

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

Fekadu Nemera¹, Tessema Zewdu² and Abule Ebro³

1Adami Tulu Agricultural Research center, P.O.Box 35, Ziway, Ethiopia, 2Haramaya University, Ethiopia and

3International livestock Research Institute (ILRI), Addis Ababa, Ethiopia

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 and 12) 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)

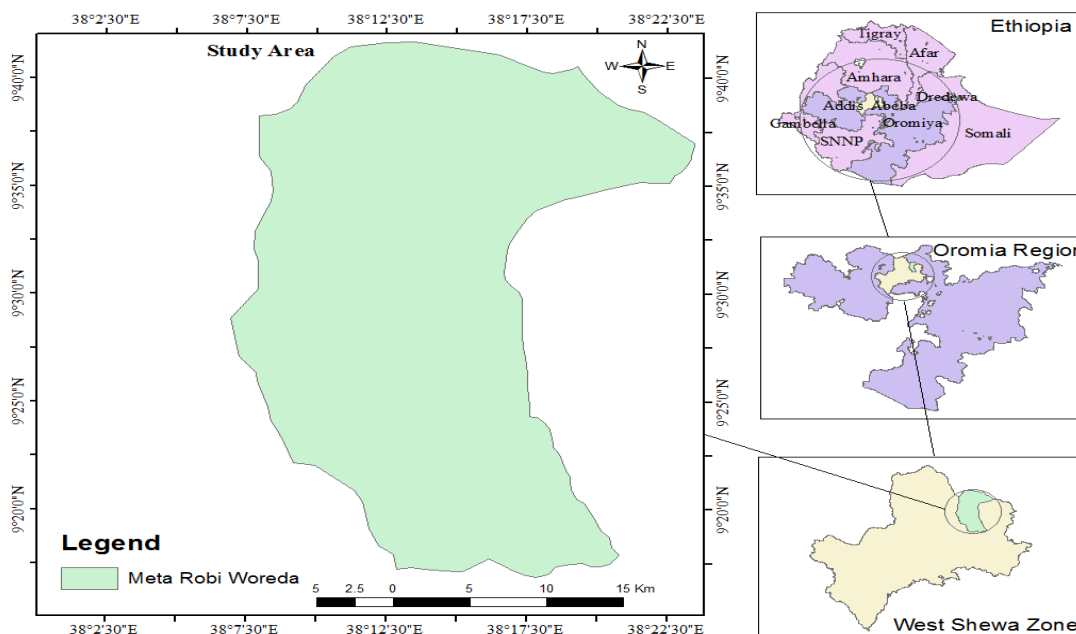


Figure 1. location of the study area (EMA 2015)

The mean annual rainfall of the study area in 2015 (figure 2) was in mm, ranging between 503.2 mm and 1573 mm 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 (figure 2). 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 Nitisols (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 1.16 ppm/kg, organic carbon of 0.98% and 20.37 ppm/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.

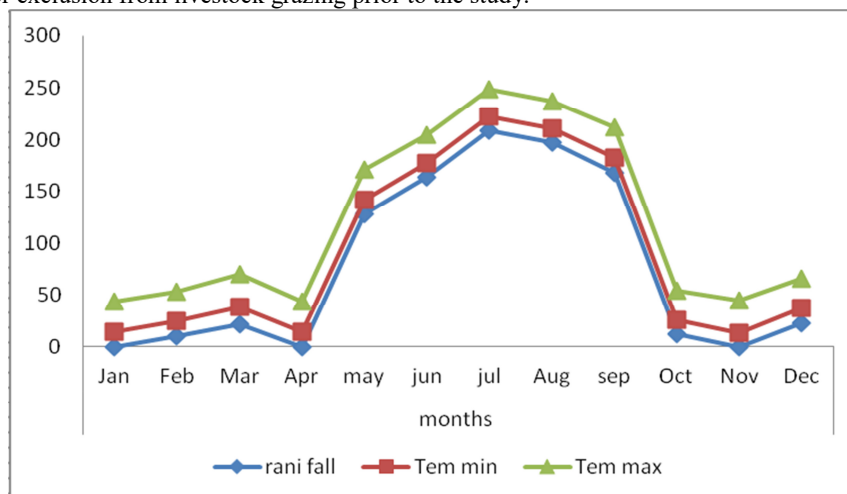


Figure 2. Rain fall and temperature of the study area: Source (EMA 2015)

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 2 tones 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 ₂ O)	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 inconsistency 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			Textural class
	Sand	Silt	Clay	
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

Treatments	Parameters									
	EC	pH	N	P	CEC	OC	Ca	Mg	Na	K
T1	0.07 ^b	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	0.29 ^a	1.04 ^a
T4	0.27 ^a	5.83 ^a	0.28 ^a	1.75 ^b	24.02 ^a	6.96 ^a	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°C, PH=H₂O, 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 inconsistency 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 (Achalal 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 laboratory 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.

ACKNOWLEDGEMENT

We are greatly happy to thank International Livestock Research Institute under LIVES project and Oromia Agricultural Research Institute for financing the research work and the District, PA administrations and the farmers of the area for permitting the grazing land to undertake the research work.

REFERENCES

- A. Jones, H. BreuningMadsen, M. Brossard, A. Dampha, J.Deckers, O. Dewitte, T. Gllali, S. Hallett, R. Jones, M. Kilasara, P. LeRoux, E. Micheli, L. Montanarella, O. Spaargaren, L. Thiombiano, E. VanRanst, M. Yemefack, R. Zougmore (Eds.), 2013 Soil Atlas of Africa, European Commission, Publications Office of the European Union, Luxembourg(2013) (176 p.)
- Abdenna Deressa, Negassa Chewaka Wakene, Tilahun Geleto. 2006. Inventory of the Exchangeable K, Ca and Mg Status in Crop Lands of Central and Western Ethiopia, “ Utilization of diversity in land use systems: Sustainable and organic approaches to meet human needs”.
- Achalu Chimdi, Heluf Gebrekidan, Kibebew Kibret and Abi Tadesse 2012 Effects of liming on acidity-related chemical properties of soils of the different land use systems in Western Oromia, Ethiopia. *World Journal of Agricultural Sciences* 8 (6):560-567, Issn 1817-304.
- Adekayode1, F.O. and Olojugba, M.R 2010 The utilization of wood ash as manure to reduce the use of mineral fertilizer for improved performance of maize (*Zea mays*) as measured in the chlorophyll content and grain yield, *Journal of Soil Science and Environmental Management*.
- Adekayode1, F.O. and Olojugba, M.R. 2010. The utilization of wood ash as manure to reduce the use of mineral fertilizer for improved performance of maize (*Zea mays*) as measured in the chlorophyll content and grain yield, *Journal of Soil Science and Environmental Management*.
- Ajiboye. B., Akinremi, O. O. and Racz, G. J 2004 Laboratory characterization of phosphorus in fresh and oven-dried organic amendments. *J. Environ. Qual.* 33:1062-106.
- Alvorson, A. D., Reule, C. A., and Follett, R. F 1999 Nitrogen fertilization effects on soil carbon and nitrogen in a dry land cropping system, *Soil Sci. Soc. Am. J.*, 63, 912–917.
- Asmare Melese and Markku Yli-Halla 2016 Effects of applications of lime, wood ash, manure and mineral P fertilizer on the inorganic P fractions and other selected soil chemical properties on acid soil of Farta District, Northwestern highland of Ethiopia. *African Journal of Agricultural Research*, <http://www.academicjournals.org/AJAR>.
- Asmare Melese, Markku Yli-Halla and Birru Yitaferu 2015 Effects of lime, wood ash, manure and mineral p fertilizer rates on acidity related chemical properties and growth and p uptake of wheat (*Triticum aestivum*) on acid soil of Farta District, northwestern highlands of Ethiopia. *International Journal of Agriculture and Crop Sciences*. www.Ijagcs.Com.
- Awodun Ma, Ojeniyi So, Adeboye A and Odedina S 2000 Effects of oil palm bunch refuse ash on soil and plant nutrient composition and yield of maize. *Am Eurasian, J. Sustain. Agric.* 1(1): 50 – 54.
- Ayan, I., Z. Acar 2008 Methods for improving rangelands in the Black Sea Region of Turkey. *J of Fac of Agric* 23: 145-151.
- Babbu Singh Brar, Jagdeep Singh, Gurbir Singh and Gurpreet Kaur 2015 Effects of Long Term Application of Inorganic and Organic Fertilizers on Soil Organic Carbon and Physical Properties in Maize–Wheat Rotation, *Agronomy* 2015, 5, 220-238; doi:10.3390/agronomy5020220, www.mdpi.Com/journal/agronomy
- Barnes, D L., Swart, M., Smith, M F. and Wiltshire, G H 1991 Relations between soil factors and herbage yields of natural grassland on sandy soils in the southeastern Transvaal. *Journal of the Grassland Society of Southern Africa*, 8 (3): 92-99.
- Benke, M. B., Hao, X., O’ donovan, J. T., Clayton, G. W., Lupwayi, N. Z., Caffyn, P. and Hall, M 2009 Livestock manure improves acid soil productivity under a cold northern Alberta climate, *Can. J., Soil Sci.*, 90: 685-69.
- Bezabih Emanu, Hadera Gebremedhin & Nigatu Regassa 2010 Impacts of Improved Seeds and Agrochemicals on Food Security and Environment in the Rift Valley of Ethiopia: Implications for the Application of an African Green Revolution. *Drylands Coordination Group Report No. 56 02*.
- Brady, N.C. 1990 The nature and properties of Soils, 10th Edition, Macmillan Publishing Company, New York,

- Pp. 243-246.
- Czarnecki S. and R. A. Düring 2015 Influence of long-term mineral fertilization on metal contents and properties of soil samples taken from different locations in Hesse, Germany.
- Demeyer A, Voundi Njc and Verloo Mg 2001 Characteristics of wood ash and influence on soil properties and nutrient uptake: An Overview. *Bio Resource Technology* 77(3): 287 - 295.
- Driven, L., Robert, B., Cate, B and Nelson, L. A., 1973. Discontinuous model for rapid correlation, interpretation and utilization of soil analysis and fertilizer response data. International soil fertility evaluation and improvement program technical bulletin No.7.
- Easter Wood, G. w and Sartain Jb 1990 Clover residue effectiveness in reducing orthophosphate sorption on ferric hydroxide coated soil. *Soil Sci Soc Am J* 54: 1345–1350.
- Eekeren Nick Van Boer, Herman De and Bloem Jaap 2009 Soil biological quality of grassland fertilized with adjusted cattle manure slurries in comparison with organic and inorganic fertilizers.
- Endale Yadessa, Abule Ebro, Lemma Fita and Getnet Asefa 2016 Livestock feed production and feed balance in Meta Robi District, West Shewa Zone, Oromia Regional State, Ethiopia. *Academic Research Journal of Agricultural Science and Research*. Vol. 4(2), 45-54.
- Erich, M.S 1991 Agronomic effectiveness of wood ash as a phosphorus and potassium source. *J. Environ. Qual.* 20:576-581.
- Erich, M.S. and T. Ohno 1992a Phosphorus availability to corn from wood ash-amended soils, *Water Air Soil Pollut.*, 64:475-485.
- Erich, M.S., and T. Ohno 1992b Titri Metric determination of calcium carbonate equivalence of wood ash, *analyst*, 117:993-995.
- Girma Tadesse, Don, P., Astatke Abiye and Ayaleneh Wagnew 2003 Effects of manure on grazing lands in Ethiopia, East African Highlands. *Mountain Research and Development*, 23(2): 156–160.
- Girma Tadesse, Don, P., Astatke Abiye and Ayaleneh Wagnew 2003 Effects of manure on grazing lands in Ethiopia, *East African Highlands, Mountain Research*. Anderson, J.M. Hart, D.M. Sullivan, N.W. Christensen, D.A. Horneck, and G.J. Pirelli 2013 Applying Lime to Raise Soil pH for Crop Production (Western Oregon), Extension Catalog: <https://catalog.extension.oregonstate>
- Goshu, Tolera Abera Semu, Ernest Debele, Tolessa Wegary, Dagne Kim, Haekoo. 2015. Nutrient Status of Soils from Farmers' Maize Fields in Mid Altitude Areas of Western Ethiopia. 113-121
- Hoffman, P. C. 2005 Ash content of forages. *Wisconsin Forage Vol 7. No.1*. [Online] Available: [Http://www.uwex.edu/Ces/Crops/Uwforage/Ash05-Fof.Htm](http://www.uwex.edu/Ces/Crops/Uwforage/Ash05-Fof.Htm).
- Hugo, L.P., Johann, B., Juergen, G., Hiremagalur, G., Mohammad, J., Victor, M., John, M., Martin, O., and Mohamed, S., 2002. Linking Natural Resources, Agriculture and Human Health: Case Studies from East Africa. *LEISA Magazine supplement*, page 17- 20.
- ICARDA 2013 *Methods of Soil, Plant, and Water Analysis: A manual for the West Asia and North Africa region -Third Edition* George Estefan, Rolf Sommer, and John Ryan.
- Insam, H., Franke-Whittle, I. H. Knapp, B. A. and Plank, R 2009 Use of wood ash and anaerobic sludge for grassland fertilization: Effects on plants and microbes.
- Jerome Lickacz 2002 Wood ash - an alternative liming material for agricultural soils.
- Josh, Mcg. and Ketterings. M 2013 Manure injection in no-till and pasture systems Rory Maguire, *Crop and Soil Environmental Sciences*, Virginia Tech Douglas.
- Khoi, C.M., Thi Guong Vo. and Pham, N. and Minh, T 2010 Effects of compost and lime amendment on soil acidity and availability in acid sulfate soil, *World Congress of Soil Science, Soil Solutions for a Changing World*, Brisbane, Australia.
- Lloyd. Drs. Murdock and Edwin Ritchey 2014 Lime and nutrition recommendations, Cooperative Extension Service, University of Kentucky College of Agriculture, Food and Environment, Lexington, Ky, 40546.
- Manitoba. 2013. Effects of Manure and Fertilizer on Soil Fertility and Soil Quality. Manske,
- Mark 2013 Best Management Practices for Wood Ash as Agricultural Soil Amendment. UGA Cooperative Extension Bulletin. 1142.
- Mark J. Kopecky 1990 Using industrial wood ash as a soil amendment.
- Messiga, A. J., Ziadi, N., Belanger, G., and Morel, C 2013 Soil nutrients and other major properties in grassland fertilized with nitrogen and phosphorus. *Soil Sci. Soc., Am. J.*, 77, 643–652c.
- Mijangos I., Garbisu C., Aristegieta A., Ibarra A., Mendarte S. and Albizu I 2005 Wood ash as fertilizer and soil acidity corrector: effects on soil quality and crop yield, *Grassland Science in Europe*, Vol., 11.
- Natural Resources Conservation Service (Nrc) 1996 *Soil Survey Laboratory Methods Manual*, Soil Survey Investigations Report No.42.Usda, Washington, Dc.
- Naylor, L.M., and E.J. Schmidt 1986 Agricultural use of wood ash as a fertilizer and liming material, *Tappi J.* 69:114-119.
- Netherlands Commissioned by Ministry of Agriculture and Fisheries 1985 *Agricultural compendium for rural*

- development in tropics and sub-tropics. The Netherlands Ministry of Agriculture and Fisheries Amsterdam, the Netherlands.
- Oac (Association of Official Analytical Chemists) 1990 Official Method of Analysis (5th Edn). Arlington: AOAC.
- Ohno, T., and M.S. Erich 1990 Effects of wood ash application on soil pH and soil test nutrient levels. *Agric., Ecosystems Environ*, 32:223-239.
- Okmanis Modris, Lazdiņa Dagnija and Lazdiņš Andis 2015 The Composition and Use Value of Tree Biomass Ash Modris, *Rural Sustainability Research*, 329, 1-6,
- Olsen, S.R. and Dean, L.A 1965 Phosphorous .in: Black, C.A.(Ed), *Methods of soil analysis part2: chemical methods*. Soil Science Society of America, Madison, Wi, USA, Pp1035-1049.
- Ritchey Edwin and Murdock, Lloyd. 2015 Lime and Nutrient Recommendations, Cooperative extension service University of Kentucky College of Agriculture, Food and Environment, Lexington, Ky, 40546.
- Saarsalmi A, Malkonen E and Piirainen S 2001 Effects of wood ash fertilization on forest soil chemical properties, *Silva Fennica*, 35(3): 355-368.
- Santamaria. O; Rodrigo. S; Poblaciones and M J; Olea. L 2014 Fertilizer application (P. K. S. Ca and Mg) on pasture in calcareous Dehesas: Effects on herbage yield. botanical composition and nutritive value. *J. Plant Soil Environ*. Vol. 60. No. 7: 303–308.
- SAS Institute (2002) SAS system for windows, Version 9.1. SAS Institute Inc., Carey, NC, USA.
- Sheldrick, B.H. and Wang, C 1993 Particle size distribution, soil sampling and methods of analysis, Canadian Society of Soil Science, Ann Arbor.
- Sharma C.M..S.K. Ghildiyal, Sumeet Gairola and Sarvesh Suyal 2009 Vegetation structure, composition and diversity in relation to the soil characteristics of temperate mixed broad leaved forest along an altitudinal gradient in Garhwali Himalaya.
- Tekalign Mamo, I. Haque and E.A. Aduayi 1991 Soil, plant, water, fertilizer, animal manure and compost analysis manual. Plant Science Division Working Document 13, Ilca, Addis Ababa, Ethiopia
- Tsutomu Ohno and M. Susan 1994 Availability in wood ash amended soils: an incubation study main agricultural and forest experiment Station, University of Erich Maine Sludge and Residuals Utilization Research Foundation, Research Report No. 2.
- Ullah, M.S. Islam, M.A. Islam and T. Haque 2008 Effects of organic manures and chemical fertilizers on the yield of brinjal and soil properties *J. Bangladesh Agril. Univ.* 6 (2): 271–276, Issn 1810-3030.
- Walkley. A. and Black. I. A 1934 An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *J. of Soil Sciences*, 37: 29-37.
- World Bank, 2008. Sustainable Land Management Project, Project Appraisal Document(PAD), Ethiopia/Report No 42927-ET, Project I.D P107139, <http://www-wds.worldbank.org/external/projects>.
- Yadav, A.C., Sharma, S.K. and Batra, B.R 2002 Effects of sodic water, FYM and gypsum on the soil.