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Full Length Research Paper

Farmer's perception of soil and watershed degradation and the assessment of soil nutrients status under agroforestry systems in the Western Highlands of Cameroon: Case of Ako sub division

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The objective of this study was to assess farmers' perception regarding the activities which degrade the soil and watershed and to analyze soil nutrients status under different agroforestry systems. The aim of the study was to identify and promote locally-known agroforestry-based practices for soil and watershed conservation in the savannah highland area of Cameroon. Semi-structured questionnaires were administered to 120 farmers purposively selected from 10 villages in the Ako sub division characterized by favorable environmental conditions for agricultural production and the presence of agroforestry systems. The 10 villages were classified following a stratified sampling based on the degree of degradation of the soil and the watershed. Ako sub division was chosen because it is a priority zone for agricultural production and some of the practices are unsustainable leading to soil and watershed degradation. Soil samples were collected from each of the agroforestry systems found in the villages sampled and were analyze for soil nutrients status. The soil nutrients that were analyzed are: Organic matter by the wet oxidation method; exchangeable cations; cation exchange capacity; total nitrogen by Kjedahl method; available phosphorus by Bray II method and carbon to nitrogen ratio. The results showed that farmers perceived poor farming methods (33.10%) and deforestation (29.58%) as the main activities degrading the soil and the watershed. The standard values developed were used to compare the level of soil nutrients in each agroforestry system. The results of the soil analysis under each agroforestry system in Ako indicated that, soils were highly deficient in phosphorus in all the systems. The values were very low in all the systems ranging from 0.21 in palm agroforestry system to 0.46 in cocoa agroforestry system. Based on the level of organic matter and cation exchange capacity observed in the different farms, the agroforestry systems that should be promoted are: Coffee agroforestry systems, and cocoa agroforestry systems.

Key words: Cocoa and coffee-based agroforestry systems, soil properties, watershed, farmers' opinion.

INTRODUCTION

Watershed degradation marks the deterioration in hydrological behavior of river systems, which reduces the health and potential of land and water there by causing a water flow of inferior quality, quantity and timing. These processes, predominantly human induced, have been a major source of conflict among various land and water users (Leslie, 2014). In the case of soil erosion associated with inappropriate land management practices, lack of effective planning and implementation for soil conservation are responsible for accelerating degradation (Wollega, 2017). Intense land cultivation, uncontrolled grazing and deforestation are also common causes of degradation.

The western highlands of Cameroon are characterized by steep isolated slopes and hills which suffer very much from excessive runoff causing soil and water conservation problems. The degradation of the soils and watersheds in Ako has depleted soil and water resources over the years, which have intensified water scarcity and soil problems. Studies by Amawa (1999) revealed that water channels have narrowed and some stream sources have disappeared. This is caused mostly by the removal of the natural forest, tree cover, loss of vegetation and the transformation of the natural forests to farmland, which leads to removal of the topsoil, therefore, reducing the capacity of natural resources to contribute to food security and other benefits such as fodder and fuelwood (Tesfa and Sangharsh, 2016).

Ngala and Amawa (2014) observed that, changes in soil quality varied across sites, soil types, and production systems. Furthermore, soil quality is only one of the many variables influencing agricultural yields, which is, in turn, only one of many factors influencing food consumption, food availability, and farm income. However, studies have revealed that agrofoestry which is the integration of a tree component within the farming system, either on bounds or on boundaries (sequentially with crops) or intercropped in an agroforestry configuration type, can lead to increased land productivity, soil conservation and watershed protection, while diversifying the farming enterprise (Pardon et al., 2017; Atta-Krah et al., 2004). Agroforestry is considered a sustainable agricultural practice that combines primary production with other ecosystem services (ES) (Torralba et al., 2016) such as carbon sequestration, protection of (ground) water quality through reduction of nitrogen leaching, biodiversity conservation and mitigation of soil erosion (Cardinael et al., 2015a).

The agroforestry systems found in the study site were: Coffee agroforestry systems, cocoa agroforestry systems, trees on croplands and palm agroforestry systems. The potentials of these agroforestry systems have not yet been estimated. This study seeks to answer the following questions: (1) What are the farmer's perceptions on the activities degrading the watersheds and soil in Ako sub division? (2) How is the soil characteristics under agroforestry systems?

METHODOLOGY

Location of study area

The research was carried out in Ako Sub Division, a fragile agro ecological component of the Western Highlands of Cameroon situated between latitudes 6°45' and 7°0' to the North of the equator, and between longitudes 10°38' and 10°52' to the East of the Greenwich Meridian (Figure 1).

The typical primitive society here is the Mbembe tribe commonly called "Njaris". It has an estimated population of 8434 inhabitants. Their main occupation is farming, business and livestock rearing.

The area of Ako has an equatorial climate, which is hot and humid with two distinct seasons; dry (December to March) and rainy seasons (April to November). The average precipitation is between 2500 and 3000 mm and the mean annual temperature is between 28 and 30°C.

This region has a series of seasonal streams and a few streams which run throughout all the seasons and rivers that meander through the area and empty into river Donga, which is located to the north, separating Cameroon from Nigeria.

The relief of Ako can be described as undulating from Nkambe at an altitude of ~1250 m above sea level (asl), where there is a steep descent through the hills to Berabe at about 800 m asl. The area to the north towards Abuenshie is fairly flat (259 m), with the centre Buku and Buku-up having an altitude of about ± 350 m.

Data collection

Farmers' perceptions of the activities degrading the soil and watershed

In order to capture the farmers' perceptions on the activities degrading the soil and the watershed, household interviews were conducted using semi-structured questionnaires. Interviews were followed by a visit with the respondents to validate responses. To increase validity and reliability of data, multiple methods including focus groups (composed of elders, male and female farmers and community leaders) were carried out. The theme covered here was the activities which degrade the soil and the watershed. The questionnaires were composed of open and closed-ended questions including:

1. Issues concerning households and farm characteristics.
2. Perceptions of the activities degrading the soil and the watershed such as poor farming methods, deforestation, fuel wood and timber extraction, livestock rearing and bee farming.

Soil samples under different agroforestry systems

In order to determine soil properties in the existing agroforestry systems, nine representative soil samples were collected from sample farms at the depth of 0 to 15 cm along a transect in a ´Z´ manner. Nine (9) soil samples were taken from four different agroforestry systems with 2 samples each for cocoa, coffee, palm tree and trees on cropland based agroforestry system and one

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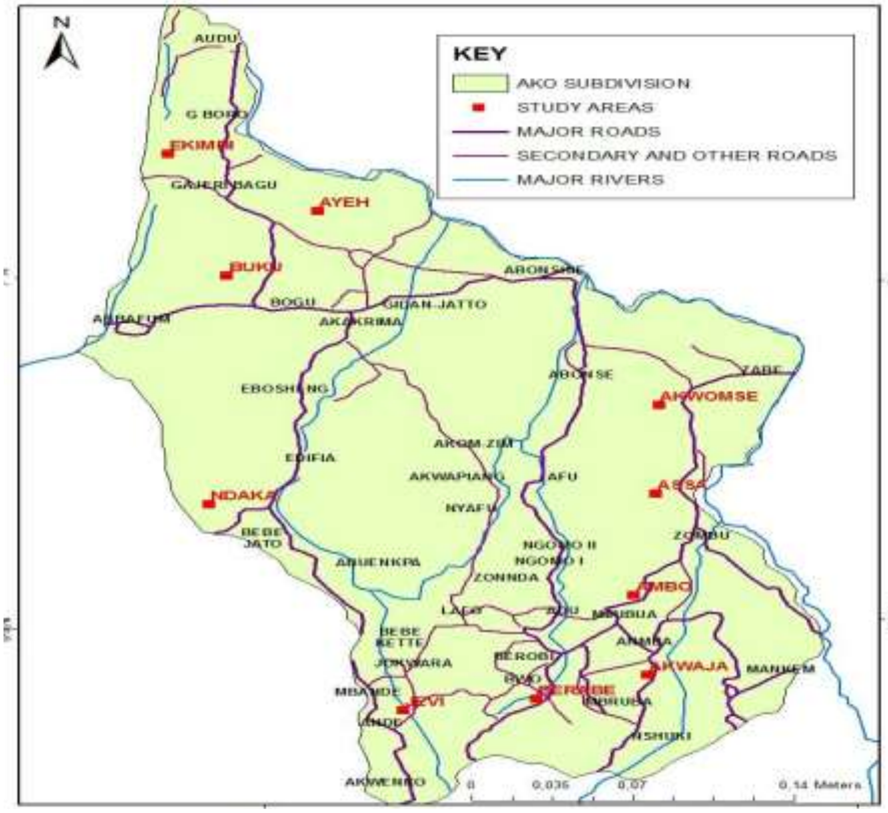

Figure 1. Map of Ako sub division and villages where samples were taken in the Western Highlands of Cameroon.

sample from a mono-cropping system. The soil samples were taken from localities with environments having similar features. Six different samples were collected from each geomorphic surface (at a depth of 0 to 15 cm) using a cutlass and thoroughly mixed and one representative composite sample of 2 kg each was taken and air - dried for 3 days and taken to the laboratory of the Department of Soil Science at the University of Dschang for analysis.

Laboratory analysis

Air dried samples were crushed to pass through a 2 mm sieve; coarse fragments larger than 2 mm were removed by dry sieving. Each soil sample was analyzed to determine the level of nutrients; total nitrogen, available phosphorus, cation exchange capacity (CEC), exchangeable bases, pH, texture, and soil organic matter contents using standards methods (Pauwels et al., 1992*)*. Soil organic carbon was estimated by wet oxidation with potassium dichromate and titration with ferrous sulfate (Walkey and black, 1934). Soil pH was measured in a 1: 2.5 soil solution ratio in 1 N Kcl (pH kcl) and distilled water (pH H2O). Exchangeable cations were determined by the complexiometric method. The concentrations of exchangeable (Na^+) and potassium (K^+) in the extract were obtained by flame photometry, and for calcium (Ca^{2+}) and magnesium (Mg^{2+}) by complexometry using a 0.002 M Na_2-EDTA solution. Total nitrogen was determined by the kjeldahl method wet digestion. Available Phosphorus was determined by Bray II method (Bray and Kurtz, 1945). Cation exchange capacity (CEC) was determined by percolating 2.5 g of soil with 100 mL of 1 N ammonium acetate buffered at pH 7, removing the excess with ethanol and displacing the absorb NH_4 ions with 1 N Kcl, determining the collected NH_4^+ ions by distillation and titration with 0.01 N sulfuric acid.

Data analysis

To get the percentages of the activities degrading the soil and watershed, Microsoft excel 2007 was used. The main activities were group and presented in the form of histograms based on their level of degradation. The critical soil values by Beernaert and Bitondo (1992) were used as basis to compare the soil samples analyzed from each agroforestry system. The soil nutrients were said to be high or low if it fell within the range of the values for low or high as shown on the Table 1.

RESULTS AND DISCUSSION

Farmers' perceptions of the activities degrading the soil in Ako

The results indicate that according to farmer's perception based on the degradation gradient, poor farming practices (33.10%); bush fires (23.39%) and overgrazing (26.34%) caused the highest damage to the soil (Figure 2). This is in line with the findings of Muia and Ndunda (2013) which indicated that the reduction of forest and

Table 1. Critical values of nutrients and soil properties.

Property	Critical value				
	Very low	**Low**	**Medium**	**High**	**Very high**
OM (%)	<1	1-2	2-4.2	4.2-6	>6
Total N (%)	< 0.5	0.5-1.25	1.25-2.25	2.25-3.0	>3.0
Ca (cmol(+)/kg)	<2	2-5	5-10	10-20	>20
Mg (cmol(+)/kg)	<0.5	0.5-1.5	1.5-3	3-8	>8
K (cmol(+)/kg)	<0.1	0.1-0.3	0.3-0.6	0.6-1.2	>1.2
Na (cmol(+)/kg)	<0.1	0.1-0.3	0.3-0.7	0.7-2.0	>2
Bray 2 – P (mg/kg)	<7	< 7-16	16-46	>46	
CEC (cmol(+)/kg)	0-20	21-40	41-60	61-80	81-100
C/N	**<10 = good, 10-14 = medium and >14 = poor**				
pH	<4 Acidic 5.3 - 6.0 moderately acid, 6.0-7.0 = slightly acid, 7.0-8.5 = moderately alkaline				

Adapted from Beernaert and Bitondo (1992).

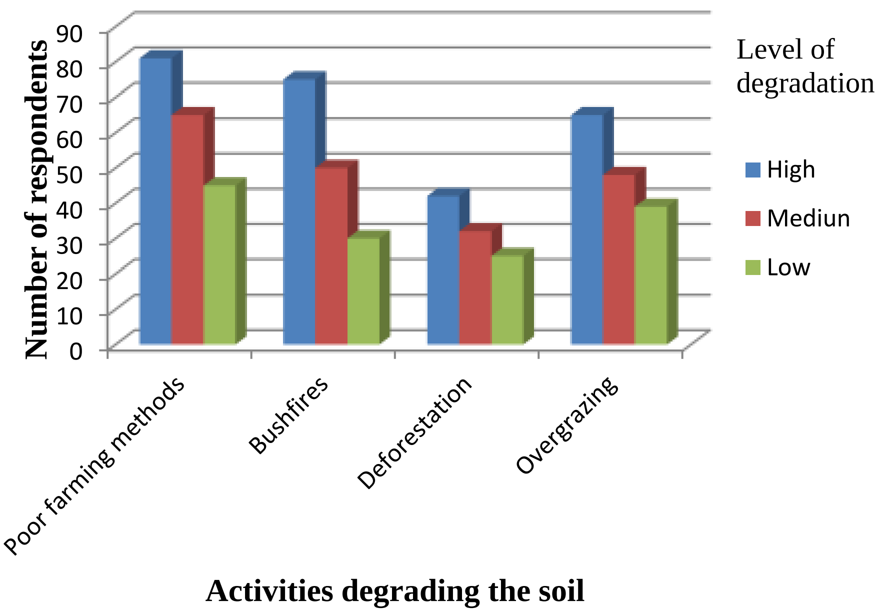

Figure 2. Farmers' perception of the activities degrading the soil - according to the site degradation gradient in Ako sub division, North West region Cameroon.

vegetation cover due to inappropriate farming methods and overgrazing leading to an increase in soil erosion and the reduction of soil fertility. Deforestation exposes the soil to water erosion (Muia and Ndunda, 2013) leading to a decline in soil fertility and loss of arable land. According to Wollega (2017), farmers perceived expansion of grazing land (7.4%) and lack of vegetation cover (22.2%) as the causes of soil erosion. Based on the findings by Tesfa and Sangharsh (2016) farmers reported improper soil and conservation practices (64.1%), traditional farming practices (68.5%), free grazing (69.6%), over cultivation (82.6%), deforestation (82.6%) as serious causes of soil and land degradation.

Farmers' perceptions of the activities degrading the watershed

The results showed that deforestation (29.58%), bush fires (15.77%), and poor farming practices (16.70%), were considered by farmers as the main activities which degrade the watershed respective of the degradation gradients (Figure 3). This is in line with reports by Hayal *et al*. (2017) in Lake Ziwag which indicated that deforestation in the watershed (57%) caused soil erosion and siltation of the lake. According to Muriuki et al. (2005), farmers perceived the reduction in forests and vegetation cover due to poor farming methods as a factor

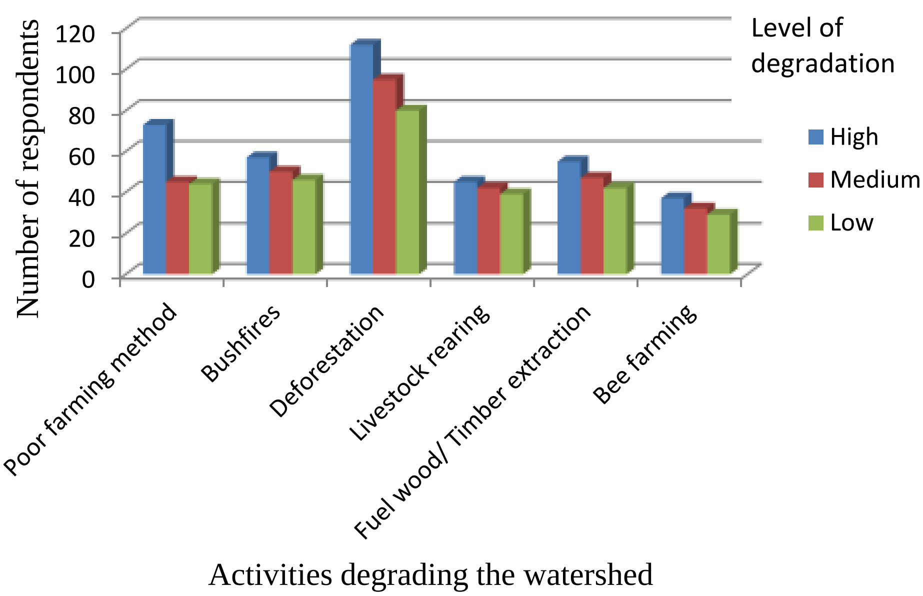

Figure 3. Farmers' perception of the activities degrading the watershed- according to the site degradation gradient in Ako sub division, North West region Cameroon.

degrading the watershed. These reports indicated that, livestock rearing (10.36%) and honeybee harvesting (9.14%) were less damageable to the watershed.

Farmers´ perceptions of soil fertility status in Ako

Farmers who thought the fertility of their farms was high constituted 40%. Twenty six percent of the farmers said their farms were moderately fertile, while 33.1% of them said their farms were low in nutrients. Only one farmer was of the opinion that the soil is deficient in nitrogen and crops perform poorly on such soils. Because farmers had the belief that their soils were fertile, they did not require additional nutrients to increase yields. Studies by Kabwe (2010) in Zambia showed that only 25% of farmers perceived their soils as good. This indicates that Ako farmers had a positive perception regarding the soils on which they cultivate.

This positive perception concerning soil fertility potentials was recorded across all age groups and communities. This observation is supported by previous studies of Lemenih et al. (2005) who estimated that, following the clearance of forest, the soil releases large quantities of nitrogen due to rapid mineralization of organic matter but that the soil organic matter reached a steady state after approximately 25 years and there after ceased to be a nitrogen source for agriculture. Karltun et al. (2011) observed that, decline in crop productivity is as a result of inadequate compensation of plants nutrients particularly nitrogen.

Forty percent of the farmers affirmed their soils were fertile because there was no significant drop in yields, while some (35%) of them thought their soils were less productive. Reports by Karltun et al. (2011), indicated that 92% of farmers in Beseku believed that the fertility of their soils was declining over time due to over cropping, and these farmers employ different methods to sustain soil fertility such as crop rotation and the used of compost (Figure 4). The latter group attributed this to phosphorus deficiency (darker green leaf, and purplish or red pigment). The deficiency of this element impairs most of the chemical processes that takes place in plants and thus results in poor crop yields.

Soil nutrients status under agroforestry systems in Ako

The results of the physical and chemical properties of the soils in Ako (Table 2) indicate that most of the samples are characterized as sandy, and the highest amounts of sand is observed in the trees on cropland and cocoa AFS. Sandy soils generally have good drainage and are easy to cultivate, but water and nutrient losses can be difficult to control. Mengel and Kirkby (1987) observed that, sites with high percentage of clay and silt are good for agriculture, as they provide good aeration and water and nutrient retention. These soils are low in the later parameters indicating low agronomic potentials.

The soils in all the agroforestry systems were moderately acidic. Average soil pH (H_2O) was 5.44 and 4.83 for pH (KCl) (Table 2). Generally, pH (KCl) ranged from 4.4 to 5.6 and was slightly lower than that of pH water that ranged from 5.2 to 5.9. The variation of ΔpH (pH (KCl) - pH (H_2O)) was negative throughout. This

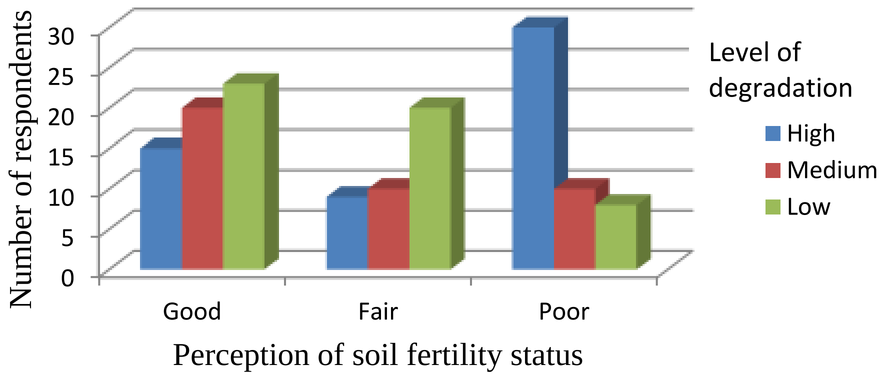

Figure 4. Farmers perception of soil fertility status.

indicates that the net charge on the exchange complex is negative, and thus exhibits cation exchange capacity properties. However, according to Yerima and Van Ranst (2005a), some tropical soils due to intensive rainfall and weathering are dominated by positive charges with anion exchange capacity predominant.

Percent of organic matter ranged from 2.99% in tree associations on cropland to 7.44% in coffee AFS with an average value of 2.4% in the entire area. The organic matter critical values varied from medium to high (Beernaert and Bitondo, 1992) (Table 2). In the tropics, soil organic matter is central to sustaining soil fertility on smallholder farms (Swift and Woomer, 1993; Woomer et al., 1994). Studies by Pardon et al. (2017) showed that the potential influence of trees on soil organic carbon was confirmed on the boundary planted fields with significantly higher soil organic carbon found near the middle-aged to mature tree rows.

In addition, soil organic carbon increases soil flora and fauna (associated with soil aggregation, improved infiltration of water and reduced soil erosion), complexes toxic Al and manganese (Mn) ions (leading to better rooting), increases the buffering capacity on low-activity clay soils, and increases water-holding capacity (Woomer et al., 1994). Continuous cropping, with its associated tillage practices, provokes an initial rapid decline in soil organic matter, which then stabilizes at a low level (Woomer et al., 1994). The highest percentages of organic matter were found in Coffee agroforestry systems and low organic matter contents were observed in monocropped systems where sand was in high concentration. This is associated with high mineralization of organic matter in sandy soils and higher organic matter in clay soils due to organic matter - clay complexes (Yerima and Van Ranst, 2005b). The low organic matter contents observed in monocropped system is due to continuous tillage which increases the mineralization of organic matter. Limited tillage reduces organic matter mineralization as was observed in coffee and cocoa agroforestry systems with values of organic matter ranging from high to very high (4.64 to 7.44).

Total nitrogen ranged from 0.1 in palm agroforestry systems to 0.22% in cocoa agroforestry systems (Table 2). From the critical values by Beernaert and Bitondo (1992) (Table 2), total nitrogen is very low (< 5). Nitrogen is highly mobile and easily lost. This necessitates that trees which contain nitrogen should be incorporated in farms to maintain the production of crops in the areas that are already vulnerable given that they are dominated by the sandy fraction. The percentage of total nitrogen ranges from 0.14 in palm to 0.17% in coffee agroforestry systems; this implies a long-term nitrogen deficiency which is manifested by low yields and less productive soils. In addition, the deficiency of nutrients like phosphorus could alter the recycling and the availability of nitrogen to farmlands

The C/N ratio varies from 10.02 in monocropped systems to 25.86 in cocoa agroforestry systems. This indicates that the soils range from good, to medium and poor in the agroforestry systems. Despite the fact that the soil are rich in organic matter, the very high C/N ratio witnessed in some areas indicate difficulties in mineralization.

Available phosphorus is associated with organic matter. It ranged from a lowest value of 0.18 in coffee agroforestry systems to low in trees on cropland to 0.56 mg/kg in cocoa agroforestry systems. Available phosphorus concentrations lower than 16 mg/kg in soils are considered low to ensure adequate phosphorus supply to most plants (Landon, 1991). The availability of phosphorus might also be limited due to the nature of the parent material that is generally granitic (Kometa, 2013), and high phosphorus sorption (Yerima and Van Ranst, 2005a). Available phosphorus is low indicating that the amount of phosphorus in farms in Ako is very low. Soils from palms agroforestry system, trees on cropland, palms agroforestry system and cocoa agroforestry systems have pH_{water} values less than 5.5. Below this pH, Al-solubility increases and phosphorus is fixed by iron and aluminium. Also at pH_{water} values less than 5.3, solubility of Mn increases and can lead to toxicity in plants (palms agroforestry system and monocropping). Therefore,

Table 2. Physico - chemical analysis of soil samples taken across different agroforestry systems in Ako.

AFS	Coffee AFS		Palm AFS		Trees on cropland		Monocropped	Cocoa AFS	
Sand (%)	58	52	49	39	49	73	59	41	68
Silt (%)	12	28	22	30	24	8	18	39	18
Clay (%)	29	19	27	30	25	17	23	19	13
pH_{water}	5.6	5.6	5.3	5.2	5.3	5.2	5.2	5.6	5.9
pH_{KCl}	4.9	5.0	4.6	4.6	4.6	4.6	4.6	5.1	5.6
Organic matter (%)	3.24	7.44	3.37	6.17	2.99	2.99	2.86	4.64	3.62
Nitrogen (%)	0.13	0.22	0.16	0.14	0.17	0.16	0.17	0.16	0.17
C/N ratio	14.92	19.56	12.19	25.87	10.10	10.90	10.02	16.36	12.51
Ca^{++} cmol(+)/kg	0.88	0.60	0.36	0.20	0.76	1.28	0.20	0.56	1.28
Mg^{++} cmol(+)/kg	1.92	3.00	2.52	0.20	1.88	3.20	1.00	3.12	5.92
K^{+} cmol(+)/kg	0.20	0.30	0.10	0.10	0.30	0.11	0.13	0.02	0.21
Na^{+} cmol(+)/kg	0.01	0.01	0.02	0.02	0.02	0.04	0.05	0.03	0.01
CEC cmol(+)/kg	19.20	25.04	20	22.4	18.16	17.60	16.56	21.20	20.88
Base saturation					**16.78**				
Bray II Phosphorus (mg/kg)	0.18	0.34	0.22	0.20	0.18	0.20	0.14	0.36	0.56

AFS = Agroforestry system.

phosphorus deficiency is a limitation to crop production in Ako. Phosphorus deficiency affects the growth of crops by interrupting with the internal transfer of energy needed to maintain plants metabolic activities (Krupnik and Jenkins, 2006).

Calcium and magnesium dominate the exchange complex but their concentrations were low ranging from 0.20 cmol (+)/kg in the palm AFS to 0.88 cmol (+)/kg in coffee agroforestry systems, for calcium (with a variance of 0.169) and 0. 20 cmol (+)/kg in palm agroforestry system to 1.28 cmol (+)/kg in cocoa agroforestry systems. According to Landon (1991), deficiencies of calcium are normal in soils with pH ≤ 5.5, which have been obtained in most sites of this study. Continous cultivation without returning residues to soil depletes this nutrient. Major sources of magnesium in soils include amphiboles, olivine, pyroxene, dolomites and phyllosilicate clay minerals (Todd, 1980). The low values of magnesium in the soils of the study area indicate that the aforementioned minerals are not present in substantial amounts.

The cation exchange capacity (CEC) of the soil according to the critical values of soil nutrients varied from very low-to-medium, ranging from 18.16 cmol (+)/kg in cocoa to 25.04 cmol (+)/kg in coffee agroforestry systems with a standard deviation of 2.62. A high CEC in these highly weathered soils indicates high levels of organic matter in these soils and these systems should be maintained.

Conclusion

Various activities such as deforestation (29.58%), poor farming methods (16.70%), bushfires (15.77%), and fuel wood/timber extraction (14.84%) were reported by the respondents as the activities degrading the watersheds; while deforestation was highly perceived as the main activity. The surface soils were slightly acidic in all the agroforestry systems with an average pH (H_2O) of 5.4 and 4.8 for pH (KCl). The organic matter contents varied from moderate to very high ranging from 2.99 in trees on cropland to 7.44% in coffee agroforestry systems. All the soils were highly deficient in phosphorus with values ranging from poor in coffee agroforestry system to very poor in cocoa agroforestry systems. The nutrient balance is extremely low most probably attributed to farming practices carried out in this area. Based on the level of organic matter, soils from coffee agroforestry system and cocoa agroforestry system with limited tillage had high CEC values associated with high organic matter contents and these agroforestry systems should thus be maintained.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Characterization of soils under major land uses in Chencha District, South Ethiopia

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Assessing land use induced changes in soil properties is essential for addressing the issues of land use planning and sustainable land productivity in highlands of Ethiopia. The surface and profile soil samples were collected from forest (FL) cultivated (CL) and grass/pasture lands (GL) in Doko Yoyira (DY), Aiezo Tula (AT) and Gendona Gembela (GG) in Chencha district, Gamo-Gofa zone in May 2014, which aims to assess different soil physicochemical properties. At surface layer of 0-20 cm, the results did not show any significant difference (*$P<0.05$*) for land uses and sites. However, differences were noticed for land uses and sites in terms of certain soil characteristics determined on soil profile basis. The cultivated soils contained less soil organic carbon and total nitrogen compared to forest and grasslands. Hence, forest and grassland systems could maintain organic carbon and nitrogen stocks in the soils. The findings have implications for developing sound land use policy to combat on ongoing soil degradation in the area.

Key words: Land use, soil physicochemical, profile, surface.

INTRODUCTION

Ethiopia's economy is chiefly agricultural with more than 80% of the country's population employed in this sector. This is constrained by the deteriorating natural resource base, especially in the highlands where 80% of the population lives (Abera and Belachew, 2011). Soil degradation in the form of plant nutrient depletion is the major agro-ecosystem problem in these areas. Previous studies showed that negative nutrient balances mainly carbon, nitrogen and phosphorus indicating that soil is already mined (Lemenih, 2004).

Rapid increase in Ethiopia population demands more production of food, fodder, fiber and fuel from the land. To meet these needs, vast tracts of land are being put under intensive cropping, and large areas of grasslands are being overgrazed and degraded in highlands of Ethiopia. Furthermore, widespread poor agricultural activities, including intensive tillage, complete removal of crop residues, low levels of fertilizer application, lack of appropriate soil conservation measures and cropping practice are also contributing factors (Haile et al., 2014).

Agricultural activities change the soil chemical, physical, and biological properties, and play the major

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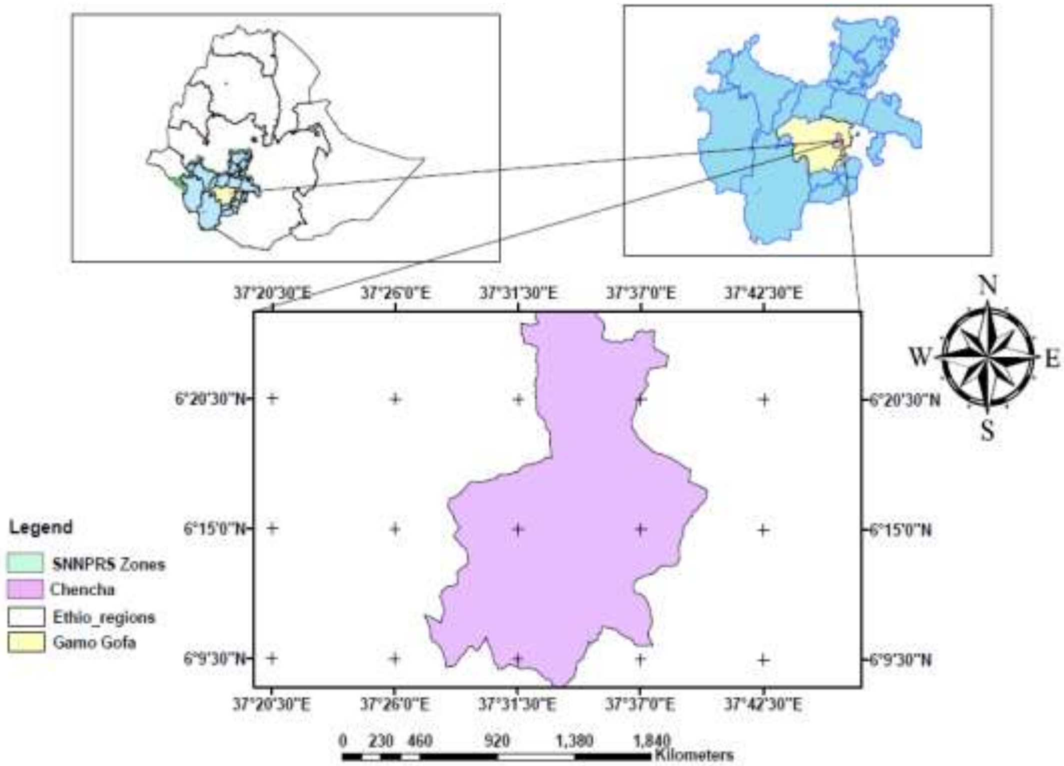

Figure 1. Map of the study area.

role for soil degradation mainly due to soil fertility decline as a result of lack of nutrient inputs. Soil resources degradation resulting from different causes threatens the long-term productivity. Nowadays, soil degradation reduces yield significantly. As a result, the communities are faced with challenges which affects all spheres of social, economic and political life of the population. It is one of the major challenges to development and food security of the country (Kassa et al., 2013). The goal of land manager should be to maintain nutrient levels in the range desirable for optimal plant growth but low enough to avoid environmental contamination (Erkossa and Teklewold, 2009).

In permanent agricultural systems, soil fertility is maintained through application of manure, other organic materials, inorganic fertilizers, lime and the inclusion of legumes in the cropping systems, or combination of these. In many parts of the world, the availability, use and profitability of inorganic fertilizers have been low whereas there has been intensification in land-use and expansion of crop cultivation to marginal soils. As a result, soil fertility has declined and it is perceived to be widespread, particularly in Sub-Saharan Africa including Ethiopia (Abera and Belachew, 2011).

Management of the fertility of soils and their dynamics due to land use changes to preserve soils for the next generation and for their most effective use is essential to understand their nature and properties. In Gamo Gofa zone currently, information is lacking for farmers and extension workers on soil fertility status and nutrient management particularly in Chencha district.

The study aims to characterize the soil physicochemical properties under different land uses, landscapes for optimum production using the major soils to come up with the data for researchers and development workers and the interpretations can be applied for decision-making processes such as soil-plant management planning in agro-ecological conditions which is paramount importance for sustained production, and thereby improving the livelihood of small scale farmers and emerging investors on agriculture in the area.

MATERIALS AND METHODS

Description of the study area

This study was conducted in Chencha district, at 37 km north of Arba Minch town, in three sites namely Doko Yoyira (DY), Aiezo Tula (AT) and Gendona Gembela (GG) in Gamo-Gofa zone, Southern Ethiopia. Selected sites are located 15 km northwest, 15 km north and 5 km east away, respectively for Doko Yoyira, Aiezo Tula and Gendona Gembela (henceforth referred to as the DY, AT and GG, respectively) sites from district town, at 491 km south of Addis Ababa (Figure 1).Chencha district is located between 1300 m and 3950 masl and between 37° 29' 57" east to 37° 39' 36" west

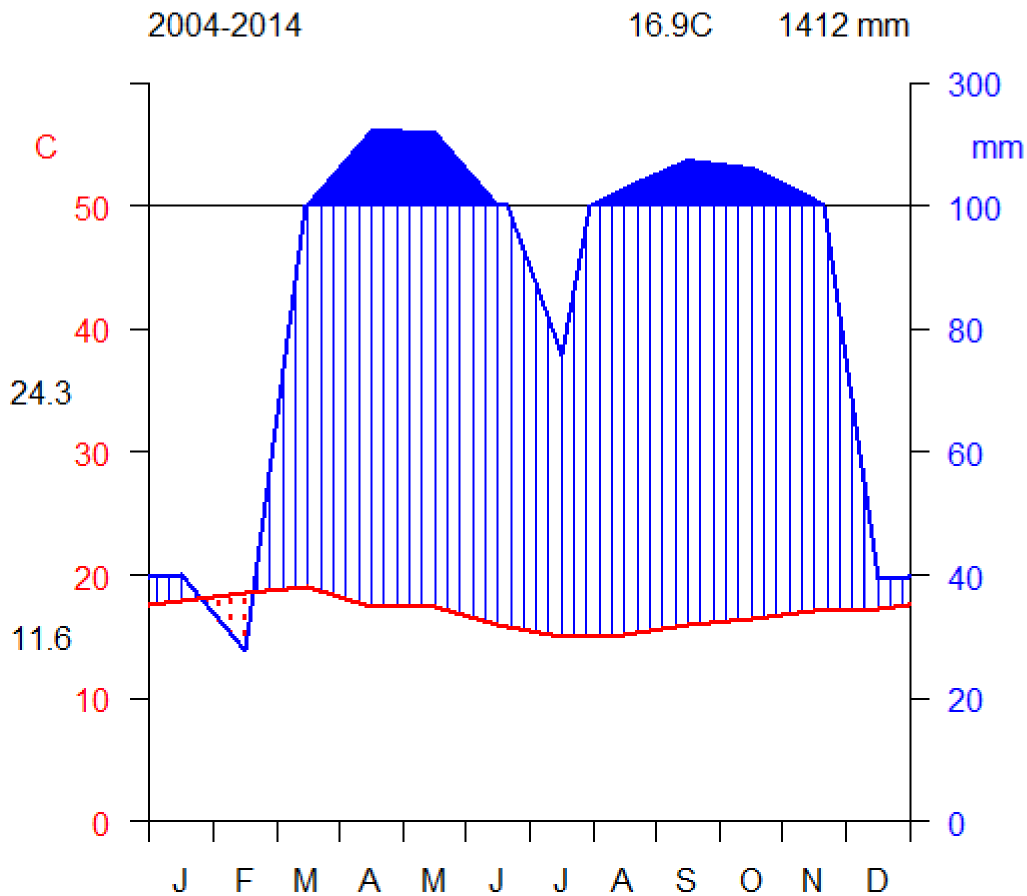

Figure 2. Ten years climatic diagram for Chencha district (taken from nearby Dorze Meteorology station, Red= deficit of precipitation, Blue=excess of precipitation (NMA, 2015).

and between 6° 8' 55" north and 6° 25'30" south.

Climate and soil resources

The rainfall regime of Chencha district is bimodal. The first round of rain occurs between March to April. The second round of rain occurs from June to August. The annual rainfall distribution in the district varies between 27 to 1412 mm (NMA, 2015). The minimum temperature in the district varies between 12 to 14°C, while the maximum temperature is in the range 20 to 24°C (Figure 2). The soils of the district are primarily clay or clay loams which have evolved from volcanic rocks (basalt) and volcanic tuff in the higher altitudes of the study area. The principal soil types are Cambisols and Nitosols (FAO, 1990).

Soil collection and analysis

Three households were selected with adjacent land uses (FL, CL and open GL) on the same soil types. For the purpose of this study, the three households were considered as replications, whereas the three land use types were considered as treatment. Barley and wheat are the two small sized seed annual crops that need intensive land preparation. Farmers have been applying inorganic fertilizer like urea and Diammonium phosphate (DAP). Organic fertilizers like compost and manure are more largely used for cereal crop production than inorganic fertilizers. Enset, apple crops are perennial crops often sole planted around their homestead. This land use is located closed to homestead, hence it received large amount of fresh manure and household wastes (Personal communication).

Nine soil profiles (three land uses x six soil depths replication) were dug and sampled in the FL, CL, and GLs with dimension of 2 m x 2 m x 2 m. Soil samples were collected from six soil depths: 0 to 2 m based on horizontal color differences in lower soil horizons under each land uses. In addition, three replications of surface soil (0-20 cm soil depth) from CL, FL and GL from higher, medium and lower slops using soil auger were sampled following hexagonal design at six points.

For each land uses, surface soil samples were sent for chemical analysis. Only nine composite surface and forty eight soil profile samples were used for chemical analysis. In addition from similar undisturbed soil samples, soil core samples were collected opposite to each pit for determination of soil bulk density and moisture contents. Thereafter, intact soil samples were collected with a manual core sampler of 10 cm height and 7.2 cm diameter, from each land use practice for soil moisture and bulk density determination. Soil-water content was determined by standard procedures described for gravimeter, with oven drying to a constant weight at 105°C for 24 h. Approximately, 1 kg of sample from each soil depth were collected and sent to laboratory then air-dried at

Table 1. Mean values for selected soil physical properties at three sites on surface soil (at 0-20cm) by land uses.

Soil properties	FL	CL	GL
WHC%	15^a	26^a	11^a
Db (g/cm^3)	0.7^a	0.7^a	0.9^a
SP (%)	73^a	74^a	65^a
Cl (%)	27^a	58^b	43^b
Si (%)	13^a	20^a	16^a
Sa (%)	60^a	23^b	41^b
TC	Cl	Cl	Cl

FL= forest land, CL= cultivated land, GL=grazing land, WHC%= % water holding capacity, Cl=Clay, Si=Silt, Sa=Sand, TC=Textural class, Scl=Sandy clay loam, Clo=clay loam, Sc=Sandy clay, Db=soil bulk density, SP=soil porosity. In each line, different letters show significant differences according to least significant differences test (LSDs) at P<0.05.

room temperature, crushed, homogenized, and passed through a 2 mm sieve before laboratory analysis. Particle size distribution was measured by the standard Bouyoucos (1962) hydrometer method (Andres et al., 2014). Water holding capacity was determined by the method (Wilke, 2005).

The amount of pore space or porosity of the soil is calculated according to the following equation:

Bulk density (Db) = mass of dry soil / total volume of soil and air (g/cm3). Particle density (Dp) = mass of dry soil / volume of soil particles only (air removed) (g/cm3):

$$Porosity = 1 - \frac{Db}{Dp} * 100 \quad (1)$$

Db was calculated by dividing the weight of oven-dried soil with the volume of the core. Db of land uses were conducted at Arba Minch University, Civil Engineering Soil Laboratory. Total nitrogen content was determined following the Kjeldahl method (Okalebo et al., 1993). The available phosphorus (Av. P) content of the soil was analyzed using 0.5 M sodium bicarbonate extraction solution (pH=8.5) following Olsen method (Okalebo et al., 1993). The organic carbon determination was made following the wet oxidation method (Walkley and Black, 1934). The sieved and stored samples were analyzed for pH in 1:2.5 soils to water ratio using the pH meter. Electrical conductivity (Ec) was measured in water as soil to water ratio of 1:5. Multiplying organic matter by 0.58 was used to estimate organic carbon (Perie and Ouimet, 2007). Cation exchange capacity (CEC) was determined using Chapman method (Reak et al., 1990). Amounts of Ca^{2+} and Mg^{2+} in the leachate were analyzed by atomic absorption spectrophotometer. K^+ and Na^+ were analyzed by flame photometer. Composite samples were sent for physico-chemical analysis at JIJE Analytical Testing Service Laboratory, Ethiopia.

Statistical analysis

All data were statistically analyzed using the Analysis of Variance (ANOVA) procedures and also the general linear model (GLM) procedure of SAS 6.12. Means separation was done using least significant difference (LSD) (SAS Institute, 1998).

RESULTS AND DISCUSSION

Impact of land use on soil properties of surface soil

Physical properties of soils of the sites (DY, AT and GG) sampled from surface *soils* (0-20 cm) are presented by land uses. Physical soil parameters: water holding capacity (WHC %), Db, soil porosity (SP) and soil texture (ST), did not show any statistically significant difference among land uses (Table 1). The results also indicated that chemical properties; pH, CEC, available K, TN, OC and C: N did not show significant differences among land uses at 0 to 20 cm soil depth (Table 2). Except soil clay contents, sand and textural classes at AT and GG at GG sites results showed that land use changes and their associated management practices could not cause significant changes in soil physical parameters under both land uses in lower soil horizons (Table 3).

Impact of land use on soil chemical properties

Doko Yoyira site

Results showed that land use changes and their associated management caused significant changes on soil Ec, pH, Av. K and P, Na, Ca, Mg, OC, TN and C: N ratio. However, land use changes did not show effect on soil CEC (Table 4). Ec of the site rated as very low under for both cultivated forest and grazing land use systems might be due to excessive leaching of exchangeable bases.

The mean value pH of FL was lower (16.7%) than CL and GL. Numerically, CL and FL had lower CEC in comparison to GL by 2.72 and 18.97% in that order. Furthermore, FL showed the slightly lower CEC in both sampled land use which was rated as medium in the soils. The reason might be due to medium organic matter

Table 2. Mean values of selected soil chemical properties of surface soil (0-20cm soil depth) by land uses.

Soil properties	FL	CL	GL
Ec (dS/m)	0.03[a]	0.04[a]	0.02[a]
pH $_{H2O}$ (1:2.5)	5.7[a]	6[a]	6[a]
CEC (cmol(+) /kg soil)	49[a]	26[b]	34[b]
Av. K (cmol (+)/kg soil)	1[a]	0.7[a]	0.5[b]
Ca (cmol (+)/kg soil)	20[b]	11[a]	8[a]
Mg (cmol (+)/kg soil)	8[ab]	5[a]	4[a]
Na (cmol (+)/kg soil)	0.2[a]	0.2[a]	0.1[a]
Av. P (ppm)	9[a]	12[a]	3[ab]
%OC	6[a]	1.6[b]	4[a]
%TN	0.5[a]	0.2[b]	0.3[a]
C:N	12[a]	9[b]	11[a]

Ec=Electrical conductivity, CEC=Cation exchange capacity, Av. K= Available potassium, OC= Organic carbon, TN=Total Nitrogen, C:N= Carbon to Nitrogen ratio. In each line, different letters show significant differences according to least significant differences test (LSDs) at P<0.05.

Table 3. Mean values of selected physical properties of soil profiles (0-200cm) of three sites by land uses.

Soil properties	DY			AT			GG		
	FL	CL	GL	FL	CL	GL	FL	CL	GL
Cl (%)	56[a]	56[a]	54[a]	61[a]	61[a]	43[b]	64[a]	78[b]	24[c]
Si (%)	27[b]	32[a]	14[b]	30[a]	23[b]	32[a]	33[b]	19[a]	45[b]
Sa (%)	17[a]	12[a]	14[a]	10[b]	17[b]	25[a]	3.5[a]	3.8[a]	32[b]
TC	Cl	Cl	Cl	Cl	Cl	Scl	Cl	Cl	Clo

FL= forest land, CL= cultivated land, GL=grazing land, Cl=Clay, Si=Silt, Sa=Sand, TC=Textural class, ns=non-significant=*significant, Scl=Sandy clay loam, Clo=clay loam, DY= Doko Yoyira, AT= AiezoTula, GG=Gendona Gembela. In each line, and for each district, different letters show significant differences according to least significant differences test (LSDs) at P<0.05.

Table 4. Some soil chemical properties of Doko Yoyira sampled from soil profiles (0-200 cm) across land uses.

Soil properties	FL	CL	GL
Ec (dS/m)	0.01[a]	0.02[b]	0.01[a]
pH H_2O (1:2.5)	5[b]	6[a]	6[a]
CEC (cmol(+) /Kg soil)	23[a]	27[a]	29[a]
Av. K (cmol(+) /Kg soil)	0.11[a]	0.75[b]	0.12[a]
Ca (cmol(+) /Kg soil)	2.5[a]	10[b]	6[c]
Mg (cmol(+) /Kg soil)	0.7[a]	6[b]	3[c]
Na (cmol(+) /Kg soil)	0.11[a]	0.2[b]	0.2[b]
Av. P (ppm)	5[a]	8[ab]	4[a]
%OC	1.6[a]	0.6[b]	1.1[b]
%TN	0.16[a]	0.08[b]	0.13[a]
C:N	9[a]	6.8[ab]	7.8[b]

Different letters show significant differences according to least significant differences test (LSDs) at P<0.05.

which could be affected by medium contribution of litter and collected for firewood from mixed *E. globules* and *Cupressus lusistanica* plantations. The Av. K showed significantly lower under FL and GL than CL by 85.33

and 84.00% respectively. The mean value of Av. K showed similar results with findings gotten by Limenih (2004) which was lower Av. K under mono *E. species* than CL but increasing in Av. K under mono *C. lusistanica* than CL. Findings made by Zewdie (2008) showed higher Av. K in contrast to the present study. This might be due to additions of organic and inorganic fertilizers under CL use systems.

Results depicted that Ca showed significant variation among land uses (Table 4). Ca content in soils was lower under FL (76.14%) and GLs (44.18%) than CLs (Table 4). The variation with Mg followed a similar pattern with that of Ca in the site. Mg content in soils of the site was lower under FL (87.11%) and GLs (45.19%) than CLs (FL<GL<CL). Mg under FLs was significantly lower (76%) than GLs ($P<0.05$). Ca content of the soil was low in the site. The reason might be excessive leaching, low contribution of litter fall for decomposition and high uptake of this nutrient by plant species which was confirmed with results reported by Limenih (2004) under *E. species* than CL. According to Landon (1991), value of Ca under FL was rated as low, Ca under CL was high; and Ca under GL was medium which was similar to report made by Ridvan and Orhan (2010). The mean value of Ca content under CL was similar with results reported by Niguse et al. (2012). The mean value of Ca contradicts the report gotten by Chimdi et al. (2012) in Western Ethiopia.

Mg content in the soil was also low in the site. This result might be due to little contribution of litter by mixed *E. species* into soil and excessive leaching caused lower Mg content under FLs. This result was comparable with findings made by Niguse et al. (2012) in Southwestern Ethiopia. Findings made by Yitbarek et al. (2013) on the other hand contradicts this result which showed an increasing order of Mg under FLs>GLs>CLs. As far as the rate of Mg is concerned, Landon (1991) stated that content of Mg in the soil was low under FL, medium under GL and high under CL use systems. These might be due to the application of organic and inorganic fertilizes than FL and GLs. Furthermore, the reason might be due to high leaching and low inputs of plant biomasses as leaf litter under FL and excessive GL by livestock under GLs. Results in Table 4 depicted that Na contents of soils showed significant variation among land use systems. Content of Na in the soil declined from GL, CL and FLs in order of 0.18, 0.16 and 0.11cmol/kg soil. Na contents of the soil demonstrated significant variation between FL and GLs; and the results also showed significant variation between FL and CLs.

According to Landon (1991), Na contents under these land uses were rated as deficient in the soil. The reason might be due to excessive leaching and soil erosion in the site. Na content in the site showed similar results with findings made by Niguse et al. (2012). The mean value of Av. P content did not show significant difference among the land use systems in the site. In both land uses, the value of available P was found to be in decreasing patterns of GL < FL < CLs.

The result of Av. P in the soil was low under FL and GLs but medium available P under CLs (Landon, 1991). The reason might be application of organic and inorganic fertilizers under CLs. This might also be due to excessive leaching, erosion and problem fixation of P in the site. The result of Av. P was similar with findings made by Kebede and Yamoah (2009). According to Landon (1991), soil organic matter (SOM) was very low both under FL and CLs. The reason might be due to low incorporation of organic matter (OM), root exudates and microbial decomposition and erosion hazard under these land systems. The trends of these results are in line with the findings gotten by Yitbarek et al. (2013), Chimdi et al. (2012) and Abera and Belachew (2011).

Average value of TN in the site did not show significant variation between CL and GLs (Table 4). The reason for the reduction of total N in the soil continuously CLs could be attributed to the rapid turnover (mineralization) of the organic substrates derived from crop residue (root biomass) whenever intensive cultivation are added. Soil TN in the site was very low under CLs; and low under FL and GLs. The reason might also be due to low application of OM, leaching and runoff hazard under both land use systems. The results showed comparable results with some of the findings made by Limenih (2004).

Narrower C: N ratios have sufficient N to supply the decomposing microorganisms and also to release N for plant use. Thus, both mean value under FL, GL and CLs showed sufficient N to supply the decomposing microorganisms and release N to soil plant use. Results in SOC status of the soils were influenced by different land use systems. The highest SOC was measured under FL (1.62) followed by GL (1.09) and CLs (0.64). Significant differences in TN content of soils were also observed among different land use systems. The mean value of soil TN under land uses showed lower under CL (50%) and GL use systems (19%) as compared to that of FLs. Significant differences in C:N ratio of soils also showed similar trends with SOC and TN among different land use systems. Therefore, results indicated that average C:N ratio of soil under land uses were lower under CL (28%) and GL use systems (17%) compared to that of FLs (Table 4). The result of C: N ratios under CL was rated as low. This might be due to higher decomposition OM which was facilitated by intensive cultivation. This is in agreement with findings made by Jesse et al. (2011) and Yitbarek et al. (2013) who reported that cultivation alters humus content and thus narrows the C: N ratio.

Aiezo Tula site (AT)

The effect of land use systems on Ec showed no significant difference among land uses. However, Ec

Table 5. Some soil chemical properties of Aiezo Tula sampled from soil profiles (0-200cm) across land uses.

Soil properties	FL	CL	GL
Ec (dS/m)	0.01a	0.01a	0.02b
pH H_2O (1:2.5)	6a	6a	6a
CEC (cmol(+) /Kg soil)	46a	19b	23b
Av. K (cmol(+) /Kg soil)	0.7a	0.4b	0.1a
Ca (cmol(+) /Kg soil)	12b	5a	8a
Mg (cmol(+) /Kg soil)	8a	3b	5ab
Na (cmol(+) /Kg soil)	0.2a	0.1b	0.2a
Av. P (ppm)	26a	13b	3.39b
%OC	5a	0.5b	0.9b
%TN	0.4a	0.1b	0.1b
C:N	13a	5b	6b

Different letters show significant differences according to least significant differences test (LSDs) at P<0.05.

under GLs was relatively higher than CL (50.0%) and FLs (50%) (Table 5). According to FAO (1976) cited in Ahmed et al. (2013), the mean value of Ec rated as very low might be due to excessive leaching of exchangeable bases. This result agrees with findings made by Kebede and Yamoah (2009).

The results depicted significant variation among land uses in CEC content of the soils (Table 5). Effect of land use systems on pH of the soils did not show significant difference among land uses. It was higher under FL than CL (4%) and uncontrolled GL (0.68%). According to Foth and Ellis (1997), pH of the soil both under land uses was rated as moderately acidic. This result is in line with the findings made by Itanna et al. (2011).

Results of CL showed lower value in CEC than FL (58%) and GLs (15%). The average value of CEC in the site did not show significant variation between CL and GLs, and showed in overall significant results among land use systems. The result might be due to the decreas in SOM under GL and CLs. Results showed CEC under FL was rated as very high in medium CEC under CL and GL use systems (Foth and Ellis, 1997). The mean values of CEC under GL and CL were in line with findings made by Chimdi et al. (2012). Furthermore, findings made by Limenih (2004) showed similar mean value of CEC under FLs.

The average value of Av. K, Na and Av. P also showed significant variation among land use systems (Table 5). Though the average values of Na were insignificant, the highest value in the soil was recorded under FL relative to CL and GL uses. According to Landon (1991), the value of Na content in the soil under both land uses were low. This might be due to low input of OM, leaching, erosion and excessive tillage under CLs. Similar increasing trends in the soil from CL to GL then to FLs uses were observed in Na contents in the soil. Similar results were also reported by Chimdi et al. (2012) and Yitbarek et al. (2013).

Av. K in the soil was rated as high under FLs. This might be due to high OM added to forest floor in the site. On the other hand, mean value of Av. K under GL was medium and low under CLs (Foth and Ellis, 1997; Landon 1991). The reason might be due to overgrazing, leaching and soil erosion under GLs. The value of Av. K under GL was similar to findings made by Chimdi et al. (2012). The value of Av. K under CL land showed comparable results with findings made by Abera and Belachew (2010).

The mean value of Av. P in the soil was rated as high under FL, medium under CL land and low under GL use systems (Landon, 1991). The reason for the deficiency of Av. P under GL might be due to additive effect of erosion, leaching and overgrazing by livestock. Addition of organic matter under FLs and application of organic and inorganic fertilizers under CL use systems might increase Av. P. The mean value of Av. P showed comparable results with findings made by Tilahun (2007) under GL and Yitbarek et al. (2013) under CLs. The present result in Av. P under FL was also comparable with findings reported by Yitbarek et al. (2013).

Results in ANOVA showed that mean value of Ca content in soils showed significant variation among land uses (Table 5). When the average value of Ca in the soil within the land uses was considered under CL and GLs but did not significantly vary with Ca content of soils. However, CL and GLs showed significant variation under FLs. The average value of Ca under FLs (11.9) showed the highest in comparisons to CL (5.2) and GLs (7.7). Mg content in the soils showed similar trend to that of Ca in sites under different land uses. According to Landon (1991), the mean value of Ca content in the soil was high under FL, medium under both CL and GLs. This might be due to Ca that is easily susceptible to leaching than other exhalable bases like Na and K. The present result is in line with the findings made by Tilahun (2007) and Yitbarek et al. (2013) under FLs. Rate of Ca content in this study showed similar results with findings made by Chimdi et al. (2012) under GLs, Kiflu and Beyene (2013) under CLs and Jamala and Oke (2013) under FL and CL uses.

ANOVA showed significant variation among land uses in Mg contents. When the average value of Mg in the soil within the land uses was considered under CL and GLs there was no significant variation in the site. However, CL and GLs present significantly vary with Mg content of the soils from FLs in the site. The average value of Mg under FLs (7.70) was very high in CL (3.0) and GLs (5.04) (Table 5). The mean value of Mg content in the soil was high under both land use systems due to Mg that might be resistant to leaching and the addition of animal manure under GL; input of leaf litter, root exudates under FLs and application of organic fertilizers (compost and animal manure) under CL use systems. Other studies showed similar results of Mg content under CLs (Belachew and Abera, 2010).

Table 6. Some soil physical properties of Gendona Gembela sampled from soil profiles (in pits) across land uses.

Soil property	FL	CL	GL
Ec (dS/m)	0.01[a]	0.01[a]	0.01[a]
pH H_2O (1:2.5)	6.0[a]	5.6[b]	6.3[c]
CEC (cmol(+) /Kg soil)	22[a]	22[a]	30.4[b]
Av. K (cmol(+) /Kg soil)	0.2[b]	0.6[a]	0.5[a]
Ca (cmol(+) /Kg soil)	8.1[a]	5.8[a]	16[b]
Mg (cmol(+) /Kg soil)	3.8[a]	4[a]	6.5[b]
Na (cmol(+) /Kg soil)	0.1[a]	0.1[a]	0.3[b]
Av. P (ppm)	6.5[a]	6.4[a]	19.2[b]
%OC	1.0[a]	0.5[b]	0.4[b]
%TN	0.1[a]	0.1[a]	0.05[b]
C:N	7.4[a]	3.8[b]	7.1[a]

Different letters show significant differences according to least significant differences test (LSDs) at P<0.05.

Results in SOC content showed significant variation among land use systems. SOC under FL depicted significant variation between CL and GLs. But, SOC did not show significant variation between CL and GLs. Average value of SOC in the site indicated from 5.05, 0.86 and 0.54 in decreasing order for CL <GL < FLs (Table 5). According to Landon (1991), SOC was rated as medium under FL, very low under CL and GL use systems. This result might be due to low input of organic matter, excessive tillage specific to CL and soil erosion. Findings made by Chimdi et al. (2012) illustrated similar results with present mean value of SOC under FL uses. Other studies, for example Belachew and Abera (2010), Tilahun (2007) and Haile et al. (2014) reported similar results in SOC under CL and GL use systems.

Similar trends were also observed in average value of TN with SOC among land uses. The average values of TN also showed insignificant difference between GL and CLs (Table 5). However, soil TN did not show significant variation between CL and GLs. Mean value in soil TN under CLs was lower than FL by 77% and GLs by 10%. Results of C: N ratios in the soil showed significant variation among land use systems. Although C:N ratio showed significant variation among sampled land uses, it did not show significant variation between CL and GLs. FLs (13.0) of the site showed the highest average value of C:N ratio of all in comparison to CL (5.5) and GLs (6.2).

The mean value of TN was rated as very low under CL, low under GL and medium under FL use systems (Landon, 1991). The reason might be due to erosion, leaching, and low input of organic matter (OM) under GL and CL than FL. Findings made by Tilahun (2007) showed similar results with mean value of TN under CL and GL uses. TN in the site indicated comparable results with report made by Amir et al. (2010) and Chimdi et al. (2012) under both land use systems. It might be due to decomposition of organic matter in the soil and released into the soil for the plant up take. This is similar to findings made by Tilahun (2007) under FL, CL and GL use systems.

Gendona Gembela Site (GG)

In this study, value of Ec showed insignificant variation among land use systems (Table 6). However, results in average values pH, CEC, Av. K, Ca, Mg, Na, Av. P, SOC, TN and C: N ratio showed significant variation among land use systems. The mean value of Ec was rated as very low under both land use systems (FAO, 1976 cited in Ahmed et al., 2013). This might be due to low exchangeable bases. The present results show similar results with findings made by Tilahun (2007) under similar land use systems. Other report by Ayalew and Beyene (2012) was comparable with this study with respect to Ec under CLs. The pH of the soil was lower under CL than FL and GLs by 7.2 and 11.2% in that order. Results showed that mean value of pH was moderately acidic under FL and CL uses (Landon, 1991). On the other hand, pH under GL was rated as slightly acidic. The reason might be due to the characteristics of litter inputs from *C. lusistanica.*

Consequently, litter inputs of the species are decreasing the pH of the soil. Leaching, erosion effect on exchangeable bases and application of N fertilizers for a long period of time under CLs might also cause the decline in pH of the soil. The results were comparable to findings reported by Yitbarek et al. (2013) in Ethiopia. Results in CEC indicated significant variation among land use systems. However, when average value in CEC between FL and GLs was considered, it did not show significant variations. GLs in GG showed significant variation between CL and FLs.

Results in CEC showed significant variation among land use systems. However, when average value in CEC between FL and GLs was considered, it did not show significant variations (Table 6). GLs in GG showed significant variation between CL and FLs. In this study, CEC under GLs showed increasing trends by 26 and 28% than FL and GLs .The mean value of CEC was rated as medium under CL and FLs, and high under GLs (Landon, 1991). The lower CEC under CL as compared to GL and FLs might be due to low input in OM (Limenih, 2004). The increase in CEC under GL might be due to the application of OM in terms of animal manure. This result is in line with the finding made by Yitbarek et al. (2013) under GLs, but CEC under FL and CL were higher than the present value of CEC.

Soil Av. K was found to be significantly affected by land uses, however within land use systems Av. K did not show significant variation between CL and GLs. It was found to be largest (0.61) in soils under CL uses whereas generally become small under FLs (0.15) and GL (0.49) (Table 6). According to Landon (1991), the mean value of Av. K was rated as low under FL, medium under CL and

GL use systems. The reason might be due to leaching of K under C. *lusistanica* plantation. The mean value of Av. K showed similar results with findings made by Yitbarek et al. (2013) and Belachew and Abera (2010) under CL and GL use systems. The results also showed similar results with findings made by Gebrelibanos and Hassen (2013) under both land use systems.

Results demonstrated that Ca contents under FL (8.07) and CLs (5.77) were significantly lower in Ca contents than under GLs (15.87) (Table 6). However, there was no variation with Ca between FL and CLs use systems. Value of Ca in the soil under GLs had clear significant variation from CL and FL use systems. According to Landon (1991), content of Ca in the soil was rated as high under GL and medium both for FL and CLs. The reason might be due to an input of animal manure, left over of crop residue and weed thrown from CL on GLs (personal observation). The reason might be due to intensive tillage and removal of crop resides under CLs which ultimately improved nutrient cycling of the soil through litter decomposition. Low input of Ca by *C. lusistanica* and Ca leaching under FLs (Limenih, 2004). This result was similar with several studies (Chimdi et al., 2012; Yitbarek et al., 2013; Asrat et al., 2014) under both land use systems.

Results in Mg content showed significant variation among land uses, whereas Mg did not show any significant difference between FL and CL uses (Table 6). Similar to Ca, average value of Mg also showed an increasing trend of GL>CL >FL by 6.50, 4.24 and 3.67 in that order. In this study, soil Na also showed similar trend with soil Ca and Mg contents under land uses which were indicated in the order of 0.25, 0.09 and 0.08. Under both land use systems, content of Mg in the soil was rated as high, whereas Na content in the soil was classified into low category under these land uses (Landon, 1991). The result showed that Mg was resistant to leaching than Na contents in the soil. The mean value of Mg and Na in the soil was similar with a study reported by Yitbarek et al. (2013) which also showed high Mg and low for Na under these land uses. In contrary, the same author had reported the land uses did not affect the contents of Mg and Na in the soil. Findings made by Asrat et al. (2014) on the other hand indicated similar results with Na content under CL use systems.

Av. P in the site showed the highest for GLs as compared to FL and CLs by 66% each (Table 6). No significant variation was observed in average value of Av. P within land use systems under CL and FLs. Land use systems had significant impacts on SOC and TN which showed trends of GL <CL < FLs. Within land use systems, no significant variations were observed between GL and FL systems in SOC; and the same trend was also seen between FL and CLs.

The Av. P in the site showed medium under FL and CL uses; and high under GL use in the site (Landon, 1991). Low amount of Av. P under FL and CL relative to GL might be due to high P fixation in the site. The mean value of Av. P under GL showed comparable results made by Yitbarek et al. (2013) and Haile et al. (2014). The result also showed similar findings with what was reported by Asrat et al. (2014) and Tilahun (2007) under CLs. Again, the mean value of Av. P illustrated similar results with a study reported by Chimdi et al. (2012) under FL use systems.

SOC under both land uses were rated as very low (Landon, 1991). These might be due to inherent property of the soil, OM removal in terms of erosion, crop uptake and crop residue under CLs. FLs especially C. *lusistanica* plantation was lower in SOC than other adjacent species of natural FLs (Limenih, 2004). Overgrazing might also affect OM under GL uses in the site. The present study goes well with findings reported by Haile et al. (2014) and Tilahun (2007) under both land use systems. Yitabarek et al. (2013) also showed similar results with the mean value of SOC under GL and CL uses (Table 6). The mean values of TN in the site were low under CL and FL uses; and very low GL use systems (Landon 1991). The reason might be due to excessive erosion, leaching, removal of OM in terms of crop residue, crop uptake of N and other processes in the site under CLs; and leaching and erosion under FL and GLs. Furthermore, this might be due to low decomposition of OM under FL and GLs which in turn stop N in the soil. These results were similar with findings gotten in the study of Yitbarek et al. (2013) and Chimdi et al. (2012) under FL and GL uses.

The C: N ratio of the soil was the highest for FLs (7.44) followed by GLs (7.11) and CLs (3.80) (Table 6). C: N ration of the soil in the site was lower. The reason might be decomposition is fast under CLs due to intensive tillage and removal of organic matter from agro-ecosystem by crop residue and animal manure for energy and livestock feeds. FL and GLs did not show impact on soil CN ratio in the site. However, there were clear significant variation between FL and CLs; and GL and CLs. The mean value of C: N ratios were too low under CL uses, consequently causing quick decomposition of OM. This might be due to excessive tillage that plants need N from soil than under FL and GL use systems. The mean value of C: N ratios was similar with the study conducted by Tilahun (2007) under FL and GL use systems. However, the trend showed similar results with studies reported by Chimdi et al. (2012) and Yitbarek et al. (2012) under CLs but the value was lower than the result gotten.

Conclusions

It is primarily the properties of surface soils that would indicate the effect of land use change of the study sites. The properties of lower soil horizons are not going to be changed over a short term cultivation practice; it is more of long term pedogenetic process than any anthropogenic factor.

Doko Yoyira site

Available potassium under forest lands and grazing lands were rated as medium, whereas sodium content under these lands uses were deficient in the soil. The result of available potassium in the soil was low under forest lands and grazing lands but medium available potassium under cultivated land use systems. Soil organic carbon both under forest and cultivated lands were very low. Soil total nitrogen in the site was very low in total nitrogen under cultivated lands; and low total nitrogen under forest and grazing lands.

Aiezo Tula site

Available potassium in the soil was rated high under forest land uses. On the other hand, mean value of available potassium was low under cultivated land uses. The value of sodium content in the soil was low under both land uses. The average value of available potassium in the soil was rated as high under forest lands, but low under grazing land use systems. The mean value of calcium content in the soil was rated as high under forest land and medium under both cultivated and grazing lands. The mean value magnesium content in the soil was high under both land use systems. The rate of soil organic carbon was classified as medium under forest land uses and very low under cultivated and grazing land use systems. The mean value of total nitrogen was rated as very low under cultivated lands, low under grazing lands. On the other hand, mean value of electrical conductivity was rated as very low under both land use systems.

Gendona Gembela site

The mean value of available potassium was demonstrated as low under forest lands, and medium under cultivated and grazing land uses. Content of calcium in the soil was rated as high under grazing lands and medium for both forest and cultivate land uses. Under both land use systems, content of magnesium in the soil was rated as high, whereas sodium content in the soil was classified into low category under these land uses.

The available potassium in the site had showed medium under forest and cultivated land uses; and high under grazing land uses. Low amount of available potassium under forest and cultivated were observed to be relative to grazing lands. The soil organic carbon under both land uses were rated as very low. The mean values of total nitrogen in the site were low under cultivated and forest land uses; and very low under grazing land use systems. Similar results in soil properties indicated that soil in the sites made up the same parent materials, and land uses had the same exposure of disturbances.

The low rates of soil properties in the sites have implications for soil degradation and serious impacts on soil production and productivity in the sites. The results also confirmed that there will be need to develop proper land use policy and sustainable soil management and cropping practices to combat ongoing soil degradation, and also improve soil fertility in the area. It is clear from the results that forest and grazing lands are relatively appropriate land use systems for improving soil properties as reflected by higher contents of sodium, organic carbon, and total nitrogen compared to cultivated lands.

To reverse the situations and to enhance sustainable agricultural production and land management there is an urgent need of appropriate land use policy and land use planning. Therefore, the following agronomic measures are recommended: minimizing frequent plowing, incorporation of crop residues, use of integrated soil nutrients management such as use of organic and inorganic fertilizers, planting legume as rotation crops and incorporation of nitrogen fixings fodder species with herbaceous species. In addition, intensifying widely adapted agroforestry systems such as legume tree species based around cultivated lands which could be an option for improving soil nutrient and carbon storage. Thus, long term effects of exotic tree species on soil degradation, soil test based for each crop responses and effect of erosion hazards on soil and moisture losses should be investigated in the future.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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