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Original Article

Effect of Deforestation on the Status of Soil Fertility

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ABSTRACT

In Ethiopia, the soil's physicochemical composition is frequently altered through the transformation of natural forests to farmland, vast pastureland, and cultivated areas. Understanding the effect of deforestation on soil fertility is the main goal of this review. Farmland, grazing land, land for other uses, and unmanaged forests are the different land use types that were taken into account. This evaluation takes into account features of the soil, such as bulk density, soil texture, and soil physical characteristics, particularly soil moisture content. Contrarily, the chemical characteristics of the soil, such as pH, EC, CEC, soil organic carbon, total N, and accessible P, are taken into account when comparing the various land uses. In forestlands, there were greater levels of clay, Acidity, cation exchange capacity, exchangeable Ca^{2+}, and the amount of organic matter and total nitrogen in the soil. Clay, available phosphorus, and exchangeable K^+ were all higher in cultivated land while exchangeable Mg^{2+} was highest in grazing land. Sand, clay, soil organic matter, cation exchange capacity, exchangeable Ca^{2+}, and Mg^{2+} all showed a greater mean difference in cultivated land compared to grazing land and forestland.

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INTRODUCTION

Agrarian production has historically been highly dependent on natural resources in Ethiopia, which form the basis of the economy (Taye, 2006). Because of this, lands used for agriculture increased in opposition to natural forests in order to supply the increased need for food due to the growing population (Bewket, 2003). Forests have been extensively exploited for building materials and fuel wood in addition to the growth of farmed and grazing grounds to accommodate the requirements of the fast-growing population (Ashagrie, 2004).

Especially severely deforested nations in sub-Saharan Africa is Ethiopia, particularly because of the degradation of the forest, which led to land for agriculture deterioration and loss of soil. A complex and interconnected sequence of events brought to the loss of forest cover in a critical watershed is responsible for the overall instability and productivity degradation of the nation's natural resources. Because of its altitude and topography, Ethiopia has a variety of agro-climatic zones. This has resulted in Ethiopia having a botanical treasure house with 6027 distinct flowering plants. Approximately 12% of these flowering plants are indigenous (FAO, 2005). These varied floras may be found in the natural woods, which previously spanned 40% of the nation's entire geographical area. However, compared to fifteen years ago, the forest cover now only covers 3% of the entire land area.

However, according to the most recent statistics on Ethiopia's forest resources, the country has a 10%–30% forest cover (FAO, 2010). Ethiopia lost 3.6% of its forest and woodland habitat between the years 1990 and 2005 when the overall rate of habitat protection is measured. This loss was a result of overgrazing, converting the forest to agricultural land, and the collecting of firewood (FAO, 2005). These natural forests' destruction has several consequences on the ecosystem, including soil erosion, low production, and other ecological imbalances with recurrent drought and desertification. Ethiopia, which has 43% of the global populace, 88 and 75% of it in terms of people and livestock, and 95% of its land is cultivated, faces a serious environmental and socioeconomic challenge due to soil erosion and the resulting degradation of its agricultural land.

While the movement of soil loss can amount to 23400 million tons annually, annually lost soil amounts to 200–300 tons per hectare. The consequences of Ethiopia losing its fertile soil are extensive. It still has an impact on 88% of the nation's overall population, in addition to 50% the agricultural area. In addition to reducing the amount of fertile soil, erosion reduces run-off water, plant nutrients, and microflora. This has an adverse impact on the ability to irrigate land and generate power. Floods in plains and valleys harm crops, animals, habitations, and communication. (Tsegaw, 2007). The low fertility of the soils is one of the biophysical constraints to raising agricultural productivity. Due to its connection to population economic prosperity and food insecurity, improving soil fertility is becoming a crucial problem in development agendas. (Bewket, 2003). The initial 20 to 25 years after a deterioration in Ethiopia's southern area, drastic declines in soil fertility have been documented. (Lemenih, 2004; Tesfaye *et al.*, 2016). A loss in soil fertility is one of several unfavorable effects of altered uses of land. (Kassa *et al.*, 2017; Lemenih, 2004; Tesfaye *et al.*, 2016). Reviewing effects of land use changes or deforestation on soil fertility is the objective of this paper.

CAUSES AND EFFECTS OF DEFORESTATION

Causes of Deforestation

Deforestation is a result of factors that push people to destroy forests. Human-made and natural elements can be employed to categorize the causes of deforestation. The most commonly recognized reasons for the loss of forests and woods include increased wood fuel collection, destruction of forests for agriculture, illicit and poorly controlled timber exploitation, social and environmental disputes, expanding urbanization, and industrialization (FAO, 2010). The majority of Ethiopia's people are still engaged in

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agriculture, but there is still pressure to clear land for farming crops and livestock, especially now that investors are attempting to convert dry land forests into the production of commercially produced grains, coffee, and tea. (David, 2008; Owen, 2006). Deforestation is a persistent problem in Ethiopia that is resulting in extinction, climate change, the eviction of native populations and desertification.

The effects of drought and spontaneous forest fires are examples of natural forces. However, the majority most of the current articles makes a distinction among two tiers of particular elements: (extension of agricultural land, fires, overgrazing, logging, fuelwood production, mining, tourism, urbanization or industrialization, and infrastructure) and indirect (transmigration and colonization, overpopulation and poverty, unequal land distribution, and corruption) causes of deforestation. (Murali & Hedge, 1997; Scrieciu, 2003).

Deforestation's Effects

Effect of the atmosphere

Ethiopia's climate and topography are changing as a result of continuous deforestation. Deforestation is frequently regarded as one of the main reasons for the increased greenhouse effect and contributes to global climate change. (David, 2008). 20% of the world's GHG emissions are attributable to tropical deforestation. Up to one-third of all anthropogenic carbon dioxide, emissions are caused by deforestation, which primarily occurs in tropical regions. (Tadesse, 2007). However, currently experts acknowledged rain forests added relatively little net oxygen to the atmosphere and that forest degradiation will have minimal impact on the level of oxygen in the atmosphere, it is still frequently thought by laypeople that Ethiopian rain forests contribute a substantial proportion of the world's oxygen. However, the burning and cremation of forest vegetation for land clearing emit tons of CO_2, which adds to global warming. Additionally, forests can remove airborne contaminants and carbon dioxide, promoting the stability of the biosphere. (Brown & Plan, 2006).

Hydrological Effect

Gore (2006) asserts that deforestation also has an impact on the water cycle. Groundwater is extracted from the ground by trees' roots and released into the atmosphere. The removal of a portion of a forest causes the trees to stop evaporating this water, creating a considerably drier environment, in Ethiopia, present periodic drought and Elnino. Deforestation decreases the amount of water in the soil, the underground water, and the atmosphere. Deforestation weakens the cohesiveness of the soil, resulting in erosion, floods, and landslides. In certain locations, forests improve aquifer recharging. However, in most places, woods constitute a major contributor to aquifer depletion. (Brown & Plan, 2006).

Decreased forest cover affects the environment's capacity to catch, hold, and dissipate precipitation. Instead of storing rainfall that later penetrates into underground waterways, deforested areas became the source of surface-level runoff, transferring much more quickly than underground flow. Rapid water from the surface flow than when there is forest cover may lead to rapid flooding and more localized floods (Pearce, 2001). Deforestation also causes a reduction in evapotranspiration, which lowers atmospheric moisture and, in certain situations, reduces the amount of precipitation that falls in the direction of the forestless areas as opposed to being lost in runoff and going directly to the seas, water doesn't return to the trees downstream (Jonathan *et al.*, 2005). The amount of water in the atmosphere, the soil, and the underground water may all change according to whether there are trees or not. Water supply for the environment or human needs is subsequently affected, as well as erosion rates. When heavy rainstorms overwhelm the forest's soil's ability for storing water and cause the soil to become saturated or near to it, drying up the rivers, streams, and springs, the forest may not have much of an effect on floods. (Susanna *et al.*, 2006).

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Soil Effect

The amount of soil being lost in untouched forest is quite low— around 2 tonnes per km^2. In general, deforestation causes rates of soil erosion to rise because it causes more runoff and less tree litter to protect the soil. This may be advantageous in tropical rainforests with soils that have been overly leached, of which Ethiopia is one. (Hobbs & Harris, 2001). A million years ago, there was a forest on the Ethiopian plateau. The plateau has been eroding ever since, making stunning carved valleys and feeding the material, which enables river to flood in its lower levels. When shallow of the soil is sufficient, tree roots serve to hold soil in place by tying it Accompanying the bedrock underneath it. Tree roots bind dirt together. Thus, cutting down trees on slopes with thin soil raises the chance of landslides, which might endanger neighbouring residents. However, the majority of deforestation mainly damages tree trunks, enabling the roots to remain firmly planted and preventing landslides (Mishra *et al.*, 2004).

Ecological Effect

Deforestation, in accordance with Arild & David (1999), causes a reduction in biodiversity. The removal of forests has resulted in a deteriorating environment with less biodiversity. Furthermore, forests encourage medicinal conservation. Forests maintain biodiversity by providing habitat for species. Deforestation can irreparably alter genetic variants (like crop resistance) because forest biotopes are an invaluable source of novel medications (Jeremy, 2008). Due to the fact that tropical rainforests have the most varied ecosystems on Earth and contain roughly 80% of all known species, the removal or loss of significant portions of forest cover has led to a degraded environment with less biodiversity (Marcoux, 2000).

In most cases, removing the forest cover causes completely distinct microclimatic conditions to exist above and in the soil, as well as a different water balance in the soil and a significantly decreased input of organic matter. (Gijsman, 1992). Because forests are the principal terrestrial sink for carbon, deforestation contributes to global warming, which results from a rise in atmospheric concentrations of greenhouse gases (GHG). The atmosphere's carbon dioxide content rises because of the disruption of the global carbon and water cycles. Furthermore, it worsens floods, and the long-term effects of deforestation on soil resources can result in significant losses in soil fertility. There are two key causes of deforestation's increased floods. First, reducing the "tree fountain" effect increases the likelihood that soils will become entirely saturated with water. The risk of flooding increases during the rainy season when the "sponge" fills up early, enabling more rainwater to drain out. Second, deforestation frequently leads to compacted soil that is unable to absorb rain. Locally, this causes streams to respond to rainfall more quickly, which might result in flash floods (Duguma *et al.*, 2019).

SOIL FERTILITY STATUS IN ETHIOPIA

Africa as a whole is seeing a decline in soil fertility (FAO, 2010). The exotic forest has been converted to agricultural usage, which has increased over the past several decades, played a prominent role in the evolution of Ethiopian landscapes, and is thought to be a contributing factor in the expansion of degraded land throughout the majority of the nation. The physical and chemical properties of soil as well as soil deterioration are impacted by various land use practices (Bewket, 2003). Land use changes often have an impact on an ecosystem's soils, making them crucial to the global soil nutrient cycle.

Soil Physical Properties

Soil Texture

The percentage of sand, silt, and clay make up soil texture. One of a soil's most crucial characteristics is its texture, which has a significant impact on how land is used and managed. It has an impact on how much water and nutrients a soil can store and provide to plants (Hajabbasi *et al.* 1997). According to Kassa *et al.* (2017), forests with high topsoil clay and silt fractions are characterized by a diversity of trees and shrubs that offer cover, litter, and root protection for the surface soil against leaching and soil erosion. Since soil

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erosion is less likely because to the forest's crown, litter, and root structure. Changes in land use and cover had a big impact on the soil types sand, silt, and clay (LULC) (Sebhatleab, 2014).

Table 1: The use of land and soil depth interactions with soil particle size distribution (sand, silt, clay, and BD) in various land use systems

Land use type	Sand (%) * soil depth (cm)		Silt (%) * soil depth (cm)		Clay (%) * soil depth (cm)		BD (g/cm3)
	0-20	20-40	0-20	20-40	0-20	20-40	
Forest	60d	60d	18de	16e	22b	24a	1.1
Grazing	68a	64c	26a	24ab	6e	12d	1.2
Cultivated	66b	64c	20cd	22bc	14c	14c	1.4

** Interaction signifies that letters that are the same within a single soil parameter do not significantly differ from one another at $P \leq 0.05$.*

Source: (Yeshaneh, 2015)

The greatest values of sand (68%) and silt (26%) contents were recorded at the surface (0–20 cm) layer of grazing land, while the highest value of clay content (24%) was recorded at the subsoil (20–40 cm) layer of forest land. When we consider *Table 1* interactions between the depth of the soil and land usage. With the exception of sand in forestland and silt in cultivated land soils, the concentrations of the ratio of silt and sand were declined as the soil depth increase in all land use groups. The subsurface soil included more clay than sand. The clay proportion in both levels of the cultivated land was the same (14%), in contrast to the other land use types (Table 1). This may be because of tillage operations that mix up the soil and generate compaction on the surface, which prevents clay particles from moving between the different layers of soil (Yeshaneh, 2015). Because changes in land management had a relatively little impact on these depths, there were significantly fewer variances in particle size distribution between subsurface of soils layers in various land use patterns (Chimdi *et al.*, 2012). As a result, the overall trend in the texture of the soil since the forest was changed to various land uses has been a rise in the sand content and a reduction in the clay content (Bewket & Stroosnijder, 2003).

Soil Moisture Content and Bulk Density

It is possible to determine how much water is present in soil by looking at its moisture content, often known as water content. The availability, transformations, and biological behavior of the soil are all influenced by the moisture content of the soil (Sebhatleab, 2014). Indicators of soil health and compaction include bulk density. It affects soil permeability, plant nutrient availability, rooting depth/restrictions, available water capacity, percolation, rooting depth, and soil microbial activity, which all affect important soil processes and production. According to *Table 1*, soil compaction caused mostly by livestock grazing may be the reason of the high soil bulk density in the grazing field. As the pressure put on the soil by the cattle's activity, livestock grazing can immediately result in an increase in soil compaction and soil strength. Because of ongoing cultivation and a decrease in organic content, agricultural land becomes denser overall. Increased bulk density will result from the transformation of forest area to farmland and barren land (Sebhatleab, 2014). The reduced porosity of the soil, which impedes water and mineral flow through the soil, may also result from the increased bulk density. The conversion of forestland or grassland to farmland results in an increase in the proportion of soil sand and bulk density, which can lower the productivity of the land (Hajabbasi *et al.*, 1997).

Soil Chemical Properties

Soil pH and Electrical Conductivity

The effects of land use change on soil pH and EC values were significant. The lowest pH value is seen on agricultural soil, which may have resulted from excessive removal of basic cations. The soils' ability to act as a buffer was eventually

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diminished as a result of the destruction of natural woodland and subsequent farming. This element, when combined with ongoing use of fertilizers containing ammonium, soil erosion, OM oxidation aided by tillage, full clearance of crop residues, and elevated Ex. Al, may have increased the acidity of soils on arable land (Iticha, 2017). The quantity of moisture that soil particles can hold has an impact on the electrical conductivity of the soil. The conductivities of sands, silts, and clays are low, medium, and high, respectively. Soil texture and electrical conductivity (EC) have a high correlation (Iticha *et al.*, 2016).

Table 2: The effect of different land uses on soil pH, EC, and Av.P.

Land use type	pH	EC (dS/m)	Av.P (ppm)
Forest	5.85	0.17	3.9
Grazing	5.52	0.12	2.74
Cultivated	5.19	0.1	1.6

Source : (Bezabih et al., 2016)

Soil Available Phosphorus

Land degradation results in a lack of readily accessible phosphorous, which is an issue for the environment. The poor phosphorus availability is partially caused by considerable phosphorus losses over prolonged periods of very strong weathering, and partially because phosphorus is not very viable in the aluminum and iron combinations that are the predominant forms of phosphorus in these soils. Available the different land use types have a big impact on phosphors (*Table 2*). The available phosphorus on cultivated land was much lower than that on grazing land, forestland, and so forth (Bezabih *et al.*, 2016). Due to the high levels of OM that released phosphorus during its mineralization, the natural forestland had one of the highest concentrations of Av.P among the various land use systems. With increasing soil depth, the amount of available phosphorus (Av.P.) decreased in all land use regimes. This could be because the soil becomes more clay-rich and less OM-rich as it gets deeper. By creating easier-for-plants-to-assimilate organophosphate complexes, anion replacement of H2PO4 from adsorption sites, humus coating of Fe/Al oxides to form a protective layer, and decreased phosphorus fixation, organic compounds in soils boost P availability (Selassie & Ayanna, 2013). This might occur as a result of the effects of crop waste clearance, excessive erosion, poor application of organic and inorganic fertilizers, and fixation in the cultivated land as compared to other land use types (Bewket & Stroosnijder, 2003).

Basic Exchangeable Cations and Exchangeable Acidity

Changes in land use from forest to other land uses have an impact on the composition of exchangeable basic cations. Compared to other land use methods, agricultural fields have greater levels of basic cation down-leaching. Conversely, exchangeable basic cation becomes low due to the influence of crop abundance and high crop yields without much or no input (Yeshaneh, 2015).

The amount and kind of clay minerals in a soil, together with its SOM content, all have a part in determining its CEC, with SOM playing a far larger influence than clay. Compared to the other three land use groups, the CEC under forests was higher (Bewket & Stroosnijder, 2003; Chimdi *et al.*, 2012).

Compared to the rest three-land use classes, forest had a higher CEC. The amount and kind of clay minerals present, as well as the SOM content of the soil, all contribute to the CEC of the soil, with SOM playing a significantly larger influence than clay (Bewket & Stroosnijder, 2003; Chimdi *et al.*, 2012).

Deforestation, intensive farming, and the use of artificial fertilizers are examples of ways that forest land is being converted to various land uses and land management practices, which raises the

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exchangeable acidity content beneath agricultural fields (Yeshaneh, 2015).

Table 3: Land use interactions with soil exchangeable cations (Ca, K, Na, and mg) and CEC)

Land use type	Ca (cmol(+)/kg)	K (cmol(+)/kg)	Na (cmol(+)/kg)	Mg (cmol(+)/kg)	Ex. acidity	CEC
Forest	15.23	2.11	0.32	5.02	0.03	28.17
Grazing	4.1	1.06	0.32	0.88	0.04	17.17
Cultivated	3.79	0.66	0.21	0.81	0.06	11.83

Source: (Yeshaneh, 2015)

Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC) refers to a soil's ability to retain these cations. (CEC). The soil's negatively charged clay and organic matter particles act as a holding force for these cations. (negative soil particles attract the positive cations). It is simple to swap out the cations on the CEC of soil particle with other cations. Because of the LULC, the soil CEC differed dramatically. It's possible that this was brought on by the organic matter and the fact that farmland had more clay in it. Given that humus and clay colloids have a negative charge, the amount of finer soil, clay, and organic matter may also affect CEC (Sebhatleab, 2014). The capacity to absorb and retain positively charged ions exists in both clay and colloidal OM, as is a common reality. The cation exchange capacity of soils with high clay and organic matter levels is therefore high (Yeshaneh, 2015).

Soil Total Nitrogen

The various land use methods substantial effect on the soil's total N levels. In comparison to developed fields, Selassie and Ayanna (2013) found that natural forest soils contained greater TN. According to Bewket and Stroosnijder (2003), The total N content of soils decreased from cultivated fields to pastures as a result of changes in SOM content, levels of erosion and leaching, soil texture, crops grown, and intensity of cultivation. The greater % TN content from forest land may be explained by the fact that the forest ecology was dominated by nitrogen-fixing plants, which may have led to biological nitrogen fixation.

Organic carbon (OC) and Soil Organic Matter

The organic carbon (OC) content varied widely under different land use systems. Changes in soil moisture and temperature regimes, the succession of plant species with varying amounts and qualities of biomass returned to the soil, and a shift in land use from forest to other land use may result in a decline in the stock of OC. Forest clearance and farming decreased organic matter by 48.8% (Selassie & Ayanna, 2013). As stated by Chimdi et al. (2012), cultivated land has a lower percentage of organic carbon (OC) and natural forests have a higher percentage of OC. The difference between the percent OC content of natural forestland and cultivated land is due to plant litter that has been mostly back to the soil's top, which increases the percentage of SOM in forestland soils, while the existence of high concentrations of iron oxide and clay lowers the percentage of OC in cultivated land. The percent OC concentrations in the soils of cultivated and grazing fields decreased by 54.62 and 49.89%, respectively, in comparison to forestland. Compared to grazing land, cultivated land saw more soil OC depletion. This is because farming enhance soil aeration, which enhances SOM decomposition, and that harvesting removes the majority of the SOM produced in cultivated soils, which results in a decrease in the soil's OC content and, consequently, an increase in bulk density and a decrease in total porosity. Reduced topsoil SOM content has been linked to the conversion of forestland to agricultural land. The soil OC may be divided into two categories: high in natural forest soils and moderate in grazing and farmed fields (Selassie & Ayanna, 2013). Studies by Bewket and Stroosnijder (2003) showed that the

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conversion of natural forest to grass, fallow land, and cultivation resulted in a reduction in soil organic carbon content. Total N was distributed according to the same patterns as soil organic carbon across all land uses. In cultivated land, it was lowest and in forested terrain, it was greatest. Total nitrogen concentration in cultivated and grazed fields decreased by 43.482 and 99.13%, respectively, when compared to soils from forest land.

When compared to forest soil, soils that were under cultivation, and soils that were used for grazing, soils under forests had the greatest SOM concentration (Bewket & Stroosnijder, 2003). As opposed to forests and pastures, agricultural land was where these processes were most active, the entire removal of crop residue from cultivated land and increased soil erosion as a result of the complete removal of crop residues in the arable land might have led to low soil OM (Adugna, 2016). This suggests that the soils' ability to deliver nutrients, store water, maintain structural integrity, and exchange cations has decreased (Iticha *et al.*, 2016). In contrast, forestland virgin soils yielded high mean values of OM, which may be related to the long-term buildup of degraded plant and animal leftovers in the absence of soil environment disturbance (Iticha, 2017). Grazing land, on the other hand, has less of a decline since grass roots are fibrous close to the soil's surface and readily degrade, hence boosting the amount of organic matter (Adugna, 2016). There appears to have been a decrease in SOM contents as a result of the transfer of forest to other uses (Bewket & Stroosnijder, 2003).

Table 4: Availability of TN and OC of different land use pattern

Land use type	Site 1		Site 2	
	TN %	OC %	TN %	OC %
Forest	0.26	4.94	0.23	4.93
Grazing	0.17	2.84	0.15	2.8
Cultivated	0.08	0.99	0.07	0.92

Source: (Selassie & Ayanna, 2013)

CONCLUSION

The review allowed one to draw the conclusion that deforestation has an impact on soil fertility. It is known that the physicochemical properties of soil are affected by changes in land use patterns, ranging from natural forests to different patterns of land usage. Comparing cultivated land to forested and grazing land, this review found the agricultural land had the list levels of organic matter, total nitrogen, cation exchange capacity, pH, and exchangeable Ca^{2+} and Mg^{2+}. Land use changes, cropping frequency and pattern, crop residue clearance, accelerated decomposition and oxidation processes, and soil erosion on cultivated areas are the main factors contributing to the lowest levels of soil organic matter. On farmed land, the prevalence of degradation may rise because of the losses of these vital components. As a result, the ability of the land to contribute to food security is reduced due to land degradation.

Recommendation

According to the review, the soil fertility is significantly impacted by the conversion of forests to other land uses, thus policymakers and land use planners must focus on forest clearing activities to lessen this impact. Implementing participatory management of land strategies, like crop rotation, crop rotation, and minimal tillage, will boost soil fertility in the soil of farmed land. Additionally, afforestation programs should be prioritized in the fight against land degradation, and agroforestry practices should be implemented to solve this issue. On the other side, government and non-governmental organizations (NGOs) aim to bring technology that has little impact on the forest in order to decrease reliance on the forest for fuel wood and raise land productivity through improved technology.

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