

# Influences of Land Use/ Cover Changes on Soil Properties in Rib Watershed, Ethiopia

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## Research

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# Abstract

## Background

The decrease in the area under natural vegetation and its conversion into other types of use has resulted in resource degradation including soil quality loss. Soil properties response to changes in land use/ cover has shown spatial and temporal variations. Hence this *study was carried out to examine the influence of land use/ cover changes on physical and chemical properties of the soils in Rib watershed. Soil samples were taken over three selected land use/ covers (natural forest, grazing and cultivated lands) in two agro- ecological zones (Dega and High Dega). Multivariate analysis of variance (MNOVA) and Pearson's correlation was computed.*

## Results

*The study revealed that land use/ cover and altitude have influenced physical and chemical properties of the soil in the study watershed. Significant difference in distribution of soil texture, BD, OC, TN and pH among land use/ covers have been observed. Natural forest had higher OC, OC stock and TN than grazing and cultivated lands. The mean OC stock ranged from 188.32 t/ha in natural forest to 72.75t/ha in cultivated lands. Soil pH was slightly higher for natural forests and lower in the soils of grazing and cultivated lands. Significant difference ( $P<0.05$ ) among the two agro ecologies were also observed in OC,  $Ca^{2+}$ , clay, and silt.*

## Conclusion

*Therefore, land use/ cover changes have affected the concentration of TN, OC, increase soil acidity and compaction that can affect productive of soils and production of crops.*

# Background

Like in most developing countries, Ethiopian economy is primarily based on agricultural production. Agriculture accounts over 50% of the country's Gross Domestic Product (GDP) and employs over 85% of the labour force (Alemu et al., 2010). These rural populations are growing rapidly, and consequently inducing many effects on the resource base to satisfy food demands (Bewket & Stroosnijder, 2003, Alemu et al., 2010). Empirical studies carried out in different parts of the country confirmed that rural population growth in Ethiopia is inducing very dynamic land use and land cover changes (Zeleeke & Humri, 2001). In this sector smallholder farmers with an average holding of less than a hectare account for over 90% of the farm land under crop production (Gebreselassie & Bekele, 2010). These farmers are responsible for over 90% of agricultural output of the country. This strong reliance on agriculture as an economic driving force entails that natural resource of agricultural significance mainly soil should be managed on a sustainable basis (Mulugeta, 2004).

Previous studies (Abate, 1994; Tekle & Hedlund, 2000; Belay, 2002; Kebede & Raju, 2011) confirmed that the decrease in the area under natural vegetation and its conversion into other types of use has resulted in resource degradation including soil quality loss. The assumption given by Bewket & Stroosnijder (2003) regarding the influences of land cover change on soil properties stated that de- vegetation leads to deterioration in the physical and chemical properties and degradation of the land. Soil properties response to changes in land use/ cover has shown spatial and temporal variations. For instance in tropical region, effects of land cover changes on soil resources resulted in conversion of climax vegetation to human managed land use systems (Hartemink et al., 2008). This has in turn triggered low soil structure stability, loss of SOM, reduction in nutrient stock and soil organic carbon (OC) (Hartemink et al., 2008). The study of (Andriamananjara et al., 2016) had uncovered that changes in land use/ cover significantly affected carbon stock by impacting the above ground biomass and soil organic carbon in Malagasy rainforest. Land use practices affect the distribution and supply of soil nutrients directly by altering soil properties and by influencing biological transformations in the root zone (Alemu, 2015)

The studies conducted in different parts of Ethiopia confirmed variation of soil quality indicators on different land use and land covers. Accordingly organic matter (SOM) and total nitrogen (TN) contents of soils in central Ethiopia declined because of deforestation and long- term cultivation (Mulugeta, 2004). In North East Wollega, the mean value of TN was highest in soils of forestland and lowest in cultivated lands (Adugna & Abegaz, 2016). Likewise, studies have shown variations in physical properties of soils over different land use/ covers. Abegaze et al. (2006) confirmed deterioration in soil bulk density (BD), porosity, infiltration, water storage and run- off resulted when natural forestland was converted into cultivated and bare lands. Mulugeta (2004) also confirmed that BD increased and pore space decreased progressively in the 0–10 cm and 10–20 cm soil layers with increasing cultivation period after deforestation.

Moreover, there are variations in soil properties in relation to variation in topographic elevation over Ethiopia (Abegaze et al., 2006; Asmamaw & Mohammed, 2012). Statistical indicators revealed that the effect of altitude on soil pH, BD and silt content were significant (Abate et al., 2013). Accordingly the midland part of Jedeb watershed of headwater part had higher soil pH and BD than the upland part.

In general soil physical and chemical properties are highly influenced by land use/ covers and agro ecological zoning which are characterized by elevation variations. These variations influence the soil's capacity to sustain plants and other organisms and the productivity in natural or managed ecosystems (Warra et al., 2015 & Mulugeta, 2004). Therefore, the main aim of this study was investigating the influence of land use/ cover changes on soil properties in Rib watershed.

## Materials And Methods

### Description of Study Area

Rib watershed is located between 11°42'00"N to 11°49'00"N latitude and 38°08'00"E to 38°15'00"E longitude (Amhara Livelihood Zone Report, 2005). The study watershed covers two small administrative units/ Kebeles (Mokes and Atadidim) in South Gondar Zone, Amhara Regional State. The watershed covers about 6608.79 ha and comprises diverse topographic conditions with elevation ranging from 2666 m to nearly 4113 m above sea level (Fig. 1). Based on altitudinal ranges, the study area is divided into two local/ tradition agro- ecological zones. These were '*Dega*' that ranges 2666–3200 m above sea level in *Atadidim kebele* and '*High Dega*', the area above 3200 m above sea level in *Mokesh Kebele* (Hurni, 1998). The study watershed is situated in the western edge of Mount Guna which is a headwater area of Upper Blue Nile/ Abay and mainly the source of Rib & Gumara Rivers which are the tributaries of Lake Tana. Rib is very important river on which irrigation dam project has been constructed and planned to irrigate about 14, 00hectars of land to benefit more than 28,000 households. This project was believed to assure food security of households by introducing irrigation system (Ambaye, 2013).

## Soil Sampling and Laboratory Analysis

According to Bewket & Stroosnijder (2003), in the absence of prior information & difficulty of establishing experimental plots to evaluate changes in soil properties, an alternative approach is to take soil samples from plots of land under different use and covers. In this study natural vegetation was taken as undisturbed or less disturbed or as control to make comparisons in soil physical and chemical properties resulting from the establishment of other land use types. Hence, after indentifying land use/ cover classes, three major land use/ cover classes (Natural forest, cultivated, and grazing lands) were selected for the study of soil properties. In the mid of May, 2020, soil samples were collected from two agro ecological zones. Soil samples were taken from each and adjacent land use/ cover type in each agro ecology with five replicates.

For each soil sample, five sub samples were collected from a square of 10 m by 10 m established on randomly selected land use/ cover classes and mixed up to obtain composite & representative samples. The samples were taken using a steel auger at two depth 0-15cm (surface layer) and 15–30 cm (subsurface layer) (Bewket & Stroosnijder, 2003). The two depths were chosen so that the surface layer represents the average plough depth and the subsurface layer represents the depth to which clay particles migrate and at which nutrients leached from the top layer (Bewket & Stroosnijder, 2003). Based on such procedure 30 soil samples were collected.

Simultaneously, separated five soil core sample were collected from each land use/ cover class within the 10 m by 10 m plot. Thus soil core were taken from 0–15 cm depth with sharp – edged steel cylinder/ core sampler of 5 cm height by 5 cm diameter forced manually into the soil & sealed in plastic bag for bulk density determination.

## Soil Data Analysis

To assess the influence of land use/ cover changes on major physical and chemical properties (soil texture, TN, Available phosphorus (Av.P), OC, pH, BD, cation exchange capacity (CEC), exchangeable cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$  and  $\text{Na}^+$ ) the samples were analyzed using standard procedures. The laboratory analysis was carried out in Adet Agricultural Research Laboratory in Amhara Regional State, Ethiopia. Soil samples were labeled, air dried, cleaned from contaminants and plant debris, ground and passed through a 2 mm sieve prior to laboratory analysis. Based on standard laboratory procedures, soil texture was determined by the Bouyoucous hydrometer method, pH by using a pH meter in 1:2.5 soil/ water ratio, soil BD determination using core method and soil OC by the Walkley- Black oxidation method (Lu, 1999; Bewket & Stroosnijder, 2003). TN content was determined with Kjeldahl digestion, distillation and titration method, available P was extracted by Olson method. CEC and concentrations of exchangeable cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$  and  $\text{Na}^+$ ) were determined by atomic absorption spectrophotometer and flame emission. Moreover, the soil carbon stock (CS) of the sample soil at each land use/ cover was derived from organic carbon concentration and bulk density as estimated by the following formula:

$$\text{CS} = \text{OC} \times \text{BD} \times \text{H}$$

Where CS is soil organic carbon stock (t/ha), OC is soil carbon concentration (%), BD is soil bulk density and H is the soil depth (cm) mean depth for (0–15 and 15–30) was taken to estimate carbon stock (Xu et al., 2011).

## Statistical Analysis

After conducting laboratory analysis, all data were exported to SPSS for windows software package version 23. Multivariate analysis of variance (MANOVA) was computed to test the significance of mean difference of each soil properties among land use/ cover types and agro ecologies by following the general linear model (GLM) procedure of SPSS (Field, 2009). After computing MANOVA, the significance of mean difference of each soil properties between two land use/ cover types and agro ecology were tested employing LSD post hoc multiple comparisons at  $P = 0.05$ . In addition, the correlation of each soil property with other properties was tested through Pearson's correlation method (Bewket & Stroosnijder, 2003).

## Results & Discussion

The soil laboratory results for the 30 samples were statistically summarized in Table 1. The result showed that soil physical & chemical properties had variation among land use/ covers and agro ecologies. Overall average of soil acidity level/ pH, OC, TN,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$  and CEC in the soils of cultivated land were very low compared to the soils under natural forest and grazing lands in both agro ecologies. Whereas, soils under natural forest had low level of Av.P compared to cultivated and grazing lands. On the other hand, in the *Dega* agro ecology, soils were high in clay content but low OC and CS as compared to *High Dega* of the study watershed. In the *High Dega* agro ecology, soil pH, available P and BD were low while the proportion of  $\text{Ca}^{2+}$  and CEC nutrients were slightly higher compared to the soils of *Dega* agro ecology (Table 1).

Table 1  
Mean of soil properties per Land use/ cover and agro ecology and overall statistical summary

Agro ecology		Dega			High Dega				Over all Mean			
		Natural F	Grazing land	Cultivated land	Mean	Natural F	Grazing land	Cultivated land	Mean	Natural F	Grazing land	Cultivated land
Soil Physical and chemical Properties	PH	7.0	5.8	5.3	6.03	6.8	5.7	4.9	5.80	6.93	5.71	5.12
	OC%	6.7	3.1	1.4	3.71	9.3	7.2	3.3	6.60	8.00	5.16	2.31
	CS t/ha	216.38	144.82	99.92	153.70	160.28	93.88	45.59	99.92	188.32	119.35	72.75
	TN%	0.4	0.3	0.1	0.25	0.5	0.5	0.2	0.41	0.47	0.36	0.17
	Av. P(ppm)	3.3	6.2	9.0	6.17	4.4	4.6	5.2	4.74	3.88	5.42	7.07
	Clay %	24.4	43.2	59.2	42.23	26.2	23.4	39.4	29.67	25.30	33.30	49.30
	Silt%	32.6	29.0	26.0	29.20	35.6	41.8	35.2	37.53	34.10	35.40	30.60
	Sand %	43.0	27.8	14.8	28.53	38.2	34.8	25.4	32.80	40.60	31.30	20.10
	BD (g/cm <sup>3</sup> )	0.9	1.0	1.1	1.02	0.9	0.7	1.1	0.88	0.89	0.86	1.10
	Ca <sup>2+</sup> (mEq100g <sup>-1</sup> )	16.5	11.9	11.5	13.29	18.7	13.1	12.3	14.72	17.60	12.53	11.89
	Mg <sup>2+</sup> (mEq100g <sup>-1</sup> )	12.1	2.4	1.8	5.46	11.0	2.4	2.4	5.29	11.58	2.42	2.12
	Na <sup>+</sup> (mEq100g <sup>-1</sup> )	0.6	0.7	0.6	0.63	0.6	0.6	0.7	0.61	0.61	0.61	0.64
	K <sup>+</sup> (mEq100g <sup>-1</sup> )	0.5	1.3	0.8	0.87	0.5	1.3	0.5	0.78	0.52	1.28	0.66
CEC(mEq100g <sup>-1</sup> )	29.7	16.3	14.7	20.25	30.9	17.4	15.9	21.38	30.30	16.84	15.31	

## Soil Texture

Variation in soil texture distribution was observed along land use/ cover types and agro ecological zones. Accordingly, the average sand fraction of soils of natural forestland was high (40.6%) whereas it was low on soils of cultivated and grazing lands (20.1% and 31.3% respectively Table 1). In the reverse clay fraction on the soils of cultivated land was > grazing land > natural forests. This finding was contradicting with the finding of Bewket & Stroosnijder (2003) and Kebede & Raju (2011) which find out highest clay fraction in the forested plots but lowest in both cultivated and grazing fields and vice-versa for sand content of the sample soils. This variation may come from the difference in the density of forest in the two study areas to prevent removal of clay fractions to the down soil profile and slope. The other likely factor for such distinctions could be the process of plowing, clearing and relative planeness of farming fields (Biro et al., 2013). According to Warra et al. (2015) the highest concentration of clay fraction on cultivated land may be attributed to ploughing accentuating weathering, making cultivated lands richer in finer materials. Moreover, the mean percentages of clay fraction in the soils of Dega agro ecological zone were greater than that of *High Dega* soils. Sand and silt contents were lower in soils of *Dega* than *High Dega* agro ecological zone.

As stated by Warra et al. (2015) and Agegnehu et al. (2019) on the downward surface elevation, increment of clay size fraction was associated with selective removal of finer and lighter materials from higher to lower elevation, as clay requires lower velocity to be transported than silt and sand particles. Thus the main effects of factors, land use/ covers and agro ecologies, were statistically significant for clay ( $P < 0.05$ , Table 2). The effects of agro ecology was significant ( $P < 0.07$ ) on clay and silt, while the effect of land use/ cover was significant on clay & sand.

Table 2  
Interaction effects of land use/ cover and Agro ecology on Major soil properties

Source	Dependent Variable	F	Sig.	F	Sig.	F	Sig.		
Agro ecology	PH	2.335	.140	Land use/ Cover	51.037	.000	Agro ecology * Land use/ Cover	.257	.776
	OC	6.109	.021		7.916	.002		.305	.740
	CS	4.341	.048		6.765	.005		.003	.997
	TN	3.924	.059		5.046	.015		.164	.850
	Av.P	.704	.410		1.169	.328		.704	.504
	Clay	10.584	.003		13.274	.000		3.456	.048
	Silt	15.944	.001		1.887	.173		1.881	.174
	Sand	2.199	.151		16.967	.000		2.612	.094
	BD	3.077	.092		3.440	.049		1.237	.308
	Ca <sup>2+</sup>	6.800	.015		43.654	.000		.609	.552
	Mg <sup>2+</sup>	.487	.492		601.481	.000		3.761	.038
	Na <sup>+</sup>	.186	.670		.259	.774		.662	.525
	K <sup>+</sup>	.900	.352		23.799	.000		.725	.495
	CEC	3.414	.077		239.104	.000		.002	.998

## Bulk Density (BD)

In both agro ecological zones, soil samples taken from the lands under cultivation have shown high BD due to high compaction compared to grazing and natural forest lands (Table 1). In the study watershed cultivated lands have high BD (mean = 1.096 g/cm<sup>3</sup>) than natural forest land (mean = 0.892 g/cm<sup>3</sup>) followed by grazing land (mean = 0.856 g/cm<sup>3</sup>). On the other hand there was variation in average BD among the soils in the two agro ecological zones (mean = 1.02 g/cm<sup>3</sup> & 0.95 g/cm<sup>3</sup> for the soils of *Dega* and *High Dega* respectively). The MANOVA result in Table 2 revealed that the effect of land use/ cover was statistically significant for soil BD ( $F = 3.004, P = 0.049$ ), whereas the effect of agro ecology was found insignificant. The LSD post hoc test suggested that there was variation in average BD of cultivated land was significantly different from natural forest land ( $P < 0.05$ ) and grazing land ( $P = 0.02$ ), Table 3. The increase in BD due to compaction in cultivated land was attributed to intensive cultivation (Reicosky & Forcella, 1998). This finding was in agreement with Mulugeta (2004) that confirmed forest and grass lands have a lower BD than farm land due to soil organic matter concentrations difference and cultivation activities. Selassie & Ayanna (2013) reported that progressive increase in BD was triggered by deforestation and continues cultivation in top plow layers that lead to decline in soil organic matter and compaction from the tillage. Thus the soil BD and SOM have inverse relationships, in turn can affect the aggregate stability of soil and the movement of water and nutrients through it (Kebede & Raju, 2011; Gardner et al., 1999).

Table 3  
LSD post hoc Multiple Comparison test of Soil Properties among Land use/ covers

Dependent Variable	(I) Interaction	(J) Interaction	Mean Difference (I-J)	Sig.
pH	Forest	Grazing	1.220*	.000
		Cultivated	1.810*	.000
	Grazing	Cultivated	.590*	.004
OC	Forest	Grazing	2.846	.058
		Cultivated	5.694*	.001
	Cultivated	Grazing	-2.848	.058
CS	Forest	Grazing	68.978541*	.039
		Cultivated	115.575231*	.001
	Grazing	Cultivated	46.596690	.154
TN	Forest	Grazing	.112	.257
		Cultivated	.303*	.004
	Cultivated	Grazing	-.191	.059
Av. P	Forest	Grazing	-1.549	.466
		Cultivated	-3.198	.139
	Grazing	Cultivated	-1.649	.438
BD	Forest	Grazing	.036	.718
		Cultivated	-.204*	.050
	Grazing	Cultivated	-.240*	.023
Ca <sup>2+</sup> (mEq100g-1)	Forest	Grazing	5.0620*	.000
		Cultivated	5.7050*	.000
	Grazing	Cultivated	.6430	.346
Mg <sup>2+</sup> (mEq100g-1)	Forest	Grazing	9.1620*	.000
		Cultivated	9.4590*	.000
	Cultivated	Grazing	-.2970	.348
Na+(mEq100g-1)	Forest	Grazing	-.0070	.896
		Cultivated	-.0360	.504
	Grazing	Cultivated	-.0290	.590
K+(mEq100g-1)	Forest	Grazing	-.7580*	.000
		Cultivated	-.1380	.250
	Cultivated	Grazing	-.6200*	.000
CEC (mEq100g-1)	Forest	Grazing	13.4590*	.000
		Cultivated	14.9900*	.000
	Grazing	Cultivated	1.5310	.054
Based on observed means. *.The mean difference is significant at the .05 level				

## Soil pH

Acidity of soils (pH values) varies significantly among land use/ cover classes in Rib watershed. As shown in Table 2, the main effect of land use/ cover was statistically significant for soil pH ( $F = 51.037, P = .000$ ). The LSD post hoc test of MANOVA shows that mean soil pH was significantly different at  $p < 0.01$

(Table 3) between cultivated and natural forest & grazing lands. Soil pH was slightly higher for soils of natural forestlands (mean = 6.93) as compared to cultivated (mean = 5.71) and grazing lands (mean = 5.12), Table 1. This indicated that soils of natural forests were slightly neutral in both *Dega* and *High Dega* agro ecological zones (7.0 and 6.8 respectively). Thus, soils in cultivated and grazing lands were more acidic than those of natural forestland soils (Agegnehu et al., 2019). On the other hand despite the variation in pH level of soils of the two agro ecologies, soils of the study watershed can be generally characterized as moderately acidic, pH ranging from 5.6 to 6.5 (Agegnehu et al., 2019). The reduction in soil pH is attributed to the ploughing processes of cultivated fields (Biro, 2013). The conversion of forestland into cultivated land has led to a drop in organic matter which in turn leads to lower pH (Khresat et al., 2008). These findings were in line with the study by Biro et al. (2013) in Northern part of Gdarif region of Sudan. Another study by Kidanemariam et al. (2012) revealed that lower pH values of cultivated and grazing land soils can be attributed to the removal of basic cations by plants, which causes continuous cultivation with little nutrient returns to the soil, erosion and overgrazing on grazing lands. Another reason for the increase of soil acidity on cultivated lands was intensive farming over a number of years with nitrogen fertilizers (Abate et al., 2013). The finding of this study was in agreement with other studies that find out soil acidity issues is becoming critical in Northwestern highlands of Ethiopia (Genanew et al., 2012; Haile et al., 2009 and Melese et al., 2016). These studies confirmed that acidic soils have poor chemical and biological properties and can affect crop production and productivity of the land.

## Soil organic Carbon (OC)

Table 1 has shown mean difference of OC content among the three land use/ covers and agro ecology. The average OC was 8.00%, 5.16% and 2.31% for soils of natural forest, grazing and cultivated lands respectively. Forest soils are one of the major carbon sinks on earth, because of the high amount of organic matter stored in forest soils (Tesfaye et al., 2018). Above all, forest soils in the first 1 m depth have held 11% of soil carbon worldwide (Negi et al., 2013). Moreover, the overall mean of OC was 3.71% in the soil of *Dega* and 6.60% in the soils of *High Dega* agro ecology. This finding was in line with the findings of Kidanemariam et al. (2012) and Warra et al. (2015) who confirmed that OC showed increasing trend with elevation in all land use/ cover types. The LSD post hoc test in MANOVA (Table 3) suggested that OC was significantly differed between natural forest, grazing lands and cultivated lands. From this finding it was possible to conclude that land use/ cover changes can affect OC concentration of soils under different use and cover (Warra et al., 2015). Continuous cultivation, removal of crop residuals, lack of crop rotation, inadequate agricultural fertilizers use and poor soil management practices were among the major factors that lead to OC deterioration in the soils (Kidanemariam et al., 2012).

## Soil Organic Carbon Stock (CS)

Soil carbon stock of the three land use/ covers was calculated based on OC content and soil BD. Variation was found in the distribution of CS among land use/ covers and agro- ecological zones owing to the existing difference in OC and BD. Thereupon, the soils of natural forests in both *Dega* and *High Dega* agro- ecological zones retained higher mean carbon stock followed by grazing and cultivated lands (Table 1) (Sebhatleab, 2014). Overall mean of natural forests' CS was more than two fold higher than cultivated lands. It was confirmed that forests sequester and stores more carbon than any terrestrial ecosystem and act as sources as well as sink of CO<sub>2</sub> (Jandl et al., 2007; Tesfaye et al., 2018)

The interaction among the three land use/ cover classes illustrated that mean CS of natural forest was significantly different from cultivated and grazing lands ( $p = 0.04$ , &  $P = 0.001$  respectively). But there was no significant mean difference between soils of grazing and cultivated lands (Table 3). This finding was consistent with the study by Solomon et al. (2018) which revealed that CS was highest in forestlands and lowest in cultivated lands. The study conducted in Chilimo, a dry Afromontana forest in Ethiopia, found out higher mean carbon stock in natural forest than any other land cover types (Tesfaye et al., 2018).

The higher soil organic carbon stock recorded in the dense forest was mainly because of the biomass inputs and low rate of litter decay. In contrast the report by Guo and Gifford (59) indicated that faster decomposition of grass roots and contribution of higher organic matter to soil exhibited higher soil organic carbon stock. This may be true in areas with conservation intervention (closure) in which free grazing was minimized (Terefe, 2020). However, in most grazing areas including Rib watershed the conversion of vegetation covers into grazing and cultivated lands had affected soil chemical properties; for instance increasing acidification and compactions in turn retarding vegetation growth and soil organic carbon accumulation.

The study of Girmay et al., (2012) also reported that alteration of dense forests to cultivated lands brought about 25% reduction in soil organic carbon. Because, forests play a vital role in the natural global carbon cycle by capturing atmospheric carbon through photosynthesis and convert it into forest biomass (Tesfaye et al., 2018).

Table 3 LSD post hoc Multiple Comparison test of Soil Properties among Land use/ covers

## Total Nitrogen (TN)

As the effects of land use/ cover changes, the lowest mean value of TN concentration was observed on the soils of cultivated (mean = 0.17%) compared to soils of natural forest (mean = 0.47%) and grazing lands (mean = 0.36%), Table 1. And also the distribution of TN showed variation among the study agro ecologies. Hence the average TN was 0.25% and 0.41% over the *Dega* and *High Dega* agro ecological zones respectively. This finding was in agreement with the study by Warra et al. (2015) in Kasso catchment of Bale Mountains. The interaction effects of factors test (Table 3) indicated that land use/ cover and agro ecology have statistically significant effect on TN ( $F = 5.046$ ,  $P = 0.015$  and  $F = 3.924$ ,  $P = 0.059$  respectively). As shown by the LSD multiple comparisons post hoc test of MANOVA (Table 3), the difference in TN concentration was statistically significant between the soils of natural forest & cultivated lands and between grazing & cultivated lands. Mulugeta (2004) stated that continuous cultivation and poor management practices coupled with rapid mineralization of organic substances and insufficient organic input application could result in lower TN in cultivated land soils.

## Available Phosphorous (Av.P)

The overall mean of Av.P were 1.07 ppm, 5.42 ppm and 3.88 ppm for cultivated, grazing and natural forest lands respectively. In similar findings higher Av.P content was also observed on cultivated fields than forests (Lisanework & Michelsen, 1994; Bewket & Stroosnijder, 2003; Kebede & Raju, 2011). These studies suggested that tree in the forests extract more phosphorous than field crops. Furthermore, Lisanework & Michelsen, (1994) reported that the higher Av.P concentration of cultivated field than forest was that, a high proportion of Av.P pool is retained and immobilized by microbes in the litter layers of forests. Among the soils of different land use/ covers of the two agro ecological zones, cultivated land of the *Dega* agro ecology was with the highest (mean = 9.0 ppm) of Av.P in the watershed (Table 1). Despite of the variations in the mean value of Av.P of the three land use/ covers and among agro ecological zones, the interaction of all these factors were statistically insignificant ( $P > 0.05$ , Table 2).

## Exchangeable Cations and CEC

Variation in land use/ cover had greater impacts on exchangeable  $Mg^{2+}$ ,  $Ca^{2+}$ ,  $K^+$  and CEC than agro ecology (Table 2). The mean exchangeable cations capacity (CEC) of the soils in Rib watershed were 30.30, 16.84 and 15.31 mEq  $100\text{ g}^{-1}$  for natural forest, grazing and cultivated lands respectively (Table 1). The finding of this study was in agreement with Adugna & Abegaz, (2016) who identified the highest mean value of CEC in the soils of forestlands and lowest in cultivated lands in Northern Wollega. The lowest CEC content of cultivated land was thought to be resulted from less soil organic matter concentration, continuous cultivation, and removal of crop residue coupled with severe soil erosion (Sebhatleab, 2014 and Bezabih et al., 2016). As shown by multivariate test, all exchangeable cations ( $Mg^{2+}$ ,  $Ca^{2+}$ , and  $K^+$ ) of the soils were significantly ( $P = 0.00$ ) affected by land use/ cover types (Table 2). Thus LSD post hoc test showed that significant difference ( $P = 0.00$ ) in  $Ca^{2+}$  and  $Mg^+$  contents between the soils under natural forest & grazing land; between cultivated and natural forestlands (Table, 3). Significant mean difference ( $P = 0.00$ ) was also observed in  $K^+$  between natural forest & grazing, between cultivated & grazing lands. On the other hand the  $Na^+$  of the soil did not differ significantly ( $P > 0.05$ , Table 2) among land use/ covers and agro ecological zones. This suggests that absence of any effects that can be linked to land use/ cover changes on  $Na^+$  in the watershed. The Pearson's correlation coefficient matrix confirmed that OC and CEC have positive and strong correlation (Correlation coefficient = 0.624,  $P < 0.001$ ; Table 4).

Table 4  
Pearson's correlation matrix of soil properties

	PH	OC	CS	TN	Av.P	Clay	Silt	Sand	BD	Ca2+	Mg2+	Na+	K+	CEC
PH	1													
OC	.506**	1												
CS	.459*	.868*	1											
TN	.422*	.902**	.639*	1										
Av.P	-.171	-.039	.000	.001	1									
Clay	-.480**	-.779**	-.579**	-.780**	.047	1								
Silt	.134	.604**	.454*	.585**	.158	-.747**	1							
Sand	.576**	.697**	.514**	.710**	-.162	-.912**	.408*	1						
BD	-.301	-.676**	-.301	-.783**	.155	.679**	-.512**	-.616**	1					
Ca2+	.752**	.626**	.620**	.504**	-.196	-.569**	.329	.578**	-.220	1				
Mg2+	.841**	.518**	.534**	.425*	-.219	-.514**	.095	.647**	-.193	.829**	1			
Na+	-.100	-.004	.012	-.005	.017	.126	-.078	-.124	-.104	-.208	-.097	1		
K+	-.273	-.200	-.192	-.099	.074	.138	.098	-.251	.007	-.340	-.500**	-.078	1	
CEC	.846**	.591**	.599**	.484**	-.220	-.565**	.207	.648**	-.220	.939**	.968**	-.141	-.410*	1

\*\*Correlation is significant at the 0.01 level (2-tailed), \*Correlation is significant at the 0.05 level (2-tailed)

## Relationships between Selected Soil Properties

According to the Pearson's correlation coefficient, BD, OC, TN, silt and sand contents were negatively and significantly correlated with one another at  $P < 0.01$ . In contrast BD had positive and strong correlation with clay fraction of the soil ( $P < 0.01$ , Table 4). The statistical analysis of the study indicated that there was significant correlation between  $Na^+$  and any of other soil chemical properties in this study. In Rib watershed soil pH was positively and strongly associated ( $P < 0.01$ ) with sand fraction, OC,  $Mg^{2+}$ ,  $Ca^{2+}$  and CEC whereas had weak correlation with TN concentration.

This finding suggested that the soil with high basic cations are less acidic and vice-versa. According to Kisinyo et al. (2014) soil acidity is associated with deficiencies of Av. P, OC,  $Ca^{2+}$ ,  $Mg^{2+}$  and  $K^+$  in the soils. Under acidic soil conditions, there has been a gradual depletion of soil bases (Kidanemariam et al.,

2013). Relating to soil pH decline ( $\text{pH} < 5.5$ ) there is probability of high concentration of aluminum, manganese and deficiency of Av. P, total nitrogen, sulfur, and other nutrient to retard crop growth. The overall findings of this study imply that soils with high  $\text{Mg}^{2+}$  and CEC were less acidic than soils having low contents of the aforementioned cations (Tables 1 and 4). This finding was in harmony with other studies carried out in different parts of Ethiopia (Adugna & Abegaz, 2016; Amare et al., 2013; Asmamaw & Mohammed, 2013). In contrast soil pH was negatively and strongly correlated with clay fraction ( $P < 0.01$ ). In other words as clay fraction of the soil increased, the acidification are likely to rise. Moreover,  $\text{K}^{+}$  has no significant correlation with all other properties except its strong & negative association with  $\text{Mg}^{2+}$  (Table 4). From this finding it might be possible to suggest that  $\text{K}^{+}$  was available at minimum amount and insignificantly associated with all soil properties except CEC. Similarly there was no significant correlation between  $\text{Na}^{+}$  and other properties of the sampled soils in this study.

## Conclusion

The study focused on the influence of land use/ cover changes on soil physical and chemical properties in Rib watershed. The study results suggest that the conversion of natural forests into cultivation and grazing has impacts on major soil nutrients. Accordingly, a significant mean difference has been observed in soils physical and chemical properties between land use/ cover types and along agro ecological zones except Av.P and Na. The soils of cultivated lands were attributed to lowest soil OC, total N, Ca, Mg and CEC compared to natural forest and grazing lands (Alemu, 2015). These in turn have contributed to low soil pH and high soil compaction/ BD in cultivated and grazing lands in the two agro ecological zones. Such higher acidity of cultivated land than natural forest and grazing lands could lead to aluminum and manganese toxicity, microbial conversion of  $\text{NH}_4^+$  to nitrate will be slow, and crops with the ability to take up nitrate ( $\text{NO}_3^-$ ) will be negatively affected (Adugna and Abegaz, 2016).

The reduction in soil OC, TN and basic cations concentration may have negative consequence for soil fertility and long- term organic carbon stock. Science acidification and compaction were higher in cultivated lands of study watershed; the recommended urgent measures were reclamation of acid soils through liming, use of acid- tolerant crop varieties and integrated soil fertility management. Liming has played an important role in rising soil pH and enhances crop productivity (Agegnehu et al., 2019). Moreover, reducing soil compaction of cultivated lands might be achieved through increasing soil organic carbon and organic matter through biological methods.

Therefore, to increase concentration of soil nutrients in cultivated lands, an integrated implementation of land management through organic fertilizer (compost), decomposing of crop residue and crop rotation should be practiced by farmers with technical support of DAs. Generally soil nutrient degradation of the study watershed can be averted by implementing conservation based production systems with the integration of regional, local authority and community.

## Declarations

## Ethics approval and consent to participate

Ethics approval letter was obtained from UNISA CAES health REC committee to collect necessary data for my thesis. Among these soil data was collected in allowed time period by the university. The Ethics approval letter is attaché as supplementary material.

## Consent for publication

I Fentanesh H. Buruso (corresponding author) declare that I participated in the development of titled Influences of Land Use/ Cover Changes on Soil Properties in Rib Watershed, Ethiopia. I have read the final version and give my consent for the article to be published in Environmental Systems Research Journal.

## Availability of data and materials

Not applicable

## Competing interests

The authors declare that there is no conflict of interest. We are confidently enough to inform you that this research article is our original work and no one has involved in any activities related to proposal writing, data collection, analysis, and manuscript preparation. In addition we didn't get bursary from any company or organization

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## Authors' contributions

The corresponding author (Fentanesh H. Buruso) has involved in the development of proposal, data collection, analysis and article development. The second author (Dr. Zenebe Admasu) has contributed a lot by recommending appropriate analysis method editing the document.

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## Conflict of interest

The authors declare that there is no conflict of interest. We are confidently enough to inform you that this research article is our original work and no one has involved in any activities related to proposal writing, data collection, analysis, and manuscript preparation. In addition we didn't get bursary from any company or organization.

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## Figures

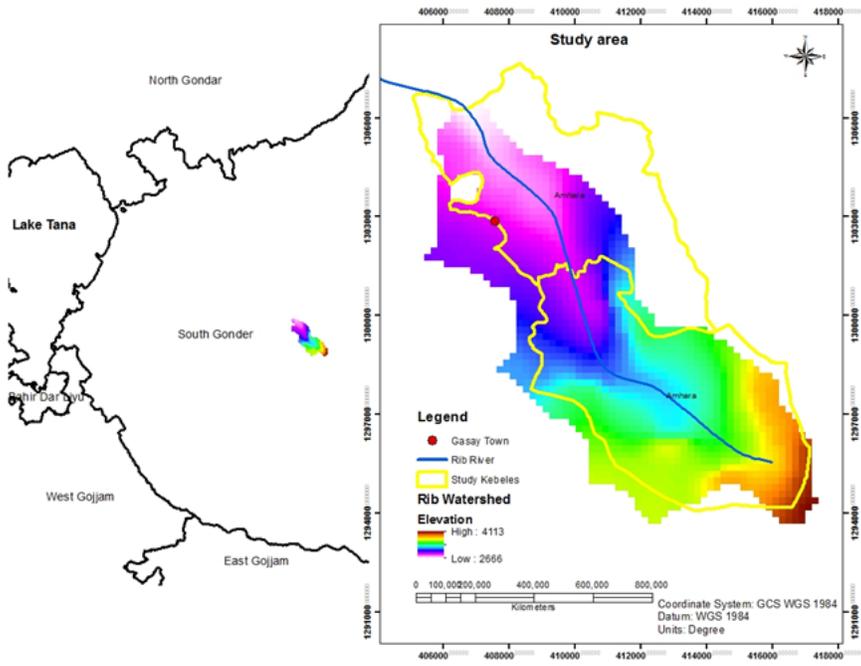


Figure 1

Location map of Study Area, Source: (CSA, 2007)