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Assessment of Catchment Hydrology and Soil Fertility Under Different Land Use Systems in Fagita Lekuma District, Ethiopia

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ABSTRACT

Acacia decurrens plantations in the Timble-Faguita-Lekma watershed are being actively expanded to accommodate various land uses, mainly to produce charcoal and construction. This study aimed to investigate the effects of various land-use types on the hydrology of a watershed and the physicochemical characteristics of soils. Experiments comprised soil depth (0-15 cm and 15-30 cm) and land cover type (arable land, pasture, 0, 2, and 4-year stand). A 5*2 factorial array of randomized complete block designs (RCBD) with 4 replicates made up the design. The physicochemical parameters of the selected soils were investigated using 40 (5*2*4) composite soil samples. A semi-structured questionnaire and a two-way analysis of variance (ANOVA) were used to investigate selected farmers' perceptions of watershed hydrology. The results revealed that soil particle size (sand, silt, clay) and SOC concentration differed significantly across all land use types and soil depths studied. Soil pH did not alter with depth (p<0.5605). At 4 years of age, wet aggregate stability (WAS), weight mean diameter (MWD), and geometric mean diameter (GMD) values were significantly different and greater. Two zero-year-old lines from an acacia decurrens plantation (p=0.0264, p<0.0001, and p<0.0161, respectively). Furthermore, WAS, MWD, and GMD scores are highly positively connected with grade (Tone p<0.0096, r=0.83 and SOC p<0.0001, r=0.85). Most households believe that recent land-use adjustments in their acacia decurrens plantations have reduced the severity of soil erosion.

INTRODUCTION

Human life is primarily dependent on agriculture and natural resource management that is both sustainable and prudent (Dejene, 2003). Increased demand for food, animal feed, bioenergy, and building materials, among other things, leads to changes in land use, most notably the conversion of forest and grazing grounds to cultivated lands (Zeleke and Hurni, 2001). Land use land cover dynamics must be investigated to build an operational framework for calculating the financial consequences of land use land cover changes (Hein et al., 2008; Girmay et al., 2008; Bruun et al., 2015). Land use and land cover changes have become an important component of today's natural resource management and monitoring systems (Rawat, 2013). Human agents or land managers intentionally apply a land management strategy to a land cover to exploit the land cover and reflect human activities such as industrial zones, residential zones, agricultural fields, and grazing (Zubair, 2006).

Land resources are currently under threat due to widespread agricultural activity and demographic pressure (Zubair, 2006). Understanding LULC and its potential for optimal use is thus critical for selecting, planning, and implementing land use systems to meet the increasing demand for fundamental human requirements and well-being. In Ethiopia, land degradation, climate change, and rapid population growth are driving additional conversion of forest and grassland to cultivated farmlands (Gebreyesus, 2013). As a result, Ethiopia loses approximately 15 billion tons of topsoil per year (Tadesse, 2001). Despite significant efforts in all Sub-Saharan African countries, including

Ethiopia, to address land degradation issues, the scope and magnitude of the problem remain, and Ethiopia is one of those that has increased cropland area at the expense of natural habitats (Yitbarek et al., 2012; Phalan et al., 2013).

Climate, land use, soil, and landscape all influence the hydrology of a catchment (Elfert and Bormann, 2010). It is critical to establish a dependable interaction between soil, water, and forest to improve terrestrial ecosystem functions and productivity (Islam and Weil, 2000). Changes in land use have an impact on natural phenomena such as soil nutrients, soil water, and ecological processes (Fu et al., 2000). Water is one of the most important aspects of supporting human health and nutrition in the environment (Maidment, 2002). Furthermore, most development operations rely on water, which has become an essential commercial natural resource. Nowadays, one of the key problems is the availability of clean water (Maidment, 2002). Water consumption increases as land use conversion, such as plantation practice, increases since the availability of water to downstream users decreases, which has a parallel effect on stream flow (Guzha et al., 2018).

Inappropriate LULC has left the ground bare, reducing biomass (vegetation cover) and resulting in a decline in soil properties such as organic matter content, nutrient availability, aggregate stability, and soil moisture (Mao & Zeng, 2010). As organic matter depletes, soil bulk density rises, influencing aggregate stability, water and nutrient movement, plant root penetration, and biological activity in the soil. However, as soil organic matter increases, aggregate stability is preserved by increasing aggregate cohesion, which reduces fine soil particle loss (Mao and Zeng, 2010).

According to Six et al. (2000), aggregate stability influences soil productivity, carbon stabilization, porosity, water infiltration, aeration, compaction, water retention, and resistance to erosion by water and wind. As a result, maintaining high soil aggregate stability is critical for conserving soil productivity, reducing soil erosion and degradation, and reducing environmental pollution processes. Soil organic carbon (SOC) and its humic compounds, according to various studies, play a role in aggregate stabilization via at least two mechanisms: first, by enhancing soil hydrophobicity, and second, by decreasing slaking degradation (Chenu, 2000). Second, SOC's cohesive force enhances aggregate stability. Soil organic carbon affects both porosity and aggregate stability, according to Lugato et al. (2009).

Among the most serious environmental concerns, today are land degradation, restoring plant cover, and mass production of tree species for fuel wood usage. As a result, selecting the appropriate tree species for afforestation operations is critical, because different tree species affect soil quality in different ways. The ability of tree species to partition rainfall into that which penetrates the soil and that which is lost from the area as runoff may also have an impact on rainfall (Li et al., 2012). Growing tree species that tolerate acidic soil conditions, such as Acacia decurrens, are spreading in northern Ethiopia (Endalew et al., 2014). Planting exotic Acacia decurrens species in farmlands has become a major characteristic in the research region, rather than planting and maintaining indigenous tree species. This Acacia decurrens plantation strategy is critical because it provides significant short-term economic benefits, access to fuel wood, construction materials for producers, and treatment for gully and other damaged landscapes.

Tree planting, according to (Sharma and Yogender, 2004), significantly altered the physical and chemical properties of soil. The effect of tree plantations on soil characteristics, however, differed depending on the tree type. Litterfall alters the physical, chemical, and biological aspects of soil (the biophysical environment) and replenishes soil nutrient resources. Fast-growing tree species are commonly planted on cropland in the Timble watershed, Fagita Lekuma district, Awi zone, northern Ethiopia. The tree species is largely used by the local community for charcoal manufacturing and construction. However, their effects on watershed hydrology and specific soil physiochemical parameters have not been thoroughly researched or published. As a result, this study was started to offer experimental evidence on the effect of Acacia decurrens plantation practice on watershed hydrology and selected soil physiochemical parameters.

MATERIALS AND METHODS

Description of the Study Area

Fagita Lekuma district is in the Amhara National Regional State's (ANRS) Awi zone, between 10°57'23"-11°11'21" North and 36°40'01"-37°05'21" East, surrounded by East Chagni, North Dangla, West Banja, and South Mecha (Figure 1). The district and watershed cover around 65,300ha and 3,038ha, respectively.

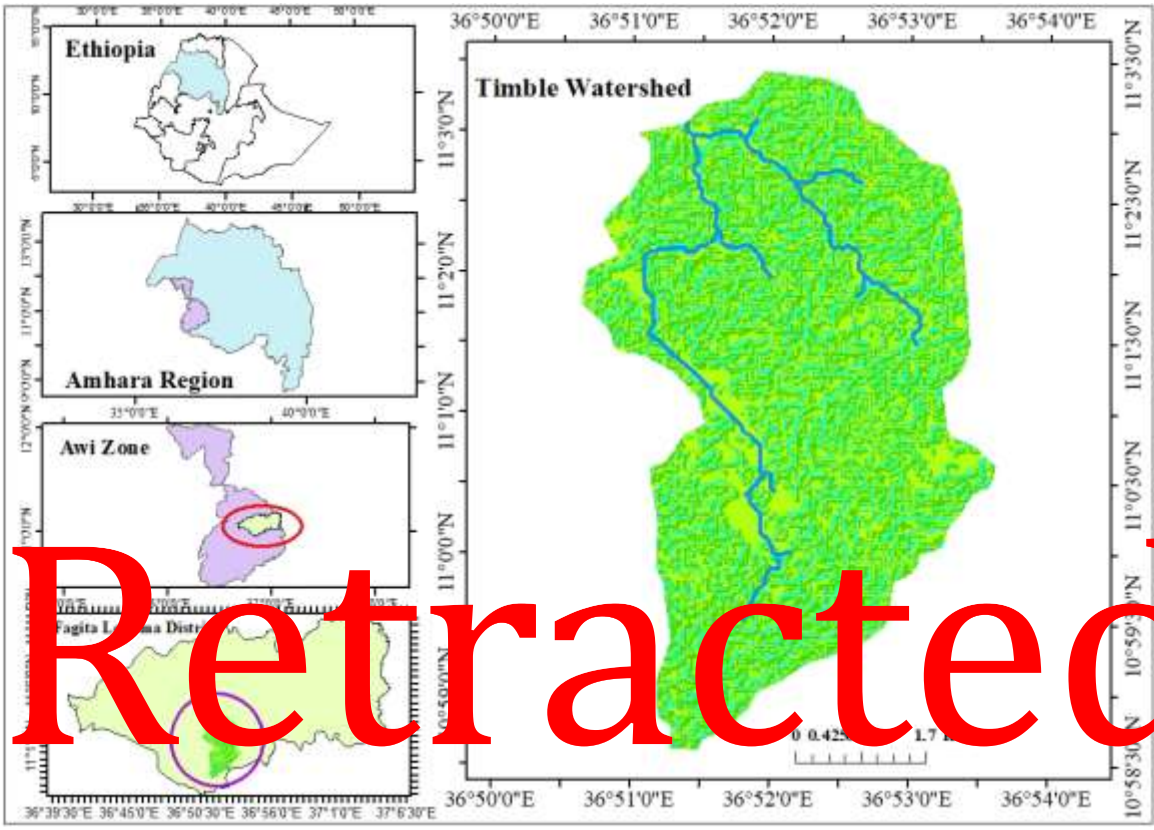

Figure 1. Location Map of the Study Area (Source: DEM and GPS Data)

Topography

The watershed has a severe topography, with 37% of the area having a slope of 0-15%, 35% having a slope of 15-30%, and 27% having a slope greater than 30%. The study area's elevation range is 2370-2921 m above sea level.

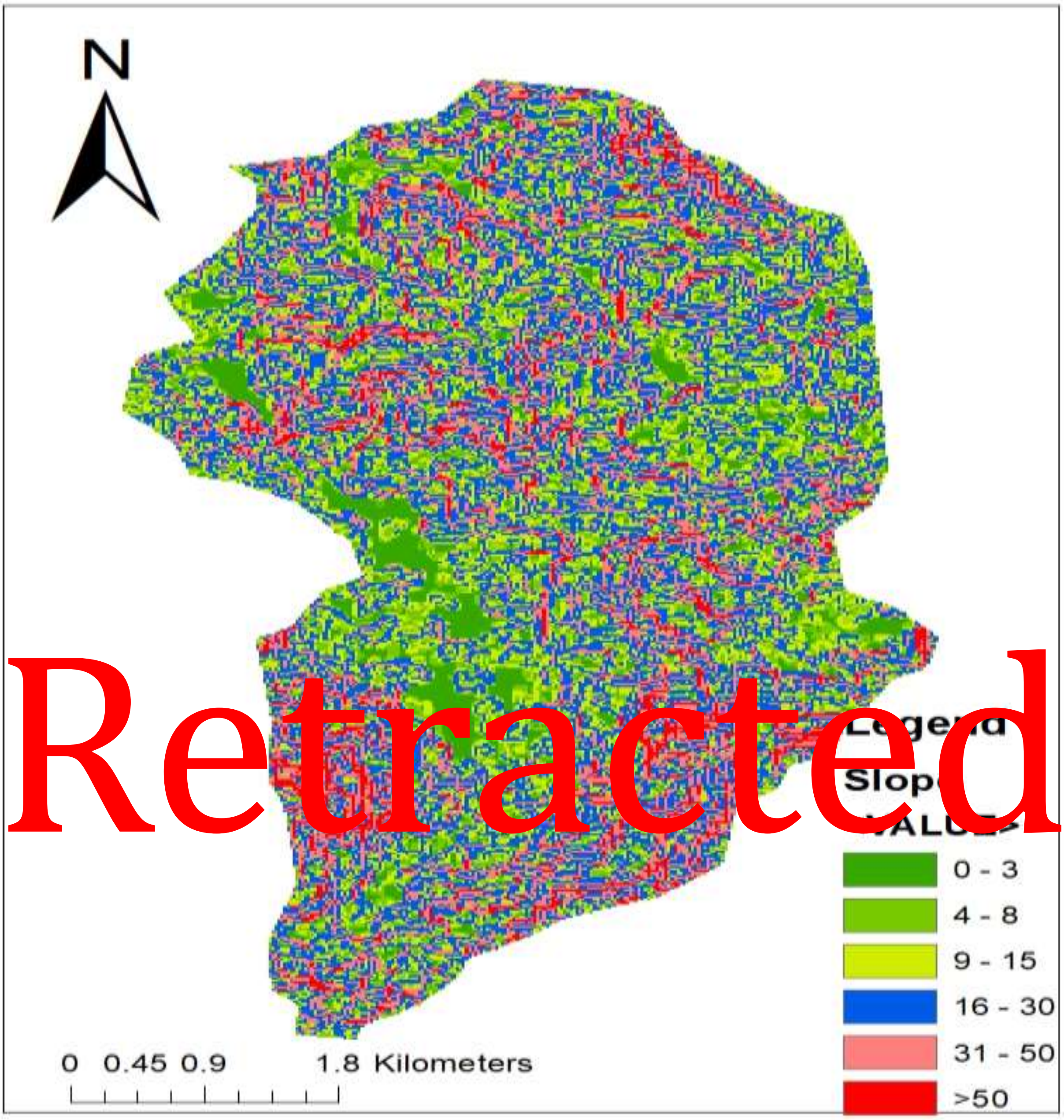

Figure 2. Slope Map of the Watershed (Source: - FAO 1984)

Climate

The area is distinguished by a bimodal rainfall pattern that includes the Belg rains from the middle of March to the end of May and the summer rains from June to October. The average annual rainfall ranges from 910 to 1200 mm, while the average annual temperature ranges from 100 to 220 degrees Celsius (NWAMC, 2019).

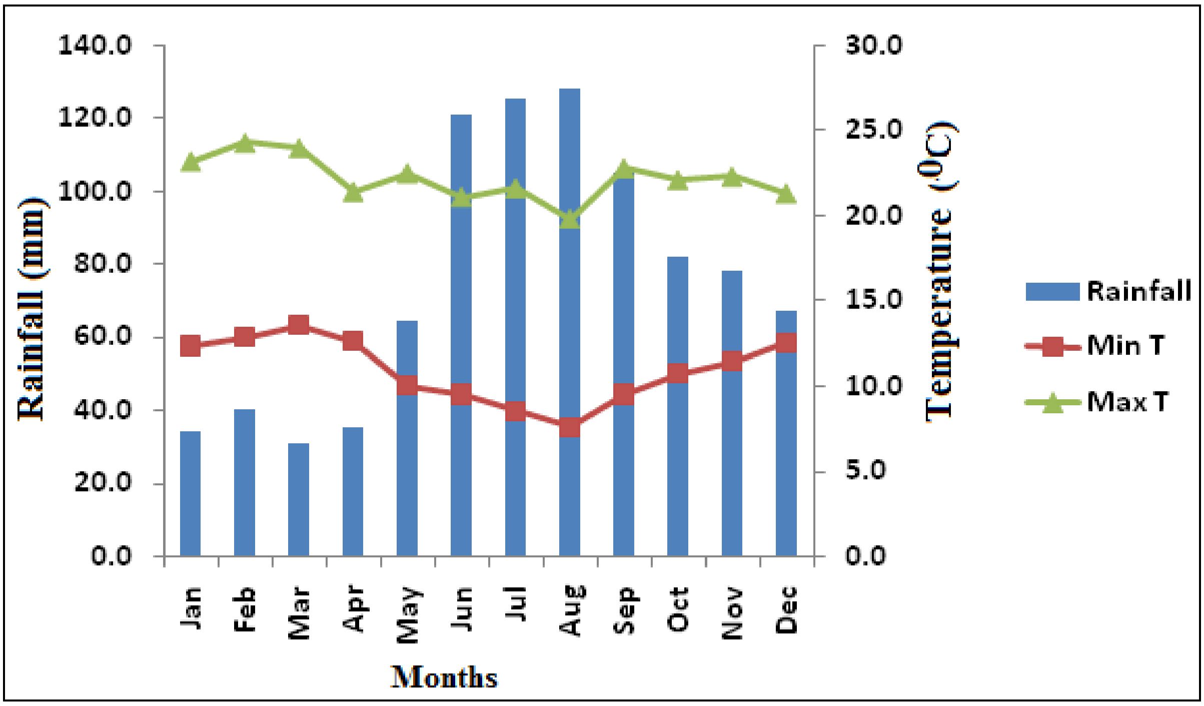

Figure 3. Mean Monthly Rainfall, Maximum and Minimum Temperature (Source: -NWRMS (Northwest Region Metrology Service).

Soil Types

Tertiary volcanic rock and quaternary basalts dominate the district's geology, and the principal soil types include Vertisol, Luvisol, Cambisol, Nitisol, and Acrisol (FAO, 1984; [illegible]eda, 20[illegible]5; Menale and Wolde, 2018). Nitisol is the most common soil type in the studied areas (FAO, 1984).

Agriculture and Vegetation Cover

The district's principal land use land cover includes approximately 48% Acacia decurrens, 30% agriculture, 20% grazing (grassland-shrubland), 4.1% woodland, and 2.2% settlement. Acacia decurrens plantation is the most common land use in the district and watershed. It is planted as woodlots in a Tangua system (the cultivation of teff crops before the establishment of Acacia decurrens plantations). This approach has been widely used, particularly during the 2000s, and as a result, its area coverage has expanded by 1.2% every year (Menale and Wolde, 2018). The most important food crops [illegible], however, are teff (Eragrostis tef), maize (Zea mays), and potatoes (Solanum tuberosum). The sale of charcoal is the primary source of income for the district's local villages. There are also various timbers, non-timber forest products, and livestock output generated from diverse agricultural methods that are used to meet household consumption and/or generate financial income (FLAO, 2019).

Reconnaissance Survey

A reconnaissance survey was carried out to choose sites and create sample techniques. Four locations in the same slope class were chosen to illustrate the rotational phase of an Acacia decurrens plantation under varied management approaches. To spatially pinpoint the sampling sites, GPS point data were acquired.

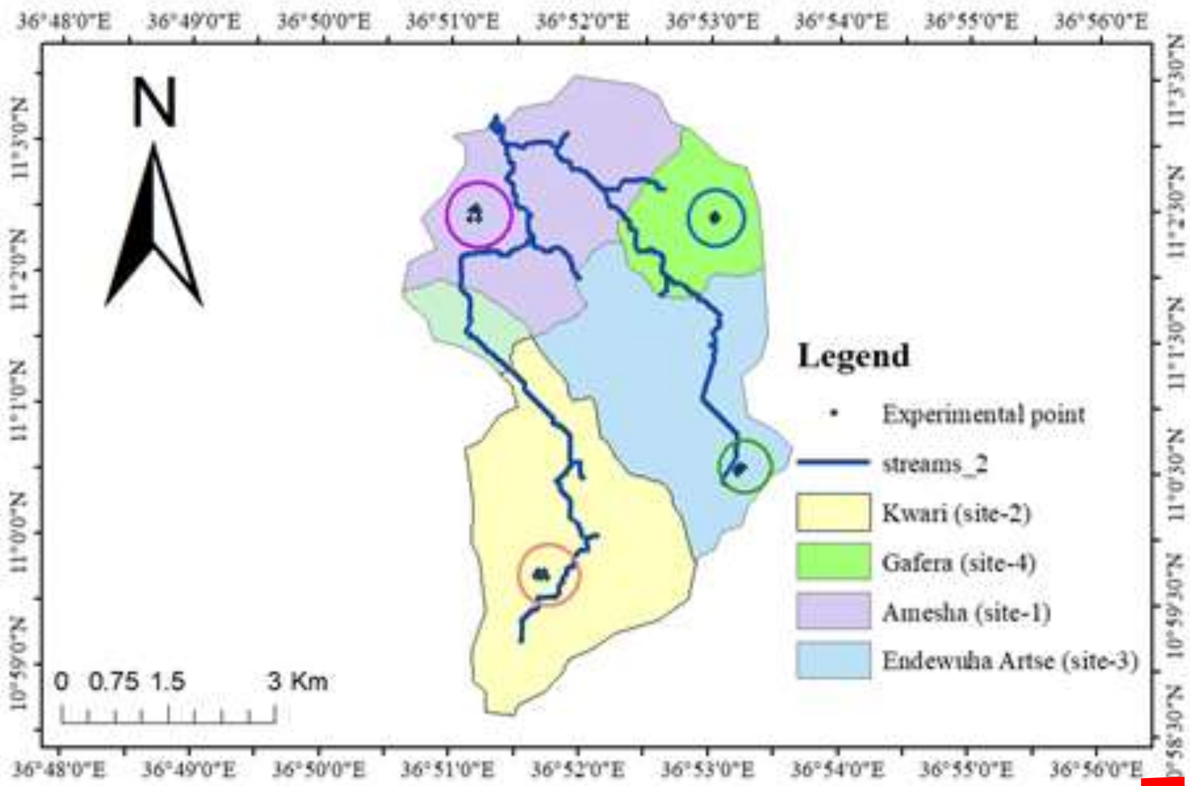

Figure 4. Map of Experimental Plot (Source: Field Survey GPS Data).

Sampling Technique

The study was carried out inside the project area which included Timbl Watershed, Fagita Lekuma district, and Awi zone. To choose and draw sample households for the study, a purposive sampling technique was adopted. The criteria for selecting households were age (40 years and older for those with good information about the experimental location) and proximity to the experimental site. Then, using the following statistical formula: n= N/(1+N $(e)^2$, where n= sample size, N= population size, and e= degree of precision (Yamane, 1967), 40 homes were chosen from four experimental sites.

Method of Data Collection

For qualitative data analysis, interviews and field observations were predominantly used. Simultaneous observation and identification of the study area were carried out. Up until the completion of the fieldwork, the investigator and development agents collected all the data. Nonetheless, before data collection began, data collectors and development agents were instructed on the substance of the questionnaire as well as the data gathering discipline.

Socioeconomic Survey

Semi-structured questionnaires with open and closed-ended questions were used to collect qualitative and quantitative data. A semi-structured questionnaire, key informants (community leaders, experts), and interviews with those with similar backgrounds or experiences were used to address the issue of interest.

Biophysical Survey

Data Collection for Mapping Catchment Hydrology

GPS point data were acquired for each water source (rivers, streams, springs, and ponds) in the watershed, and the data was processed using Arc GIS 10.1 to create the hydrology map.

Experimental Design

The trial design is like a randomized complete block design (RCBD) factorial layout. In the catchment, experimental locations were chosen at random. Each site treatment was discovered by selecting the nearest site that met the land use selection criteria. The total number of experimental plots (n) was calculated by multiplying the number of treatments (t) by the number of replications (r), resulting in n = rt=4 *5 =20 panels. The plot size for each treatment was 10 m x 10 m =100 m2. The investigation included two variables: land use with rotational age of Acacia decurrens planted and soil depth. The land use had five (5) treatment levels: zero (newly planted fields), second and fourth-year stand ages, grazing cropland, and two levels of depth factor. The topsoil is represented by the surface soil layer, which is 0 -15 cm deep, and the other subsurface soil layer is 15 - 30 cm deep. According to Trudi Grant (2010), the RCBD is the conventional design for catchment locations in which similar experimental units are organized into blocks or repetitions.

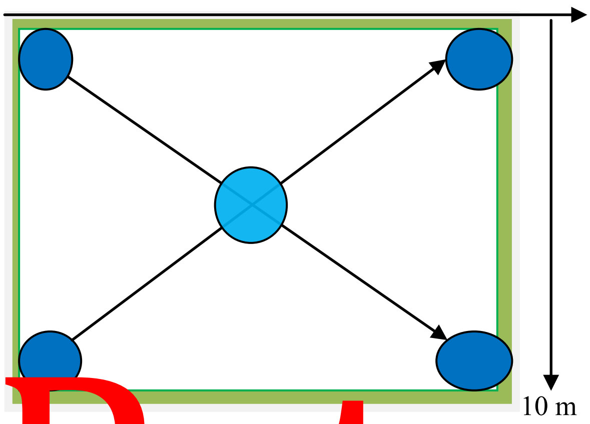

Figure 5. Design of Sampling Plot (Source: Field Survey, 2022)

Soil Sampling and Preparation

Soil samples were collected from three different land uses (grazing area, agriculture, and an Acacia decurrens plantation with three stand age levels) and two soil depths with four replications, for a total of 40 composite samples. As a result, samples from the same standard age, land use, and depth were mixed to form a single composite sample, and approximately one kilogram of composite sample from each soil depth was taken and placed in polythene bags before being transported to the laboratory. Similarly, for the wet aggregate stability study, 20 samples were obtained from the center of each plot of the cylindrical core. Before analyzing chosen soil parameters (particle size distribution, pH, and SOC), samples were air-dried, crushed with a mortar and pestle, mixed thoroughly, and passed through a 2 mm screen. Similarly, a 0.5mm filter size was utilized for soil organic carbon.

Analysis of Selected Soil Properties

Soil analysis was performed using conventional techniques at the Gondar soil testing center and the Amhara design and supervision work business. After eliminating organic matter with hydrogen peroxide, the hydrometric approach was used to examine soil particle distribution (Gee and Bauder, 1982). Soil pH was evaluated using a digital pH meter in a supernatant suspension with a soil-to-water ratio of 1:2.5 (Rhoades, 1995). The wet oxidation method was used to determine soil organic carbon (Walkley and Black, 1934).

Soil Aggregate Stability Determination

The wet aggregate stable (WAS) was calculated using the wet sieving approach published by (Eftekha et al., 2017). During this operation, a 50 g soil sample with an aggregate diameter of 8 mm was deposited on the upper half of a nest of sieves with declining mesh size openings of (2mm, 1mm, and 0.5mm). After immersing the samples in distilled water overnight, sieves were oscillated up and down for 10 minutes at a rate of 30 oscillations per minute. Water-stable aggregates and sand/aggregate-sized gravels retained on each screen were dried for 24 hours at 105 Co and weighed using an electronic balance. Finally, all oven-dried aggregates were dispersed using sodium hexametaphosphate and a mechanical stirrer to estimate the net mass of water-stable aggregates. The dispersed material was then rinsed back into sieves of identical diameters. After the second sieving, the weight of sand (gravel) kept on each sieve is removed from the total oven-dry weight of un-dispersed materials.

To compute the percentage of WAS on each sieve size range, the following equation was used:

$$WAS\% = [(M_{a+s} - M_{s}) / (M_t - M_s)] \times 100 \quad \text{.........} (1)$$

Where Ma+s denotes the mass of the water-stable aggregates plus sand (g), Ms the mass of the sand fraction (g), and Mt is the total mass of the sieved soil (g) (Eftekha et al., 2017).

The soil aggregate stability indices' MWD (mean weight diameter) and GMD (geometric mean diameter) were derived as follows.

$$MWD\ (mm) = \sum_{i}^{n}{}_{=1} w_i x_i \quad \text{......................} (2)$$

$$GMD\ (mm) = \exp\left(\sum_{i}^{n} = w_i \log x_i\right) \quad \text{................} (3)$$

Where xi is the arithmetic mean diameter of each size fraction (mm), and wi is the net proportion of aggregate size fraction relative to total sample weight after subtracting the gravel/sand weight (after dispersion and passing through the same sieve) as indicated above, and n is the number of size fractions (Eftekha et al., 2017).

Statistical Analysis

The independent variables were soil depth and land use system, and the dependent variables were soil parameters (sand, silt, clay, SOC, MWD, GMD, WAS, and pH). The analysis of variance (ANOVA) followed by the GLM approach was used to examine the significant variation of soil quality indicators with land use systems and soil depth at ($P < 0.05$). When the analysis of variance revealed a statistically significant difference at ($P<0.05$), the least significant difference (LSD) test was utilized for mean comparison. The Pearson correlation matrix was used to determine the correlations between dependent variables.

RESULTS AND DISCUSSION

Household Characteristics

Among the 40 sampled households, 57.5%, 37.5%, and 5% of the respondents were between the ages of 40 and 50, 51-65, and 66-75, respectively. The frequency distribution results also revealed that most respondents (23) were between the ages of 40 and 50, and the minority of respondents were between the ages of 66 and 75 (Table 1).

Table 1. Distribution of Sampled Household Headed by Age

Age	Frequency	Percent
40-50	23	57.5
51-65	15	37.5
66-75	2	5
Total	40	100

Source: Field Survey, 2022

Demographic Characteristics

Male respondents made up 55% of the total homes polled, while female respondents made up 45%. In contrast, 57.5% of respondents were literate, while 42.5% were illiterate (Table 2).

Table 2. Demographic Characteristics of Respondents

Characteristics of Household Headed		Frequency	Percent
Sex	Male	22	55
	Female	18	45
Educational status	Literate	17	42.5
	Illiterate	23	57.5

Source: Field Survey, 2022

Effect of Land Use Change on Teff (*Eragrostis tef*) Yield

According to the frequency distribution, only 2.5% of respondents believe that a greater mean yield of Teff (approximately 16 quintal/ha) was observed before the introduction of Acacia decurrens into the project site. While most respondents (approximately 62.5%) say that Teff production was as low as 4-8 quintal/ha before the establishment of the Acacia decurrens plantation (Table 3). This could be related to poor soil fertility conditions caused by macro and micronutrient loss due to soil erosion and inadequate organic matter input. This finding is consistent with Ermias et al. (2017)'s finding that low organic matter content in all land use regimes could have degraded soil physical characteristics and increased loss of basic cations through soil erosion and leaching.

Table 3. Perception of Farmers on Teff (*Eragrostis tef*) Yield Before Introduction of *Acacia Decurrens*

Estimated mean yield of teff quintal/ha before *Acacia decurrens*	Number of respondents (N=40)	
	Frequency	Percent
4-8	25	62.5
9-12	12	30
13-16	2	5
17-20	1	2.5
Total	40	100

Source: Field Survey, 2022

After the introduction of Acacia decurrens, the estimated production of Teff in the study region ranged from 4 to 8 quintals/ha to 13 to 16 quintals/ha (Table 4). However, most responders (67.5%) felt that the introduction of this foreign species helped them achieve a better Teff yield than they had previously. This could be attributed to enhanced organic matter formation and subsequent mineralization to release critical nutrient components, reduced soil erosion, increased soil moisture content, and increased microbial activity. This study is consistent with the findings of Ermias et al. (2017), who indicated that the presence of rich organic matter could boost microbial activity and nutrient availability for plant growth.

Table 4. Perception of Farmers on Teff (*Eragrostis tef*) Yield After Introduction of *Acacia Decurrens*

Estimated mean yield of teff (*Eragrostis*) quintal/ha after *Acacia decurrens*	Number of respondents (N=40)	
	Frequency	Percent
4-8	1	2.5
9-12	9	22.5
13-16	26	65
17-20	4	10
Total	40	100

Source: Field Survey, 2022

Effect of Land Use Change on Catchment Hydrology

The results reveal that land use change affects all aspects of watershed hydrology differently. Most respondents (82.5%) believe that changes in the flow of streams and rivers are seasonal, whereas the minority (17.5%) believe that the flow of rivers and streams is constant throughout the year (Table 5). Most respondents (67.5%) do not believe that gullies are produced because of erosion, whereas the minority (32.5%) feel that the formation of gullies is directly related to the occurrence of erosion (Table 5). Water scarcity for home consumption was seen by most farmers (52.5%) but not believed by the minority (47.5%). The decreasing volume and distribution of springs as well as the scarcity of water for family use, following the introduction of exotic Acacia decurrens, could be attributed to Acacia decurrens' high water consumption, climatic fluctuation, and over-exploitation of resources. This result is consistent with the findings of previous studies (Scott, 2005; Sujay et al., 2017), which suggested that fast growth rates of tree species require a large quantity of water, and hence water security cannot be restored without considering the interplay between land use system and climate change.

The observed increase in water purity on the one hand, and the observed decrease in soil erosion and subsequent gully formation on the other, could be linked to the local community's recent initiatives to cover their lands with Acacia decrrens plantings. Furthermore, periodically executed mass mobilization operations in the research area to protect natural resources may influence boosting water quality and minimizing runoff. In keeping with this study, Lu et al. (2007) stated that once a watershed is protected by forest vegetation, the likelihood of receiving quality water and a surrounding area less prone to erosion increases.

Table 5 Farmer's perception of catchment hydrology after the introduction of *Acacia decurrens*

Variables	Residents (N =40)	
	Frequency	Percent
Water flow change (streams, rivers)		
Yes = Flow has increased in the rainy season but decreased in the dry season	33	82.5
No there is a change in water flow throughout the year	7	17.5
Change of spring in amount and distribution		
Yes = Spring flow is now higher in the rainy season – lower the dry season	30	75
No there is no change	10	25
Formation of gullies due to erosion after the introduction of *Acacia decurrens*		
1. Yes-erosion has increased	3	7.5
2. Yes-erosion has decreased	35	87.5
3. No-there is no change in erosion	2	5
Shortage of water for households increased.		
Yes	21	52.5
No	19	47.5

Formation of erosion due to runoff		
Yes= it is increased	3	7.5
No, it is decreased	37	82.5
Change in quality of water in terms of purity.		
Better	28	70
Worse	9	22.5
no change	3	7.5

Source: Field Survey, 2022

Yazie Chanie & Anteneh Abewa (2021) Expansion of Acacia decurrens plantation on the acidic highlands of Awi zone, Ethiopia, and its economic value was done in Fagita-Lokoma district to examine primary farmer motivations for A. decurrens plantation expansion.

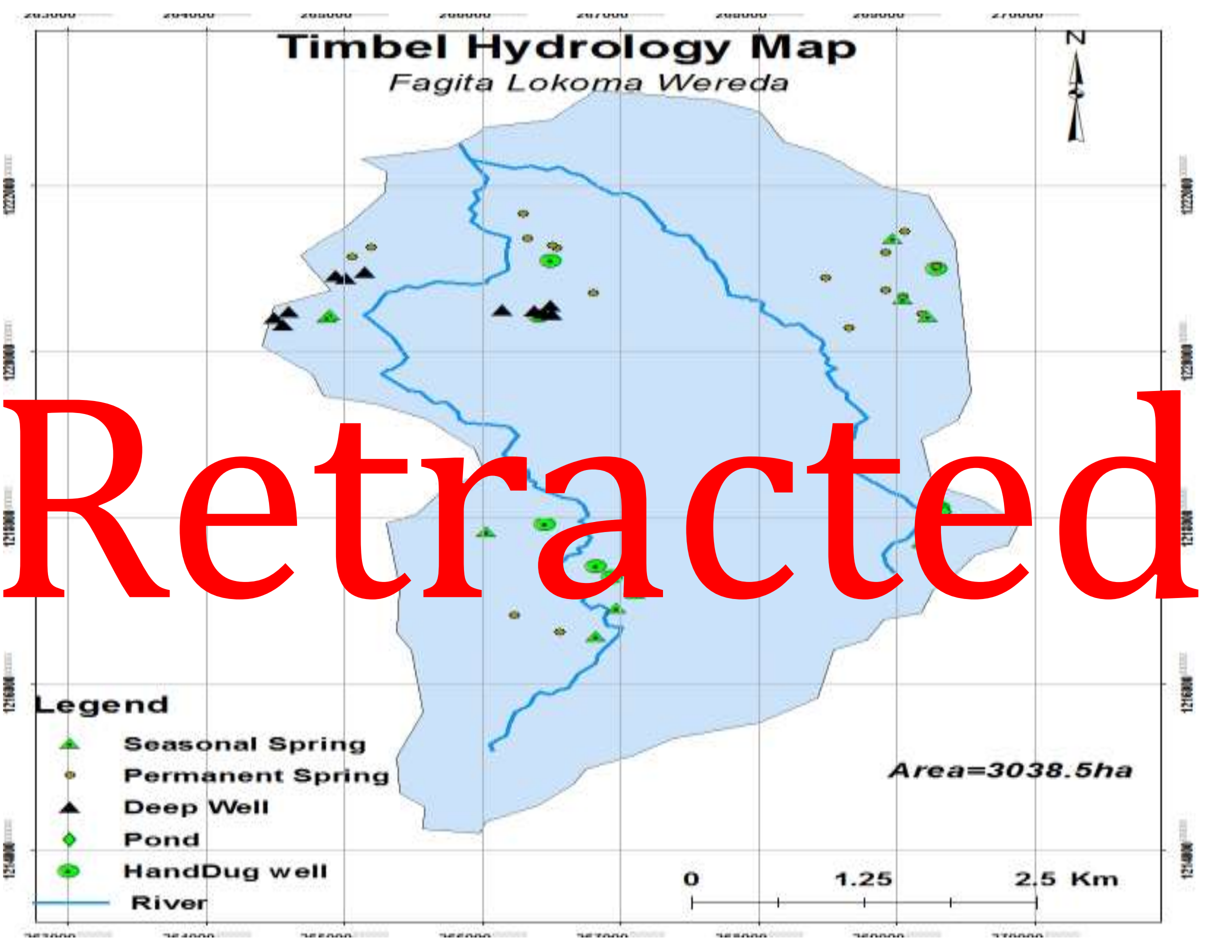

Figure 6. Catchment Hydrology Map (Source: Field Survey by GPS)

Effect of Land Use Change on Soil Physical Properties

Table 6 describes the results of soil particle size analyses derived from various land use types and depths. Sand, silt, and clay particle sizes were substantially different ($P<0.05$) for the various land use types evaluated. Depth-wise significant variations ($P<0.05$) were identified only for sand and silt particle sizes, while the interaction effect was significant ($P<0.05$) for clay fraction (Table 6). The overall mean value of sand particle size was significantly higher under grazing land (35.95%; Table 6) than other land use types, and silt and clay particle size were significantly higher under 4th age second rotation (36.9%, 31.1%), respectively than other land use types. In terms of soil depth, the overall mean particle size of silt and clay was larger (36.2%, 33.2%) in the subsurface soil layer and lower (28.9%, 31.4%) in the topsoil layer. The overall mean value of sand, on the other hand, was higher (37.4%) in the topsoil layer and lower (25.6%) in the subsurface soil layer. The higher clay fraction in the subsurface layer than in the top surface soil layer may be a sign of possible clay translocation from the top layer to the layer below (Awdenegest et al. 2013; Melku et al. 2019), reported that the higher clay fraction in the subsurface layer than in the top surface soil layer may be a sign of possible clay translocation from the top layer to the layer below. The other study (Gebeyaw, 2007; Adugna and Abegaz, 2015) discovered that the highest sand fraction and lowest clay fraction values observed on the topsoil layer of bush areas were associated with a faster rate of downhill soil erosion and clay particle removal.

Table 6. Particle Size Distribution with Respect to Land Use Types (Mean ±S. E)

Parameters	Depth(cm)	Land use				
		4^{th} age	2^{nd} age	Zero age	Grazing land	Cropland
Sand (%)	0-15	37.6± (2.4)	33.35± (4.7)	37.9± (4.1)	43.1± (3.7)	35.1± (3.3)
	15-30	26.3± (1.4)	22.5± (1.6)	27.5± (2.7)	28.8± (2.2)	24.0± (1.5)
	Overall	31.9(±1.9) ^{BA}	27.5(±3.2) ^{B}	32.7(3.4) ^{BA}	35.9± (3)^{A}	29.1(2.4) ^{B}
Silt (%)	0-15	31.7± (4.8)	30.2± (0.3)	22.7±1.4	29.7±2.9	28.7± (2.7)
	15-30	42.0± (1.4)	40.2± (0.6)	49.2± (2.6)	28.2± (3.4)	37.2± (2.1)
	Overall	36.9(±3.1) ^{A}	35.2(±0.5) ^{A}	34.5(±2) ^{A}	28.9(3.2) ^{BA}	32.5(2.4) ^{B}
Clay (%)	0-15	30.3± (4.3)	23.8± (3.1)	30.3± (3.3)	17.5± (3.6)	26.3± (3.3)
	15-30	31.8± (2.1)	31.3± (2.2)	23.3± (4.1)	31.3± (3.2)	18.8± (2.2)
	Overall	31.1± (3.2) ^{A}	29.1(±2.7) ^{A}	26.8(±3.7) ^{BA}	24.4(±3.4) ^{B}	22.6(±2.8) ^{B}

This means that the same letters in rows are not significantly different ($p<0.05$)

Wet Aggregate Stability (WAS), Mean Wet Diameter (MWD), and Geometric Mean Diameter (GMD)

Table 7 shows aggregate stability results for several land use types. The overall mean value of WAS greater in the fourth-age second rotation (73.4%), followed by the second-age second rotation (55.7%) and the zero-age second rotation (53.7%). While cropland had the lowest mean value (43%), pastureland had the highest (48.3%; Table 7). The highest MWD (4.2) was found in the 4th age second rotation land use type, while cropland had the lowest MWD (2.1) (Table 7). GMD was higher (0.41) in the 4th age second rotation and lower (0.21) on cropland (Table 7). WAS, GMD, and MWD were statistically different in the different land use categories evaluated (p = 0.0264, p0.0161, and p0.001, respectively). WAS, MWD, and GMD were highly and positively linked with clay (r = 0.85**, 0.68**, 0.83**, and SOC (r = 0.67**, 0.62**, and 0.85**, respectively) in the correlation matrix.

The higher WAS, MWD and GMD values observed in the 4th age second rotation of Acacia decurrens plantation could be attributed to the presence of abundant organic material; greater structural stability; binding agents; minimum tillage and microbial activity; SOC, and the age of the forest, as the size and stability of soil aggregate increases with forest age. According to (Ashura 2016; Singh et al., 2010; SSSA 2019), the highest MWD under forest and silvopastoral could be attributed to higher SOC content, reduced continuous tillage, plant residue deposition and higher biological activities, which increased production of organic binding agents that promote soil aggregation. Similarly, another author, Eftekhar et al. (2017), observed that higher MWD and GMD values indicate greater structural stability of large macro-aggregates.

In this study, lower WAS, MWD, and GMD values were observed under cropland and grazing lands. This could be attributed to organic material loss, continued cultivation, and overgrazing, which results in a reduction of binding agents, which could lead to structural instability. This finding is also consistent with the (Ashura, 2016; SSSA, 2019), which claimed that the lowest MWD of soils under farmed land compared to other land use systems may be attributed to human activities such as intense tillage, overgrazing, and poor soil organic carbon value.

Bulk Density

The results demonstrate that bulk density differed considerably across all land use types ($p<0.001$). When compared to other land use types, grazing lands (2.03 g/cm3) and croplands (1.36g/cm3) had higher BD values. Whereas the 4th age second rotation Acacia decurrens plantation had the lowest BD value (1.16g/cm3, Table 7). The Pearson correlation matrix showed that BD was highly and adversely linked with SOC (r = -0.97**, Table 10).

The greater mean value of BD in grazing areas and agriculture may be attributable to low organic matter concentration, animal compaction, and continual cultivation. This finding is consistent with previous research by Theobald et al. (2018), who indicated that the higher value of BD under-cultivated compared to other land use types may be attributed to the presence of low organic matter. Other authors (Abiot and Ewuketu, 2017) noticed changes in BD values as one moved from under the canopy of a tree to the open canopy, and the soil bulk density (BD) increased from 0.19 g/cm3 to 0.26 g/cm3. This was linked to low organic matter coverage in open lands. The presence of a considerable amount of organic matter and microbial activity could explain the lower mean value of BD under Acacia decurrens plantation, notably in the 4th age second rotation. Similar findings, which link lower BD values in forest land to higher organic matter buildup from added organic amendments, have also been reported (Theobald et al., 2018; Wondimagegn et al., 2018).

Table 7. Mean value of WAS, MWD, GMD, and BD with standard error under different land use systems

Soil layer (cm)	Land use	WAS (%)	MWD (mm)	GMD (mm)	BD (g/cm^3)
0-15	4th age second rotation	$73.4\pm(4.9)^{A}$	$4.2\pm(1.2)^{A}$	$0.41\pm(0.1)^{A}$	$1.16\pm(0.2)^{C}$
	2nd age second rotation	$55.7\pm(4.7)^{AB}$	$3.8\pm(2.1)^{A}$	$0.36\pm(0.3)^{BA}$	$1.25\pm(0.4)^{CB}$
	Zero-age second rotation	$53.7\pm(10.5)^{B}$	$3.2\pm(2.5)^{B}$	$0.26\pm(0.2)^{BC}$	$1.32\pm(0.1)^{B}$
	Grazing land	$48.3\pm(7.7)^{B}$	$2.7\pm(1.6)^{BC}$	$0.24\pm(0.1)^{C}$	$2.03\pm(0.1)^{A}$
	Cropland	$43.0\pm(9.0)^{B}$	$2.1\pm(1.9)^{C}$	$0.21\pm(0.2)^{C}$	$1.36\pm(0.3)^{B}$

Means with the same letters are not statistically different ($p< 0.05$).

The Effect of Land Use Change on Soil Chemical Properties

Soil organic carbon concentration in the study area differed significantly ($p<0.0001$) across land use types and soil depths. The interaction effects of land use types and soil depths, on the other hand, were not significant (P=0.3634, Table 3). The overall mean value of soil organic carbon content in the fourth age second rotation (6.2%) and second age second rotation (4.9%) was greater than in other land use types (Table 8). Similarly, the level of soil organic carbon in the surface soil layer was higher in land use types with 4th age second rotation (7.7%), followed by the second age second rotation (5.4%; Table 8). The soil organic carbon content in the research area is high according to established values (Thakur et al., 2012). In general, SOC was negatively connected with sand (r=-0.57*) and favorably correlated with clay (r=0.59*) and pH (r = 0.64*) across different land use types and soil depths (Table 9).

Lower SOC concentrations under farmland compared to other land use types may be attributable to organic matter loss through natural processes, low organic matter input into the soil, and reduced litter fall. In agreement with this finding (Awdenegest et al., 2013; Melku et al., 2019) reported that the lower SOC content of cultivated land compared to grazing land and protected forest could be due to a low amount of organic material, a high oxidation rate of soil organic matter due to continuous cultivation, loss of organic matter due to erosion, and a low input of litterfall. Soils under pasture and cultivated land showed lower SOC concentrations than soils under forest land, according to Kyung et al. (2010). This could be due to animal grazing or the periodic clearance of wastes for feeding livestock and continuous cultivation.

In contrast, the observed greater SOC concentration in a land use type under the fourth age compared to the other land use types could be attributable to a significant amount of organic matter buildup in the same land use type. According to Awdenegest et al. (2013), the higher concentration of SOC in protected forests than in cultivated fields may be attributable to significant organic matter accumulation and input of root and ground biomasses. The surface soil layer had a greater SOC value than the deep soil layer, which might be attributed to the large buildup of organic matter on the top layer. This finding is consistent with the findings of Alabi et al. (2019), who found that SOC declined with depth in agriculture due to the existence of plant density at the topsoil layer, which produces high biomass that decomposes to form soil organic carbon.

Table 8. SOC and pH in Relation to Different Land Use Types and Soil Depths

Parameters	Depth (cm)	Land use				
		4th age	2nd age	Zero age	Grazing	Cropland
SOC (%)	0-15	7.7± (1.1)	5.4± (0.8)	4.9± (0.6)	3.9± (0.2)	3.3± (0.7)
	15-30	4.7± (0.3)	4.3± (0.6)	3.4± (0.8)	2.6± (0.6)	1.9± (1.0)
	Overall	6.2± (0.7) A	4.9± (0.1) B	4.1± (0.1) CB	3.3± (0.4) CD	2.6± (0.9) D
pH	0-15	6.5± (0.2)	6.1± (0.3)	6± (0.2)	5.7± (0.2)	5.4± (0.1)
	15-30	6.4± (0.2)	5.8± (0.1)	5.7± (0.1)	5.8± (0.3)	5.5± (0.1)
	Overall	6.45± (0.2) A	5.9± (0.2) B	5.85± (0.2) B	5.7± (0.3) CB	5.45± (0.1) C

This means that the same letters in rows are not statistically different (p<0.05)

Soil pH

The ANOVA findings revealed that different land use types had a significant effect on soil pH values (P<0.001). The laboratory study results also revealed that soil pH levels ranged from 5.4 in croplands to a significantly higher value of 6.5 in the land use type under the fourth age second rotation (Table 9). Depth-wise statistically significant fluctuations in soil pH, on the other hand, were not found (p= 0.5605). Clay had a substantial and positive correlation with soil pH (r= 0.62**, Table 9). Thakur et al. (2012) determined that the general pH of the examined area was somewhat acidic.

[illegible] Shows the Pearson Correlation matrix for soil physiochemical characteristics (0-15cm).

[illegible]ariable[illegible]	Sand	Cl[illegible]	Silt	pH	SOC	WA[illegible]	MWD	GMD	B[illegible]
[illegible]nd	1								
[illegible]ay	-[illegible]497*	1							
[illegible]lt	-[illegible]48*	-0.[illegible]*	1						
[illegible]	0.[illegible]	0.6[illegible]	-[illegible]55	1					
SOC	-0.57*	0.59*	0.35	0.64*	1				
WAS	-0.71**	0.85**	0.14	0.75**	0.67**	1			
MWD	-0.97**	0.68**	-0.07	0.85**	0.62**	0.79**	1		
GMD	-0.98**	0.83**	-0.16	0.81**	0.85**	0.65*	0.90**	1	
BD	0.25	-0.57*	-0.45*	-0.55*	-0.97**	-0.65*	-0.54*	-0.44	1

NB ** significant at 1% and * significant at 5% respectively

In general, croplands were found to have much lower pH values than other land use groups. This could be due to crop harvesting removing basic cations, leaching of basic cations, and soil erosion removing basic cations. This finding is consistent with the findings of (Gebeyaw, 2007; Wondimagegn et al., 2018), who indicated that the lower pH value in croplands compared to forest lands could be attributed to the continual removal of basic cations and accelerated leaching of basic cations. The presence of a high amount of soil organic carbon in the surface soil layer also resulted in a higher soil pH value in all land use types of surface soil layers than in subsurface soil layers. Melku et al. (2019) discovered a similar conclusion, noting that the top layer of soil pH was higher than the sub-layer due to greater SOC buildup.

Conclusion

Land use and land cover changes in the research area have altered watershed hydrology, some soil physiochemical characteristics, and wet aggregate stability. Acacia decurrens plantings may be responsible for observed changes in water quality in terms of purity, lower volume of flowing water decreased amount and distribution of springs in the catchment, and decreased severity of soil erosion due to runoff.

The size of soil particles varied with land use type and soil depth. The surface soil layer had more sand, while the subsurface soil layers had more fine clay particles. In terms of land use, particle sand was higher in grazing land and lower in 2nd age, second rotation Acacia decurrens plantation. Clay and silt content, on the other hand, were higher in the second and fourth age second rotation Acacia decurrens plantations, respectively.

The subject region was examined for variations in wet aggregate stability under different land use strategies. distinct land use strategies resulted in statistically distinct soil aggregate stability indices. The highest wet aggregate stability values were found in the 4th age second rotation, 2nd age second rotation, and zero age second rotation, whereas agriculture and pasture lands had the lowest. All land use classes had statistically different mean weight diameters and geometric mean diameters.

As a result, the 4th age, 2nd age, and zero age second rotation Acacia decurrens plantation had the highest mean wet diameter and geometric mean diameter, while cropland and grazing land had the lowest values. Dry bulk density was statistically altered across all land use types in the same way. The highest mean value of BD was found in grazing land and cropland, respectively. On the other hand, the lowest mean value of BD was found in Acacia decurrens plantations at the fourth, second, and zero age rotations, respectively.

In terms of soil chemical characteristics, SOC differed significantly across all land uses and soil depths investigated. However, there was no statistically significant variation in pH regarding soil depth. Changes in land use and land cover altered soil physiochemical characteristics. As a result, the SOC and pH values were greater in the 4th age second rotation Acacia decurrens plantation and lower in the crop field. SOC values were higher in the surface soil layer and lower in the subsurface soil layer as soil depth increased.

Local farmers may benefit more from the Tangua system if Acacia decurrens plantation is harvested at the fourth stand age to improve structural stability in erosion-prone farmed areas. More field experimental research on Acacia decurrens water consumption and the impact on crop production should be conducted with a larger area coverage. To boost soil fertility, fast-growing tree species such as Acacia decurrens must be planted. As a result, any change in soil management or land use should be evaluated and tracked.

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