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Effect of Organic and Inorganic Fertilizers Applications on the Highlands Grasslands of the Acidic Soil Physical and Chemical Properties: The Case of Meta-Robi District

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Abstract

The study was undertaken at Meta Robi District, from June-October 2015, to evaluate the soil physical and chemical properties of the degraded natural grassland through application of chemical fertilizer, cattle manure, wood ash and lime.

The plot sizes were 4m x 4m with three replications arranged in randomized complete block design. The space between plots and replications were 1m and 2m respectively.

Soils in Ethiopian highlands have low levels of plant nutrients due to its removal by erosion and leaching by high rainfall. One of the major constraints natural pastures in hay production in the study area is improper nutrient management due to soil pH. Therefore, the objective of this study was to evaluate the effects of organic and inorganic fertilizers on soil property of degraded grasslands of Meta-Robi. The soil lab analysis results before the study indicated that the soil was salt free, slightly acidic pH (5.9), greater in cations exchange capacity (20.37), low in available Phosphorous (1.6ppm). The organic carbon and total nitrogen were rich (0.98% and 0.081%), higher in exchangeable Calcium (0.98) and Magnesium, sodium and potassium were ((3.6, 0.46 and12) respectively. The study indicated that the amelioration of the degraded grazing land with wood ash increased the soil pH.

Keywords: Soil pH, Meta Robi, Cattle Manure, wood ash and Lime

INTRODUCTION

The vast area of Africa in general and Ethiopia in particular is characterized by low soil fertility, high soil degradation, rain-fed and fragmented land holding, extremely low external inputs such as fertilizer and agro-chemicals, and the use of traditional farming techniques (Bezabih et al 2010). The Soil acidity is one of the chemical soil degradation problems affects productivity of the soil in high land in Ethiopia (Hugo et al 2002). According to World Bank (2008), Ethiopia high lands including the study areas are most seriously affected by land degradation resulting in low and declining agricultural productivity, persistent food

insecurity and rural poverty. Fertilization of inorganic and organic fertilizers is common in grassland management, especially when initial levels are low; soil organic matter content and soil biological activity can be enhanced through inorganic as well as organic fertilizers (Eekeren et al 2009). Balanced and integrated use of organic and inorganic fertilizers may enhance the accumulation of soil organic matter and improves soil physical properties. Application of inorganic fertilizers results in higher soil organic matter (SOM) accumulation and biological activity due to increased plant biomass production and organic matter returns to soil in the form of decaying roots, litter and crop residues (Babbu et al 2015). There are considerable evidence in literature suggesting that application of lime, wood ash, manure and mineral Phosphorous fertilizers can be used for the control of acidity related problems and Phosphorous deficiency in acid soils (Asmare and Markku 2016). The grasslands soil of the study area prone to acidic due to high precipitation need to be amended with better soil amendment materials.

Therefore, the objective of this study was to evaluate effects of organic and inorganic fertilizers on soil property of degraded grasslands of in the study area.

MATERIALS AND METHOD

Experimental site

The study was undertaken between June to October 2015 during the 2015/16 growing season on communal grazing area of Meta Robi of western Shoa zone of western highlands of Ethiopia. Meta-Robi district is 110 km far from the capital Addis Ababa, and located at 13°59′ N, 38°28′ E at an altitude of 2473msl above sea level (figure1)

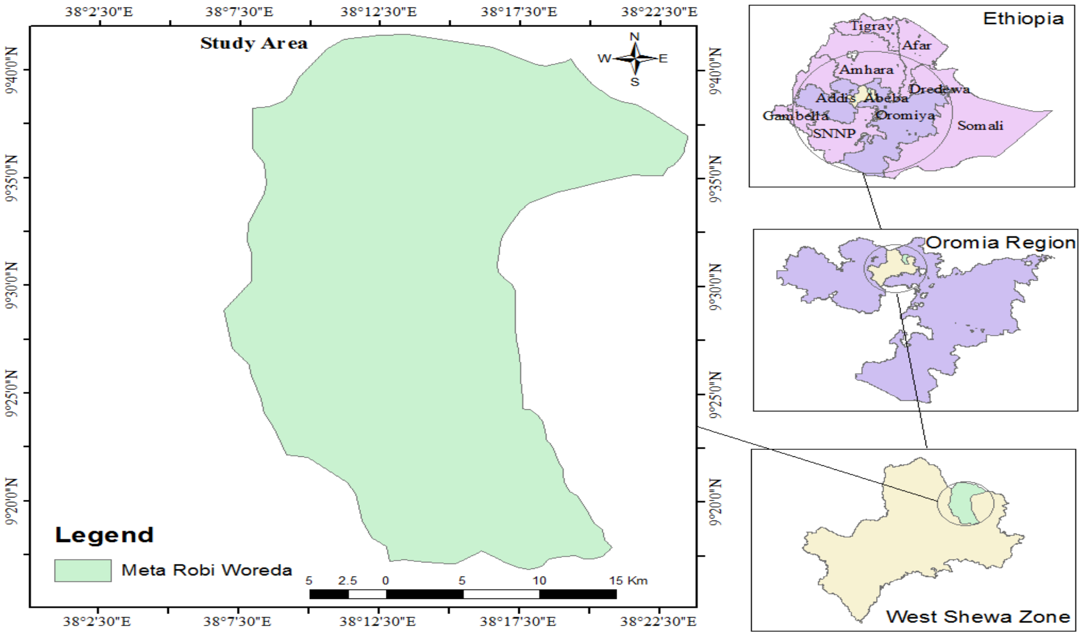

Figure1.location of the study area (EMA 2015)

The mean annual rainfall of the study area in 2015 (figure2) was in mm, ranging between 503.2 mm and 1573mm and was highly variable among years. The main rainy season was July to September. The mean annual minimum and maximum air temperatures of the experimental site were 15 °C and 31 °C, respectively (figure2). The experimental site was characterized by flat land, valley, mountains and rugged area estimated to be 60%, 8%, 9% and 23% respectively. The soil types of the district are classified into humic Nitosols (one of the best and most fertile soil, can suffer acidity and phosphorous fixation, and it becomes very erodible). The 0 to 20 cm soil layer of the experimental site was characterized by a pH of 4.94, a total N content of 0.296%, available phosphorus at (P) content of 1.16ppm/kg, organic carbon of 0.98% and 20.37ppm/kg of cations exchange capacity(Yadessa et al 2016). Visual observations in most parts of the grazing areas of the study site were conducted.

Then, based on severity of degradation, the degraded grazing land represented the study area was selected and fenced for exclusion from livestock grazing prior to the study.

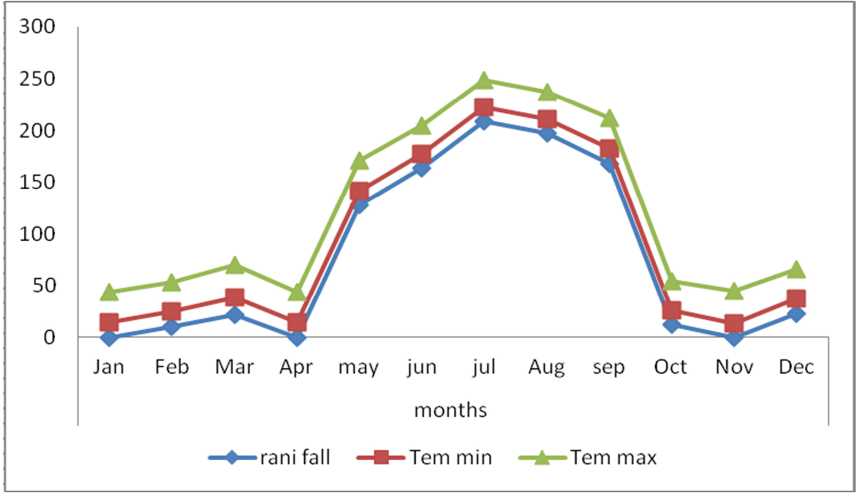

Figure 2.Rain fall and temperature of the study area: Source (EMA 2015)

Experimental Design

The study was undertaken using a 4m×4m factorial experiment arranged in a randomized complete block design with three replications. The space between plots and replications were 1m and 2m, respectively. The distance of experimental plots from boarder was 2m to reduce boarder effects. The total experimental site was 20m x 30m. The treatments for this study were chemical fertilizer (a combination of urea and diammonium phosphate fertilizer), cattle manure, wood ash and lime application. The amounts of both organic and inorganic fertilizers used were 100 &150kg, 7.5, 3 and 2tones for chemical fertilizer, cattle manure, wood ash and lime respectively (Anderson et al 2013; Asmare et al 2015 and Ritchey et al 2015). The chemical fertilizer and lime were acquired by purchasing while both cattle manure and wood ash collected from farmers in the study area.

The degraded grazing land was ripped to incorporate the treatments in to the soil and to prevent nutrients leaching before applications of treatments. After land preparation and plot lay out, the amount of treatments needed for each plots were weighed using sensitive balance and applied. Then diammonium phosphate (DAP) and urea were sown over and mixed using rack except plots for control. Cattle manure was dissolved in to water and applied in the form slurry. Wood ash and lime were slightly rinsed with water to prevent blowing and uniformly scattered over the plots (Mark 1990).

Soil samples collection and analysis

The soil samples from degraded grassland were collected by randomly selected soil sample taking area by considering attaining the target representative soil sample of the study area. Accordingly 15 soil samples were collected from 15 plots at a depth of 0-20cm using augur. The soil samples collection procedure from a plot was followed a" zigzag" pattern to increase precision (ICARDA 2013). Then, the samples were pulled together to form one composite sample representing experimental site. Then after 90days, soil samples were collected followed by the same procedure from 15 plots of each treatment.

The soil samples collected from degraded grasslands before and after experiment were dried and mixed thoroughly (composited) to determine both the physical and chemical soil properties. Then after the determination of soil pH, organic carbon (OC), electric conductivity (EC), available phosphorus (P), exchangeable potassium (K), total nitrogen (N), exchangeable calcium sodium, magnesium and texture were analyzed.

Accordingly, the soil textural analysis was performed using the hydrometer method, total nitrogen (N) found in the soil samples was analyzed using Kjeldahl method. Soil organic matter (SOM) was determined by multiplying of percentage of organic carbon (% OC) by the factor of 1,724 (Brady 1990). Available Phosphorous was determined using Olsen method (Olsen and Dean 1965). The electrical conductivity in water suspension with soil to water ratio 1:2.5 was determined by electric conductivity meter and in the same manner the pH of the soil was determined in water suspension with a soil to water ratio of 1:2.5. Cation exchange capacity (CEC) was analyzed by ammonium acetate. Exchangeable cations: sodium (Na), potassium (K) was extracted by flame photometer. Magnesium (Mg) and calcium (Ca) were extracted by EDTA titration. The soil analysis was undertaken at Ziway soil laboratory.

Statistical analysis

The data obtained from the experiment was subjected to analysis of variance using the General Linear Model Procedure of SAS (SAS 2002).

RESULTS AND DISCUSSION

Physical and chemical characteristics of soil of the experimental site

Table1.

Soil property of the study area before conducting the experiment

Soil property	Unit	value
Sand	%	23
Silt	%	19
clay	%	58
Textural class	%	clay
Electric conductivity	mmohs/cm	0.09
pH of the soil	1:2.5(H_2O)	5.9
Total nitrogen	%	0.08
Available phosphorous	ppm	1.36
Cation exchange capacity	meq/100gm soil	20.37
Organic carbon	%	0.98
Exchangeable calcium	meq/100gm soil	12
Exchangeable Magnesium	meq/100gm soil	3.6
Exchangeable sodium	meq/100gm soil	0.23
Exchangeable potassium	meq/100gm soil	0.46

The soil of the experimental site was clay soil (table1) and the mineralogy of the clay sized fraction was mostly kaolinitic, confirming that the soil is highly weathered. The rather high cation exchange capacity suggests that the soil also contained a substantial amount of smectitic clay as per the rating suggested by Jones (2003). The mean value of cation exchange capacity of the soil before conducting the experiment was in agreement with

(Abera et al 2015) at Bako. The clay soils are negatively charged and such soils are rich in organic matter, have good water holding capacity than soils with low cation exchange capacity, where as soils with low cation exchange capacity tend to develop magnesium and phosphorous. The electrical conductivity of the soil before conducting the experiment was salt free which was in agreement with standard indicated by (Tekalign et al 1991). The mean pH of the soil of the composite sample before conducting the experiment was slightly acidic (table1) in agreement with (Abera et al 2015). The available phosphorous before conducting the experiment, was 1.6ppm which is considered as very low based on Olsen method <3ppm very low and >20ppm very rich) and Bray method (<5ppm very low and >30ppm very rich) because soil pH between 5.5 and 7.5 limit availability of phosphorous (Driven et al 1973). The percentage of organic carbon and total nitrogen content of the experimental site pre-experiment were (table1) indicating that the study site was rich in organic carbon and total nitrogen in reference to standard range of organic carbon inconsistence with (Driven et al 1973; Tekalign et al 1991).

According to Driven et al (1973); Tekalign et al (1991) the recorded calcium value was higher. But Abdena et al (2006) noted that, the exchangeable calcium in west Shoa was negligible. The amount Mg and K (table1) recorded were in agreement with (Anderson et al 2013, Brennan and Bell 2013).

Effects of organic and inorganic fertilizer applications physical and chemical properties of soil of degraded grasslands

Results of the soil textural analysis indicated (table2) after experimental indicates that, soil textural class with the proportions of sand, silt and clay were significantly varied by the applications of organic and inorganic fertilizer (P>0.05) even though, statically none significant.

Table2.

Soil physical property of the study area after conducting the experiment

Treatments	**Parameters**			
	Sand	**Silt**	**Clay**	**Textural class**
Chemical Fertilizer	51.67^{a}	29.00^{a}	19.40^{a}	loam
Cattle Manure	48.33^{a}	27.67^{a}	24.10^{a}	Sandy clay loam
Wood Ash	54.33^{a}	27.67^{a}	18.20^{a}	Sandy clay loam
Lime	49.00^{a}	28.33^{a}	22.80^{a}	Sandy clay loam
Control	54.33^{a}	24.33^{a}	21.50^{a}	clay
CV	9.319	12.50	28.59	
Mean	51.53	27.40	21.20	
SEM	23.07	11.73	36.20	
LSD	9.04	6.45	11.41	
LS	0.44	0.54	0.20	

^{a,b} means in a column with the same category having different supper scripts differ (P<0.05); CV = Coefficient of variations; LSD = Least significance difference; SEM = Standard error of the mean and SL= Significance level.

The comparison of the pre and post experimental soil analysis result showed us the change of textural class was not as results of the treatments (compare table1&2) as the control or without treatments was changed similarly with plots of treatments.

Table3

Soil chemical properties of improved grasslands after experiment

	Parameters									
Treatments	**EC**	**pH**	**N**	**P**	**CEC**	**OC**	**Ca**	**Mg**	**Na**	**K**
T1	0.07b	5.46^{a}	0.40^{a}	3.02^{ab}	34.81^{a}	8.84^{a}	11.73^{a}	4.93^{a}	0.34^{a}	0.75^{bc}
T2	0.20^{ab}	5.96^{a}	0.39^{a}	9.07^{a}	21.79^{a}	6.96 ^{a}	12.93^{a}	3.07^{a}	0.28^{a}	0.90^{ab}
T3	0.24^{ab}	6.06^{a}	0.34^{a}	2.33^{ab}	29.08^{a}	8.12 ^{a}	12.00^{a}	4.93^{a}	0.29a	1.04^{a}
T4	0.27^{a}	5.83^{a}	0.28^{a}	1.75^{b}	24.02^{a}	6.96a	11.86^{a}	4.00^{a}	0.19^{a}	0.63^{c}
T5	0.15^{ab}	5.76^{a}	0.39^{a}	1.54^{b}	31.56^{a}	8.32^{a}	13.60^{a}	4.40^{a}	0.33^{a}	0.87^{abc}
Mean	0.19	5.82	0.36	3.50	28.25	7.84	12.43	4.27	0.29	0.84
CV	54.21	10.52	41.82	54.61	29.74	49.57	26.16	31.63	32.89	15.62
LSD	0.19	1.15	0.29	6.78	15.82	7.32	6.12	2.54	0.18	0.25
SEM	0.01	0.37	0.02	12.97	70.58	15.10	10.57	1.82	0.01	0.02
SL	0.02	0.79	0.84	0.05	0.38	0.96	0.94	0.46	0.42	0.04

^{ab} means in a column with the same category having different supper scripts differ at (P<0,05); CV=Coefficients of variations; LSD = Least significance difference; SEM=Standard error of the mean and SL=Significance level, T1=chemical fertilizer, T2=cattle manure, T3=wood ash, T4=lime and T5=control; EC= mmohs/cm at 25^{o}C, PH=H_2O, N&OC= %, P=ppm, CEC and exchangeable Ca, Mg Na and K = meq/100gm soil.

The reason for textural change from sandy to clay was due to high moisture contents of the soil during sampling time. while, the variation in soil chemical property was observed due to effects of organic and inorganic fertilizer applications. The values for soil chemical properties in (table3) indicated that electrical conductivity of the soil property was significantly affected ($P<0.05$) by application of lime and wood ash treatments. The soils with such amount of electrical conductivity are considered as free of salts (Tekalign et al 1991). This was due to ca and mg in wood ash pH stabilizing property. Unlikely application of the treatments did not bring significant change in pH of the soil properties ($P>0.05$) but the pre experimental pH mean value result of soil sample indicates that pH increase relatively by wood ash, lime and cattle manure in post experiment soil analysis (table 3). The highest PH was recorded at both wood ash and lime applications because of the wood ash and lime strong neutralizing effect (Asmare et al 2015). Wood ash increased soil pH over lime in this study, which was proved by several studies that the highest composition and release of calcium and magnesium of wood ash which affect the soil pH made wood ash best alternative to be preferred as liming materials and soil amendment. The studies by Adekayode et al (2010); Tsutomu and Erich (2010) and Mijangos et al (2015), had shown that wood ash application enhanced soil biological quality and fertility in acid soils and can be a valid alternative to the traditional treatment with lime. Application of cattle manure exhibited higher the available phosphorous ($P<0.05$). The highest mean value for available phosphorous was scored cattle manure application (table3) might be due to the fact that cattle manure is rich in phosphorous, potassium, magnesium and calcium and the significant proportion of phosphorus in manure mineralize slowly and gradually to release plant available phosphorous (Ajiboye et al 2004; Benke et al 2009 and Manitoba 2013). The increased amount of available phosphorus after harvest observed in cattle manure application treatments also might be attributed from the release of soluble humic material or organic acids from the decomposing of the organic residues and manures contribute greatly to decrease P adsorption capacity and increased available P that occurs in soils (Easter wood and Seatrain 1990; Hue, 1990; 1992). The soil organic carbon and total nitrogen content were not significantly affected by application of the treatments ($P>0.05$). But from comparison of pre and post soil samples analysis higher organic carbon and total nitrogen were observed at chemical fertilizers. The fact that the chemical fertilizer increased total nitrogen and organic carbon was due to urea fertilizer good sources of nitrogen (Khoi et al 2010). From the current study slight nitrogen increment observed after harvest than pre experiment soil total nitrogen and the total nitrogen recorded in both post pre experiments was favorable for plant growth and found within a range by (Driven et al 1973) classification and rating. The current study was inconsistence with findings by Ullah et al (2008), who reported that chemical fertilizer increased organic carbon than cattle manure and Czarnecki and Düring (2015), who reported that addition of chemical fertilizers to soil influences the chemical composition of soil solution. Messiga et al (2013) also indicated that organic carbon tends to rise with increased nitrogen application. The cations exchange capacity was not affected ($P>0.05$) by effects of treatments applications. However similarly to total nitrogen, the higher cations exchange capacity was recorded at chemical fertilizer application. This was due to chemical fertilizer contribution of plant growth and return to soil through decomposition and helped to possessed higher cation exchange capacity and good soil texture (Babbu et al 2015). The exchangeable sodium was not affected significantly as effects of treatment ($P>0.05$). However, variations were observed in all application treatments. The highest exchangeable (Na) of the soil property was recorded at chemical fertilizer application treatment which implies that urea has a role to increase exchangeable sodium in relation to increasing soil organic carbon and total nitrogen which was previously increased the CEC of soil factor as amount of sodium depends on CEC of soil factor . Similarly, exchangeable magnesium was not affected ($P>0.05$) by applications of the treatments. However the applications of the chemical fertilizer and wood ash increased the exchangeable magnesium than the other treatments applications. This was due to the soil highest composition of organic carbon and total nitrogen of the grassland contributed to increase the cation exchange capacity of the soil to hold higher nutrients (Manitoba, 2013). The increase of Mg in wood ash was due to high consistence of alkali metals that made to be preferred as best liming materials (Achalu et al 2012) and this was proved by Okmanis et al (2015), that one tone sieved wood ash can bring in soil about 170kg of liming material or 150kg calcium and 20kg magnesium. Eventhough statistically non significant variation was observed ($P>0.05$) in the mean values of exchangeable calcium the soil samples libratory analytical results indicate that, the exchangeable calcium for most of the treatments were considered as higher in this study. But the post harvest results showed decrease trend in all applications of treatments. The Netherlands Lime miller (2001), reasoned, this might be the fact that various processes of interconnected with plant up take and reactions with fertilizer brought about the loss of calcium from the soil. The reduction of exchangeable calcium at chemical fertilizer application could be the tendency of calcium to offset the hydrolysis of the urea to reduce soil acidity by increasing the amount of cations exchange capacity (Jones et al 2013). Exchangeable potassium was significantly affected ($P<0.05$) by wood ash application. Previous studies had indicated that wood ash is similar in liming effects with commercial lime and in these several studies where traditional limestone and wood ash had been compared their results had confirmed wood ash is better for plant growth responses than limestone because of the additional nutrients that the wood ash contained (Awodun et al 2007).

CONCLUSION AND RECOMMENDATION

The soil lab analysis results before the experiment indicated that the soil was salt free; slightly acidic pH, higher in CEC, low in available P the organic carbon and total nitrogen were rich, higher in exchangeable Ca and M. Na and K were (3.6 , 0.46 and 12) respectively.

Application of wood ash increased the soil pH property while application of cattle manure and wood ash increased available phosphorous and exchangeable potassium respectively.

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