lands by crop cultivation and settlement. Land users should take into account not only the immediate economic and social benefit in the area but they should also consider the sustainability of the land. Policy intervention should be put in place to protect forest lands and improve agricultural productivity.

**Data availability statement**

Data will be made available on request

**Conflicts of interest**

The authors declared that there is no conflict of interest.

**Acknowledgements**

We acknowledge Srinka Agricultural Research Center for timely analysis of soil samples.

**References**

Abad, J. R. S., Khosravi, H., and Alamdarlou, E. H. (2014). Assessment The Effects Of Land Use Changes On Soil Physicochemical Properties In Jafarabad Of Golestan Province, Iran. *Bulletin of Environment, Pharmacology and Life Sciences* 3(3): 296-300.

Abbasi, M.K., Zafar, M., and Khan, S.R. (2007). Influence Of Different Land-Cover Types on The Changes of Selected Soil Properties in the Mountain Region of Rawalakot Azad Jammu and Kashmir. *Nutrient Cycling in Agroecosystems* 78: 97-110.

Abate, N., and Kibret, K. (2016). Effects of land use, soil depth and topography on soil physicochemical properties along the toposequence at the Wadla Delanta Massif, Northcentral Highlands of Ethiopia. *Environment and Pollution*, *5*(2): 57-71.

Ahmad, A., and Quegan, S. (2012), November. Analysis of maximum likelihood classification technique on Landsat 5 TM satellite data of tropical land covers. In *2012 IEEE International Conference on Control System, Computing and Engineering* (pp. 280-285). IEEE.

Assefa, F., Elias, E., Soromessa, T., and Ayele, G.T. (2020). Effect of changes in land-use management practices on soil physicochemical properties in Kabe Watershed, Ethiopia. *Air, soil and water research*, 13: 1-13.

Aytenew, M., and Kibret, K. (2016). Assessment of Soil Fertility Status at Dawja Watershed in Enebse Sar Midir District, Northwestern Ethiopia. International Journal of Plant and Soil Science 11(2): 1-13.

Biro, K., Pradhan, B., Buchroithner, M., and Makeschin, F. (2013). Land use/land cover change analysis and its impact on soil properties in the northern part of Gadarif region, Sudan. Land Degradation & Development, 24(1): 90-102.

Blake, C.A. (1965). Introduction Methods of Soil Analysis. Agronomy Part I, No. 9, 374-399. American Society of Agronomy, Madison, Wisconsin, USA.

Bore, G., and Bedadi, B. (2015). Impacts of Land Use Types on Selected Soil Physico-Chemical Properties of Loma Woreda, Dawuro Zone, Southern Ethiopia. Science, Technology and Arts Research Journal 4(4): 40-48.

Chapman, H.D. (1965). Cation exchange capacity. In: Methods of Soil Analysis. Part II, Black, C.A. (Ed.). Agronomy No. 9. American Society of Agronomy, Madison, Wisconsin, USA. pp. 891-901.

Chidumayo, E.N., and Gumbo, D.J. (2013). The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. Energy for Sustainable Development, 17(2): 86-94.

Day, P. R. (1965). Particle Fractionation and Particle-Size Analysis. In: Methods of Soil Analysis. Part I, Black, C.A. (Ed.). Agronomy No. 9. American Society of Agronomy, Madison, Wisconsin, USA. pp. 545-567.

Duguma, L., Hager, H., and Sieghardt, M. (2010). Effects of Land Use Types on Soil Chemical Properties in Smallholder Farmers of Central Highland Ethiopia. Ekologia 29(1): 1-14.

Fekadu, E., Kibret, K., Bedadi, B., and Melese, A. (2018). Characterization and classification of soils of yikalo subwatershed in Lay Gayint District, northwestern highlands of Ethiopia. Eurasian Journal of soil science 7: 151-166.

Fisseha, G., Gebrekidan, H., Kibret, K., Yitaferu, B., and Bedadi, B. (2011). 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 1(6): 184-198.

Gebrelibanos, T., and Assen, M. (2014). Effects of Slope Aspect and Vegetation Types on Selected Soil Properties in a Dryland Hirmi Watershed and Adjacent Agro-Ecosystem, Northern Highlands of Ethiopia. African Journal of Ecology 52(3): 292-299.

Getahun, H., Fisseha I., Beyene T., and Getachew A. (2022). Variation in soil properties under different land use types managed by smallholder farmers in central Ethiopia, Sustainable Environment, 8 (1): 1-16.

Göl, C., Çakir, M., Edis, S., and Yilmaz, H. (2010). The effects of land use/land cover change and demographic processes (1950-2008) on soil properties in the Gökçay catchment, Turkey. African Journal of Agricultural Research, 4(13): 1670-1677.

Haghighi, F., Gorji, M., and Shorafa, M. (2010). A study of the effects of land use changes on soil physical properties and organic matter. Land Degradation & Development, 21(5):496-502.

Hazelton, P., and Murphy, B. (2016). Interpreting soil test results: What do all the numbers mean?. CSIRO publishing.

Khresat, S. E., Al-Bakri, J., and Al-Tahhan, R. (2008). Impacts of Land Use/Cover Change on Soil Properties in The Mediterranean Region of Northwestern Jordan. Land Degradation and Development 19(4): 397-407.

Kindu, M., Schneider, T., Teketay, D., and Knoke, T. (2013). Land Use/Land Cover Change Analysis Using Object-Based Classification Approach in Munessa-Shashemene Landscape of the Ethiopian Highlands. Remote Sensing 5(5): 2411-2435.

Kolay, A.K. (2000). Basic concepts of soil science, 2nd edn. New Age International Publishers, New Delhi.

Lechisa, T., Achalu, C., and Alemayehu, A. (2014). Dynamics of Soil Fertility As Influenced by Different Land Use Systems and Soil Depth in West Showa Zone, Gindeberet District, Ethiopia. Agriculture, Forestry and Fisheries 3(6): 489-494.

Majaliwa, J.G.M., Twongyirwe, R., Nyenje, R., Oluka, M., Ongom, B., Sirike, J., Mfitumukiza, D., Azanga, E., Natumanya, R., Mwerera, R., and Barasa, B. (2010). The effect of land cover change on soil properties around Kibale National Park in South Western Uganda. Applied and Environmental Soil Science, 2010(1): 1-8.

Mekonnen, Z., Taddese Berie, H., Woldeamanuel, T., Asfaw, Z., and Kassa, H. (2018). Land Use and Land Cover Changes and the Link to Land Degradation in Arsi Negele District, Central Rift Valley, Ethiopia. Remote Sensing Applications: Society and Environment 12: 1-9.

Mengistu, C., Kibebew, K., and Tarekegn, F. (2017). 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. International Journal of Environmental Sciences & Natural Resources 4(2): 555634.

Mengistu, T., and Dereje, T. (2021). Impact of land use types and soil depths on selected soil physicochemical properties in Fasha District, Konso Zone, Southern Ethiopia Journal of Soil Science and Environmental Management 12(1): 10-16.

Meshesha, T.W., Tripathi, S.K., and Khare, D. (2016). Analyses of land use and land cover change dynamics using GIS and remote sensing during 1984 and 2015 in the Beressa Watershed Northern Central Highland of Ethiopia. Model. Earth Syst. Environ. 2: 1-12.

Molla, E., Gebrekidan, H., Mamo, T., and Assen, M. (2010). Patterns of land use/cover dynamics in the mountain landscape of Tara Gedam and adjacent agro-ecosystem, northwest Ethiopia. SINET: Ethiopian Journal of Science 33(2): 74-88.

Molla, E., Getnet, K., and Mekonnen, M. (2022). Land use change and its effect on selected soil properties in the northwest highlands of Ethiopia. Heliyon, 8(8).

Mulat, Y., Kibret, K., Bedadi, B., and Mohammed, M. (2021). Soil Quality Evaluation under different Land Use Types in Kersa Sub-Watershed, Eastern Ethiopia. Environmental Systems Research 10: 1-11.

National Meteorological Service Agency, (2019). Temperature and Rainfall Data of Habru District Ethiopia. Unpublished Document. Addis Ababa.

Nguyen, K.P., Tran, T.T., Le, H.D., Nguyen, P.T., Pham, H.T.T., Nguyen, D.T. and Nguyen, N.H. (2024). Influence of different land-use types on selected soil properties related to soil fertility in A Luoi District, Thua Thien Hue, Vietnam. Soil Ecology Letters, 6(1): 1-10.

Olsen, S.R., Watenabe, V.C., and Dean, L.A. (1954). Estimate of available phosphorous in soil by extraction with sodium bicarbonate. USDA Circular. No. 939. USA.

Qadir, M., Quillérou, E., Nangia, V., Murtaza, G., Singh, M., Thomas, R. J., and Noble, A. D. (2014). Economics of salt-induced land degradation and restoration. In Natural resources forum (Vol. 38, No. 4, pp. 282-295).

Rasiah, V., Florentine, S. K., Williams, B. L., and Westbrooke, M.E. (2004). The Impact of Deforestation and Pasture Abandonment on Soil Properties in the Wet Tropics Of Australia. Geoderma 120(1-2): 35-45.

Rowell, D. (1994). Soil Science: Methods And Applications. Longman Limited. England. 350p.

Sabiela, F.F., Kehali, J., and Endalkachew F. (2020). Land Use and Land Cover Dynamics and Properties of Soils under Different Land Uses in the Tejibara Watershed, Ethiopia. The Scientific World Journal, 2020: 1-12.

Sebhatleab, M. (2014). Impact of land use and land cover change on soil physical and chemical properties: a case study of Era-Hayelom Tabias, Northern Ethiopia. Land Restoration Training Programme Keldnaholt. Final Report. 112 Reykjavik, Iceland, United Nations University.

Tadesse, T., Haque, I., and Aduayi, E. (1991). Soil, Plant, Water, Fertilizer, Animal Manure & Compost Analysis Manual.

Tellen, V.A., and Yerima, B.P.K. (2018). Effects of land use change on soil physicochemical properties in selected areas in the North West region of Cameroon. Environmental System Research, 7:3: 1-29.

Tufa, M., Melese, A., and Tena, W. (2019). Effects Of Land Use Types On Selected Soil Physical And Chemical Properties: The Case Of Kuyu District, Ethiopia. Eurasian Journal of Soil Science 8(2): 94-109.

Van Reewijk, L. (1992). Procedures For Soil Analysis 3rd Edition. International Soil Reference And Information Center (ISRIC), Wageningen, 34.

Walkley, A., and Black, I.A. (1934). An Examination Of The Degtjareff Method For Determining Soil Organic Matter, And A Proposed Modification Of The Chromic Acid Titration Method. Soil Science 37(1): 29-38.

Yu, Z., Lu, C., Tian, H., & Canadell, J. G., 2019. Largely Underestimated Carbon Emission from Land Use and Land Cover Change in The Conterminous United States. Global Change Biology 25(11): 3741-3752.