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Analysis of nutrient composition of small-holder farmers' compost in semi-arid areas of Africa: A case study of Tigray region, northern Ethiopia

K. TEKA and Y. WELDAY
Department of Land Resources Management and Environmental Protection, Mekelle University, P.O. Box 231, Mekelle, Ethiopia
Coresponding author: kassateka2012@gmail.com

ABSTRACT
This study aimed at exploring the plant nutritive composition of small holder farmers' compost, proportion of composting materials and the actual compost production level in the semi-arid areas of Africa in Tigray region, northern Ethiopia. Compost samples were taken from 354 farming households. Our findings indicated that compost production volume ranged from 3.8 to 11 m^3. Nine composting materials were commonly used in the region in which livestock manure (28%) takes the highest share. The produced composts had a basic pH with an unacceptable range (>8.4) for plant growth in about one third of the study area. The salinity level (4.2–8.2 mS/cm) was also categorized in the high level category. Nevertheless, the organic carbon (2.5–6.4%), available phosphorus (333-737 ppm) and total nitrogen (0.3–1.0%) contents were classified in the low level category. In general, the farmers' composts in the region had lower plant nutrient content to sustain soil productivity and crop production. Hence, integration of research-policy-extension is needed to work on approaches which can improve compost quality.

Key words: Compost, nutrient, cluster, composting materials, blended fertilizer, Tigray

RÉSUMÉ
Cette étude visait à explorer la composition nutritive des plantes du compost des petits agriculteurs, la proportion de matériaux de compostage et le niveau réel de production de compost dans les zones semi-arides d'Afrique dans la région du Tigré, au nord de l'Ethiopie. Des échantillons de compost ont été prélevés auprès de 354 ménages agricoles. Nos résultats ont indiqué que le volume de production de compost variait de 3,8 à 11 m3. Neuf matériaux de compostage étaient couramment utilisés dans la région où le fumier de bétail (28 %) occupe la part la plus élevée. Les composts produits avaient un pH basique avec une plage inacceptable (> 8,4) pour la croissance des plantes dans environ un tiers de la zone d'étude. Le niveau de salinité (4,2–8,2 mS/cm) a également été classé dans la catégorie de niveau élevé. Néanmoins, les teneurs en carbone organique (2,5 à 6,4 %), en phosphore assimilable (333 à 737 ppm) et en azote total (0,3 à 1,0 %) ont été classées dans la catégorie des niveaux faibles. En général, les composts des agriculteurs de la région avaient une teneur en éléments nutritifs inférieure pour soutenir la productivité du sol et la production agricole. Par conséquent, l'intégration de la recherche-politique-vulgarisation est nécessaire pour travailler sur des approches qui peuvent améliorer la qualité du compost.

Mots clés: Compost, nutriment, grappe, matériaux de compostage, engrais mélangé, Tigré

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BACKGROUND

Agricultural soils in semi-arid areas in general and the Tigray region in northern Ethiopia in particular are characterized by low soil fertility, high soil degradation and extremely low external inputs such as fertilizer and agrochemicals (Araya, 2010; Bezabih *et al*., 2010). In the semi-arid areas of Ethiopia, which cover about 60% of the total area, nitrogen and phosphorus are highly deficient (Melese *et al*., 2015). Hence, the sustainability of agricultural systems in these areas has been severely hindered leaving the cultivation of land to smallholder farmers, who cultivate small plots (< 1 ha) of land to sustain their immediate family need (Araya, 2010; Teka *et al.,* 2010; Teka and Haftu, 2012; Teka *et al.,* 2015a; Teka, 2017).

Hence, as a strategy, the Ethiopian Government issued the Environmental Policy of Ethiopia (EPA, 1997) to protect the natural resource degradation and improve soil fertility (Araya, 2010). The main focuses of this policy were: 1) promoting the use of appropriate organic matter and nutrient management for improving soil structure, nutrient status and microbiology; (2) protecting the physical and biological properties of soils through improved management practices such as green manures, farm yard manures and compost; (3) promoting effective ground cover for erosion control. Various soil fertility improvement measures such as chemical and organic fertilizers were also introduced since the initiation of the policy.

The use of chemical fertilizers in major part of Ethiopia until 2014 was a blanket recommendation of two fertilizer types: Di-Amonium Phosphate (DAP = 100 kg ha^{-1}) and Urea (50 kg ha^{-1}) (Elyas, 2002). This recommendation was not based on detailed study of the specific soil and crop requirements. The nutrient composition of these fertilizers is of only nitrogen – N and phosphorus – P while other macro and micro-nutrients were not given due attention in the fertilizer recommendation formulation. The result is that these limited nutrients could not bring the expected yield, and food insecurity remained a challenge to this area. Bearing these challenges in mind, in July 2014, the Ethiopian Government through the Ministry of Agriculture and Ethiopian Agricultural Transformation Agency (MoA/ATA, 2014) inaugurated a soil fertility status and fertilizer recommendation atlas for Tigray region where the study took place. The new fertilizer formula recommendations include additional nutrients such as sulfur, potassium, iron, zink and boron based on a relatively detailed study of the soils of the entire region. This atlas classified the soils of Tigray region into eleven clusters based on the existing soil fertility status.

On the other hand, the Government of Ethiopia has introduced organic fertilization technologies such as compost to small holder households so as to maintain and enhance farm production per hectare of available land (Araya and Edwards, 2006; Mugwe *et al.,* 2007; Araya, 2010; Azadi *et al.,* 2011). Studies have shown that organic agriculture has the potential to increase yields through increased farm productivity (Morshedi *et al.,* 2017). The variety of production in organic agriculture can also decrease the risk of crop failure (Azadi and Ho, 2010). More nutrients given to the soil result in an increased soil biodiversity and less soil erosion due to improved soil structure, and infiltration rate, hence reduced run-off (Teka *et al.,* 2014) and, which in turn improve food security in the long-run (Azadi *et al.,* 2011).

Compost, as stabilized organic matter, has been used for recovery of degraded soils and their fertility restoring in the last decades in many countries (Pergola *et al.,* 2018). A study in Riverside, Ventura, Kern, Stanislaus and Monterey counties indicated that compost application increased soil organic carbon by 3 fold, soil microbial activity by 2.2 and gravimetric water by 1.6, and reduced bulk density by 0.87 fold in comparison to the non-composted soils (Brown and Cotton, 2011).

Despite the fact that compost contributes a positive impact to the food basket, there was a challenge to integrate it with chemical fertilizers and define its application rate for different crops on different soil types. This was due to unknown contents of the compost produced by farmers. Hence, this study aimed at exploring: i) the plant nutritive composition of farmers' compost, ii) the proportion of composting materials used, and iii) small holder households' compost production level.

MATERIALS AND METHODS

Description of the study site. This study was conducted in Tigray region, northern part of Ethiopia (Figure 1). The region has a total area of 54,572 km^2 (Teka *et al.,* 2013) and is located between 12 15'- 4 50'N and 36 27' - 39 59'E. It has a diverse topography with an altitude that varies from about 500 to almost 4000 m above sea level (Teka *et al.,* 2013). The region is currently classified into seven administrative zones (zonal names are provided in the entire regional map).

Tigray is a semi-arid area characterized by sparse and highly uneven rainfall distribution and frequent drought (Teka *et al.,* 2013). The main rainfall season called 'kiremti' starts in mid-June and ends in the beginning of September. In some parts of the region, there is a short rainy season called 'belg' that falls in March, April and May (Tegene, 1996; Teka *et al.,* 2014). Average annual rainfall varies from about 200 mm in the northeast lowlands to over 1000 mm in the southwest highlands (Nega, 2008). According to the CIA World estimate for July 2020, the Tigray population was 6,594,902 (6.1% of the Ethiopian population which is 108,113,150) (Factbookhttps://theodora.com/wfbcurrent/ethiopia/ethiopia_people.html).

About 85% of the population earns their living from agricultural activities (Teka *et al.,* 2015b). Agriculture in the region consists of crop husbandry, animal husbandry and mixed farming (CSA, 2008; Teka *et al.,* 2015b). Smallholder agriculture predominates with an average land holding of less than one hectare per family (Araya, 2010; Teka *et al.,* 2010; Teka and Haftu, 2012; Teka *et al.,* 2015a; Teka, 2017).

Major crops grown include *Sorghum bicolor* L. (Sorghum), *Eragrostis tef* L., *Zea mays* L., *Eleusine coracana*, *Triticum aestivum* L. and *Hordeum vulgare* L. (Teka *et al.,* 2013). The average crop yield is about 1 ton ha^{-1} (Teka *et al.,* 2015b), which is less than the average national annual grain yield, 1.2 ton ha^{-1} (Abrar *et al.,* 2004). Besides crop

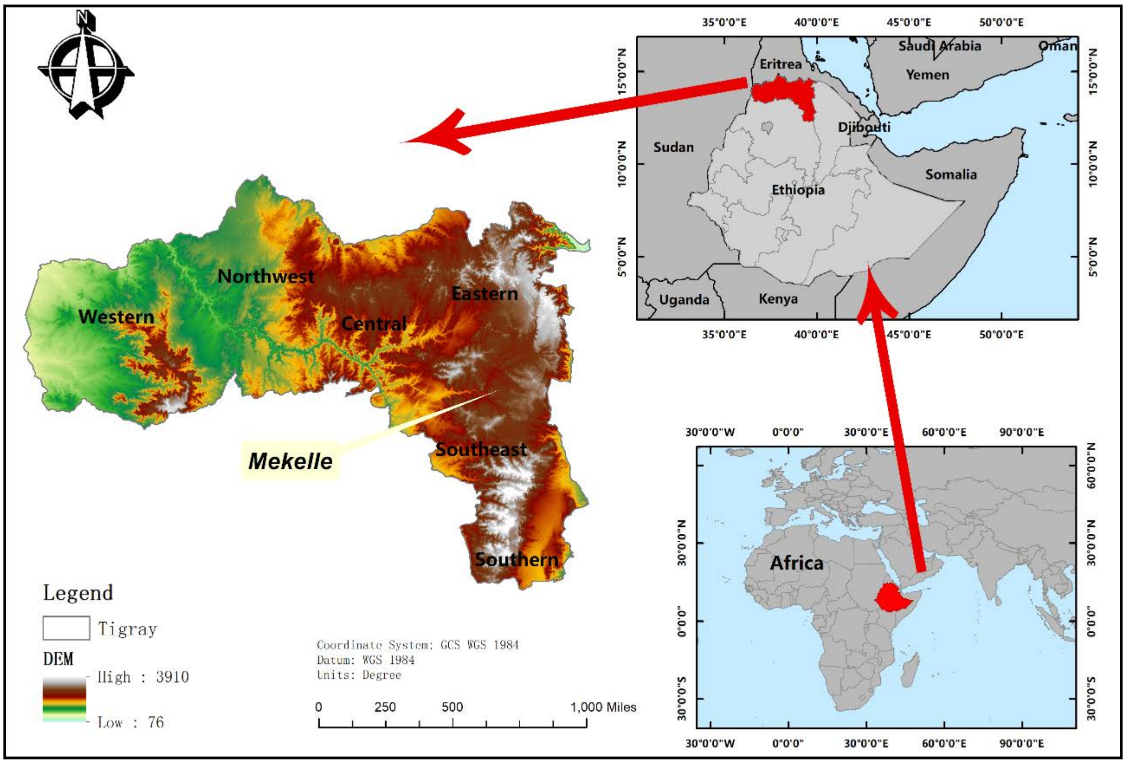

Figure 1. Location map of the study area

production, livestock play important role in the life of rural households (CSA, 2008). Most farming households keep livestock (e.g. sheep, goat and cattle) which, are kept on rangeland during the growing season, and on farm fields after crop harvest or dry season (Teka *et al.,* 2013).

There is no systematic soil survey undertaken for the whole Tigray Region. However, only few researchers have carried spot level soil survey (Hunting-Technical-Services, 1975; Nyssen *et al.,* 2008; Van de Wauw *et al.,* 2008; Teka *et al.,* 2010; Teka and Haftu, 2012; Teka *et al.,* 2015a; Teka, 2017). Based on these researches, the major soils of the region are Cambisols, Luvisols, Rendzinas, Lithosols (Leptosols), Fluvisols, Nitosols, Arenosols, Vertisols, Xerosols, Regosols, Calcisols, Fluvisols and Andosols.

Data collection and analysis. Sample sites were selected based on the eleven blended fertilizer clusters (MoA/ATA, 2014) developed for Tigray region (Table 1). In each cluster, farmers who practice compost were selected following a stratified sampling technique (based on gender). In total, 354 farmer households (306 male and 48 women headed households) were considered. Six or more months old composite compost samples (354), sampled from the entire depth, were taken for laboratory analysis. Tests primarily focused on the elements recommended in the blended fertilizer package proposed by the Ministry of Agriculture: Nitrogen (N), Phosphorus (P), Potassium (K), Sulfur (S), Iron (Fe), Zinc (Zn) and Boron (B).

Total nitrogen (Nt) content was determined by the modified Kjeldahl method (Christensen and Fulmer, 1927), while P availability was determined by the sodium bicarbonate procedure of Olsen (Olsen *et al.,* 1954). Available Potassium was determined by Ammonium Acetate method. Micro - nutrients and available Sulfur were analyzed using DTPA Extraction method. pH and EC were measured in the supernatant suspension of a 1:5 soil: liquid (v/v) mixture (ISO, 1994). Organic matter was determined following the procedure developed by Balkley and Black (Walkley and Black, 1934).

To estimate farmer level compost production, volume of produced compost was estimated from compost owner's interview and on field measurement. The compost weight of each compost pit/heap was, therefore, estimated from the weight of compost taken from a sample volume of 0.20 m width x 0.20 m length x 1.0 m depth following equation below.

$$\text{Total Weight of Pit Compost} = \frac{\text{Volume of pit compost (m}^3\text{)}}{\text{Sample Volume (m}^3\text{)}} * \text{Sample weight (kg)}$$

The composting materials used for compost making were identified through interview and direct observations. The proportion of each composting material was estimated through participatory proportionate techniques, in which each farmer was provided with 100 stones/bean grains and asked to estimate the proportion or rank each composting material. Finally, data collected from smallholder farmers' were expressed as mean ± S.E and analysis of variance (ANOVA). Least Significant Difference (LSD) test was carried out using SPSS to determine significant differences (p 0.05).

RESULTS AND DISCUSSION

Smallholder Households' Compost Production. Two composting methods, heap and pit, were identified in the region. The pit composting method was the common type practiced by about 84% of the sampled households. A similar study in north Ethiopia (Araya, 2010; Teka *et al.,* 2014) also indicated pit composting method as the dominant method in the region. The age of compost which ranges from 7 months in cluster two to 13 months in cluster three showed significant difference among farming households and clusters (p = 0.000). The average volume of compost pit/heap (Figure 2) also varies from 3.8 m^3 at cluster eight to 11 m3 at cluster one with a significant variation among farming households and clusters (p=0.004). The compost production volume per pit in the region, 3.8 - 11 m^3, was higher than the reported volume (2.25 m3) for Tahtay Maichew in 2007 (Araya, 2010).

Table 1. Description of the study clusters

Cluster	Description	Zone	Districts	Tabia/village	GPS-coordinate (village center)
1	NPKS	Eastern	Atsbi-womberta	Felegeweyni	13 54’48.79”N, 39 44’44.77”E, elev.2748 m
		Southern	S/Tsaeda-emba	Hawile	14 05’27.73”N, 39 41’40.84”E, elev.2921 m
			Enda -mokoni	Hzeba-teklehaimanot	12 48’18.24”N, 39 32’58.31”E, elev.2437 m
2	NPKSB	Eastern	Atsbi-womberta	Era	13 41’42.92”N, 39 43’54.69”E, elev.2294 m
		Central	Weri-Leke	Werei	14 01’28.63”N, 38 58’14.22”E, elev.1873 m
3	NPKSFeZn	South-East	Hntalo-wejerat	Dejen	13 18’26.92”N, 39 19’33.01”E, elev.2337 m
		North-West	Tselemti	Tseda-kerni	13 33’07.56”N, 38 02’01.22”E, elev.1117 m
4	NPKSFeZnB	Eastern	Ganta-Afeshum	Gola-genahtiy	14 17’08.22”N, 39 29’37.16”E, elev.2548 m
			Atsbi-womberta	Golgol-naele	13 52’50.00”N, 39 44’08.79”E, elev.2728 m
5	NPKSZn	Southern	Emba-alaje	Atsela	12 55’39.65”N, 39 31’36.34”E, elev.2466 m
			Emba-alaje	Betmera	13 01’33.48”N, 39 31’29.33”E, elev.2463 m
		Eastern	Hawziyen	D/Brhan	13 52’45.14”N, 39 25’29.77”E, elev.2107 m
6	NPKSZnB	Eastern	Hawziyen	Freweiniy	14 00’50.54”N, 39 28’00.99”E, elev.2255 m
		Southern	Raya-alamata	Selam-bikalsi	12 26’16.70”N, 39 35’57.22”E, elev.1470 m
7	NPSB	Central	T/Abergele	Hadush-tekli	13 36’25.26”N, 38 59’24.24”E, elev.1813 m
		Eastern	Atsbi-womberta	Kelesha-emni	13 38’44.14”N, 39 43’21.62”E, elev.2403 m

8	NPSFeZn	Central	Laelay-maychew	Modegoy	14 05’50.31”N, 38 42’15.33”E, elev.2116 m
9	NPSFeZnB	Eastern	S/Tsaeda-emba	Guemse	14 02’44.94”N, 39 35’26.79”E, elev.2515 m
		South-East	Hntalo-wejerat	Hareko	13 18’17.14”N, 39 24’28.86”E, elev.2525 m
				Hntalo	13 18’59.17”N, 39 27’33.35”E, elev.2215 m
10	NPSZn	North-West	Asgede-tsmbla	Debre-bay	13 49’20.36”N, 38 07’41.74”E, elev.1571 m
11	NPSZnB	Eastern	Kilte-awulalo	Aynalem	13 45’19.13”N, 39 32’59.35”E, elev.2006 m
		South-East	Enderta	Arato	13 30’05.79”N, 39 44’46.10”E, elev.2279 m

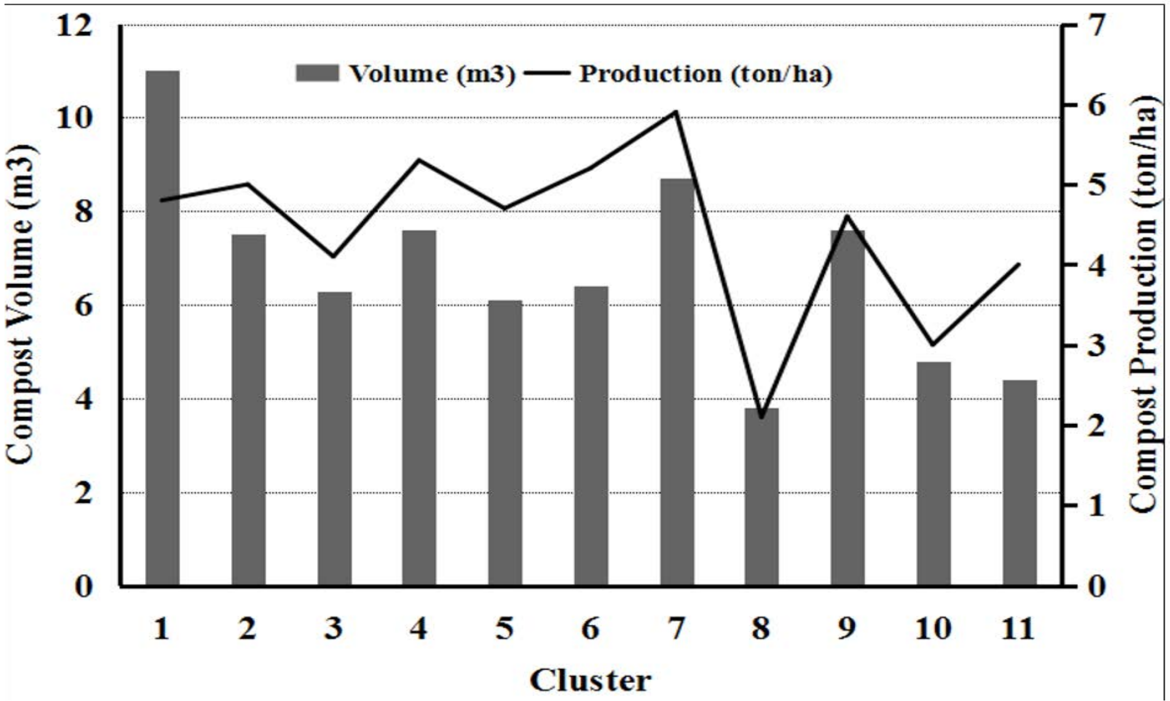

Figure 2. Household’s Compost Production as affected by cluster

Table 2. Compost material proportion (%) as affected by cluster

Cluster	M1	M2	M3	M4	M5	M6	M7	M8	M9
1	13.72	11.21	25.47	6.86	5.15	11.67	5.72	7.43	12.78
2	9.04	12.71	22.34	6.43	4.24	10.81	4.77	21.19	8.48
3	12.28	14.04	22.12	6.27	7.02	8.94	3.63	14.62	11.08
4	0.00	13.11	29.16	13.55	5.98	11.39	6.73	9.97	10.10
5	8.31	15.22	30.57	7.46	6.75	11.72	0.00	0.00	19.97
6	20.24	14.99	23.69	6.41	4.85	13.74	5.92	0.00	10.15
7	0.00	11.82	28.74	9.65	5.91	19.05	5.91	5.91	13.01
8	0.00	5.78	36.25	7.51	6.74	19.65	8.67	15.41	0.00
9	5.92	11.85	31.52	13.17	9.87	11.21	4.72	0.00	11.74
10	15.37	20.49	19.47	7.10	0.00	0.00	0.00	15.37	22.20
11	3.80	15.05	38.28	5.50	5.32	16.85	0.00	0.00	15.20
Sig (5%)	0.000	0.620	0.000	0.000	0.256	0.000	0.012	0.028	0.000

M1=Dry grass, M2=Weed, M3=Livestock manure, M4=Ash, M5=Soil, M6=Old straw, M7=Chicken manure, M8=House wastes, M9=Plant leaves

Regardless of the highly significant variation in compost production volume, the weight based compost production level showed insignificantly (p=0.334) higher value (5.3 ton pit^{-1}) in cluster 3. This might be related to the composting materials used and the decomposition level of composting materials. In cluster 3, maximum number (nine) of composting materials with higher topsoil volume as compared to other clusters was used (Table 2). The key to good composting is to have a variety of materials and a balanced carbon to nitrogen ratio which increases the types of micro-organisms at the pile and the chance of obtaining a nutrient rich compost (University-of-Illinois-Extension, 2017).

The compost volume produced by women headed households was insignificantly (p=0.527) lower (6.9 m^3) as compared to their male counterpart (8.0 m^3). This might be due to limited access to work labor and time of women headed households. Women are more likely to work in jobs that offer flexible working arrangements (such as in house jobs) as compared to men so that they can combine work with care responsibilities which lead them to have limited time for external activities (World-Bank, 2012). Regardless of the lower volume, the weight based compost production by women headed households (4.7 ton) was insignificantly (p=0.859) higher than those of male headed households (4.0 ton). This might also be due to the utilization of higher amount of ash and chicken manure on composts prepared by women headed households as compared to that of male-head households'. These materials have high carbon to nitrogen ratio and total dry solid mass (NebGuide, 2012).

Composting materials used by smallholder households. Nine composting materials, livestock manure (28%), weeds (13%), old straw (12%), plant leaves (12%), dry grass (8%), ash (8%), house wastes (8%), soil (6%) and chicken manure (4%) were commonly used in the Tigray region. Hence, more diverse material use was reported as compared to the findings of Araya (2010) who reported livestock manure, weeds, old straw (farm residue) and plant leaves (green matter) were the dominant composting materials in Tahtay-Maichew (Tigray). Except for weed and soil, the amount (proportion) of composting materials used significantly varied within the different clusters (Table 2). Livestock manure was the dominantly used composting material while chicken manure was the least used. The use of livestock manure ranges from 19% in cluster ten, where livestock in most cases are kept overnight in different locations which makes manure collection difficult, to 38% in cluster eleven where livestock are kept in house compound which makes manure collection easier.

The composting materials used in the region were also evaluated against gender (Table 3). The use of weed, livestock manure and old straw significantly varied by gender with significantly higher weed and livestock manure on composts made by male headed households, while the use of old straw was significantly higher on composts made by women headed households. The use of dry grass, ash and chicken manure were insignificantly higher on composts made by women headed households. The higher livestock manure and weeds utilization by male headed households' might be due to their higher number of livestock and farm plots holding. This corresponds with the findings reported for Tigray region (Debela, 2016) stating that female-headed households own significantly fewer livestock and lower endowment of land area compared to male headed households.

Compost nutrient content status of smallholder households. The farming households' compost in the region had a basic pH (Table 4), which corresponds with the findings of previous studies (Araya, 2010; Teka *et al.*, 2014). In addition to the semi-arid climate effects, the use of manure and ash as composting materials can lead to increased pH in the produced compost (Brodie *et al.,* 1996). According to Woods-end-research-laboratory (2005), wastes treated with ash may have a very high pH (up to 11.0). The pH values showed significant variation (p=0.000) among clusters with values ranging from 7.2 in cluster

Table 3. Compost material proportion (%) as affected by gender

Gender	M1	M2	M3	M4	M5	M6	M7	M8	M9
Male	11.10	12.26	25.26	7.33	5.25	10.89	4.48	11.15	12.28
Female	13.43	9.63	22.97	8.47	5.74	13.73	4.51	10.43	11.09
Sig (5%)	0.628	0.030	0.012	0.424	0.829	0.047	0.772	0.844	0.261

M1=dry grass, M2=weed, M3=livestock manure, M4=ash, M5=soil, M6=old straw, M7=chicken manure, M8=house wastes, M9=plant leaves

Table 4. Compost macro nutrient composition

Cluster	pH	EC	OC	Pav	Nt	Kav	Sav	C/N
1	8.5(±0.4)	5.4(±1.7)	4.14(±0.9)	495.3(±142.6)	0.5(±0.1)	3814(±242.4)	963.4(±707.5)	7.8(±1.1)
2	8.1(±0.4)	8.1(±2.8)	6.38(±2.6)	511.3(±175.4)	0.8(±0.3)	5181(±1579)	1275(±863.4)	8.3(±0.9)
3	8.3(±0.5)	6.9(±2.3)	3.18(±2.0)	422.1(±152.4)	0.4(±0.2)	4313(±1226)	854.5(±129.9)	7.8(±0.9)
4	8.8(±0.2)	8.2(±3.5)	5.82(±2.2)	736.9(±159.5)	0.7(±0.2)	4852(±1759)	1421 (±573.8)	8.5(±1.4)
5	8.5(±0.4)	4.2(±2.3)	4.48(±2.3)	370.0(±51.9)	0.5(±0.1)	2910(±1195)	754(±308.3)	9.3(±3.3)
6	8.3(±0.4)	5.2(±1.6)	4(±1.0)	532(±151.7)	0.5(±0.1)	4123(±1769)	882(±937.5)	8.2(±1.3)
7	8.1(±0.4)	6.5(±1.1)	8.6(±1.7)	447.8(±174.2)	1.0(±0.3)	4764(±879)	928.9(±352)	9.4(±4.6)
8	8.2(±0.4)	5.2(±2.7)	2.5(±2.4)	435.1(±166.6)	0.3(±0.3)	4496(±1496)	580.7(±578.7)	7.2(±1.1)
9	8.6(±0.2)	5.1(±2.3)	3.23(±0.7)	468.1(±131.3)	0.4(±0.1)	3063(±1002)	692.1(±315.6)	8.0(±1.2)
10	7.2(±0.3)	5.6(±1.8)	5.4(±1.6)	383.3(±62)	0.76(±0.2)	4091(±732)	1041(±230)	7.2(±0.8)
11	8.3(±0.1)	7.0(±4.8)	3.55(±0.9)	333.2(±54.8)	0.5(±0.1)	3938 (±1455)	1020 (±261.7)	7.4(±0.3)
Sig (5%)	0.000	0.032	0.000	0.000	0.000	0.012	0.278	0.802

EC (mmhos/cm), OC (%), Nt (%), Pav (ppm), Kav (ppm) and Sav (ppm) ten to 8.8 in cluster four. The pH has also shown an insignificantly (p=0.298) higher value on composts made by women headed household (8.5±0.4) than that of male headed household's (8.3±0.4). These variations could be related to the higher chicken manure and ash used by women headed households as compared to their male-counterpart. Composts in clusters one, four, five and nine were classified within the unacceptable range (> 8.4) for sustainable soil management and crop production (Woods-end-research-laboratory, 2005). Ideally, the pH of any product, particularly compost, should be neutral to slightly acid (6.0 – 7.5) and efforts should be made to control it if it exceeds about 8.4, where it becomes potentially harmful to plants, and is associated with odor and ammonia loss (Woods-end-research-laboratory, 2005).

The salinity (EC) of farming household's compost in the region was significantly affected by spatial variation (p=0.032). The EC values range from 4.2 mmhos/cm in cluster five to 8.2 mmhos/cm in cluster four. These values are higher than the 0.3 mmmhos/cm EC value reported for the northern and eastern part of the region (Teka *et al.,* 2014), and the 0.6 – 4.7 mmhos/cm EC value reported for Tahtay Maichew (Araya, 2010). These values, except for cluster five, are within the class of high level (Woods-end-research-laboratory, 2005). The Woods end research laboratory classified EC of compost as very low (<1.0 mmhos/cm), low (1–2 mmhos/cm), medium (2–5 mmhos/cm), high (5–10 mmhos/cm) and very high (>10 mmhos/cm). Low value indicates lack of available minerals, while high value indicates large amount of soluble minerals which may inhibit biological activity or cause problems with land application if large quantities of the materials are used (woods end research laboratory, 2005). High EC also implies reduced soil water potential, making water less available to plants. The salt, therefore, causes water stress in the plant (Rhoades and Loveday, 1990).

The organic carbon (OC) contents of farming households' compost had significant variation among clusters with values ranging from 2.5% in cluster eight to 6.4% in cluster two. Thus, compost products in the region, except for cluster two and seven, were below the minimum limit set at 6% (Hogg *et al.,* 2002). These results, are lower than the values (OC = 9.72%) reported for northern Ethiopia (Teka *et al.,* 2014), and for Tahtay Maichew (OC = 4.2 – 8.7%), and for central south Chile (OC = 25.7%) (Valarini *et al.,* 2009).

The available phosphorus (Pav) content had significant variation (p=0.000) among clusters with values range from 333 ppm in cluster eleven to 737 ppm in cluster four. These results are equivalent to the findings in central south Chile, Pav = 441 ppm (Valarini *et al.,* 2009) and in Tahtay Maichew, Pav 260 – 525 ppm (Araya, 2010). The compost product in the region, therefore, had lower Pav value compared to the limit set at 1200 – 2400 ppm (Hogg *et al.,* 2002). The Pav content was also significantly (P=0.033) affected by gender. Composts managed by women headed households had higher Pav content (553 ppm) as compared to those of male headed households' (455 ppm). This could be related to the extra chicken manure used by women headed households as composting material. Chicken manure contains high levels of phosphorus than other organic fertilizers such as horse and cow manure (Duncan, 2005). According to Duncan, phosphorus within chicken manure is considered to be 75% more beneficial and readily absorbed by plants than chemical fertilizers.

Total Nitrogen (Nt) content significantly varied (p=0.000) among clusters with values ranging from 0.3% in cluster eight to 1.0% in cluster seven. The compost products in the region (except for clusters two, four, seven and ten) had lower Nt value compared to the lower limit set at 0.6% (Zmora-Nahum *et al.,* 2007) quoted in (Campitelli and Ceppi, 2008). This corresponds with the findings of Teka *et al*. (2014) for northern Ethiopia that reported an average Nt value of 0.8%, Araya (2010) for Tahtay Maichew (Nt = 0.24 – 1.05%) and Valarini *et al*. (2009) for central south Chile (Nt = 0.99%).

Table 5. Compost micro nutrient composition (ppm)

Cluster	Fe	Mn	Zn	Cu
1	37603(±14358)	823(±450)	84(±41.7)	36 (±18.2)
2	19553(±5482)	300(±66)	90(±24.3)	17.7(±5.6)
3	37883 (±8197)	550(±151)	100(±15)	40.5(±12)
4	19039(±6312)	547(±224)	65(±26.7)	14.7(±8.0)
5	38289(±12390)	461(±134)	86(±19.1)	40(±23.5)
6	22764(±15390)	308(±134)	60(±28.4)	21(±20.4)
7	23947(±2309)	346(±49)	104(±58)	23(5.9)
8	70941(±12567)	1015(±237)	100(±40)	32(±17)
9	25283(±3852)	613(±318)	83(±13.2)	27.6(±9.1)
10	40412 (±8971)	462 (±115)	159 (±85)	27(±9.5)
11	28929 (±9643)	552(±154)	144(±108)	45 (±27.6)
Sign (5%)	0.000	0.000	0.021	0.004

Available Potassium (Kavzoglu *et al.,* 2013) had significant variation (p=0.012) among clusters with values ranging from 2910 ppm in cluster five to 5181 ppm in cluster two. The compost product in the region (except for clusters one, five, nine and eleven) exceeded the Kav value compared to the limit set at 2000 – 4000 ppm (Hogg *et al*., 2002). These values correspond with the findings of Araya (2010) for Tahtay Maichew (Kav = 1313 - 10218 ppm). However, they are lower than the values reported for north Ethiopia, 14000 ppm (Teka *et al.,* 2014) and for central south Chile, 8730 ppm (Valarini *et al.,* 2009).

Available Sulfur (Sav) values ranged between 581 ppm in cluster eight and 1421 ppm in cluster four. Thus, the Sav content of compost product in the region (except for clusters eight and nine) has exceeded the minimum limit set at 750 ppm for dairy manure but it was below the value (1600 ppm) set for poultry manure (Schulte and Kelling, 2004a).

The carbon to nitrogen ratio (C/N) varied between 7.2 (in both clusters two and eight) and 9.4 (in cluster seven). These values are within the range (6 – 21) reported for Tahtay Maichew (Araya, 2010). These values are below the maximum limit, about 30 (Edwards and Bater, 1992) and 25 suggested by Woods-end-research-laboratory (2005). This suggests that as the C/N value is lower than the threshold (< 30), mineralization is faster, and nutrients eventually become available and a large amount of N is lost (Teka *et al.,* 2014).

The Iron (Fe) content of smallholder farming households' compost showed a significant variation (p=0.000) among clusters with values ranging between 19039 ppm in cluster four and 70941 ppm in cluster eight. These values are 32 to 118 fold higher than that reported for northern Ethiopia, 600 ppm (Teka *et al*., 2014). Hence, the Fe content of compost product in the region is beyond the limit set at 250 – 2500 ppm for livestock manure (Schulte, 2004).

The Manganese (Mn) content of smallholder farming households' compost also showed significant variation (p=0.000) among clusters with values ranging between 300 ppm in cluster two and 1015 ppm in cluster eight. These results correspond with the findings of previous studies in northern Ethiopia, 400 ppm (Teka *et al.,* 2014). Hence, the Mn content of compost product in the region was below the limit set at 3000 ppm (Schulte and Kelling, 2004b).

The Zinc (Zn) content of farming households' compost has shown a significant variation (p=0.021) among clusters with values ranging between 60 ppm in cluster six and 159 ppm in cluster ten. These results are lower than the findings of Teka *et al*. (2014) for northern Ethiopia (Zn = 800 ppm). Hence, the Zn content of compost product in the region was below the maximum limit set at 700 ppm (Cant and Van der Werf, 2006).

Copper (Cu) content of smallholder farming households' compost has shown a significant variation (p=0.004) among clusters with values ranging between 15 ppm in cluster four and 45 ppm in cluster eleven. These results are lower than the findings of Teka *et al*. (2014) for northern Ethiopia (Zn = 500 ppm). Thus, the Cu content of compost product in the region was below the maximum limit set at 400 ppm (Cant and Van der Werf, 2006).

CONCLUSIONS

The study results indicated that heap and pit were the composting methods used in the region in which pit method was practiced by about 84% of the sampled households. The composting materials used in the region were more diverse as compared to other semi-arid areas of Africa. The commonly used composting materials in the region were livestock manure, weeds, old straw, plant leaves, dry grass, ash, house wastes, soil and chicken manure. The nutrient contents of smallholder farming households' compost, except for available Sulfur, have shown significant variation among clusters. However, only available Phosphorus was significantly affected by gender difference.

The produced compost had a basic pH with unacceptable range (> 8.4) for crop production in about 36% of the clusters. The salinity level was also classified in the high level category implying the presence of large amount of soluble minerals which may inhibit biological activity. The organic carbon, available phosphorus and total Nitrogen contents were classified in the low level category, hence, low nutrient addition to soils. However, the available Potassium, available Sulfur and Iron contents were classified in the high level category implying extra addition of the produced compost can hinder plant growth. The Manganese, Zink and Copper contents were within the acceptable range for plant growth.

In general, the farmers' compost regardless of spatial and gender variations had lower plant nutritive composition to sustain soil productivity and crop production. Hence, research-policy-extension integration is required to work on approaches which can improve compost quality so as to sustain soil productivity and crop production.

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STATEMENT OF NO CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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