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Soil Nutrient Stock Evaluation under Different Land Use Types in the Smallholder Farming Systems of Jimma Zone, Ethiopia

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ABSTRACT
The threats of soil nutrient depletion and food insecurity due to unsustainable farming practices are the problems for most of developing countries including of Ethiopia. This investigation was conducted to determine the status of soil nutrient stock under different land use types in the smallholder farmers and to evaluate the relationship between N, P and K stocks, different soil parameters and land use types. Soil samples were collected from each land use types and tested in laboratory for bulk density, % sand, % silt, % clay, total N, total P and total K. Soil N, P and K stocks for the land use types were calculated through multiplying the concentration of N, P and K with their respective bulk density and sampling depth. Mean comparisons were carried out to soil bulk density, % sand, % silt, % clay, total N, total P and total K. One way ANOVA was used to determine N, P and K stocks significant difference ($p = 0.05$) under different land use types. Also, 2-tiled Pearson´s correlation coefficient was used to determine the relationship between soil nutrient stocks, soil parameters and land use types. Accordingly, the mean values of soil physico-chemical properties were varied among land use types but none significant difference ($p<0.05$) was observed for N, P and K stock. Because, soil nutrient management practices applied to each land use types are not adequate to improve soil nutrient stocks and compensate losses. There was a positive correlation between some soil physico-chemical properties, nutrient stocks and land use types. Therefore, to improve soil nutrient stocks and availability of nutrients for plants in order to achieve food security intensive soil nutrient management practice across land use types are compulsory.

Key words: Nutrient depletion, soil physico-chemical properties, N, P and K stock, land use types

INTRODUCTION
Soil nutrient stock is the reserve of N, P, K and other essential elements in the soil that can be available to plants during time scale of 5 to 10 years (Sanchez and Palm, 1996). Several studies conducted in Sub Sahara African (SSA) countries showing N, P and K socks have been declining. The major causes of nutrient stock depletions are less attention paid to the rural areas, land degradation, inadequate nutrient replenishment, late adoption of improved soil fertility management technologies, poor agronomic practices and lack of ample natural land resources management policies (Sanchez *et al.*, 1997; Stoorvogel and Smaling, 1990). Consequently, per capita food production is diminishing in the continent and thousands of peoples are depending on food aid (FAO, 2001).

Nutrient balance studies conducted in different parts of Ethiopia at various levels such as field, farm sections, farm, watershed, regional and national showing high N, P and K depletion is takes place in the smallholder farm (Elias *et al.*, 1998; Haileslassie *et al.*, 2005; Aticho, 2011). To overcome the problems of soil nutrient and ensure food security, Ethiopian Ministry of Agriculture and Rural Development (EoMARD) as well as some national and international nongovernmental organizations has been involved in different soil nutrient management activities through offering training, extension and rewarding early technology adopting farmers.

Resembling other Sub Sahara Africa (SSA) Ethiopian farmers are less aware to the existing problems as a result the acceptance levels of new soil nutrient management technologies is varying among farmers and locations (Braun *et al.*, 1997; Haileslassie *et al.*, 2005). Also, the introduced technologies such as rate mineral fertilizer (DAP and urea) and combination of mineral and organic fertilizer addition per unit of area are not supported with adequate field tests at national level (Kebebe *et al.*, 2007). Consequently, farmers are complaining on the response of fertilizer applied to crops because the same amount and types of fertilize applied on same land and crop at different growing season but, yield is decreasing through time. This is happened due to soil nutrient (N, P and K) stock depletion, soil toxicity (high H^+, Al^{3+} concentration) and rainfall variability (Elias, 2002). N, P and K nutrients are required by plants in higher concentrations than other elements. The imbalance in the supply of one of these nutrients compromise plant growth, affecting root development, cell division, crop quality, crop yield and resistance to disease and drought. In the study area N, P and K stock under different land use type is not studied. Therefore, this study was conducted to determine the status of soil nutrient stock under different land use types in the smallholder farmers and to evaluate the correlation between N, P and K stocks, different soil parameters and land use types.

MATERIALS AND METHODS

Description of the study area: The study was conducted in the Segno Gebeya Village (Kebele), Seka Chekoruisa District (Woreda), Jimma Zone, Southwestern Ethiopia. Which is 390 km away from Addis Ababa and 35 km from Jimma town. It has an elevation ranges from 1580-2560 m above sea level (m.a.s.l), mean annual rainfall 1592 mm and temperature 15°C (Aticho, 2011). The dominant soils are Nitisol and cambsoil (FAO, 1994).

A land survey conducted at Jimma Zone showing that land use of the study district are 45.3% arable, 6.1% pasture (communal), 25.8% forest and the remaining 22.8% is considered swampy and/or degraded (SEPJZG, 2006).

Integration of livestock with crop cultivation is the major agricultural activity in the area. Enset (*Enset ventricosum)*, Wheat (*Triticum* spp.), Oat (*Avena sativa*), Barley (*Hordeum vulgare*) and Tef (*Eragrostis tef*) are the major agricultural crops while animals like cow, ox, calf, sheep, goat, donkey, horse and mule. Lands are used for crop and grazing in rotation due to limited accesses of communal grazing land (Aticho, 2011; Aticho *et al.*, 2011). Livestock play key role in crop production (draught power, manure supply, transportation, income generation etc.) in the study area (Yisehak, 2008).

Data collection and analysis: Composite soil samples were collected from 15 cm depth from the following land use types; Enset (*Enset ventricosum*), Wheat (*Triticum* spp.), Oat (*Avena sativa*), Barley (*Hordeum vulgare*) and Tef (*Eragrostis tef*). Also, an undisturbed core samples were collected from each land use type to determine soil bulk density. The total numbers of soil samples collected for the analysis were fifteen (each land use type has three replications i.e., 5×3 = 15).

The collected soil samples were air dried, sieved by 2 mm sieve and analyzed by following standard laboratory procedures. Laboratory analysis was carried out in Hawassa University and research center. Soil texture was determined by Bouyoucos method (Jaiswal, 2003). Bulk density was determined by measuring the wet weight of each core and converting to dry mass equivalent per unit volume of soil using moisture data and the known volume of the cores (Klute, 1986). Total N was determined by Kjeldahl method (Houba *et al*., 1989). Both total P and K concentrations in the soil were extracted with fluoroboric acid digestion method and the stock of P and K in the solution were determined Atomic Absorption Spectroscopy. Finally, soil N, P and K stocks (kg ha^{-1}) were calculated according to Bond (2010).

Statistical analysis: All statistical analyses were carried out using SPSS version 16. Mean comparisons were carried out to the physico-chemical properties of soils under different land use types. One way analysis of variance (ANOVA) was employed to determine N, P and K stocks significant difference ($p = 0.05$) under different land use types. The 2-tiled Pearson's correlation coefficient was used to determine the relationship between soil nutrient stocks, soil parameters and land use types.

RESULTS AND DISCUSSION

Soil physico-chemical properties: The mean values of soil particle size distribution showed land used for Enset (*Enset ventricosum*) and Wheat (*Triticum* spp.) were mostly clay loam soil (Table 1). While, the lands use for Barley (*Hordeum vulgare*) and Tef (*Eragrostis tef*) were silt clay loam. Different land use types with the same soil texture found in the study area demonstrates land use types or changes have no effect on soil texture. But, the cause of difference or similarity in soil texture is due to similarity or difference in parent materials from which they developed.

The mean value of bulk density under Enset (*Enset ventricosum*), Wheat (*Triticum* spp.), Oat (*Avena sativa*), Barley (*Hordeum vulgare*) and Tef (*Eragrostis tef*) were 1.01±0.03, 1.25±0.11, 1.21±0.02, 1.23±0.11 and 1.27±0.05 g cm^{-3}, respectively (Table 1). This is agreed with the findings of Landon (1991), bulk density of clay loam and silt loam topsoil is ranges from 1.00-1.60 g cm^{-3} depending up on the management condition. That is why in this study soils of same texture has differences in bulk density. Increase in bulk density inhibits plants ability to exploit the available resources in the environment through restricting the root system. In the study area soil bulk density related problems were not observed thus it should be mentioned through the

Table 1: Mean value of selected soil physico-chemical properties in topsoil (0-15 cm) in different land use type

	Soil physico-chemical properties						
Land use types	% Sand	% Silt	% Clay	BD (g cm^{-3})	TN (%)	TP (mg kg^{-1})	TK (mg kg^{-1})
Enset (*Enset ventricosum*)	12.70±1.61	48.33±2.52	38.97±3.59	1.01±0.03	0.28±0.03	314.39±53.97	103.88±18.79
Wheat (*Triticum* spp.)	17.06±0.88	52.67±3.79	30.28±4.62	1.25±0.11	0.20±0.02	318.43±63.08	121.78±44.61
Oat (*Avena sativa*)	14.07±3.00	41.40±11.66	44.53±12.20	1.21±0.02	0.21±0.08	212.85±73.24	126.47±33.42
Barley (*Hordeum vulgare*)	13.07±3.52	48.57±6.08	38.37±9.40	1.23±0.11	0.19±0.01	207.20±48.81	103.64±48.81
Tef (*Eragrostis tef*)	18.40±2.51	47.67±7.51	33.93±5.37	1.27±0.05	0.24±0.02	288.27±88.90	133.12±28.62

±Values are Mean±SD, BD: Soil bulk density, TN: Total nitrogen, TP: Total phosphorous, TK: Total potassium

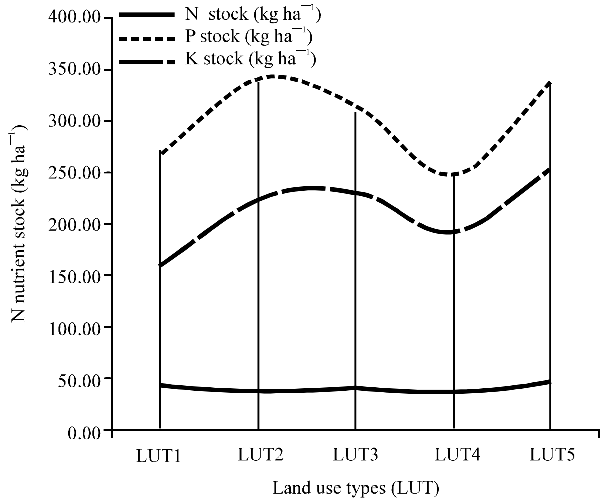

Fig. 1: Soil N, P and K stock under different land use types (LUTs). (LUT 1): Enset (*Enset ventricosum*), LUT 2: Wheat (*Triticum* spp.), LUT 3: Oat (*Avena sativa*), LUT 4: Barley (*Hordeum vulgare*), LUT 5: Tef (*Eragrostis tef*)

possible management practices like organic matter addition, crop rotation, fallowing and decreasing compaction caused by overgrazing.

When the mean values of bulk density compared with land use types the smaller value was observed under Enset (*Enset ventricosum*) crop. This is associated with the land used for Enset (*Ensete ventricosum*) plantation was not subjected to grazing and intensive mulching with organic materials for the whole years. The result of this study is agreed with the findings of Seneviratne *et al.* (2006) and Benjamin *et al.* (2007). But, other land use types were used both for grazing and crop production rotationally consequently, crop residues are removed from field through grazing, burning to clean land from weeds, bush growth and debris in order to facilitate cultivation then soil organic matter is depleted and bulk density under annual cropping system becoming higher than the perennial.

As illustrate in Table 1, the mean value of total N was relatively higher on lands used for Enset (*Ensete ventricosum*) and Tef (*Eragrostis tef*) than the other land use types. This result is agreed with the findings of Havlin *et al.* (2005). According to Landon (1991) rating the levels of N under Enset *(Enset ventricosum*) and Tef (*Eragrostis tef*) is medium while in Wheat (*Triticum* spp.), Oat (*Avena sativa*), Barley (*Hordeum vulgare*) and Tef (*Eragrostis tef*) low. This happened due to continuous mulching of Enset (*Ensete ventricosum*) garden with organic matter which is the potential source of soil N.

The mean value of total P was 314.39±53.97 in Enset (*Enset ventricosum*) and 318.43±63.08 under Wheat (*Triticum* spp.) which is comparatively higher than other land use types. Because of nutrient recycling through manure addition or litters fall. According to Barber (1995) rating the total P concentration in soils of the study site is found in the normal range. According to Havlin *et al.* (2005) rating the total K in the soils of the study area is very small. This happened due to, soil of the study area is highly weathered; absence of K based fertilizer addition and adsorbed in large quantity by plants next to N. Generally there was difference in soil physico-chemical properties under different land use types, which is agreed with Onweremadu (2007).

N, P and K stocks under different land use types: Total N, P and K (kg ha^{-1}) stock in the top 15 cm depth were varied for different land use types. When we compare the stock depletion more P and K losses were observed on the land that was used for Barley (*Hordeum vulgare*) production than others Enset (*Enset ventricosum*), Oat (*Avena sativa*), Tef (*Eragrostis tef*) and Wheat (*Triticum* spp.) (Fig. 1). Because, P and K removed with Barley (*Hordeum vulgare*) biomass was a bit higher than other crops. The stock of N was similar for all land use types due to its high demand by all crops for vegetative growth and loss caused by environmental condition (leaching due to high rain fall and gaseous loss). The total N, P and K stock has not any relationship with the amount currently available to plants; it will be available for plants progressively 5-10 years (Sanchez and Palm, 1996). Soil N, P and K stock improvement is not to maximize their stocks in soil but rather to maintain the minimal quantity that will maximize service flows for sustainable crop production.

Statistical analysis for N, P and K stocks for different land use types showed none significant ($p = 0.05$) differences between and within groups (Table 2). This revealed soil of the study area was developed from similar parent material with analogous climatic and biotic influences. Consequently, the existing soil nutrient management practices have miniature influence on the total amount of N, P and K stock. Because, the quantity of manure and crop residues once or gradually added to the soil was inadequate and not able to increase soil nutrient stock. Study conducted at the site showed high amount of N, P and K are removed from agricultural lands either with service and wastage (leaching, erosion and gaseous lose) flow (Aticho *et al*., 2011).

Correlation between nutrient stock, land use types and other soil parameters: Correlation analysis of nutrient stock, land use types and other soil parameters (bulk density, % sand, % silt and % clay) indicated strong relationship (Table 3). Positive correlation was observed between

Table 2: One-way ANOVA for soil nutrient stock in 15 cm depth under different land use types

Nutrient (kg ha^{-1})	Land use types	Mean square	df	Significance
N stocks	Between groups	56.81	4	NS
	Within groups	54.03	10	
P stocks	Between groups	634.04	4	NS
	Within groups	629.49	10	
K stocks	Between groups	414.97	4	NS
	Within groups	530.12	10	

NS = None Significant difference at p = 0.05

Table 3: Pearson Correlation matrix for Bulk Density (BD), % sand, % silt, % clay nutrient stock (N, P and K kg ha^{-1}) and land use types (LUTs)

Nutrients and LUTs	LUTs	% Sand	% Silt	% Clay	BD (kg m^{-3})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
LUTs	1							
% Sand	0.34	1						
% Silt	-0.11	0.19	1					
% Clay	-0.04	-0.54**	-0.93**	1				
BD (kg m^{-3})	0.62*	0.22	-0.04	-0.05	1			
N (kg ha^{-1})	0.06	-0.15	0.04	0.02	0.03	1		
P (kg ha^{-1})	0.37	0.53*	0.07	-0.26	0.37	-0.03	1	
K (kg ha^{-1})	0.28	0.31	-0.22	0.07	0.23	0.15	0.68*	1

*Correlation is significant at the p = 0.05 and **at p = 0.01 level bulk density and N, P and K stock at correlation coefficient (r) of 0.03, 0.37 and 0.23, respectively. This illustrates improvement in soil bulk density improves N, P and K stocks. The available options used by smallholder farmers to improve soil bulk density were organic matter addition and reducing grazing pressures (grazing is the cause of soil compaction since machineries were not used for cultivation). Therefore, organic matter added to soil to improve bulk densities and N, P and K stocks. Also, significant (p = 0.01) correlation (r = 0.62) between land use types and bulk density was observed. This exhibits soil bulk density has a close relation with land use types. Soils with high bulk density is less preferred for crop production since high soil bulk density (compacted soils) limits nutrient, moisture and air flow to plant root which results in yield reduction, this idea is agreed with the findings of Awodun (2007). Despite of this, negative correlations were observed between land use types and % silt and clay, % sand and clay, % clay and bulk density.

CONCLUSION AND RECOMMENDATIONS

The types of soil nutrient management practices used by smallholder farmers in the study area for different land use types has no longer contribution to improve soil N, P and K stocks. Because, nutrients added to the soil is not yet adequate to compensate the annual loss with service (nutrient with biomass) and wastage flows (nutrient loss with leaching and water erosion). To ensure food security at household and country level soil nutrient stock improvement and increasing the availability of nutrients for crops should be improved through nutrient recycling and external inputs (mineral and organic fertilizer) addition. To do this, site specific researches should be done in different parts of the country on the rate of soil nutrient depletion, amount of nutrients required to stop depletion and increase the stock, factors that limits the availability of nutrient stocks to plant and how to overcome these restrictive factors.

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