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Research Article

Status of Soil Quality Under Different Land Use: The Case of Juka Watershed of North-East Wollega, Western Ethiopia

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Abstract

In densely populated area, there is highly degraded land with a lot of dynamics such as, land use land cover change, human activity, and urbanization and other environmental factors in which soil interact within that affect soil quality. The main objective of this study was to identify status of soil quality under different land use at Juka Watershed of North-East Wollega, Western Ethiopia. Totally, 12(3x4) soil samples were collected from three different land uses based on different land use. Soil parameters were analyzed using XL-STAT software version in 2017. Hence, soil texture of the study area were various and pH of soil, % of clay contents, % of silt contents, % of SOM, % of CEC, % of CaCO3, Exchangeable of K and Na+ Cmol/Kg, and av. P mg/l, were higher in FL than others land uses whereas % of sand contents, % of TEA, % of TN and BD g/cm3 were found higher in CL than others land use. Some of soil parameters like % of sand, % of clay, BD g/cm3, pH, %SOM and %TN, %TEA, %CaCO3, av. P, Ex. Na, and % CEC of soil were significant at $P<0.05$ whereas both Ex. K and percentage of silt contents were insignificant at ($p>0.05$).

Correlation matrix revealed that BD g/cm3 was strongly and positively significant ($p<0.05$) with sand ($r=0.99$). Clay soil was more correlated with %SOM at $P<0.05$. Both TEA% and %CaCO3 were strongly and negatively significant with pH and BD g/cm3 in respectively. Similarly, all parameters were analyses among and within different land use systems. Therefore, reducing intensity of cultivation, adopting environmental friend of soil fertility management and application of organic fertilizers must maintain and replenish soil quality. Similarly, addition of lime and compost to cultivated land are maintaining quality of soil which make sustainability of production of soil which depends on an environmental health at watershed level.

Introduction

In watershed, soil is the most vital resources in our environment, and this is critical to promote sustainable development, to feed the growing world population, nearly 85% of the population depends on subsistence agriculture, which depends on environmental health [1-3]. The achievements of soil management to conserve soil quality rely on an understanding of how soils respond to land use and its practice management over time [4-5]. The fitness of soil for crop production is determined by its fertility level, which is evaluated based on the quality of the soil's physical, chemical and biological properties. Land use land cover change makes different land uses which affects the productivity of a soil and led to famine and poverty in Ethiopia [6-7]. Particularly in Ethiopia, soil degradation and nutrient depletion have gradually increased [7-8].

Therefore, the health and welfare of human being rely on the health of environment [8-9]. Climate and geological history are prominence factors that affect soil properties on regional and continental scales [9-10]. Though, land use might be the dominant factors of soil properties under small watershed [10-11]. To tackle such problems integrated watershed management (IWM) based on up-stream and down streams watershed are very important. In line with this, IWM serves as carbon Sequestration, in turns, to increase the SOC stock and soil quality and also to reduce soil degradation, and as well as to rise productivity, and mitigate climate change [11-12].

The major problems which affect soil quality are scarcity of land, high population growth, deforestation and pre-urban area of stakeholders and farmers have forced to remove crop residues from farm lands for animal feed, for marketing to get income and for fuel wood that decline maintenance of soil fertility and productivity. All these problems were too initiated as the researcher to select this topic and conduct to the study area. The general objective of this study was to identify status of soil quality under different land use at Juka Watershed of North-East Wollega, Western Ethiopia.

Materials and Method

Description of the study area

Geographically, Juka watershed is located western Ethiopia, in the Oromia national and Regional State; Horo Guduru Wollega Zone at Horo District and it is bounded by the Abbay Chomen district in the East, Jarte-Jardega and Horo Buluq District in the North, Abedenogoro in the West and Jimma Genet and Jimma Rare in South direction (Figure1). It is located at a distance of 145 km North-East from Nekemte, the capital city of Wollega and it is far away in West Ethiopia about 315 km from Addis Ababa (Figure1).

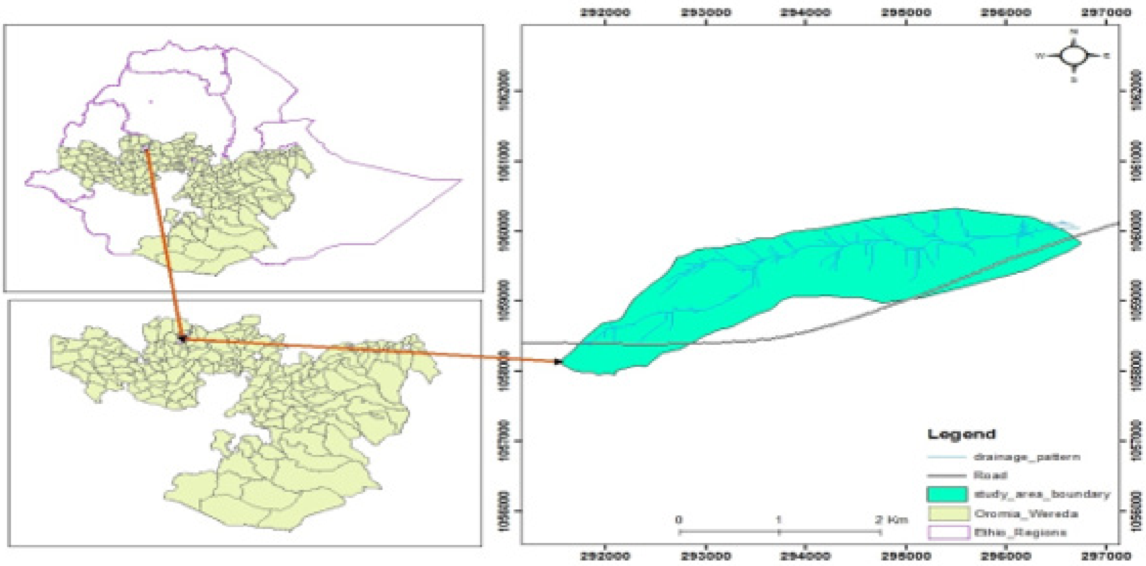

Figure1: Location map of the study area.

Climate and rainfall

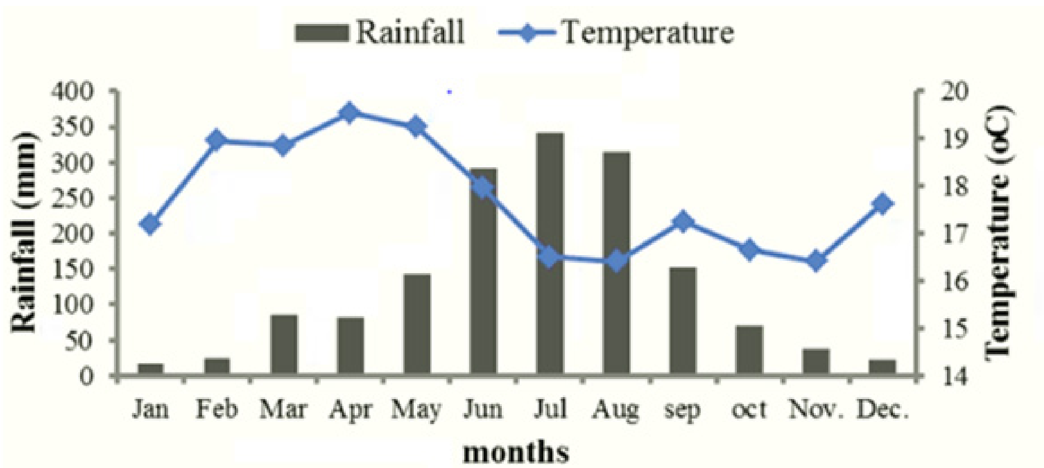

Figure 2: mean monthly rainfall (mm) and temperature (oC) from 2010 to 2019 years at the study area.

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As traditional climate classification system based on altitude and temperature into five, the study areas are mainly fall under Temperate-Baddaa, Sub-tropical-Badda daree [12] and the rainfall pattern of study area is characterized by unimodal rainfall pattern and high range within May to September get mainly high rainfall [13]. The mean minimum mean maximum monthly temperatures were 14.5°C and 20 °C, respectively (NMAS, 2019) (Figure 2).

Method of soil sampling

Soil data collection was carried out based on types of land use, similarity of slope, and diversity of plant species and rely on pre-survey field using GPS and slope consideration by clinometer and cultivation history. Following this, by stratifying three representative land uses (3x4) forest land, built up land, and cultivated land and then, from each land use by 20mx 20m diagonal by composite. Following these both disturbed and undisturbed soil samples were collected and totally twelve soil sample was prepared and packed in a plastic bowl, and transported to soil testing Centre for further analysis after labeled, air dried, cleaned from contaminants and plant debris, ground by mortar and pestle and finally sieved with a 2 mm sieve for analysis (Figure3)

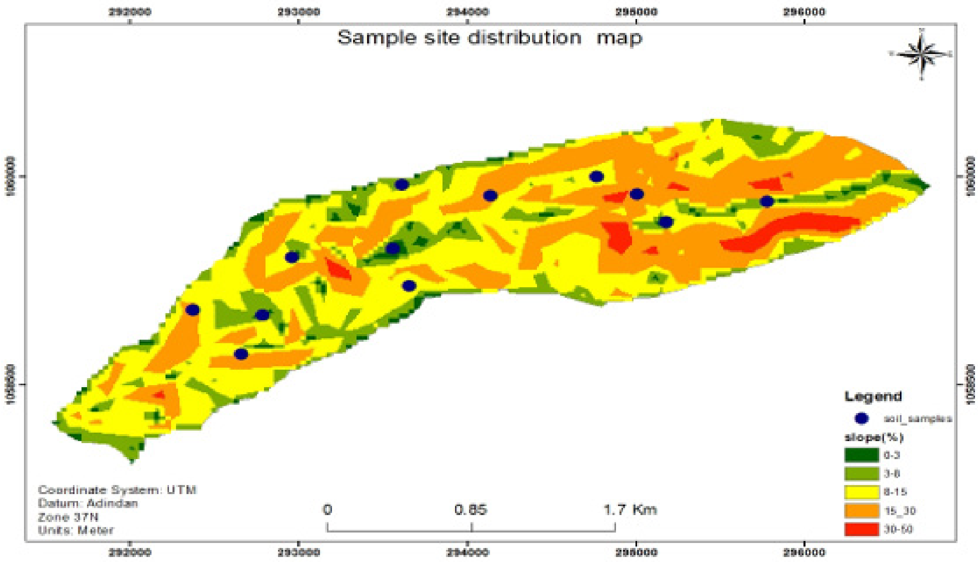

Figure3: soil sample site distribution with slope consideration.

Data analysis

Soil texture was determined by the hydrometer method after dispersion of the soil with sodium hexameta phosphate [14] and soil bulk density was determined after drying a defined volume of soil in an oven at 105 ℃ to constant weight, Soil pH (H_2O) was determined in 1:2.5 soil water suspension using glass electrode pH meter. Soil pH (KCl) was determined by dispersing 10 g of soil in 25 mL of 1M KCl after shaking for 2 hr at 20 ppm with (Orbital shaker model SO1) [15]. Soil organic matter (SOM) was determined by using Walkley and Black method by dichromate oxidation technique[16]. Cation exchange capacity (CEC) of the soil was determined from ammonium acetate saturated samples through distillation and total nitrogen was determined by measuring the ammonium using the modified Kjeldahl procedure as described by[17]. Available P was determined following Bray II method. Exchangeable acidity was determined by tit ration with NaOH. Exchangeable K^+ and Na^+ were determined by using UV-flame photometer and the calcium carbonate content of the soil was determined by acid neutralization method by treating the soil sample with standard HCl.

Statistical Data Analysis

Soil laboratory result was subjected to analysis of variance and analysis was done using XL-STAT software version in 2017. Mean comparisons were made using the least significant difference (LSD) at $P<0.05$. Significance level and Descriptive statistics described in the form of mean, standard deviation (SD), minimum, maximum, and coefficient of variation (CV), used to determine parameter of soil quality. Also the CV was used to describe the amount of variability for each soil parameter within and among land use and the relationship between different parameters of soil properties within and among land use types were expressed.

Results and Discussions

Status of soil physical quality under different land use land cover

Soil texture: As the result revealed that the highest (59.9%) mean sandy soil was found in cultivated land this is perhaps due to high amount of rainfall in the area that washes away the finer soil particles (clay) leaving behind the sand fractions while the

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lowest was in forest land. Unlike this, clay soil was higher in forest land than both cultivated and built up lands. Silt content of soil was not statistically significant with land use, and soil type. Despite, slightly the higher (26%) silt content was observed in forest land and the lower (24.4%) was in cultivated land [18]. Alike, the highest percentage of both clay (20%) and silt (26%) contents were recorded in forest land. Therefore, the result revealed that soil which has high SOM were associated with high clay of soil contents that was found more in forest land [19].

Comparatively, depending on these result, the textural class of soil in built up land, forest land and cultivated land in Juka watershed as USDA classification system were Sandy loam, Loamy, and Sandy loam in respectively. This demonstration that, the textural class of all land use types was various at the study area indicating that due to different in parent material, geology, and temperature at different land use land cover within Juka watershed (Table 1).

Table 1: Mean values of soil texture and bulk density of soil at the study area.

LUT	Particle size distribution (%)			Textural class	BD (g/cm³)
	Sand	Clay	Silt		
Built up land	58±1.67	17.50±2.43	24.50±2.66	Sandy loam	0.69±0.01
Forest land	54±1.41	20±1.41	26±0.63	Loam	0.64±0.04
Cultivated land	59.9±1.05	16.17±2.32	24±2.37	Sandy loam	0.71±0.06

LUT: Land use type, **BD:** Bulk density, g/cm³: gram per centimeter cube.

Soil bulk density: For each land use types the higher and lower soil bulk density indicated in cultivated and forest land were 0.71 g/cm³ and 0 .64 g/cm³ in respectively. Bulk density of soil in cultivated land was higher than others land uses. This is due to removal of topsoil or/and low SOM that reduced by erosion due to highly weathered area that increased bulk density of soil and it is significantly increasing with cultivation period. Soil with very high bulk density, highly compacted soil can hamper root growth, aeration and reduce movement of essential plant nutrients like K and P [20-21]. Additionally, due to soil texture, cultivated land had more sand soil, the mean amount of bulk density was higher observed in cultivated land. So that, soil bulk density affected by land use type and the highest mean value of soil bulk density was on the cultivated land than others land use types. Therefore, generally soil bulk density were increased from FL< BL<CL (0.64, 0.69, 0.71) in g/cm³ at the study area (Table1).

Soil ph and total exchangeable acidity: The soil pH by KCl and H_2O in study area were less than neutral, indicated that the area is acidity. As the result revealed that soil pH in cultivated land was lower than both forest and built up land. The maximum (5.68) and the minimum (5.23) of pH (H_2O) were found in forest and cultivated land which was indicate moderately acidic (pH 5.6-6.0): strongly acidic (pH 5.1-5.5) in respectively. Like to this the highest and lowest of PH (KCl) that distinguished in forest and cultivated land were 4.83 and 4.19 in respectively. Hence, soil pH measured by KCl was lower than pH by water, demonstrating that decreasing in soil pH when measured in KCl solution indicates high amount of exchangeable hydrogen (H) has been allowed into the soil solution through exchange reaction with potassium (K) in the KCl solution. Decreasing pH was (increase in soil acidity) due to measurement of pH in KCl solution to high potential acidity of the soil system. So, the main reasons for the lowest value of soil pH in the cultivated land are due to inappropriate use of ammonium-based fertilizers that implied the deterioration of soil quality [22].

The total exchangeable acidity (TEA) of the study area was increased from forest land to cultivated land that means; 0.43%, 0.49%, 1.17% in FL, BL and CL in respectively. This finding agreed with research [23,24]. This is due to the fact that forest land has high soil organic matter that formed strong bonds, known as "chelates," with aluminum that make unavailable aluminum nutrient in forest land and the other reason that make high %TEA in cultivated land than other land uses types is due to the reason of exchangeable bases decreased Achalu *et al.* [20]. So, %TEA of Juka watershed which was expressed in built up land, forest land and cultivated land were 0.49%, 0.43% and 1.17% in respectively (Table2).

Calcium carbonate and exchangeable bases: In cultivated land there was no $\%CaCO_3$ (limestone) these indicated that high soil acidity at the study area that affects the quantity, activity, and types of microorganisms Alemayehu and Assefa [24]. The amount of limestone/calcium carbonate is decreased as a result of soil bulk density increased due to land use changed. Both calcium carbonate and soil bulk density were inversely proportion to each other nevertheless $\%CaCO_3$ was more directly proportion with percentage contents of silt, clay soil, and soil organic matter those found more in forest land. In this finding percentage of calcium carbonate ($CaCO_3$) in the FL, BL and CL were; 0.39%, 0.07% and 0.0 % in respectively (Table 2).

Table 2: Mean values of pH, %TEA, %CaCO3, and exchangeable bases (K and Na).

LUT	Soil pH		%TEA	%CaCO³	Ex. K Cmol/Kg	Ex.Na Cmol/Kg
	pH (H_2O)	pH (KCl)				
BL	5.61±0.07	4.67±0.07	0.49±0.16	0.07±0.08	12.84±2.07	3.33±0.51
Fl	5.68±0.15	4.83±0.17	0.43±0.14	0.39±0.60	16.19±3.71	3.42±1.06
Cl	5.23±0.05	4.19±0.28	1.17±0.39	0.0±0	8.34±1.13	1.71±0.35

Similarly, available of %$CaCO_3$ in forest land was higher than other land use types. Despite, contrasting in forest land, %$CaCO_3$ was unavailable in cultivated land. This is because of exchangeable bases percolated and leached by soil erosion as a result of continuous tillage and the area is highly weathered. Due to this, forest land has high %SOM and % CEC which can hold and store plant nutrients whereas cultivated land had more replaced by acidic nutrient soil like Al^{2+} and H^+ due to highly degraded land.

Furthermore, the mean highest and lowest Ex. K was 16.24 Cmol/Kg and 8.34 Cmol/Kg that found in the forest and cultivated land in respectively. Yet, this finding was promise with [25] state that the rate of mean exchangeable K values saw in study area ranged from high in cultivated land to very high in forest land. Juka watershed is highly weathered due to fluctuated slope of land as a result of population growth with more concentration of cultivation practices plus use of farmer's inorganic fertilizer on acid soil that disturbs the distribution of K in the soil and reduces its availability Wakene & Heluf [4].

However, unlike N and P, K no causes on off-site environmental problems rather on site when it leaves the soil system because it is insignificant among land use type. In the same way, lower available exchangeable Na^+ cation under cultivated land is an indicative for the depletion of the surface soils of the study area. Furthermore, a serious cultivation and continuous use of inorganic fertilizers in the cultivated fields that increases soil acidity (lowering soil PH) and also it will increase loss of base cation like Na^+ through leaching, erosion and crop harvest which promise with [26]. Generally, in overall %$CaCO_3$ and exchangeable K Cmol/Kg were higher in forest land than others land use types. This is due to forest land has high infiltration rate which reduce erosion of soil because of land cover that causes forest land has high Soil Organic Matter and due to high regeneration capacity. Also, it had high %CEC those are to maintain nutrient status of soil in forest land at optimum level within a balanced ecosystem health which fight famine and droughts in the country.

Cation exchangeable capacity and soil organic matter: In the study area among land uses, forest land had very high %CEC in the soils as compared to other land use types that familiar with [27]. This is because of the amount and nature of the organic matter content of forest soil and %SOM shows a strong response to land use, land use change, and land degradation which agree with Alemayehu & Assefa [24]. Relatively, high %CEC values in forest land may attribute to store high percent of SOM and had larger ability to hold cations there by resulted greater potential fertility in the soil. Then, soil which has high %CEC is expected to increase through improvement of the soil organic matter content.

Even soil organic matter in cultivated land of Ethiopia as a general and at the study area in particularly was very low (2.28%) and usually less than 3% resulting in a very low productivity [28]. Also, this finding agree with other research, which stated that organic carbon content in soil samples were found very low (< 4%) studied by Zelalem [21] in Shewa Robit, Amhara Regional State, Ethiopia. In the same way, the amount of both %CEC and %SOM were decreasing from forest to cultivated land due to land use land cover changes (FL>BL>CL) in this finding that means; percentage of CEC were 19, 18.50, and 13 and percentage of SOM were: 3.32, 2.18 and 1.34 that found in FL, BL and CL in respectively. Maybe, in all there is no too exposed soil erosion in forest lands due to land cover that makes high %SOM and %CEC and %CEC the opposite of this in cultivated lands there is high %SOM and %CEC that coincide with [29] (Table3).

Table 3: Mean values of the %CEC, %SOM, %TN and Av. P g/ml.

Land use Type	CECCmol/Kg	%SOM	%TN	Av. P mg/L
Built up land	18.50±4.04	2.18±0.33	1.09±0.23	27.09±2.16
Forest land	19±6.78	3.32±0.33	1.01±0.05	28.40±1.72
Cultivated land	13±1.79	1.34±0.30	2.30±0.34	22.84±0.59

CEC: cation exchangeable capacity, SOM: soil organic matter, TN: total nitrogen, Av. P: available phosphorous

Table 4: Pearson's Correlation matrixes for selected soil physicochemical parameters.

Variables	Sand	Clay	Silt	BD	pH (H_2O)	TEA	$CaCO_3$	Ex. k	Ex. Na	CEC	SOM	TN	av. p
Sand	1	-0.99	-1	0.99**	-0.8	0.76	-0.99	-0.94	-0.7	-0.76	-0.98	0.74	-0.85
Clay	-0.99	1	0.95	-0.98	0.85	-0.81	0.97	0.97	0.8	0.82	0.99**	-0.8	0.89
Silt	-0.97	0.95	1	-0.98	0.66	-0.6	0.99	0.85	0.58	0.6	0.92	-0.59	0.72
BD	0.99**	-0.98	-1	1	-0.76	0.71	-0.99**	-0.92	-0.7	-0.72	-0.97	0.7	-0.81
PH(H_2O)	-0.8	0.85	0.66	-0.76	1	-0.99	0.73	0.95	0.99	0.99**	0.89	-0.99	0.99**
TEA	0.76	-0.81	-0.6	0.71	-0.99**	1	-0.68	-0.93	-1.00**	-1.00**	-0.85	1.00**	-0.98
$CaCO_3$	-0.99	0.97	0.99	-0.99**	0.73	-0.68	1	0.9	0.66	0.68	0.96	-0.67	0.78
Ex. K	-0.94	0.97	0.85	-0.92	0.95	-0.93	0.9	1	0.92	0.93	0.98	-0.92	0.97
Ex. Na	-0.74	0.8	0.58	-0.69	0.99	-1.00**	0.66	0.92	1	1	0.84	-1.00**	0.98

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CEC	-0.76	0.82	0.6	-0.72	0.99**	-1.00**	0.68	0.93	1	1	0.85	-1.00**	0.98
SOM%	-0.98	0.99**	0.92	-0.97	0.89	-0.85	0.96	0.98	0.84	0.85	1	-0.84	0.92
TN%	0.74	-0.8	-0.6	0.7	-0.99	1.00**	-0.67	-0.92	-1.00**	-1.00**	-0.84	1	-0.98
av. P	-0.85	0.89	0.72	-0.81	0.99**	-0.98	0.78	0.97	0.98	0.98	0.92	-0.98	1

Values in bold and ** are different a significant level at $p < 0.05$.

In parallel way, by understanding all the above mentioned, soil organic matter can consider as the most powerful indicator for evaluating soil potential efficiency in different land uses types and managements of nutrients in the world which reach agreement. Significantly reduction of %SOM by changing forest to cultivated land has been reported and its content in soils quality decreased rapidly in the first from cultivation land due to anthropogenic factors. Additionally, in cultivated land, the amount of soil organic matter (1.34%) was less than two percent which indicate more soil erosion and degradation involving a highly increased risk in tropical soil [30]. Depending up on those, cultivated soil generally have low soil organic matter compared to others land use type; the reasons are the fact that cultivation increases aeration of soil which enhances the decomposition of soil organic matter contents Achalu, et al. [20].

Additionally, mainly due to the whole removal of biomass for animal feed, for house building, for energy supply, for marking to generate income, especially those who life around pre-urban area, and continuous cultivation; lack of fallow periods due to scarcity of land, Soil organic matter are more reduced and its potential in soil declined and that worsens status of soil quality in the cultivated land in Ethiopia particularly at the study area.

Total nitrogen and available phosphorous (P Ava.): As result revealed that the highest and the lowest of %TN that found in cultivated and forest land were 2.3% and 1.01% respectively. This might be due to many reasons. The first reason is the farmers used inorganic (N) fertilizer in the form of nitrate on their cultivated land. Secondly, due to removal of crop residue from cultivated land, lack of crop rotation, and absence of organic fertilizers like compost, manures at the study area made low carbon contents of the cultivated land. Lastly may be due to reason of acid forming rainfall that makes high percentage of TN Alemayehu and Assefa [24].

Likewise, availability of P in the BL, FL and CL were 27.09mg/l, 28.40mg/l, 22.84mg/l in respectively. From this high P 28.40mg/L was in forest land and the lowest 22.84mg/l was in cultivated land. This is may be a pool of available P could be trees in the forest land with abundant microorganisms that return via litter fall to the soil. The other reason is due to alteration of forest land to build up land and then to agriculture land, available phosphorus (P) was reduced most probably due to decline in both %SOM and %CEC and soil acidification Achalu, et al. [20] as conducted by Birhanu, et al. [27] alteration of forest land to agricultural land decreased availability of phosphorus (P) from 4.04 ppm to 1.95 ppm in Komto, Western Ethiopia.

So that really, LULC change did significantly affect available of Phosphorous. In forests land, fallen vegetation cover and natural pruning of tree can return into soil when they decomposed, and they can increases %SOM content, which lead to increases available Phosphorous content. Consequently, available P content was significantly ($P<0.05$) among different land use systems that come to an agreement with Alemayehu and Sheleme [9].

As Pearson's correlation matrix revealed that, the mean values of both clay and silt contents of soil was negatively insignificant with sand at ($p>0.05$) ($r=-0.99$, -0.97) in respectively whereas silt contents was positively insignificant with clay at ($p<0.05$). Similarly, land use system was significantly affected sand and clay contents but insignificant silt contents of the soil in the Juka watershed. Even BD was strongly and positively significant with sand contents at ($p<0.05$) ($r=0.99$**). On the other hand, bulk density was negatively insignificant with both clay and silt contents ($p>0.05$). In line to this, PH was negatively insignificant ($p>0.05$) with both sand and BD contents. However, it was positively insignificant ($p>0.05$) with both clay and silt content of soil at the study area. Likewise, limestone or %$CaCO_3$ was strongly and negatively significant with BD ($p<0.05$) ($r=-0.99$**) (Table 4).

Conclusion and Recommendations

Conclusion

The results of the study revealed that, soil texture was identified as acidic and the textural class of soil in BL, FL and CL in Juka watershed as USDA classification system were Sandy loam, Loamy, and Sandy loam in respectively. The %clay contents (20), % silt contents (26), %SOM (3.32), %CEC (19), %$CaCO_3$ (0.39), Ex. K (16.19), Na^+ (3.42) Cmol/Kg, and av. P (28.40) mg/l, were higher in Conclusion FL than other land uses whereas %sand contents (59.9), %TEA (1.17), %TN (2.30) and BD (0.71) g/cm^3 were found higher in CL than other land use. Similarly, some of soil parameters like %sand, %clay, BD g/cm^3, pH, %SOM and %TN, %TEA, %$CaCO_3$, av. P. Ex. Na^+, and % CEC were significant at ($P<0.05$) due to the effect of land use whereas both Ex. K and % silt contents were insignificant at ($p>0.05$). Therefore, due to high input of inorganic fertilizer on agricultural land and continuously removed of crop residues from CL, soil fertility were negatively affected mainly on cultivated land. So, soil quality status was lower in cultivated land than other land use. Consequently, in Ethiopia, soil management strategies like application of organic fertilizers, liming, composting, and manure are used to ameliorate soil acidity and increasing sustainability of soil quality and its productivity must be considered at the watershed level that fight famine and droughts in our country.

Recommendation

- Reducing intensity of cultivation, adopting integrated soil fertility management and application of organic fertilizers like manure, compost rather than inorganic fertilizers are more recommended at the study area.
- At the study area in order to reduce such environmental health problem, proper land use must be followed.
- In order to maintain environmental soil productivity and nutrient status at the study area, addition of lime to cultivated land must be needed for high land slope of cultivated land whereas for low land slope at which flooding possible, flooding is necessary to raise PH of the cultivated land.
- Maintaining forest land to safe environmental quality and sustainability development must be considered at the scale of watershed level.

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Conflict of Interest

No conflict of interest.

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