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IMPACTS OF LAND-USE CHANGES ON SOIL PROPERTIES, ORGANIC CARBON STOCK, AND SOIL QUALITY IN ETHIOPIA:

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ABSTRACT

One of the major causes of soil quality degradation and carbon stock degradation is land-use changes (LUC), which are predominantly caused by deforestation and soil disturbance. Thus, the objective of this study was to assess how land-use changes impacted soil properties, soil organic carbon stock and quality in Ethiopia. Relevant information was gathered from secondary sources such as research papers, journals, textbooks, and the internet, and a total of publications/articles/research papers were reviewed. Land-use changes from Forest, pasture land, swamp/ Wetland, shrubland, and rangeland, on the other hand, fell by 19%, 18%, 32%, 7%, and 5%. The physical and chemical qualities of soil were modified by changes in land use change. Physical soil properties such as The BD of farm land was 0.3 g/cm3 higher than that of forest land and 0.2 g/cm3 higher than that of grass land. Highest carbon stock was recorded in agriculture as compared to forestlands changes of SOC (8.99 Mg ha-1) The moisture content and soil texture altered according to land-use change, with clay contents (percent) and silt contents (percent) being higher in forest land and lower in cultivated land. Chemical soil qualities such as exchangeable CEC (percent), CaCO3 (percent), exchangeable K and Na^+ (Cmol/kg), and AV. P (mg/kg) were higher in forest land enclosure land, although sand content (percent), TN (percent) were lower. Forest lands had greater chemical soil qualities such exchangeable calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+). Organic carbon, available potassium (AVP), total nitrogen (TN), exchangeable calcium (Ca^{2+}), exchangeable magnesium (Mg^{2+}), exchangeable potassium (K^+), and exchangeable cation capacity (CEC) were all higher in forest lands than in cultivated lands. In comparison to cultivated and grazed fields, forest land had greater pH, SOC, TN, av. phosphorus, and CEC. To save Ethiopia's soil, workable land use policy has to be developed. In addition, restoration methods, such

as reducing the intensity of cultivation, integrated soil water conservation, integrated soil fertility management, and adequate land use management practises must be implemented.

Keywords: Deforestation, land degradation, Land-use change, soil carbon stocks, soil quality

INTRODUCTION

One of the main driving forces on global and local environmental changes is land use change, which is produced by the interaction of demographic and socioeconomic changes, as well as biophysical conditions (Birhanu *et al*., 2019 and Dagnew and Yesuph, 2019). At local, regional, and global stages, it has a multidimensional impact on essential Earth ecosystem processes and services (Dagnew and Yesuph, 2019). Land-use change has been identified as a global issue because it is one of the primary causes of environmental change (Sharma *et al*., 2019). Land use change has a significant impact on soil carbon stocks and their distribution in ecosystems, and so play an important role in global carbon dynamics (Sharma *et al*., 2019). Land -use change; in particular, result in the loss of natural vegetation and a shift in the carbon intake and outflow from soil, resulting in a decrease in soil carbon stock (Ostle *et al*. 2009). Soils have become one of the world's most vulnerable resources due to climate change, land degradation, and biodiversity loss (FAO, 2017).

Soil degradation and deterioration of physical and chemical qualities can be exacerbated by changes in land use change (Seyum *et al*, 2019). The degradation of soil physical and chemical qualities in Ethiopia was exacerbated by a lack of agricultural inputs, traditional farming methods, and overgrazing (Heluf and Wakene, 2006). Misuse and mismanagement of soil resources can lead to degradation (Nega, 2006).Changes could result in a loss of vegetation cover and a disruption of the natural ecosystem, as well as a fall in soil organic matter (SOM) and plant nutrients (Seyum *et al*., 2019). SOC may be higher in natural forests and protected forestland than in other land uses (Seyum *et al.*, 2019). Overpopulation, deforestation, and urbanization have all resulted in the depletion of natural resources (FAO, 2008). Deforestation has historically resulted in considerable losses of soil organic carbon (SOC) and inorganic carbon (SIC) around the world (Lal, 2002). Small changes in soil carbon stocks can have a big impact on the amount of carbon in the atmosphere and how it affects climate change (Smith, 2012). SOC is an energy source for microorganisms and has a significant impact on soil physical, chemical, and biological features (Seyum *et al*., 2019). Soil quality deterioration is caused by a variety of factors, including changes in land-use types, such as forest arable land (Oguike & Mbagwu, 2009) and the repercussions of intensive land usage (Jamala and Oke, 2013). Changes in soil indicators and other characteristics can be used to measure improvements in soil quality due to alternative land-use types or crop rotation (Müller and Zeller, 2002; Reynolds *et al*., 2007). SOC is important for soil fertility and is a good indicator of a soil's biological health, as well as its chemical, biological, and physical processes (Chan *et al.*, 2010). Despite extensive research into the impacts

of various land-use types on SOC, TN, and pH, the results are still unclear. SOC content in wooded land is higher than in other land-use types, according to Abbasi et al. (2007), Dengiz *et al.* (2015), and Kalu *et al*. (2015). On the other hand, Jonczak (2013) claims that fallow land has the highest SOC content, while Shi *et al* (2010) claims that paddy rice has the highest SOC content. TN in croplands was much lower than in wooded land, according to Chen *et al* (2016); however, Dagnachew and Yimer (2013) stated that TN did not demonstrate any significant difference across all land-use types. Different land-use types also alter soil pH (Fayissa *et al*., 2015).

In general, many parts of the Ethiopia region are characterized by severe environmental degradation caused by decades of mismanagement of land resources (Dereje *et al.* 2002 and Mekuria *et al.*, 2007). On degraded areas, soil water conservation and area enclosure have been applied (Mekuria *et al*., 2007). However, little is known about how different land use change and management scenarios affect Ethiopia's carbon and nutrient status. As a result, Ethiopian regions are a typical and interesting area for integrated assessment of soil properties and soil quality changes related to land-use changes and soil management due to increasing human disturbance and past deforestation on the one hand, and restoration measures underway on the other. Thus, the present study was aimed to assess the impacts of land-use changes on soil properties, soil carbon stock, and soil quality.

1. METHODOLOGY

Land is the stage on which all human action takes place, as well as the source of the materials required to carry it out. Human use of land resources results in "land use," which varies depending on the goals it serves, such as food production, shelter, recreation, material extraction and processing, and so on, as well as the bio-physical properties of the land itself. Land use change can take two forms: (a) conversion from one type of use to another, which alters the mix and pattern of land uses in an area, or (b) alteration of a specific land use. The conversion of land use owing to human involvement for diverse objectives such as agriculture, settlement, mining, logging, and transportation is referred to as land use change (Williams, 1 994; Meyer, *et al*., 1 994; Turner *et al*.,1 995).

The impact of land use changes on soil carbon stock and soil quality in Ethiopia is examined in this review paper. The review was divided into three sections with subtopics for ease of understanding. As a result, all the data for this paper was gathered from secondary sources using the narrative synthesis method, which is a systematic review and synthesis of findings from different studies focusing on land use changes in Ethiopia. The search was based on the exact sentences 'impacts of and use changes on soil organic carbon stock and soil quality in Ethiopia' in the Web of Google Scholars, which searches each article's title, abstract, keywords, years of publication, and 'keywords plus,' a set of additional relevant keywords selected by well-

known databases such as Google Scholars, within the title, abstract, keywords, and years of publication. Journals, articles, and research papers were found to be relevant to the broad topic of land use change impacts on soil carbon stock and soil quality. Articles/journals/theses were selected and systematically reviewed to determine the strength and research gaps in the study of the impacts of land use changes on soil organic carbon stock and soil quality in Ethiopia.

2. REVIEW RESULTS AND DISCUSSION

2.1. Land Use Change: Concept

Land use change simply refers to the conversion of a piece of land's use by humans, from one purpose to another. For example, land may be converted from cropland to grassland, or from wild land (e.g. tropical forests) to human-specific land uses (e.g. palm oil plantations). Certain types of land use change have well known words associated with them, such as deforestation, afforestation (Lee-Gammage, 2018). Direct land use change refers to a specific piece of land, whose use has been converted by humans from one purpose to another and Indirect land use change takes place when a direct change in land use in one location, is causally connected to a corresponding change in land use in another location (Lee-Gammage, 2018). Land-use changes are frequently indicated as one of the most significant human-induced influences on the hydrological system (Dams, 2007). Land-use change is fueled by a synergistic combination of factors such as resource scarcity, which increases production pressure on resources, changing market opportunities, outside policy intervention, loss of adaptive ability, and changes in social organization and attitudes (Lambin *et al.*, 2007). Land-use conversions are complicated processes that result from changes in the land-cover conversion process (Noe, 2003). Despite this complexity, little is understood about how humans and the environment interact to influence land-use patterns and hydrological processes (LUCID, 2004). The land-use category specified (Forest Land, Cropland, Grassland, and Wetland) is divided into sub-categories based on the plant type. The vegetation type of the given land-use category (forest land, farmland, grassland, and wetland) is divided into sub-categories based on vegetation features and composition (INEGI, 2015). Decomposition and carbon removal are accelerated when forestland is converted to other land uses, such as agriculture (Girmay *et al.*, 2008; IPCC, 2013). The removal of vegetation exposes the land to the effects of rains. When steeper slopes are cultivated in high erosivity circumstances, the situation gets worse, especially in the absence of appropriate soil conservation measures (Assen, 2021).

Fig.1 Causes of land-use change: Steep slopes used for cultivation, making the soil susceptible to erosion/degradation (Gete, 2001).

2.2. Dynamics of Land Use Changes in Ethiopia

Land use change dynamics signify the conversion of land use owing to human involvement for diverse reasons such as agriculture, settlement, mining, logging, and transportation in Ethiopia, according to numerous researches. In this graph, significant land use change dynamics from 1993 to 2003, 2003 to 2014, and 1993 to 2014 are shown, as well as major land use change dynamics in percentage (Garima *et al.*, 2019, Table 8, page 17). Between 1993 and 2003, there were 14.14 percent and 6.84 percent changes in forest types, respectively (Garima *et al.*, 2019). According to a research published by Zeleke (2022), natural forest cover has decreased from 27 percent in 1957 to 2 percent in 1982 and 0.3 percent in 1995. During the years 1993–2003 and 2003–2014, changes from agricultural land to forest were 4.98 percent and 0.86 percent, respectively (Garima *et al*., 2019). This finding is consistent with the fact that agricultural land use rose in all of the studies reviewed (Hailu, 2020), whereas forest land usage dropped in all of the cases studied, with the exception of the rise mentioned by Hailu (Gebreselassie, 2014). Agricultural land, a body of water, a commercial farm, and bare/rock Outcropping, accumulation, and settlement grew by 32 percent, 17 percent, 3%, 21%, and 191 percent, respectively. 7 percent of forest area was converted to agricultural land in both the 1993–2003 and 2003–2014 eras, and roughly 15% of agricultural land changed (Garima *et al*., 2019).

(a);Soil erosion, (b) Land degradation, (c); Farm land Eucalyptus plantation, (d) distressed cows, (Hailu *et al*., 2020).Changes in land use have a number of negative repercussions, including decreased soil fertility, carbon and nitrogen stocks (Tesfaye *et al*., 2016; Henok *et al*., 2017). Within the Sidama zone's Genale river watershed, land usages have altered considerably during the last 30 years (Bastian, 2015, Table 4). From 39.54 percent in 1985 to 5.77 percent in 2015, forest cover has declined. According to a comparable study by Zeleke (2022), natural forest cover decreased from 27 percent in 1957 to 2 percent in 1982 and 0.3 percent in 1995. Between 1957 and 1995, 7259.3 acres of natural forest were destroyed, accounting for nearly all of the forest cover that existed in 1957. (Zeleke, 2022, Table 2; Page 188). Grazing land has declined from 48.88% in 1985 to 26.69% in 2015. Agricultural land, on the other hand, increased from 39% to 49%. Cultivated land, on the other hand, increased from 39% in 1957

to 70% in 1982 and 77 percent in 1995(Zeleke, 2022). Though farmed land expanded by 95% from 1957 to 1995, the most of the expansion happened between 1957 and 1982 (78 percent in nearly 2 1/2 decades), with only 10% occurring from 1982 to 1995 since there was almost no land remaining (Zeleke, 2022). Similarly, Forest, pasture land, swamp/ Wetland, shrubland, and rangeland, on the other hand, fell by 19%, 18%, 32%, 7%, and 5%, respectively (Motuma, 2018). The findings were consistent with Abraham's analysis, which found that the proportion of cultivated land and settlement covers increased from 17 percent and 0.07 percent in 1972 to 62.84 percent and 2.98 percent in 2017. Temesegn and Tesfahun (2014) estimated a 72.7 percent increase in cultivated land in the eastern part of Lake Tana, northern Ethiopia, between 1985 and 2011. Eleni *et al.* (2013) documented consistent growth in settlement areas in the Koga Catchment, northern Ethiopia, spanning 40 years in their investigations.

3.3. Land use change and soil degradation in Ethiopia

The agriculture sector in Ethiopia is being challenged by increased population expansion and the steady depletion of natural resources (Amare *et al*., 2005). As a result, the country's forest cover, which was thought to be over 40% before the turn of the twentieth century, has decreased to less than 5%, with an estimated annual rate of deforestation of 0.15 to 0.2 million hectares (Girmay,2009). Reduced plant cover and natural ecosystem disturbance have resulted in extensive soil degradation, resulting in lower concentrations of soil organic matter (SOM) and accessible nitrogen (N) pools (Mulugeta *et al.*, 2005; Girmay *et al*., 2008; Gelaw *et al.*, 2014). Although the impact of land use and management on soil characteristics varies by soil and Eco region, it is widely acknowledged that such changes have increased soil erosion and degradation. Increased agricultural production and economic growth in Ethiopia have been restricted by land use change and consequent soil degradation due to soil erosion (Amare *et al*., 2005; Hengsdijk *et al*., 2005; Girmay *et al*., 2008). Moreover, the removal of agricultural residue and animal dung for domestic use, either as household fuel or as animal feed, exacerbates the process of soil fertility depletion (Amare *et al*., 2005; Girmay *et al*., 2008). Nutrient imbalances were found in a few investigations conducted around the country. Eyasu (2002) and Amare *et al*. (2006), for example, found -102- and -72-kg ha-1 N budgets in soils of Ethiopia's Southern and Central highlands, respectively. Similarly, according to a research by Zenebe (2007), using dung as fuel rather than organic fertilizer would diminish Ethiopia's agricultural GDP by 7%.

3.4. Land Use Change Impacts in Ethiopia

3.4.1 Soil properties

3.4.1.1 Effect of land use change on the soil physical properties

Soil Particle Size Distribution and texture

In comparison to other land use change, the sand proportion was higher in natural and mixed forest land (60.7 5.74) and open- and bush land (59.3 5.74). (Wandimagne *et al*., 2018, Table 1, Page 5). When cultivated land (33.8 5.74) was compared to other land use types, the total mean sand fraction was lower (Wandimagne *et al*., 2018). This is in line with the average percentage of sand in cultivated land being 61 percent and forest land being 52 percent, with cultivated land having the highest percentage of sand and grazed land having the lowest (50 percent). While cultivated sand accounted for 58 percent, forestland for 45 percent and pasture lands for 54 percent. Table 2, Page 7 (Deginet and Getahun, 2021). The soil textural fractions of sand, silt, and clay considerably altered with land use changes, and the interaction impact for the sand fraction was considerable (Awdenegest, 2013). Under agricultural, pasture, and forest fields, the mean values of silt were 33.5 percent, 38 percent, and 43.5 percent, respectively (Deginet and Getahun, 2021). Free grazing land had a higher amount of sand than enclosed land (Abinet, 2011). Clay fractions are more likely

to be lost to erosion and migration down the soil profile when plant cover is limited (Woldeamlak, 2003). The distribution of soil texture, on the other hand, was not significantly changed by LUC types (Hayicho *et al.*, 2019). Similar findings were observed in various sections of Ethiopia's southeast (Fantaw *et al*., 2006) and in northeast Wollega (Alemayehu and Assefa, 2016). Plowing, clearing, and leveling of farming fields may be to blame for the lower proportion of sand and increased content of clay fractions in farmed land (Alemayehu and Assefa, 2016).

Soil Bulk Density

Of all the LUC kinds, farm land had the highest average bulk density while forest land had the lowest. The BD of farm land was 0.3 g/cm3 higher than that of forest land and 0.2 g/cm3 higher than that of grass land (Mulugeta *et al*, 2014). Highest carbon stock was recorded in agriculture as compared to forestlands changes of SOC (8.99 Mg ha-1) (Seyum, Taddese, and Mebrate, 2019). The second largest SOC (8.69Mg ha-1) was observed in land use changes from agriculture to open grazing land, and the least value of SOCst was obtained in agriculture-to-agriculture land use changes (5.78 Mg ha-1) (Seyum, Taddese, and Mebrate 2019). The lowest carbon stock content in agricultural land might be due to low TOC and loss of soil structure by continues mono cropping and removal of crop residues (Seyum, Taddese, and Mebrate, 2019). In comparison to other land use types, bulk density in soil was found to be highest under cultivated land (0.97), followed by open bush land (0.95) (Wandimagne *et al.*, 2018, Table 1, Page 6). This is similar to the findings in Fikadu (2021, Table1 P 4) who found that soil bulk density was 0.71 g/cm3 and 0.64 g/cm3 on cultivated and forest land, respectively, and that soil bulk density was increased from FL,B L,CL (0.64, 0.69, 0.71) in g/cm3. The mean value of BD under forest, agricultural, and grazing land was 1.08 g/cm3, 1.62 g/cm3, and 1.63 g/cm3 (Deginet and Getahun, 2021). The increased bulk density of grazing land is owing to the grazing's higher compaction effect and erosion of the topsoil due to the lack of vegetation cover (Abinet, 2011). Fantaw and Abdu (2015) both came to similar conclusions and they concluded that the lower bulk density in soils under forest and higher bulk density in soils under cultivated land were due to differences in soil organic matter and less disturbances in the forest than in the cultivated land. Higher bulk density in cultivated land, on the other hand, may be due to the impact of repetitive tillage, which disrupts the soil structure and results in a compacted surface soil layer (Takele *et al*., 2015).

Soil Moisture

Soil moisture content was higher under natural and mixed forest land use (21.72 1.4) than other land use types, while it was lowest in soil under cultivated land (15.37 0.9) (Wondimagegn *et al*., 2018). There was a difference between the soil moisture contents among land use changes, according to Deginet and Getahun (2021), with the mean value at soils 20.6 percent, 10.84 percent, and 14.76 percent respectively, and the mean value of moisture in forest land, cultivated land, and grazing land being 25.85 percent, 10.86 percent, and 15.12 percent respectively. According to Adingo *et al*. (2021), farmland had the highest average soil

water content value (4%) compared to abandoned farmland, natural grassland, artificial lemon woodland, and poplar woodland, which had average soil water content values of 1%, 0.9 percent, 0.7 percent, and 0.8 percent, respectively.

3.4.1.2. Effect of land use change on soil chemical properties

Soil pH (H_2O)

The results showed that land use change had a considerable impact on soil pH, with a mean of 5.4 and a range of 5.83 to 5.22 across land use change. In comparison to other land uses, the total mean soil pH in wild and mixed forests was significantly higher (5.83 0.1) and lower (5.32 0.1) in Eucalyptus plantations. However, when compared to other land uses, the mean pH value was higher in wild and mixed forest (5.83 0.1) and lower in Eucalyptus plantation (5.22 0.1), respectively (Wandimage *et al*., 2018). This finding is consistent with that of Eshete *et al*. (2011), who found that the majority of Eucalyptus species have an acidifying influence on soil characteristics. The higher acidity (lower pH) in cultivated land compared to forest land was most likely due to continuous removal of basic cations by crops, increased leaching of basic actions by crops' harvest and washed away of exchangeable bases by soil erosion. According to Fentanesh and Zenebe (2020), the pH of soils in the natural forestlands (mean = 6.93) was slightly higher than that of cultivated (mean = 5.71) and grazing lands (mean = 5.12). The conversion of forestland to cultivated land has resulted in a decrease in organic matter, which has resulted in a dip in pH. (Khresat *et al*., 2008). These findings matched those of a research conducted by Biro *et al*. (2013) in Sudan's northern Gdarif region. The findings of this study corroborated those of earlier studies, indicating that soil acidity is becoming a serious problem in Ethiopia's Northwestern highlands (Genanew *et al*., 2012; Haile *et al*., 2009 and Melese *et al*., 2016).

Soil Organic Carbon

The average OC for natural forest, pasture, and cultivated lands soils was 8.00 percent, 5.16 percent, and 2.31 percent, respectively (Fentanesh and Zenebe, 2020). Because of the large amount of organic matter retained in forest soils, forest soils are one of the world's largest carbon sinks (Tesfaye *et al*., 2018). When compared to other land uses, the overall mean SOC concentration was greater in natural and mixed forest (3.62, 0.22) and lower in cultivated land (1.97, 0.16). SOC concentrations were greater in soil under natural and mixed forest land use (4.58, 0.31) and lower in soil under cultivated land (1.6, 0.22) than in other land uses (Wandimagne *et al*., 2018). This conclusion is consistent with the fact that SOC content in forest land (2.88%) is higher than in cultivated and grazing land, and SOC content declines significantly as soil depth increases (Dagnachew *et al*., 2019). This research supports Muktar *et al* (2018). Findings that indicated substantial differences in soil organic carbon (SOC) content (g/kg) for both land-use changes. The study

coincided with Deginet and Getahun (2021) and Moges *et al.* (2013), who found that land-use change impacted soil organic carbon (SOC).

Total Nitrogen (TN)

The total nitrogen content of land use varies, with greater mean values (0.24 percent) in forest land and lower mean values (0.14 percent) in intensively cultivated outfields, whereas grazing land and homestead garden fields have similar mean values (Elias, 2020, Table 4). However, total nitrogen content was higher (0.24) in forest land and lower (0.14) in agriculture (Elias, 2020, Table 4). Its return to the soil is high in forests and grazing pastures with a healthy cover of natural flora, which raises the SOM content, which in turn increases the total nitrogen content of these soils (Elias, 2020). The ideal C/N ratio is between 10:1 and 12:1, which delivers nitrogen in excess of microbial requirements (Negassa, 2002). This discovery is consistent with the findings of Abinet (2011), who found that total nitrogen in free grazing pasture was lower than in the enclosure. The lowest mean value of TN concentration was found on cultivated soils (mean = 0.17 percent) compared to natural forest soils (mean = 0.47 percent) and grazing pastures (mean = 0.36 percent) as a result of land use/cover changes (Fentanesh and Zenebe, 2020). This conclusion matched that of Warra *et al.* (2015) in the Kasso watershed in the Bale Mountains.

Available Phosphorous (Av.P)

Land use change had an impact on available phosphorus, with the greatest mean values (16 mg/kg) under forest land, followed by grazing land (14.27 mg/kg), and intensively cultivated outfields (9.13 mg/kg) (Elias, 2020). Abinet (2011) found that the mean value of available Phosphorous for free grazing area is higher than that of the enclosure in a similar study. Awdenegest (2013) found that the mean Av. P in the topsoil layer was much greater (5120 mg kg1) in farming than in other land use types, which could be attributed to the usage of animal manure, compost, and household wastes such ashes to improve soil quality. Phosphorus fixation may be linked to P content in the protected forest (Yimer, 2006).

Available Potassium (Av.K)

The overall mean of Av.P for cultivated, grazed, and natural forest lands was 1.07 ppm, 5.42 ppm, and 3.88 ppm, respectively (Fentanesh and Zenebe, 2020). In comparable findings, cultivated lands had higher Av.P concentration than rainforests (Bewket & Stroosnijder, 2003; Kebede & Raju, 2011). Awdenegest (2013) found that available potassium varied considerably with land-use types, with higher levels in protected-forest soil (0.26) and farmlands soil (0.24) than in other land-use categories, with little fluctuation. The interaction impacts of both LULC types greatly altered exchangeable K. (Hayicho *et al*., 2019). K. content was also found to be lower in intensively cultivated soils (Fantaw *et al*., 2011). As a result of the difference in

exchangeable K content between farmland (0.15) and forest land (0.19) cmol+/kg soil, the lowest level for K has decreased (Fantaw *et al.*, 2011; Abiye *et al*., 2008).

Electrical Conductivity (EC)

The highest mean EC was recorded in CL (0.12dSm) followed by GL (0.11dSm), and the lowest value recorded in FL (0.10dSm) (**Kassaye et al. 2020**). Similar result reported by (Getahun *et al.*, 2016).the highest (210 S cm-1) but also (50 S cm-1) occurs in unirrigated Vertisols, and the highest EC value under unirrigated (Luvisols) land may be due to its highest exchangeable, no content, whereas the lowest soil EC value under irrigated (Vertisols) land may be due to cation loss (Ca^{2+} and Mg^{2+}) after deforestation and intensive cultivation This finding is consistent with Abinet's (2011) study, which found that the mean electrical conductivity values for free grazing fields and area enclosures were 0.52 and 0.04 units, respectively.

3.4.1.3. Effect of land use change on soil Biological properties

Soil microbial respiration (SMR) decreased significantly from 101.40 mg C day-1 kg-1 for grazing soils to 88.40 mg C day-1 kg-1 for cultivated soils, with the highest SMR in the TS position and the lowest in the BS position, according to the study (Shamallah et al., 2013). Negative effects of LUC on soil Microbial Biomass Carbon (MBC) were found for LUs like BL,CL, GL, and HL. For example, MBC levels decreased significantly for BL (−61.3%) and CL (−25.7%) over the FL but changes in GL (−29.5%) and HL (−10.3%) were non-significant. These results indicate that the conversion of FL to other LUs (BL/ CL/GL/HL) could result in the decline of MBC content in soils (Rajeev. 2022). The average MBc in cropland and forest ecosystems (43570 g C g soil-1) was more than double that in other land use systems (14337-18051 g C g soil-1) (Dessie, 2017). The highest SOC concentration was found in AF (6.4 g kg-1), followed by IR (5.9 g kg-1), and the lowest was reported in RF (3.2 g kg-1). As a consequence, SOC in AF (Agroforestry) land use was substantially greater (P 0.05) than in RF (Dryland agricultural production) land use (Aweke. 2013). It did not, however, differ significantly between AF (Agroforestry) and (irrigation-based fruit production), or between IR (irrigation-based fruit production) and RF land uses (Aweke. 2013). SOC and MBC are two major soil characteristics that have an impact on biological processes and soil quality (Aweke. 2013). MBC was somewhat greater in IR-treated soils (100.1 mg kg-1) than in AF and RF-treated soils, but the differences were not statistically significant (Aweke. 2013). Higher MBC values under IR compared to AF and RF could be explained by reduced soil disturbance under IR compared to other intensively tilled land uses (Aweke. 2013). Our findings revealed that SMR fell dramatically from 101.40 mg C day-1 kg-1 in pasture soils to 88.40 mg C day-1 kg-1 in cultivated soils (Shamallah *et al*., 2013). The decrease in SMR correlated with the fall in SOC in various hillslope positions (Shamallah *et al*., 2013). The living fraction of the SOM, excluding soil animals larger than plant roots, is referred to as soil microbial biomass (Jenkins on, 1988). In this study, wild pasture soils had higher microbial biomass C and N than cultivated soils (Shamallah *et al*., 2013). The

most dependable techniques for studying the effects of faunal activity on soils are micro morphological and microscopic research (Khormali *et al*., 2009; Ayoubi *et al*., 2012).

3.4.2 Soil Carbon Stock

3.4.2.1 Impact of land use change on SOC stock

At a rate of 1.4 mg Cg soil-1 yr-1, conversion of forest to cropland and grazing land reduced soil carbon content by 68-72 percent (Demise, 2017). Onversion of natural forests into croplands induced a strong reduction of organic carbon in the soil. At Katassi and Gelawdios, the SOC stock was reduced by 87% and 50% respectively that seems the average rate of loss of SOC is 0.42 kg m−2 yr−1 at Katassi and 0.23 kg m−2 yr−1 at Gelawdios for the 50 year period (Dessie., 2017). Chronosequence studies have shown that the conversion of forests to cropland caused a rapid initial decrease in SOC stocks, followed by a slow decline (Deng *et al*., 2016; Wei *et al*., 2014). Reforestation of degraded grazing area with eucalyptus plantings, on the other hand, raised SOC stock by 24% at a rate of 0.3 mg C g soil-1 yr-1 (Demise, 2017). Highest carbon stock was recorded in agriculture as compared to forestlands changes of SOC (8.99 Mg ha-1) (Seyum, Taddese, and Mebrate 2019). The second largest SOC (8.69Mg ha-1) was observed in land use changes from agriculture to open grazing land, and the least value of SOCst was obtained in agriculture-to-agriculture land use changes (5.78 Mg ha-1) (Seyum, Taddese, and Mebrate 2019). The lowest carbon stock content in agricultural land might be due to low TOC and loss of soil structure by continues mono cropping and removal of crop residues (Seyum, Taddese, and Mebrate 2019). According to Girmay & Singh (2012), the total SOC stock stored (up to 80 cm) by all land-use types at Maileba and 172, 615Mg C at Gum Selassa was estimated to be 159, 516Mg C at Maileba and 172, 615Mg C at Gum Selassa, with 48 percent found in soil at both sites. The mean SOCand SOCS in the grazing land (18.5 g kg-1, 42.9 t/h) was significantly higher than cultivated (13 g kg-1, 32.6 t/h) and was the lowest in fallow land (9.7 g kg-1, 23.0 t/ha) respectively(Muktar *et al*., 2018). The highest SOCS in the grazing land use could be related to the high amount roots of grass and high grass root biomass turnover rate, which is important as protection from erosion and lack of tillage (Muktar *et al*., 2018). Various studies in Ethiopia have indicated losses in soil C stocks ranging from 2.3 mg ha-1 to 8.0 mg ha-1 per year owing to deforestation (Assefa *et al*., 2017, Kassa *et al*., 2017). In south western Ethiopia, higher above ground carbon was found in coffee agroforestry than in woodland, grassland, and cropland, but somewhat less than in natural forests (Dereje et al., 2016). Cultivated lands and grazing land, on the other hand, cover the most acreage in the catchments, accounting for around 80% and 16% of SOC stock, respectively, at Maileba and 86 percent and 13%, respectively (Gum Selassa Girmay & Singh, 2012). Though there is little information on carbon stock grazing land in Ethiopia's highlands, communally managed semi-arid rangelands in southern Ethiopia reported 128.39 t/ha below ground (soil and root) and 13.11 t/ha above ground organic carbon (Bikila *et al*., 2016). Kassa *et al*. (2017) found that LU conversions of natural forests to farmland resulted in annual losses of SOC ranging from 3.3 to 8.0 mg ha-1 at several areas in Southwest Ethiopia. Using the ecosystem model Biome BGC, Belay *et al*. (2018) anticipated a 40% loss of

soil carbon, mostly organic, after 40 to 50 years of converting forests to agricultural land in Ethiopia's Amhara area. Conversion of farmland to Eucalyptus, on the other hand, increased SOC supplies in all climate scenarios (Tebkew, 2018, Table 5 Page 8).

Furthermore, land conversions from natural forest to bush land, natural forest to Eucalyptus, and bush land to cropland could result in soil carbon losses of 17.3, 15.6, and 3.4 Mg ha-1, respectively (Tebkew, 2018). According to a comparable study by Muktar *et al*. (2018), the mean SOC Stock in grazing land (42.9 t/h) was significantly greater than farmed (32.6 t/ha) and was the lowest in fallow land (23.0 t/ha) in surface soils (Muktar *et al*., 2018). Tesfaye *et al.* (2016) detected 1.8 mg ha-1 yearly SOC accumulation following 28 years of Eucalyptus saligna plantation on degraded land in southern Ethiopia. The highest carbon stock was found in agriculture compared to forestland fluctuations of SOCst (8.99 Mg/ha), according to Seyum *et al.* (2019, Table 7, P 28). Land-use shifts from agriculture to open grazing land had the second-largest SOCst (8.69 Mg/ha), while agricultural-to-agriculture land-use changes had the smallest SOCst (5.78 Mg/ha) (Seyum *et al.*, 2019).

3.4.2.2 Conversion forest to cultivated/crop land

Natural and mixed forest conversion to farmed land reduced the SOC stock by 36.12%. (Wandimage *et al*., 2018). This could be due to a lack of organic materials applied to the soil, as well as reduced physical protection of SOC as a result of intensive cultivation, increased oxidation of soil organic matter, and complete removal of biomass from the field, as well as severe deforestation, steep relief, and high erosion hazards (Wandimagn *et al*., 2018). Conversion of natural forests to croplands resulted in a significant loss of organic carbon in the soil, according to similar findings (Dessie *et al*., 2017). The SOC stock at Kattasi and Gelawdios was reduced by 87 percent and 50 percent, respectively, implying that the average rate of SOC loss over the 50-year period is 0.42 kg m-2 yr-1 at Kattasi and 0.23 kg m-2 yr-1 at Gelawdios (Dessie *et al*., 2017). Another study found that when forests were converted to agriculture, SOC stocks dropped rapidly at first, then gradually declined (Deng *et al*., 2016; Wei *et al*., 2014). Similar findings have been reported for other sites in Northern Ethiopia, where cultivation land in Northwest Tigray had a 58 percent lower SOC level than forest land (Gebremariam and Kebede, 2010), and cropland in the southern highlands of Ethiopia had a 63 percent lower SOC level than forest after 30 years of cultivation (Gebremariam and Kebede, 2010). Another study found that when dry deciduous forest was replaced with other land types, such as cropland (15.33 t/ha), scrubland (12.87 t/ha), fallow land (11.8 t/ha), and thorn forest (9.37 t/ha), the rate of decline in SOC was higher between 1993 and 2003(Solomon *et al*., 2002). This is consistent with the fact that SOC levels decreased at 98 percent of the locations after forests were converted to agricultural land; the average reduction in SOC stocks was 44.5 6 1.0 percent (Wei, 2013).

After the land-use change, SOC stocks grew at the remaining 2% of the locations. The average increase at these locations was 23.6 6 8.9%. (Wei, 2013). SOC stocks declined by 34.7 6 1.6 percent on average across all forest types at sites in the early stage (10 years), 45.3 6 1.4 percent at sites in the intermediate stage (11–50 years), and 53.2 6 3.4 percent at sites in the late stage (50 years) of cultivation (Wei, 2013). Soil carbon storage was reduced by up to 88 percent when land was converted from forest to farmland or grazing area. Using the SOC storage of existing remaining forests and assuming a 40% forest cover, the Amhara region's SOC store was roughly 1.5 Gt C before 50 years ago(Solomon *et al*., 2002).

3.4.2.3 Conversion of forest to Grazing land

The conversion of natural forest to grazing area also resulted in a 53% decrease in SOC stock in the soil (Assefa, 2017). On other highlands sites, Bewket and Stroosnijder (2003) found that grazing land had 48 percent lower levels of SOM than natural forest. Because fine root biomass in grasslands is only 10% of that in natural forests at the highland sites studied (Assefa, 2017), necromass inputs must have decreased significantly. Furthermore, overgrazing has degraded the majority of the grasslands. The grazing land is frequently depleted. According to Desta *et al* (2000), the stocking density (23 livestock unit (LU) ha1) in grasslands is ten times the carrying capability (2–3 LU ha1). Abera and Belachew (2011) found that soils under forest sites were well protected, with little disturbance, but that soils on open bush lands were poorly managed, extensively overgrazed, and prone to surface erosion and water logging.

3.4.2.4 Conversion of Grazing to exclosure land

After an 8-year exclosure period, the conversion of badly degraded grazing area to exclosure in Ambober boosted SOC stock the soil layer by 42 percent compared to cropland (Girmay *et al*., 2008). Exclosure has also been demonstrated to improve carbon stock in other research (Girmay *et al*., 2008; Li *et al*., 2012; Mekuria *et al*., 2009). For example, Li *et al*. (2012) observed that SOC stock in the top layer rose from 93 to 638 g m-2 over a 26-year exclosure period at a rate of 31 g C m-2 yr-1 on rangelands in Inner Mongolia, while no significant variation was found after an 8-year exclosure period (107 g m-2). The mean SOCS in the grazing land (42.9 t/h) was significantly higher than cultivated (32.6 t/h) and was the lowest in fallow land (9.7 g kg-1, 23.0 t/ha) respectively (Yared *et al*., 2018). The rise in SOC stock in the exclosure region suggests that increased vegetation growth and carbon input can begin to rebuild SOC stocks, although it will take a long time to recover to near-original SOC stock levels.

3.4.3. Soil Quality

3.4.3.1 Impacts of Land Use Changes on Soil Quality

SOC is the most essential measure of soil quality, according to several researchers (Andrews *et al*, 2002), because it determines many of the physical, chemical, and biological soil attributes (Wang *et al*. 2003). The

average sand percentage of natural forestland soils was high (40.6%), while it was low on cultivated and grazing land soils 20.1 percent and 31.3 percent respectively (Fentanesh and Zenebe, 2020, Table 1 Page 4). On the soils of cultivated land, the reverse clay fraction was > grazing land > natural forests (Fentanesh and Zenebe, 2020). According to Kassaye *et al.* (2020), the mean value of clay was highest on cultivated land (41.67 percent), followed by forest land (24.33 percent), and grassland (23.33 percent) (19 percent). The different land use types had statistically different bulk density, porosity, and aggregate stability. This result agrees with Kassaye *et al.* (2020), who found that FL 1.4g/cm3 have the highest bulk density, followed by GL 1.33g/cm3. CL 1.16g/cm3 had the lowest BD, while Yared *et al*. (2021, Table 1.2, Page 17) found that bulk density was much higher in fallow land than in grazing and cultivated lands. Getahun and Bode (2015) found that the mean bulk density of grazing and cultivated land soils increased by 27.1 percent and 19.62 percent, respectively, when compared to nearby forest land soils (Getahun and Bode, 2015,Table, Page 43). In comparison to the natural forest, Eyayu *et al*. (2009) found that the bulk density in grazing and cultivated fields increased by 15.5 and 10.7%, respectively (Getahun and Bode, 2015).

A reduction in pore size distribution was attributed to a decline in total porosity in grazing and cultivated land soils as compared to forest land soils, and it is also directly related to the quantity of SOM loss, which depends on the intensity of soil management methods (Achalu *et al*., 2012). Soil pH varied significantly depending on the influence of land-use changes on forest conversion (Emmanuel *et al.*, 2021, Table 1, page 153), with the lowest pH (5.7) in degraded soils and the greatest pH (7.1) in horticulture soils (Emmanuel et al., 2021, Table 1, page 153). FL had the highest soil pH (6.54), followed by GL (6.51). CL 96.31 had the lowest soil pH, which is slightly below the recommended pH range for plant growth (Kassaye *et al.*, 2020). Land use change had a similar impact on soil pH, which ranged from 6.37 to 6.89, with only the soil from the eucalyptus stand being much lower than the other land use types (Yoseph *et al.*, 2017). In comparison to other soils, degraded soils have significantly lower pH due to the repercussions of basic cation leaching and the dominance of exchangeable H^+ and Al^{+3} (Neina, 2019). Acidity in degraded soils was also caused by accelerated leaching of basic cations (Ca, Mg, K) due to increased rainfall and erosion (Neina, 2019). In agreement to the above statement CEC was highest on forestland 25.5c mol (+)/kg) and followed by open grazing land (24.02c mol (+)/kg), whereas it was the lowest on agricultural land 15.5c mol (+)/kg which is closely related to high organic matter content of the forest soil (Seyum, Girma and Tesfaye, 2019).) As the soil carbon decreases the CEC decreases too, and the role it plays as a source of energy for microorganisms diminishes (Zvoleff, 2014).

TOC content in soils under agriculture and degraded lands fell by 1.6 to 2.7 times after forest conversion. The TOC in horticulture and fallow soils was more than 2 times lower than in forest soils (Emmanuel *et al*., 2021). SOC concentration varies with land use, ranging from 1.42 percent to 2.02 percent, with GL (2.02 percent) having the greatest SOC, followed by FL (1.85 percent) and CL (1.42 percent) (Kassaye *et al*.,

2020). According to Yoseph *et al.* (2017), natural forest soil had much higher SOC and TSN than soils from the other examined land uses, whereas agriculture soil had the lowest SOC and TSN. Because N is stoichiometrically connected to C in SOM (Kirby *et al*., 2013), increased litter intake, C: N stoichiometry, and biological N fixing by naturally occurring leguminous vegetation resulted in higher TN content in forest soils than in horticultural and agricultural soils (Moges *et al*., 2013). These findings are also consistent with Solomon *et al.* (2001) and Wakene and Heluf (2003), who found that plant cover in land use change, can alter soil P. Nonetheless, the current findings were in contradiction to those of (Alemayehu and Sheleme, 2013), who found that cultivated land soils had more accessible P than grassland soils.

This study's findings are consistent with those of (Girma and Endalkachew, 2013), who suggested that low accessible phosphorus could be linked to continuous cropping, surface erosion, and a lack of biomass addition to soils. The lowest TN content was found in deteriorated soils due to C:N stoichiometry, soil erosion, and a lack of N fertilisation continuity(Girma and Endalkachew, 2013). Similarly, in degraded soils, a much reduced amount of AP was likely linked to a lack of P fertilisation and increased P fixation by ferruginous minerals (Yimer *et al*., 2007; Koda *et al*., 2018). While P fixation is a concern in ferrallitic-ferruginous soils, horticulture soils' higher TOC content may have reduced P fixation and enhanced AP (Moges *et al*., 2013; Kalu *et al*., 2015). Reduced K+ fixation and a release of K+ due to the interaction of TOC with clay minerals may have contributed to the enhanced availability of K^+ in horticultural soils (Sharma *et al*., 2001). In soils used for horticulture and agriculture, the Ca^{2+}: ($Mg^{2+\,+}$, $K^{+\,+}$, Na^+) ratio, which evaluates soil resistance to aggregate dispersion in response to rainfall impacts, erosion, and flooding, was higher. This could be linked to the usage of domestic biomass ashes, liming, and vegetation recycling of basic cations from the subsurface and returning them to the topsoil.

SOC and MBC are two important soil variables that influence biological processes and soil quality (Aweke. 2013). SOC concentrations were found to be highest in AF (6.4 g kg-1), followed by IR (5.9 g kg-1), and lowest in RF (3.2 g kg-1) (Aweke., 2013). As a result, SOC in AF (Agroforestry) land use was substantially greater (P 0.05) than in RF (Dryland crop production). However, no statistically significant differences were found between AF and IR, or between IR (irrigation-based fruit production) and RF land uses (Aweke. 2013). MBC was somewhat greater in IR-treated soils (100.1 mg kg-1) than in AF and RF-treated soils, but the differences were not statistically significant (Aweke. 2013). Higher MBC values in IR than in AF and RF could be explained by less soil disturbance in IR than in other intensively tilled land uses (Aweke. 2013). Our findings revealed that SMR fell dramatically from 101.40 mg C day-1 kg-1 in pasture soils to 88.40 mg C day-1 kg-1 in cultivated soils. The decrease in SMR correlated with the fall in SOC in various hillslope positions (Shamallah *et al*., 2013). The living fraction of the SOM, excluding soil animals larger than 5 9 $103lm^3$ and plant roots, is referred to as soil microbial biomass (Jenkins on, 1988). In this study, wild pasture soils have higher microbial biomass C and N than cultivated soils (Shamallah *et al.*, 2013). The most

dependable techniques for studying the effects of faunal activity on soils are micro morphological and microscopic research (Khormali *et al*., 2009; Ayoubi *et al*., 2012).

3.4.3.2 Impact of land-use change on Soil Quality Index (SQI)

The calculated SQI ranged from 0.27 to 0.79 at Maileba and 0.22 to 0.72 at Gum Selassa. Cultivated land at Maileba and plantation area at Gum Selassa scored the lowest SQI and were classified as 'degraded,' implying that these land-use types are in jeopardy and require immediate soil restoration and conservation measures for long-term productivity. (2012) (Girmay & Singh, 2012). According to Amoakwah *et al.* (2021), fallow and degraded soils had lower SQ by 5 and 16 percent, respectively, indicating a significant SQ degradation over time when compared to the forest, and SQ values of degraded lands were also significantly lower by 9 to 11 percent than agriculture and fallow lands. On the other hand, the SQ in horticulture was much higher by 5%, implying a similar or even better SQ than in the forest. Clay, sand, bulk density, aggregate stability, soil pH, cation exchange capacity, SOC, and AvP were all included in the SQI (Yared *et al.*, 2021). According to Yared *et al*. (2021), the integrated soil quality index values for land uses were 0.69 for grazing land, 0.62 for cultivated land, and 0.59 for fallow land, all of which are classed as intermediate soil quality (0.55 SQI 0.70) and statistically significant. This indicates that soils in the Kersa watershed that are used for grazing have improved soil functioning and soil quality. Higher SQI in area exclosure at Maileba and cultivated land at Gum Selassa, on the other hand, indicates that soils under these land-use types are better off in terms of soil functioning and soil health (Andrews *et al*,. 2003). More physical, chemical, and biological soil variables, such as soil structure, infiltration, water-holding capacity, soil respiration, microbial biomass C and N, possibly mineralizable N, and soil aggregate stability, might be measured and included to improve the SQI result (Girmay & Singh., 2012). Area exclosures, on the other hand, have been shown in this and other Tigray research to be effective in improving the soil quality of deteriorated soils (Mekuria *et al*., 2007).

3.4.4 Implications of land use change

3.4.4.1 Implications of the land use change on soil erosion

The removal of vegetation exposes the land to the effects of rains. When steeper slopes are cultivated in high erosivity circumstances, the situation gets worse, especially in the absence of appropriate soil conservation measures (Assen, 2021). In the watershed, conversion of forest and shrubland to cultivated land has raised mean sediment yield from 6.79 tha-1year-1 in 1973 to 8.65 tha-1year-1 in 1995 and 9.44 tha-1year-1 in 2015. (Gashaw, 2019). Aneseyee *et al*, (2020) conducted a research in the Winike Watershed, Omo Gibe Basin, Ethiopia, and found that total soil loss and sediment export rose by 176.35 and 3.85 thousand tonnes, respectively, between 1988 and 2018, due to changes in land use. Another study in Ethiopia's Upper Blue Nile Basin found that rapid expansions of cultivated land and built-up area at the expense of forest,

shrubland, and grasslands increased the watershed's average soil erosion rate from 35.5 tha-1year-1 in 1985 to 55 tha-1year-1 in 2015, as well as the sediment yield from 14.8 tha-1year-1 in 1985 to 22.1 tha-1year-1 in 2015. (Kidane *et al*, 2019). In the Gelda Catchment, Northwestern Highlands of Ethiopia, Esa *et al*. (2018) observed that expansion of farming techniques raised the mean annual soil loss rate by 16.3 tha-1year-1 and the amount of mean sediment carried at the outlet increased by 16 percent between 2004 and 2014. As a result, the percentage of land subject to soil erosion has risen from 79.31 percent in 1965 to 85.56 percent in 1996 and 87.32 percent in 2007. (Assen, 2021). Where grassland, forest land, and aquatic vegetation LUC were converted to cultivated and rural settlement area, the situation might become serious (Assen, 2021). As a result, soil erosion affected over 26 ha of land (or 0.23 percent of the land prone to erosion in 1965, or 0.19 percent of the entire watershed area) (Assen, 2021). This means that in Ethiopia, cultivated land, particularly steep slope farming, is the primary source of soil erosion (Hurni, 1983). As a result, in the research region, the presence of rocky and steep topography in the eastern and northeastern parts of the watershed is the most important element in gully formation. (Assen, 2021).

3.4.4.2 Implications of the land use change on land degradation

Soil degradation is one of the symptoms of land use change, which increases the risk of land degradation (Abrham *et al*., 2021). For all land uses and research sites, organic carbon (OC), nitrogen (N), accessible P, K, CEC, and porosity result in a negative degradation index (Girmay, 2010). The conversion of natural forest to Eucalyptus plantations and farmed land hastens soil degradation (Girmay, 2010). Mulugeta *et al*. (2005) reported a negative degradation index for porosity, soil C, total N, and CEC in a study on soil-fertility decline in the tropics following deforestation and conversion to agricultural fields in southern Ethiopia, which was similar to our results. The perceived effects of soil degradation as a result of land use change were ranked highest by farmers. These findings corroborate those of Karl *et al.* (2009), who found that soil degradation caused a decrease in crop output due to its negative effects on plant growth. Poor land use/cover management in the catchment, according to Asmamaw *et al*. (2012), could result in excessive soil erosion and gullies (Abrham *et al*., 2021). Changes in vegetation cover not only remove soil physically, but they also hasten the loss of essential soil qualities, resulting in a decrease in soil fertility (Warra *et al*., 2013). The loss of biodiversity is another sign of land degradation caused by LULC change (Abrham *et al.*, 2021). The data demonstrate that the area covered by natural vegetation in the Mida Woremo watershed has decreased during the last four and a half decades. In addition to the dangers of soil erosion and deterioration of soil quality, a decrease in vegetation cover may alter the natural ecosystem, resulting in biodiversity loss (Abrham *et al*., 2021). Though the findings of this study are consistent with those of many earlier studies (Wubie *et al*., 2016; Birhan and Asefa, 2017) undertaken in Ethiopia's highlands, the causes and effects of LULC changes on biodiversity vary by location.

3.4.4.3 Implications of the land use change on hydrology and water ecology

Land use changes have a direct impact on the hydrological process, as well as the water ecology and quality of a given watershed (Assen, 2021). The balance between rainfall, evaporation, and runoff response of a region is altered by land use and land cover change, which is primarily influenced by anthropogenic interference (Chimdessa *et al*., 2018). Within a watershed, changes in LUC affect infiltration, groundwater recharge, surface runoff, and river flow (Getahun and Haj. 2015). As a result, a better knowledge of land use change in Ethiopia and its impact on hydrological processes is critical for the country's water resource management. Haregeweyn *et al* (2015) found that increasing cultivated land by 15.4 percent and settlements by 9.9 percent at the expense of shrubland and grazing lands increased annual surface runoff by 101 mm, reduced groundwater recharge by 39 mm, and reduced annual evapotranspiration by 91 mm between 1976 and 2003 in the Gilgel Tekeze Catchment, Northern Highlands of Ethiopia. Similarly, Gashaw *et al*. (2018) found that between 1985 and 2015, the continual development of cultivated land and built-up area, as well as the reducing of forestland, shrubland, and grassland, had increased the annual average temperature. Wet seasonal flow increased by 4.6 percent, surface runoff increased by 9.3 percent, and water yield increased by 2.4 percent. In the Andassa Watershed, Ethiopia's Blue Nile Basin, the observed alterations lowered dry season flow by 2.8 percent, lateral flow by 5.7 percent, groundwater flow by 7.8 percent, and evaporation and transpiration (ET) by 0.3 percent (Ajanaw., 2021). According to Chimdessa *et al*. (2018), land use and land cover changes in the Didessa River Catchment, Southwest Blue Nile Basin of Ethiopia, and increased average monthly river flow by 4.9 m3/s, 5.7m3/s, and 10.6 m3/s, respectively, between 1986 and 2001, 2001 and 2015, and 1986 and 2015.

4. CONCLUSION AND PROSPECTS FOR FUTURE WORKS

4.1 CONCLUSION

Anthropogenic factors or human intervention in Ethiopia has accelerated land use changes for various purposes such as agriculture, settlement, mining, logging, and transportation, and the change has an impact on humans and other natural resources in general, as well as water and soil resources in particular. As a result, the primary objective of this review was to examine the impacts of land use changes in the country on soil characteristics, soil carbon stocks, and soil quality processes.

Land-use change is one of the most important elements affecting soil parameters have the greatest impact on the soil. Land use change and management changes can have a big impact on the amount and dynamics of soil organic matter functions. Soil organic carbon stores, as well as the physical, chemical and Biological features of land use, have all been shown to be impacted by land use changes in previous studies. During the

conversion of cultivated land at the expense of forest land, shrubland, and grassland in the country, soil organic carbon stock and most physical and chemical properties, including P, CEC, K, and N, were much greater in the forest than grazing land and cultivated land. In forest land, however, pH and bulk density were lower.

Changes in SOCst in the soil resulted from changing from one land use to another. Land use transitions from forest to agriculture had the lowest SOCst value. Forestland had a higher SOCst than agricultural and open grazing grasslands. When land use transitions from forest to cultivated or bare land to cultivated or forest to bare land, the soil bulk density increases. As one moves from cultivated fields to the forest, homesteads garden fields, and grazing regions and follows the pattern of organic matter levels, the nitrogen content of the soils is generally low to medium. The accessible phosphorus concentration of the soils was similarly low in cultivated fields and high in forest, pasture, and homestead garden fields. The soils' accessible potassium (Av.K) concentration was low under cultivated land but high under forest, grazing, and homestead garden fields. From woodland to farmed land, soil CEC was dropping. represents the percentage of CEC and the percentage of SOM in FL, BL, and CL, respectively.

Land use modifications that impacted soil quality had a considerable impact on soil physical, chemical, and biological characteristics. When farmed or other land uses were converted, forest soils had a higher SQ than other land uses. TOC, Ca^{2+}: (Mg^{++}, K^{++}, Na^{+}), K, TOC: clay, CPC, BS, ASI, and clay all showed considerably lower values as a result of land-use changes when primary forest was converted to alternative land uses. The disparity in soil quality indices across land changes could be attributed to plentiful biomass, which influences all other soil quality parameters. Land use management is an important step in protecting existing soil carbon while also helping to increase soil carbon. In order to improve soil organic carbon stock and soil quality, Ethiopia must retain forest land, reduce agricultural intensity, and implement integrated soil fertility management. Overall, the evidence from various studies shows that, in order to mitigate the potential impact of land use change on SOC stocks, soil properties, and soil quality, there is an urgent need for sustainable management of current production systems and natural resources that increase soil carbon in Ethiopia's land use systems.

4.2 PROSPECTS FOR FUTURE WORKS

Anthropogenic influences are hastening land use changes in Ethiopia, affecting humans and other natural resources in general, as well as soil and water resources in particular, which are vital to human survival. As a result of the review, it was determined that the expansion of cultivated land at the expense of forest, shrubland, and grassland in Ethiopia has increased the rate of soil erosion, organic matter loss, sediment yield, annual surface runoff, mean wet monthly flow, mean annual stream flow, and water yield in various regions of the country. This demonstrates that previous research on the effects of land use changes on soil resources and water adequately demonstrates the change in soil carbon stock and soil quality as a result of changing land use in the country for agricultural purposes. As a result, future study should:-

- More emphasis should be placed on investigating the effects of land use changes on the country's soil resources, as well as conservation and rehabilitation of land use changes through reforestation.
- Pay more attention to forecasting future soil loss and hydrological imbalances as the country's land use evolves backed up by soil water conservation studies.
- As several study recommendations suggested, our people lack sufficient information and understanding about the implications of land use changes on product and productivity, necessitating much more research to better understand the impacts of land use changes on crop output and productivity.

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