EJED 2(2) 2019: 1 – 26
Ethiopian Journal of
Environment and Development
http://www.du.edu.et/duj
EJED

Effect of Applied Lime and Mineral Phosphorus Fertilizer on Phosphorus Transformation in Acid Soils of West Wollega, Ethiopia

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Received: 10 Oct, 2019 /Accepted: 8 December, 2019

ABSTRACT

Prevalent occurrence of P deficiency in strongly acid soils is one of the major problems limiting crop production in high rainfall regions of Ethiopia where Phosphorus (P) fixation, nutrient leaching and soils erosion are common. This work investigated effect of liming and applied mineral P on the P transformation of acid soils of West Wollega, Ethiopia. To study the P transformations, P fractionation was carried out to determine distributions of P in the various P pools. The soils were categorized as strongly acidic in which the pH (H_2O) values varied between 4.35 and 4.82. Cation exchange capacity (CEC) of the soils ranged from 20 to28 cmolc kg^{-1}. Lime requirements to raise the soil pH to target values of 5.5, 6.5 and 7.2 varied from 4.27 to 8.18 tons $CaCO_3$ ha^{-1}. The total P contents of the studied soils ranged from 298.46 to 392.12 mg kg^{-1}. Available P(Bray I-P, Mehlich 3-P and $CaCl_2$-P) ranged from 1.12 to 1.82 mg kg^{-1} and considered as very low available P content. On average, distributions of applied P in the various fractions of the soils followed the order: iron bound P (Fe-P) > aluminum bound P (Al-P) > calcium bound P (Ca-P) > easily soluble P (ES-P) > reductant soluble P (RS-P). Clay content was highly positively correlated with total P, Fe-P, Ca-P, organic P and Bray I -P ($r = 0.86$, 0.76, 0.88, 0.89 and 62 respectively at $p < 0.01$ and $p < 0.05$). CEC was significantly correlated with total P, Fe-P, Ca-P, organic P ($r = 0.92$, 0.98, 0.89 and 0.78 respectively at $p < 0.001$ and $p < 0.01$). Desorption of P in the Fe-P and Al-P fractions were highly affected by the pH while desorption of P in the other fractions were modestly affected. The recovered mean percentages of the applied P were different among the soil types and P treatments ranging from 44.30% to 90.83%. This indicates that with proper lime treatment and optimum mineral P application, plant availability of P be increased in acid soils that highly fix applied P fertilizer.

Key words: *P fractions, lime requirement, available P. P transformation, P recovery*

1. INTRODUCTION

Phosphorus (P) is one of essential macronutrients for plant growth and productivity. However, the plant available form of P in soil is low relative to those of other major macronutrients. This is because P, in the form of high valence phosphate (PO_4^{3-}), is strongly fixed by low solubility oxides of iron, aluminum and manganese or occluded into hydroxy-Al-interlayered montmorillonite clay particles. This transformation of inorganic P into unavailable forms is very severe in highly weathered acid soils in which iron, aluminum and manganese oxides are ubiquitous and the clay content is large (Jain, *et al.*, 2012). In highly weathered acid soils, even the momentary applied fertilizer P tends to become immediately and progressively less soluble over time (Eghball, *et al.,* 1996). This indicates that sufficient P application alone could not provide adequate P nutrient for healthy plant growth and maximum crop yield. In such highly weathered acid soils, acidic cations of Al, Fe, and Mn exist in high concentrations. These acid cations do not only aggravate soil acidity by displacing H^+ from solid soil particles, but also occupy large part of the available exchangeable sites of soil colloids, rendering the soil poor in exchanging the very essential nutrient cations such as Ca^{2+}, Mg^{2+} and K^+. Acid cations may occur as free cations in the soil solution, as exchangeable cations occupying exchangeable sites of soil colloids, or as mineral oxide clay-sized colloids with various levels of crystallinity. Applied or native P species significantly react with the acidic cations and become inactive (Brady and Weil, 2014). After sorption onto the acidic oxide surfaces, P will be only poorly desorbed. As time goes, P becomes more and more retained and unavailable (Martin, *et al.,* 2002).

The less productive crop growth in highly acidic soils in general and acid soils of Western Wollega in particular is related to P nutrient deficiency due to low native available form of P and high capacity of the soils to fix applied fertilizer P into strongly insoluble forms. Cultivation and other soil management activities bring significant differences in soil P chemistry in the area. Types of parent materials, degree of chemical weathering, soil ages, cultivation and fertilizer practices are among the major factors determining distribution of inorganic P forms in soils. (Achalu, *et al.* 2013; Sharpley and Smith, 1983).

Low-P availability problems in acidic soils can be alleviated by liming the soils for pH neutralization. Application of lime makes the carbonate (CO_3^{2-}) to be hydrolyzed and produce hydroxide ions (OH^-), which increase soil solution pH. The hydroxide ions react with Al oxides and reduce their positive surface charge. This in turn reduces the P retention capacity of the oxides (Mora *et al.* 1999). The increased concentration of OH^- ions in soil solution compete with P species (anions) for positive exchange sites on soil colloids. Thus liming reduces the ability of the acidic oxide surfaces to retain P in two ways: first reduces surface positive charge by pairing with the negative charges on OH^- ions; second by making the OH^- ions compete with PO_4^{3-} ions for the available positive sites on soil colloidal surfaces. The cumulative consequence is increased P availability (Kisinyo *et al*. 2014). Another method of alleviating P fixation problem is applying fertilizer P in excess quantity. This method temporarily addresses the low P availability but does not alleviate the root of the problem, that is, the acidic soil activity.

Soil P dynamics and its exchanges between the inorganic and organic pools highly affect its plant availability (Beck and Sanchez, 1994; Kpomblekou and Tabatabai, 1997). Several investigators reported effective use of P fractionation procedures or their modifications in estimating P forms associated with soil materials (Lopez-Pineiro and Garcia-Navaro, 2001). Fractionation procedure was developed based on the assumption that various extractants extract P selectively from discrete P pools. This approach is used to quantify the different chemical forms of P in soils (Hedley *et al*, 1982). The two dominant P reactions in soils are adsorption reaction at low P concentration and precipitation reaction at higher P concentration (Lin, *et al*, 1983; Mehadi and Taylor, 1988). The former is dominant over a short period while the later largely depends on the nature of cations in the soils. Several studies reported that there is correlation between the forms of inorganic P, status of available P, and transformation of inorganic fractions into fixed and occluded forms. This transformation depends on levels of added P, time of incubation and soil properties (Tekalign and Haque, 1991; Indiati, *et al*, 1992). The problem of low P availability and dynamics has been recognized and addressed in the past years, and there are several researches conducted in highly weathered soils in different parts of the world (Guedes *et al*. 2012; Tiecher *et al*. 2013; Asmare Melese, 2013). However, P dynamics in highly weathered acid soils of Western Wollega has not been studied. Thus, the aim of this work was to investigate the two methods of improving P availability, liming and P addition and to assess their effectiveness in relation to certain soil properties. It is also believed that high level of acidity and related soil properties largely affect general P dynamics of soils and its plant availability. Although there were studies made on soil P status and its adsorption/desorptions in some parts of Ethiopia (Tekalign and Haque, 1987; Duffera and Robarge, 1999; Achalu, *et al*, 2013), information on P adsorption-desorption properties of Western Wollega soils is lacking. To understand the prevalent occurrence of P deficiency in these soils, it is necessary to study the soil components that may be responsible for the distribution, availability, and P adsorption behavior of the soils. Therefore, this study investigated the change in the amounts and distribution of applied mineral P as affected by liming and the factors that might influence P adsorption and availability in four highly weathered acid soils of West Wollega, Ethiopia.

2. MATREIALS AND METHODS

2.1. Sites Description

Soil samples were collected from West Wollega Zone, Oromia region of Ethiopia, which is found at about 477 - 575 Km west of Addis Ababa. The districts selected for sample collection were Mana Sibu, Kiltu Kara, Nedjo and Boji Dirmaji. The altitude, the mean annual rainfall and the mean temperature of these areas range from 1300 to 1800 masl, 1000 to 2400 $mmyr^{-1}$, and 12.5 to 29 ^{0}C respectively. The areas receive rainfall in one season annually which lasts from April to October. The predominant soil type in southwest and western Ethiopia in general and the study area in particular is Nitisols according to FAO (2001) soil classification system. Its vernacular name is "*BiyeDima*" meaning red soil. Nitisols are deep and highly weathered, well drained, clay in texture and strongly acidic in reaction in the warm and humid areas of the west and southwest Ethiopia (FAO, 2001). The major crops grown in the zone include cereals (maize, teff, millet, sorghum, and barley), pulses (faba bean and field peas), oil crops (niger seed, rapeseed and sesame) and coffee.

2.2. Soil Sample Collection

Surface soil samples (0-20 cm) were randomly collected from each of the sampling sites in each district. The randomly collected soil samples were thoroughly mixed to form one composite sample for each site and a total of four composite soil samples were collected and packed in plastic bags. After bringing to HU soil laboratory, the collected samples were air-dried and ground to pass through a 2 mm sieve to be tested for selected soil physico-chemical parameters (bulk density, texture, pH, exchangeable acidity, organic carbon (OC), total nitrogen (TN), CEC, available P, exchangeable Mn, Al, and Fe) following standard laboratory procedures as described below. For greenhouse experiments, soils were collected from the same sites following the same procedures assuming 5 Kg soil for each pot experiment.

2.3. Physicochemical Analysis of the Soils

Selected physical and chemical properties of the soils were analyzed following their respective standard procedures. Particle-size distributions were measured by Bouyoucos hydrometer; organic matter was determined by wet oxidation; pH was measured before and after liming using a pH meter with combined-glass electrode in a 1:2.5 soil to solution suspension in deionized water. CEC of the soils was determined by ammonium acetate method. Organic carbon was determined by oxidizing with potassium dichromate in sulfuric acid solution and total nitrogen was investigated by the Kjeldahl procedure. Exchangeable acidity was measured by leaching hydrogen and aluminum ions from the soil by a neutral 1N potassium chloride and titrating the acidity brought into solution with standard solution of 0.02M NaOH (Van Reeuwijk, 1992). Al, Fe and Mn oxides were determined by extracting with ammonium oxalate measuring with atomic absorption spectroscopy, and electrical conductivity (EC) (1:1 H_2O) by following the methods according to Rowell (Van Reeuwijk, 1992). Available form of P was determined following Bray I (Bray and Kurtz, 1945), Mehlich 3-P (Mehlich, 1984) and $CaCl_2$ extraction methods.

2.4. Mineral Phosphorus Application, Liming and Incubation of the Soils

Lime requirements (LR) of the soils were determined to identify the correct quantity of lime to be added in each soil to obtain target pH values of 5.5, 6.5 and 7.2. In each of four bottles containing 10 g soil, an increasing volumes (0, 3, 6, and 9 mL) of 10 mM calcium hydroxide ($Ca(OH)_2$) solution was added. Then deionized H_2O was added to a total liquid volume of 25 mL, so that 1:2.5 w/v ratios of soil to solution were obtained. The bottles were shaken frequently for 7 days, and at the end of this equilibration period, the soil pH values were recorded. Next, mmolc $Ca(OH)_2$ g^{-1} soil that was used to achieve the target pH values was calculated, and this was extrapolated at field level (tones of equivalent $CaCO_3$ ha^{-1}) assuming a depth of incorporation of 30 cm and a bulk density of a value that was measured from core sample. After the liming test, 5 Kg soil samples were placed into pots and three levels of lime, as obtained from LR calculation for the three target pH values, were added to the soils in pots and thoroughly mixed and watered to field capacity. The treated soils were incubated for 56 days at room temperature. After 56 days of incubation, mineral phosphorus was added to the four soil samples as KH_2PO_4 in rates equivalent to 0, 50, 100, and 150 mg P kg^{-1} soil. Then the soils were mixed thoroughly and watered to field capacity. Control samples (without additions of P and lime) were included. Lime was analytical grade fine-sieved $CaCO_3$ powder. All the treatments and controls were in replicates. The resultant 128 pots (4 soils x 4 P levels x 4 lime levels x 2 replicates) were placed in an illuminated greenhouse for additional 56 days. Thus, the total incubation period was about 110 days, which corresponds to one cropping season. Finally, effects of the treatments and measured soil properties on phosphorus adsorbing capacities of the different P pools (fractions) were investigated by P fractionation method.

2.5. Phosphorus Fractionation

At the end of incubation period (110 days), the replicate samples of each P treatment were sampled, air-dried, ground for the subsequent P determinations. The fractionation procedures were based on the differential solubility of the various inorganic P forms in various extracts (Kuo, 1996). Ammonium chloride (NH_4Cl) was used first to extract easily soluble and loosely bound P (ES-P), followed by separating Al-P from Fe-P with ammonium fluoride (NH_4F), then extracting Fe-P with sodium hydroxide (NaOH). The reductant-soluble P (RS-P) was extracted with sodium citrate-sodium dithionite-sodium bicarbonate extraction (CDB). The Ca-P was extracted with sulfuric acid (H_2SO_4) since Ca-P is insoluble in CDB.

The extraction procedures were as follows: Three replicates of 1.0 g (<2 mm) of soil were added into a 100 mL centrifuge tubes. Then, 50 mL of 1*M* NH_4Cl was added to each tube and shaken for 30 min to extract the soluble and loosely bound P. The supernatant was centrifuged and decanted into a 50-mL volumetric flask and brought to volume with deionized water (extract A). Next, 50 mL of 0.5 *M* NH_4F (pH 8.2) was added to the residue and the suspension was shaken for 1 h to extract aluminum phosphates. Again, the supernatant was centrifuged and decanted into a 100-mL volumetric flask (extract B). Then, the soil sample was washed twice with 25-mL portions of saturated NaCl and centrifuged. The washings were combined with extract B and brought to volume with distilled and deionized water. Next, 50 mL of 0.1 *M* NaOH was added to the soil residue and shaken for 17 h to extract iron phosphate. Then, the supernatant solution was centrifuged and decanted into a 100-mL volumetric flask (Extract C). The soil was washed twice with 25-mL portions of saturated NaCl and centrifuged and the washings were combined with extract C and brought to volume distilled and deionized water. Next, 40 mL of 0.3 *M* $Na_3C_6H_5O_7$ and 5 mL of 1 *M* $NaHCO_3$ were added to the residue and the suspension was heated in a water bath at 85 °C. Then, 1.0 g of $Na_2S_2O_4$ (sodium dithionate) was added and the suspension was stirred rapidly to extract reductant soluble P. After continuously heated for 15 min, the suspension was centrifuged. Then, the supernatant solution was decanted into a 100-mL volumetric flask (extract D). The residual soil was washed twice with 25- mL portions of saturated NaCl and centrifuged. The washings were combined with extract D and diluted to volume. Then, extract D was exposed to air to oxidize $Na_2S_2O_4$. Finally, 50 mL of 0.25 *M* H_2SO_4 was added to the soil residue and shaken for 1 h. The suspension was centrifuged for 10 min and the supernatant was decanted into a 100-mL volumetric flask (extract E). Then, the residual soil was washed twice with 25-mL portions of saturated NaCl, and centrifuged. The washings were combined with the extract E and diluted to volume.

After five extracts were obtained for extraction of P from the different pools, an aliquot containing 2 to 40 µg P was taken from each of extracts A, B, C, D, and E into separate 50-mL volumetric flasks. Then, some deionized water and five drops of *p*-nitrophenol indicator were added to the volumetric flasks containing extracts C and E and the pH was adjusted with 2 *M* HCl or 2 *M* NaOH until the indicator color changed. To the volumetric flask containing extract B, 15 mL 0.8 *M* H_3BO_3 was added. Phosphorus concentrations in the various solutions (extracts A, B, C, D and E) were determined using the ascorbic acid method (Murphey and Riley, 1962) by preparing P standards that contain the same volume of extracting solution as in the extracts. Total P was determined by digestion with perchloric acid ($HClO_4$) as described by Sommers and Nelson (1972). Soil P availability indices were determined using Bray I, Mehlich 3, and $CaCl_2$ extraction methods. Using the determined values of P in the different extracts (pools), distribution of applied mineral phosphorus in the different P pools, effects of liming and applied P rates on desorbable phosphorus from the different P pools were investigated.

2.6. Statistical Data Analysis

For all of the measured parameters, two-way analysis of variance (ANOVA) was performed; one factor being lime and the other added P. The statistical difference between means was evaluated at the level of $P < 0.05$ with the least significant differences test. Correlation analyses between soil properties and the P extracted from the P pools as well as total P were done. For the statistical analysis, SAS statistical package was used.

3. RESULTS AND DISCUSSION

3.1. Selected Physicochemical Properties and lime requirements of the Acid Soils

The soil samples were collected from regions of high rainfall and highly weathered soils. Properties of the soils such as low pH, high levels of available aluminum, clay sized oxides and hydroxides of metals such as iron and aluminum, deep red to bright orange-red color, low exchangeable cations and organic matter, and reduced fertility makes them likely be classified under Oxisols according to the USDA classification system, though there is no information on soil classification in the area. All the soils were collected from cultivated lands.

Selected chemical and physical properties of the soils are given in Table 1. The soils were acidic with low pH values. Clay contents of the soils were medium. The soils had high CEC. The soil contained very low organic matter. The soils contained large amounts of exchangeable acidities. The oxalate extractable concentration ranges of acidic cations were 932 to 1134, 584 to 823, and 9.83 to 13.86 mg Kg^{-1} for Fe, Al and Mn respectively. The soil had very low available P form. This low available P could be due to high acidity and high P fixing cations of the soils. This is because the soils are highly weathered, typical acid soils with high concentrations of acidic cations aluminum, iron and manganese occurring either as free cations in the soil solution, as exchangeable cations occupying the best part of the available exchangeable sites of soil colloids, or as mineral oxide clay-sized colloids with various levels of crystallinity. Such acidic cations react with P species, dramatically reducing their activity (Brady and Weil 2014). Once sorbed onto oxide surfaces, P is capable of being only poorly desorbed, and P retention becomes progressively stronger with time (Martin, *et al.,* 2002). In addition, the soils showed significant differences in their P availabilities. This could be due to differences in their clay contents, cultivation and other soil management activities. This is in agreement with the work that reported that the distribution of inorganic P forms in soils reflect genetic differences, degree of chemical weathering, and fertilizer practices among soils (Sharpley and Smith 1983).

Table 1. Selected Physico-chemical properties of the soils

Soil Parameters	Soils			
	Boji Dirmaji	Nedjo	Kiltu Karra	Mene Sibu

(1:2.5 Soil/H_2O)	4.70	4.39	4.82	4.35
k density (g cm^{-3})	1.14	1.26	1.33	1.16
y (%)	55	48	46	45
C (cmolc Kg^{-1})	28	25	22	20
:h. Ca^{2+}	2.41	3.53	2.14	2.44
:h. Mg^{2+}	1.26	1.62	0.74	0.86
:h. K^{+}	0.26	0.32	0.17	0.18
ɔ) (mg Kg^{-1})	976	1120	932	1134
ɔ) (mg Kg^{-1})	584	722	764	823
(O) (mg Kg^{-1})	9.83	13.34	14.18	13.86
:h. acidity (cmolc Kg^{-1})	1.62	1.31	1.74	1.66
ıy I P (mg Kg^{-1})	1.82	1.45	1.12	1.64
hlich 3 P	6.12	3.48	4.32	8.64
Cl_2 P	0.03	0.04	0.12	0.13
:otal) (mg Kg^{-1})	384.82	392.12	298.46	367.74
M (g Kg^{-1})	1.24	1.84	2.28	3.14

$Fe_{(O)}$, $Al_{(O)}$ and $Mn_{(O)}$ stands for 0.2*M* ammonium oxalate extractable Fe, Al, and Mn respectively, SOM = Soil organic matter, CEC = Cation exchange capacity

Lime requirement of the soils to raise the pH to target values of 5.5, 6.5 and 7.2 (Appendix Table 1) varied from 4.27 to 4.70; 5.38 to 6.44 and 6.98 to 8.18 tons $CaCO_3$ ha^{-1} respectively.

3.2. Transformations and Distributions of Applied P in the Different P Fractions

The forms and distribution of P in soils provide useful information in assessing P mode of transformations, status of available P and degree of chemical weathering in soils. The total P and plant available P indices of the treated soils were indicated in Appendix Table 2. For the four soils, distribution of applied P in different fractions is presented in Tables 2a, 2b, 2c and 2d. The extracted amounts of easily soluble P (ES-P), which are readily soluble and considered to be biologically available P (labile P) were much lower than those of residual P in all of the P and lime treated soils.

Table 2a. Effect of treatments on Phosphorus fractions, cumulative recovery and percent recovery of applied P in Boji Dirmaji soil

atment	P Fractions (mg Kg^{-1})						Cum.P Recov	%P Recov
	ES-P	Al-P	Fe- P	RS-P	Ca-P	Org.P		
P_0L_0	0.73^{i}	5.01^{m}	13.6^{n}	0.07^{m}	0.12^{j}	0.83^{m}	C	C
P_0L_1	0.82^{i}	4.93^{m}	13.2^{o}	0.12^{m}	0.89^{h}	1.14^{l}	C	C
P_0L_2	1.19^{h}	9.71^{l}	13.95^{m}	0.37^{l}	0.38^{i}	1.92^{k}	C	C
P_0L_3	2.3^{g}	9.54^{l}	14.35^{l}	0.74^{k}	0.86^{h}	1.16^{l}	C	C
P_1L_0	3.21^{f}	17.42^{i}	14.44^{l}	1.01^{j}	1.64^{g}	2.14^{j}	19.50	39.00
P_1L_1	3.07^{f}	15.93^{j}	33.33^{j}	1.87^{i}	1.58^{g}	2.36^{i}	37.04	74.08
P_1L_2	3.16^{f}	22.58^{h}	35.86^{i}	3.11^{f}	2.64^{f}	3.78^{e}	43.61	87.22
P_1L_3	3.59^{e}	23.77^{g}	32.48^{k}	2.65^{g}	7.61^{b}	3.52^{f}	44.67	89.34

P_2L_0	4.82^{b}	15.65^{k}	47.02^{h}	2.25^{h}	5.51^{c}	2.42^{h}	57.31	57.31
P_2L_1	3.76^{e}	24.47^{f}	55.86^{g}	3.06^{f}	3.57^{e}	3.46^{g}	73.08	73.08
P_2L_2	4.39^{c}	36.84^{e}	66.08^{d}	4.29^{d}	7.65^{b}	4.75^{c}	96.48	96.48
P_2L_3	4.05^{d}	36.93^{e}	58.35^{f}	3.57^{e}	7.75^{a}	4.63^{d}	86.33	86.33
P_3L_0	4.74^{b}	39.38^{d}	59.82^{e}	7.99^{a}	5.51^{c}	3.44^{g}	100.52	67.01
P_3L_1	5.68^{a}	45.4^{c}	76.84^{c}	5.02^{c}	3.5^{e}	3.76^{e}	119.1	79.40
P_3L_2	4.77^{b}	50.29^{a}	98.6^{a}	6.85^{b}	7.78^{a}	6.92^{a}	147.69	98.46
P_3L_3	5.66^{a}	48.96^{b}	91.4^{b}	4.21^{d}	5.35^{d}	6.87^{b}	133.5	89.00
CV	3.90	0.577	0.299	3.42	1.53	0.800		
F- test	***	***	***	***	***	***		
R^2	0.994	0.999	0.999	0.998	0.999	0.999		

Means followed by the same letter within a column are not significantly different at $P > 0.001$; CV = coefficient of variation; *** = significantly different at $p < 0.001$; R^2 = correlation coefficient; C = P control sample; ES-P = easily soluble P; Al-P = Al bound P; Fe-P = Fe bound P; Ca-P = Ca bound P; RS-P = reductant soluble P; Org.-P = Organic P; P_0, P_1, P_2, and P_3 are P rates (kg P ha^{-1}) at 0, 52.77,105.51and 158.29; and L_0, L_1, L_2 and L_3 are lime rates (tons ha^{-1}) at 0, 4.27, 5.98 and 7.69. Means down the column with the same superscript letters are not significantly different. The means separating superscript letters work only down the columns.

Table 2b. Effect of treatments on Phosphorus fractions, cumulative recovery and percent recovery of applied P Nedjo soil

atment	P Fractions (mg Kg^{-1})						Cum.P	%P
	-P	P	P	-P	-P	g.P	Recov	Recov.
P_0L_0	0.18^{l}	5.28^{m}	7.76^{m}	0.42^{o}	0.8^{n}	1.24^{l}	C	C
P_0L_1	0.36^{k}	4.11^{n}	6.26^{o}	1.01^{n}	0.38^{o}	1.35^{k}	C	C
P_0L_2	0.67^{j}	6.92^{l}	13.93^{l}	1.74^{m}	1.33^{m}	2.13^{j}	C	C
P_0L_3	0.54^{j}	7.18^{k}	7.01^{n}	1.97^{l}	1.69^{l}	2.28^{i}	C	C
P_1L_0	1.45^{i}	17.79^{h}	16.86^{j}	4.15^{j}	3.18^{k}	2.14^{j}	29.89	59.78
P_1L_1	1.51^{i}	16.32^{i}	14.17^{k}	3.83^{k}	8.2^{i}	2.16^{j}	32.72	65.44
P_1L_2	3.59^{g}	17.92^{h}	27.61^{i}	4.42^{i}	13.43^{e}	3.22^{g}	43.47	86.94
P_1L_3	2.96^{h}	12.09^{j}	27.86^{h}	4.65^{h}	15.28^{b}	3.24^{g}	45.41	90.82
P_2L_0	4.89^{f}	20.05^{g}	37.91^{g}	8.88^{g}	12.82^{c}	3.46^{f}	72.33	72.33
P_2L_1	5.18^{e}	26.79^{f}	42.01^{f}	10.97^{f}	7.25^{j}	2.65^{h}	81.38	81.38
P_2L_2	7.92^{c}	32.98^{e}	48.06^{e}	13.06^{c}	14.82^{c}	4.78^{c}	94.9	94.90
P_2L_3	7.12^{d}	33.24^{d}	41.94^{f}	11.7^{d}	12.02^{g}	4.19^{e}	89.54	89.54
P_3L_0	7.89^{c}	33.29^{d}	53.58^{d}	12.52^{d}	10.28^{h}	4.54^{d}	106.42	70.95
P_3L_1	7.81^{c}	40.13^{c}	60.2^{c}	14.15^{b}	10.3^{h}	4.86^{b}	123.98	82.65
P_3L_2	9.89^{a}	55.24^{a}	82.43^{b}	15.02^{a}	18.15^{a}	5.62^{a}	159.63	106.42
P_3L_3	8.62^{b}	42.23^{b}	85.65^{a}	12.34^{d}	13.82^{d}	3.47^{f}	145.46	96.97
CV	2.30	0.399	0.331	1.634	1.072	0.854		
F- test	***	***	***	***	***	***		
R^2	0.999	0.999	0.999	0.999	0.999	0.999		

Means followed by the same letter within a column are not significantly different at $P > 0.001$; CV = coefficient of variation; *** = significantly different at $p < 0.001$; R^2 = correlation coefficient; C = P control sample; ES-P = easily soluble P; Al-P = Al bound P; Fe-P = Fe bound P; Ca-P = Ca bound P; RS-P = reductant soluble P; Org.-P = Organic P; P_0, P_1, P_2, and P_3 are P rates (kg P ha^{-1}) at 0, 52.77,105.51and 158.29; and L_0, L_1, L_2 and L_3 are lime rates (tons ha^{-1}) at 0, 4.34, 6.24 and 8.13. Means down the column with the same superscript letters are not significantly different. The means separating superscript letters work only down the columns.

Table 2c. Effect of treatments on Phosphorus fractions, cumulative recovery and percent recovery of applied P in Kiltu Karra soil

atment	P Fractions (mg Kg^{-1})						Cum.P	%P
	-P	P	P	-P	-P	g.P	Recov.	Recov.
P_0L_0	0.48^{l}	1.34^{p}	10.42^{o}	0.45^{l}	0.87^{l}	2.16^{n}	C	C
P_0L_1	0.25^{l}	2.34^{o}	13.42^{n}	0.76^{k}	0.73^{l}	2.42^{m}	C	C
P_0L_2	0.78^{k}	3.15^{n}	15.33^{m}	0.34^{l}	1.10^{k}	3.11^{l}	C	C
P_0L_3	1.19^{j}	3.78^{m}	16.57^{l}	0.86^{k}	1.48^{j}	3.28^{k}	C	C
P_1L_0	2.11^{i}	8.050^{l}	16.66^{l}	6.05^{i}	5.64^{g}	3.10^{l}	25.89	51.78
P_1L_1	2.94^{h}	12.43^{k}	25.46^{j}	5.61^{j}	5.38^{h}	3.48^{j}	35.38	70.76
P_1L_2	4.94^{g}	24.36^{i}	26.48^{i}	6.44^{h}	4.70^{i}	4.19^{i}	47.3	96.60
P_1L_3	4.96^{g}	20.67^{j}	24.53^{k}	7.76^{ef}	7.39^{d}	4.30^{h}	42.45	84.90
P_2L_0	8.27^{e}	27.56^{g}	30.00^{h}	7.89^{e}	8.76^{c}	4.45^{g}	71.21	71.21
P_2L_1	5.82^{f}	25.85^{h}	37.33^{g}	7.45^{g}	7.05^{e}	4.83^{f}	68.41	68.41
P_2L_2	8.38^{e}	37.22^{e}	57.73^{d}	7.54^{fg}	5.78^{g}	5.99^{c}	98.83	98.83
P_2L_3	10.05^{d}	30.31^{f}	51.24^{f}	7.89^{e}	11.19^{a}	5.92^{c}	89.44	89.44
P_3L_0	11.01^{c}	40.94^{c}	52.44^{e}	8.81^{c}	9.70^{b}	5.66^{e}	112.84	75.22
P_3L_1	10.88^{c}	47.16^{b}	68.48^{c}	8.29^{d}	6.75^{f}	5.82^{d}	127.46	84.97
P_3L_2	12.92^{a}	50.00^{a}	91.28^{a}	9.95^{b}	8.89^{c}	7.96^{a}	157.19	104.79
P_3L_3	12.53^{b}	39.80^{d}	84.08^{b}	10.52^{a}	11.23^{a}	7.26^{b}	138.26	92.17
CV	2.735	0.626	0.517	2.921	1.741	1.252		
F test	***	***	***	***	***	***		
R^2	0.999	0.999	0.999	0.998	0.999	0.999		

Means followed by the same letter within a column are not significantly different at $P > 0.001$; CV = coefficient of variation; *** = significantly different at $p < 0.001$; R^2 = correlation coefficient; C = P control sample; ES-P = easily soluble P; Al-P = Al bound P; Fe-P = Fe bound P; Ca-P = Ca bound P; RS-P = reductant soluble P; Org.-P = Organic P; P_0, P_1, P_2, and P_3 are P rates (kg P ha^{-1}) at 0, 52.77,105.51and 158.29; and L_0, L_1, L_2 and L_3 are lime rates (tons ha^{-1}) at 0, 4.46, 5.38 and 6.98. Means down the column with the same superscript letters are not significantly different. The means separating superscript letters work only down the columns.

Table 2d. Effect of treatments on Phosphorus fractions, cumulative recovery and percent recovery of applied P in Mene Sibu soil

atment	P Fractions (mg Kg^{-1})						Cum.P	%P
	-P	P	P	-P	-P	g.P	Recov	Recov
P_0L_0	0.46^{kl}	2.77^{n}	14.15^{m}	1.60^{k}	0.66^{l}	4.43^{i}	C	C
P_0L_1	0.56^{k}	2.42^{o}	13.3^{o}	1.39^{kl}	1.59^{k}	4.17^{j}	C	C
P_0L_2	0.24^{l}	3.01^{n}	13.94^{mn}	2.15^{j}	2.38^{j}	5.26^{h}	C	C
P_0L_3	0.64^{k}	3.36^{m}	14.70^{l}	2.36^{j}	2.88^{j}	5.28	C	C
P_1L_0	1.10^{j}	6.00^{l}	13.70^{n}	1.16^{l}	3.30^{i}	5.28^{h}	6.47	12.94
P_1L_1	1.78^{i}	12.52^{k}	16.32^{k}	2.32^{j}	4.43^{h}	5.88^{g}	19.82	39.64
P_1L_2	3.06^{g}	13.57^{j}	28.64^{i}	3.45^{i}	5.43^{f}	7.38^{d}	34.55	69.10
P_1L_3	2.82^{h}	14.8^{i}	22.75^{j}	4.60^{g}	4.95^{g}	7.06^{e}	27.76	55.52
P_2L_0	2.85^{gh}	16.24^{h}	47.85^{g}	4.24^{h}	4.76^{gh}	4.25^{ij}	56.12	56.12
P_2L_1	3.91^{f}	35.15^{g}	47.19^{h}	4.15^{h}	5.57^{ef}	4.32^{ij}	76.86	76.86

P_2L_2	4.50^e	40.21^d	68.27^c	8.84^d	8.80^c	6.49^f	110.13	110.13
P_2L_3	4.95^d	38.31^f	60.15^e	7.99^f	4.75^{gh}	6.90^e	93.83	93.83
P_3L_0	5.90^c	39.40^e	58.54^f	8.40^e	5.92^e	6.62^f	100.71	67.14
P_3L_1	6.53^b	56.94^c	65.48^d	9.28^c	6.50^d	8.12^c	129.42	86.28
P_3L_2	9.72^a	70.24^a	83.13^a	12.94^a	13.30^a	10.92^b	173.27	115.51
P_3L_3	6.53^b	61.50^b	70.72^b	10.5^b	9.35^b	12.19^a	141.57	94.38
CV	4.045	0.656	0.378	2.948	4.174	2.272		
F- test	***	***	***	***	***	***		
R^2	0.998	0.999	0.999	0.998	0.996	0.997		

Means followed by the same letter within a column are not significantly different at P > 0.001; CV = coefficient of variation; *** = significantly different at $p < 0.001$; R^2 = correlation coefficient; C = P control sample; ES-P = easily soluble P; Al-P = Al bound P; Fe-P = Fe bound P; Ca-P = Ca bound P; RS-P = reductant soluble P; Org.-P = Organic P; P_0, P_1, P_2, and P_3 are P rates (kg P ha^{-1}) at 0, 52.77,105.51and 158.29; and L_0, L_1, L_2 and L_3 are lime rates (tons ha^{-1}) at 0, 4.70, 6.44 and 8.18. Means down the column with the same superscript letters are not significantly different. The means separating superscript letters work only down the columns.

This indicates low P availability and infrequent as well as low P fertilizer application in these soils. The amounts of P extracted by sodium hydroxide (NaOH) and ammonium fluoride (NH_4F) were much greater than the other fractions of inorganic P. These inorganic P forms are iron oxide bound P (Fe-P) and aluminum oxide bound P (Al-P) forms respectively, and their occurrence in greater amounts evidences that the soils were highly weathered and rich in clay sized oxides. The relatively very large Fe-P fraction indicates that the soils contain high content of iron oxides that fix P. This is a common property of highly weathered acid soils of high rainfall regions (Verma, *et al.,* 2005; Tiecher, *et al.,* 2013). The lower RS-P fraction may be due to the fact that the soils contain large quantities of iron and aluminum oxides that the less soluble P forms exist in these fractions rather than in reductant soluble forms. On average, the P fraction in the four soils followed the order: Fe-P > Al-P > Ca-P > ES-P > RS-P. All these observations were also reported by several investigators (Dobermann, *et al.,* 2002; Zheng *et al.,* 2002; Zheng *et al.,* 2003; Verma *et al.,* 2005).

The correlations of P-fractions with the P taken up by plants were studied by several researchers and it was reported that the various P pools (fractions) are important source of available P in soils (Lopez-Pineiro and Garcia-Navaro, 2001). However, according to the present study, the various P fractions correlated with the P availability indices in large differences (Table 3.). The ES-P and Al-P fractions were highly significantly correlated to the three P availability indices and organic P significantly correlated to Bary I-P and Mehlich 3-P. However, the other P fractions did not correlate to the P availability indices except Fe-P with Mehlich 3-P which correlated significantly at $p < 0.01$.

Table 3. Linear correlation coefficients for availability indices and P forms

:actions	P availability indices		
	Bray I –P	Mehlich 3-P	$CaCl_2$-P
:al P ($HClO_4$)	NS	NS	NS
-P	0.91***	0.96***	0.82**
P	0.94***	0.86***	0.84**
P	NS	0.80**	NS
-P	NS	NS	NS
-P	NS	NS	NS
;.- P	0.79**	0.76*	NS

*,**, *** = Significant at P < 0.05, 0.01, 0.001 respectively and NS = not significant
ES-P = easily soluble P; Al-P = Al bound P; Fe-P = Fe bound P; Ca-P = Ca bound P; RS-P = reductant solubleP; Org.-P = Organic P

3.3. Effects of Selected Soil Properties on Extractable Phosphorus in the Different P Pools

The correlations between selected soil parameters and the P extracted from different pools are listed in Table 4. Clay content was highly correlated with total P, Fe-P, Ca-P, organic P and Bray I -P (R^2 = 0.86, 0.76, 0.88, 0.89 and 62 respectively at $p < 0.01$ and $p < 0.05$). This could be attributed to the properties of clay and clay-sized minerals that influence P adsorption and availability in acid soils. As the clay content increases, the proportions of P accumulating (adsorbing) soil components increases and as a result the desorbable total P increases. There was very strong correlation between CEC and several P fractions such as total P, Fe-P, Ca-P, organic P (R^2 = 0.92, 0.98, 0.89 and 0.78 respectively at $p < 0.001$ and $p < 0.01$). This is because soil colloids with high CEC adsorb phosphate ions strongly and in turn, the adsorbed phosphate ions alter the surface properties of colloids and impact the CEC. Exchangeable acidity also significantly correlated to Ca-P, organic P, BrayI-P and Mehlich 3-P (0.66, 0.72, 0.66 and 0.69 respectively at $p < 0.05$). This can be attributed to the fact that exchangeable acid cations of H^+ and/or Al^{3+} on the active sites of soil particle would exchange to relatively soluble cations such as K^+, Ca^{2+} etc, losing their adsorbed phosphate ions. As may be expected, pH was significantly correlated with a number of the P fractions. This is because many of soil reactions including P adsorption/desorption and surface properties of soils highly dependent on pH of the soils.

Table 4. Linear correlation coefficients for selected soil properties and P forms

		:lay	C	ɔ)	ɔ)	(O)	acidity	M
:al P	1*	6**	2***				8**	
-P			4*					
P	7**				8**			

P	7^{**}	6^{**}	8^{***}	6^{**}				5^{*}
-P								
·P	6^{**}	8^{**}	9^{**}				6^{*}	4^{*}
ganic P		9^{**}	8^{**}				2^{*}	6^{**}
y I –P	4^{*}	2^{*}					6^{*}	
hlich 3-P	7^{*}		2^{*}	5^{*}			9^{*}	
Cl$_2$-P			2^{*}					

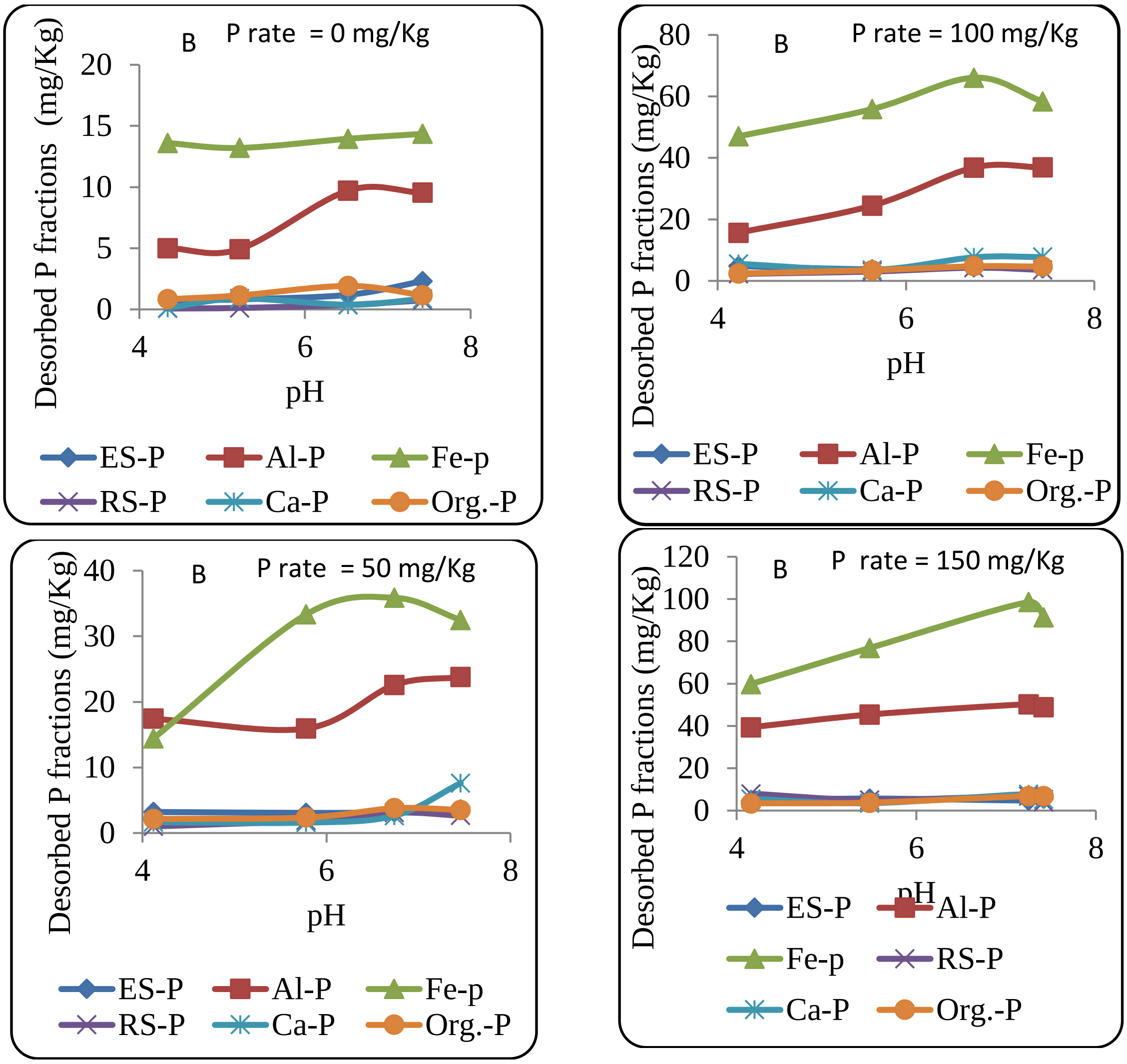
*,**, *** = Significant at $P < 0.05$, 0.01, 0.001 respectively; NS = not significant; ES-P = easily soluble P; Al-P = Al bound P; Fe-P = Fe bound P; Ca-P = Ca bound P; RS-P = reductant solubleP; Org.-P = Organic; SOM = soil organic matter, CEC = cation exchange capacity

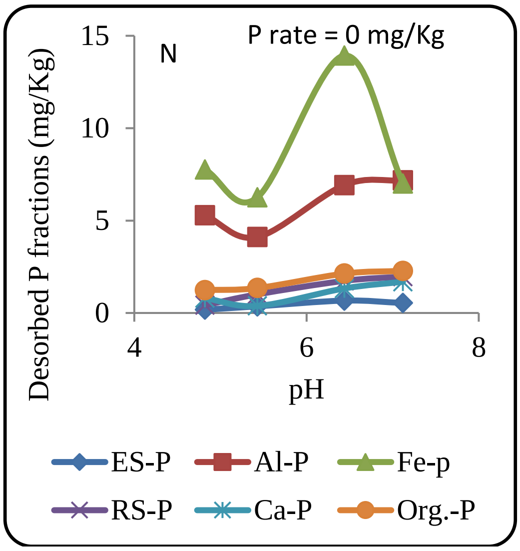
3.4. Effect of pH on Desorption of Applied P in the Different P Fractions

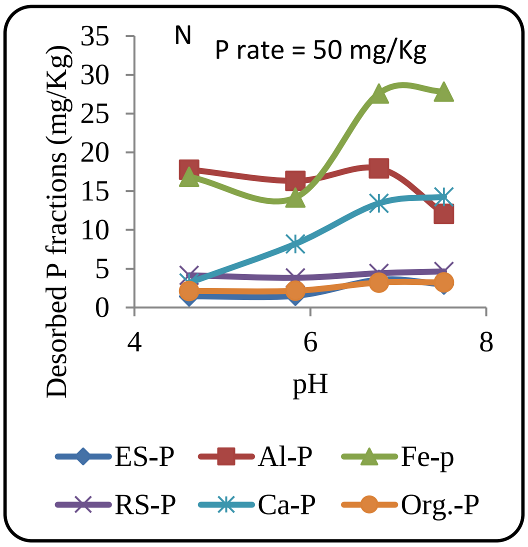
Desorptions of P in the various fractions (pools) were differently affected by the soil pH (Figure 1). The soil pH values were varied according to the lime and mineral P treatments. In general, desorption of P in the Fe-P and Al-P fractions were highly affected by the pH while desorption of P in the other fractions were modestly affected. This is because as pH of the soil increases the OH^- concentration increases and competes with P (PO_4^{3-}) for the positive sites on the Fe and Al oxide surfaces. Maximum P desorptions in the Fe-P fraction were observed at pH values of 7.25, 7.40, 7.25 and 7.27 for Boji Dirmaji, Nedjo, Kiltu Karra and Mene Sibu soils respectively. For the Al-P pool, maximum desorptions were obtained at pH values 7.25, 7,45, 7.25 and 7.27 and all were near to that of Fe-P fractions. Desorptions of P in the ES-P, RS-P, Ca-P and org.-P were slightly increased with pH and maximum desorption values were observed after pH value of 5.5.

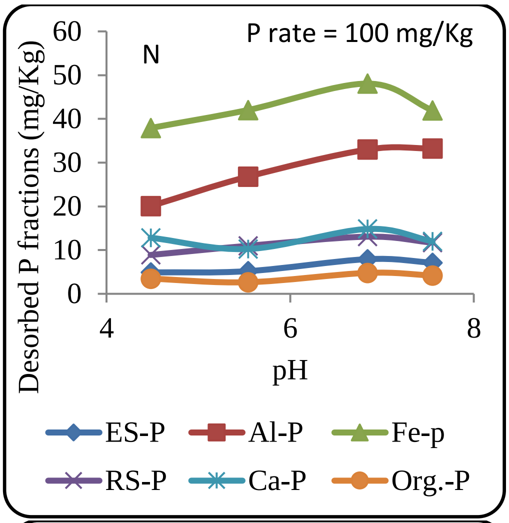
In general, at higher pH P (PO_4^{3-}) was more increasingly desorbed. This could be attributed to the effect of increased OH^- concentration that competes for positive sites on the surfaces of soil colloids and makes PO_4^{3-} ions less attracted. However, there was no uniform increment of P desorption. The maxima desorptions lied between about 5.5 to 7.25 depending on the sample backgrounds and level of treatments. However, at very high pH, P solubility began to decrease due to Ca-P mineral precipitation. This observation is in agreement with the results reported by Hartikainen and Simojoki (1997), Devau *et al*. (2011) and Weng *et al*. (2011). Researchers forwarded different reasons to explain the non uniformity of pH effects on P desorption. Harsh and Doner (1985) hypothesized based on their studies with P sorption onto hydroxy-Al-interlayered montmorillonite that increasing pH led to an increased stability of the hydroxy-Al interlayers and, therefore, to an increased P sorption and hence low P desorption. Hartikainen and Simojoki (1997) attributed the increased P solubility at low pH to the dissolution of Ca-P minerals such as apatite, which are known to exist also in acid soils

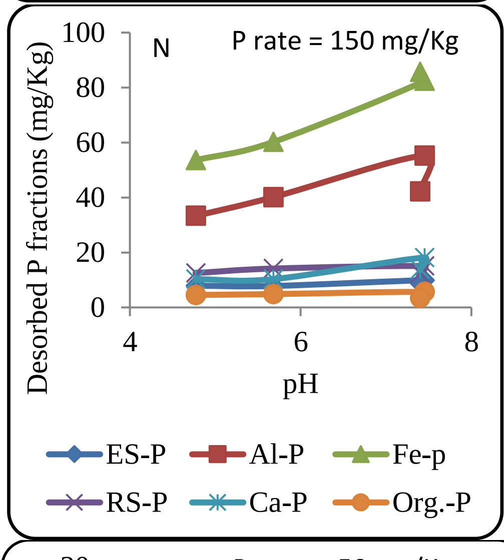
(Beauchemin *et al*., 2003). The sample background (pre treatments properties of the soils), applied mineral P rates and lime rates contributed to the varying P desorption maxima of the four soils. The larger the applied P rate, the higher the P desorption observed. This could be due to the fact that as the sorption sites on the soil colloids became saturated, P in the form of PO_4^{3-} became less adsorbed and stay in the solution form. This was observed in all of the four soils. The variation in P desorption among the soils types could be due to differences in clay mineralogy of the soils. The effect of liming rates depended on the rates of applied P. in relative term, desorptions of the residual P were less influenced by the liming and hence by the pH.

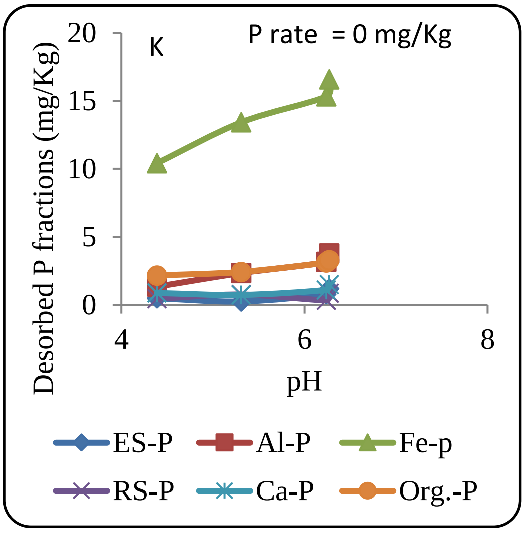


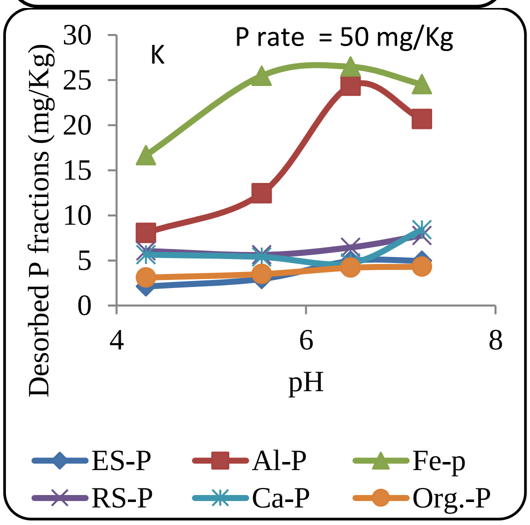

N
P rate = 0 mg/Kg
Desorbed P fractions (mg/Kg)
15
10
5
0
4
6
8
pH
ES-P
Al-P
Fe-p
RS-P
Ca-P
Org.-P


N
P rate = 50 mg/Kg
Desorbed P fractions (mg/Kg)
35
30
25
20
15
10
5
0
4
6
8
pH
ES-P
Al-P
Fe-p
RS-P
Ca-P
Org.-P


N
P rate = 100 mg/Kg
Desorbed P fractions (mg/Kg)
60
50
40
30
20
10
0
4
6
8
pH
ES-P
Al-P
Fe-p
RS-P
Ca-P
Org.-P


N
P rate = 150 mg/Kg
Desorbed P fractions (mg/Kg)
100
80
60
40
20
0
4
6
8
pH
ES-P
Al-P
Fe-p
RS-P
Ca-P
Org.-P


K
P rate = 0 mg/Kg
Desorbed P fractions (mg/Kg)
20
15
10
5
0
4
6
8
pH
ES-P
Al-P
Fe-p
RS-P
Ca-P
Org.-P


K
P rate = 50 mg/Kg
Desorbed P fractions (mg/Kg)
30
25
20
15
10
5
0
4
6
8
pH
ES-P
Al-P
Fe-p
RS-P
Ca-P
Org.-P

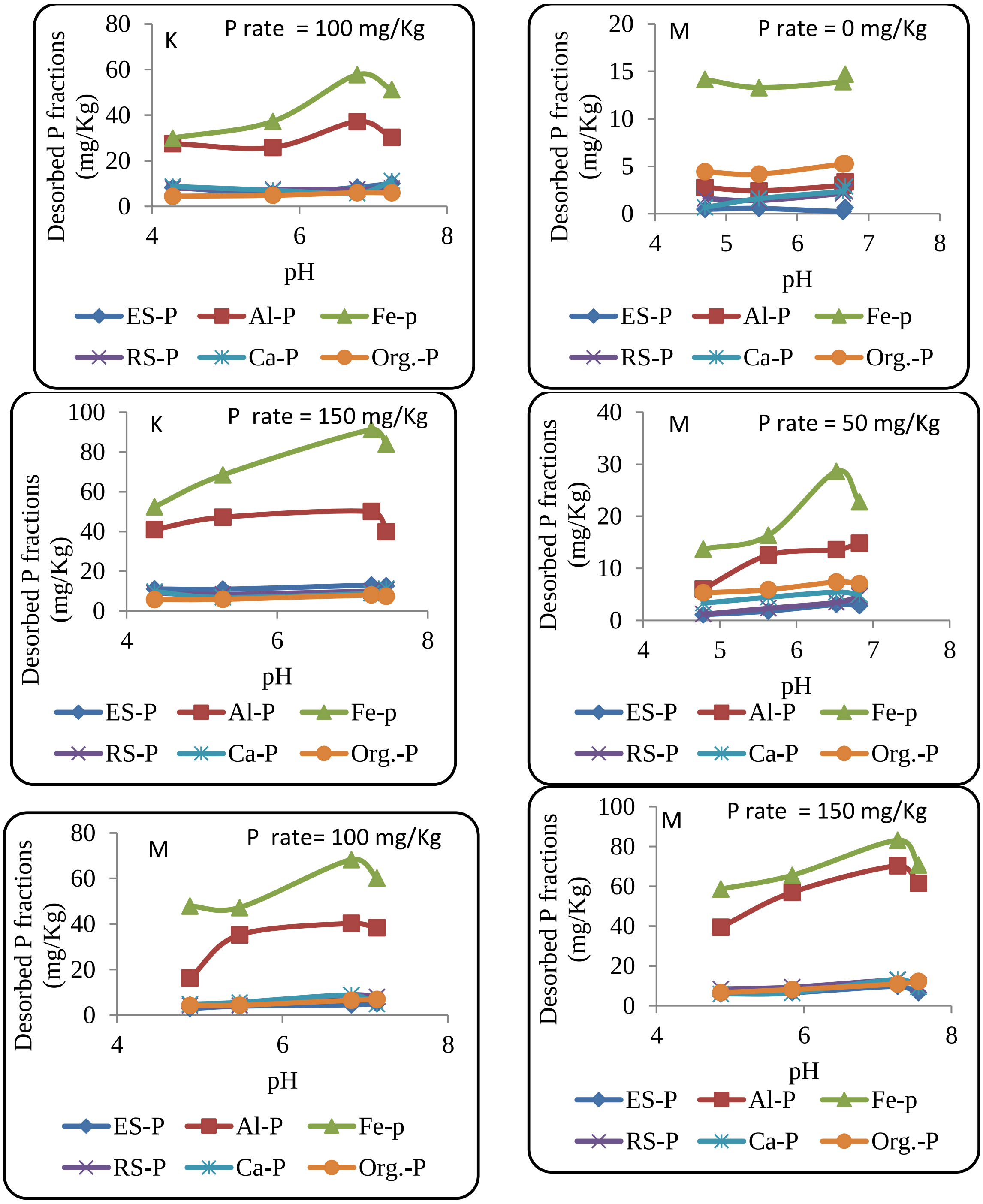


Figure 1. Effect of pH on desorbable P fractions at different applied P rate in the four soils B = Boji Dirmaji soil; N = Nedjo soils; K = Kiltu Karra soil; M = Mene Sibu soils; ES-P = easily soluble P; Al-P Aluminum bound P; Fe-P = Iron bound P; RS-P = Reductant soluble P; Ca-P = Calcium bound P; Org.-P = organic P

3.5. Effect of P Rates and Liming on Distributions of Applied P in the P Fractions

The effects of liming and applied P on the P fractions and total P recovery are presented in Table 5. The recovered mean percentage distributions of the applied P were significantly different among the sample types and P treatments. This could be attributed to three facts: first, these soils are acidic and elements such as aluminum, iron and manganese and clay sized sesquioxides are abundant adsorb P in different degrees; second, the different levels of P applications contribute different amounts of P to each P fractions; third, the extracting abilities of the different extractants lead to different amounts of extracted P.

Although the effect of lime treatment was low compared to P application, liming brought considerable effect on the cumulative amounts of P fractions recovered. This can be seen by comparing the amounts of P recovered from no lime and high level of lime treatments in which P level was constant. For example, the ES-P recovered from P_3L_0 ranges from 4.74 to 11.01 mg P Kg^{-1} while that recovered from P_3L_3 ranges from 5.66 to 12.53 mg P Kg^{-1}. This shows that by applying appropriate rate of lime only about 17% of the already existing P could be made plant available. In general, the distribution patterns of the P fractions in the four soils showed that ES-P in Kiltu Karra, Al-P and organic P in Mene Sibu, Fe-P in Boji Dirmaji and RS-P and Ca-P in Nedjo soils were the dominant fractions. This could be attributed to differences in clay mineralogy, P application and soils managements of the sampling areas. However, the level and patterns of organic P fractions of the four soils were relatively similar. This is because organic matter contents of all the soils were very low.

Table 5. Range of the total recovery of the added phosphorus

Soils	Recovery ranges	Applied P rates (mg Kg^{-1})		
		50	100	150
iDirmaji	Range (%)	39.00 – 89.34	57.31 – 96.48	67.01 – 98.46
	Mean (%)	72.41	78.30	83.47
Nedjo	Range (%)	59.78 – 90.82	72.33 – 94.90	70.95 – 106 - 42
	Mean (%)	75.75	84.54	89.25
Kiltu Karra	Range (%)	51.78 – 96.60	71.21 – 98.83	75.22 – 104.79
	Mean (%)	76.01	81.97	89.29
Mene Sibu	Range (%)	12.94 – 69.10	56.12 – 110.13	67.14 – 115.51
	Mean (%)	44.30	84.25	90.83

CONCLUSION

In this experiment, P fractionation was carried out after incubating the strongly acid soils to study effect of liming on applied P distribution among the P pools. The soils were strongly acidic and have low levels of available P. The levels of acidic cations of Al and Fe were very high, therefore, the soils adsorb and fix large portion of added P.

The results of this incubation experiment showed that applications of mineral P and lime significantly increased the amounts of P desorbed from all of the P fractions. It was observed that appropriate liming rates could make the unavailable, even strongly fixed soil P to become plant available. Therefore, applying sufficient amounts of mineral P alone is not enough in regions of strongly acidic soils with high P fixing capacity. Rather, applying good quality liming materials with appropriate rates is among the best management strategies for the sustainable use of the potentially productive but strongly acidic and highly weathered farmlands in the high rainfall regions of Ethiopia. This amendment of strongly acid soils by liming has dual benefits. First, it minimizes the cost required to apply large quantity of mineral fertilizer by reducing P fixation. Second, it reduces environmental pollution caused due to excess application of mineral P. The effects of clay mineralogy of the soils and the most appropriate timing of lime application in relation to fertilizer application and planting crops are all important additional factors to be investigated in further research.

AKNOWLEDGEMENTS

This work was supported by Haramaya University research grant and Ethiopian Ministry of Education. We, thus, acknowledge these institutions and the staff members of the School of Natural Resources Management and Environmental Sciences and Department of Chemistry, Haramaya University, for providing us with the necessary supports to accomplish this work.

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APPENDIX TABLES

Appendix Table 1. Lime Requirements (LR) of the four soils (tons $CaCO_3$ ha^{-1})

ls	pH of the soils	Target pH Values		
		5.5	6.5	7.2

	LR (tons $CaCO_3$ ha^{-1})			
i Dirmaji	4.38	4.27	5.98	7.69
djo	4.82	4.34	6.24	8.13
tu Karra	4.39	4.76	6.58	8.98
ne Sibu	4.70	4.70	6.44	8.18

Appendix Table 2. Total P and available P indices of the soils (mg Kg^{-1})

Treatments	Boji Dirmaji				Nedjo			
	Total P	Bray I P	Mehlich 3P	$CaCl_2$ P	Total P	Bray I P	Mehlich 3P	$CaCl_2$ P
P_0L_0	384.82	1.82	3.12	0.03	392.12	1.45	3.48	0.04
P_0L_1	381.73	2.15	4.66	0.08	391.23	2.45	6.65	0.02
P_0L_2	384.66	2.51	9.41	0.19	394.61	3.53	8.73	0.13
P_0L_3	388.38	2.82	9.73	0.14	398.33	2.84	8.14	0.08
P_1L_0	396.78	2.15	5.32	0.14	398.71	2.23	8.22	0.11
P_1L_1	408.47	2.16	10.84	0.33	418.42	2.26	10.46	0.16
P_1L_2	421.77	2.46	13.16	0.58	428.71	2.46	14.46	0.24
P_1L_3	414.34	2.75	13.70	0.52	434.24	2.54	14.72	0.20
P_2L_0	410.83	1.58	7.18	0.42	445.88	1.46	10.46	0.16
P_2L_1	433.44	3.36	13.76	0.46	463.44	3.16	14.96	0.62
P_2L_2	461.23	4.55	15.25	0.72	481.93	4.22	16.52	0.78
P_2L_3	459.34	4.52	14.84	0.65	489.24	4.64	17.66	0.69
P_3L_0	470.48	2.75	9.25	0.44	517.38	2.96	10.92	0.54
P_3L_1	512.73	3.56	14.63	0.76	528.23	3.96	17.56	0.83
P_3L_2	531.65	7.38	18.48	0.92	541.52	7.88	19.84	1.22
P_3L_3	523.42	5.52	19.12	0.87	538.14	5.56	18.78	1.47

Appendix Table 2. (Continued)

Treatments	Kiltu Karra				Mena Sibu			
	Total P	Bray I P	Mehlich 3P	$CaCl_2$ P	Total P	Bray I P	Mehlich 3P	$CaCl_2$ P
P_0L_0	298.46	1.12	4.32	0.12	367.74	1.64	8.64	0.13
P_0L_1	290.83	2.85	4.85	0.12	361.43	2.25	8.29	0.10
P_0L_2	294.34	2.06	5.16	0.15	374.52	2.56	8.86	0.27
P_0L_3	296.63	2.82	5.84	0.18	382.48	2.82	12.12	0.28
P_1L_0	318.61	2.65	4.65	0.11	388.38	2.85	9.89	0.21
P_1L_1	318.42	2.16	5.16	0.18	400.17	2.66	12.66	0.28
P_1L_2	328.91	2.16	7.45	0.29	411.00	3.79	16.70	0.32
P_1L_3	334.84	2.24	7.24	0.30	415.94	3.24	14.94	0.36
P_2L_0	385.80	1.58	8.85	0.15	420.08	2.58	12.48	0.25
P_2L_1	363.73	3.37	9.27	0.82	437.34	3.36	17.32	1.32
P_2L_2	388.98	4.53	12.13	0.98	451.44	4.55	20.75	1.48
P_2L_3	399.14	4.52	10.82	0.90	462.54	4.52	17.52	1.92

P_3L_0	416.28	2.25	11.20	0.64	484.48	2.79	14.19	1.64
P_3L_1	428.63	4.56	14.16	0.82	509.23	3.56	20.76	2.22
P_3L_2	443.02	7.35	17.37	1.66	514.60	7.78	24.88	2.96
P_3L_3	438.17	5.56	15.96	1.89	513.92	5.57	22.97	2.89

P_0, P_1, P_2, and P_3 are P rates (mg/Kg) at 0, 50,100 and 150. L_0, L_1, L_2 and L_3 are lime rates (mg/Kg soil) at 0, 15.2, 30.4, and 45.6 for Boji Dirmaji; at 0, 14.5, 29.0, and 43.5 for Nedjo; 0, 13.5, 27.0, and 40.5 for Kiltu Karra and at 0, 18.5, 37, and 55.5 for Mene Sibu respectively.

EJED 2(2) 2019: 1 – 26

Ethiopian Journal of Environment and Development

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EVALUATION OF THE EFFECT OF PARTHENIUM (*Parthenium hysterophorus* L.) WEED DENSITY ON THE VEGETATIVE GROWTH AND GRAIN YIELD OF TEFF (*Eragrostis tef* Zucc. Trotter) *IN SHEWA-ROBIT DISTRICT, NORTH SHEWA, ETHIOPIA*

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Received: 10 May, 2019 /Accepted: 21 December, 2019

Abstract
Parthenium weed (*Parthenium hysterophorus* L.), is one of the top alien invasive weed species in more than 40 countries, including Ethiopia. It infests several crops and causes significant yield losses, the extent of which depends, among others, on the density of weed and characteristics of crop species. Therefore, the objective of this study was to evaluate the effect of Parthenium (*Parthenium hysterophorus L.*) weed density on vegetative growth and grain yield of teff (*Eragrostis tef* Zucc. Trotter) using field experiment. Factorial combination of two traditional teff landraces namely *Nech* and *Seregegna*; and three levels of weed density (0, 5% and 10%) were used in the study. The experiment was arranged in randomized complete block design (RCBD) with four replications. To determine the extent of growth and yield loss caused by weed treatment, the differences between the means recorded for each trait at each treatment and weed free control plot were compared using Two-way ANOVA and the Tukey`s significant difference test. The results obtained in the study revealed that there was statistically significant difference ($P \leq 0.05$) on the effect of Parthenium weed density on vegetative growth and grain yield of the two landraces of teff studied. However, the difference between landraces was not significant. The mean maximum grain yield/plot (738.5 ± 49.2 gram) was obtained from control plot and the lowest grain yield/plot (482.2 ± 57.8 gram) was recorded from 10% Parthenium weed density treatment plot, which makes percent yield loss of 34.6% compared to the control plot. This in turn corresponds to a yield loss of 640.75 kg/ha. In general, the observed yield loss with increasing density of weed might attribute to reduction in availability of moisture, soil nutrients and light. Thus, there is a need for proper management of Parthenium weed starting from early period of seedling emergence of the test crop.

Key Words: Eragrostis teff, Grain yield, *Parthenium hysterophorus*, vegetative growth, Weed density

1. Introduction

Among the biotic barriers of crop production, weeds take the foremost position in affecting crops more than agricultural pests in the world (Maskey, 1997). They cause a loss of agriculture productivity, primarily through crop growth and yield reduction that occurs due to their competitiveness and in the second place by raising the financial and labor input to control them (Agrow, 2003). Swanton *et al*. (2015) reported that the annual economic loss caused by noxious weeds at a global level has been estimated to be more than $100 billion.

Like other parts of the world, weed infestation is the chief production constraint in Ethiopia. Especially in recent years the problem has been exacerbated by the arrival of various alien noxious weed species (Kebede, 2000; EIAR, 2011). Among which, Parthenium weed (*Parthenium hysterophorus* L), is one of the top disastrous weed species reported to be introduced to the country accidentally in the 1980's through grain food aid for famine relief. Today, the weed infests many agricultural fields and causes severe yield losses in major food crops and has become a major problem for sustainable crop production (Tamado *et al*. 2002, Safdar *et al*. 2016). Tamado *et al.* (2002b) reported 40 to 90% sorghum grain yield reduction in eastern Ethiopia, due to Parthenium weed competition from plots which were left uncontrolled throughout the cropping season. Mitiku (2011) reported a grain yield loss 18.5% to 86.5% of common bean due to Parthenium weed in eastern Ethiopia. Asresie *et al*. (2010) also reported 79.5% yield loss of sorghum crop due to Parthenium invasion northeastern Ethiopia indicating the extent of damage caused by this weed species. More recently, Ali *et al* (2018) reported 3, 6, 8 and 15% yield loss of maize from Parthenium weed competition study conducted 2, 4, 6 and 8 weeks after crop emergence, respectively as compared with the season long weed-free treatment.

Teff (*Eragrostis tef* L.) is one of the most staple grain crops for more than 50 million people in Ethiopia (CSA, 2010). The grain of teff is ground to flour that can be fermented and made into the Ethiopian flat sour dough bread known as '*injera'*, which is the Ethiopian staple food(Gilbertson, *et al*.,1993). Abebe *et al*.(2007) also documented that teff grain has many important nutritional value, and it leads all of the other food crop grains by being vital source of dietary minerals (such as iron, calcium phosphorus and copper),and the essential amino acids needed for the body's growth and repair. Gilbertson, *et al.* (1993), documented that teff grain has two other important health related nutritional values. First, since teff grain lacks gluten, it can be used to produce gluten-free food products for people who are allergic to gluten. Secondly, whole teff grain is rich source of dietary fiber (bran), which is important in blood sugar management to prevent diabetes and in maintaining colon health. Besides to its high quality nutritional values for human consumers, teff has other significant economic importance for the farming community such as a profitable cash crop with a rewarding market value (Berhane *et al*. 2011), crop residue with high quality nutritional value for livestock feed (Tesfaye, 2001).

Although teff is adaptable to wide range of environmental conditions and highly tolerant to moisture stress and water logging conditions (Seifu, 1997), it is intolerant to weed infestations such as Parthenium (Rezene and Zerihun, 2001). However, so far quantitative information on the effect of Parthenium weed on growth and yield of teff is scanty. This study therefore, stems from this understanding and aimed at examining the growth and yield response of teff to varying densities of Parthenium weed treatment using a field experiment.

2. Materials and Methods

2.1 Description of the study area

The field experiment was carried out in Shewa Robit district situated between $39^{0}52'$ to $39^{0}58'$ E & $09^{0}57'$ to $10^{0}03'$ N at edge of the Great Rift Valley at an altitude of 1280 masl. It is found 225 Kms north east of Addis Ababa (Figure 1). The soil of the study area is clay loam with pH= 8.3, organic matter =3.7%, total nitrogen = 0.20% and available phosphorus= 5.3 ppm (Andargie *et al*., 2013). The mean maximum and minimum temperature is 31.23 ^{o}C and 13.3 ^{o}C respectively (North Shewa Agricultural office). The area receives an average annual rainfall of 851.7 mm, and the main rainy season is July to (North Shewa Agricultural office).

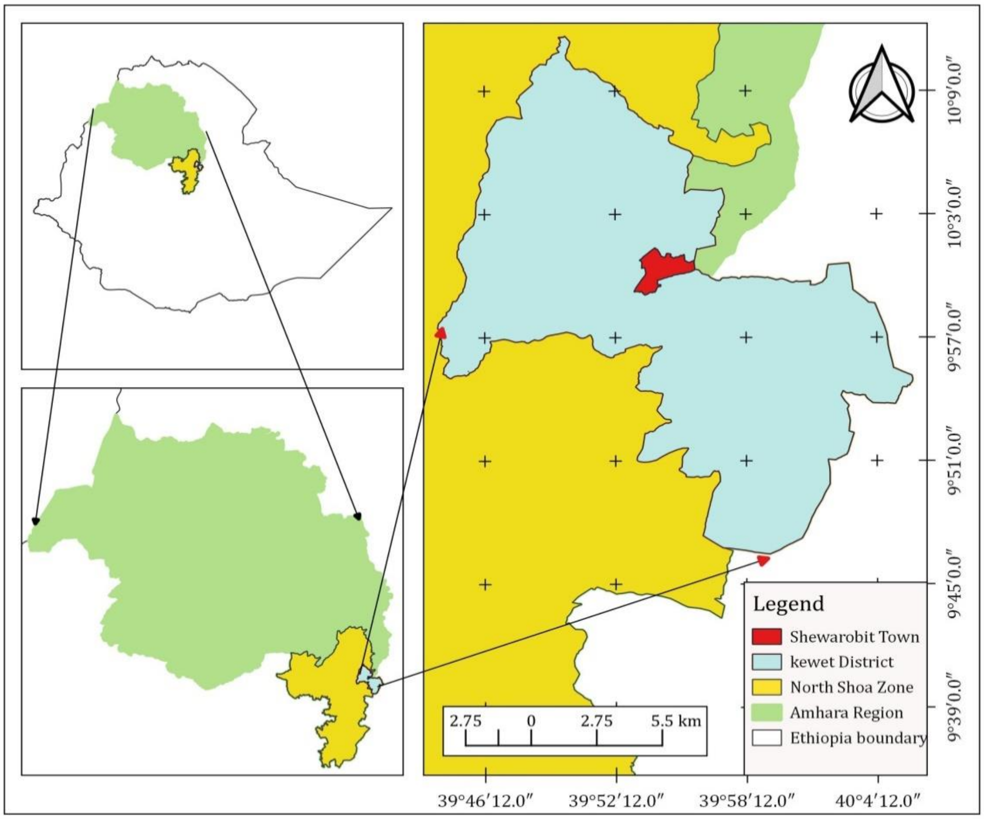

Figure 1 Location Map of the study area

2.2 Agricultural practices of the study area

The study area is characterized by cereal based cropping system and teff *(Eragostis tef)* and Sorghum *(Sorghum bicolor)* are the two major crops that are widely cultivated. However, teff is the most dominant and widely grown crop relative to sorghum.

2.3 Site Selection, Experimental Design and Treatments

Shoa Robit district-was selected as study site because it is heavily infested by Parthenium weed and known by teff production. The field experiment consisted of three weed densities (0, 5% and 10%) and two landraces of teff locally called *Nech* and *Seregegna teff*, which were arranged in randomized complete block design with four replications. The experimental plot of 2m by 2m was used for the study. In each treatment plot 2 gram of seed of test crop was sown with varying seed mass of Parthenium weed keeping the seed mass of the test crop constant following Rejamanek *et al*., (1989). Accordingly, a mixture of 2g seed of teff and 0.1g seed of Parthenium weed was sown in rows for 5 % of Parthenium weed density treatment plot. Similarly, a mixture of 2g seed of teff and 0.2g seed of Parthenium weed was sown in rows for 10 % of Parthenium weed treatment plot. Throughout the experiment other weeds, other than the experimental weed, were regularly removed by hand. The experiment was conducted during the main teff cropping season of the study area that is from July 2016 to October, 2016.

2.4 Data collection and measurement

2.4.1 Growth parameters

Data on vegetative growth such as height, leaf length and width and number of tillers were collected after 40 days of crop emergence. Measurement of stem height was made from the ground level to the tip of the longest and recently expanded leaf. Leaf length was measured from the base of leaf sheath to the tip and leaf width was taken at the broadest point of the lamina. Leaf area was estimated as a product of leaf length, leaf width, and 0.75 (shape factor). Measurement of plant height and leaf length and width was done using a ruler. On the other hand, tiller number on each plant was counted. Growth data were taken from 20 plants which were located at the central row of the experimental plot to avoid what so called “marginal effect”.

2.4.2 Grain yield

Grain yield data were collected and recorded following harvesting. Harvest was carried out 114 days after seedling emergence when the plant reached physiological maturity. Harvest of plants of all experimental treatment was carried out on the same day by using a sickle. The harvested crop from each plot was stacked into piles separately and kept intact for air drying. After seven days of air drying, the harvested crop from each plot were placed on a plastic sheet and the seed heads were threshed vigorously by hands, until all the seeds had been dislodge. Then, the seeds collected were carefully separated from the stubble and cleaned by sieving and winnowing. The cleaned seeds from each experimental plot were then weighed by using a precise laboratory beam balance which has a sensitivity of 0.01 g.

2.4.3 Estimation of yield loss

The magnitude of crop loss that occurred due to weed treatments was computed and described as a percent of the respective weed free control group, using the formula developed by Panda (2010):

$$\mathrm{YL} = \frac{\mathrm{Y1} - \mathrm{Y2}}{\mathrm{Y1}} \times 100$$

Where YL is percent of grain yield loss or the reduction that occurred on the growth parameter, $Y_1$is the average value of each measured trait obtained from the weed free control plots, and Y_2 is the average value of the respective trait recorded at each treatment level (5%& 10%) of Parthenium weed.

2.5 Statistical analysis

To determine the extent of crop damage caused by weed treatment (whether it is significant or not), the differences between the means recorded for each trait at the weed free control plot and each of the treatment type were evaluated using ANOVA, and the Tukey`s significant difference test, with the help of statistical software.

3. Results

3.1 Effect of Parthenium weed on vegetative growth

3.1.1 Height

The effect of Parthenium weed density on height growth of two varieties of teff was presented in Figure 2. In both varieties, plant height decreased with increased density of weed. The mean maximum height of 23.6 and 23.7 cm for V1 and V2, was recorded respectively from a control plot and the mean minimum height of 21.9 and 21.8 for V1 and V2, was recorded respectively from a plot receiving 10% weed density treatment. The ANOVA test also showed the observed variation in height between treatments is statistically significant at $P \leq 0.05$. However, the difference in height between varieties and variety by weed density interaction was not significant.

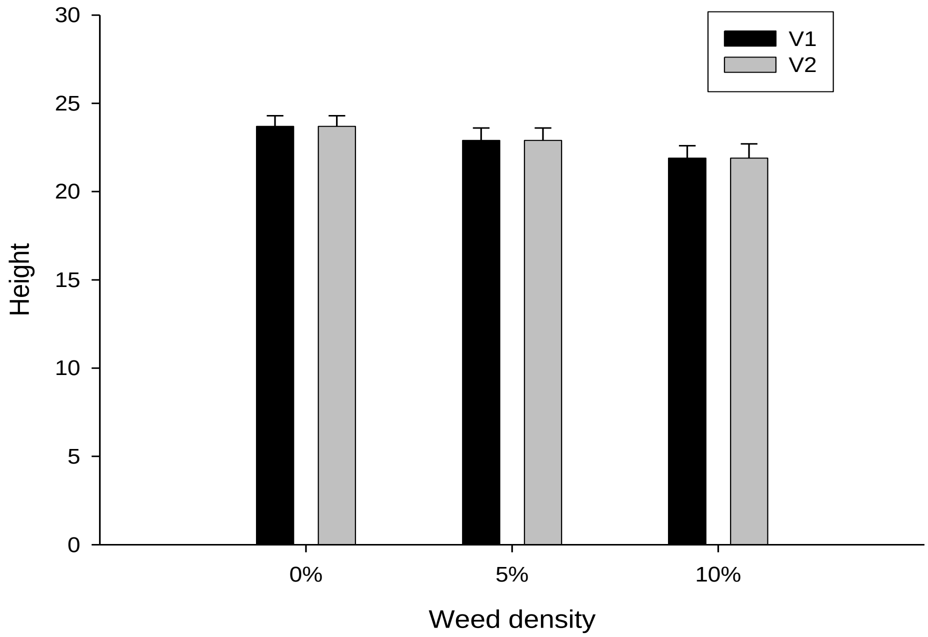

Figure 2 Height (cm) of two varieties of teff as influenced by weed density

3.1.2. Leaf area

The effect of varying weed density of *Parthenium* on leaf area growth of two varieties of teff is presented in Fig 3. The maximum leaf area of 13.4 and 13.6 in V1 and V2, was recorded respectively from control plot, whereas the minimum of 11.7 and 11.8 in V1 and V2 was recorded at a plot with 10% weed density. Results of ANOVA showed the presence of significant ($P \leq 0.05$) effect of weed density on leaf area. However, the effect of variety and variety by weed density interaction on leaf area was not significant

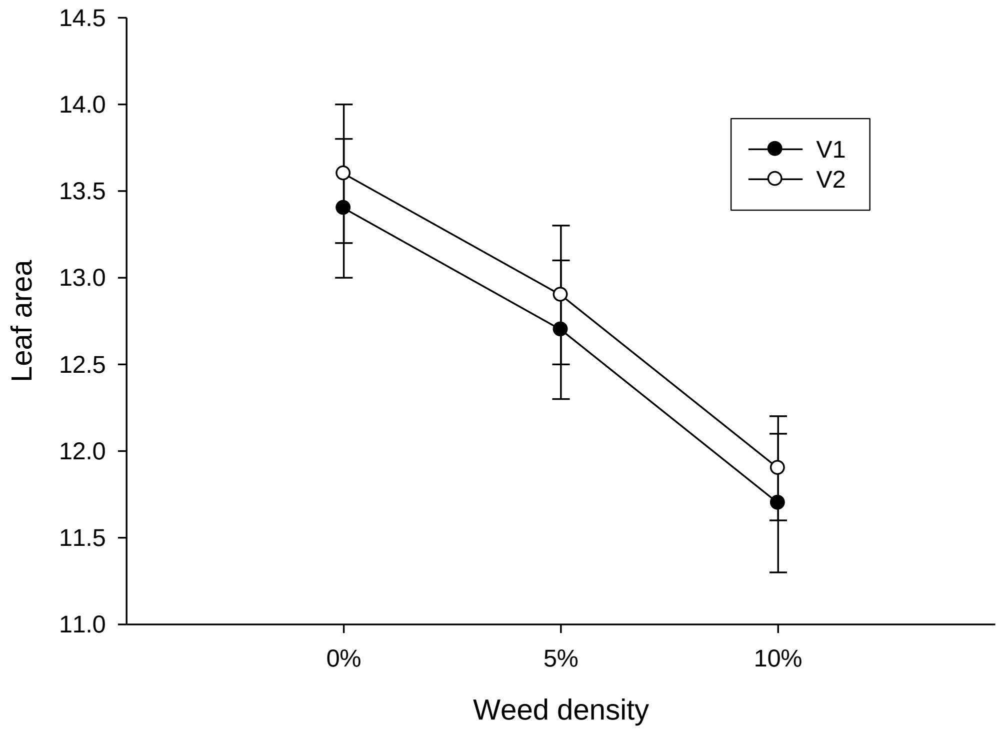

Figure 3. Leaf area (Cm2) of two varieties of teff as influenced by weed density

3.1.3 Tiller number

The effect of varying weed density of *Parthenium* on tiller production of two varieties of teff is presented in Table 1. The maximum number of tillers, 5.7 $\pm$ 0.07 and 5.8 $\pm$ 0.1, in V1 and V2, was recorded respectively from control plot, whereas the minimum of 5.5 $\pm$ 0.1 and 5.4 $\pm$ 0.2 in V1 and V2, was recorded respectively at a plot with 10% weed density. Analysis of variance (Appendix 2) showed statistically significant ($P \leq 0.05$) effect of weed density and variety on number of tillers/plant though the interaction was not significant.

Table 1. Mean leaf area of two varieties of teff in relation to different levels of Parthenium weed density

	Weed density		
Variety	0	5%	10%
V1	5.7 $\pm$ 0.07^{a}	5.6 $\pm$ 0.02^{ab}	5.5 $\pm$ 0.1^{b}
V2	5.8 $\pm$ 0.1^{a}	5.6 $\pm$ 0.1^{ab}	5.4 $\pm$ 0.2^{b}
Overall mean	5.75 $\pm$ 0.08^{a}	5.6 $\pm$ 0.06^{ab}	5.45 $\pm$ 0.15^{b}

Means in the same column represented by same letter are not significantly different at $P \leq 0.05$

3.2 Effect of Parthenium on crop yield

The effect of varying density of weed of *Parthenium* on grain yield of two varieties of teff is presented in Table 2. The mean maximum and minimum grain yield obtained in the study ranges from 764.4 ± 49.2 to 490.2 ± 52.2 and 712.6 ± 49.2 to 474.2 ± 63.2 in variety one and variety 2 respectively (Table 2). Analysis of variance (Appendix 2) also showed statistically significant ($P \leq 0.05$) effect of weed treatment level on grain yield of teff though weed treatment by variety interaction was not significant. Moreover, the yield loss caused by 5% and 10% Parthenium weed treatment level was found to be 14.9 and 38.9 respectively in variety one and 13.9 and 33.4, respectively in variety two. In general, ANOVA showed that the level of Parthenium weed treatment can result in significant grain yield loss on teff crop.

Table 2. Effect of weed density on yield of two varieties of teff

	Weed density		
Variety	0	5%	10%
V1	764.5 ± 49.2^{a}	650.3 ± 39.9^{b}	490.2 ± 52.5^{c}
V2	712.6 ± 49.2^{a}	613.6 ± 59.5^{b}	474.2 ± 63.2^{c}
Overall mean	738.5 ± 49.2^{a}	631.9 ± 49.9^{b}	482.2 ± 57.8^{c}

Means in the same column represented by same letter are not significantly different at $P \leq 0.05$

4. Discussion: Effect of Parthenium weed on vegetative growth and grain yield of teff

Irrespective of the difference in varieties, Parthenium weed treatment decreased the height growth of teff compared to the control. At 10% weed density treatment, the reduction in height computed to be 7.2% and 8% in variety one and variety two respectively. Since height of a plant is an effective component of competitive struggle for light, the observed reduction in height growth of the test has a significant impact on crop productivity mainly by affecting crop's competitive ability for resources such as light. In similar studies, the effect of Parthenium weed on vegetative growth and dry matter production of crop plants such as soy bean and haricot bean was well documented (Masum *et .al.* 2013). Parthenium weed was also reported to reduce vegetative growth on a wide range of cereal crops such as rice (*Oryza sativa L*.), wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and sorghum *(Sorghum bicolor* L.) in different parts of the world (Adkins and Shabbir, 2014).

The study showed the presence of statistically significant ($P \leq 0.05$) effect of Parthenium weed density on leaf area. In general, in both varieties of teff, the leaf area was reduced with increased density of weed treatment. Accordingly, at 10% weed density treatment, the percent reduction was 12.8 and 13.2 in V1 and V2 respectively. Verities in duration, intensity and quality, light regulates many aspects of plant growth and development. Leaves are the sites of light interception and plants with large leaf area have a great competitive advantage over plants with smaller leaf area. Thus, the observed reduction in leaf area in response to increased density of weed definitely affects plant growth and development not only by reducing the amount of light intercepted but also the surface area for photosynthesis.

The result of the present study showed statistically significant ($P \leq 0.05$) effect of weed treatment level on grain yield of the two varieties of teff studied. Moreover, the yield loss caused by 5% and 10% Parthenium weed treatment level was found to be 14.9 and 38.9 respectively in V1 and 13.9 and 33.4, in V2. However, direct comparison of the results of the present study with other similar studies is not possible for a number of reasons mainly due to the fact that the extent of yield loss due to weed competition against a given crop depends on several factors, mainly on the type of weed species and its population density (Gallandt, 1997; Schonbeck, 2013). Nevertheless, yield loss caused by Parthenium weed has been documented for a wide range of other cereal crops such as rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and sorghum *(Sorghum bicolor* L.) in different parts of the world. In such crops, Parthenium weed has been shown to reduce yields by as much as 40% in India (Adkins and Shabbir, 2014).

Moreover, previous studies have confirmed that vegetative growth parameters such as stem height, leaf length and tillering are positively correlated with grain yield of teff (Solomon, 2010).However, the negative impact of the experimental weed at the 5% treatment level on such yield related traits of the test crop varieties was not consistent with the extent of grain yield loss that occurred due to its competition under the same treatment level. The Tuky's SD test indicated that the means of the vegetative growth features under the 5% treatment were not statistically significant from the weed free control, whereas with regard to grain yield at harvest, the data indicated that grain yield was significantly lower than that of the weed free control group. While there may be a number of possible factors, the reason for such disparity can be hypothetically attributed to the fact that the relatively lower population density (5%) of the experimental weed might have delayed the critical period of weed interference and thus did not exert marked impact on the growth of the test crop varieties during their early growth period. On the other hand, relatively severe weed competition, which resulted in grain yield loss could have occurred during the late growing season of the experimental crop. In line with this assumption Hall *et al*. (1992) reported that the beginning of the critical period of weed interference for a given crop can vary with several factors and weed density is one of the major factors, which determine the beginning of the critical period. It has been indicated by the same author that at conditions of relatively lower weed density, the critical period of weed- crop tends to start late and vice versa.

5. Conclusions and recommendations

The present study showed significant effect of Parthenium weed density on vegetative and grain yield of teff varieties. The extent of crop yield loss that occurred due to weed competition at each treatment level was assessed by comparing with the weed free control group. A relatively higher (between the 10% & 0%weed treatment levels) and moderate(between the 5% & 0% weed treatment levels) differences were observed in all of the measured traits of the experimental teff varieties, indicating that both weed treatment levels had an impact on the growth and grain production of the experimental crop varieties. Nevertheless, the impact of Parthenium weed competition at the 5% treatment level on the growth parameters of the test crop varieties was not statistically significant , whereas with regard to grain yield at harvest, the result indicated that grain yield was significantly affected at both treatment levels (5% and 10%).The possible cause of this disparity can be attributed to the relatively lower density of the experimental weed and its late emergence relative to the crop that might have delayed the onset of the critical period of weed–crop competition, so that the weed did not cause significant crop loss during their early growth period (at least until 40 DAE the crop). On the other hand, relatively severe weed competition which caused the recorded grain yield loss could have occurred during the late growing season of the test crop varieties.

Based on the result of this experiment, it seems to be reasonable to conclude tentatively that under relatively lower levels of infestation (< 5%) Parthenium weed competition may not affect teff plant during the crop's early growth period and the subsequent risk of grain yield loss can be minimal. The basis for this suggestion is the delayed onset of the weed's critical period of competitiveness and its late emergence relative to the crop.

Acknowledgments

The authors are sincerely grateful to Shewa Robit agricultural bureau for providing an experimental plot and their unreserved help during the entire period of field work. The authors also thank the local farmers and agriculture development agents for providing us seeds of selected varieties of teff and for their generous hospitality and support.

Conflicts of interest

The authors declare no conflicts of interest.

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EJED 2(2) 2019: 1 – 26
Ethiopian Journal of
Environment and Development
http://www.du.edu.et/duj
EJED

Determinants of Farmers' Decision to Use Improved Land Management Practice in Gindara Watershed, Southern Ethiopia

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Received: 10 Feb, 2019 /Accepted: 12 December, 2019

Abstract

The principal environmental problem in Ethiopia is land degradation in the form of severe soil erosion, gully formation and soil fertility loss. To overcome this problem, promoting appropriate land management technologies are best options. However, farmers' decisions to use land management practices are determined by complex factor. Thus, this study was conducted in Gindara watershed with the objective of analyzing the status of farmers' choice of improved land management practices and investigating determinants of farmers' decisions to use improved land management practices. The total of 286 samples household heads were selected using randomly sampling procedure with sample size allocation procedures of probability proportional to size method. Data were gathered through questionnaires, key informant interview, field observation and focus group discussions. Data were analyzed and presented quantitatively using different statistical methods such as percentage, mean, frequency, Chi-square (categorical variables) and (F-test for continuous variables), F-test and Chi-square test were employed to test the variation of the sample respondents towards farmers' decisions to use improved land management practices and also used to describe the patterns of the sample data. The result of multinomial logic model indicated that respondent' level of education, family size, access of credit, off-farm income, farm size and land tenure security of the households were positively and significantly determined farmers' decision to use fanyajuu. The result also revealed that farmers' educational level, family size, access of credit, off-farm income, farm size, extension services and slope of farmland were positively correlated and significantly determined farmers' decision to use stone bund. Based on the finding of the current study, it is recommended that agricultural extension service workers *should give due attention to these variables, which may greatly contributes farmers' decision to use improved land management technologies.*

Keywords: Land management practice, Gindara watershed, fanaya juu,

1. INTRODUCTION

Land degradation is a problem of global dimensions and affects all terrestrial ecosystem services on every continent and it has been recognized for over 100 years in Africa (Kotiaho & Halme, 2018). Land degradation also refers to any reduction or loss in the biological or economic productive capacity of the land caused by human activities, exacerbated by natural processes, and often magnified by the impacts of biodiversity loss (UNCCD, 2013). Similarly, land degradation is the consequence of multiple processes that both directly and indirectly reduce the utility of land and adverse effects on the biodiversity (Ajeye, 2014). It negatively affects the state and the management of the natural resources such as water, soil, vegetation and animals and hence reduces agricultural production (Vlek et al., 2010; Eni, 2012; Pingali et al., 2014).

In other side, land management practices refer to activities on the ground that uses appropriate technologies for the improvement or maintenance of productive capacity of the land. This includes activities such as soil and water conservation, soil fertility management and controlled-grazing. It incorporates the adoption of land use systems through appropriate management practices that enable land users to maximize the economic and social benefits from the land while maintaining the ecological functions of the land resources (FAO, 2009). In addition to this, Sustainable Land Management (SLM) is defined as knowledge-based procedure that helps integrate land, water, biodiversity, and environmental management (including input and output externalities) to meet rising fiber and food demands while sustaining ecosystem services and livelihoods (INTOSAI, 2013; GEF, 2016).

Hence, majority of the population of Ethiopia consists of farmers and their families who reside in rural areas and whose life is almost entirely dependent on agriculture and agricultural products (Megersa, 2011). However, land degradation in the form of soil erosion has been remained the major challenge that is adversely affecting the agricultural performance of the country (Amdihun et al., 2014). Similarly, the productive land in Ethiopia generally and Southern region specifically has been exposed to degradation and threat to productive soil. The proximate drivers of land degradation in the country include forest degradation and soil surface exposure (high removal of vegetative cover); detrimental cultivation practices with emphasis on small seed crops that require a fine tillage and overgrazing (Gebreselassie et al., 2016). It also reduces productivity and increases formation of rills and gullies in both farming and grazing lands through time (Nachtergaele et al., 2010; Heyi & Mberengwa, 2012; Selassie & Amede , 2014). Hence, the call for improved land management practices is the best options.

Accordingly, decisions made on land management practices have also a significant effect on environmental quality, agricultural production and land management conditions. These decisions also can be private decisions made by farm households and collective decisions made by groups of farmers and communities. On the other hand, communities also can influence land management practices through their collective decisions (Pender & Ehui, 2006).

The general objective of this study was to identify determinants of farmers' decisions to use improved land management practices in Gindara watershed. Thus, this study is significant in the identification of contextual based determinant factors of farmers' decisions to use improved land management practices and it will inform decision makers to design context-specific factors such as socio-economic, physical, institutional and household context based on sustainable land management practices.

Hence, farmers land management practices are determined by household and village level factors, among others. Household factors include physical, human and social capital, whereas village level factors include population pressure, access to markets, agricultural potential, local markets, presence of programs and local institutions (Heyi & Mberengwa, 2012). In the same way, farmers make decisions on their farmlands whether to use land management practice or not by considering different factors. Such factors include individual, social, economic, institutional and environmental context (Temu, 2013).

A numbers of studies have been conducted to investigate land degradation and land management activities in different parts of Ethiopia. A study conducted by Gebreselassie *et al*., (2016) indicated that better understanding of households' behavior about land management, policy and institutional factors that affect such decisions are crucial, but usually these factors are underestimated in most measures to address land degradation in the country. In addition, soil erosion is particularly serious in the high and low potential cereal zones of the north-central highlands. Study made by Megersa (2011) focused on traditional land management practices without encompass improved/introduced land management technologies. Meseret (2016) also argue that, land degradation in Amhara region is continuing with increasing rate. This was mainly due to over exploitation and mismanagement of the land resources. Heyi & Mberengwa (2012) also reported that land degradation is increasing with gullies and rills are common features rendering some areas out of use. Heyi & Mberengwa (2012) found that higher soil loss has been estimated at densely populated highlands of Southern Ethiopia.

These studies mainly focused on land degradation and its land management technologies. Most of these studies found that there is high degree of land degradation and land mismanagement practices. Therefore, there is a research gap on considering multivariate variables issue of what personal, social-economic, institutional and natural factors that determine the farmers' decisions to use improved land management practices. In an attempt to contribute in bridging the above stated gap, this study tries to address multivariate variables. It will add to the stock of knowledge on the factors that determine farmers' decision to use improved land management practices and provide information and recommendations to policy makers and others involved in promoting sustainable land management.

2. Materials and methods

2.1. Study Area description

This study was conducted at Gindara watershed which is part of Gibe III watershed in southern part of Loma district in Dawuro Zone, SNNPR of Ethiopia. It is located between 6°34'00" to 6°50'15"N latitude and 37°04'00" to 37°12'00"E longitude (Fig.1). The watershed is located at 540 Km in south west of Addis Ababa, the capital city of Ethiopia, and 340 Km from Hawassa, the capital city of Southern Nations Nationalities and Peoples Region. The watershed covers a total area of 158.22 Km^2 and is inhabited by 11,104 people distributed within the watershed. The crude population density of the watershed was 121 persons per square kilometer. The watershed included Arga bacho and Dissa kebele in upper streams; Wasara Talo kebele in middle stream, and Hala Bacho and Sayki kebele in lower streams (Loma woreda agriculture and rural development office, 2013).

The elevation ranges lie between 1254m – 2428m above sea level. The large part of the watershed was entirely falls into sub-tropical (*Woina-dega*) and tropical (*kola*) agro-climate. The mean annual temperature range is 15.1 to 27.5°C (BoFED, 2014/15). Rainfall ranges from 1401mm-1800mm. The rainfall is a bimodal type in the watershed: the short rainy season is between March and May, and the long rainy season is between June and September. The geology of the study area is abundant with *rhyolites* and *trachy* basalts mainly overlying in the Precambrian basement and tertiary volcanism. Most of the area has dissected and rugged landscape, having well drained and moderately weathered brown soil (*Nitisols*) and *Orthic Acrisols* (Getahun and Bode, 2015). Thus, soil erosion in the area is mainly attributed to the dissected and rugged topography.

Agriculture is mainly composed of crop production and animal husbandry and it is the main source of livelihood of the population in the Watershed. The dominant activities under land use pattern in the study area include cultivation of perennial crops such as enset, banana, coffee, mango, avocado and etc., whereas the annual food crops include cereals (maize, sorghum, teff), pulses (beans, peas), (maize and teff are largest produced), and root crop like potatoes, yams, sweat potatoes and cassavas. Generally, mixed agriculture is the major economic activity in this watershed (Loma woreda agriculture and rural development office, 2013).

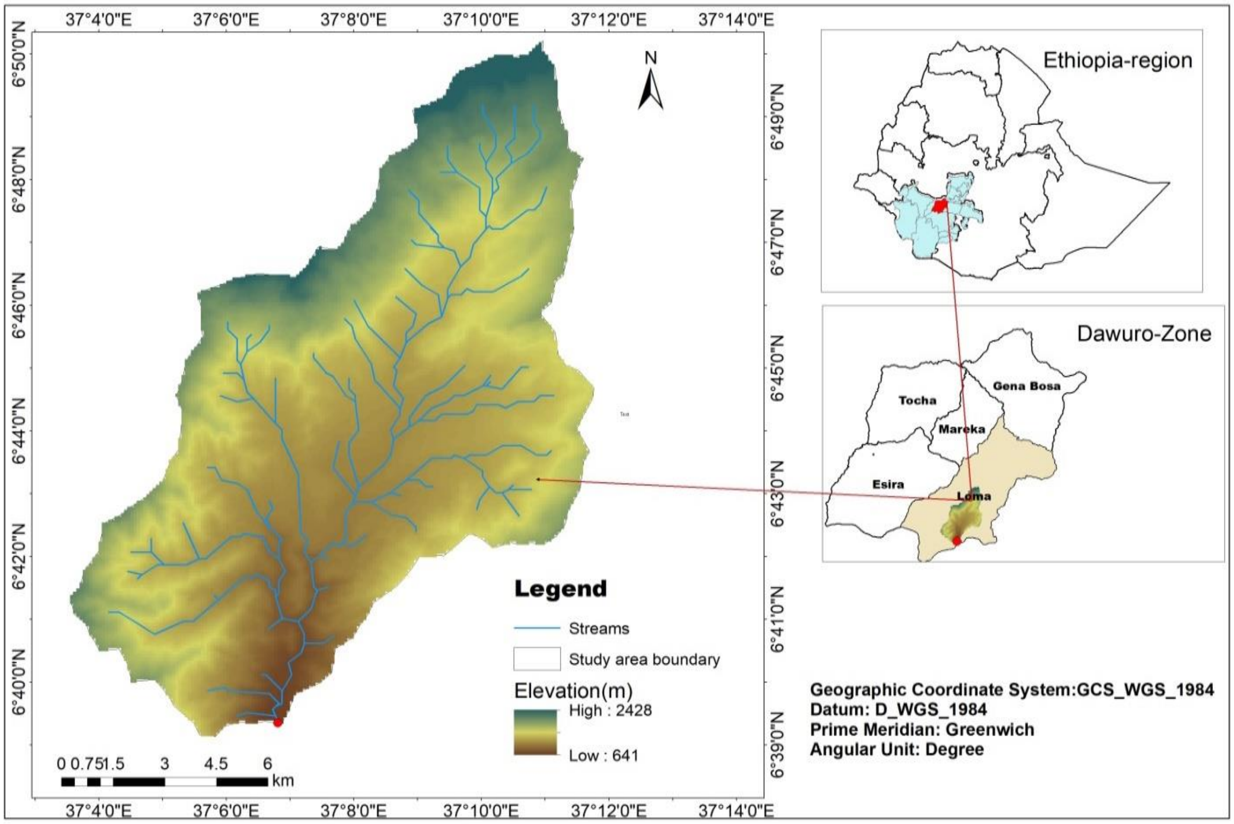

Figure 1 Locational Map of the study area

2.2 Sampling Design

Multi-stage sampling techniques were employed to select sample household farmers for the study from entire watershed. In the first stage, the watershed was purposively classified in to three parts depending on its topography i.e. upper, middle and lower streams of the watershed. In the second stage, the household heads stratified based on their residence in to upper, middle and lower streams of watershed to avoid the bias in generating information.

Finally, a total of 286 sample households were selected randomly from three streams of the watershed on the basis of probability proportional to size (PPS) sampling procedure. These sample farm household heads were determined using the following formula provided by Yamane (1967).

$$n=\frac{N}{1+N(e)^2}\text{..(Eq.1)}$$

Where; n= sample size

N=total population (the total household head)

e= level of precision (margin error) = 0.05

Based on the above formula, the total sample household heads were calculated as follow:

$$n=\frac{1,009}{1+1,009(0.05)^2}=286$$

Table 1 Distributions of household head and determinations of sample size

Categories of Watershed	**Household heads in each stream**		**Total households**	**Sample size**		**Total sample Size**
	Male	Female		Male	Female	
Upper streams	386	23	409	109	7	116
Middle streams	302	15	317	86	4	90
Lower streams	272	11	283	77	3	80
Total	**960**	**49**	**1,009**	**272**	**14**	**286**

2.3 Method of Data Collection

To attain the objective of the study, data were collected from both primary and secondary sources. The primary data were collected through questionnaire, key informant interviews, FGDs and field observations. Close ended and open ended format questions were prepared and distributed to the selected sample farmers' household heads, and interview questions administered through face to face interview to get information about determinants of farmers' decision to use improved land management practices. In addition, three focus group discussions among a small group of six to seven members of the farmers were carried out in the watershed. Moreover, key informant interviews were held with respondents from different sections of the community such as three development agents, two from non-government organizations, four model farmers, and three elderly farmers. Furthermore, secondary data were collected from published and unpublished documents, reports from the study area of different governmental organizations and non-governmental organizations.

2.4 Data Analysis Techniques

Qualitative data (data which were gathered through observation, interview and focus group discussions) were analyzed by using thematic analysis of categorization. Descriptive statistics and multinomial logistic regression model were employed to analyze the quantitative data. Important statistical measures that were used to summarize and categorize the research data were means, percentages, frequencies and standard deviations. These analyses were made by using SPSS version window 20. Comparisons between land management technology user's and non-users were carried out through application of chi-square and F-test. The relative influences of various explanatory variables on the dependent variable were also analyzed.

Specification of the Logistic Model

Multinomial logistic regression is used to predict categorical placement in or the probability of category membership on a dependent variable based on multiple independent variables. The independent variables can be either dichotomous (i.e., binary) or continuous (i.e., interval or ratio in scale). Multinomial logistic regression is a simple extension of binary logistic regression that allows for more than two categories of the dependent or outcome variable (Schwab, 2002).

In the econometric analysis, multinomial logistic model was applied in this study to identify the factors that determine farmers' decision to use improved land management practices such as *fanyajuu* and stone bund. Attempting bivariate modeling excludes useful economic information contained in the interdependent and simultaneous adoption practices (Bekele, and Drake, 2003; Wagayehu, 2003). Multinomial logistic model is more appropriate to treat the determinants of farmers' decision to use land management technologies as a multiple choice decision.

Accordingly, the multinomial logistic model for a multiple choice problem is specified as follows:

$$P\ (y = j) = \frac{e^{Bjxi}}{\sum e^{Bkjxi}} \qquad \text{..........2}$$

Probabilities for the j + 1 choice for a decision maker with characteristics *xi*. Before proceeding, we must remove indeterminacy in the model. If we define B*****j= Bj + Z for any vector Z, then the identical sets of probabilities result because the terms involving Z all drop out. A convenient normalization that solves the problems of the probabilities which Bo = 0 are:

$$P\ (y = j) = \frac{e^{Bjxi}}{1+\sum e^{Bkjxi}} \qquad \text{..........3}$$

for j= 1, 2…………………………………………………………………………..…k

$$\text{Prob}\ (y = 0) = \frac{1}{1+\sum e^{Bkjxi}}$$

Preconditions and Adjustment made before Analysis

The existences of multi-collinearity is assessed for continuous explanatory variables by using a technique of variance inflation factor (VIF) and tolerance level (TOL) where each continuous explanatory variable is regressed on all the other continuous explanatory variables and coefficient of determination is computed (Addisu, 2013). Thus, a measure of multi-collinearity associated with variance of inflation factor is defined as:

VIF (Xi) =(1-Ri^2-11)……………………………………………………………...…....…4

Where $R^2$is the coefficient of determination when the variable Xj is regressed on the others explanatory variables.

$TOL (Xi) = 1 - Ri^2$……………………………………………………………………………………..5
Where, TOL = Tolerance level of explanatory variable
$R^2 i$=Coefficient of determination of explanatory variable
Therefore, the multinomial logistic model was used to identify the factors that determine farmers' decision to use land management practices, and the goodness of model fit and the result depicts that the model has a value of chi-square at less than one percent level of significance that shows the parameters in the model except the constant are different from zero.

According to Agboola et al. (2015), Also important to note is that in a multinomial logistic model, the marginal probabilities resulting from an item alter in an independent variable must sum up to zero, since the predictable increases in marginal probabilities for certain options persuade a decrease for the other options within a set. In this case, the choice of improved land management practices is then modeled as a function of demographic, socio-economic, institutional and characteristics as well as physical factors. This can be presented as a general form equation:
$Zit = f(X_i)$ ………………………………………………………………………………6
Where Zit takes on values 1, 2… k, if individual i chooses alternative j; the MNL model is, however, operationalized empirically with the following equations.

$$Z_{ot} = \alpha_o + \beta_{10}X_1 + \beta_{20}X_2 + \text{---------------} + \beta_n X_n + \epsilon_1 \ldots\ldots 7$$

$$Z_{1t} = \alpha_1 + \beta_{11}X_1 + \beta_{21}X_2 + \text{---------------} + \beta_n X_n + \epsilon_1 \ldots\ldots 8$$

$$Z_{2t} = \alpha_2 + \beta_{12}X_1 + \beta_{22}X_2 + \text{---------------} + \beta_n X_n + \epsilon_1 \ldots\ldots 9$$

X_i…………………X_n represent vector of the explanatory variables where n = 1---------10
β_1……………….. β n represent the parameter or coefficients
ϵ_i represents the independent distributed error term and α_o, α_1, α_2 *and* α_3 shows the intercept or constant term.

3. RESULTS AND DISCUSSION

3.1 The Status of Farmers' Decision to Use Improve Land Management Practices

The status of farmers' decision to use improved land management practices are shown in table below

Table 2 Distribution of respondents by farmers' decision to use improve land management practices

Types of ILMPs	Farmers' decision category: Used		Not-used		Total	
	N	%	N	%	N	%
Fanyajuu	111	38.8	175	61.2	286	100
Stone bund	191	66.8	95	33.2	286	100

Source: own survey data (2018)

Fanyajuu: It is an improved physical land management measures in the study area. It is made by digging a trench and throwing the soil uphill to form an embankment and over time creates sloping bench-like terraces. The result showed that cumulatively, (61.2%) of the farmers did not practice land management technology of *fanyajuu,* while about (38.8%) of farmers used improved land management practices of *fanyjuu*. This implies that *fanyajuu* was not widely used by the farming household heads in their farm plots.

Stone bund: is an improved physical land management technology. It prevents humus of soil fertility and control erosion by shortening the length and minimizing the gradient of the slope. The structures of stone bunds are recommended to be constructed on the farmland with slope ranging between 3% up to 30% (MoARD, 2010). The study further revealed that about (66.8%) of the farmers used stone bund, while about (33.2%) of farmers did not practice improved stone bunds in their farmlands. Its construction length and width depends on topography of the slope.

Results from key informant interview suggested the limitations of stone bund in the farm plots. It takes much labor forces to construct and when sudden destruction happens on a single upslope bund, it causes a serious destruction. Consequently, it results in the destruction of the remaining down slope bund, which in turn results in a huge amount of soil erosion.

3.2 Descriptive Results

This section presents the descriptive statistics results between farmers' decision category for both dummy and continuous variables of improved land management technologies among farming household heads in the study area.

Table 3 Descriptive statistics between farmers' decision category for dummy variables

Explanatory Variables	Farmers' decision category				χ^2
	Used		Not-used		
	N	%	N	%	
Sex of HHs	167	58.4	119	41.6	8.056**
LANDSEC	183	64	103	36	22.378***
LABORG	156	54.5	130	45.5	2.364^{Ns}
SLOPE	206	72	80	28	55.510***

Source: own survey data (2018); ***, ** and Ns significant at 1, 5%, not significant probability level, respectively

As specified by survey result in Table 2 showed majority of household heads (58.4%) used improved land management technologies, whereas only (41.6 %) of household heads did not use improved land management practices. In addition to this, chi-square analysis of these data showed that there is a statistically significant variation between farmers' decision category in terms of sex of the household heads at less than 5% probability level.

On the other hand, majority of sampled respondents (64%) used improved land management technologies and have secured their land, whereas only (36%) of sampled respondents did not use improved land management practices and have not secured their farmlands. Analysis of chi-square test showed that there is a statistically significant difference between farmers' decision category in terms of land security household heads at 1% probability level.

Furthermore, survey results also showed that about majority of respondents (54.5%) had labor force to construct land management technologies, whereas only (45.5 %) of respondents lack labor force to construct land management technologies in their farm plots. Similarly, Tesfaye (2017) found that the number of labor force available in the family is assumed to influence decision of farmers to adopt SLM practices. Families with large household members will be able to supply the extra-labor that could be required for adoption and continuous implementation of SLM activities. During focus group discussions participant recognized that labor is important for physical management practices in mutual cooperation. They also suggested that family labor hire mutual cooperation with community and labor hire with neighbors are the solution to reduce labor shortage for improved land management practices.

Slope of the land determines land degradation in general and soil erosion potential in particular. The result also showed that the large number of farmers (72%) practiced improved land technologies along steep slope areas which need much attention. On the other hand, only (28%) of the farmers did not practice improved land management practices along steep slope areas that need relatively less attention than users for constructing structural land management practice. The chi-square result indicated that the sampled respondents land slope was statistically significant at less than 1% probability level. From this point of view, the farmers who had steep slope farmland practiced improved land management technologies more than gentle slope to reduce the impact of soil erosion and land degradation on their farmlands.

Accordingly, during focus group discussions farmers suggested that as the slope of farmland increases, farmers also strengths structural land management technologies to control soil erosions. Moreover, field observation results revealed that stone bunds are constructed more along sloppy farmlands than flat farm plots because sloppy farm plots are more exposed to land degradation and soil erosion. Similar result has been reported by Miheretu & Yimer (2017). They reported that farmers are more likely to use physical land management practices on sloppy lands that are susceptible to more rapid runoff and soil erosions.

Table 4 Descriptive statistics between farmers' decision category for continuous variables

Explanatory Variables	Farmers' decision category Used	Not-used	F-test

	Mean	SD	Mean	SD	
Age of HHs (in years)	40.96	10.64	43.4	8.83	4.55***
EDUHH (in years)	2.12	1.084	1.33	0.669	7.70***
FAMSIZE(in numbers)	6.92	2.38	6.04	2.28	2.45*
CREDIT (in frequency)	2.05	1.027	1.15	0.925	0.187
OFFINCOM in ETB	616.92	255.4	405.61	182.3	1.50
TLU	2.78	3.09	2.45	2.27	10.20***
FARMSIZE in ha	1.87	1.38	1.3	0.72	4.92***
EXTSERVICE (in frequency)	1.17	0.83	0.67	0.59	2.4*
DISTPLOT in Km	0.29	0.57	0.52	1.09	2.27***

Source: own survey data, 2018 ; ***, * significant at 1, 10% probability level

Survey results indicated continuous variables in Table 4 The mean age of 40.96 with standard deviation of 10.64 of the farmers used improved land management technologies, while the mean age of 43 with standard deviation of 8.83 of the farmers did not use improved land management technologies in their farm plots. This implies that the farmers who are in working age groups have a good understanding of the environmental problems due to access of information and flexibility and they are more interested in land management technologies. Similarly, Tesfu (2012) reported that younger farmers have longer planning horizon and they are more flexible in deciding to use new ideas and technologies. On the other hand, older farmers usually have short planning horizon and the practices of land management declines if there is no person in the family who can contribute labor. The result of one-way ANOVA also indicated that (F=4.55) there is a statistically significant difference between farmers' decision category in terms of age household heads at 1% probability level to practice land management technologies.

Farmers with the mean years of schooling, 2.12 and 1.084with standard deviation used improved land management technologies, whereas farmers with the mean years of schooling 1.33 and 0.665 standard deviation did not practice improved land management technologies in their farm plots. This implies that when farmers' year of schooling increases, their access for information about soil erosion increase which in turn increase land management practices. In addition, the analysis of one way ANOVA revealed that (F=7.70) there is statistically significant difference at 1% probability level. This showed that there is a systematic association between the years of schooling of farmers and their use of land management technologies.

Farmers with the mean family size of 6.92 and 2.38 standard deviation used improved land management technologies, whereas the mean family size of 6.04 with standard deviation of 2.28 of the household heads did not practice improved land management technologies in their farm plots. In addition, information collected from focus group discussants suggested that the existence of large number of family size contributes significant labor hiring for social activities in structural land management technologies. This implies that farmers with a larger numbers of family size and relatives invest more in land management than farmers with small family size. The result of this study is similar to a study conducted in Silt Woreda by Mushir and Kedir (2012). They reported that households with larger family size maintain conservation structures of land management than their counterparts due to availability of laborers. The result of one-way ANOVA also indicated that (F=2.45) there is a statistically significant difference between farmers' decision category in terms of households size at less than 1% probability level to practice land management technologies.

Farmers, who received loans from various institutions for the cultivation of new crops and for livestock farming, significantly involved in continued use of land management technology. This implies that the use of credit motivated farmers to produce more cash crops and get more income which lead to better implementation of land management technologies. The mean yearly frequency of access to credit was found to be 2.05 and 1.15 with standard deviation of 1.025 and 0.925 for land management technology users and no users of land management technologies respectively.

In rural area, off-farm activities are usually considered as significant sources of employment and income for the rural farmers that help to decrease burden on the land and encourages land management practices. The mean off farm incomes of users and non-users of improved land management technologies were 616.92 and 405.61 with a standard deviation of 255.4 and 182.3, respectively.

Livestock are as means of the indicator of wealth or assets and used for food, transport from place to place, cash requirement, credit payment for taxes and farmers kept them for beef farming in the study area. The mean size of livestock in TLU was 2.78 with standard deviation of 3.09 for the sampled farmers who used improved land management technologies, while the mean size of livestock was 2.45 in TLU with standard deviation of 2.27 for sampled farmers who did not use improved land management technologies. This implies that the farmers with more livestock have better availability of manure, and invest more in land management technologies. The analysis of one way ANOVA revealed that (F=10.20) it is statistically significant at 1% probability level. This showed that there is a systematic association between livestock ownership of farmers and decision to practice land management technologies.

As survey result also showed, the mean size of farmland in hectare was 1.87 with standard deviation of 1.38 for the sampled farmers who used improved land management technologies, while the mean farmland size of 1.3 in hectare with standard deviation of 0.72 for the sampled farmers who did not use improved land management technologies. The result of one-way ANOVA also indicated that (F=4.92) there is a statistically difference between farmers' decision category in terms of farm land size at 1% probability level to practice land management technologies. In addition to this, the information from FGDs and key informant interviews indicated that farm size determines fallow period, the farmers who have large farm size increases fallow period to enhances better land management practices and the farmers who have small farm size cultivates in continuous way decreases fallow period leads to decline of soil fertility and productivity. They also suggested that farm size also determines the designing and planning of physical land management technologies.

Accesses to agricultural extension service to farmers are likely to increase their awareness about the effects of land degradation, soil erosion and the understanding about the land management technologies and their benefits. As survey result also depicted, the mean monthly frequency of extension services was found to be 1.17 with standard deviation of 0.83 for farmers who used improved land management technologies, whereas the mean monthly frequency of extension services was 0.67 with standard deviation of 0.59 for non-users of improved land management technologies. The result of one-way ANOVA also indicated that (F=2.4) there is a statistically significant difference between farmers' decision category in terms of mean monthly extension visit at less 10% probability level.

During FGDs, the discussants claimed that access to agricultural extension services is provided experience and information sharing and better understanding about the environmental problems particularly soil erosion. But, Extension trainers most of the time focused on improved seed and artificial fertilizers, but they did not focus on the ways of land management technologies.

Distance from farm plots influence a land management decision for two reasons: the closer supervision and attention it gets from the family. Adoption of labor-intensive land management practices is greater on homestead plots than on rain fed plots away from the homestead. Furthermore, survey result also showed that the mean distance from farmers' plot in kilometer was found to be 0.29 and 0.52 with standard deviation of 0.57 and 1.09 for users and no users of land management technologies respectively. The result of one-way ANOVA also revealed that (F=2.27) there is a statistically significant difference between farmers' decision category in terms of distance from plots and residence at less 1% probability level. This implies that farmers who have farm plots near homestead invest more on their farm plots than far away from their dwellings. In line with this, farmers whose farms are nearer to their residence use application of manure and compost than distance farm plots (Fikru, 2009). Daniel and Mulugeta (2017) also found farmlands far away from homesteads require more time and energy for the conservation of farmlands.

3.3 Causes of Declining Soil Fertility

Soil fertility depletions are considered as main indicators of land degradation (Adimassu & Kessler and Aad, 2012).

Table 5 Major causes of declining soil fertility

No_	Cause of declining soil fertility	Percent
1.	Continuous cultivation	51.0
2.	Deforestation	46.6
3.	Poor agricultural land management	36.0
4.	Soil erosion	21.0

5.	Overgrazing	16.8
6.	Rugged topography	16.4

Note: A multiple response provided was used. Source: Own survey result (2018),

In this study discussants in the FGD have listed six indicators like continuous cultivation, deforestation, poor agricultural land management, soil erosion, rugged topography and over grazing are causes for the decline of soil fertility on the study area. Based on this, 51%,46.6%, 36%, 21%, 16.8% and 16.4% of 16.8% of FGD participants indicated that continuous cultivation, deforestation, poor agricultural land management, soil erosion, overgrazing, and rugged topography as the main causes of declining soil fertility in their area respectively (Table 5). Thus, it is clear that majority of the discussants replied that continuous cultivation, deforestation and poor agricultural land management were the main causes of declining soil fertility in the study area. Moreover, during observation period, some farmers practiced inappropriate design with poorly constructed land management practices on their farm plots.

3.4 Econometric Model Results

3.4.1. Test result for multi-collinearity among specified variables in the model

Before doing the econometric analysis, it was necessary to check for the existence of multicollinearity among the continuous variables and verify the degree of association among discrete variables. Variance Inflation Factors (VIF) and Tolerance (TOL) test show the degree of multicollinearity among the explanatory variables used in this analysis. The result showed that there was no serious multicollinearity problem between the continuous variables. This is because they did not exceed threshold point. For continuous variables, according to Gujarati (2004) if the value of VIF is ten and above, the variables are said to be collinear. Test result also revealed that the VIF has not reached the tenth point mark; on the other hand, the tolerance factor is greater than 0.1 point mark for all the explanatory variables in the model.

3.4.2 Determinants of farmers' decisions to use improved land management practices

The analysis of multinomial logistic regression was used to identify the factors that determine farmers' decision to use improved land management practices in the study area. The results of multinomial logistic regression analysis for improved land management practices indicated in Table 6 below. The dependent variable used in this study improved land management practices were *fanyajuu* and stone bunds.

Data in Table 6 revealed that the maximum log likelihood ratio -294.452 with *Chi square* test value of 252.723 at statistically significant at 1% probability level. These imply that the model is a good fit in this study. The pseudo R square result was 0.812 showed that about 81.2% of the explanatory variable had the variation of in decision to use improved land management technologies.

The total of 13 independent variables was hypothesized to analyze determinants of farmers' decision to use *fanyajuu* and stone bund as improved land management technology in the study area. Thus, only seven explanatory variables (level of education, family size, access of credit, off-farm income, farm size and land security of the households) were positively and significantly determined farmers' decisions to use *fanyajuu as* land management technologies, whereas only eight explanatory variables (level of education, family size, access of credit, off-farm income, farm size, extension services and slope of farmland were positively correlated of farmers' decision to use stone bund improved land management technology. In addition, the age of households was negatively correlated and significantly determined farmers' decisions to use *fanyajuu* and stone bund as land management technologies.

Table 6 Results of logistic regression for *fanyajuu* and stone bund land management technologies

Fanyajuu					**Stone bund**			
Variables	Estimated Coefficient	Standard error	Marginal effect	P-value	Estimated Coefficient	Standard error	Marginal effect	P-value
SEX	.312	.705	1.367	.658	-.233	.677	.792	.730
AGEHH	-.696	.289	.498	.016**	-.855	.278	.425	.002***
EDUHH	.317	.076	.729	.042*	.406	.171	.667	.018**
FAMSIZE	.191	.057	1.210	.001***	.205	.055	1.228	.000***
CREDIT	1.491	.358	.225	.000***	.918	.486	2.503	.0471*
OFFINCOM	2.077	.446	7.980	.000***	1.574	.417	.207	.000***
TLU	.071	.073	1.073	.333	.063	.067	1.065	.344
FARMSIZE	.200	.090	.819	.026**	.416	.128	.660	.001***
EXTSERVICE	-.547	.425	.579	.198	1.948	.441	.143	.000***
LANDSEC	1.629	.379	.196	.000***	-.207	.338	.813	.540
LABORG	.680	.373	1.975	.068	-.377	.380	.686	.321
SLOPE	.044	.214	1.045	.836	.796	.238	2.216	.001***
DISTPLOT	-.294	.274	.745	.283	-.289	.247	.749	.242

***, **, * represents significant at 1%, 5%, 10% probability level, respectively

Age of households: As hypothesized, the model output showed that age of households was found statistically significant at less than 5% and 1% probability level with the expected value and negatively related with farmers' decision to use *fanyajuu* and stone bund as land management technologies respectively. Accordingly, if age of households increases by one unit it decreases the probability to use *fanyjuu* and stone bund improved land management technologies by factor of 0.498 and 0.425 respectively. The result confirmed that adult households more likely decide to use *fanyajuu* and stone bund as land management technologies than households who are older. This finding corroborates study made by Heyi & Mberengwa (2012) and Simon et al. (2013) that reported age of the household affects decision on land management practices and conservation strategies negatively. Miheretu & Yimer (2017), and Tesfaye (2017) also reported that older farmers probably have shorter planning horizons and are physically weaker, more resistant to change, and hence they are not interested in adopting land management technologies, which have long-term effects. On the contrary, study made in Ngaciuma Sub-Catchment in Kenya by Chris et al., (2012) reported that it is true that older farmers were likely to have more farming experience and would therefore be likely to be more receptive to improved land management technologies.

Level of Educational: Level of education was found to be statistically significant at less than 10% and 5% probability level to use *fanyajuu* and stone bund respectively. As hypothesized, the positive coefficient of educational level indicates that one unit of schooling of farmers increase their decisions making and it also increases the probability to practice *fanyajuu* and stone bund improved land management practices by factor of 0.729 and 0.667 respectively. This implies that farmers with more years of schooling decide to use *fanyajuu* and stone bund improved land management technologies. It is in line with previous study made by Gemechisa (2017) that reported that relatively better educated farmers are engaged in the adoption of the newly introduced SWC practices. This finding is also similar to the finding of Gemechisa (2017).

Family Size: The family size influences the decision of farmers to undertake the type of land management activities. The multinomial logistic regression analysis also revealed that family size was found to be statistically significant at 1% probability level to use *fanyajuu* and stone bund. *T*he positive coefficients indicate that a unit increase in family size with the probability to adopt *fanyajuu* and stone bund improved land management technologies by factor of 1.210 and 1.228 respectively. This implies that the labor requirement is substantially increased farmers' decision to use *fanyajuu* and stone bund land management technologies in their farmlands. This study is in line with Berhan et al., (2016) and Heyi and Mberengwa (2012). They reported that households with large family size of members undertake more diverse land management practices as they are more likely to have the labor required to carry out land management activities. However, Agboola et al., (2015) in North central Nigeria reported that the larger households tend to hold smaller farms as a result of pressure on land which brings about land fragmentation and cannot afford to fallow; hence the use of bush fallow as a land management technique might not be feasible.

Access to Credit: The result revealed that access to credit has positively determined farmers' decision to use *fanyajuu* and stone bund improved land management practices. An increased access to credit by a unit increases the probability to adapt *fanyaju* and stone bund improved land management practices by factor of 0.225 and 2.503 at less than l% and 10% significance level respectively. This implies that farmers obtain credit motivated to invest more *fanyajuu* and stone bund land management technologies. The finding of this study is similar to a study made by (Gemechisa, 2017). They reported that the use of credit encouraged farmers to invest in land management practices.

Off-farm Income: The result revealed that off-farm income has positively correlated with farmers' decisions to use *fanyajuu* and stone bund improved land management practices. An increase off-farm income for farmers by a unit increases the probability to adapt *fanyaju* and stone bund improved land management practices by factor of 7.980 and 0.207 respectively at l% significance level. This implies that the farmers with higher yearly off-farm income were more likely to invest on land management technologies. And off-farm income is generating activities compete for labor resource that the household uses as an input in land management activities. This finding contradicts with the findings of Amsalu and deGraaff (2007). They reported that farmers who are involved in off-farm activities may encounter time and labor constraints for investing in land management technologies.

Farm Size: The result showed that farm size for households was found statistically significant at 5% and 1% probability level with the expected value and positively related with farmers' decision to use *fanyajuu* and stone bund as land management technologies respectively. Keeping other factors constant, an increase in farm size for farmers by a unit of hectare increases the probability to adapt *fanyaju* and stone bund improved land management practices by factor of 0.819 and 0.66 respectively. This means that farmers with larger farm sizes are expected to practice better land management practices. Sagni (2015) found similar results that large farm sizes are positive toward land management technologies and farmers more likely invest on it because they have funds to do so, while those who are holding small farm size have negative attitudes towards physical land management measures. On the other hand, Gemechu (2018) reported that land holding size would cause a decrement in farmers` level of perception on soil erosion.

Access to Extension Service: Extension service plays a great role in awareness about environmental problems and the possibility of farmers to practices land management technologies. The result revealed that extension service has positively correlated with farmers' decisions to use stone bund as improved land management practices. All other factors constant, an increase in extension service frequency for farmers by a unit increases the probability to adapt stone bund improved land management practices by factor of 0.143 at l% significance level. This implies that the frequency of extension service increases, it increases the possibility of the farmers to practice improved land management technologies. Similarly, Tesfaye (2017) found that the message/contents that farmer gain from extension agents help them to initiate to use the newly introduced land management practices on their farm to protect their land from erosion and to improve its fertility.

Land Security: As hypothesized, land security has positively correlated with farmers' decisions to use *fanyajuu* as improved land management practices. Keeping other variables constant, an increase land security for farmers by a unit increases the probability to adapt stone bund improved land management practices by factor of 0.196 at less than l% significance level. This implies that farmers who own and secure their land tend to invest in land management practices because as no one can take over the land in the future. Similarly, Ragassa (2005) found that security of land owner ship encourages manure use and construction of structural management practices, but not the use of inorganic fertilizer. Meseret(2014) also reported that farmers own secured land tend to be more conserved than rented or sharecropped plots.

Slope of Farmland: Slope of the land determines farmers' decisions on particular land management technologies. The result showed that slope of farmland was found to be statistically significant at 1% probability level to construct stone bund. *T*he positive coefficient indicates that a unit increase of slope of farmland with the probability to adopt stone bund improved land management technology by factor of 2.216. This implies that on steep slope farmers are more likely construct stone bund because the impact of soil erosion and land degradation would be more visible to the farmers. Kifle et al., (2016) also found similar results. The higher slope category of a plot, the greater will be the severity of soil erosion. On the other hand, Meseret(2014) found, the structures of soil and water conservation take more area of land and it will create inconvenience for farm operation like oxen plough.

4. Conclusions

The study identified determinants of farmers' decision to use improved land management practice in the study area. The study has focused on the major factors that determine farmers' decision to use improved land management practices. These factors are grouped as personal, institutional, socio-economic and physical. Analysis of multinomial logic model reveals that the explanatory variable household heads of educational level, family size, access to credit off-farm income and farm size were identified to have significant positive relationship on farmers' decision to use *fanyajuu* and stone bund improved land management technologies, while age of households was negatively related on farmers' decision to use *fanyajuu* and stone bund improved land management practices. As the result also revealed that extension service and slope of farmland were positively correlated with farmers' decisions to use stone bund, and land security has positive impact on farmers' decision to use *fanyajuu* as improved land management practices. It was concluded the results obtained from FGDs also revealed that continuous cultivation, deforestation, poor agricultural land management, soil erosion and rugged topography were the main causes of declining soil fertility in the study area. Based on finding it is recommended that policy makers and local government leaders should arrange a strategy to focus on enhancing extension delivery to farmers in the study area to appropriate design of *fanyajuu* and stone bund with supporting practices to their farmlands.

Conflict of interest

The authors would like to declare that there is no conflict of interest.

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Ethiopian Journal of
Environment and Development
EJED 2(2) 2019: 1–14

MACRO AND MICRO MINERAL STATUS OF DAIRY FEEDS IN EAST SHOA ZONE, OROMIA REGION STATE, ETHIOPIA

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Received 5th September 2019,
Accepted 22nd December 2019

Abstract

The aim of this study was to evaluate different feed types collected from two districts (Ada'a and Adama zuria) of two production systems (urban and peri-urban) based on season's (dry and wet) in East Shoa Zone, for their macro and micro mineral concentrations. Feeds in the selected districts comprised of roughages, concentrates, and non-conventional feeds. All feed samples were taken directly from the field supplied by the farmers. The feed samples were analyzed for the macro and micro minerals namely Ca, P, Mg, Cu, Fe, Zn, and Co, using atomic absorption flame emission spectrometer and P concentration was measured by the spectrophotometer. The critical level (CL) used in this article is defined as the concentration of minerals below the level considering the requirements for dairy cows. The mean calcium concentrations in roughage varied from (0.13 to 0.55%); concentrate (0.14 to 0.64%) and non-conventional feed (0.34 to 0.69%) DM respectively. Out of the total feeds analyzed only, 26.92%, 66.15% for roughage (natural grass hay, sugar cane tops, and silage) and concentrates (noug seed cake, ground maize, cotton seed cake, and lean seed cake), respectively were found to be deficient in Ca. The mean phosphorus and magnesium values were not deficient in analyzed feeds. The mean Copper concentrations varied in roughages (6.99 to 10.65 ppm); concentrate (6.67 to 8.78 ppm) and non-conventional (6.31 to 9.72 ppm) DM respectively. When those values are compared to the critical value (< 8ppm) of feeds analyzed only 19.23%, 79.92% and 65.22% for roughage (*Triticum aestivum*, *Medicago sativa*, *Pennisetum purpureum*), concentrates (wheat bran, wheat middlings, noug seed cake, cotton seed cake and concentrate mix) and non-conventional feeds (brewery by-products industrial, poultry liters) respectively were found to be deficient in Cu. The mean Iron concentrations varied in roughages (68.5 to 176.80 ppm); concentrate (73.94 to 174.81 ppm) and non-conventional (65.92 to 157.93 ppm) DM respectively. When those values are compared to the critical value of (50 ppm) of feeds analyzed only 48.1% and 34.8% for roughage (natural pasture, *Pennisetum purpureum*), sugar cane top) and non-conventional feeds (brewery by-products industrial), respectively were found to be deficient in Zn. The interaction effect of dairy feeds for most analyzed feed samples were significantly different ($P < 0.05$) for all Ca, P, Mg, Cu, Fe, and Zn within the study districts. Similarly, the interaction effect between feed types and production systems were significantly different ($P < 0.05$) for Ca, P, Mg, Cu, and Zn but non-significant ($P > 0.05$) for Fe. Moreover, the interaction effect of feed based on sampling season was significantly different ($P < 0.05$) for Ca, P, Mg, and Zn but non-significant ($P > 0.05$) for Cu and Fe. Minerals such as Ca, Cu Zn and Co were present in inadequate amounts. Therefore, supplementation of these mineral elements is very likely to produce beneficial results in the ration of dairy. Hence, there is an urgent need for appropriate research to formulate area specific mineral mixture, and to devise supplementation packages for bio-available mineral salts.

Keywords: Dairy cows, Districts, Feed, Macro and micro-minerals, Production system, Season

1 Introduction

In Ethiopia, cattle rarely obtain mineral supplements with the exception of common salt. The use of commercial feed supplements is limited due to the cost incurred and their unavailability (Fekede *et al*., 2013). Dairy cattle are mainly fed on natural pasture (grazing and/or hay), crop residues, and different agro-industrial by products, and locally available by-products (Atela) as supplementary feeds. In the past, extensive studies were carried out in the country to explore the nutritional limitations of such feeds to improved livestock production; in this case dairy cattle cannot perform to their full genetic potential unless their mineral needs are met, even if they receive 100% of their protein and energy requirements (Prasad *et al*., 2007; Fekede *et al*., 2015). Unfortunately, forages often do not provide all of the needed minerals, which animals require throughout the year. The concentration of mineral elements in pasture forage is a function and property of soil (parent material, soil fertility, soil pH and soil drainage). Plant species and climatic factors influence the mineral concentration of pastures (Lemma *et al*., 2002). On the other hand, substantial improvements have been reported by supplementing with forage legumes and agro-industrial by-products (Alemayehu, 2003).

Micronutrients, particularly the mineral elements though required in very small amounts are considered inevitable for the normal functioning of metabolic and physiological processes of life. In tropical countries, grazing livestock often does not receive minerals in required quantities and must depend almost exclusively upon forages for their requirements (McDowell and Valle, 2000). The essentiality of minerals for growth, health, reproduction as well as normal physiological functions of the animal's body was reported (Lemma *et al*., 2002). To obtain improvement in animal production, proper attention should be given to mineral nutrition, whether the animal is in a free-ranging system or under confinement. A lack of consideration for the mineral content of the total ration frequently leads to increased disease and reproductive problems (Radostits *et al*., 2007). Identifying and having awareness of the mineral composition of feeds contribute in determining the types and amount of minerals to be supplemented.

In Ethiopia, in spite of the fact that indication on the mineral content of feeds of various natures is accessible, but attention given so far to the mineral status of feeds has been little as related to macronutrients (Diriba *et al*., 2001; Aschalew, 2006). Some studies (Lemma *et al*., 2002; Fekede *et al*. 2015) have shown the low status of essential mineral elements in natural pastures, crop residues, and other feed resources in central and western parts of Ethiopia with particular emphasis to season and altitude. But there is no evidence of study on mineral content in dairy feeds in the rift valley of East Shoa zone with regard to importance of season and production system. Furthermore, there is very little information and organized data on important dairy mineral concentration in dairy feeds throughout Ethiopia though the problem is sever. The aim of this study was to quantify the mineral content of different feeds used in the districts as dairy cow feed and to provide a basis for subsequent investigation.

2 Materials and Mehods

2.1 Description of the Study Area

The study was conducted in urban and peri-urban production systems of Ada'a and Adama districts in East Shoa Zone. The study zone extends between 7^o33'50"N - 9^o08'56"N and 38^o24'10"E - 40^o05'34"E with a total area of approximately 10241 km^2. Ada'a district is located at 08^o44'E latitude and 38^o58'N longitude with an altitudinal range of 1540 - 3100 m a.s.l. (AWAO 2018). The largest portion (95%) of the district has mid highland agro-climate and the remaining portion (5%) has highland agro-climate. Mean annual temperature ranges from about 80 ^{o}C to 280 ^{o}C (Alemayehu *et al*., 2012).

Adama district is located at 8^o33'35" N - 8^o36'46" N latitude and 39^o11'57"E - 39^o21'15"E longitude about 99 km Southeast of Addis Ababa (CSA, 2005). It is situated at an altitude ranging from 1400 to 2700 m a.s.l. (DOA, 2013). The area receives an average annual rainfall ranging from about 600 to 1150 mm, which is erratic in nature. There is a significant seasonal variation for rainfall. More than 67% of the mean annual rainfall occurs in the four rainy (Wet) months: June, July, August and September (ADARDO 2013). Some additional rains (about 23%) occur in the remaining dry months with mean monthly values of rainfall as low as zero millimeters. The minimum and maximum daily temperatures of the area are 12 and 33oC respectively (NMSA, 2013).

2.2 Study Design

A cross-sectional study involving purposive selection of study areas, but a random selection of dairy farms and farm owners from the urban and peri-urban were conducted. The study areas were purposively selected as they have high potential for dairy production. The sampling frame of Kebles and dairy farms were obtained from respective district livestock and agriculture development offices. Depending on the frame lists and information obtained, Kebles from each production system (urban- and peri-urban) of each district were purposively selected based on the availability of crossbred dairy cattle and dairy production experiences. In Ethiopia, urban dairy farming is a system involving highly specialized, businessmen owned farms, which are mainly concentrated in major cities with no access to grazing land. The main feed resources are agro-industrial by-products and purchased roughage (Belete *et al*., 2010). Moreover, according to Fekede *et al*. (2013), urban dairy production is relatively intensive and mainly based on stall-feeding using purchased roughages and concentrates. However, Peri-urban production has access to land and usually practice mixed crop–livestock farming, which produces part of the feed in the form of crop residues and grazing (Azage *et al*., 2013).

2.3 Sample Collection and Preparation

In the present study, a total of 140 samples belonging to different agro-industrial by-products and locally available feeds were collected to assess their mineral status based on seasonal availability (wet and dry) from the two districts (Ada'a and Adama) of each production systems (urban and peri-urban). In general, the feed sample collection was season based (dry and wet), in which wet season was (from July to August) and the other was in the dry season (from January to February). These categories of feeds were purposively made for the sake of data analysis and result presentation and interpretations. Available dairy feed samples were collected from feed stores and sites of individual HH's, then labeled, and stored in airtight self-sealing polythene bags. The samples were grouped into three categories based on the nature and relative similarities according to their production system and seasonal availability in to roughage feeds natural pasture hay (*Andropogon*, *Digitaria*, *Panicum*, *Pennisetum* and *Trifolium*), teff straw, wheat straw, silages (maize), improved forage crops, sugar cane top), cereal grain and oilseed (wheat bran(*Triticum aestivum*), wheat middlings, concentrate mix (Faba bean mixed hull X wheat Bran(WB)), noug seed (*Guizotia abyssinica*) cake, ground maize, cottonseed cake, lean seed cake) non- conventional feeds (brewery by-product, Atela (traditional brewing by-product), poultry liter) Table 1.

Table 1 Types of feed samples collected based on seasonal availability from study area

Sampled feeds	No of samples	Season of collection	Locations
A. Roughage *i. Green feed*			
Oats vetch	4	dry & wet	Ada urba and peri-urban
Alfalfa	3	wet	Ada urba and peri-urban
elephant grass	4	wet	Ada urba and peri-urban
Sugar can top	7	dry & wet	Adama periurban
ii. Dry feed			
Teff straw	10	dry	Both Ada & Adama
Wheat straw	7	dry	Both Ada & Adama
Natural grass hay	14	dry & wet	Both Ada & Adama
B. Oil seed			
Cotton seed cake	8	dry & wet	Adama urba and peri-urban
Concentrate mix(Alema)	11	dry & wet	Both Ada & Adama
Noug (Guizotia abyssinica) seed cake	18	dry & wet	Both Ada & Adama
Linseed cake	5	dry & wet	Both Ada & Adama
C. Grain mill by-products			
Wheat bran	8	dry & wet	Both Ada & Adama
Wheat middling	5	dry & wet	Both Ada & Adama
ground maize	10	dry & wet	Both Ada & Adama
D. Brewery residues / local and industrial			
Atela	8	dry & wet	Both Ada & Adama
Brewery by products	8	dry & wet	Both Ada & Adama
Others			
Poultry manure	7	dry & wet	Ada urban and per urban
Silage	3	dry	Ada urban
Total	**140**		

2.4 Feed mineral analysis

The samples collected from different categories of supplementary feeds were milled through a 1mm sieve size for laboratory analysis. From each sample, a minimum of 300g feed was dried at 60 ^{o}C for 72 hours until a constant weight was obtained (Aschalew, 2006). For determination of both the macro- and trace minerals, the ground samples were dried and ashed at 450 ^{o}C for 4 hours in a furnace (Fekede *et al*., 2015). The feed samples were digested by the method of Trolson (1969) and 1g of previously ground and stored samples were taken in digestion tube and 5 ml of concentrated HNO_3 and 1ml of concentrated sulphuric acid (H_2SO_4) was added and mixed well and then was filtered through a filter paper. The analysis was made for a total of seven selected minerals including three macro-minerals (Ca, P, and Mg) and four trace minerals (Cu, Fe, Zn, and Co), by using Atomic absorption spectrophotometer (AAS), using Inductively Coupled Plasma-Optical Emission Spectroscopy, Perkin Elmer Analyst 200 Atomic Absorption Spectrometer except P. the selection for analysis of only such six minerals was made because of some technical constraints (AAS capacity of reading and bulkiness of the samples during the time of analysis).

The P concentration was measured by spectrophotometer according to Murphy and Riley (1962). The concentrations of Ca, P, Mg, Cu, Fe, Zn and Co were analyzed using the atomic absorption flame emission spectrometer. The critical level (CL) is used in this article is defined as the concentration of minerals below the level considering the requirements for dairy cows (McDowell *et al*. 1993; NRC, 2001). While digesting the feed samples, simultaneous digestion of reagent blank was undertaken and the final volume was similarly made up to 10 ml to have a blank.

2.5 Sample size determination

The sampling frame comprises those farmers keeping crossbred dairy cows and willing to participate in the study. Generally, it was made a total of 250 households (125 from each district) who were purposively selected. Dairy owners were also be designated into 'urban' and 'peri-urban', categories based on the location of the same in the town (Adama and Adaa districts) area, respectively (Table 2.). The sample size is restricted in accordance with the logistics available for laboratory analysis.

Table 2 Specific location of dairy owners used for data and sample collection with respect to localities

	Districts			
	Ada'a		Adama	
No	Urban	Peri-urban	Urban	Peri-urban
1	Kebele-09 (Babogaya)	Dhankak	Kebele-01	Mormmorsa
2	Kebele-15	Gudino	Kebele-02	Guraja Furda
3	Kebele-01(Aleka Amba)	Udde	Kebele-04	Wanji kurifti
4	Kebele-03	Hidi	Kebele-13	Wonji shoa
5	Kebele-08	Wajito	Adama village	Dobe Soloke

A total of 250 households were included in the study according to the formula given by Arsham (2002). A standard error of 0.032 with a 95% confidence level was taken. From 250 dairy owners 140 feed samples were collected and made composite based on production systems of the respective districts. The difference in HH's and feed sample collected was due to involuntary of farmers and nature of similarity.

$$n = 0.25/SE^2 \quad (1)$$

Where, n= Sample size, SE= Standard error

2.6 Statistical Model and Data Analysis

Experimental data were subjected to analysis of variance using the General Linear Model procedure of the SAS program (SAS, 2002). When the interaction between factors was non-significant, only the main effect means were presented and discussed, otherwise simple effect means were presented. Mean separation was done using Tukey test at 5% probability. The following statistical models were used.

- **Feed experiment**: $Y_{ijk} = \mu + A_i + B_j + C_k + (ABC)_{ijk} + e_{ijk}$

Where, Y_{ijkl} = measured data (Ca, Mg, P, K, Mn, Mo, Co, Fe, Cu) for feed sample,
μ= overall
A_i= effect of ith location (1,2)
B_j= effect of jth season (1,2)
C_k= effect of kth production system (1, 2)
(ABC)= Interaction effect of location, season & production system
eijk= the random error associated to the yijk observation

3 Results

Mineral Profile Dairy Feeds

Analysis of the average of individual feeds which were available and collected from the study area was made to know the macro and micro mineral concentrations of dairy feeds (% and mg/kg dry matter basis) throughout the study area to compare with the critical values of respective minerals Table 3. The collected feed sample was analyzed individually per season and production system, but the result obtained indicated that the average of the mean of the two season and production system.

Mean values of the macro and micro minerals of dairy feed collected from the selected study areas based on seasonal availability, production system and localities is given (Table 4 to 6). Grass hay and different crop residues were found to be the major feed source in the ration of dairy cows and all feeds collected were (roughage feeds, Cereal grain & oilseed cakes and non-conventional feeds).

Table 3 Summary of over all the average concentration value of individual feeds of macro and micro mineral in dairy feeds (% and mg.kg^{-1} dry matter basis) throughout the study area in relation to critical values of respective minerals

Types of Feeds N= 140	Macro minerals (%)			Micro minerals (mg/kg)			
	Ca	P	Mg	Cu	Fe	Zn	Co
Roughage feeds n=52							
Tef (*Eragrostis tef*) straw n=10	0.39 ± 0.07	0.61 ± 0.09	1.16 ± 0.11	9.00 ± 0.64	68.50 ± 15.59	39.14 ± 1.89	ND
Wheat straw (*Triticum aestivum*) n=7	0.35 ± 0.07	0.61 ± 0.09	0.63 ± 0.11	6.99 ± 0.64	82.74 ± 15.59	30.53 ± 1.89	ND
Natural grass hay n=14	0.13 ± 0.07	0.82 ± 0.09	0.31 ± 0.11	8.72 ± 0.64	112.40 ± 15.59	27.49 ± 1.89	ND
Oat vetch (*Avena sativa*) n=4	0.54 ± 0.07	0.52 ± 0.09	0.70 ± 0.11	10.65 ± 0.64	176.80 ± 15.59	38.39 ± 1.89	0.09 ± 0.00
Alfalfa (*Medicago sativa*) n=3	0.55 ± 0.07	0.70 ± 0.09	0.85 ± 0.11	6.96 ± 0.64	128.39 ± 15.59	32.56 ± 1.89	0.05 ± 0.00
Elephant grass (*Pennisetum purpureum*) n=4	0.50 ± 0.08	0.44 ± 0.09	1.32 ± 0.12	6.96 ± 0.69	128.05 ± 15.59	28.82 ± 2.04	0.06 ± 0.00
Sugar cane (*Saccharum officinaru*m) tops n=7	0.28 ± 0.08	0.28 ± 0.09	1.75 ± 0.12	10.51 ± 0.69	114.97 ± 16.86	23.80 ± 2.04	ND
Silage n=3	0.14 ± 0.08	0.67 ± 0.09	1.39 ± 0.12	8.97 ± 0.69	92.92 ± 16.86	40.04 ± 2.04	ND
Overall mean ± **SE**	0.36 ± 0.08	0.58 ± 0.09	1.01 ± 0.12	8.60 ± 0.66	113.10 ± 15.91	32.60 ± 1.95	0.025 ± 0.00
P-value	0.6054	0.0636	0.0396	0.9149	0.6015	0.8540	
Cereal grain & oilseed cakes n= 65							
Wheat bran (*Triticum aestivum*) n=8	0.64 ± 0.6	0.68 ± 0.07	0.39 ± 0.09	7.68 ± 0.51	73.94 ± 14.70	48.98 ± 2.99	ND
Wheat middling n=5	0.38 ± 0.6	0.51 ± 0.07	0.32 ± 0.09	6.67 ± 0.51	84.39 ± 14.70	57.71 ± 2.99	ND
Concentrate mix (Faba bean mixed hull x WB) n=11	0.48 ± 0.6	0.41 ± 0.07	0.54 ± 0.09	7.90 ± 0.51	105.81 ± 14.70	46.06 ± 2.99	ND
Noug seed cake (*Guizotia abyssinica*) n=18	0.23 ± 0.6	0.42 ± 0.07	0.75 ± 0.09	7.98 ± 0.51	126.26 ± 14.70	31.85 ± 2.99	ND
Ground maize n=10	0.27 ± 0.6	0.64 ± 0.06	0.41 ± 0.08	8.59 ± 0.48	174.81 ± 13.74	33.61 ± 2.79	ND
Cottonseed cake n=8	0.14 ± 0.6	0.59 ± 0.07	0.54 ± 0.09	7.74 ± 0.5	111.15 ± 14.70	30.02 ± 2.99	ND
Lean seed cake(*Linum usitatissimum*) n=5	0.29 ± 0.6	0.89 ± 0.07	0.87 ± 0.09	8.78 ± 0.51	107.02 ± 14.70	36.84 ± 2.99	ND
Overall mean ± **SE**	0.35 ± 0.6	0.60 ± 0.07	0.54 ± 0.09	7.91 ± 0.51	112.02 ± 14.56	40.72 ± 2.96	ND
P-value	0.2103	0.0021	0.2830	0.7750	0.0573	0.0007	
Non-conventional feeds n= 23							
Atella/ local n=8	0.34 ± 0.04	0.79 ± 0.06	0.41 ± 0.09	9.72 ± 0.50	157.93 ± 6.82	34.30 ± 1.49	ND
A brewery by-products/industrial n=8	0.69 ± 0.04	0.81 ± 0.06	0.51 ± 0.08	6.31 ± 0.47	65.92 ± 6.37	27.53 ± 1.40	ND
Poultry manure n=7	0.62 ± 0.04	0.74 ± 0.06	0.50 ± 0.08	7.55 ± 0.47	103.90 ± 6.37	32.47 ± 1.40	ND
Overall mean ± **SE**	0.55 ± 0.04	0.78 ± 0.06	0.47 ± 0.09	7.86 ± 0.48	109.25 ± 6.52	31.43 ± 1.43	ND
P-value	0.8502	0.0281	0.0217	0.0426	0.9842	0.0035	
Critical level*	< 0.30%	< 0.25%	< 0.20%	< 8ppm	< 50ppm	< 30ppm	< 0.1ppm

*Concentrations below which (Ca < 0.30%; P < 0.25%; Mg < 0.20%; Cu < 8ppm; Fe < 50ppm; Zn < 30ppm; Co < 0.1ppm) Ca=calcium; P=phosphorus; Mg=magnesium; Critical level based on (McDowell *et al*., 1993; NRC, 2001); SE=standard error. This table indicated that the individual feed mineral concentration which helps to identify mineral concentration of feeds in rift valley area, WB= wheat bran.

Table 4-6 show mean values of the macro and micro minerals of dairy feed collected from the selected study areas based on seasonal availability, production system and localities. Identification of macro and micro minerals such as Ca, P, Mg, Cu, Fe, Zn, and Co were made from feeds. Grass hay and available crop residues were found to be the major feed source in the ration of dairy cows (Natural grass hay, *Triticum aestivum*, *Eragrostis tef*. The majority of milk producers use feeding as supplement. These are oilseed cake, wheat bran, wheat middlings, and ground maize, local and industrial brewery by-products. In this study, it was indicated that only general macro and micro mineral status of feed resources were collected analyzed and categorized as deficient or sufficient based on the critical values given by (McDowell *et al*., 1993; NRC, 2001) (Table 3).

The mean Calcium (Ca) concentrations in roughage varied from (0.13 to 0.55%); Cereal grain & oilseed cakes (0.14 to 0.64%) and non-conventional (0.34 to 0.69%) DM bases respectively. There was no statistically significant difference (P > 0.05) in the concentration of calcium levels in roughage, Cereal grain & oilseed cakes and non-conventional feeds in the study areas. Out of the total feeds analyzed, 12.92, 26.15% for roughage (natural grass hay, sugar cane tops and silage) and Cereal grain & oilseed cakes (noug seed cake, ground maize, cottonseed cake and lean seed cake), respectively, were found to be deficient in Ca comparing to critical level (Table 7).

Phosphorous (P) concentration was no significant difference ($p > 0.05$) between roughage feeds, but in between Cereal grain & oilseed cakes feeds as well as non-conventional feeds, P content was significantly different ($P < 0.05$) from collected samples during the study period. When P concentration levels are compared to the critical level, it was sufficient to the dairy (McDowell *et al*., 1993; NRC, 2001). Out of the total feeds analyzed, 17.0, 2.5% for roughage (natural grass hay, sugar cane tops and silage) and Cereal grain & oilseed cakes (noug seed cake, ground maize, cottonseed cake and Lean seed cake), respectively, were found to be deficient compared to critical level (Table 7), whereas the majority of sampled feeds P concentration was sufficient (Table 3).

Magnesium (Mg) concentration was no significant difference ($p > 0.05$) between roughage feeds, Cereal grain & oilseed cakes and non-conventional feeds from collected samples during the study period in the study areas. When the Mg concentration level is compared to the critical level, it was sufficient to the dairy cattle (McDowell *et al*., 1993; NRC, 2001). Out of the total feeds analyzed, Mg was deficient only for roughage feeds, but for the rest feed resource, it was not deficient compared to critical level.

There was no significant difference ($P > 0.05$) of copper (Cu) concentration in roughage and concentrate feeds. However, a significant difference ($P < 0.05$) was observed in non-conventional feeds. When those values are compared to the critical value (< 8ppm) of feeds analyzed, 49.23, 76.92% and 65.22% for roughage (*Triticum aestivum*, *Medicago sativa*, *Pennisetum purpureum*), Cereal grain & oilseed cakes (wheat bran, wheat middling's, noug seed cake, cottonseed cake and concentrate mix) and non-conventional feeds(brewery by-products industrial and poultry liters) respectively were found to be deficient in Cu.

The mean iron (Fe) concentrations varied in roughages (68.5 to 176.80 ppm); Cereal grain & oilseed cakes (73.94 to 174.81ppm) and non-conventional (65.92 to 157.93 ppm) in DM bases respectively. When those values are compared to the critical value of (50 ppm), no sample of feeds was deficient in Fe.

The mean zinc (Zn) concentrations varied (23.80ppm to 40.04 ppm) in roughages; Cereal grain & oilseed cakes (30.02ppm to 57.71 ppm) and non-conventional (27.53ppm to 34.30 ppm) in DM, respectively. When those values are compared to the critical value of (50 ppm), feeds analyzed were found to be deficient in Zn (48.08%, 11.45% and 34.78%) for roughage, concentrate and non-conventional feeds, respectively (Table 5).

The current study showed that except some roughages (*Avena sativa*, *Medicago sativa*, and *Pennise tumpurpureum*) feeds, totally for Cereal grain & oilseed cakes and non-conventional feeds, cobalt (Co) concentration was not detected from the sampled feeds. The value of Co level in roughages, Cereal grain & oilseed cakes and non-conventional feeds from collected feeds was below the critical level 0.1 ppm. The category of deficient or sufficient is based on the critical values of (McDowell *et al*., 1993; NRC, 2001) (Table 5 and 6).

Interaction effect of mineral concentration in dairy feeds was highly significant ($P < 0.01$) between districts, production system and sampling season (Table 4, 5, and 6).

Table 4 Effect of districts on macro and micro mineral concentration in the study districts

Feed type	Districts	Macro minerals (% DM)			Micro minerals(mg/kg DM)			
		Ca	P	Mg	Cu	Fe	Zn	Co
Roughage n=52	Ada'a	0.59[ab]	0.49[b]	1.02[a]	8.91[a]	101.78[b]	33.16[b]	0.07
	Adama	0.70[a]	0.73[a]	1.09[a]	8.02[a]	125.17[ab]	32.17[b]	0.06
Cereal grain & oilseed cakes n= 65	Ada'a	0.43[b]	0.59[ab]	0.58[b]	8.68[ab]	89.31[b]	37.79[a]	ND
	Adama	0.30[b]	0.64[ab]	0.49[b]	7.05[b]	142.26[a]	42.86[a]	ND
Non-conventional n=23	Ada'a	0.49[b]	0.75[a]	0.35[b]	7.13[b]	89.09[b]	32.56[b]	ND
	Adama	0.59[ab]	0.74[a]	0.55[b]	7.27[b]	124.95[ab]	29.77[b]	ND
Overall mean (N=140)		0.52	0.66	0.68	7.84	112.09	34.72	
SEM		0.034	0.034	0.048	0.267	6.527	1.131	
P-value								
Feed type		0.0001	0.0134	0.0001	0.0001	0.0013	0.6288	
Districts		0.5465	0.0131	0.3115	0.0002	0.0001	0.7335	
Feed x districts		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	

ND= not detected; value without superscript =indicated not significantly different; Means with the same superscript of each feed catagories among the districts in the same column (a, b) are not significantly different. Critical level=is concentrations below which feeds are deficient.(Ca < 0.30%; P < 0.25%; Mg < 0.20%; Cu < 8ppm; Fe < 50ppm; Zn < 30ppm; Co < 0.1ppm), Ca=calcium; P=phosphorus; Mg=magnesium; Critical level based on (McDowell *et al*., 1993; NRC, 2001)

Table 5 Effect of production system on macro and micro mineral concentration in the study districts

Feed type	Production system	Macro minerals (%)			Micro minerals (mg/kg)			
		Ca	P	Mg	Cu	Fe	Zn	Co
Roughage n=52	Urban	0.59[ab]	0.54[b]	0.94[a]	7.93[b]	100.16	33.71[b]	ND
	per-urban	0.66[a]	0.63[ab]	1.07[a]	8.41[ab]	122.99	31.78[b]	0.03
Cereal grain & oilseed cakes n=65	Urban	0.43[bc]	0.61[ab]	0.42[b]	7.36[b]	102.84	41.40[a]	ND
	per-urban	0.28[c]	0.63[ab]	0.66[b]	8.53[ab]	130.81	38.46[a]	ND
Non-conventional n=23	Urban	0.54[ab]	0.79[a]	0.45[b]	9.63[a]	95.84	33.25[b]	ND
	per-urban	0.55[ab]	0.75[a]	0.44[b]	6.51[b]	106.84	29.62[b]	ND
Over all mean (N= 140)		0.51	0.65	0.66	7.73	109.91	34.70	
SEM		0.034	0.033	0.047	0.256	6.473	1.132	
P-value								
Feed type		0.0001	0.0020	0.0001	0.0533	0.2960	0.0001	
Production system		0.5816	0.4798	0.0264	0.5961	0.0074	0.0342	
Feed x Production system		0.0001	0.0058	0.0001	0.0001	0.0254	0.0001	

ND= not detected; value without superscript =indicated not significantly different; Means with the same superscript of each feed catagories among the production system in the same column (a, b) are not significantly different; Critical level=is concentrations below which feeds aredeficient.(Ca < 0.30%; P < 0.2%; Co < 0.1ppm); Ca=calcium; P=phosphorus; Mg=magnesium; Mg < 0.20%; Cu < 8ppm; Fe < 50ppm; Zn < 30ppm; Critical level based on (McDowell *et al*., 1993; NRC, 2001)

The interaction effect of Ca, P, Mg and Zn concentration of dairy feeds, were highly significant ($P < 0.01$) between districts, production system and sampling season (Table 4, 5, and 6). Whereas, Cu and Zn concentration of dairy feeds were not significantly different ($P > 0.05$) with seasons (Table 6).

Table 6 Effect of season on macro and micro mineral concentration in the study districts

		Macro minerals (%)			Micro minerals(mg/kg)			
Feed type	Season	Ca	P	Mg	Cu	Fe	Zn	Co
Roughage n=52	Dry	0.61^{a}	0.50^{ab}	0.86^{a}	8.47	103.25	32.46^{b}	ND
	Wet	0.63^{a}	0.64^{b}	1.09^{a}	8.49	115.26	33.41^{b}	0.06
Cereal grain & oilseed cakes n=65	Dry	0.35^{b}	0.59^{ab}	045^{b}	7.71	106.24	38.38^{ab}	ND
	Wet	0.38^{b}	0.64^{b}	0.58^{b}	8.01	122.15	41.46^{a}	ND
Non-conventional n=23	Dry	0.50^{ab}	0.65^{b}	0.34^{b}	7.54	95.27	30.15^{ab}	ND
	Wet	0.59^{a}	0.89^{a}	0.54^{b}	7.68	106.13	33.00^{b}	ND
Overall mean (n= 140)		0.51	0.65	8.07	7.98	108.05	34.81	
SEM		0.034	0.033	0.047	0.264	6.543	1.139	
P-value								
Feed type		0.0001	0.0003	0.0001	0.079	0.408	0.0001	
Season		0.702	0.754	0.0009	0.084	0.094	0.857	
Feed x Season		0.0001	0.0001	0.0001	0.124	0.357	0.0001	

ND= not detected; value without superscript =indicated not significantly different; Means with the same superscript of each feed catagories among the season in the same column (a, b) are not significantly different; Critical level=is below which feeds aredeficient.(Ca < 0.30%; P < 0.25%; Mg < 0.20%; Cu < 8ppm; Fe < 50ppm; Zn < 30ppm; Co < 0.1ppm), Ca=calcium; P=phosphorus; Mg=magnesium; Critical level based on (McDowell *et al.*, 1993; NRC, 2001)

Table 7 Critical level based macro & micro mineral status of feed resources in different dairy feeds in the study districts

Minerals	Critical	Roughage %		Cereal grain & oilseed cakes %		Non-Conventional feeds%	
N=140	level*	sufficient	deficient	sufficient	deficient	sufficient	Deficient
Ca	< 0.30	87.08	12.92	73.85	26.15	100	-
P	< 0.25	83.0	17.0	97.50	2.50	100	-
Mg	< 0.20	89.10	11.0	100	-	100	-
Cu	< 8ppm	50.77	49.23	23.08	76.92	34.78	65.22
Fe	< 50ppm	100	-	100	-	100	-
Zn	< 0.30ppm	51.92	48.08	88.55	11.45	65.22	34.78
Co	< 0.1ppm	2.27	97.73	-	100	-	100

*Critical level=is concentrations below which feedsare deficient. (Ca < 0.30%; P < 0.25%; Mg < 0.20%; Cu < 8ppm; Fe < 50ppm; Zn < 0.30ppm; Co < 0.1ppm), Ca=calcium; P=phosphorus; Mg=magnesium; Critical level based on (McDowell *et al.*, 1993; NRC, 2001); (-)=indicated that either deficient or sufficient.

Table 8 Summary of seasonal variation along with production system some macro mineral status of feed resources in different dairy feeds in the study area based on critical level

		Districts N=140								
		Ada'a				Adama				
		Urban		Periurban		Urban		Periurban		Critical
Mineral	Season	Sufficient	Deficient	Sufficient	Deficient	Sufficient	Deficient	Sufficient	Deficient	level
Ca	dry	73.37	26.67	70.13	29.87	68.33	31.67	80.33	19.67	< 0.30
	wet	88.33	11.67	78.33	21.67	77.33	22.67	89.33	10.67	
P	dry	88.68	11.32	92.66	7.34	85.55	14.45	90.33	9.67	< 0.25
	wet	86.77	13.23	89.31	10.69	83.70	16.30	88.70	11.30	
Cu	dry	62.11	37.89	52.44	47.56	73.53	26.47	53.66	46.34	< 0.8
	wet	72.92	27.08	60.65	39.35	62.61	37.39	62.55	37.45	
Zn	dry	54.4	45.60	62.66	37.34	36.55	63.45	72.37	27.63	< 0.30
	wet	46.77	53.23	53.66	46.34	64.63	35.37	68.79	31.21	
Co	dry	-	ND	-	ND	-	ND	-	ND	0.1
	wet	0.55	99.45	-	ND	-	ND	-	ND	

*Critical level=is concentrations below which feedsare deficient. (Ca < 0.30%; P < 0.25%; Mg < 0.20%; Cu < 8ppm; Fe < 50ppm; Zn < 0.30ppm; Co < 0.1ppm), Ca=calcium; P=phosphorus; Mg=magnesium; Critical level based on (McDowell *et al*., 1993; NRC, 2001); (-)=indicated that either deficient or sufficient.

High proportion of Ca was deficient during dry compared to wet season. Small proportion P was deficient in Cereal grain & oilseed cakes as compared to roughages whilst relatively high deficiency in wet season as compared to dry. The result indicated that high P deficiency proportion occurred in wet season whereas, Ca deficiency occurred in dry season. Moreover, high proportion of Cu and Zn deficiencies occurred in collected feeds in all feed type and season. From the majority of feeds collected, Co was not detected in the laboratory Table 5 and 6.

4 Discussion

The Macro and Micro Mineral Concentration of Feeds

The mean concentrations of important macro and trace minerals in the different categories of dairy feed resources evaluated in this study in comparison to the respective critical level (CL) recommendations for dairy cattle (McDowell *et al*., 1993; NRC, 2001) indicated in (Table 3). The mean calcium value in different types of roughage, Cereal grain & oilseed cakes and non-conventional feeds in both districts were majorly found to be above critical level (< 0.30 percent), which is in agreement with the findings of Tiwary *et al*. (2007). This indicated that tropical forages feeds are rich in Ca. However, roughage feeds, natural grass hay, sugarcane tops, and silages are deficient in Ca in comparison to the critical levels (McDowell *et al*., 1993; NRC, 2001). The current results are in agreement with the report of Aschalew *et al*. (2006), which indicated that tropical dry forages are deficient in Ca. This might be due to variations in forage species, plant composition, and stage of maturity, seasons, and variations in soil characteristics as well as the location of the different feed sources in the study area.

The current study revealed that from analyzed mineral samples, legume forages contained more mineral concentrations than in grass species and crop residues. This finding is in line with the report of Khan *et al*. (2007) that indicated that legume forage species are richer in Ca than grasses. The variations in different studies of mineral composition could be due to differences in the type of feeds, soil, the season of sampling and analytical procedures and technique (McDowell, 2003).

The mean Ca concentration in the oilseed cakes was found to be below the critical level, which is in line with the report of (NRC, 1989, 2001; Fekede *et al*., 2015) that indicated the Ca content in oilseed cake fall below the critical level. Therefore, dairy animals need to be supplemented with other sources of minerals when oilseed cakes are used as supplementary feeds. Moreover, in the current study, non-conventional feeds like brewery by-products (local and industrial) had higher Ca content in relation to the critical level of different minerals. This result is in line with the report of NRC (2001); Fekede *et al.* (2015) reported that the brewery by-products evaluated had much higher Ca content than the maximum tolerable concentration.

The feed resources like roughage, Cereal grain & oilseed cakes, and non-conventional feeds had a high P concentration as compared to the critical level of dairy animals (Table 3). The result of this study is unlike the result of Tiwary *et al.* (2007), who indicated that P was found to be deficient in different feeds based on its critical level (McDowell *et al.*, 1993; NRC, 2001). This difference could be due to maturity, species diversity as the samples were not of the same type. Moreover, McDowell (1997); Aschalew *et al.* (2006) reported that P composition dropped from 0.3% in the early growing season to less than 0.15% after maturity and management.

The concentration of P during the dry season was relatively higher than during the wet season concentration (Table 8). This study is in agreement with the result of Tapiwa (2012), which indicated that P was higher in the dry season than in the wet season. This may be due to leaching or translocation of P by the flood to the root system during the rainy season and also due to excess of Ca, Fe or aluminum in soil reduces the availability of P to plants (Radostits *et al.*, 2000). Similarly, the current study is in agreement with the result of Khan et al. (2007), which indicated that during the wet season, plants will not contain an adequate amount of phosphorus due to inadequate amounts P in the soil, plant uptake of minerals is slow in the cool and wet conditions. Furthermore, the current study is in agreement with the report of (Fekede *et al.*, 2015). The result showed that P content of the wheat bran, wheat middlings, and brewery by-products was fairly within the range of recommended critical level in dairy cattle diets (NRC, 2001).

Magnesium levels in most of the sampled feeds were found above the critical level (McDowell *et al.*, 1993; NRC, 2001). The results of this study were in line with the result of Underwood and Suttle (1999); Goff (2000), which indicated that the recommended concentrations for dietary magnesium to range within 0.2 - 0.4% of total DMI. However, there were differences in the Mg content of feeds in this study. It may be due to differences between forage species, level of Mg in the soil, influences of locality and climate, growth stage, the proportion of leaf and stem fractions collected for mineral analysis, and season when herbage sampling was done (Radostits *et al.*, 2007). Even if in the current study the availability of Mg was high in animal feeds, the dietary Mg availability markedly affected by other dietary components, especially K. High dietary levels of K and N will inhibit Mg absorption from the rumen (Dua and Care, 1995). Moreover, Ca and soluble carbohydrates may respectively increase and decrease dietary Mg requirements of dairy cows. Likewise, an increment in dietary P levels appears to lower the requirements for both Ca and Mg (Judson and McFarlane, 1998). Even though the feeding systems prevailed the requirements of Mg could be met without any supplementation, Ruminant animals generally are at risk from hypomagnesemia when the forage contains less than 0.20% of Mg and if the soil is high in K content (Michal, 1999; Garg *et al.*, 2003a).

The current study revealed that copper content was below the critical level in the majority of the feed samples (roughages, concentrate and none conventional) analyzed, in all study districts, production systems and seasons. The result of this work is in line with that of Tiwary et al. (2007b) which indicated that animal feeds are deficient in Cu. This may be due to typical soil conditions that might be restricting its accumulation in plants and their availability (Gustavo *et al.*, 2016). Moreover, the current result disagree with the report of Fekede *et al.* (2015),which indicated that the majority of feeds like wheat bran, wheat middlings, brewery by-products' Cu concentration satisfied the dairy requirements. However, the concentration of Cu obtained from such feeds was deficient. This might be because of high iron concentration and also molybdenum in the soil of the study area, which in turn reduces the copper availability in plants (Underwood, 1977; Gustavo *et al.*, 2016). Moreover, the report of Sharma *et al.* (2005) showed that copper deficiency in livestock can result from low dietary Cu levels, high levels of Mo, and high sulfates compound in drinking water or the feed. Moreover, low forage Cu concentration at the end of the wet season could be due to a mature stage of the forages. During this period plants lose green color and become high in fiber and lignin, similarly, mineral availability also decreases, likewise, the interaction of Cu in soil with elements like Fe and Ca that affect its absorption (McDowell *et al.*, 1996). Therefore, copper contents in the majority of dairy feeds are below the critical level. As a result, copper deficiencies in forages can cause poor reproduction, broken bones, weak calves, scours and discoloration normally occur, first around the eyes and tips of the ears. Its supplementation in the ration of animals is very essential.

Iron is reported to be most abundant in this study, the content in different feed samples (roughages, concentrate and none conventional) analyzed, showed adequate to high levels, comparing to critical level < 50 ppm (McDowell *et al*., 1993; NRC, 2001). The current study showed a significant ($P < 0.05$) effect of districts on the concentration of Fe in the analyzed feeds items. The season had no significant effect ($P > 0.05$) on Fe concentration of analyzed feeds. On the contrary, with the current study, Lemma, *et al*. (2002) indicated that feeds during the dry season far exceeded the wet season values, but the difference was not significant. Forage Fe levels during the study season were sufficient for the requirements of dairy cattle for optimal performance. Variations in the contents of Fe concentration among roughages, Cereal grain & oilseed cakes and none conventional could be partly due to the content of Fe in the soil, and climatic conditions between localities. Likewise, forage Fe content is a function of forage species, soil Fe content, nature, and type of soil on which forages are grown (McDowell, 1992; ZafarIq, 2006). In the current study, even roughages contained a very high concentration of Fe, which were a poor source for many other mineral elements.

The average zinc concentration in the majority of feeds was found above its critical level (< 30 ppm) but in some roughages had lower levels of Zn. The result agrees with the report of (McDowell, 1985; Cuesta, 1993) which showed that Zn content was below the critical level in all the straws except some roughage feeds. This low forage Zn concentration observed in this study may be due to plant maturity and the tissue type of plants taken for analysis. However, the efficiency of Zn utilization of these forages would depend on zinc bioavailability and its interaction with other mineral elements. Metallic cations such as Ca, Fe and Mn, when found in high concentration, interfere with plant Zn uptake (Tisdale *et al*., 1985; Elisa *et al*., 2018). Excess iron inhibits the utilization of zinc and copper by plants and thus results in a secondary deficiency in plants (Underwood, 1977; Gustavo *et al*., 2016).

The mean cobalt concentration in the majority of dairy feed samples was found to be below its critical level. That was some roughage feeds were found to be fairly deficient in cobalt concentration. The result of current study when compared to previously reported study by McDowell (2003) indicated that forages consistently contain less than 0.08 ppm Co, the Co deficiency in dairy animals. In the majority of dairy feeds, it was not detected this might be due to high soil Mn content depresses uptake of Co in forages which could have led to reduced Co absorption by plants and subsequently low levels in plant tissues, as it was not in detectable range in the feedstuffs analyzed. Moreover, Co concentration was not detected from the sampled feed by AAS reading may be due to calibration.

5 Conclusions and Recommendations

The present study was carried out with the objective of assessing the status of some macro and micro-minerals in dairy feeds. In the study area based on seasons, roughages were found to be the main source of feeds in the ration of dairy cows (Natural grass hay, *Triticum aestivum*, and/or *Eragrostis tef*). It was noticed that some of the dairy producers fed improved forages like *Pennisetum purpureum*, *Avena sativa*, *Medicago sativa*. It was evident from the present study that majority of the dairy cows feeds analyzed, only 26.92%, 66.15% for roughage (natural grass hay, sugar cane tops, and silage) and concentrates (noug seed cake, ground maize, cotton seed cake, and lean seed cake), respectively, were deficient for Ca. Moreover, the concentration of Cu compared to the critical value (< 8ppm) of analyzed feeds types (19.23%, 76.92%, 65.22%) for roughage (*Triticum aestivum*, *Medicago sativa*, *Pennisetum purpureum*), Cereal grain & oilseed cakes (wheat bran, wheat middlings, noug seed cake, cottonseed cake and concentrate mix) and non-conventional feeds (brewery by-products industrial, poultry liters) respectively. Likewise, Zn concentration in feeds analyzed was only 48.08% and 34.78% deficient compared to critical levels for roughage (natural pasture, *Pennisetum purpureum*, sugar cane top) and non-conventional feeds (brewery by-products industrial), respectively. Moreover, Co was not detected from the majority of feeds implying that Co from sampled feeds was below the critical level. Due to such deficiency of minerals, production, and productivity, as well as the health of dairy cows were severely affected. However, the levels of P, Mg and Fe in all analyzed feeds were found to be sufficient to meet estimated nutritional requirements for dairy cows.

Therefore, among analyzed feeds for minerals present in inadequate amounts like Ca, Cu Zn should be supplemented to produce beneficial results on dairy production. Hence, there is an urgent need for appropriate research to develop area specific mineral mixtures that are highly bio-available for supplementation.

Conflict of interest

The authors affirm that there is no conflict of interest in the work described.

Acknowledgment

The authors would like to thank Getu Kitawu, Ms Workinesh Seid, Dr. Sofia, Dr. Diriba Geleti, and Dr. Fekede Feyissa for their technical and all-round assistance. The authors would also like to thank Debreziet and Holota Agricultural research laboratory staffs. This study was partially supported by funds from the Ethiopian Institute of Agriculture Research, AGPII and Addis Ababa University Research and Technology transfer funded thematic research entitled as "Promotion of improved dairy technology and investigation into reproductive diseases of dairy for better health, productivity, and development of the dairy sector".

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EJED 2(2) 2019: 1 – 26
Ethiopian Journal of
Environment and Development
http://www.du.edu.et/duj
EJED

Informal Economy and Livelihood: Experiences of Women in Dilla Town, Southern Ethiopia

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Received: 15 January , 2019 /Accepted: 2 November, 2019

Abstract

This study investigates the nexus between the informal economy and women's livelihood improvement in developing economies like Ethiopia. Women in developing countries in general and in Ethiopian developing economy in particular face multi-dimensional challenges that include economic, political, social and cultural factors which undermine both of their agency and capability. The high incidence of poverty and family responsibility under such circumstances compels them to the informal sector where operations are far from getting policy support. The objective of this research is to investigate the role of the informal economy in improving the livelihood of women in terms of income, employment and reduction of poverty of households led by women operating in the informal sector in Dilla town.This research sought to examine the contribution of the informal sector to the livelihood improvement of women in Dilla town. The specific focus was on women informal sector operators in the street/trading areas. The study used quantitative and qualitative research methods in order to get a deeper understanding of how the informal sector is contributing to the improvement of the livelihood of women. Both qualitative and quantitative data sets were collected and analyzed. The qualitative data were analyzed by using a thematic analysis approach and the quantitative data were analyzed using descriptive and inferential statistical summaries. The findings of the study revealed that informal sector has a lot of contribution to improve livelihoods of women through employment creation, supporting incomes to the household, reducing poverty. The major reason to operate in the informal sector is to generate livelihood income and the pushing factors are unemployment, poverty and lack of source of income. The result also revealed that after they involved in the informal business, to some extent, the livelihood of women is improved. Therefore, by understanding this potential of

the informal sector, the government in collaboration with the other sectors should work on it to create a better working environment.
Key Words: *Informal Economy, Livelihoods, Women, Poverty*

1. Introduction

The informal sector exists in all countries, irrespective of the individual country's level of socio-economic development, but it is far more prevalent in developing countries.The informal economy provides the largest share of employment globally and is vital to the jobs, incomes, and consumption of poor women and men. Of those that are employed globally, 61.2% are in the informal economy (ILO, 2018). Poor people are more likely to be in informal than formal employment (Avirgan *et al.*, 2005; IIED, 2016; ILO, 2018; Bonnet *et al.*, 2019). Informality rates are higher among young people, the elderly, women, minority ethnic communities, workers with disabilities and, more generally, those groups in society that experience economic and social disadvantage, labor market discrimination and lack of adequate access to education, training, and capital (Pathways Commission, 2018). People living in rural areas are twice as likely to be in informal employment as those in urban areas (ILO, 2018).

Informal employment is the main source of employment for Africa, accounting for 85.8 % of all employment or 71.9% excluding agriculture. While there is little variation in the share of informal employment among countries in Northern Africa, there is substantial variation among the countries of sub-Saharan Africa. This is a major difference that characterizes countries in Southern Africa and explains to a large extent some of the differences observed for informality (ILO, 2018).

Most workers (76.0 %) are in informal employment in the informal sector, with a relatively small proportion of informally employed in the formal sector (5.5%) and in house holds (4.3%). In this region, a higher proportion of women's employment (89.7%) is informal than men's (82.7%). Young people (94.9%) and older persons (96.0%) have very high levels of informal employment. The level of education is closely linked to informality in all sub-regions. Informal employment dominates the labor market in both rural (88.3%) and urban areas (76.3%) (ILO, 2018). Within sub-Saharan Africa, informal employment is the main source of employment in Central Africa (91.0 %), Eastern Africa (91.6 %) and Western Africa (92.4 %) (ILO, 2018).

The significance of informal sector activities is gradually emerging worldwide (Darbi & Knott, 2016), as a tool to reducing poverty (Chidoko & Makuyana, 2012), which has been noted as a key challenge to humanity (Sutter *et al.*, 2019). Thus, informal sector activities are viable in reducing poverty among women in the informal sector. Yet, the full potential of the informal sector in reducing poverty among women may not be realized when women encounter challenges that could retard the attainment of the United Nations poverty-related Sustainable Development targets (Veronica *et al.*, 2019).

Female representation in the urban informal sector is higher in many countries across the globe especially in developing countries (Tinuke, 2012). With the already constraints women face in society and barriers in theformal job market, female labor participation in the urban space is predominantly informal (Carrol, 2011; Ramanietal, 2013). The sector has been of great benefit to women in diverse ways in terms ofemployment, income, and realization of self-esteem (Forkuor *et al.*, 2017).

The subordinate status and limited access of women into the formal labor market have resulted in many seeking refuge in the informal sector (Kishor & Gupta,2009; Osei- Asibey, 2014). The informal sector employs about two-thirds of the global active labor force and has contributed to poverty reduction (Chen, 2008; World Bank, 2009; Chant, 2012; UN, 2018). The majority of informal economy workers across the globe are women (Tinuke, 2012).

The unfavorable climate of doing business in Ethiopia and government policies in place are assumed to be the critical factors for business entry, growth and development (IFC, 2015). Reforms in the business climate and job creation that emanate from the existing policies of Ethiopia are increasingly resulting in unemployment and barriers to business entry (Tesfaye, 2015). These trends are seemingly perpetuating barriers and the growing involvement of the poor in the informal business sector is the result of these.

In Ethiopia, the unemployed prefer the informal sectors in the absence of the formal sector to accommodate under-skilled labor force at one hand and government capacities and resources and work to formalize and support the informal sector operators. The poor engage in these sectors as protection of families from the claws of poverty (MoLSA, 2013). The informal sector contributes to about 38.6 % of national GDP in Ethiopia as compared with an average of 38.4 % for SSA and 38 % for all low-income countries (IMF, 2013).

The relevance of the informal economy for the growth and transformation of the economic pattern in Ethiopia is evident from works of (MoLSA, 2013; IMF, 2013). The sector is dominated by women and street vendors, as business operators, are increasingly related to informal sector businesses – which scholars categorize as “survivalist and growth-oriented” (Filimon, 2009).

The informal sector remains the major source of employment for women and the sector is yet the most excluded from policy incentives and supports. In the context of policy exclusion and lack of support, the dynamism of the informal sector in job creation and value addition is particularly becoming strong and worth for research. The informal sector accommodates 80 % of the total unskilled labor force in Ethiopia. The sector also provides the operators with the means of livelihood and an essential supplement to incomes. The informal sector is becoming a source of livelihood income for poor women in cities; in the absence of the formal sector support for this segment of the labor force (MoLSA,2013; Filimon, 2009).

According to Young (1993), Kabeer (1996), Chant (2003) the time poverty, which gender scholars also term as double-day burden inflict the chances of girls and constitute a life-time obstacle for girls’ preparedness to the labor market. Because of this, unprepared women end up operating in the informal sector both as a way out to their exclusion from the formal labor market and economy and in looking for family provision incomes. This process perpetuates the trend of women poverty and their families as distinct from the male counterpart in the Ethiopian society.

In Ethiopia, there are limited studies regarding the role of the informal sector for women. It is, therefore, necessary to understand the role of informal sector for livelihood improvement of women.It will also help to provide practical recommendations and solutions to reduce the poverty of women in the country. Therefore, the main objective of the study is to assess the contribution of the informal sector for livelihood improvement of women by taking women traders as a case study in Dilla town and specifically, it explores general context in which the informal sector business in Gedeo Zone-Dilla.

2. Materials and Methods

2.1. Description of the Study Area

This study was carried out in Gedeo Zone; Dilla town.Gedeo Zone is a Zone in the Southern Nations, Nationalities, and Peoples' Region (SNNPR) of Ethiopia. Gedeo extends south as a narrow strip of land along the eastern escarpment of the Ethiopian Highlands into the Oromia Region, which borders the Zone on the east, south, and west; Gedeo shares its northern boundary with Sidama. Dilla is the administrative center; the altitude of the Zone ranges from 1268 meters above sea level in the vicinity of Lake Abaya to an elevation of 2993 meters at HaroWolabu Pond (Kippie , 2002).

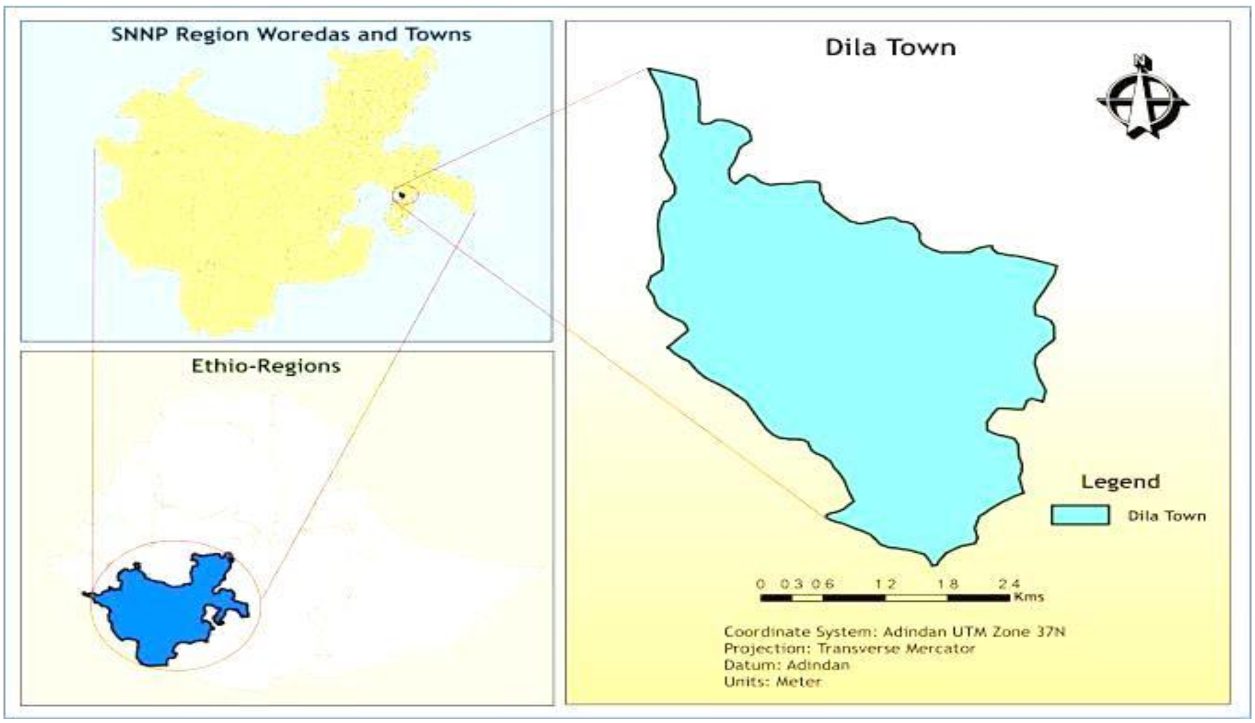

Figure 1 Map of the study area

Based on the figures from the CSA (2007), the Gedeo Zone had an estimated total population of 975,506 of which 486,996 were males and 488,510 were females with an annual growth rate of 2.9%.This zone is one of the most densely populated area in the country with an estimated population density of 769 people per square kilometer (CSA, 2007)

The study area,Dilla town is a market town and separate woreda in southern Ethiopia. Dilla town is the administrative center of the Gedeo Zone in the Southern Nations, Nationalities, and Peoples

Region (SNNPR). It is located on the main road from Addis Ababa to Nairobi. The town is located betweeb 6°24′30″N -38°18′30″E with an elevation of 1570 meters above sea level.

2.2 Sampling Techniques

2.2.1.Sample size Determination

This study used both probability and non-probability sampling method. Applying the probability sampling method in this kind of study is more difficult and costly. However, probability samples are the only type of samples where the results can be generalized from the sample to the population.

Before the actuao data collection, the researchers made a baseline survey to ensure that the desired numbers of informal sector participants are found in the trading areas found in Dilla town and to grasp the business environment and to prepare the questioners based on the business situation. The informal sector operators are addressed using systematic sampling by using every (N^{th}) of the population. Determining the adequate sample size is the most important design decision that the researchers' findings will become sound. Usually,the sample size is determined based on the sampling technique. Since prior information is lacking, a pilot survey was conducted on each of the populations to estimate the probability of success (p).

The total sample size was determined by using the unknown sample size determination formula (Sarantakos, 1998).

$$n = \frac{Z^2 p(1-p)}{d^2} = \frac{1.96^2(0.25)(0.75)}{0.07^2} = 196$$

2.2.2. Selection of Respondents

In order to select those women who are participating in the informal sector, the Multistage sampling method was applied in order to reduce sampling error.In the first stage, Dilla town was selected as a study area because Dilla town is the market and administrative center of the Gedeo zone. The three Kifile Ketema of Dilla town (HaroWolabu, Sessa and Bedecha) were selected for the study. Then, these Kifile Ketema were divided into trading areas and 14 trading areas were chosen by using SRS. Finally, since the number of informal sector participant women in each trading area was unknown, the total sample size was divided by the number of selected trading areas, which was equal to 196/14 = 14. These 14 informal sector participant women were selected from each trading area using a systematic sampling method.

Moreover, [Please put the number here. how many?] officials or experts in Dilla town Trade and Industry Development Bureau, Dilla town Women,Children, and Youth Affairs Bureau and Micro and Small Scale enterprise were purposefully selected for this study.

2.3 Data Collection and Analysis

Data were used from both primary and secondary sources. Primary data was obrained through questionnair collected from 196 systematically selected respondents who were running informal business. To collect the questionnaire, the researchers used the PAPI method. The researchers interviewed all groups of the respondents on each of the questionnaire items and filled the responses on the questionnaire items. On the other hand, Interview was held with women informal sector operators and government officials. Secondary data were collected from reports of different concerned organizations, articles, and journals which are related to this study.

Data collected using questionnaire was entered into SPSS version 22 windows for the statistical analysis. Descriptive statistics like frequencies, percentage, figure, pie-chart, bar-chart; and inferential statistics like one sample proportion (binomial) test and inferential statistics like binary logistic regressionare were used to facilitate meaningful analysis and interpretation of research findings. Data collected through interview wsa analyzed using thematic data analysis techniques.

Variables of the Study

Variables considered in this study are categorized into dependent and explanatory/predictor variables.

Dependent variable is a variable whose values are influenced by the values of other variables or dependent variable as a variable that is potentially influenced by the independent variables, because it is influenced by, and thus to some extent depends on the independent variables. In this case, the dependent variable of the study is the livelihood improvement of women in the informal sector.

The explanatory/predictor variables: are those variables that are presumed to affect or determine a dependent variable. They can be changed as required and their values do not represent a problem requiring explanation in the analysis but are taken simply as given.The explanatory variables included in this study are age, educational level, marital status, no of dependents at home, place of birth, having other jobs, saving status, start-up capital, linkage with the formal sector, no of years stayed in current work and profit per day.

3. Result and Discussion

3.1. General characteristics of the informal sector operators

3.1.1. Age of the sampled respondents

The respondents were categorized under five groups. Below 14 years, 15-24 years, 25-54 years, 55-64 years and 65 years and above. The data in Figure 1 below showed that the majority of women operators are found in the active age group. From the total respondents of the operators, the age group 25-54 years constituted 56.6 %. About 32.1 % were between 15-24 years and the rest 3.6 % and 7.7 % were found between below 14 years and 55-64 years respectively.

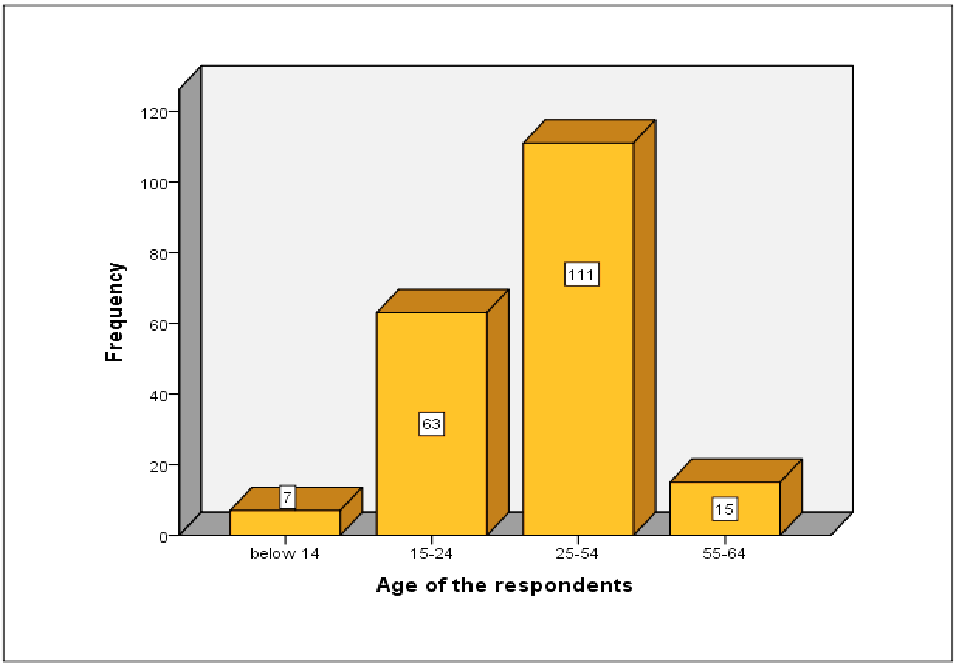

Figure 2 The age structure of the respondents

The distribution shows that the informal sector is made up of the people who can actually work productively in the formal sector, given an opportunity. At the same time, results of the findings showed that informal sector activities were carried out by different age groups through the dominant group was between 25 to 54 years.

3.1.2. Educational level

The data presented in Figure 3 below showed that out of 196 informal sector operators that filled the questionnaire, only 13.8 % attended some level of secondary education. Those with primary education constituted 54.1 % and the remaining respondents who did not attend any formal education but engaged in informal sector business operation were 32.1 %.This was particularly the case because most of the school leavers and non-formal school leavers could not get jobs in the formal sector forcing them to join the informal sector for survival.

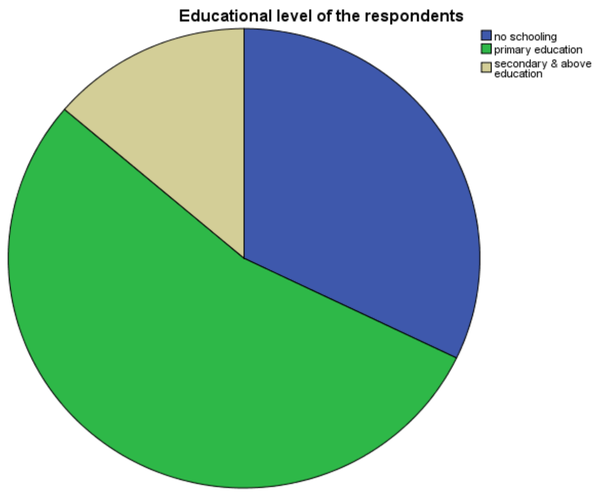

Figure 3 Educational level of the sampled respondents

This implies that access to education is not easy for women or the opportunity to get an education is very low.Because of the reality in rural Ethiopia, family preference is sending boys to a school than girls. Additionally, Poverty and family responsibility are also higher for women with low education and they engage in the informal sector. ILO (2018) report says the level of education is a key factor affecting the level of informality. This means globally, when the level of education increases, the level of informality decreases. People who have completed secondary and tertiary education are less likely to be in informal employment compared to workers who have either no education or completed primary education. In addition, People living in rural areas are almost twice as likely to be in informal employment as those in urban areas. Globally, about 91 % of women in the informal economy are illiterate or have finished only primary education while women having completed secondary and higher education are less likely to be engaged in this work (ILO, 2018). Women with lower levels of education tend to develop and accumulate their skills through "on-the-job" training over time – either at home, through friends and the community, or informal apprenticeships.

3.1.3. Marital status

Regarding marital status, Figure 4 shows that among those engaged in the informal sector, 55.1 percent were married. Single women constituted 27.6 %, and the remaining 9.2 % and 8.2 % of the respondent were divorced and widowed respectively.

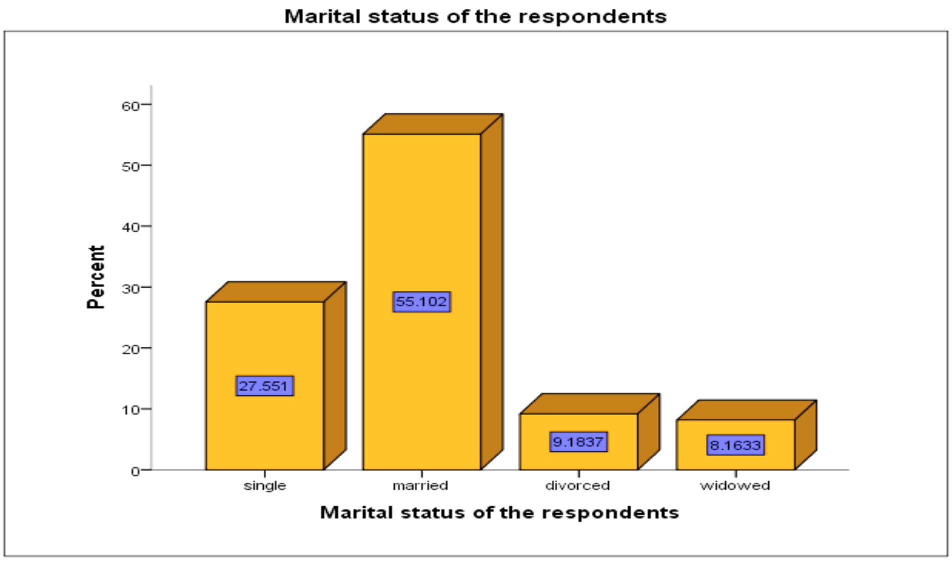

Figure 4 Marital status of the sampled respondents

From the above graph, one can draw that the chance of women to be an informal sector operator will increase when they are married.This could be attributed to the fact that married people needed more income to support their families and this also means that woman wants to do a job to generate livelihood income.

3.1.4. Place of birth of sampled informal sector operators

The data results in Binomial test Table1 below showed that 55 % of the respondent's place of birth is in the Gedeo zone and the remaining 45 % of the sampled informal sector operators came from other areas of the country.

Table 1 Binomial test of Place of birth of the sampled respondents

Place of birth	N	Observed Prop.	Test prop	Exact Sig. (P-value)
In gedeo zone	108	0.55	0.50	0.000
Other place	88	0.45		
Total	**196**	**1.00**		

The above binomial test Table implied that most of the respondents who are significantly above 50% are native to the town. This implies that the respondents of the informal sector are preferred to work on their own locality. This will create a better opportunity for their own business they run because they are familiar with the area and they better communicate with the consumer, producer and they will have better business skills than those who are migrated from the other place. Even if most of them run their own business in their own locality, a significant number of informal sector operators are migrated from another area. According to Gupta (1993), a rural development policy cannot mitigate the problem of rising unemployment in the urban sector resulting from rural-urban migration.

3.2. Respondent's job history before starting this Business

The data presented below in Binomial test Table 2 show that of the total respondents of the informal sector operator, 76 % were unemployed and 24 % of them were employed.

Table 2 Binomial test of the job history of the sampled respondents

Level of employment	N	Observed Prop.	Test prop	Exact Sig. (P-value)
Unemployed	148	0.76	0.50	0.000
Employed on other job	48	0.24		
Total	196	1.00		

From the above binomial test Table, since the p-value (0.000) is less than the level of significance (α=0.05), the null hypothesis is rejected because significantly above half of the women were unemployed before starting this business. This means the informal sector can create employment for a significant number of women.

The study of ILO mentioned that the informal sector is capable of absorbing a large proportion of the new entrants into the labor force that the formal sector is unable to cope with the increasing numbers of the poor, unskilled, and illiterate (ILO,1972). The majority of survival needs drivers such as the majority to create employment or self-employment and generate income in the informal sector. In addition, the informal sector is the major provider of job for the youth in Africa (ILO,2011) and in Ethiopia. In addition, unemployment is the major driving force to be an informal sector operator and the limited capacity of the shrinking formal economy to absorb surplus labor.

3.3. Push and Pull factors for engaging in the informal sector operator

Table 3 Push factors for engaging in the informal sector operator

Why informal sector?	**Number of Sampled Informal Sector Operators**	**Percent%**
As a source of income	110	55
No education	8	16
Securing livelihood independence and self-sustenance	16	32
The capital is small which I able to invest	3	6
Divorced and Widowed	4	8

Note: n=196, the percentage is not out of 100% since multiple answers are possible.

The result in Table 3 showed that the majority of the operators; about 55 % agree that they operate in the informal sector because it's the only source of livelihood income. About 32.5 % of them responded that they involve in the informal sector because of securing livelihood independence and self-sustenance. About 15 % of the respondents involved in this sector because they are not educated and the rest 7.5% mentioned divorced and widowed as a reason. This shows that the informal sector is a survival option for the poor to generate livelihood incomes. Informal business activities are closely linked with inadequate income maintenance or income generation activities and such an economy consists of sets of survival activities performed by destitute people on the margins of society and economic dynamism of unregulated income-generating activities.

The interview result from women informal sector operators and government officials of Dilla town showed that the pushing factors to be an informal sector operator are:

Unemployment

This was identified as the main driver of rising informal sector activities not only in the country but in most urban areas. The findings underline the need for employment, which requires concerted efforts of both the public and private to turn the unfortunate tide. Employment is a critical issue in Ethiopia considering the high levels of over 19.1 % unemployment that the country is facing. The differentials of unemployment rate by sex demonstrate female unemployment rate (26.4 %) is more than double as compared to male (12.2 %) and this leads to searching alternative livelihood income which is Informal sector (Unemployment rate, 2018).

In addition, the presence of gender inequalities in Ethiopia also forces women to informal sector operation; especially to the street which is highly hazardous, requires high time investment with low return, bad working conditions, and place. The women engaging in this sector are from rural areas that are not educated because of lack of opportunity to get education and family preference in sending boys than girls to schools. Additionally, girls who escape early marriage and related challenges in rural locations migrate to urban areas in search of a better life and work; and finally, end up in pursuing informal sector businesses.

Poverty

The study revealed that poverty in both rural and urban settings has contributed to the growth of the informal sector in Dilla. The government officials attributed a worsening economic outlook in the country to the rising informal sector. The informal sector covers a wide range of activities. Some activities included in this study are selling fruits and vegetables, clothes and shoes, food and non-food processing and etc. This means it has an important role in poverty alleviation by providing employment opportunities and generating income for the poor who live in the town. It also offers a livelihood option for the poor for women and youth groups of the society.

Source of Incomes

The dwindling income levels of many households are driving many into the informal sector. According to the officials and women interviewed, many members of the household are pushed into vending or other informal activities out of a need to supplement the incomes of main bread winners. From this analysis of reasons given for engaging in informal sector activities, it is apparent that the lack of meaningful alternative employment options coupled with an inability by most respondents to meet their basic needs has led to the drift into informal sector activities.

In addition to the above,interviewed government officials explained that the numbers of people who are participating in the informal sector are increasing from time to time. This is because people who have low skill and have limited or no education have high chance to involve in the informal sector business rather than formal business sector.

Table 4 Push factors for engaging in the informal sector operator

Why informal sector	Number of Sampled Informal Sector Operators	Percent%
Avoiding taxation and/or registration fee	3	6
For profit-making	6	12

The reason mentioned as push factors in the above Table is the operators are working in this sector in fear of government taxation and to generate more profit.

3.4. Livelihood improvement

Table 5 Binomial test of the sampled respondents on the current work improve their livelihood

Your livelihood has improved due to this job	N	Observed Prop.	Test prop	Exact Sig. (P-value)
Yes	156	0.80	0.50	0.000
No	40	0.20		
Total	**196**	**1.00**		

The respondents were asked, "Your current work/business improves the livelihood income and improve your life in a better way" From the binomial test table4 since the p-value (0.000) is less than the level of significance (α=0.05), the null hypothesis is rejected. That means livelihood has improved and the living condition of those women who are involved in the informal sector are significantly changed in a better way.

3.5. Future interest of the sampled informal sector operators

Table 6: Binomial test of the future plan of the sampled respondents

Next plan	N	Observed Prop.	Test prop	Exact Sig. (P-value)

Continue with the same operation	42	0.21	0.50	0.000
Expand the business and shift to the formal sector	154	0.79		
Total	**196**	**1.00**		

From the above binomial test Table, since the p-value (0.000) is less than the level of significance ($\alpha=0.05$) reject the null hypothesis. That means significantly above 50 % of women who are involved in the informal sector are planning to expand and transform the business into the formal sector. This imples that the sector serves as a survival strategy on one hand and to develop business skills on the other hand.

About 79 % of the respondents wanted to transform into the formal business environment. From this one can infer that the sector is a stepping stone to transform into the formal sector and the sector helps those women either to survive or to improve the livelihood income of their own and their family. In addition, it helps a lot to develop the business skill or capital they need and they transform the business into the formal sector. The spillover effect will be economic development of the country on one side by generating revenue (tax) from those who transfer into the formal sector and it enhances women'slivelihood improvement on the other hand.

In light of the above analysis, Addis Ababa Chamber of Commerce (2001) explained that the informal sector is regarded as the natural home of entrepreneurship which provides an ideal environment for building the foundation for economic growth and social progress. It helps to develop the business know how and skills of the operators in the pursuit of employment creation, generation of income and more equitable distribution of resources and through the development of entrepreneurship, the informal sector helps them to transform into the legal business environment. Finally, it helps to minimize problems of unemployment and poverty.

The remaining 21 % were not interested to transform the business into the formal sector. This is likely because they fear the government bureaucracy, registration process (cost and time) and taxation system.

Based on the data, if the legal environment is suitable, they want to come into the legal business environment. Therefore, the government should reduce bottle necks to transform the informal sector into a formal business environment. This study is also supported by the legalist school of thought. They advocate that the informal sector as comprised of "plucky" (brave and courageous) micro-entrepreneurs who choose to operate informally in order to avoid the costs, time and effort of formal registration and this hostile legal system leads the self-employed to operate informally with their own informal extra-legal norms (De Soto,2 000).

To solve the above problems, the legalist school of thought and the neoliberal theorists argue that the governments should decrease government regulation or introduce simplified bureaucratic procedures to encourage informal enterprises to register and extend legal property rights for the assets held by informal operators in order to unleash their productive potential and convert their assets into real capital (Williams, 2012).

3.6. Additional work

Table 7 Binomial test of additional work or activity that the sampled respondents are engaged

Do you have other jobs?	N	Observed Prop.	Test prop	Exact Sig. (P-value)
Yes	24	0.12	0.50	0.000
No	172	0.88		
Total	196	1.00		

The result in the binomial test in the above Table shows that 88 % responded "No", they have not been engaged other than this business. According to the study, the remaining 12 % of the operators responded "Yes", they do additional work besides this business like washing clothes and making injera. This indicates that the informal economy is one of the majority options for many low-income citizens and it implies that the work activity requires a high time investment in order to get considerable profit.

3.7. Determinants of women livelihood improvement

Table 8 Parameter Estimates for the proportional odds model

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	No improvement	2.129	1.603	1.764	1	0.184	-1.013	5.271
	Little improvement	3.892	1.620	5.774	1	0.016	0.718	7.067
	Moderate improvement	6.290	1.659	14.379	1	0.000	3.039	9.541
Location	Age	0.101	0.299	0.114	1	0.736	-0.486	0.688

Education Level	0.368	0.148	6.183	1	0.013	0.078	0.658
Startup capital	0.275	0.140	3.858	1	0.049	0.001	0.549
# of Dependents	-0.330	0.153	4.645	1	0.031	-0.630	-0.030
How long stayed	0.290	0.129	5.054	1	0.025	0.037	0.543
Hours per Day	0.564	0.266	4.496	1	0.034	0.043	1.085
Days per week	0.380	0.180	4.457	1	0.035	0.027	0.733
Marital status							
[Single]	2.169	0.717	9.141	1	0.002	0.763	3.574
[Married]	1.432	0.574	6.224	1	0.013	0.307	2.557
[Divorced]	1.810	0.691	6.868	1	0.009	0.456	3.163
[Widowed.**ref**]	0[a]	.	.	0	.	.	.
Place of Birth							
[Gedeo Zone]	-0.580	0.237	5.989	1	0.014	-1.045	-0.115
[Other.**ref**]	0[a]	.	.	0	.	.	.
[otherJ=1] Yes	0.222	0.097	5.281	1	0.022	0.032	0.412
[otherJ=2] No	0[a]	.	.	0	.	.	.
[whatki=1]	0.371	0.364	1.040	1	0.308	-0.342	1.085
[whatki=2]	0[a]	.	.	0	.	.	.
[relationship=2]	0.069	0.453	0.023	1	0.879	-0.820	0.957
[relationship=3]	0.120	0.405	0.087	1	0.768	-0.674	0.914
[relationship=4]	-0.017	0.407	.002	1	0.966	-.814	0.780
[relationship=5]	0[a]	.	.	0	.	.	.
[relationshipCP=1] Ex	0.346	0.174	3.954	1	0.047	0.005	0.687
[relationshipCP=2] V.g	0.340	0.136	6.250	1	0.012	0.073	0.607
[relationshipCP=3] G	0[a]	.	.	0	.	.	.

From the above Table, the variables Education Level, Startup capital, Number of Dependents, How long stayed, Hours per Day, Days per week, Marital status, Place of birth, Having other job and Relationship with consumer and producers were found to be significant; while Age, Kind of goods sold and relationship with government were not significant.

Since the coefficients are positive, as the education level of the respondent's increases, so does the probability of one's life is improved. This means, when the educational levels of the respondents increases, the probability of the livelihood improvement of the informal sector also increase. This might be due to the reason that when the educational level of one person increases the capacity of the business and ability to communicate will increase simultaneously.

According to UN Women (2015), Education is an important asset for women as it provides them with a range of positive outcomes, including a greater awareness of their rights, a greater participation in decision- making, a reduced probability of early marriage and child bearing, and access to better employment opportunities. Education has the potential of reducing the likelihood that women will work in the informal economy – but this, of course, is also contingent upon the availability and quality of jobs available in the labor market.

And those respondents who had a higher startup capital are found to have a greater probability that their livelihood is improved.The odd of attaining better livelihood improvement are also determined by the start-up capital of the respondents. An operator whose start-up capital was higher has shown more likelihood in livelihood improvement than those operators with a little start-up capital. This tells us an improvement in livelihood is dependent onan increase in start-up capital. This may be because operators whose start-up capital is higher can bring different kinds of goods to the market and they generate considerable benefit from each item unlike that start-up capital is small.

Since the coefficient is negative, when the numbers of dependents that the respondents have increased, then their likelihood of having moderate improvement in livelihood decreases.This tells us, when dependents in the household decrease, the cost of living will be small and the livelihood earning income is enough in the household and vice versa is true.

The finding also depicts that the longer the operators stayed in the business, the better the chance of improvement in the livelihood as compared with the operators who stayed a short period of time. The implication of this result is the better improvement in livelihood is associated with a longer stay in the business. This may be because the operators develop business skills, they are familiarized with the business environment (they can easily identify what measure enhances profit or loss) and they are well aware of the business. This will help to generate more profit, which helps to improve the livelihood.

Since the coefficient is positive, respondents whose place of birth was in the Gedeo zone were found to have a better probability of having moderate improvement in livelihood than those from other places. Operators from other places have fewer odds of livelihood improvement compared with those operators who are native to the town. Most of the times, operators who are from other places are confronted with different challenges while struggling to adjust themselves with the town lifestyle. Accordingly, those native operators may have better livelihood improvement opportunities because they may have access to information to the market, they can communicate easily, and they also can get credit facilities and other opportunities. This may help the business to grow and to generate high profit and this helps to improve livelihood.

In addition to the above, since the coefficients are positive, hours per day and days per week worked increases, marital status, place of birth, having other jobs and relationships with consumers and producers, the chance of the respondents that their livelihood being even moderately improved increases.

Since the coefficient is positive, the chance of having moderate improvement in livelihood for respondents who have another job was found to be greater than that for those who did not have another job. Besides, those who had an excellent and very good relationship with their consumers and producers had a higher probability of livelihood improvement than those who had a good relationship.

2. Conclusion and way forward

This research confirmed the livelihood of women is improved after involving in the informal sector by contributing to livelihoods by enhancing income earning capacity, uplifting standards of living among the urban poor.

The informal sector serves as a bridge to escape poverty for most women who are poor. The informal business activities are closely linked to inadequate income maintenance or income-generating activities and such an economy consists of sets of survival activities performed by destitute people of the society.

Most of the informal sector operators involved in this business are because of push factors like to secure livelihood income, to reduce the incidence of poverty,to secure livelihood independence and self-sustenance and no education. There are also pull factors like to generate more profit and to avoid government taxation. The future plan of most of the informal sector operators are (79%) is to transform the business into the formal sector.

The research findings show that the informal sector provides a lot of contribution to the impoverished section of society by providing jobs and generating income. Therefore, the government, at both the local and national levels should help the informal sector operators by creating a more favorable environment for trade, improved access to the market, provide credit facilities, and information on organizing and running a small business for women. Moreover, the government at both the federal and local levels should work together in order to organize and formalize the informal sector business into a formal business environment.

The concerned bodies should give attention to organize and formalize the informal sector in a much more planned and calculated manner in order to generate more employment, secure reasonable livelihood, and use it as a tool for poverty reduction for the low-income members of the society (the less educated and the youth).

Proactive policies, which ensure that girls have equal access to educational opportunities from early childhood and place greater value on skills and lifelong learning might help to change social norms and empower women.

Acknowledgments

We would like to thank Dilla University for covering the necessary cost for this research project. Our special thanks go to women informal sector operators and government officials who provided valuable information and data that helped us in compiling this research study.

Conflict of Interest

The authors declare that there is no conflict of interest.

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