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Full Length Research Paper

Spatial distribution of heavy metals in soil with distance from Tazama pipeline through the Mikumi National Park, Tanzania

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A total concentration of six studied heavy metals Arsenic (As), Lead (Pb), Chromium(Cr), Mercury (Hg) Cadmium (Cd) and Copper (Cu) were measured in soil across distances from TAZAMA pipeline in transects which have incidences of oil spillage and those which have no history of oil spillage. All studied heavy metals were detected in the study area. As, Pb and Cr were detected in both transects, that is, with oils spills and those with no history of oil spillage to a distance of 0-35 m from the edge of the pipeline, with higher mean concentration in transects with oil spillage compared to those with none. From 50-200 m away from the pipeline these four metals were detected in transects with oil spillage only. Hg and Cd were detected in transects with history of oil spillage only. Cu was detected in all transects and at all ranges of distance. Concentration of studied heavy metals decreased with increased distance from the edge of the pipeline in both transects to all directions. The decrease was statistically significant in transects with oil spillage and insignificant with transects of no history of oil spillage.

Key words: Soil contamination, pollution, oil spill effects, Mikumi National Park ecosystem, endangered species.

INTRODUCTION

The global increase of oil need has resulted in exploration of new crude oil production sites and construction of new pipelines as a means of transportation. Pipelines are widely used due to their advantages like low cost, high efficiency and large volume of transportation (Saadi et al., 2018). Despite their advantages pipelines pose many challenges to the biotic and abiotic environment that they pass through.

Likewise, protected areas worldwide are under pressure of oil development. More than 25% of World heritage

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sites are in the pressure of existing or future oil activities (Osti et al., 2011). Major challenges facing protected areas from oil pipelines are pollution and habitats destruction, raising a concern among biodiversity conservationists all over the world (Hebblewhite, 2017).

The Tanzania Zambia Mafuta (TAZAMA) pipeline started operation in 1968; by the year 1973 it had experienced 100 spills at different locations along its route (TAZAMA 2016). Oil spillage in the soil contributes to the addition of heavy metals, some of which are very hazardous to flora and fauna inhabiting a particular soil (Gordon et al., 2018). Moreover, oil pollutants present a major threat to many ecosystems (Xie et al., 2018). The effects of pollution are extended to many flora and fauna since some of oil pollutants including heavy metals can persist in soils for decades (Buskey et al., 2016; Pennings et al., 2014). Studies have documented effects of crude oil pipelines leakages on soil health and plants biological diversity (Allison et al., 2017; Asadirad et al., 2016; Oriaku et al., 2017). Crude oil spillage from pipelines is experienced along pipelines during times of construction, operation and maintenance (Vaezi and Verma, 2018).

Mikumi National Park is an important ecosystem as it shares boundary with Selous Game Reserve – a world heritage site. Crude oils contain hazardous pollutants including heavy metals and hydrocarbons. These pollutants are very toxic and are furthermore not easily degraded once in soil (Bai et al., 2019).

Despite the importance of the global ecosystem in Mikumi, the sensitivity of the general infrastructure element running through the area and the possible pollutants from oil, little is known about the amount of heavy metals that have been released to the environment and its spatial distribution in Mikumi National Park. Therefore, this study was conducted to examine the spatial distribution of heavy metals across the segment of the TAZAMA pipeline through the Mikumi National Park (MINAPA). Moreover, no Environmental Impact Assessment was conducted during the construction of the pipeline and hence no baseline information is available (TAZAMA, 2016). To cover that gap, the study involved a comparison between segments of the pipeline with history of and segments, which never experienced leakages. The following objectives were addressed during the study:

(i) What is the concentration of total heavy metals in soil in oil spilled compared to non-oil spilled segments of the pipeline?
(ii) Does the concentration of heavy metals in soil vary significantly with distance from the edge of the pipeline?

MATERIALS AND METHODS

Study area

The study was conducted in Mikumi National Park, Tanzania across the segment of the TAZAMA pipeline. Five transects across the pipeline were studies, three with known history of oil spillage and two, which never experienced oil spills (Figure 1).

Soil sampling and heavy metals analysis

Transects were set at each site perpendicular to the pipeline. Soil was sampled at a distance of 0 m, 5, 20, 35, 50, 100 and 200 m away from the edge of the pipeline to the North and South. At distance of 0 m, soil samples were taken by auger to a depth of 80 cm in spilled transects and 60 cm in non-spilled transects. More depth was possible at 0 m on oil spilled transects because there were piles of soil above the general soil surface resulting from re-covering of the sites after addressing the spillage by the TAZAMA staff. At distances 5, 20 and 35 m from the pipeline soil profiles were excavated to a depth of 1.5 m or a limiting layer, total of 30 soil profiles were excavated. At 50 m, 100 m and 200 m soil samples were also taken by auger to a depth of 60 cm. Soil samples were taken from each designated horizon described using the FAO guidelines for soil profiles description (FAO 2006) (Figure 2).

Heavy metals checked were the ones, which reflect the chemistry of the oil through the TAZAMA pipeline. Six heavy metals were analysed from the soil samples including Hg, As, Pb, Cd, Cr and Cu. Total trace elements were extracted from soil by acid digestion Nitric/Perchloric acid 5:1 as described by Stewart et al. (1974). During digestion large amount of the sample was taken, that is 100 g of soil was mixed with 50 ml Nitric/Perchloric acid and digested using hot plate until the sample became colourless. After digestion the samples were filtered through suction pump and the leaching of minerals facilitated by adding 100 ml of dionazed water. The filtrate was collected in to 250 ml flask after which metals were concentrated by removing excess water using rota vapour at 60°C. The resulting concentrated solution of 10 ml was analysed for heavy metals. Metals' concentration were done to offset the detection limits using AAS which is 0.01-0.001 depending on metal detection limits according to the calculation below.

$$\text{Heavy metalsconc. (mg/g)} = \frac{\text{Concentration from AAS x Extraction volume}}{10^4 \text{ x Sample wt(g)}}$$

The analysis of the levels of heavy metals was done at the University of Dar es Salaam Tanzania, using Perkin-Elmer 3100 Atomic Absorption Spectrophotometer. For each sampling point, samples were analysed in triplicates; therefore the values presented are the means of three samples.

Data analysis

Continuous vertical variability of heavy metals was modelled using equal area spline functions to get values for each soil depth (Bishop et al., 1999). Descriptive statistics were involved in calculating the mean and range of concentration of heavy metals. Linear regression analysis was involved in determination of the rate of change concentration of heavy metal along the distances from the edge of the pipeline.

RESULTS

Comparison between spilled and non-oil spilled transects

All six studied heavy metals were detected in the study

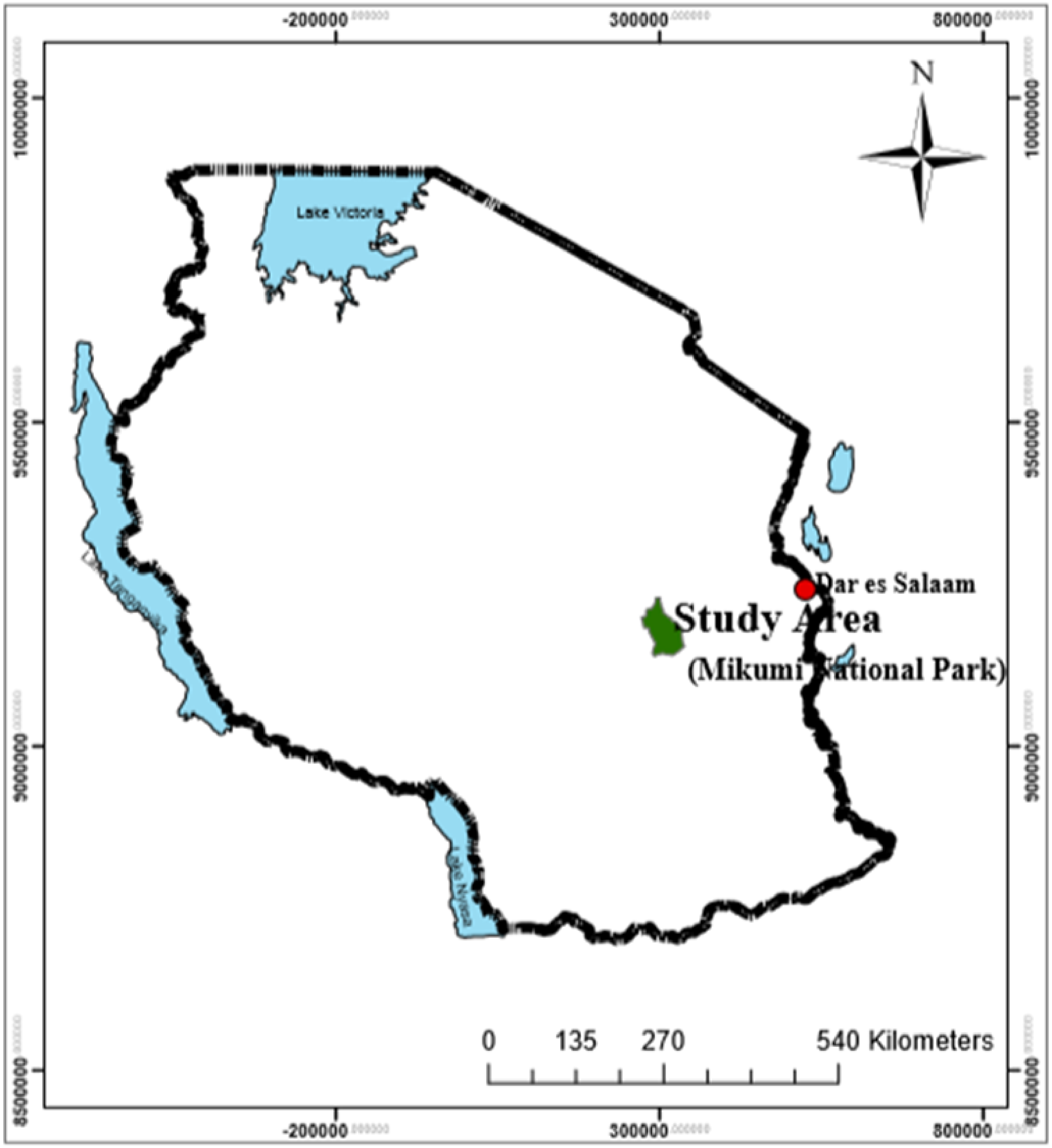

Figure 1. Map of the study area within the Mikumi National Park.

area. As, Pb and Cr were detected in both transects, that is, with oils spills and those without history of oil spillage to a distance of 0-35 m from the edge of the pipeline, with higher mean concentration in transects with oil spillage compared to those without (Table 1). From 50-200 m away these four metals were detected in transects with oil spillage only. Hg and Cd were detected in transects, with history of oil spillage only. Cu was detected in all transects and at all ranges of distance. In the manner of abundance metals were Cu>Pb>Cr>As>Hg>Cd. Copper was the most abundant metal of all and Cadmium was the least found.

Variation of concentration of heavy metals with distance from the edge of the pipeline

Concentration of all detected heavy metals decreased with increased distance from the pipeline to both North and South direction. The rate of change of concentration of each metal per 1 m increases in distance, at each transects in both direction (Table 2). Rate of change of concentration was statistically significant in transects with oil spills for As, Pb and Cr; in transects with no oil spillage the change was not statistically significant. Hg and Cd decreased with increased distance but the increase is not

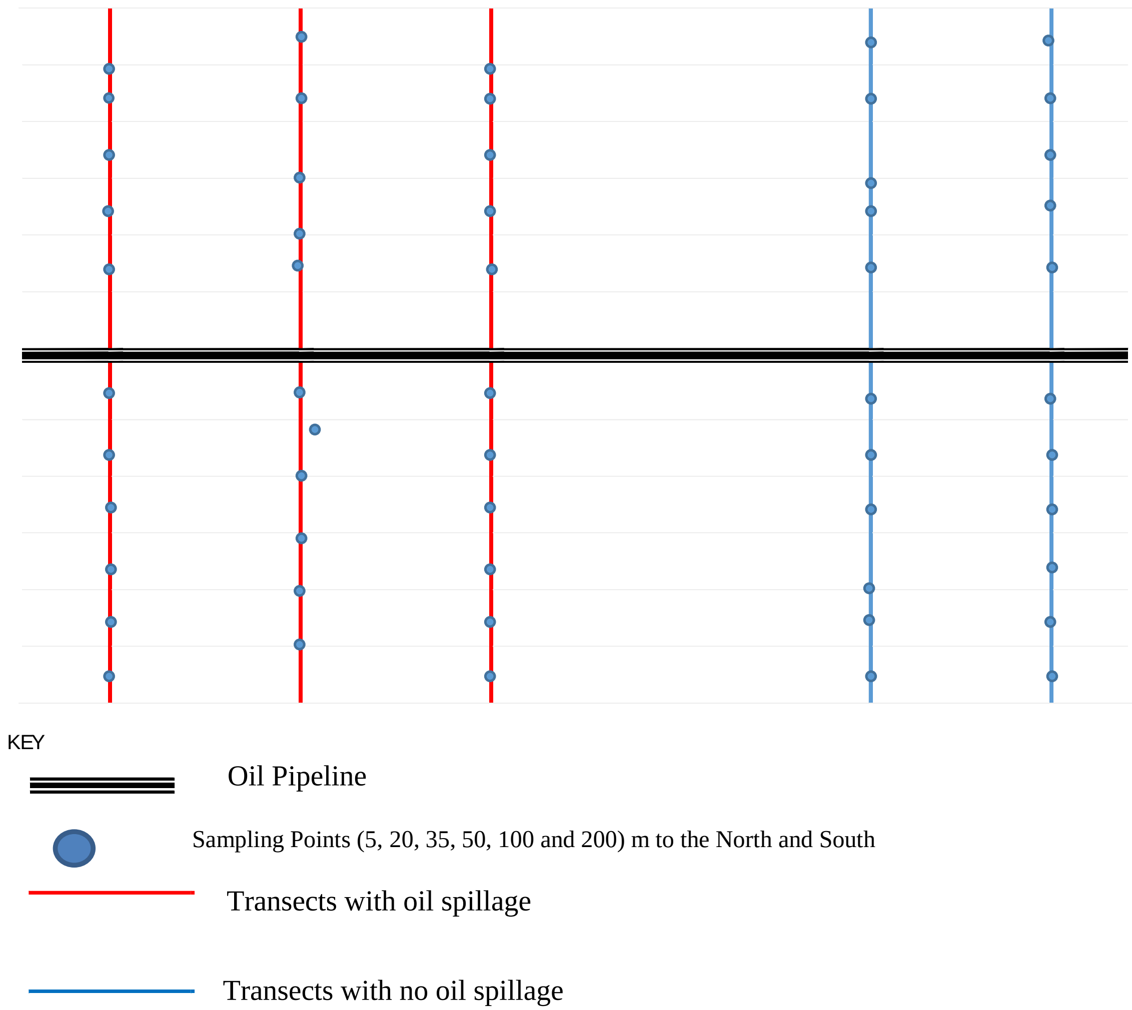

Figure 2. Sketch of arrangement of transects and sampling points along the pipeline.

statistically significant. Cu decreased with increased distance on both transects but the increase is not statistically significant (Table 4). Total concentration of all detected heavy metals were below those established by World Health Organisation WHO (Solek-Podwika et al., 2016) and Tanzania soil quality-limits for soil contaminants in habitat and agriculture (Tanzania Bureau of Standards, 2007) maximum permissible levels (Table 3).

DISCUSSION

Crude oils vary in their Chemistry hence their heavy metals contents vary from one to another. The oil transported through the TAZAMA pipeline is a murban crude oil, which is composed of gas oil and naphtha. Total heavy metals contained in the TAZAMA pipeline are Pb, As, Hg, Cr and Cu (TAZAMA, 2016). Therefore, these were the selected metals which were checked in sampled soils. Transects with oil spillage had higher mean heavy metals concentrations compared to those without. This suggests crude oil from the pipelines contributes to the addition of concentration of heavy metals in soils (Fei et al., 2019). Total heavy metals concentration decreased with increased distance from the pipeline in both transects. This may be due to the increased distance from the source of pollution. Same findings were reported by Sun et al. (2019) when assessing the level, source and distribution of heavy metals from a typical coal industrial city of Tangshan China. The decrease of concentration of heavy metals in both transects suggests that the pipeline leads to the increase of heavy metals with and without oil spills. According to Jasper (2012), oil leakage happens in pipelines during their check-ups and maintenance. This can lead to the emission of heavy metals to the soil even when a recorded oil spillage has not occurred. Metals like Hg and Cd were only detected in transects with oil spillage. This may be due to the fact that their presence

Table 1. Mean concentration of heavy metals at each sampling point in (µg/g) in each transect.

Metal	0 m	20 m		35 m		50 m		100 m		200 m	
		North	South	North	South	North	South	North	South	North	South
Pb. *sp*	9.628	6.651	10.382	0.404	7.889	0.025	0.017	0.0004	ND	0.109	ND
Pb. *sp*	9.056	7.831	8.287	7.822	7.859	0.015	0.276	0.0002	0.001	0.001	0.001
Pb. *sp*	8.523	8.544	7.834	9.048	7.455	0.007	0.001	0.004	0.001	0.003	ND
Pb. *unsp*	8.339	9.840	12.441	6.712	6.712	ND	ND	ND	ND	ND	ND
Pb. *unsp*	6.807	8.334	7.007	7.739	ND	ND	ND	ND	ND	ND	ND
As. *sp*	1.269	0.870	0.634	1.015	1.063	0.009	0.002	ND	ND	0.002	ND
As. *sp*	1.202	1.269	1.363	1.226	1.308	0.003	0.005	0.001	0.002	0.0003	0.0001
As. *sp*	1.319	1.361	1.223	1.218	1.312	0.001	0.001	0.001	0.002	0.001	ND
As. *unsp*	1.216	0.721	1.363	1.210	0.821	ND	ND	ND	ND	ND	ND
As. *unsp*	1.369	0.747	1.368	ND	ND	ND	ND	ND	ND	ND	ND
Hg. *sp*	0.293	0.132	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hg. *sp*	0.724	0.0001	0.001	ND	ND	ND	ND	ND	ND	ND	ND
Hg. *sp*	0.164	0.075	0.261	ND	ND	ND	ND	ND	ND	ND	ND
Hg. *unsp*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hg. *unsp*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd. *sp*	0.293	0.132	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd. *sp*	0.228	0.0003	0.0004	ND	ND	ND	ND	ND	0.0003	ND	0.0002
Cd. *sp*	0.164	0.749	0.261	ND	ND	0.0001	ND	0.0001	0.0004	ND	ND
Cd. *unsp*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd. *unsp*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr. *sp*	8.696	5.744	4.006	6.819	7.174	0.775	0.041	0.009	ND	0.141	ND
Cr. *sp*	8.207	8.693	9.390	8.376	8.987	0.021	0.394	0.0003	0.002	0.0002	0.0001
Cr. *sp*	9.064	9.376	8.356	8.316	9.013	0.001	0.011	0.005	0.019	0.004	ND
Cr. *unsp*	8.230	4.650	9.394	8.255	5.434	ND	ND	ND	ND	ND	ND
Cr. *unsp*	5.297	9.879	4.407	4.842	ND	ND	ND	ND	ND	ND	ND
Cu. *sp*	41.931	22.431	19.004	12.987	13.096	0.007	0.006	0.037	0.038	0.130	0.001
Cu. *sp*	136.395	1.830	2.245	3.926	1.765	0.002	0.405	0.0003	0.004	0.0002	0.001
Cu. *sp*	5.228	3.140	7.534	3.141	2.149	0.102	0.011	0.006	0.019	0.005	ND
Cu. *unsp*	3.884	2.564	2.465	2.191	2.195	0.006	0.005	0.003	0.002	0.002	0.002
Cu. *unsp*	3.135	2.349	2.110	2.334	0.002	0.002	0.002	0.002	0.001	0.005	ND

Key: sp - transects with oil spillage
unsp - transects with no oil spillage
ND- not detected (below detection limit)
For each sampling point, samples were analysed in triplicates, therefore the values presented are the means of three samples.

is mainly attributed by anthropogenic sources particularly petroleum (Yadav et al., 2019). Fernández-Martínez et al. (2019) suggest that Hg total concentration in soils is mainly due to petroleum activities and mines than other anthropogenic activities. Higher concentration of heavy metals in transects with oil spillage than without may be due to presence of petroleum pollutants. Cu was detected in abundance in both transects; the rate of change of Cu was insignificant in all transects at all intervals. This may be due to the fact that it is an essential micronutrient in the soil. According to Chrysargyris et al. (2019), Cu is among the essential micronutrients though its availability in excessive levels may be harmful to the plants (Wyszkowski, 2019). The concentration of heavy metals in all transects were below the WHO and TZS maximum permissible limits in soils. Moreover, the TZS limits are too general and do not specify the kind of land use for a particular soil. However, more attention should be paid to the pipeline safety and maintenance since the concentration in transects with oil spillage is higher compared to the ones without.

Conclusion

The level of heavy metals concentration detected in all the transects is below the WHO and the Tanzania soil quality-limits for soil contaminants in habitat and agriculture (TZS) maximum permissible limits. However, the concentration is higher in transects with history of oil

Table 2. Rate of change of total concentration of heavy metals away from the pipeline to north and south direction at each transect.

Metal	SP1		SP2		SP3		UNSP1		UNSP2	
	North	South	North	South	North	South	North	South	North	South
Pb	-0.042	-0.053	-0.048	-0.050	-0.048	-0.046	-0.051	-0.119	-0.046	-0.035
As	-0.006	-.0005	-0.007	-0.007	-0.008	-0.008	-0.006	-0.006	-0.006	-0.006
Hg	-0.001	-0.001	-0.002	-0.003	-0.001	-0.001	ND	ND	ND	ND
Cd	-0.001	-0.001	-0.001	-0.0004	-0.001	-0.001	ND	ND	ND	ND
Cr	-0.041	-0.034	-0.048	-0.051	-0.053	-0.051	ND	ND	ND	ND
Cu	-0.014	-0.189	-0.285	-0.487	-0.026	-0.031	-0.018	-0.018	-0.029	-0.013

Key: sp - transects with oil spillage
unsp - transects with no oil spillage
ND **-** not detected (below detection limit).

Table 3. Mean concentration of heavy metals in spilled and non-oil spilled transects in both directions in comparison to WHO and TZS maximum permissible levels in (µg/g).

Metal	SP1		SP2		SP3		UNSP1		UNSP2		Maximum permissible levels	
	North	South	North	South	North	South	North	South	North	South	WHO	TZS
Pb	3.565	5.156	4.699	4.882	4.804	4.522	4.921	16.948	4.553	3.002	100	200
As	0.062	0.504	0.698	0.743	0.751	0.739	0.551	0.578	0.506	0.604	20	1
Hg	0.009	0.070	0.146	0.199	0.054	0.083	ND	ND	ND	ND	2	2
Cd	0.009	0.70	0.009	0.039	0.062	0.083	ND	ND	ND	ND	3	1
Cr	4.062	3.341	4.771	5.104	5.159	5.076	3.688	3.891	3.499	2.732	100	-
Cu	12.521	16.443	21.507	37.633	2.379	2.871	1.709	1.698	2.589	1.096	100	200

(Sołek-Podwika, Ciarkowska, & Kaleta, 2016; Tanzania Bureau of Standards, 2007)
Key: sp - transects with oil spillage
unsp - transects with no oil spillage
ND **-** not detected (below detection limit)
For each sampling point, samples were analysed in triplicates, therefore the values presented are the means of three samples.

Table 4. P and T values for Statistical test for rate of change of heavy metals with distance at each transects.

Metal	SP1		SP2		SP3		UNSP1		UNSP2	
	North	South	North	South	North	South	North	South	North	South
Pb	INSG	P<0.05 T=-2.64	P<0.05 T=-2.65	P<0.05 T=-2.65	P<0.05 T=-2.55	P<0.05 T=-2.74	P<0.05 T=-2.68	INSG	INSG	INSG
As	P<0.05 T=-2.67	P<0.05 T=-2.61	P<0.05 T=-2.64	P<0.05 T=-2.69	P<0.05 T=-2.72	P<0.05 T=-2.68	INSG	INSG	INSG	INSG
Hg	INSG	INSG	INSG	INSG	INSG	INSG	INSG	INSG	ND	ND
Cd	INSG	INSG	INSG	INSG	P<0.05 T=-2.42	INSG	ND	ND	ND	ND
Cr	P<0.05 T=-2.65	P<0.05 T=-2.01	P<0.05 T=-2.64	P<0.05 T=-2.69	P<0.05 T=-2.72	P<0.05 T=-2.69	INSG	INSG	INSG	INSG
Cu	INSG	INSG	INSG	INSG	INSG	P<0.05 T=-2.69	P<0.05 T=-2.75	INSG	INSG	INSG

Key: sp - transects with oil spillage
unsp - transects with no oil spillage
ND **-** not detected (below detection limit).

spillage compared to those without. This calls for more attention since prevention of heavy metals pollution is currently a global agenda. For the Mikumi National Park in particular, more attention should be given for the TAZAMA pipeline since it is a home for various species of flora and fauna including the endangered and critically endangered species.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFFERENCES

Allison C, Godwin O, Prince EN, Jamiu AS (2017). “Dealing with Oil Spill Scenarios in the Niger Delta: Lessons from the Past.” In The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem.10.1016/B978-0-12-809399-3.00023-9

Asadirad MHA, Mazaheri MA, H Rashedi, Nejadsattari T (2016). “Effects of Indigenous Microbial Consortium in Crude Oil Degradation: A Microcosm Experiment.” International Journal of Environmental Research 10(4):491-498.

Bai J, Guangliang Z, Qingqing Z, Qiongqiong L (2019). “Arsenic and Heavy Metals Pollution along a Salinity Gradient in Drained Coastal Wetland Soils: Depth Distributions, Sources and Toxic Risks.” Ecological Indicators 69:331-339. 10.1016/j.ecolind.2018.08.026

Bishop TFA, McBratney AB, Laslett GM (1999). “Modelling Soil Attribute Depth Functions with Equal-Area Quadratic Smoothing Splines.” Geoderma 91(1-2):27-45. 10.1016/S0016-7061(99)00003-8

Buskey EJ, White HK, Esbaugh AJ (2016). “Impact of Oil Spills on Marine Life in the Gulf of Mexico.” Oceanography 29(3):174-181. 10.5670/oceanog.2016.81

Chrysargyris A, Eleftheria P, Spyridon AP, Nikolaos T (2019). “The Combined and Single Effect of Salinity and Copper Stress on Growth and Quality of Mentha Spicata Plants.” Journal of Hazardous Materials 368(1):584-593. 10.1016/j.jhazmat.2019.01.058

FAO (2006). “Soil Profile Description Guideline.” http://www.fao.org/3/a-a0541e.pdf

Fei X, Christakos G, Reen Z (2019). “Improved Heavy Metal Mapping and Pollution Source Apportionment in Shanghai City Soils Using Auxiliary Information.” Science of the Total Environment 661(12):168077. 10.1016/j.scitotenv.2019.01.149

Fernández-Martínez R, Jose Mª, Pablo H, Isabel R (2019). “Comparison of Mercury Distribution and Mobility in Soils Affected by Anthropogenic Pollution around Chloralkali Plants and Ancient Mining Sites.” Science of The Total Environment 671:1066-76. https://www.sciencedirect.com/science/article/pii/S0048969719313464.

Gordon G, Ilan S, Uri S, Ravid R (2018). “Oil Spill Effects on Soil Hydrophobicity and Related Properties in a Hyper-Arid Region.” Geoderma 312:114-120 10.1016/j.geoderma.2017.10.008

Hebblewhite M (2017). “Billion Dollar Boreal Woodland Caribou and the Biodiversity Impacts of the Global Oil and Gas Industry.” Biological Conservation 206:102-111 10.1016/j.biocon.2016.12.014

Jasper A (2012). “Oil/Gas Pipeline Leak Inspection and Repair in Underwater Poor Visibility Conditions: Challenges and Perspectives.” Journal of Environmental Protection 3(5):394. 9910.4236/jep.2012.35049

Oriaku TO, Udo NA, Iwuala IS (2017). “Assessment of Oil Spill Occurrences in Sections of the Niger Delta Region: Causes, Effects and Remedial Actions.” In Nigeria Annual International Conference and Exhibition 10.2118/189090-MS

Osti M, Lauren C, Joshua BF, Bastian B, Jonathan MH (2011). “Oil and Gas Development in the World Heritage and Wider Protected Area Network in Sub-Saharan Africa.” Biodiversity and Conservation 19(1):2010. 10.1007/ s10531-011-0056-6

Pennings SC, Brittany DM, Linda HB (2014). “Effects of Oil Spills on Terrestrial Arthropods in Coastal Wetlands.” BioScience64(9):789-795. 10.1093/biosci/biu118

Saadi FH, Nathan SL, Eric WM (2018). “Relative Costs of Transporting Electrical and Chemical Energy.” Energy and Environmental Science 11(3):469-475. 10.1039/C7EE01987D

Sołek-Podwika K, Krystyna C, Dorota K (2016). “Assessment of the Risk of Pollution by Sulfur Compounds and Heavy Metals in Soils Located in the Proximity of a Disused for 20 Years Sulfur Mine (SE Poland).” Journal of Environmental Management 180:450-458. 10.1016/j.jenvman.2016.05.074.

Sun L, Dengkui G, Ke L, Hui M (2019). “Levels, Sources, and Spatial Distribution of Heavy Metals in Soils from a Typical Coal Industrial City of Tangshan, China.” Catena 75:101-109. 10.1016/j.catena.2018.12.014.

Stewart EA, Grimshaw HM, John AP, Christopher Q (1974). “Chemical analysis of ecological materials” ____Journal of Chromatographic Science 16(6):14a. 10.1093/chromsci/16.6.14A-a

Tanzania Bureau of Standards (2007). “Tanzania Standards, Soil Quality - Limits for Soil Contaminants in Habitat and Agriculture (TZS 972:2007).” 3(5842).

TAZAMA (2016). “Brief Notes on Tazama Operations.” https://diggers.news/wp-content/uploads/2017/02/TAZAMA-OPERATIONS2.pdf.

Vaezi A, Manish V (2018). “Railroad Transportation of Crude Oil in Canada: Developing Long-Term Forecasts, and Evaluating the Impact of Proposed Pipeline Projects.” Journal of Transport Geography 69(C): 98-111.10.1016/j.jtrangeo.2018.04.019

Wyszkowski M (2019). “Soil Contamination with Copper and Its Effect on Selected Soil Properties After Applying Neutralizing Substances.” Polish Journal of Environmental Studies 28(4):2465-2471. 10.15244/pjoes/90357

Xie Y, Xiaowei Z, Jianghua Y, Seonjin Kim, Seongjin H, John PG, Un HY, Won JS, Hongxia Y, Jong SK (2018). “EDNA-Based Bioassessment of Coastal Sediments Impacted by an Oil Spill.” Environmental Pollution 238:739-748. 10.1016/j.envpol.2018.02.081

Yadav IC, Devi NL, Singh VK, Li J (2019). “Spatial Distribution, Source Analysis, and Health Risk Assessment of Heavy Metals Contamination in House Dust and Surface Soil from Four Major Cities of Nepal.” Chemosphere 218(3):1100-1113.

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Characterization and agricultural potentials of some pedons derived from sand stone parent rock near Abeokuta, Southwestern Nigeria

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Successful crop production requires the knowledge of soil variation and the evaluation of the agricultural potentials of the land. Detailed land resource survey of approximately 100 ha land in Abeokuta North Local Government Area of Ogun State was carried out. Identified soil mapping units were examined in modal profiles. The soils were classified using the USDA Soil Taxonomy, FAO/IUSS World Reference Base (WRB) system and local soil series methods. Five soil mapping units were identified and were classified as Ilaro Series (Kanhaplic Haplustalf), Ibeshe (Typic Kandiustalf), Kulfo (Udic Kandiustalf), Molo (Rhodic Kandiustalf) and Otteyi Series (Lithic Haplustept). The soils were classified as Alfisols (71.56%) and Inceptisols (28.44%). Land Capability Classification (LCC) revealed that Ilaro, Ibeshe and Molo series belong to Capability Class II while Kulfo series was Class III but Otteyi series is of non-arable Class VI. Otteyyi Series had severe limitations of very shallow soil depth, high slope gradient and high gravel content. The area has good potential for crop production if soil fertility can be managed with appropriate fertilizer application and seasonal water deficit ameliorated by supplemental irrigation. Otteyi Series that is non-arable could be used for farm buildings and other physical infrastructures or animal grazing.

Key words: Land evaluation, fertility capability class, soil series, limitations, arable cropping.

INTRODUCTION

Soils differ in their behavior due to differences in morphological, physical, chemical, biological and mineralogical properties (Msanya, 2018). These variations are due to differences in soil forming processes operating on different parent materials, under different climatic, topographic, and biological conditions over varying periods of time (Soil Survey Staff, 1993). In the past, decisions on land use are made indiscriminately based mainly on economic, cultural and political considerations, with little or no consideration for the biophysical status of the soils (Orimoloye et al., 2007; Nuga and Akinbola, 2011). The knowledge of the pattern of soil distribution and the characteristics of each unit of soil are very essential for a better understanding, use and management of soils (Ogunkunle, 2005; Lufega and Msanya, 2017). This will help maximize sustainable production

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Plate 1. Google earth imagery of the study area near Abeokuta.

and satisfy the diverse needs of society while at the same time conserving fragile ecosystems. A soil survey delineates the soil types in a given area, classifies soils according to a standard system of classification, plots boundaries of the soils on a map and makes predictions about the behaviour of the soils (Soil Survey Staff, 1993). The information is interpreted in land evaluation to assist the development of land use plans, evaluates and predicts the effects of land use on the environment (Shepande, 2002). The objectives of most soil survey investigations are to provide data for the rational planning and adjustment of land use patterns (Hubrechts et al., 2004).

Fasina et al. (2007) had observed an increasing demand for information on soils as a means to enhancing agricultural production in Nigeria. Soil characterization provides the information for our understanding of the physical, chemical, mineralogical and microbiological properties of the soils we depend on to grow crops, sustain forests and grasslands as well as support homes and society structures (Ogunkunle, 2005). Soil classification, on the other hand, helps to organize our knowledge, facilitates the transfer of experience and technology from one place to another and helps to compare soil properties. It is therefore pertinent that for the full potentials of an agricultural land to be maximized, there is need to have a good understanding of the different alternative uses that a land can be put as land use ought not to be based primarily on the needs and demands of users, but rather on the understanding of the suitability of each land for the intended use in order to achieve environmental sustainability (Nuga and Akinbola, 2015). There is therefore an urgent need for evaluation of agricultural lands and associated planning, owing to problems faced in recent years in the form of increasing pressure on agricultural lands from other uses, coupled with increasing demand for agricultural products due to population growth.

Soils of the Abeokuta North Local Government Area of Ogun State, Nigeria, are mainly of the sedimentary origin. Oral tradition from the locals indicates that the soils of the study area have been variously used at different times by peasants and institutions without any systematic soil study, leading to decline in yield and subsequent abandonment. A renewed interest in agricultural development by government and private investors has led to the allocation of large portions of this track of land to interested commercial farmers. A platform is thus created for a systematic soil study in this area to prevent seeds being sown on the proverbial 'stony ground'. This study was carried out therefore to characterize the soils of the study area and assess the land for general arable cropping.

MATERIALS AND METHODS

Description of the study site

The study area by its geomorphic and landscape characteristics typifies a wide expanse of land covering over 200,000 ha of land spread across several local government areas including Egbado/Yewa North, Owode and Ewekoro LGAs. The detailed study was carried out on a rectangular shaped land area situated along JogaOrile and Ilewo-Orile earth road, west of Abeokuta town. It is defined between latitudes 7° 8'5.60"N and 7° 8'38.40"N and longitudes 3° 8'44.40"E and 3° 9'45.30"E. Plate 1 shows the satellite imagery of the study area and Figure 1 the location map of

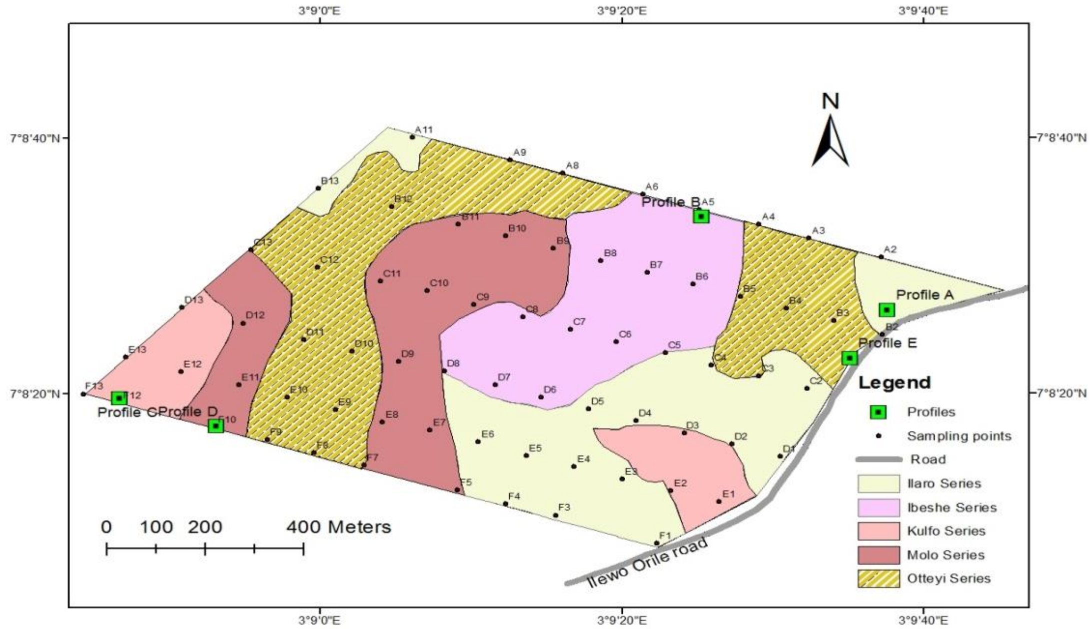

Figure 1. Soil map of study area near Abeokuta.

Table 1. Mean monthly weather condition at Abeokuta (20 km west of the study area).

Weather element	Months												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm)	4.4	0.0	137.1	102.7	84.2	252.8	150.6	182.1	245.6	194.9	5.4	0	1368.8
Rainy days	1	0.0	4	8	5	18	10	22	18	12	2	0	83
Evapotranspiration (ml)	5.2	9.1	6.6	3.3	3.1	2.1	1.7	1.5	1.8	1.8	3.4	5.1	3.7
Min. Temp. (°C)	19.9	17.3	20.6	22.2	21.8	21.1	20.7	20.7	21.3	21.8	22.5	19.1	20.7
Max. Temp. (°C)	34.0	35.1	36.0	32.3	32.2	29.9	28.1	27.8	29.5	29.4	33.4	33.8	31.8
Wind speed (km/h)	76.9	70.3	98.2	12.6	114.4	96.4	68.6	50.9	13.8	23.7	10.4	10.5	53.9
Soil (30 cm) Temp (°C)	37.9	37.9	39.6	38.2	37.9	35.7	34.1	33.3	31.5	34.9	38.3	37.4	36.4
RH at 0900 h (%)	79	46	68	81	82	84	87	89	86	86	77	65	77

Source: Department of Meteorological Services, Abeokuta (2003-2012).

the study area. The study area is located within the Zone Q (Very humid Lagos-Benin-Asaba lowlands) of the Agro-ecological zones of Nigeria (Ojanuga, 2006). The mean annual rainfall of the area is about 1,368 mm (Abeokuta). Length of dry season ranges between 120 and 130 days. The mean daily maximum and minimum temperature of 32 and 21°C, respectively were recorded at Abeokuta (Table 1). The study area belongs to the sedimentary upland underlain by Tertiary and Cretaceous sedimentary rocks (mainly sands and clays, sandstone and shales) (Olabode and Mohammed, 2016). The land area is characterized by ironstone capped sandstones overlaying heavily mottled ferrugenized clay. The dominant land use type in the area is mainly cassava-based arable cropping.

Field studies

A rigid grid method of soil survey was adopted for the land resource survey in May, 2015. The extent of the area to be surveyed was determined with the help of a perimeter survey. Transects were laid out at 200 m apart and auger observations were taken at 100 m interval along the transects to ensure at least one observation in every 2 ha of land. Examination points were pre-determined in a GIS environment and the co-ordinates were pre-loaded into a Global Positioning System (GPS) devise with which the points were located on the field. With the aid of Dutch Soil Auger and Munsell Soil Colour Charts, the soils morphological properties were examined at soil depth intervals of 0 - 15, 15 - 30, 30 - 60 and 60 - 90 cm except where plinthite or hard pan did not permit augering to the depth of 90 cm. Thereafter, using the soil morphological and physical properties, similar examination points were grouped together at the series level to form mapping units. Five mapping units were identified. In each of the mapping units, modal profile pits were dug, described and sampled according to international standards of soil profile description (FAO, 1991). In addition, surface soil (0-30 cm depth) samples were collected at each auger

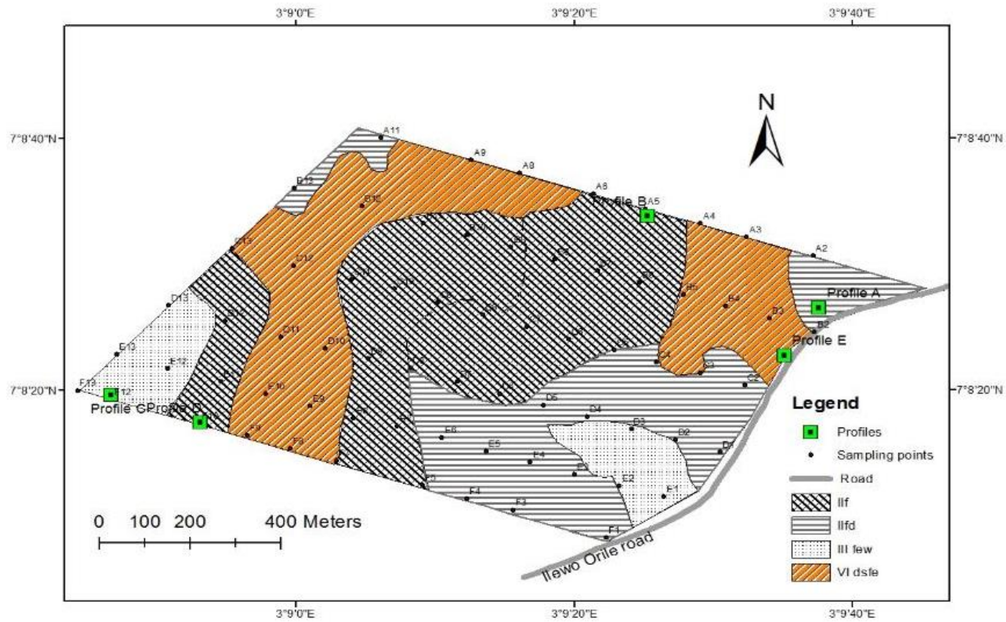

Figure 2. Land capability classification map of the study area.

examination point for soil fertility assessment. The soil samples were appropriately labeled and conveyed to the laboratory for processing and analysis for the physical and chemical properties of the soils. All necessary environmental information relating to the study area and the soil morphology were recorded on a proforma. A total of 84 soil samples made up of 26 profile and 58 surface soil samples were taken from the study area for analysis.

Laboratory analysis

The soil samples were air dried, crushed and sieved through a 2mm mesh. The gravel content (portion with particle size greater than 2 mm in diameter), was calculated as a percentage of the total air-dried soil. The particle size fractions were determined by the modified hydrometer method. The soil pH was determined in 1:1 soil: water ratio and potassium chloride (KCl) media using glass electrode pH meter. Organic carbon was estimated by Dichromate wet oxidation method of Walkley and Black (1934). Total nitrogen was determined by the micro-Kjeldahl method (Jackson, 1958). Available phosphorus was evaluated by Bray P1 method of Bray and Kurtz (1945), while exchangeable cations (Ca, Mg, K and Na) were extracted by neutral Ammonium acetate (NH_4OAC). Calcium, Potassium and Sodium were measured through flame photometer, while Magnesium was determined by Atomic Absorption Spectrophotometer (Rhoades, 1982). Exchangeable acidity was determined by 1N KCl extraction and titrated with 0.05N NaOH solution (Black, 1975). Effective Cation Exchange Capacity (ECEC) was calculated by the summation of the values of exchangeable cations and exchangeable acidity. The micro-nutrients (Fe, Mn, Cu and Zn) were determined in normal hydrochloric acid (1N HCl) and evaluated using the Atomic Absorption Spectrophotometer (AAS) (Jackson, 1958). Base saturation was computed as the summation of the basic cations (Edmeades, 1982).

Soil classification

The soil types on the study site were identified, characterized and classified using two international systems (Keys to Soil Taxonomy by Soil Survey Staff, 2014; WRB System of FAO, 2014). The soils were also classified at the series level using the approach of Moss (1957) that described the soils of sedimentary deposits of Southern Nigeria. The modified Land Capability Classification (LCC) system of the USDA by Klingebiel and Montgomery (1961) was adopted for the evaluation of the study site for sustainable land management for arable crop production and general land use. Fertility Capability Classification (FCC) was carried out based on the results of laboratory analyses of the top soil samples, along with their morphological properties as outlined by Sanchez et al. (2003).

RESULTS

Five soil mapping units were delineated within the study area. The soils are generally sandy loam at the top with the clay content generally increasing with depth. The soil map of the study area is presented in Figure 2. The physical/morphological and chemical properties are presented in Tables 2 and 3, respectively while the pedological classifications of the soil are shown in Table 4.

Soil physical and morphological characteristics

The soils Mapping Unit A was classified as Ilaro Series. The soils are well drained, friable to firm consistence with sub-angular blocky structure at depths from 17 cm. Theyare very dark brown (7.5YR 3/3 moist) at the top and become dark red (2.5YR 4/6 moist) at the subsoil. These are underlain by variegated yellow (10YR 8/6 moist) and strong brown (7.5YR 4/6 moist) mottled sandy clay loam plinthic layer that is not indurated but soft.

Table 2. Physical and morphological properties of the soils of the study area.

Profile	Hor	Depth	Gravel	Sand	silt	Clay	Texture	Colour	Mottles	Structure	Consistency	Roots	Stoneniness	Boundary
		cm		(%)										
A	A	0-17	1.21	80.0	9.4	10.6	SL	7.5YR 3/3	-	fc	fc	mx, ma	Nil	sm, cl
	AB	17-36	7.2	76.0	7.4	18.6	SL	5YR4/6	-	sab	fr	md, ma	Nil	sm, cl
	Bt1	36-61	2.6	54.0	5.4	40.6	SC	2.5YR4/6	-	sab	hd	mx, fi	Nil	sm, cl
	Bt2	61-92	2.2	54.0	3.4	42.6	SC	2.5YR 4/6	-	sab	hd	md, vfw	Nil	sm, cl
	Btcv	92-146	16. 7	68.0	11.4	20.6	SCL	7.5YR4/6	10YR 8/6	m	hd	Nil	Nil	-
B	A1	0-14	2.86	80.0	9.4	10.6	SL	10YR 5/2	Nil	md,cr	fr	mx, ma	Nil	sm, cl
	A2	14-29	1.72	78.0	5.4	16.6	SL	7.5YR 5/3	Nil	sab	fr	co, fw	Nil	sm, cl
	Bt1	29-58	4.10	64.0	3.4	32.6	SCL	7,5YR 3/6	Nil	sab	mod, hd	fi, vfw	Nil	sm, df
	Bt2	58-89	1.41	58.0	7.4	34.6	SCL	5YR 6/6	Nil	sab	hd	md, vfw	Nil	sm, df
	Bt3	89-120	0.66	60.0	5.4	34.6	SCL	5YR 7/8	Nil	sab	hd	fi, vfw	Nil	sm, df
	Bt4	120-158	5.09	64.0	7.4	28.6	SCL	5YR 6/8	Nil	sab	Hd	Nil	Nil	-
C	A1	0-17	0.70	80.0	9.4	10.6	SL	7.5YR 3/2	Nil	fc	Fr	mx, ma	Nil	sm, cl
	A2	17-36	0.56	84.0	7.4	8.6	LS	7.5YR 4/3	Nil	sab	Fr	mx, ma	Nil	sm, cl
	B1	36-70	0.75	76.0	7.4	16.0	SL	5YR4/4	Nil	sab	Fr	mx, ma	Nil	sm, df
	B2	70-92	0.93	74.6	7.4	18.0	SL	5YR 4/6	Nil	sab	Fr	mx, ma	Nil	sm, df
	Bt1	92-136	1.83	70.6	11.4	20.0	SCL	5YR 4/6	Nil	sab	Fm	fi, fw	Nil	sm, cl
	Btv	136-160	2.57	48.6	9.4	42.0	SC	5YR 5/6	7.5 6/8YR	sab	Fm	fi, fw	Nil	-
D	A	0-15	2.75	70.6	9.4	20.0	SCL	10YR 4/2	-	md, cr	Fr	mx, ma	Nil	sm, cl
	AB	15-27	2.9	68.6	17.4	14.0	SL	7.5YR 5/4	-	sab	Fr	co, ma	Nil	sm, cl
	Bt1	27-56	3.5	58.6	9.4	32.0	SCL	2.5YR 4/6	-	sab	Hd	mx, fw	Nil	sm, cl
	Bt2	56-117	1.7	48.6	9.4	42.0	SC	2.5YR 4/8	-	sab	Hd	md, vfw	Nil	sm, df
	Bt3	117-140	4.7	62.6	9.4	28.0	SCL	2.5YR 5/8	2.5Y 7/6	sab	Hd	md, vfw	Nil	-
E	AC	0-10	31.5	74.6	3.4	22.0	SCL	10YR 5/4	Nil	co, cr	Fr	fi, ma	v.st	sm, cl
	C1	10 -50	17.8	46.6	11.4	42.0	SC	10R4/6	7.5YR 8 /6	sab	Hd	fi, ma	Nil	sm, cl
	C2	50-65	62.5	46.6	11.4	42.0	SC	2.5YR 4/6	10YR 8/6	m	M	mx, ma	v.st	sm, cl
	C3	65-170	10.7	42.6	5.4	52.0	C	2.5YR 3/6	2.5Y 8/4	sab	Hd	mx, fi	Nil	-

ma= many, fa = faint, fc= fine crumbs, sab= sub-angular blocky, co= coarse, cr= crumb, m= massive, md= medium, SCL= sandy-clay-loam, LC= Loamy-clay, SL= Sandy-loam, CL=Clay-loam, C= Clay, fr= friable, hd= hard, fm = firm, fi= fine, vfw = very few, mx= mixed, sm= smooth, cl= clear, df =diffuse, v.st= very ston.

They possess appreciable amount of loose ferruginous and Fe/Mn concretions at depth from 92 cm. The soils of Mapping Unit B was classified

Table 3. Chemical properties of the soils of the study area.

Profile	Hor	Depth	pH H_2O	T.N	O.C	Av.p	Exch Acid	Ca	Mg	K	Na	ECEC	ECEC/Clay	ESP	B. Sat	Fe	Mn	Zn	Cu
		cm		g/kg		mg/kg	cmol/kg						%			mg/kg			
	Ap	0-17	7.0	0.22	2.45	2.02	0.4	1.6	1.9	0.1	1.5	5.4	51.1	29.5	92.61	221.0	133.0	1.4	10.8
	AB	17-36	6.2	0.23	2.15	10.24	0.7	0.5	0.8	0.1	1.6	3.6	19.6	54.6	80.80	263.0	31.5	1.0	6.4
A	Bt1	36-61	6.3	0.20	2.10	7.07	0.6	0.4	0.8	0.1	1.8	3.8	9.3	57.8	84.04	253.0	0.8	1.1	7.0
	Bt2	61-92	6.4	0.21	1.99	11.74	0.6	0.5	0.3	0.0	1.1	2.6	6.1	57.0	76.79	242.0	12.1	1.8	6.2
	Btcv	92-146	6.7	0.21	2.00	10.37	0.6	1.0	0.1	0.0	0.7	2.4	11.7	40.8	75.12	329.0	3.8	1.3	5.8
	A1	0-14	7.4	0.17	1.68	10.93	0.4	4.3	0.9	0.1	1.7	7.4	69.9	24.2	94.60	225.0	138.0	1.5	7.0
	A2	14-29	6.8	0.16	1.55	0.10	0.6	1.2	1.6	0.1	1.7	5.3	31.7	37.3	88.59	260.0	37.6	2.5	8.8
B	Bt1	29-58	6.4	0.16	1.56	0.60	0.5	0.7	3.5	0.1	0.9	5.6	17.2	17.9	91.09	314.0	8.4	3.3	9.7
	Bt2	58-89	6.4	0.15	1.44	12.49	0.5	0.6	0.1	0.1	0.8	2.0	5.9	50.7	75.54	183.0	5.7	7.9	5.6
	Bt3	89-120	6.4	0.17	1.29	7.94	0.6	0.6	0.1	0.1	0.7	1.9	5.6	49.2	68.83	231.0	4.7	5.8	5.5
	Bt4	120-158	6.4	0.10	1.10	4.39	0.6	0.6	0.1	0.0	0.7	2.0	6.9	50.4	69.73	198.0	2.5	6.2	5.4
	A1	0-17	7.2	0.24	2.23	10.93	0.4	3.1	1.0	0.1	0.6	5.2	48.6	12.8	92.24	153.0	183.0	6.6	6.7
	A2	17-36	7.3	0.20	2.10	8.44	0.4	1.4	1.4	0.0	1.7	4.9	57.3	36.5	91.88	147.0	166.0	7.3	6.9
C	B1	36-70	7.0	0.19	2.01	9.18	0.5	0.7	0.7	0.0	1.7	3.8	23.5	53.5	86.68	114.0	185.0	7.4	6.1
	B2	70-92	7.1	0.17	1.99	7.50	0.3	0.9	0.4	0.1	0.7	2.4	13.6	32.5	87.72	407.0	125.0	6.8	6.7
	Bt1	92-136	7.0	0.18	1.68	8.37	0.4	1.1	0.9	0.2	0.7	3.3	16.3	25.9	87.73	325.0	116.0	7.9	7.0
	Btv	136-160	7.2	0.16	1.44	8.87	0.4	1.7	1.2	0.1	0.7	4.1	9.8	19.9	90.27	337.0	26.7	7.4	6.5
	A	0-15	7.2	0.28	2.68	8.37	0.5	4.0	2.9	0.1	0.7	8.2	41.0	8.5	93.91	311.0	73.2	11.4	6.3
	AB	15-27	6.4	0.22	2.25	7.44	0.8	0.6	0.5	0.1	0.8	2.7	19.1	41.7	70.10	398.0	29.3	8.5	5.3
D	Bt1	27-56	6.4	0.19	2.10	6.88	0.7	0.8	0.4	0.1	0.7	2.7	8.3	35.6	73.61	164.0	5.3	7.6	6.1
	Bt2	56-117	6.4	0.27	2.24	6.07	0.8	1.1	0.3	0.1	0.7	3.0	7.1	31.8	73.20	334.0	7.3	7.6	5.0
	Bt3	117-140	6.7	0.20	1.90	8.37	0.9	1.2	0.3	0.1	0.6	3.0	10.7	29.1	69.96	381.0	4.3	7.2	5.6
	AC	0-10	6.4	0.26	2.46	12.11	0.8	1.7	1.4	0.2	0.7	4.8	21.6	16.5	83.17	117.0	2.5	9.5	6.1
E	C1	10 -50	6.7	0.19	1.69	8.62	0.5	0.3	0.1	0.1	0.6	1.6	3.7	53.7	67.79	212.0	1.0	9.0	5.6
	C2	50-65	6.4	0.22	1.90	9.87	0.9	0.3	0.1	0.1	0.6	2.0	4.8	50.7	55.33	215.0	1.3	7.9	3.8
	C3	65-170	6.7	0.18	1.55	10.87	0.6	0.2	0.1	0.1	0.6	1.6	3.0	59.0	61.50	210.0	0.3	9.8	4.2

TN= Total nitrogen, OC = Organic carbon.

as Ibeshe series. This mapping unit occupy about 18.5% of the total land area and is found on a gently sloping (4 - 6% slope) terrain underlain by

Table 4. Summary of pedological classification of the soil mapping units of the study area.

Mapping unit	Local (Moss 1957)	USDA soil taxonomy (Soil Survey Staff, 2014)	WRB (2014)	Size (ha)	Coverage (%)
A	Ilaro Series	Kanhaplic Haplustalf	Plinthic Lixisol (Vetic)	23.85	24.15
B	Ibeshe Series	Typic Kandiustalf	Haplic Lixisol (Loamic, Ochric)	18.29	18.52
C	Kulfo Series	Udic Kandiustalf	Haplic Lixisol (Eutric)	8.81	8.92
D	Molo Series	Rhodic Kandiustalf	Rhodic Lixisol (Hypereutric)	19.72	19.97
E	Otteyi Series (Shallow variation	Lithic Haplustept	Leptic Cambisol (Geoabruptic)	28.08	28.44

ferruginous sandstone parent materials of the Eocene age and is located at the middle slopes of disintegrating laterite caps. The soils are well drained, deep and had no laterite or ironstone within the profile depth. Consistency is friable to hard (dry) with sub-angular blocky structure throughout the profile except the A horizon. The colour ranges from greyish brown (10YR 5/2) at the top to yellowish red (5YR 4/6) at the subsoil with good profile development evidenced from the clay illuviation down the profile.

The soils represented by Mapping Unit C was classified as Kulfo Series and occupies about 8.92% of the total land area and is found mainly at the lower slope positions. The soils are fairly well drained and deep. Fe-rich variegated mottling suggesting redox reactions occasioned by periodic moisture saturation were noticed at depths below 140 cm. Consistency is friable (moist) almost throughout the profile. The colour ranges from dark brown (7.5YR 3/2) at the top to yellowish red (5YR 5/6) at the subsoil. Mapping Unit D was classified as Molo Series and it occupies about 19.97% of the total land area. The soils are well drained and deep with no laterite or plinthite within the profile depth. Consistency is friable to hard (dry) with sub-angular blocky structure throughout the profile except the A horizon. The colour ranges from dark greyish brown (10YR 4/2) at the top to red (2.5 YR 5/8) at the subsoil. A higher clay content at the subsoil than the top is as a result of pedogenetic processes (especially clay migration) was observed, leading to the formation kandic subsoil horizon.

Mapping Unit E which was classified as Otteyi Series (shallow variation) covers about 28.4% of the land mass and was classified as Otteyi Series (Shallow variation). The soils occupy the hill crests of the laterite and ironstone caped almost flat upper slope positions on the landscape. They are well drained soils formed from sandstone parent materials. The soil surface is characterized by ironstone rubbles sometimes of boulder sizes. The soil colour ranges from dark grayish brown (10YR 5/4) becoming dark red (2.5YR 3/6) with highly ferrugenised mottled clay under the pan rubble. The textural class of the fine earth materials ranges from sandy clay loam increasing in clay content to become clay with depth. The gravel content is high ranging from 10.7 to 31.5%.

Soil chemical characteristics

The soil chemical characteristics are as presented in Table 3. Ilaro Series is generally slightly acidic to neutral in reaction (pH 6.2 - 7.0) with high base saturation (75.12 - 92.61%). The ECEC is very low (2.4 - 5.4 cmol/kg), while the organic carbon is moderate (19.90 - 24.50 g/kg); the highest value being at the upper horizons, decreasing with depth. Ibeshe Series soils are generally slightly acidic to neutral in reaction (pH 6.4 - 7.4) with the lowest acidity at the surface. Base saturation is high (69.73 - 94.60%) and the ECEC is very low to moderate (1.90 - 7.4 cmol/kg), while the organic carbon is low (11.00 - 16.50 g/kg); the highest value being at the upper horizons, decreasing with depth. The soil reaction in Kulfo is mostly neutral (pH 7.0 - 7.3). Base saturation is high (86.68 - 92.24%) and the ECEC is low ranging from 2.4 to 5.2 cmol/kg, while the organic carbon is relatively low (14.40 - 22.23 g/kg); the highest value being at the upper horizons as expected, decreasing with depth. The soils in Molo Series (Mapping Unit D) are slightly acidic (pH 6.4 - 7.2) with acidity increasing with depth. The topsoil is relatively richer in organic matter content (26.8 g/kg) than the subsoil (4). Nitrogen and phosphorus content are 2.8 g/kg and 8.74 mg/kg, respectively at the topsoil. They are also generally low in exchange cations even though high (>50%) in base saturation. The micro-nutrient contents are low for Cu and Zn but adequate for Mn and Fe. In addition to the aforementioned, they have a texture of sandy loam of 30 cm or more thick within 50 cm of the soil surface. The soils of Otteyi Series are slightly acidic (pH 6.4 - 6.7); moderately high in organic carbon content (24.6 g/kg) at the surface decreasing with depth to 15.5 g/kg. The ECEC is low (1.60 - 4.8 cmol/kg) also decreasing with depth.

Taxonomic classification

At the higher categories the soils of Mapping Unit A was classified as Plinthic Lixisol (Vetic) (FAO/IUSS, 2014) and Kanhaplic Haplustalf (Soil Survey Staff, 2014). They experience ustic moisture regime with argillic horizons at the subsoil. At the lower category they are classified as Ilaro series (Moss, 1957). They display distinct mottled clay structure, in addition to the attributes described. The soils of Unit B was classified as at WRB categories as Haplic Lixisol (Loamic, Ochric) (FAO/IUSS, 2014) and Typic Kandiustalf (Soil Survey Staff, 2014). They possess low activity clays (1:1 lattice clay minerals) with more than 50% base saturation in the major part between 20 and 100 cm from the soil surface and 80% or more in some layers within 100 cm of the soil surface. They experience ustic moisture regime with a Kandic B horizons at the subsoil. At the lower category they are classified as Ibeshe series (Moss, 1957).

The soils of Mapping Unit C are classified as Haplic Lixisol (Loamic, Ochric) (FAO/IUSS, 2014) and Udic Kandiustalf (Soil Survey Staff, 2014). They possess low activity clays (1:1 lattice clay minerals) with more than 50% base saturation in the major part between 20 and 100 cm from the soil surface and 80% or more in some layers within 100 cm of the soil surface. They experience ustic moisture regime with a Kandic B horizons at the subsoil. At the lower category, they are classified as Kulfo series (Moss, 1957). They are therefore classified as Molo series (Moss, 1957); Rhodic Lixisol (Hypereutric) (FAO/IUSS, 2014) and Rhodic Kandiustalf (Soil Survey Staff, 2014). The ironstone pan rubble in this soil is characteristically hard and somewhat metallic and occurs mostly at the surface making effective soil depth in this unit less than 15 cm. Hence, they are classified at the series level as Oteyyi Series (Shallow variation) (Moss, 1957). The soils are classified as Leptic Cambisol (Geoabruptic) (FAO/IUSS, 2014) and Lithic Haplustept in the USDA soil taxonomy.

Land capability classification (LCC)

A summary of the classification of the mapping units into capability classes is presented in Table 5 while the land capability map is presented in Figure 2. Soil Mapping Units B and D (Ibeshe and Molo Series) are grouped into Capability Unit IIf. This unit occupies about 60% of the total area of site 1 (Figure 2). The soils are deep, occupying gentle to almost flat positions on the landscape with little or no risk of accelerated erosion and runoff. The major limitation is that of fertility (f). The soils do not have problems of stoniness and excessive gravel content to limit plant roots proliferation. The effective soil depth of the unit is more than 160 cm. Thus, for most arable and tree crops hard pan is not a limiting factor. For oil palm, the roots are essentially fibrous and can exploit the soil laterally and also due to the fact that the greatest quantity of the roots is to be found between soil depths of 20 and 60 cm, and most of the absorption of nutrients have been known to be through the quaternary roots and absorbing tips of the primary, secondary and tertiary roots to this depth. The soils can be tilled and ridged for cassava, yam and maize though mechanical tillage. Though, the slope gradients are not too steep to warrant high susceptibility to erosion, tillage should be done across the slope contour to prevent erosion. If nutrients as the only limiting factor this unit could be supplied through sound fertility management, it is capable of optimal arable crop production.

Soil Mapping Unit A (Ilaro Series) is classified into Capability Unit IIdf. This is moderately good unit for crop production with effective soil depth (d) (<100 cm), and low fertility (f) being the major limiting factors, for arable crop production. The capability unit occupies about 24.15% of the land area (Figure 2). It is concentrated in the south central portions of the land area. Maintenance of soil surface cover inform of cover crops or green mulch and manual land clearing will go a long way to reduce the possibility of erosion on the unit. Though, this land has an ironstone layer, it occurs in most parts of the unit below 80 cm depth. Thus, for most arable crops, except tap rooted tree crops, the hard pan may not be a serious limiting factor, since most of the plant's feeder roots are concentrated in the upper 60 cm. Some form of moisture stress may be expected at the height of dry season. This can, however, be minimized by the application of green or dry mulch. The limiting factor identified are mild and readily be corrected through management practices.

Mapping Unit C (Kulfo Series) was grouped into Capability Unit IIIfew. Fertility (f), erosion (e) and possibility of wetness at the peak of high rainfall are the major limiting factors. The unit is marginally capable for arable but is good for tree crop production. Due to the torrential nature of the rainfall in the area, coupled with sloping (6-8%) nature of the area, it is predisposed to accelerated erosion if large tracts are opened up at once. The site is recommended for tree crop production like oil palm which can keep the soils covered and prevent erosion. This unit because of the periodic high water table may make an excellent area if supplementary water could be provided, for off-season vegetable production. Soil surface cover should be maintained as much as possible.

Fertility capability classification

The fertility capability classification rating as obtained by adding the dominant textural class of the type, substrata

Table 5. Land capability classification of the mapping units.

Mapping unit	Characteristics/Limitations	Capability unit
A	Moderate capability, with low fertility level and soil effective depth <100 cm as the main limitations	IIfd
B	Low to medium fertility	IIf
C	Moderate liability to run-off and low to medium soil fertility and possibility of periodic high water table	IIIfew
D	Low to medium fertility	IIf
E	Very shallow soil depth, stoniness, low fertility and possibility of erosion	VIdefs

II = Capability class II (Moderately Arable); III = Capability class III (Marginally Arable); VI = Capability class VI (Non-Arable except for few tree crops or rangeland); f = Fertility deficiency; e = Erosion limitation; d = Effective soil depth limitation (indurated hard pan layer); w = wetness, possibility of seasonal high water table; s = stoniness.

Table 6. Fertility capability classification (FCC) of the soils of the study area.

Mapping unit	Soil series	Size (ha)	Coverage (%)	Horizon (depth)	Textural class	Type	Type/ Substrata	K Reserve (k)	CEC (e)	Rooting (r)	Na sat (n)	FCC
				0-17	SL	L	-	0.1	5.4			
A	Ilaro Series	23.85	24.15	17-36	SL	L	-	0.1	3.6	-	-	LCke
				36-61	SC	C	C	0.1	3.8			
				0-14	SL	L	-	0.1	7.4			
B	Ibeshe Series	18.29	18.52	14- 29	SCL	C	-	0.1	5.3	-	-	SLke
				29-58	-	-	-	0.1	5.6			
				0-17	SL	L	-	0.1	5.2			
C	Kulfo Series	8.81	8.92	17-36	LS		S	0	4.9	-	-	SLke
				36-70	SL	-	S	0	3.8			
				0-15	SCL	L		0.1	8.2			
D	Molo Series	19.72	19.97	15-27	SL		L	0.1	2.7	-	-	Lke
				27-56	SCL		L	0.1	2.7			
E	Otteyi Series	28.08	28.44	0-10	SCL	L		0.2	4.8			Lr***
				10-50	SCL		L	0.1	1.6	***		

Coarse loamy top soils; sandy loams. L- Fine loamy top soils; sandy clay loams and loams. Fine clayey sub-soils; sandy clay to clay. L - Fine loamy sub-soil; sandy clay loams and loams Condition Modifiers. k- Soils having very low amounts of potassium (exchangeable K less than 0.2cmol/100g soil). e- Soils with low CEC in the plow layer. r- soils with root restricting layers such as gravel or hard pan.

and the limiting condition modifiers for each soil series and this is shown in Table 6. Ilaro Series had a Loamy starata with a clayey substarata types. The type is the dominant textural class within 0 to 25 cm of the soil series while the substrata represent the dominant textural class at

25 to 50 cm or the plow layer. A CEC value of <15 cmol/kg indicates low CEC and K value of <0.2 cmol/100 g of soil indicates K deficiency. The low CEC and low K reserves were common to almost all the Pedons in the study area. Otteyi Series had serious root restriction limitations resulting from pan rubbles on or close to the soil surface. This renders this pedon inappropriate for cropping.

DISCUSSION

The soils of the study are generally sandy loam at the top with the clay content generally increasing with depth and were classified as Kanhaplic Haplustalf, Typic Kandiustalf, Udic Kandiustalf, Rhodic Kandiustalf, and Lithic Haplustept in the USDA soil classification system. In the order level of classification, 71.56% of the soils are Alfisols and 28.44% Inceptisols. The difference between Typic Kandiustalf and Udic Kandiustalf is that though they both have a kandic B horizon at the subsoil, Typic Kandiustalf experiences an ustic moisture regime whereas Udic Kandiustalf experiences a higher soil moisture (at a lower slope position) similar to udic moisture regime described as a humid climate with about eight to nine months of rainfall in a year (Ojanuga, 2006). In terms of colour, the soils are characterized by dark brown to dark red, greyish-brown to yellowish-red, dark-brown to yellowish-red, dark greyish brown to red and dark greyish brown to dark red. The yellowish red, red and dark red coloration indicates the presence of iron oxides; dark brown color indicates high organic matter content (Brady and Weil, 1999).

The soils are generally slightly acidic to neutral (pH 6 2 - 7.4). Soil acidity can affect nutrient availability, herbicide persistence and toxicity of heavy metal, all of which can adversely crop production (Reeves and Liebig, 2016). The degree of leaching, nature of parent material, intensity of cropping going on in the soils are likely factors affecting the pH of the soil (Leibig et al., 2004). On a general note, the fertility status of the soils is higher at the upper horizons than the sub-soils which aligns with previous findings (Sharu et al., 2013, Belachew and Abera, 2010). The nitrogen status is higher than the critical level of 1.5 g/kg (Fontes and Ronchi, 2002) in about 90% of the land area. However, it must be noted that N is a dynamic nutrient and the present status is a result of organic matter accumulation on the surface soils which mineralizes rapidly on land clearing. Available P is generally deficient as less than 10% of the land area contains the required critical range of 15 to 45 mg/kg for sustainable arable cropping (Weaver and Wong, 2011). The soils are generally deficient in potassium, having values less than the critical level of 0.2 to 2.6 cmol/kg (Anderson et al., 2013) throughout the whole land area. The ECEC values of the soils are above the minimum standard of 4.0 cmol/kg in all portions of the land area owing principally to Calcium levels that are generally higher than the minimum requirement of 3.8 cmol/kg in all the soils. These according to Crespo et al. (2017) are dependent on such parameters as pH and organic matter content of the soils. The organic carbon levels of the soils are low ranging from 1.1 to 2.68 g/kg which is far below the critical level of 30 g/kg proposed by ISRIC (1995). The low organic carbon might have resulted from the high mineralization rate and cropping history of the area. The micro-nutrients (Mn, Cu and Zn) are at sufficiency level only at the top soil. Their critical values are 20 to 25, 1.2 to 2.0 and 3.0 to 3.45 mg/kg, respectively. The iron (Fe) content of the soils are however very high, far above the critical value of 161 mg/kg (Feiziasl et al., 2009; Crespo et al., 2017). Those nutrient elements that are below the critical levels need be supplied through deliberate fertilizer application to build up their levels in the soil. It was observed that Mapping Units A, B, and D are moderately capable of supporting arable cropping with limitations such as low fertility and soil effective depth for Mapping Unit A, low to medium fertility for Mapping Units B and D. Mapping Unit C is marginally capable with limitations such as moderate liability to run-off and low to medium, soil fertility and possibility of periodic high water table (wetness) whereas Mapping Unit E is non-arable with limitations such as very shallow soil depth, stoniness, low fertility and possibility of erosion.

Based on fertility capability classification, of the seventeen different condition modifiers used in the evaluation, potassium deficiency (k- <0.20 cmol/100 g) and low cation exchange capacity (e- <15 cmol/kg) occurred in 100% of the soils studied. The mapping units were thus classified as LCke, SLke, SLke, Lke and Lr*** for Ilaro, Ibeshe, Kulfo, Molo and Otteyi Series, respectively. Potassium deficiency occurred in all soils because majority of the soils are very high in sand content, the sandy texture of the soils as well as high concentration of the gravel in the soil must have encouraged the leaching of the available soil nutrients as K^+ which are highly soluble (Datnoff, 2007; Senjobi, 2007). Potassium plays a lot of roles in plants such as protein synthesis, opening and closing of stomata, activation of some enzymes, phloem solute transport, and maintenance of cation: anion balance in the cystol and vacuole, a deficiency in K will impair a plants ability to maintain the processes. The low CEC of the soil is also attributed to the sandy texture of the soils. The CEC of soils influence soil structure stability, nutrient availability, soil pH and other ameliorants (Hazleton and Murphy, 2007). Soils with low CEC are more likely to develop deficiencies in K, Mg and other cations (CUCE, 2007).

Conclusion

The soils generally are slightly acidic to neutral and of low fertility status; all the soils are deficient in exchangeable potassium and low CEC. Hence, the major management problems of the soils which are relevant to agricultural production are those related to the maintenance of soil fertility under continuous cropping. The productivity of the soils can be improved through the judicious use of organic and inorganic fertilizers. Land use type and land capability need to be considered in taking appropriate approach to soil rehabilitation or improvement for agricultural uses in these soils. Organic matter management is essential for good crop production.

Organic matter accumulation through green and/or dry mulching should be encouraged. This will enhance the physical properties (bulk density, infiltration rate, hydraulic conductivity, water holding capacity, etc.) of the soils. The chemical fertility will also be enhanced as the organic carbon increases leading to the improvement of the status of nutrient elements in the soil.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Anderson G, Chen W, Bell R, Brennan R (2013). Critical values for soil P, K and S for near maximum wheat, canola and lupin production in Western Australia. WA Crop Updates 2013. Department of Agriculture and Food, P 4.

Belachew T, Abera Y (2010). Assessment of Soil Fertility Status with Depth in Wheat Growing Highlands of Southeast Ethiopia. World Journal of Agricultural Sciences 6(5):525-531.

Black CA (1975). Methods of soil analysis. Agronomy No. 9, Part 2, American Society of Agronomy, Madison. Wisconsin.

Brady NC, Weil RR (1999). The nature and properties of soil. Prentice Hall, New Jersey, USA. 12th Edition. P. 881.

Bray RH, Kurtz LT (1945). Determination of Total and Available forms of Phosphate in Oils. Soil Science 59:225-229.

Cornell University Cooperative Extension (CUCE) 2007. Cation Exchange Capacity (CEC). Agronomy fact sheet series # 22. Department of Crop Sciences, College of Agriculture and Life Sciences, Cornell University.

Crespo CJQ, Zenteno MDC, Intriago FLM, Alvarado RAC (2017). Nutrient critical levels and availability in soils cultivated with peach palm (Bactris gasipaes Kunth) in Santo Domingo de Los Tsáchilas, Ecuador. Acta Agronomie 66(2):235-240. doi.org/10.15446/acag.v66n2.55026

Datnoff LE (2007). Mineral Nutrition and Plant disease. The American Phytopathological Society ISBN0-89054-346-1

Edmeades DC (1982). Effects of lime on effective cation exchange capacity and exchangeable cations on a range of New Zealand soils. New Zealand Journal of Agricultural Research 25(1):27-33. DOI: 10.1080/00288233.1982.10423369

Food and Agriculture Organization (FAO) (1991). Guidelines: land evaluation for extensive grazing. Soils Bulletin 58. Food and Agriculture Organization of the United Nations, Rome, Italy.

Food and Agriculture Organization (FAO) (2007). Land Evaluation. Towards a Revised Framework. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO/IUSS (2014). World Reference Base for Soil Resources (2014). International soil classification system for naming soils and creating legends for soil maps. World Soil Resources. Reports No. 106. FAO, Rome. http://www.fao.org/3/i3794en/I3794en.pdf

Fasina AS, Omolayo FA, Ajayi SO, Falodun AA (2007). Influence of Land Use on Soil Properties in Three Mapping Units in Southwestern Nigeria-Implications for Sustainable Soil Management. In: Uyovbisere, E.O, Raji, B.A, Yusuf, A.A, Ogunwale, J.O, Aliyu, L. and Ojeniyi, S.O (Eds). Soil and water management for poverty alleviation and sustainable Environment Proceedings of the 31st annual conference of SSSN/ABU Zaria Nigeria November 13th to 17th, 2006.

Feiziasl V, Jafarzadeh J, Pala M, Mosavi SB (2009). Determination of Critical Levels of Micronutrients by Plant Response Column Order Procedure for Dryland Wheat (*T. aestivum* L.) in Northwest of Iran. International Journal of Soil Science 4:14-26 doi: 10.3923/ijss.2009.14.26

Fontes PCR, Ronchi CP (2002). Critical values of nitrogen indices in tomato plants grown in soil and nutrient solution determined by different statistical procedures. Pesquisa Agropecuária Brasileira, 37(10):1421-1429.

Hazleton PA, Murphy BW (2007). Interpreting Soil Test Results: What Do All The Numbers Mean? CSIRO Publishing.

Hubrechts L, Vander PK, Vanclosster M, Deckers J (2004). From Soil Survey to quantitative land evaluation in Belgium. European Soil Bureau Research Report No 4. www.nlfb.de/bode/downlonds/proceed/32.pdf Retrieved 15/5/04

Jackson ML (1958). Soil Chemical analysis. Prentice Hall. Inc. Englewood Cliffs, NJ, 498.

Klingebiel AA, Montgomery PH (1961). Land capability classification. USDA Agricultural Handbook 210. US Government Printing Office, Washington, DC.

Leibig MA, Tanaka DL, Wienhold BJ (2004). Tillage and cropping effects on soil quality indicators in the northern Great Plains. Soil and Tillage Research 78:131-141. doi:10.1016/j.still.2004.02.002

Lufega SM, Msanya BM (2017). Pedological Characterization and Soil Classification of Selected Soil Units of Morogoro District, Tanzania. International Journal of Plant and Soil Science 16(1):1-12 DOI: 10.9734/IJPSS/2017/32681

Moss RP (1975). Report on the classification of the soils found over sedimentary rocks in Western Nigeria. Soil Survey Report. No. 67. Institute of Agricultural Research and Training. University of Ife, Ibadan. P. 90.

Msanya BM, Mwasyika TA, Amuri N, Semu E, Mhoro L (2018). Pedological Characterization of Typical Soils of Dodoma Capital City District, Tanzania: Soil Morphology, Physico-chemical Properties, Classification and Soil Fertility Trends. Annals of Advanced Agricultural Sciences 2(4):59-73. https://dx.doi.org/10.22606/as.2018.24002

Nuga BO, Akinbola GE (2011). Characteristics and Classification of Soils Developed Over Coastal Plain Sand and Shale Parent Material in Abia State Nigeria. Journal of Technology and Education in Nigeria (JOTEN), 16(1):36-58. Retrieved 23rd August 2015 at http://www.researchgate.net/publication/236852990

Nuga BO, Akinbola GE (2015). Land Suitability Evaluation of Soils on Two Mapping Units for Some Arable Crops in South Eastern Nigeria. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 8(3):66-73 www.iosrjournals.org

Ogunkunle AO (2005). Soil Survey and Sustainable Land Management. Invited paper at the 29th annual conf. of SSSN held at University of Nigeria, Abeokuta, from 6th to 10th December. 2004.

Ojanuga AG (2006). Agroecological Zones of Nigeria Manual. Berding F. and Chude V.O. (Eds). National Special Programme for Food Security (NSPFS), FAO and FMA & RD. P. 123.

Olabode SO, Mohammed MZ (2016). Depositional facies and sequence stratigraphic study in parts of Benin (Dahomeh) Basin, SW Nigeria: Implications on the re-interpretation of tertiary sedimentary successions. International Journal of Geosciences 7:210-228.

Orimoloye JR, Nuga BO, Akinbola GA (2007): Evaluation of some pedons of basement complex of Southwestern Nigeria for rainfed maize, cassava and rubber cultivation. Chemtech Journal 3:483-490

Reeves JL, Liebig MA (2016). Depth matters: soil pH and dilution effects in the northern Great Plains. Soil Science Society of America Journal 80:1424-1427. doi:10.2136/sssaj2016.02.0036n

Sanchez PA, Palm CA, Buol SW (2003). Fertility Capability soil classification: a tool to help assess soil quality in the tropics. Geoderma114:157-185.

Senjobi BA (2007). Comparative Assessment of the Effect of Land Use and Land Type on Soil Degradation and Productivity in Ogun State, Nigeria. 161pp. Unpublished Ph.D. Thesis submitted to the Department of Agronomy, University of Ibadan, Nigeria.

Sharu MB, Yakubu M, Noma SS, Tsafe AI (2013). Characterization and Classification of Soils on an Agricultural landscape in Dingyadi District,Sokoto State, Nigeria. Nigerian Journal of Basic and Applied Science (June, 2013), 21(2):137-147.

Shepande C (2002). Soils and land use with particular attention and land evaluation for selected land use types in the Lake Naivasha Basin. Kenya. Unpublish. M.S.C. Thesis in Soil information, ITC. Enschede Netherlands.

Soil Survey Staff (1993). Soil Survey Manual. Soil Conservation Service, United State Department of Agriculture. Agricultural Handbook 18. (Online). Available at http://soils.usda.govt/technical/manual/ contents/index.html (Accessed 17 July 2011).

Soil Survey Staff (2014). Keys to Soil Taxonomy. 12th Edition, USDA Natural Resources Conservation Service, P. 332.

Walkley A, Black IA (1934). AN examination of the Degitareff method for determining soil organic matter and proposed modification of the Chromic acid titration method. Soil Science 37:29-38.

Weaver DM, Wong MTF (2011) Phosphorus balance efficiency and P status in crop and pasture soils with contrasting P buffer indices: scope for improvement. Plant and Soil 349:37-54.

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Evaluation of some selected forage grasses for their salt tolerance, ameliorative effect and biomass yield under salt affected soil at Southern Afar, Ethiopia

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Soil salinity is a growing problem on many irrigated parts of arid and semi-arid areas of Ethiopia. Utilization of improved salt-tolerant forage grasses help farmers to maximize production and reclaim saline soil. A study was conducted at Werer Agricultural Research Center (WARC) from 2012 to 2014 to evaluate performance of four forage grass species of salinity tolerance, ameliorative effect and biomass production. The result showed that dry matter yield obtained under saline soil was higher in *Cinchrus ciliaris* (37 ton/ha/year) followed by *Chloris gayana* (36 ton/ha/year), while the smallest was recorded from *Sorghum sudanese* (27 ton/ha/year). After exposing for salt stress, *C. gayana* and *C. ciliaris* dry matter production relative to normal soil only decrease by 15 and 9%, respectively. While, *Panicum antidotale* and *S. sudanese* dry matter reduction was Severe, by 53 and 45%, respectively. Reduction in electrical conductivity (ECe) varied between 52.60 and 74.81% in the upper 0 to 30 cm soil layer and 54.76 to 79.63% in the lower 30 to 60 cm. The highest reduction percentage of salinity under surface (74.81%) and sub-surface (79.63%) layer soil occurred under *C. gayana* grass. *C. ciliaris*, *P. antidotale* and *S. sudanese* cause the reduction at surface soil layer ECe by 70.55, 66.42 and 54.76%, respectively. The same trend was observed for reduction of ESP and pHe as a result of growing of grass species. Generally, *C. gayana* and *C. ciliaris* have excellent potential for its high salinity stress tolerance, biomass production and ameliorative effect on soil properties.

Key words: Salinity, amelioration, forage grasses, biomass yield.

INTRODUCTION

Salinity is a soil degradation process that significantly reduces plant diversity and agricultural yield, land productivity and value in arid and semi-arid climate regions. High ground water, wrong irrigation practices, low irrigation water quality and topographic of the land are particularly important among the factors that cause salinization of soils (Munns and Tester, 2008; Munns, 2011). The increase in salinity in these regions is adversely affecting crop productivity and in some cases making portions of farms unprofitable or waste land (Setter et al., 2004; Farifteh et al., 2006; Rasool et al., 2007; Elgharably et al., 2010; Al-Dakheel and Hussain, 2016). In addition to this, it is estimated that salinization of irrigated lands causes annual global income loss of about US$ 12 billion (Ghassemi et al., 1995), impacting aggregate national incomes in countries affected by

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degradation of salt-affected land and saline water resources (Qureshi et al., 2017). Most large-scale irrigated farms in Ethiopia were established without preliminary soil survey, land preparation, proper structures for the delivery of irrigation water and provision of drainage facilities for the safe disposal of excess water (Heluf, 1985; Ashenafi et al., 2016). As a result, secondary salinization becomes a challenge affecting productivity of substantial areas of farms.

Regardless of the cause, the salinity problem appears to be increasing and farmers must learn to effectively manage salinity to remain profitable. Efforts to deal with soil salinity have been varied as the nature of the problem itself. Two approaches have been followed to cope with soil salinity (FAO, 1988, 1994). The first and most common approach is to modify the saline soil conditions to suit the crop plant. In this case, engineering approach of reclamation of salt affected soils requires that the soluble salts from the profile are leached and drained through a suitable system of drainage. There is however situations where farmers forced to live with soil salinity problem in which engineering approach of reclamation is impractical due to economic and technical reasons (Siyal et al., 2002; Hanay et al., 2004). The second approach is to exploit the genetic potential of plants for their adaptability to adverse soil conditions. This approach is based on the identification and intensive cultivation of salt tolerant plants. Growing of salt-tolerant plants is a sustainable approach to biological amelioration of saline wastelands (Haynes and Francis, 1993; Chang et al., 1994; Kushiev et al., 2005). Singh et al. (2002) reported that plants of economic value can be used for reclamation of saline and sodic soils. So the present situation demands biological endeavors to focus on plantation of salt tolerant plants so as to overcome the problems of salinization. Salt-affected lands can be effectively used and ameliorated through judicious use of various plant species (Chang et al., 1994; Kushiev et al., 2005).

Growing of salt-tolerant plants is a sustainable approach to biological amelioration of saline wastelands through bio-drainage for small holder farmers (Hanay et al., 2004). Utilization of improved salt-tolerant forage grass is one new tool that will help farmers maximize production on saline soils and achieve that goal. Beside the identified salt tolerant, forage grass species and uses for bioremediation is very useful as it requires low initial investments, improves the soil quality and the produced crops can be used as an animal feed lots. The aim of this study was to appraise some selected forage grasses for their salt tolerance, ameliorative effect and biomass yield under salt affected soils.

MATERIALS AND METHODS

Characteristics of the study site

The experiment was conducted at Werer Agricultural Research Center is located at 278 km to the east of Addis Ababa at an altitude of 740 masl and located at 9°12’8”N latitude and 40°15’21” E longitude. The topography of the study area reflects the recent geomorphic history of the Middle Awash Valley, through which deposits from the Awash River formed on extensive alluvial plain (AVA, 1960). Slope gradients are generally very low and predominantly lying in the range between 1 and 2%. The predominant soil types are Vertisols and Fluvisols having alluvial origin deposited from Awash River. The soil structure is generally weekly developed. Vertisols are silty clay to clay while Fluvisols are sandy loam to silty loam in texture (Heluf, 1985; Wondimagegne and Abere, 2012). Fluvisols are constituents of muscovite/illite clay minerals and vertisols are dominated by montmorillonite clay minerals (Wondimagegne and Abere, 2012). According to the result obtained from Ashenafi and Bobe (2016), the study area is characterized by bimodal rainfall pattern. The mean annual rainfall is 571.3 mm and the mean minimum and maximum temperatures are 19.6 and 34.4°C, respectively. The mean annual free water evaporation by the Class A pan and relative humidity recorded are 2803.7 mm and 50%, respectively. The area has five times higher annual free water evaporation than annual mean rainfall, which could be one of the causes for the formation of salt affected soils and nutrient imbalance for plant growth (Ashenafi and Bobe, 2016).

Biological test for evaluation of salt tolerant forage grasses

Four improved forage grasses (*Cinchrus ciliaris, Panicum antidotale, Sorghum sudanese* and *Chloris gayana*) were evaluated for their ameliorating effect and forage yield performance; from 2012-2014 at WARC under salt affected soil condition. Treatments were laid out in randomized complete block design (RCBD) with three replications in a plot size of 70 m^2. Forage grasses were established during the month of June, 2012. Agronomic practices recommended in the area were followed. After attaining optimum harvesting time, nine cuts were made at 45 day interval till January 2014. Plant height and total fresh biomass yield of each harvest was measured and recorded. From each harvest, 300 g sample of each grass species were taken, oven dried at 65°C for 72 h, then weighted and dry matter yield estimated gravimetrically. Mean plant height, biomass yield, and also relativity reduction in plant height and biomass yield to that under normal soil condition was assessed.

Soil test

Treatment wise, soil samples were collected before planting and after last harvest of experimental period at a soil depth of 0-30 and 30-60 cm and analyzed for selected soil physico-chemical properties. Soil particle size distribution was determined by the Boycouos hydrometer method (Bouyoucos, 1962). According to Blake (1965) undisturbed soil samples were collected using core-sampler method to determine bulk density (BD). Soil reaction (pHe) and electrical conductivity (ECe) were determined from saturated paste extract following the methods described by FAO (1999). Cation exchange capacity (CEC) of the soil was determined by 1 M ammonium acetate (NH_4OAc) saturated samples at pH 7 (Van Reeuwijk, 1992). Samples were analyzed for exchangeable sodium, potassium, calcium and magnesium extracted in 1 M ammonium acetate pH 7 (Van Reeuwijk, 1992). Exchangeable sodium percentage (ESP) was computed as the percentage of exchangeable Na divided by the CEC of the soil as follows:

$$\mathrm{ESP}\ (\%) = \frac{\mathrm{Exchangeab\ le\ Sodium\ (Na)}}{\mathrm{CEC}} * 100$$

Table 1. Effect of surface bulk density as influenced by growing of forage grasses under salt affected soil condition.

Treatment	Mean Bulk density (gm/cc^{-3})			
	BP	AFH	∆ Bulk density	% Reduction
Cinchrus ciliaris	1.34	1.18	0.162	12.09
Panicum antidotale	1.33	1.19	0.145	10.90
Sorghum sudanese	1.31	1.20	0.115	8.78
Chloris gayana	1.35	1.17	0.176	13.04

BP = Before planting; AFH = after final harvesting.

Table 2. Mean values of ECe and pHe as influenced by growing of forage grasses

Grass species	Soil depth (cm)	Mean ECe (dS/m)				Mean pHe			
		BP	AFH	∆ ECe	% Reduction	BP	AFH	∆ pHe	% Reduction
Cinchrus ciliaris	0 - 30	16.06	4.73	11.33	70.55	7.8	7.6	0.2	2.6
	30 - 60	14.32	4.56	9.76	68.16	7.7	7.6	0.1	1.3
Panicum antidotale	0 - 30	12.06	4.05	8.01	66.42	7.6	7.5	0.1	1.3
	30 - 60	8.82	3.68	5.14	58.28	7.6	7.5	0.1	1.3
Sorghum sudanese	0 - 30	9.81	4.65	5.16	52.60	7.8	7.6	0.2	2.6
	30 - 60	7.67	3.47	4.20	54.76	7.8	7.6	0.2	2.6
Chloris gayana	0 - 30	18.06	4.55	18.51	74.81	8.1	7.7	0.4	4.9
	30 - 60	17.82	3.63	14.19	79.63	7.9	7.7	0.2	2.5

BP = Before planting; AFH = after final harvesting.

where concentrations are in cmol $_{(+)}$ kg^{-1} of soil.

Ameliorative effect forage grasses on soil salinity, alkalinity and bulk density characters were assessed. The field was irrigated with lowery saline and lowery sodium content in irrigation water (ECe 0.92 dS m^{-1} and ESP 2.4%).

Statistical analysis

The collected mean data was used for descriptive statistics in the form of tables, graphs and charts. Analysis of mean was performed to assess the differences in soil and agronomic parameters between each treatment using the general linear model procedure of the statistical analysis system.

RESULTS AND DISCUSSION

Initial soil physicochemical properties

Selected physicochemical properties of surface and sub-surface soils of the study site were characterized based on the analytical results of the composite soil samples collected at depth of 0-30 and 30-60 cm from experimental site before planting salt tolerant forage grasses. The results indicated that texture of the soil of the experimental site was dominated by the clay at 0-30 cm and silty clay at 30-60 cm soil depth. On the basis of particle size distribution, the soil contained sand 6.48%, silt 34.00%, and clay 59.52% at surface soil. While sub-surface, the soil contained sand 8.48%, silt 46.00%, and clay 45.52%. According to the soil textural class determination triangle, soil of the experimental site was found to be from clay at surface soil to silt clay at sub-surface soil. The surface soil bulk density of the study site ranged from 1.31 to 1.35 g cm^{-3} (Table 1).

The analytical results (Table 2) indicated that the soil reaction of the saturated paste extract of the study area at soil depths of 0-30 and 30-60 cm varied from 7.6 to 8.1 and 7.6 to 7.9, respectively. According to the rating of Jones (2003), soil reaction (pHe) from pest extracted of study area was rated from slightly alkaline to moderately alkaline. High pHe of the study area might be from excessive accumulation of exchangeable Na and $CaCO_3$ in the soil. Most of the crops get nutrient from surface soil, as a result of this soil reaction of irrigated dry land with soluble salt highly affect the solubility and availability plant nutrient in root zone.

Ameliorative effect of salt tolerant forage grasses on soil physicochemical properties

As evidenced from changes in soil ECe, pHe, ESP and

Table 3. Mean values of Exchangeable sodium percentage as influenced by growing of forage grasses

Treatment	Soil depth (cm)	Mean Exchangeable sodium percentage (%)			
		BP	AFH	∆ ESP	% Reduction
Cinchrus ciliaris	0-30	25.14	10.24	14.9	59.27
	30-60	23.15	10.38	12.77	55.16
Panicum antidotale	0-30	31.14	14.68	16.46	52.86
	30-60	28.43	16.01	12.42	43.69
Sorghum sudanese	0-30	21.14	13.08	8.06	38.13
	30-60	23.10	12.91	10.19	44.11
Chloris gayana	0-30	27.14	9.75	17.39	64.08
	30-60	28.08	8.37	19.71	70.19

BP = Before planting; AFH = after final harvesting; ESP = exchangeable sodium percentage.

bulk density attained after last harvest over initial values (before planting), remarkable improvement in soil quality indicators was observed. Reduction in ECe varied between 52.60 and 74.81% in the upper 0-30 cm soil layer and 54.76 to 79.63% in the lower 30-60 cm (Table 2). Soil salinity in all experimental plots was observed to decrease; extent of reduction varied among forage grasses treatments. Reduction in surface soil salinity was higher in *C. gayana* and *C. ciliaris* in which a decline of about 74.81 and 70.55% took place, respectively. Rhodes grass (*C. gayana*), and baffle grass (*C. ciliaris*) were reported as promising grasses for sodic soils (Maqsood and Imtiaz, 2004).

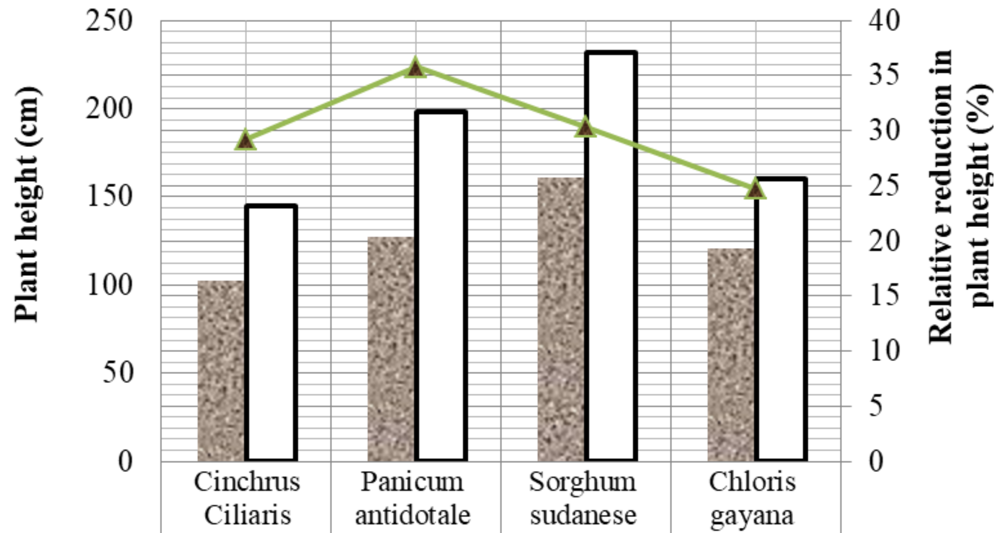
Planting of salt tolerant forage grasses markedly reduce on sodium hazard and soil reaction over the initial soil ESP and soil reaction pHe values of soil. Reduction in ESP varied between 38.13 and 64.08% in the upper 0-30 cm soil layer and 44.11 to 70.19% in the lower 30-60 cm (Table 3), whereas decline in pHe varied between 1.3 and 4.9% in the upper 0-30 cm soil layer and 1.3 to 2.6% in the lower 30-60 cm (Table 2). Though sodium hazard and soil reaction in all experimental plots was seen to decrease; extent of reduction varied among forage grasses treatments. Reduction in surface soil sodicity was higher in *C. gayana* and *C. ciliaris* in which a decline of about 64.08 and 59.27% took place, respectively. While, the higher reduction in surface soil reaction (pHe) was recorded under *C. gayana* (4.9%) and *C. ciliaris* (2.6%). These forage grasses were strongly reclaimed sodicity of soil through biodrainage as compared to other tested forage grasses species. These results agreed with those reported by Qureshi and Barrett (1998) and Maqsood and Imtiaz (2004). In general, the forage grass species is rated as a potential biotic material for soil amelioration (Kumar and Abrol, 1984; Qadir et al., 2008).

Cultivation of salt-tolerant grass helps to restore soil structure and permeability through penetration of their roots and solublization of native-soil calcium carbonate and thus enhanced leaching of salts (Qadir et al., 2007; Qadir et al., 2008). Decline in salinity due to cultivation of grass could be attributed to enhance leaching of salts from upper to lower soil layer due to improved soil physical conditions (Quirk, 2001; Qadir and Schubert, 2002). The result obtained from undisturbed soil sample showed that, the highest percent reduction in surface soil bulk density (13.04%) value was recorded under *C. gayana* grown area. Decline of bulk density might be from the cementing agent of organic matter that create aggregate to dispersed soil due to increasing soil organic matter as a result of cultivated grass species. Similar results were reported by Qadir and Schubert (2002) and Qadir et al. (2008).

Forage crop growth parameters and biomass yields

Plant height

The mean values for soil plant height of forage grass species were highly affected by salinity and sodicity of the soil. The highest plant height was recorded from *S. sudanese* grass followed by *P. antidotale* than that of *C. gayana* and *C. ciliaris* grasses species (Figure 1). However, the effect of salinity stress was less pronounced in *C. gayana* (24.72%) and *C. ciliaris* (29.22%) in which forage species plant height appeared comparable to that under normal soil condition. While relatively, the highest reduction of *P. antidotale* and *S. sudanese* in plant height was recorded at 35.78 and 30.37%, respectively (Figure 1). This could be due to salt tolerance and bio-drainage in a forage grass species; there must be sufficient genetic variation within the species in response to salt and this variation should be genetically controlled to make selection and breeding



	Cinchrus Ciliaris	Panicum antidotale	Sorghum sudanese	Chloris gayana
PH (cm) saline soil	102.74	127.10	160.85	120.54
PH (cm) Normal soil	145.15	197.92	231.85	160.13
Relative reduction in PH (%)	29.22	35.78	30.37	24.72

Figure 1. Effect of plant height forage grasses under saline soil condition.

possible for a target trait (Epstein and Norlyn, 1977; Shannon, 1978; Epstein et al., 1980). In addition to this, due to the gradual decrease in plant height with increase in salt stress, there could be an inhibitory effect of salt in shoot growth as compared to normal soil. This is in agreement with reports in intermediate spring wheat (Ashraf and McNeilly, 1988), pearl millet (Singh et al., 1999), perennial rye grass (Horst and Dunning, 1989), and sorghum (Marambe and Ando, 1995).

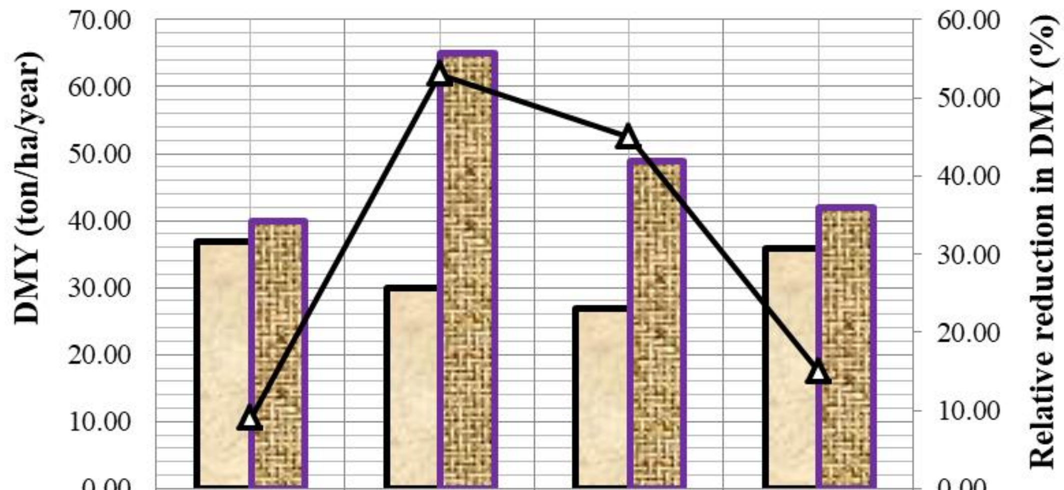
Dry matter yield

Dry matter yield of forage grasses was affected under salt affected soils as compared to normal soil. The highest dry matter yield was recorded under *C. ciliaris* (37.0 ton/ha/year) and *C. gayana* (36.0 ton/ha/year) than that of *P. antidotale* (30.0 ton/ha/year) and *S. sudanese* (27.0 ton/ha/year). The salinity and sodicity problem was highly pronounced in *S. sudanese* (45%) and *P. antidotale* (53%) in which forage species dry matter yield appeared comparable to that under normal soil condition than other tested forage grasses (Figure 2). This could be due to leaf area index and plant height of forage grasses decreased as salinity of soil increase. Decreases in leaf area index and plant height also resulted in a decrease of dry matter yields of forage grasses especially *Sorghum sudanese* and *P. antidotale* grasses. Several other researchers have also reported that a decrease in leaf area index and plant height leads to a decrease in the dry matter yields (de Luca et al., 2001; Hay and Porter, 2006; Taleisnik et al., 2009).

In saline soils, plant spends more energy for taking water, therefore water intake from the soil decreases. This situation negatively affects dry matter yield and quality of the forage grasses. In this study, performance and yield parameters according to standard soil conditions of forage grasses which have different tolerance levels for salinity and alkalinity were compared. However, this may be explained by genetic differences by which each plant demonstrates different characteristics in taking nutritional elements from soil and collecting these elements. Hence, it has also been determined in several other studies that grass yield in saline soils is declined (Masters et al., 2007; Qadir et al., 2008; Kopittke et al., 2009; Kandil et al., 2012).

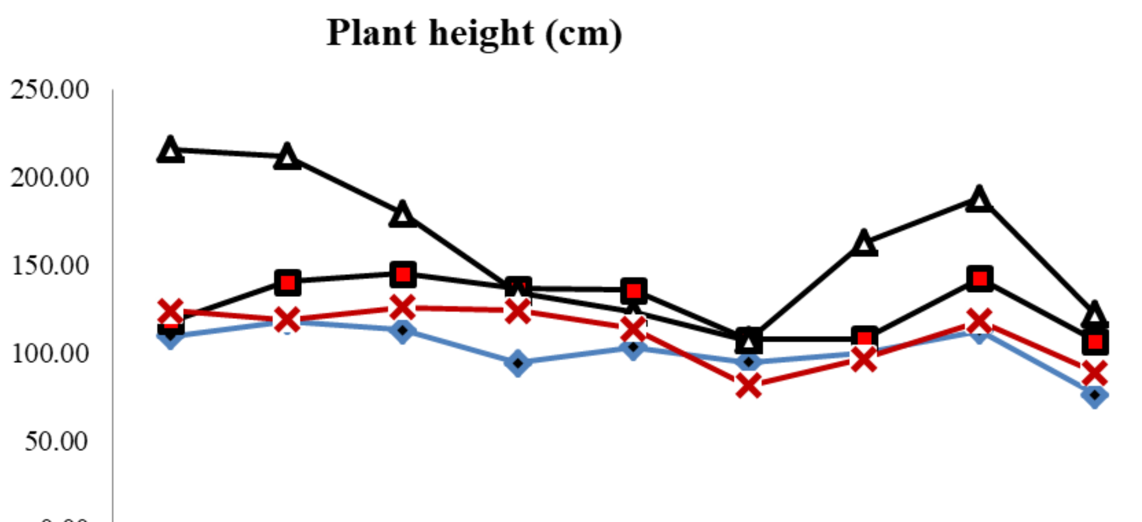
Number of cuts forage grasses on plant height and dry matter yields

Even though the decline of plant height and dry matter with cutting was not constant, the number of cutting increased, total dry matter and plant height of tested forage grass decreased. The forage grasses varied considerably in their overall tolerance to salinity and numbers of cuts have a key role for determining forage grass biomass yield and qualities (Jensen et al., 2011). Based on the result obtained from the field, the highest plant height was recorded at first cut of *S. sudanese* whereas the lowest plant height was recorded at 9th cut of *C. ciliaris* grass species (Figure 3). The consequence



	Cinchrus Ciliaris	Panicum antidotale	Sorghum sudanese	Chloris gayana
DMY (ton/ha/year) saline soil	37.00	30.00	27.00	36.00
DMY (ton/ha/year) Normal soil	40.00	65.00	49.00	42.00
Relative reduction in DMY (%)	9.00	53.00	45.00	15.00

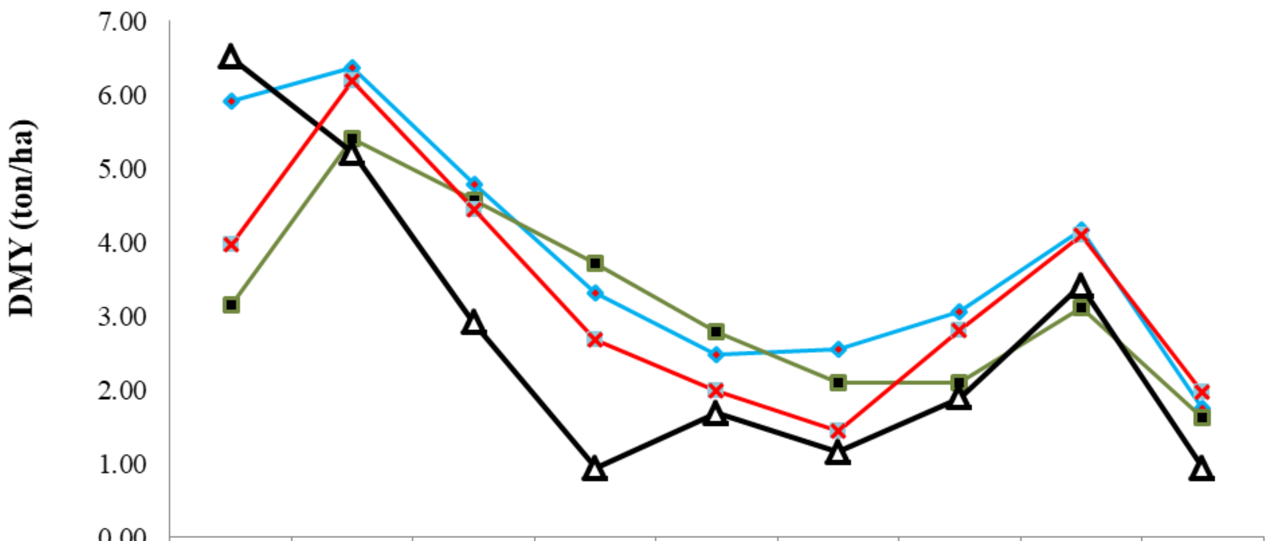
Figure 2. Mean dry matter yield (DMY) of forage grasses under saline soil condition.



	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Cinchrus ciliaris	109.73	118.33	113.53	94.80	103.60	95.00	100.20	112.80	76.67
Panicum antidotale	118.53	140.73	145.47	136.73	136.20	107.87	108.27	142.80	107.33
Sudan grass	216.13	212.13	179.67	135.00	123.60	107.67	162.83	188.27	122.33
Chloris gayana	124.20	119.13	126.27	124.47	114.33	81.80	96.80	118.53	89.33

Figure 3. The effect of plant height (PH) in different harvesting stage of forage grasses under saline soil condition.

of relative reduction of plant height within 9th cut was less pronounced *P. antidotale* follow by *Chloris gayana* grass species appeared comparable to *C. ciliaris* and *S. sudanese* grass species. This could be decrease in plant



	1st Harvesting	2nd Harvesting	3rd Harvesting	4th Harvesting	5th Harvesting	6th Harvesting	7th Harvesting	8th Harvesting	9th Harvesting
Cinchrus ciliaris	5.92	6.37	4.80	3.31	2.48	2.56	3.07	4.17	1.76
Panicum antidotale	3.15	5.40	4.58	3.72	2.80	2.10	2.10	3.12	1.62
Sudan grass	6.51	5.21	2.92	0.94	1.68	1.16	1.89	3.41	0.94
Chloris gayana	3.98	6.19	4.45	2.68	2.00	1.44	2.80	4.10	1.97

Figure 4. The effect of dry matter yield (DMY) in different harvesting stage of forage grasses under saline soil condition.

height as increase number of forage grass cuts for longer periods of physiological growth with reduced defoliation frequency stimulating stem growth at the expense of leaf production. These results are in line with the results of Qadir et al. (2008) and Xie et al. (2012).

Results indicated that investigated dry matter yield of forage grass were influenced by numbers of cuts. The highest dry matter yield was recorded at first cut of *S. sudanese* grass species, whereas the lowest dry matter yield in percentage was recorded at 9th cut of *S. sudanese* grass species (Figure 4). Dry matter yield of *S. sudanese* grass specie was highly affected as number of cuts increase under saline soil condition as compared to other tested forage grass species. The relative reduction trend of dry matter yield in forage grass species showed that as increase numbers of cuts were highly pronounced in *S. sudanese* follow by *P. antidotale* and *C. gayana* grass species appeared comparable to *C. ciliaris* grass species. The decrease in dry matter yield with increase in the number of cuts agrees with the reports of Smart et al. (2004) and Tessema et al. (2010) that dry matter yield with decrease in defoliation frequency.

In general, the forage grasses varied dramatically in dry matter biomass accumulation potential under different number of cuts. *C. ciliaris* and *C. gayana* grasses species are the most salt tolerant forage grass species and also a number of forage biomass was harvested in long period of time with more biomass at the higher salinity. This suggests that the actual forage species preference in saline drainage water reuse systems will be dependent upon the salinity of the water being reused, as well as management practices that affect salinity in the crop root zone. The same result was reported by Robinson et al. (2004) for salt tolerant forage species of California.

CONCLUSION AND RECOMMENDATION

Biological reclamation of salt affected soil is more important from stabilization of soil quality and eco-restoration points of view. Under all treatments, the soil maintained improvement in soil salinity, alkalinity and bulk density characters. Result clearly indicates the possibility of reclamation of salt affected soils through cultivating salt tolerant forage grass while obtaining reasonable forage yield. Both biomass and dry matter yield parameters of forage grass species tested were reasonably high enough and closely comparable to that under normal soil condition. Outcome obtained so far clearly indicates salinity tolerance and ameliorative effect of these forage grass species under saline soil condition while providing promising economic return as a feed source. Among tested grass species *C. gayana* has shown high salinity stress tolerance and remarkable biomass production under saline soil. Under medium saline soil condition, *C. ciliaris* also performed with regard to salinity tolerance and biomass yield. Both *C. gayana* and *C. ciliaris* could be a candidate in grass forage production system under such marginal environment. These alternative crops, in addition to their tolerance to salinity and ameliorative effect, require less input to produce and have uses as forage production, which make them promising candidates for the diversification of production system and economic use of marginal quality soil and water resources. Cultivating these forage crop in salt affected soil of pastoral and agro-pastoral area of Afar region, their use is many fold.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Al-Dakheel AJ, Hussain IM (2016). Genotypic Variation for Salinity Tolerance in Cenchrus ciliaris L. Frontiers in Plant Science 7:1090. doi:10.3389/fpls.2016.01090.

Ashenafi W, Bobe B (2016). Studies on Soil Physical Properties of Salt Affected Soil in Amibara Area, Central Rift Valley of Ethiopia. International Journal of Agricultural Sciences and Natural Resources 3(2):8-17.

Ashenafi W, Bobe B. Muktar M. (2016). Assessment on the Status of Some Micronutrients of Salt Affected Soils in Rift Valley of Ethiopia. Acadimic Journal. Agricultural Research 4(8):534-542.

Ashraf M, McNeilly T (1988). Variability in salt tolerance of nine spring wheat cultivars. Journal of Agronomy and Crop Science 160:14-21.

Awash Valley Authority (AVA) (1960). Technical Report of Awash valley authority report, Werer, Ethiopia.

Blake CA (1965). Methods of soil analysis. Part I, American Society of Agronomy. Madison, Wisconsin, USA.

Bouyoucos GJ (1962). Hydrometer method improved for making particle size analysis of soil. Agronomy Journal 54:464-465.

Chang MA, Mirbahar MB, Marri MK (1994). Comparative value of organic, inorganic and biological method in reclaiming saline-sodic soils under tile drainage system. Journal of Drainage and Reclamation 6:36-40.

de Luca M, Garcia SL, Grunberg K, Salgado M, Corrdoba A, Luna C, Ortega L, Rodriguez A, Castagnora A, Taleisnik E (2001). Physiological causes for decreased productivity under high salinity in Boma, a tetraploid Chloris gayana cultivar. Australian Journal of Agricultural Research 52(9):903-910.

Elgharably A, Marschner P, Rengasamy P (2010). Wheat growth in a saline sandy loam soil as affected by N form and application rate. Journal of Plant and Soil 328:303-312.

Epstein E, Norlyn JD (1977). Sea-water based crop production: A feasibility study. Science 197:249-251.

Epstein E, Rush DW, Kingsbury RW, Kellery DB, Cunningham GA Worna AF (1980). Saline culture of crops: A genetic approach. Science 210:399-404.

Food and Agriculture Organization (FAO) (1988). Salt Affected Soils and Their Management. Soil Resources, Management and Conservation Service FAO Land and Water Development Division. FAO Soils Bulletin 39, Rome, Italy.

Food and Agriculture Organization (FAO) (1994). Water quality for agriculture. FAO Irrigation and drainage paper 29 rev. Reprinted 1989, 1994. Rome, Italy

Food and Agriculture Organization (FAO) (1999). Soil Salinity Assessment: Methods and Interpretation of Electrical Conductivity Measurements. FAO Irrigation and Drainage Paper 57, Rome, Italy.

Farifteh J, Farshad A, George RJ (2006). Assessing salt-affected soils using remote sensing, solute modeling and Geophysics. Geoderma 30(2):191-206.

Ghassemi F, Jakeman AJ, Nix HA (1995). Salinisation of Land and Water Resources: Human Causes, Extent, Management and Case Studies. CABI Publishing: Wallingford.

Guney K, Cetin M, Guney KB, Melekoglu A (2017). The Effects of Some Hormone Applications on *Lilium martagon* L. Germination and Morpholgical Characters. Polish Journal of Environmental Studies 26(6):2533-2538. DOI: 10.15244/pjoes/70895

Guney K, Cetin M, Sevik H, Guney KB (2016). Chapter 4: Effects of Some Hormone Applications on Germination and Morphological Characters of Endangered Plant Species *Lilium artvinense* L. Seeds. “New Challenges in Seed Biology - Basic and Translational Research Driving Seed Technology”. Intech Open, Eds: Araújo Susana, Balestrazzi Alma 4:97-112, ISBN:978-953-51-2659-1.

Guney K, Cetin M, Sevik H, Guney KB (2016). Influence of germination percentage and morphological properties of some hormones practice on Lilium martagon L. seeds. Oxidation Communications 39(1):466-474.

Hanay A, Buyuksonmez F, Kiziloglu FM, Canpolat MY (2004). Reclamation of saline-sodic soils with gypsum and msw compost. Compost Science & Utilization 12 (2):175-179.

Hay R, Porter J (2006). The physiology of crop yield. Blackwell Publishing, Singapore.

Haynes RJ, Francis GS (1993). Changes in Microbial Biomass C, Soil Carbohydrate Composition and Aggregate Stability Induced by Growth of Selected Crop and Forage Species under Field Conditions. Journal of Soil Science 44:665-675.

Heluf G (1985). Investigation on Salt-affected Soils and Irrigation Water Quality in Melka Sadi-Amibara Plain, Rift Valley Zone of Ethiopia. MSc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Horst GL, Dunning NB (1989). Germination and seedling growth of perennial ryegrasses in soluble salts. Journal of the American Society for Horticultural Science 114(2):338-342.

Jensen E, Farrar K, Thomas-Jones S, Hastings A, Donnison I, Clifton-Brown J (2011) Characterization of flowering time diversity in Miscanthus species. Global Change Biology Bioenerg 3:387-400.

Jones JB (2003). Agronomic Hand Book: management of crops, soils and their fertility. CRC Press, Washington.

Kandil AA, Sharif AE, Abido WAE, İbrahim MM (2012). Effect of salinity on seed germination and seedling characters of some forage sorghum cultivars. International Journal of Agriculture Sciences 4(7):306-311

Kaya E, Agca M, Adiguzel F, Cetin M (2018). Spatial data analysis with R programming for environment. Human and Ecological Risk Assessment: An International Journal. https://doi.org/10.1080/10807039.2018.1470896

Kopittke PM, Kopittke RA, Menzies NW (2009). Measurement and interpretation of salinity tolerance in four perennial grasses. Journal of Plant Nutrition 32:30-43.

Kumar A, Abrol IP (1984). Studies on the reclaiming effect of Karnal-grass and para-grass grown in a highly sodic soil. Indian Journal of Agricultural Sciences 54:189193.

Kushiev H, Noble AD, Abdullaev I, Toshbekov U (2005). Remediation of Abandoned Saline Soils Using Glycyrrhiza glabra: A Study from the Hungry Steppes of Central Asia. International Journal of Agricultural Sustainability 3(2):102-113.

Maqsood A, Imtiaz Q (2004). Rehabilitation and Productive Use of Salt-Affected Land through Afforestation. Rangeland Research Programme, NARC, Islamabad. Quarterly science vision 9:1-2.

Masters DG, Benesand SE, Norman HC (2007). Biosaline Agriculture for Forage and Livestock Production. Agriculture, Ecosystems & Environment 119:234-248.

Munns R, Tester M (2008). Mechanisms of salinity tolerance. Annual Review of Plant Biology 59:651-681.

Munns R (2011). Plant adaptations to salt and water stress: differences and commonalities. Advances in Botanical Research 57:1-32.

Qadir I, Khan ZH, Majeed A, Yaqoob S, Khan RA Anjum K (2008). Effect of salinity on forage production of range grassesPakistan journal of science 60(1-2):59-63.

Qadir M, Schubert S (2002). Degradation processes and nutrient constraints in sodic soils. Land Degradation and Development 13:275-294.

Qadir M, Sharma BR, Bruggeman A, Choukr-Allah R, Karajeh F (2007). Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries.

Agricultural Water Management 87:2-22.

Quirk JP (2001). The significance of the threshold and turbidity concentrations in relation to sodicity and microstructure. Australian Journal of Soil Research 39:1185-1217.

Qureshi AS (2017). Sustainable use of marginal lands to improve food security in the United Arab Emirates. Journal of Experimental Biology and Agricultural Sciences 5:(Spl-1-SAFSAW). DOI: http://dx.doi.org/10.18006/2017.5(Spl-1-SAFSAW).S41.S49

Qureshi RH, Barrett-Lennard EG (1998). Saline Agriculture for Irrigated Land in Pakistan: A handbook, ACIAR Monograph No. 50, Australian Centre for International Agricultural Research, Canberra, Pp: 142.

Rasool R, Kukal SS, Hira GS (2007). Soil physical fertility and crop performance as affected by long term application of FYM and inorganic fertilizers in rice-wheat system. Journal of Soil and Tillage Research 96(1-2):64-72.

Robinson PH, Grattan SR Getachew G, Grieve CM, Poss JA, Suarez DL, Benes SE (2004). Biomass accumulation and potential nutritive value of some forages irrigated with saline-sodic drainage water. Animal Feed Science and Technology 111:175-189.

Setter TL, Waters I, Khabaz-Saberi H, McDonald G, Biddulph B (2004). Screening for water logging tolerance of crop plants pp. 20-24. In‘8th Conference of the International Society for Plant Anaerobiosis, 20–24 September 2004. International Society for Plant Anaerobiosis. Perth, WA.

Sevik H, Cetin M (2015). Effects of water stress on seed germination for select landscape plants. Polish Journal of Environmental Studies 24(2):689-693.

Sevik H, Cetin M, Kapucu O, Aricak B, Canturk U (2017). Effects of light on morphologic and stomatal characteristics of Turkish Fir needles (Abies nordmanniana subsp. bornmulleriana mattf.). Fresenius Environmental Bulletin 26(11):6579-6587.

Shannon MC (1978). Testing salt tolerance variability among long wheatgrass lines. Agronomy Journal 70:719-722.

Singh B, Tarawali S, Gupta S, Tabo R, Nokoe S, Odion E (1999). Farmer participatory evaluation of improved strip intercropping system in Northern Nigeria. Agronomy Abstracts, Annual Meeting P 37.

Singh YP, Tomar OS, Minhas PS, Sharma VK, Gupta RK (2002). Performance of 32 tree species and soil conditions in a plantation established with saline irrigation. Forest Ecology and Management 177:333-346.

Siyal AA, Siyal AG, Abro ZA (2002). Salt Affected Soils Their Identification and Reclamation. Pakistan Journal of Applied Science 2(5):537-540.

Smart AJ, Schacht WH, Moser LE, Volesky JD (2004). Prediction of leaf/stem ratio using near-infrared reflectance spectroscopy (NIRS). Agronomy Journal 96(1):316-318.

Taleisnik E, Rodríguez AA, Bustos D, Erdei L, Ortega L, Senn ME (2009). Leaf expansion in grasses under salt stress. Journal of Plant Physiology 166:1122-1140.

Tessema ZK, Mihret J, Solomon M (2010). Effect of defo liation frequency and cutting height on growth, dry-matter yield and nutritive value of Napier grass (Pennisetum purpureum (L.) Schumach). Grass and Forage Science 65:421-430. DOI: 10.1111/j.1365-2494.2010.00761.x

Van Reeuwijk LP (1992). Procedures for soil analysis (3rd Ed.). International Soil Reference Center, Wageningen, Netherlands.

Wondimagegne C, Abere M (2012). Selected Physical and Chemical Characteristics of Soils of the Middle Awash Irrigated Farm. Ethiopia Journal of Agriculture Science 22:127-142.

Xie T, Su P, Shan L, Ma J (2012). Yield, quality and irrigation water use efficiency of sweet sorghum [Sorghum bicolor (Linn.) Moench] under different land types in arid regions. Australian Journal of Crop Science 6:10-16.

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Review

Impacts of soil and water conservation on crop yield, soil properties, water resources, and carbon sequestration: A review

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This paper reviews the impact of soil and water conservation (SWC) measures on crop yield, soil properties, water resources and carbon sequestration. Land degradation due to soil erosion in Ethiopia is too severe which affects the livelihood of a community and ecosystem functions. The dry and highland part of the country was identified as seriously vulnerable to land degradation because of soil erosion. And, soil erosion can be limited with proper land management. Ethiopia started construction of SWC on cultivated land nearly 40 years ago. However, the efficiency of structures showed mixed results that are influenced by the type of measures and the agro-ecology. The physical SWC measures in Ethiopia were most widely applied throughout the country. However, the rate of adoption was considerably low due to space competition, inhibition to farming activity, water logging, weed, and rodent problems, topdown approach, and huge maintenance requirement. Majority of studies showed that crop yield on conserved dry land was increased significantly and the economic evaluation also showed positive increment with conservation. In addition, SWC resulted in positive relationship with soil quality improvement and enhancement of water resources. Moreover, SWC measures enhanced carbon sequestration of the soil due to improvement of soil fertility status.

Key words: Carbon sequestration, crop yield, land management, soil bunds, soil erosion.

INTRODUCTION

Land degradation in the form of soil erosion and nutrient depletion threatens food security and the sustainability of agricultural production in sub-Saharan Africa (Teramaj, 2015). The severity of land degradation process makes large areas unsuitable for agricultural production because the topsoil and even part of the sub-soil in some areas haave been removed, and stones or bare rocks are exposed at the surface (Badege, 2009). Soil erosion is one facet of land degradation that affects the physical and chemical properties of soils (Yibabe et al., 2002). Loss of the soil resulting from erosion, depletion of organic matters and nutrients are much faster than they can be replaced (Hurni, 1993). The Ethiopian drylands in general (which account for 67% of the country's total land area) and the agriculture sector in particularil have been identified as vulnerable to land degradation (Belay, 2016).

Land degradation problem is manifested mainly in the form of soil erosion, gully formation, soil fertility loss and crop yield reduction (Teramaj, 2015). The excessive

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dependence of rural population on natural resources, particularly land as a means of livelihood is an underlying cause for land and other natural resources degradation (EPA, 2004). Soil degradation as a reduction of resource potential by combination of processes acting on the land, such as soil erosion by water and wind, bringing about the deterioration of physical, chemical and biological properties of soil. Soil degradation in Ethiopia can be seen as a direct result of past agricultural practices in the highlands. Those are dissected terrain; areas with slopes above 16%, the high intensity of rainfall lead to accelerated soil erosion once deforestation occurs and some of the farming practices within the highlands also encourage soil erosion (Badege, 2009).

In Ethiopia, deforestation and conversion of marginal land to agriculture has been followed by soil erosion that has caused crop production losses, which resulted in economic losses. Due to soil and nutrient loss through erosion, the country has been annually losing US$ 106 million (Anissa et al., 2011). From Ethiopia's total surface area of 112 million ha, 60 million ha is estimated to be agriculturally productive, 27 million ha is significantly eroded, 14 million ha is seriously eroded, and 2 million ha has reached the point of no return with an estimated total loss of 2 billion m^3 of topsoil per year (Getachew et al., 2016). Besides, Anissa et al. (2011) reported that Ethiopia has lost an estimate of 17% of the potential annul agricultural gross domestic product (GDP) of the country due to physical and biological soil degradation.

The Ethiopian aggregated national scale nutrient loss was 41 kg ha^{-1} $year^{-1}$ for N, 6 kg ha^{-1} $year^{-1}$ for P and 26 kg ha^{-1} $year^{-1}$ for K (Stoorvogel and Smaling, 1990). Ademola et al. (2008) estimated that Ethiopia loses over 1.5 billion tons of topsoil per year by soil erosion. Though, soil and water resource degradation advanced by natural and anthropologic activities are usually controlled by soil conservation techniques and water harvesting constructions (Hurni et al., 2016). Hence, in Ethiopia, construction of soil and water conservation (SWC) structures have been implemented on cultivated land for nearly 40 years to reduce soil loss, improve crop yields and enhance people's livelihoods in the country (Asnake et al., 2018). This review stands with the objective of compiling and summarizing literatures on impacts of SWC measures on improving crop yield, soil property, water holding and carbon sequestration as well as interpreting and discussing the results and making available for development workers and scientific community.

HISTORY OF SOIL WATER CONSERVATION IN ETHIOPIA

Soil and Water Conservation in Ethiopia has a long history (Ciampalinia et al., 2012). In Aksum area, northern Ethiopia, SWC measures have been applied for centuries and most likely first implemented during the Aksumite Kingdom (400 BC to 800 AD) (Haregeweyn et al., 2015). The traditional terraces in Konso constitute a spectacular example of a living cultural tradition stretching back to more than 400 years (Beshah, 2003). Virgo and Munro (1977) reported that terracing was developed under traditional agriculture in Tigray and Chercher Highlands. And, scattered contributions have been made on bench terracing for khat (*Catha edulis*).

However, institutionalized SWC activities in Ethiopia were very localized and insignificant before the mid-1970s. The most widely applied interventions include the use of soil or stone bunds that have walls 0.3 to 1.2 m high and also include trenches and/or agroforestry in croplands and on slopes (Taye et al., 2015) and area exclosures on steep slopes in which natural vegetation is protected from humans and livestock, which are enhanced with planting of tree seedlings, stone bunding and check dams in gullies (Frankl et al., 2013).

To address land degradation and loss of soils in Ethiopia, extensive conservation schemes were launched by governments and development agencies, particularly after the famines of 1970s. Since then huge areas have been covered with different SWC measures and millions of trees seedlings have been planted to improve environmental conditions and ensure sustainable and increased agricultural production. However, the rate of adoption of the interventions is considerably low due to space occupied by SWC structures, impediment to traditional farming activity, water logging problems, weed, and rodent problems and huge maintenance requirements are some of the reasons that cause farmers refrain from implementing SWC measures. In addition, topdown approach in the extension activity, focusing mainly on structural SWC technologies and land security issues contribute much to the failure of SWC works (Vancampenhout et al., 2006).

The history of SWC activities in Ethiopia was very restricted and insignificant before the mid- 1970s. However, the ministry of agriculture after critical observation of the problem of soil erosion in different part of the country, the ministry had established SWC division that can support regions in implementing land management practices (MOA, 2006). The major difficulties in the highlands of the North and Eastern part of the country were erosion on steep slopes and poor drainage which collect water (Yeshambel, 2013). The 1973/1974 drought drew attention of people, government and outside agencies to the soil erosion problem. It was recognized that soil erosion and other degradation due to bad land use and an increasing human and animal population and ecological degradation ingeneral contributed to a large extent to the famine disaster (Hurni, 1993). As a result of these facts, SWC soon became a priority of Ethiopian government and its activities institutionalized in the Ministry of Agriculture (Yeshambel, 2013).

From a policy point of view, even though there was lack of conducive policy that promotes sound environmental management practices and technology adoptions, the 1974 Land Reform Proclamation and the subsequent formation of Peasant Associations demarcated the area of responsibilities and provided the means of mobilizing resources for large-scale conservation activities (Yeshambel, 2013). The Ethiopian Government was highly dedicated in mobilizing multiple foreign co-operations to design and implement SWC programmes. This marked the first step of Ethiopian embarkment on massive SWC which began in the mid-1970s. However, emphasis was given to mechanical measures and tree planting (Yeshambel, 2013).

Since the beginning of the 1990s, Ethiopian SWC tactic was watershed management approaches that integrate SWC, intensified natural resource use, and livelihood objectives have been implemented in several micro-watersheds (Haregeweyn et al., 2012a). In Ethiopia, indigenous SWC practices are generally poorly recorded and not considered by SWC experts and policymakers (Mekuria et al., 2007).

IMPORTANCE OF SOIL AND WATER CONSERVATION MEASURES

Soil and Water Conservation is necessary for sustained productivity of land because soil erosion is prevented or reduced to a tolerable level and water is conserved for judicious utilization (Wubet et al., 2013). Sustainable production implies that agricultural practices would lead to economic gains without impairing environmental quality and the usefulness of the soil for future generation. Hence, SWC are planned to promote of proper land use, prevent soil erosion, restore the productivity of eroded land, maintain soil productivity, control of runoff, and regulate water resource through irrigation and drain and maintain environmental quality by preventing land and water pollution (Mansfield, 1979). The measures are designed to intercept and reduce runoff velocity, pond and store runoff, convey runoff at non-erosive velocities, trap sediment and nutrients, promote formation of natural terraces over time, protect the land from erosion, improve water quality, enhance biodiversity of downstream, prevent flooding, reduce sedimentation of waterways, streams and rivers, improve land productivity and provide diverse ecosystem services (Blanco and Lal, 2008).

The major mechanical measures include construction of bunds, check dams, micro-basins and hillside terraces. Whereas, biological measures include enclosure of degraded land from human and animal interferences, planting of tree seedlings on farmlands (agro-forestry), afforestation, and tree plantations around the homesteads and tree plantation in exclosures as enrichment to the natural regeneration (Mekuria et al., 2011). The intention of the interventions was to reduce soil erosion, restore soil fertility, rehabilitate degraded lands, improve micro-climate, improve agricultural production and productivity and restore environmental condition (Vancampenhout et al., 2006; Mekuria et al., 2007; Bewket and Teferi, 2009).

IMPACTS OF SOIL AND WATER CONSERVATION MEASURES ON CROP YIELD

Soil erosion-productivity relationships for tropical soils indicate a strongly curvilinear yield decline with erosion having large impacts for initial soil losses. By using the relationships for yield decline with cumulative soil loss for different levels of management, it is possible to predict yield changes over time (Stocking and Peake, 1996). The effect of soil loss on crop production varies depending upon the type and depth of the topsoil. The decline in yield with the reduction in topsoil depth can be related to A-horizon thickness. A study conducted by Stallings (1964) showed that as A-horizon thickness increased from 3.8 to 7.5 cm, there was a corresponding increment in corn yield of 728 kg ha^{-1}. The change in soils A-horizon thickness plays a significant role in changing the amount of soil moisture and nutrients that form store for the plant use (Jones and Tengberg, 2000).

Masila (2015) investigated that soil erosion and absence of soil moisture could be a major constraint in crop production in the arid and semi-arid areas and farmers overcome the challenge by using appropriate SWC technologies. Investments in SWC contribute to the intensification of agricultural system which enhance food production and alleviates poverty. Terrace technologies control soil erosion by reducing the slope of the cultivated land and this facilitates the conservation of moisture for crop use, which leads to increased crop yields (Adgo and Teshome, 2010).

Wubet et al. (2013) found that SWC measures improved land suitability that further improves the yield of major crops. They identified that the watershed was moderately and marginally suitable for the major crops such as teff, barley, wheat, and maize before SWC implemented. However, after massive SWC significant improvement on land suitability was achieved. Hence, after implementing SWC measures about half of the area has been changed to highly suitable for wheat and teff, and the remaining has been changed to moderately suitable class for barley and maize.

Byiringiro and Reardon (1996) found that farms with greater investment in soil conservation had much greater land productivity than did farms without such

Table 1. Mean grain and straw yields of wheat and bean from different soil and water conservation portion.

Soil group	Wheat		Faba bean	
	Grain	Straw	Grain	Straw
	kg/ha			
Accumulation zone of terrace	1601[a]	2825[a]	806[b]	1203[b]
Erosion zone of terrace	851[b]	1454[b]	549[b]	749[b]
Non-terraced land (upslope)	664[b]	1169[b]	537[b]	643[b]

Table 2. Soil bund age supported with different biological measure on yield.

Treatment	Grain yield (kg ha^{-1})
Control (non-conserved land)	561.25[d]
6-year-old soil bunds + lucerne tree	1284.25[c]
9-year-old soil bunds + lucerne tree	1878.75[a]
9-year-old soil bunds + vetiver	1187.50[c]
9-year-old soil bunds	1712.50[b]

investment. The study conducted by Shively (1998a) found that positive and significant impact was found on crop yield using contour hedgerows . Kaliba and Rabele (2004) found significant and positive association between wheat yield and soil conservation measures. Similarly, Mekonen and Gebreyesus (2011) found that implementing SWC measures had positive impact on grain and biomass yield and the increment of more than 25% for grain and 30% for biomass yields.

The study conducted by Mulinge (2010) revealed that the construction of terraces improved grain yield dramatically; the yield is the highest in maize production where it was more than double when the crop is grown on terraced farms as compared to non-terraced farms. He further mentioned that the highest increment in crop yield was realized in the upper slopes where maize yields were increased by more than 150% and beans yields increased by 200%. Yohannes (1989) also compared barley crop and biomass yields above the bund (soil accumulation area) and below the bund (soil loss area) of fanya juu terraces in the Andit Tid area of northern Shoa. The average barley yield was 1650 kg ha^{-1} $year^{-1}$ above the bund, which was 43% higher than below the bund. The yields of maize were found to be higher in the soil accumulation zone (above bunds) than in the soil loss zone (below bunds). Tilahun (2006) also estimated that the yields of wheat and Fababean grown on soil accumulation and soil erosion segments of terraces and on un-terraced (upslope) areas in Degua Tembien area and their findings indicated that the yields were the highest at the accumulation zone of the terraces as shown in Table 1.

Tadele and Yihenew (2015)) indicated that Barley grain yields were higher in plots that were treated with soil bunds or soil bunds supported with biological measures such as lucerne tree and vetiver grass (*Vetiveria zizanioides*) compared with the untreated plots as indicated in Table 2. In this study, they concluded that the age of bund and the presence of lucerne tree have significant difference on yield of Barely yield.

However, Herweg (1993) found that fanya juu, soil/stone bund, and grass strips did not increase crop yield and biomass production in the highlands of Ethiopia and Eritrea. They justified that unless productivity was increased by increasing fodder grass production on bunds, SWC measures could not be characterized as a “win-win” measure to reduce soil erosion. Masila et al. (2015) studied the influence of SWC on household food security among small-scale farmers in Keniya and they found that it is insignificant at 5% level of significance. From the study they concluded that SWC technologies alone do not necessarily influence household food security positively. Because frequent and prolonged rainfall failures and poor agronomic practices are some of the important factors that deny farmers the full benefits of SWC technologies. In addition, Kassie and Holden (2005) found that physical soil conservation measures resulted in lower yield in a high-rainfall area of Ethiopian highlands, compared to plots without conservation measures.

Many researchers justified that physical SWC structures consume productive farmland area. The yield variation due to the implementation of SWC measures showed negative during the initial stage, because there is a significant land loss of about 10-15% for soil bund construction and 8% for stone bunds. However, the size of farmland lost due to construction of physical SWC structures depends on the slope of the area. And this sizeable land loss has been resulted in

Table 3. Economic advantages of terraces for different crops.

Crop/Treatment	Revenue US$ ha^{-1}	Expenses US$ ha^{-1}	Net profit US$ ha^{-1}
Teff			
Terraced	292.6	271.7	20.9
Un-terraced	144.1	256.3	-112.2
Barley			
Terraced	382.3	197.1	185.2
Un-terraced	98.5	139.6	-41.1
Maize			
Terraced	245.7	280.2	-34.5
Un-terraced	102.2	203.0	-100.8

yield reduction unless the lands occupied by the structures are used for production purposes (Vancampenhout et al., 2006).

The role played by SWC structures in improving crop yield was due to reduction of runoff and soil loss, as perceived by 27.6 and 54.0% in the upper and lower watershed, respectively. The combination of reduced runoff and soil loss and water retention ability were perceived to improve crop yield by 72.4 and 46.0% of respondents in the upper and lower watershed, respectively (Kebede et al., 2013). Conservation measures can reduce yield variability in at least two ways. First, conservation can improve moisture retention during low-rainfall periods and thereby reduce moisture stress and enhance plant growth. Second, conservation technology can mitigate the consequences of flooding and thus can reduce associated crop damage and topsoil loss during high-rainfall periods. Pender and Gebremedhin (2006) found that higher crop yields from plots with stone terraces with an average yield increment of 23% and estimated the average rate of return to stone terrace investment to be 46%.

ECONOMIC IMPORTANCE OF SOIL AND WATER CONSERVATION

Farmers obviously need economic evaluations of proposed conservation measures as a basis for selecting the measures and types of programs that represent profitable investments for them. They need to know not only the character of the program to apply but also the most profitable intensity with which to apply (Wagayehu, 2003). According to Holden et al. (2005), structural technologies (graded bund and *fanya juu* terraces) have very low payoffs. Hence, they do not seem to offer poor farmers sufficient economic incentives to pay for the necessary investments. However, investment in grass strips appeared promising (yielding a positive net present value). On the contrary, Wubet et al. (2013) conducted a study at Anjeni watershed in different years and found that the economic benefits of SWC for the major crops of watershed is promising as indicated in Table 3.

Based on experimental evidence collected in the semi-arid central Tigray, estimated that stone terraces yielded up to 50% rate of return (Gebremedhin et al., 1999). The econometric analyses of household survey data suggest that the economic returns to SWC investments are greater in lower rainfall areas than in higher rainfall areas. In addition,; Bakker et al. (2005) investigated that in low rainfall area of eastern Ethiopia, level bunds had a clear dominance over the no conservation condition. Kassie and Holden (2005) also used cross-sectional farm-level data from a high rainfall which showed that yield distributions without conservation unambiguously dominated yield distributions with conservation (graded fanya juu) for all yield levels. According to Adgo and Teshome (2010) report, implementation of SWC had long-term economic benefits to smallholder farmers.

Food security can be increased through improved land use and land management practices (Asefa et al., 2003). Holden et al., (2005) in their findings specified that, except for low-cost technologies like grass strip, returns to soil conservation investments were too low. Negative net present value (NPV) values for bench terraces were observed in Peru when crop yield data were actually measured and profitability was lower than farmers' estimation (Posthumus and Graaff, 2005). The yield cumulative distribution with conservation is to the left of the without- conservation yield distribution for Tigray region indicating that yield with conservation first order stochastically dominated the yield distribution without conservation. The results implied that the chance of getting higher yield is higher for plots with conservation than plots without conservation, given the same probability.

Kassie and Holden (2005) estimated that the existence of a positive additional significant yield premium of Ethiopian Birr (ETB) 412 (US$ 59) and ETB 299 (US$ 47) per ha for conserved and non-conserved plots, respectively in low rainfall area. However, in the high rainfall area of Tigray region treated with stone bunds, the estimated total benefit would have been about ETB 52 million (US$ 7 million) and ETB 38 million (US$ 6 million) per ha for conserved and non-conserved plots, respectively. In their study they concluded that stone bunds have a positive and statistically significant impact on productivity in low rainfall areas.

THE IMPACTS OF SOIL AND WATER CONSERVATION ON CARBON SEQUESTRATION

The pool of organic carbon in soils plays a key role in the carbon cycle and has a large impact on the greenhouse effect. Soils contain an estimated $1.5 \times l0^{18}$ g of carbon or twice as much as the atmosphere and three times the level held in terrestrial vegetation (Post et al., 1990; Schlesinger, 1990). The annual net release of carbon from agriculture has been estimated at 0.8×10^{15} g or about 14% of current fossil fuel emissions (Schlesinger, 1995). The global carbon sequestration potential of agricultural soils amounts to 0.73 to 0.87 Pg carbon year^{-1} (Blanco and Lal, 2008). Soil O rganic Carbon (SOC) accumulation largely depends on vegetation cover. Hence, any change in land use may significantly alter related source or sink characteristics for atmospheric CO_2 and other Greenhouse Gases (GHGs) (Poeplau et al., 2011).

SOC plays an important role in maintaining and improving soil fertility and quality, as well as in mitigating climate change (Xu et al., 2015). The earth's surface soil contains large quantities of organic carbon, storing about 1462 to 1548 Pg carbon in the top 1 m depth. Therefore, small changes in the SOC pool can have a great implication for atmospheric CO_2 concentrations which later alter the climatic change (Hong et al., 2014).

Implementation of different SWC measures, especially check-dams in gully rehabilitation and bunds in steep streams improve the climate of the area as a result of increased vegetation cover. Mekonen and Gebreyesus (2011) conducted survey on impacts of soil conservation and the respondents confirmed that the hot and dry air that previously dominated the watershed has been replaced by moist and cooler air after implementation of SWC measures. This is because of increasing vegetation cover in the catchment, which is a direct reflection of the improvement of available water, improvements of soil fertility and implementation of biological SWC measures that can sequester carbon from the watershed. The reduction in erosion accomplished by introducing different kinds of production technologies that include SWC practices; these practices easily reduced the soil erosion at a rate ranging from 10 to 2 t ha^{-1} year^{-1}. The saving of at least 8 t ha^{-1} year^{-1} compared to un-conserved plot. Which resulted in 2 to 5 g kg^{-1} SOC loss, this means that the total SOC saved is at least 16 to 40 kg C ha^{-1} year^{-1} (Stroosnijder et al., 2001).

The mean SOC content of the different land use types occurred in the following order: forestland > terraced cropland > grassland > sloping cropland. The mean SOC density under the four land use types in the catchment occurred in the following order: terraces > forestland > grassland > sloping cropland. The mean SOC densities of terraces, forestland, grassland, and sloping cropland were 4.40, 4.31, 3.86, and 3.62 kg/m^2, respectively (Guoce et al., 2015). Forestland and grassland exhibit higher incorporation of aboveground biomass and higher input of belowground biomass (Pe´rez-Cruzado et al., 2012). The conversion from natural vegetation to cropland often depletes the SOC stock due to the reduced input of biomass and enhanced decomposition (Poeplau et al., 2011). Terraces are comparatively well managed agriculturally, with very low soil erosion and nutrient losses. The mean SOC content was therefore lowest in sloping cropland. Because of the relatively large bulk density of terraces, the mean SOC density in the catchment occurred in the following order: terraces > forestland > grassland > sloping cropland. This order differs from that of mean SOC content under the different land use types. Hence, the main influencing factor on SOC content was land use (Guoce et al., 2015).

THE IMPACTS OF SOIL AND WATER CONSERVATION ON SOIL PROPERTIES

Soil is a critically important natural resource. Hence, the efficient management of which is vital for economic growth and development for the production of food, fiber and other necessities. To accommodate the increasing demand for food, either production per unit area must be intensified or more land must be cultivated. Continuously cultivating the same land without appropriate and sufficient management to replenish or maintain nutrient will likely lead to soil degradation (Kebede et al., 2013).

Bunds modify land conditions by reducing slope angle and length. As a result, it influences the soil properties by changing soil erosion and deposition processes. Accordingly, there existed significant difference in soil properties with the implementation of different SWC measures. According to Weigel (1986b), the concentration of plant available phosphorus was higher in the soil accumulation zone than in the soil loss zone as indicated in Table 4).

Vagen (1996) studied soils in a topo-sequence of terraced (down- and mid-slope) and non-terraced land

Table 4. The different soil property change on accumulation and loss zones of bunded area.

Soil characteristics	Topsoil (0 - 25 cm)		Subsoil (25 - 50 cm)	
	Accumulation zone	Loss zone	Accumulation zone	Loss zone
Organic matter (%)	4.16	3.44	4.13	2.72
Total nitrogen (%)	0.17	0.15	0.20	0.14
Extractable P (mg/kg)	11.89	8.19	8.02	5.69
Exchangeable K (cmol/kg)	0.86	1.12	0.46	0.89
Clay content (%)	42	49	48	56

Table 5. Comparison between means and mean differences of sand, silt and clay contents of un-conserved with conserved plots

Treatments mean	Sand (%)		Silt (%)		Clay (%)	
	Mean	Differences	Mean	Differences	Mean	Differences
Control	17.42[c]	-	23.74[b]	-	58.84[a]	-
3-year soil bund + *Pennisetum pedicellatum*	27.19[b]	9.77*	22.23[b]	1.51	50.59[b]	8.25*
6-year soil bund + *Pennisetum pedicellatum*	30.35[a]	12.93*	36.98[a]	13.24*	32.66[c]	26.18*
6-year soil bund alone	28.73[ab]	11.31*	36.37[a]	12.63*	34.90[c]	23.94*
LSD (0.05)	2.963	3.225	4.453	-	4.453	-
CV (%)	8.92	7.85	7.30	-	7.30	-

Table 6. Extractable phosphorus in the soil from different parts of terraces under bean and wheat cultivation

Location	Extractable phosphorus		
	Bean	Wheat	Average
		mg/kg	
Bench of terrace	12.07[b]	16.07[a]	14.07[a]
Soil loss zone of terrace	10.31[b]	10.39[b]	10.35[b]
Non-terraced (up-slope)	11.16[b]	10.22[b]	10.69[ab]

up-slope in the Hagere Selam uplands in Tigray. Surface soils from terrace benches and the soil loss zone of terraces had the highest clay contents, while soils from non- terraced land were more sandy. Non-terraced areas which were located only on the concave upper part of the slopes had been cleared much later than the terraced areas, leaving less time for depletion of organic matter and consequently nitrogen. Teramaj (2015) reported that SWC affects soil physico-chemical properties. Hence, un-conserved plot of the cropland had the highest mean percent (58.84%) clay content and the lowest mean percent (17.42%) sand, which were significantly ($p \leq 0.05$) different from other treatments handled through different SWC measures.

Generally, relative to the non-conserved treatment, the 3-years old soil bund stabilized with desho, 6-year old soil bund alone, and 6-year old soil bund stabilized with desho had 8.25, 23.94 and 26.18% lower percent of clay fractions, respectively (Table 5).

Soils from terraced benches had higher concentrations of available P than soils from the loss zone of terraces and from non-terraced land. Phosphorus is normally strongly bonded to soil particle and therefore easily transported downslope during erosion, giving higher concentrations of available P in the soil accumulation zone of terraces. As indicated in Table 6 below, higher extractable P is found in terraced plot than un-terraced up-slope. Furthermore more time will probably lead to greater differences in available P between soil groups due to prolonged erosion, particularly between non-terraced land and soil accumulation zones on terraces (Tadele et al., 2011)

The implementation of SWC measures affects soil bulk density, the relatively lower bulk density associated with treatments conserved with various measures could be attributed to the presence of significantly ($p \leq 0.05$) higher organic matter content in those treatments (Teramaj, 2015). Bulk density can also be changed by

Table 7. Mean soil organic carbon content under terraced and unterraced cropland.

Depth (cm)	Terraced		Un terraced	
	SOC (g/kg)	Bulk density (g/cm^3)	SOC (g/kg)	Bulk density (g/cm^3)
0-20	6.46	1.45	6.07	1.31
20-40	4.21	1.58	3.87	1.55
40-60	3.23	1.61	2.87	1.59

management practices that affect soil cover, organic matter, soil structure, compaction, and porosity (Tadele et al., 2011). Wadera (2013) found that relatively higher (1.5 g/cm^3) average bulk density on un-bunded farmland compared to average bulk density (1.38 g/cm^3) for the bunded farm plots considered on average ground slopes of 3, 8 and 13% at Laelay-Maychew, Central Tigray. Tadele (2013) in his study investigated that the concentrations of divalent basic cations were higher in accumulation zone than the loss zone of the terraced watershed, which could be due to washing away of cations from the loss zone and accumulations in the deposition zone.

Mekonen and Gebreyesus (2011) in their study found that the implementation of SWC measures resulted in soil accumulation along the bunds and check dams was up to 1.5 m deep. The sediment depth varied according to land use, slope and sediment source area. For example, more than 1.5 m soil was deposited in the gullies treated with check dams integrated with biological SWC measures. On cultivated land treated with stone terrace, the sediment depth was more than 0.80 m, whereas for closed areas, the accumulation of soil reaches up to 1.2 m and in the degraded grazingland the accumulation soil was about 0.6 m high.
According to Berhe and Kleber (2013), soil erosion and deposition processes have significant effects on SOC redistribution in the terrestrial biosphere. Table 7 clearly indicated that higher SOC and soil bulk density for terraced plot than un-terraced plot. Soil Organic Carbon can be exported from watershed by soil erosion with water and sediment (Ran et al., 2014)

THE IMPACTS OF SOIL AND WATER CONSERVATION MEASURES ON WATER RESOURCE

According to Mekonen and Gebreyesus (2011) survey conducted in Medego watershed in Tigray region, they found that the impact of SWC measures such as bunds and check dams increased the availability of surface and subsurface water for traditional irrigation and other uses. They also described that water availability by rehabilitating the gullies using check dams was the main source of surface irrigation water, which was supplemented by shallow and deep groundwater wells. The respondent households confirmed that bunds and check-dams greatly increased the amount of surface water. Groundwater levels in the wells increased up to 2.5 m while irrigation area increased many times and the number of hand-dug wells also significantly increased. Newly emerging springs and irrigated fields as well as increasing crop diversity and yields were some of the indicators for the improved water resources and supply as a result of SWC measures.

Soil and water conservation measures enhance rapid recharge of the water table and development of new springs. This is because the time for infiltration has increased after installation of the stone/soil bunds and check dams, which raises the water table level. As Mekonen and Gebreyesus (2011) mentioned that farmers of the study area described that: “Ten years ago, it was difficult to get water by digging 3 to 4 m deep, but after SWC was implemented the possibility of having water at this depth is too much higher. Soil and water conservation activity done at Abba Gerima watershed, in Amhara region by Amhara Region Agricultural Research Institute (ARARI), Water and Land Resource Center (WLRC) and Office of Agriculture in collaboration. Currently, about 85% of the watershed was conserved by soil bund, area closure, gully rehabilitation, and home garden practices. The farmers confirmed that the intervention resulted in the development of about 64 hand dug wells which were previously unexpected. The research groups of WLRC study the impact of intervention SWC on hydrology between the base year (2012) and 2014. Their preliminary observations show that the dry season base flows in all streams have increased compared to the baseline situation of 2012 (WLRC, 2015).

Adgo and Teshome (2010) found that the implementation of terraces improved water productivity of the three crops by at least 100% against un-terraced plots, which clearly shows that the advantage of terracing in terms of efficient use of rainwater. Terraced barley had the highest water productivity in terms of grain yield per mm of water consumed (1.35 kg mm^{-1}) followed by maize (1.21 kg mm^{-1}) and teff (1.01 kg mm^{-1}). A study conducted by Jay et al. (2010) in May Zeg-Zeg catchment in Tigray region is positively influenced by run-off coefficient after installation of SWC measures. Most of the measures implemented in the catchment reduced the runoff by trapping overland flow, for instance in trenches behind stone bunds or in small basins behind check dams. Accordingly, the mean annual runoff and runoff coefficient were 26.5 mm and 8%, respectively before SWC implemented. However, after implementation of SWC measures, the mean annual runoff and runoff coefficient were significantly reduced to 5.1 mm and 1.6%, respectively.

Nyssen et al. (2010) in their study in north Ethiopia showed that the positive effect of catchment management by SWC is the rapid recharge of the water table from a very deep water table (due to water abstraction for irrigation) to a water table reaching the soil surface. If infiltration rate has indeed increased after installation of the stone bunds, then the water table should show a greater rise in level for the same amount of rainfall. The ratio of maximal water table rise (ΔT) over rainfall (P) for that period was calculated to allow this comparison. The years before installation of stone bunds (2002 and 2003) show an average ratio ($\Delta T/P$) of 0.38. However, after installation of stone bund (2006) the ratio increased to >0.56 which is >46% increment. When the ΔT to the water storage (WS) over that period an even larger and significant difference seen between 2002/2003 and 2006 was 3.4 and 11.1, respectively

Nyssen et al. (2009c) found that from thesis study on impacts of catchment management on the hydrology are positive. The main observed changes in hydrology are the decrease of the annual runoff coefficient by 81% (from 8% before catchment management down to 1.6% after catchment management), the rapid recharge of the groundwater table after the dry season and the prolonged water supply at springs. These changes indicated that SWC measures increase infiltration and spread runoff in time. They further identified that the reduced runoff and higher infiltration rates have a positive influence on the water balance in the catchment. Increased water availability leads to higher crop yield and crop diversity due to irrigation. Indications for an improvement of the water balance are an increased base flow and groundwater table, the development of springs in the gully channels, the establishment of cropland and rehabilitation of former vegetation cover in the gully system, and the creation of irrigated fields in the upper and lower parts of the catchment. Most commonly peak flows are leveled down but remain strong after catchment management. Generally, spring discharge and base flow of uttermost importance in semi-arid areas are on the rise after catchment management. Obviously, SWC measures increase infiltration and cause a rise in the water table and improved water availability over time (Nyssen et al., 2009c).

CONCLUSIONS AND RECOMMENDATIONS

From this review, proper land management through implementing of SWC practices played a great role in improving soil fertility, soil water holding capacity, carbon sequestration and crop yield. Most of the literatures revealed that even though SWC is the most important land management practices, farmers are regretting from implementing the mechanical structures mainly due to its space competition which leads to land loss. Besides, the implanted structures in many areas were inappropriate which immediately devastated because of technical problems. However, the structures that were appropriately implemented in many lowland areas showed significant yield increment and consequently improved economic status of the farmers. The improvement of crop yield on plots with SWC structures was due to reduction of run-off, soil loss and soil fertility enhancement. As a result of implementing SWC measures, the mean run-off and run-off coefficient were significantly reduced which later improve water productivity. Land management activities improved SOC; hence, terracing is the second practices next to afforestation in sequestering carbon which play great role in mitigating climate change. However, all SWC practices are not equally important in all agro-ecologies. Therefore, identifying appropriate technology for specific agro-ecology is the most important in implementing SWC technologies. Therefore, experts in different level should identify SWC technologies for all localities and implement accordingly. In addition, physical structures should be integrated with biological measures and other yield enhancement inputs should be supplied with SWC technologies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Ademola K, Braimoh, Paul LG (2008). Impact of land use on soil resources. Springer P 254.

Adgo E, Teshome A (2010). Effects of long-term soil and water conservation on agricultural productivity: A case study of Anjeni watershed, Ethiopia. IMAWESA Working Paper 17.

Anissa G, Shinji S, Fumio W (2011). Soil erosion assessment using USLE in East Shewa, Ethiopia. Journal of agricultural science, Tokyo University of Agriculture 56(1):1-8.

Asefa DT, Oba G, Weladji RB, Colman JE (2003). An assessment of restoration of biodiversity in degraded high mountain grazing lands in northern Ethiopia. Land Degradation and Development 14(1):25-38.

Asnake M, Andreas H, Gete T, Hurni H (2018). Factors influencing the adoption of physical SWC practices in the Ethiopian highlands. International Soil and Water Conservation Research 6:23-30.

Badege B (2009). Deforestation and land degradation in the Ethiopian highlands: a strategy for physical recovery: Ethiopian e-Journal for Research and Innovation Foresight 1:4-15.

Bakker MM, Govers G, Kosmas C, Vanacker V, Van Oost K, Rounsevell MDA (2005). Soil erosion as a driver of land-use change. Agriculture, Ecosystems and Environment 105:467-481.

Belay A (2016). Effect of soil and water conservation measures on soil macronutrient and moisture status in Guba-Lafto woreda, North Wollo, Ethiopia. MSc Thesis Submitted to the Center of Environmental Science, Addis Ababa University.

Berhe A, Kleber M (2013) Erosion, deposition and the persistence of soil organic matter: mechanistic considerations and problems with terminology. Earth Surf Process Land 38:908-912.

Beshah T (2003). Understanding farmers explaining soil and water conservation in Konso, Wolaita and Wello, Ethiopia. PhD thesis, Wageningen University Research Center ISBN 90-6754-691-7.

Bewket W, Teferi E (2009). Assessment of soil erosion hazard and prioritization for treatment at the watershed level: A case study in the Chemoga watershed, Blue Nile Basin, Ethiopia. Land Degradation and Development 20:609-622.

Bhan C (1988). Spatial analysis of potential soil erosion risks in Welo Region, Ethiopia: a geomorphological evaluation. Mountain Research and Development 8:139-144.

Blanco H, Lal R (2008). Principles of Soil Conservation and Management. Springer, New York.

Byiringiro R (1996). Farm productivity in Rwanda: effects of farm size, erosion, and soil conservation investments.

Ciampalinia R, Billi P, Ferrari G (2012) Soil erosion induced by land use changes as determined by plow marks and field evidence in the Aksum area (Ethiopia). Agriculture, Ecosystems and Environment 146:197-208.

Environmental Protection Authority (EPA) (2004). National Action Programme to Combat Desertification: Federal Democratic Republic of Ethiopia Environmental Protection Authority, Addis Ababa.

Food and Agriculture Organization (FAO) (2003). Food and agriculture for poorest countries. URL :http//blog.populationinstitute.org/2010/11/18 / fao-another-food-crisis/http : //www.fao.org/

Getache WE, Getachew F, Mulatie M, Assefa M (2016). Evaluation of technical standards of physical SWC practices and their role in soil loss reduction: The Case of Debre Mewi Watershed, North-west Ethiopia. Landscape Dynamics, Soils and Hydrological Processes in Varied Climates, Springer Geography.

Guoce Xu, Kexin Lu, Zhanbin Li, Peng Li, Tian W, Yuanyuan Y (2015). Impact of soil and water conservation on soil organic carbon content in a catchment of the middle Han River, China. Environmental Earth Sciences 74:6503-6510.

Haregeweyn N, Atsushi T, Jan N, Jean P, Mitsuru T, Tsegaye D, Adgo E, Tegegne F (2015). Soil erosion and conservation in Ethiopia: A review Progress in Physical Geography 1-25.

Haregeweyn N, Berhe A, Tsunekawa A (2012a) Integrated watershed management, an effective approach to curb land degradation: A case study of the Enabered watershed, northern Ethiopia. Journal of Environmental Management 50: 1219-1233.

Herweg K (1993). Problems of acceptance and adoption of soil conservation in Ethiopia. Tropics Applied Resource Management 3:391-411.

Holden S, Shiferaw B, Pender J (2005). Policy Analysis for Sustainable Land Management and Food Security in Ethiopia. A Bioeconomic Model with Market Imperfections. Research Report 140. International Food Policy Research Institute: Washington DC.

Hong W, Jianen G, Xinghua Li, Hongjie W, Yuanxing Z (2014). Effects of SWC Measures on Groundwater Levels and Recharge. Water 6:3783-3806;

Hurni H (1993). Land degradation, famine, and land resource scenarios in Ethiopia, Cambridge University Press, Cambridge pp. 27-62.

Hurni H, Berhe WA, Chadhokar P, Daniel D, Gete T, Zeleke Grunder M, Kassaye G (2016). Soil and water conservation in Ethiopia: Guidelines for development agents, Bern, Switzerland: Centre for Development and Environment (CDE); Bern, Open Publishing (BOP) .URI: https://boris.unibe.ch/id/eprint/80013.

Jones T, Tengberg A (2000). The impact of indigenous soil and water conservation practices on soil productivity: Examples from Kenya, Tanzania, and Uganda. Land Degradation and Development 11:19-36.

Kaliba ARM, Rabele T (2004). Impact of adopting soil conservation practices on wheat yield in Lesotho. In Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa, edited by A. Bationo. Cali, Columbia: International Center for Tropical Agriculture (CIAT), Tropical Soil Biology and Fertility Institute.

Kassie M, Holden ST (2005). Parametric and non-parametric estimation of soil conservation adoption impact on yield and yield risk." Paper presented at the 6thInternational Conference of the European Society for Ecological Economics, Lisbon, Portugal. June 14-18, 2005.

Kebede W, Awdenegest M, Fantaw Y (2013). Farmers" perception of the effects of soil and water conservation structures on crop production: The case of Bokole watershed, Southern Ethiopia. African Journal of Environmental Science and Technology 7(11):990-1000.

Kirubel Mekonen K, Tesfahunegn GB (2011). Impact assessment of soil and water conservation measures at Medego watershed in Tigray, northern Ethiopia Maejo International Journal of Science and Technology 5(03):312-330.

Mansfield JE (1979). Land capability for annual rainfed arable crops in Northern Nigeria based on Physical limitations. In Lal R, Greenland DJ (Eds.), Soil physical properties and crop production in the tropics. New York pp. 407-426.

Masila T, Maurice O, James U (2015). The influence of soil water conservation technologies on household food security among small-scale farmers in Kyuso sub-county, Kitui county, Kenya. Academia Journal of Agricultural Research 3(2):023-028.

Mekuria W, Veldkamp E, Corre MD (2011). Restoration of ecosystem carbon stocks following exclosure establishment in communal grazing lands in Tigray, Ethiopia. Forest, Range and Wildland Soils 75(1):1-11.

Mekuria W, Veldkamp E, Haile M (2007). Effectiveness of exclosures to restore degraded soils as a result of overgrazing in Tigray, Ethiopia. Journal of Arid Environments 69:270-284.

Nyssen J, Clymans W, Descheemaeker K (2010). Impact of soil and water conservation on catchment hydrological response: A case in North Ethiopia. Hydrological Processes 24(13):1880-1895.

Nyssen J, Poesen J, Deckers J (2009c). Land degradation and soil water conservation in tropical highlands. Soil and Tillage Research 103(2):197-202.

Pe´rez-Cruzado C, Mansilla-Salinero P, Rodrı´guez-Soalleiro R, Merino A (2012). Influence of tree species on carbon sequestration in afforested pastures in a humid temperate region. Plant Soil 353(1/2):333-353

Poeplau C, Don A, Vesterdal L, Leifeld J, Van Wesemael B, Schumacher J, Gensior A (2011) Temporal dynamics of soil organic carbon after landuse change in the temperate zone-carbon response functions as a model approach. Global Change Biology 17(7):2415-2427.

Post WM, Peng T, Emanuel WR, King AW, Dale VH, DeAngelis DL (1990). The global carbon cycle. American Scientist 78:310-3.26.

Posthumus H, de Graaff J (2005). Cost-benefit analysis of bench terraces: A case study in Peru. Land Degradation. Develop, 16, 1-11. http://dx.doi.org /10.1002/ldr.637

Ran LS, Lu XX, Xin ZB (2014). Erosion-induced massive organic carbon burial and carbon emission in the Yellow River basin, China. Biogeosciences 11:945-959.

Schlesinger WH (1990). Evidence from chronosequence studies for a low carbon-storage potential of soils. Nature 348:23:2-234

Schroeder P (1994). Carbon storage benefits of agroforestry systems. Agroforestry Systems 27:89-97.

Shively GE (1998a). Modeling impacts of soil conservation on productivity and yield variability: evidence from a Heteroskedastic Switching Regression. Paper presented at the American Agricultural Economics Association Annual Meeting, Salt Lake

City, Utah, August 2-5, 1998.

Stallings JH (1964). Phosphorous and water pollution. Journal of Soil and Water Conservation 22(6):228-231.

Stocking M, Peake L (1996). Crop yield losses from the erosion of Alfisols, Tropical Agriculture, Trinidad 63:41-45.

Stoorvogel S (1990). Assessment of soil nutrient depletion in sub-Saharan Africa: 1983-2000, Vol. 1. Winand Staring Centre, Wageningen

Stroosnijder L, de Ridder N, Kiepe P (2001). Nutrient balances in sahelian villages. In "Agro- Silvo-Pastoral land use in sahelian villages". Advances in GeoEcology. Catena Verlag GMBH. Ch 4.3:213-235.

Schlesinger WH (1995). An overview of the carbon cycle. pp. 25:9-25. In: R. LaL J. Kimble. E. Levine and B.A. Stewart (eds.) Soils and Global Change. Advanced Soil Science. CRC Press. Boca Raton. FL.

Tadele A, Yihenew GS, Mitku H, Yamoh C (2011). Effect of soil and water conservation measures on selected soil physical and chemical properties and barley (Hordeum spp.) yield. Journal of Environmental Science and Engineering 11:1483-1495.

Tadele A, Yihenew G (2015). Conserving soils: Evidence-based soil conservation measures that improve soil physical and chemical properties and barley yield. In: Nicol, A., Langan, S., Victor, M. and Gonsalves, J. (eds), Water-smart agriculture in East Africa. Colombo, Sri Lanka: IWMI and CGIAR research program on WLE; Kampala, Uganda: GWI EA 74:231-236.

Taye G, Poesen J, Vanmaercke M (2015). Evolution of the effectiveness of stone bunds and trenches in reducing runoff and soil loss in the semi-arid Ethiopian highlands. Zeitschrift für Geomorphologie 59(4):477-493.

Teramaj B (2015). Effect of SWC Measures on Land Productivity and Crop Yield in Mirab Abaya Woreda of Southern Nations Nationalities and People‟s Region, Ethiopia, M.Sc. Thesis Haramaya University.

Tilahun K (2006). Analysis of rainfall climate and evapo-transpiration in arid and semiarid regions of Ethiopia using data over the last half a century. Journal of Arid Environments 64(3):474-487.

Vagen TG (1996). Phosphorus status in soils from terraced and un-terraced land on highly eroded slopes in Tigray, Ethiopia. Master's thesis, Agricultural University of Norway, Norway.

Vancampenhout K, Jan N, Desta G, Jozef D, Jean P, Mitiku H, Jan (2006). Stone bunds for soil conservation in the northern Ethiopian highlands: Impacts on soil fertility and crop yield, Soil and Tillage Research 90:1-15.

Virgo KJ, Munro RN (1977). Soil and erosion features of the central plateau region of Tigrai, Ethiopia. Geoderma 20:131-157.

Wagayehu B (2003). Economics of Soil and Water Conservation: Theory and Empirical Application to Subsistence Farming in the Eastern Ethiopian Highlands. Doctoral thesis Swedish University of Agricultural Sciences, Uppsala. ISSN 1401-6249, ISBN 91576-6433-1

Wilkinson BH, McElroy BJ (2007). The impact of humans on continental erosion and sedimentation. Geological Society of America Bulletin 119:140-156.

WLRC (2015). Generating and improving knowledge, management and decision support on water and land resources. Project Implementation Progress Report. URLhttp://www.wlrc-eth.org/publications/summary/3-progress-reports/76-eth-wlrc-progress-report-july-dec-2015// 12/10/2018 www.wlrc-eth.org.

Woubet G, Alemu TA, Birru Y, Yihenew G, Bettina W, Hurni H (2013). Impacts of Soil and Water Conservation on Land Suitability to Crops: The Case of Anjeni Watershed, Northwest Ethiopia. Journal of Agricultural Science 5(2):95.

Xu GC, Li ZB, Li P, Lu KX, Wang Y (2013b). Spatial variability of soil organic carbon in a typical watershed in the source area of the middle Dan River, China. Soil Research 51:41-49.

Yeshambel M (2013). Indigenous knowledge practices in soil conservation at Konso people, South Western Ethiopia. Journal of Agriculture and Environmental Sciences 2(2):1-10.

Yibabe T, Kjell E, Tor-Gunnar V, Mitiku H (2002). Soil Conservation in Tigray, Ethiopia, Noragric Report No. 5.

Yihenew T (2012). Conserving soils: Evidence-based soil conservation measures that improve soil physical and chemical properties and barley yield. In: Nicol, A., Langan, S., Victor, M. and Gonsalves, J. (eds), Water-smart agriculture in East Africa. Colombo, Sri Lanka: IWMI and CGIAR research program on WLE; Kampala, Uganda: GWI EA. 74:231-236.

Yohannes GM (1989). Crop production and conservation methods in Andit Tid area, northern Shoa. Soil Conservation Research Project, Addis Ababa.

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Full Length Research Paper

Soil characterization and evaluation of blended (YaraMila cereal) fertilizer for bread wheat (*Triticum aestivum* L.) production at Aleltu areas in North Shewa Zone of Oromia region

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The main objective of the study was to characterize the soils on the basis of selected soil physicochemical properties and to evaluate the effects of blended fertilizer (YaraMila cereal) applications on yield and yield components of bread wheat on the major soil types in the study area. The field experiment involved 5 treatments (control, three rates of blended fertilizer and recommended nitrogen and phosphorus fertilizers) laid down in randomized complete plot design with three replications. Soil samples were collected from the experimental field before planting and from 2 freshly opened soil profiles to study selected soil physicochemical properties. The results showed that the textural classes for both profiles were clay. The bulk density of the surface composite soil for sites was 1.18 g cm^{-3} and that of profiles increased consistently with depth. The particle density value of the surface composite soils was 2.31 g cm^{-3}. The pH value of the composite surface soils was neutral and increased with profile depth. Low organic matter and total nitrogen, very low to high available phosphorus (0.06 to 19.17 mg kg^{-1}) and very high available potassium, cation exchange capacity and percent base saturation was obtained at the experimental site. The applied fertilizers significantly influenced most of the crop parameters. The grain yield (4383.3 kg ha^{-1}) was obtained due to the application of the highest rate of blended fertilizer while the minimum was from the control.

Key words: Soil, composite soils, profiles.

INTRODUCTION

No single resource is more important in achieving a sustainable agriculture than the soil which contains essential nutrients, stores the water for plant growth and provides the medium in which plants grow (FAO, 1998). However, the total quantity and particularly plant availability of the essential nutrient elements (soil fertility) is a complex quality of soils that is closest to plant nutrient management. It is the component of the overall soil productivity that deals with its available nutrient status, and its ability to provide nutrients out of its own

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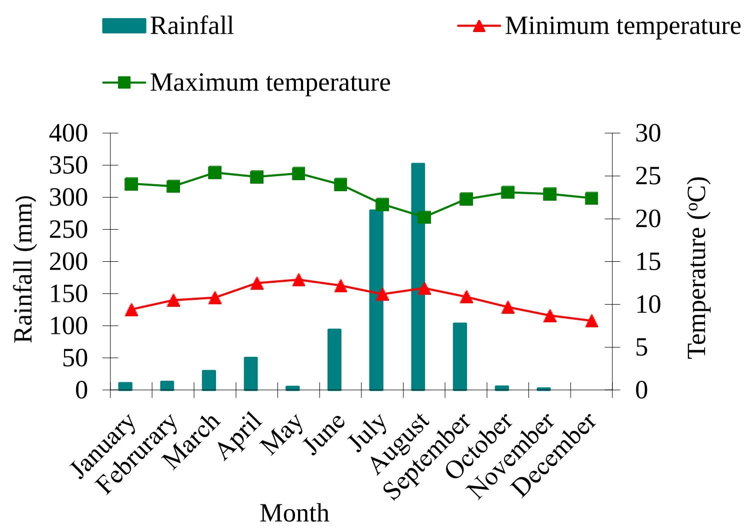

Figure 1. Monthly total rainfall, and mean maximum and minimum temperatures at the study area during the 2013.

reserves and through external applications for plant growth and production. It combines several soil properties (biological, chemical and physical), all of which affect directly or indirectly nutrient dynamics and availability.

Soil nutrient depletion and related low agricultural productivity are serious problems particularly in small scale farmers of sub-Saharan Africa and most other developing countries (Tilahun et al., 2001). In a study on soil nutrients balances at national and regional level, Haileslassie et al. (2005) reported large variations in the nutrient balances of different cropping systems, ranging from nutrient accumulating systems (e.g. enset, *Ensete ventricosum*) to nutrient depleting including cultivation of most cereals (e.g. teff, *Eragrostis tef*) with strongly negative nutrient balances.

In Ethiopia, soil fertility is one of the factors limiting the yield of crops, including wheat. It may be caused as result of removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residue from farm land, and lack of proper crop rotation program (Tamire, 1982). Micronutrients like zinc (Zn) and boron (B) and secondary nutrients like sulfur (S) are needed in small quantities by crops but are as important as nitrogen (N), phosphorus (P) and potassium (K) for plant growth and increasing the quality and quantity of crop yields. Insufficient soil micronutrients is affecting both crop yield and produce quality and it is partly responsible for decreasing efficiency of N, P and K fertilizers. In rainfed areas, in spite of subsistence agriculture over a long period, soils are depleted not only major nutrients but also micro-and secondary nutrients (FAO, 2006).

Ethiopia is the second largest producer of wheat in sub-Saharan Africa, following South Africa. Wheat is one of the major cereal crops in the Ethiopian highlands that lie between latitude 6 and 160 north and longitude 35 and 420 east and is widely grown from 1500 to 3000 m.a.s.l. The most suitable areas for wheat production, however, fall between 1900 and 2700 m.a.s.l (Hailu, 1991). Wheat is the 4th most important crop in both the total area and in production in Ethiopia (CSA, 2012). The high yield levels obtained in cereal crops on many highly productive soils are a result of suitable crop growth conditions, optimal and balanced nutrient management and adoption of best management practices (FAO, 2006).

In Ethiopia, application of micronutrient containing fertilizers is not a common practice and experiment has not been conducted on these fertilizer rates and the response of wheat crop to their application. Therefore, pre-assessment of crop response to these fertilizers is required for development of their optimal recommendation rates. Thus, this study was initiated to characterize the soils at the Aleltu area on the basis of selected soil physicochemical properties and to evaluate the effects of blended fertilizer (YaraMila cereal) applications on yield and yield components of bread wheat on the major soil types in the study area.

MATERIALS AND METHODS

The study was conducted during the 2013 main cropping season under rain fed conditions at Maru kebele of farmers' fields in Aleltu District, North Shewa Zone of Oromia Regional State. Aleltu is located in the central highlands of Ethiopia at about 55 km north of Addis Ababa on the main road to Mekelle. Geographically, this area is situated at 9° 19′ 43″ to 9° 4′ 43″ north east latitude and 39° 16′ 16″ to 39° 1′ 16″ east longitude. The altitude of the District ranges between 2200 and 2900 masl. The study area is characterized by a unimodal rainfall pattern. The average annual rainfall ranges from 800 to 1170 mm (Figure 1). Based on color, the soils of the study area are black soil covering 21%, red soil 20% and brown soil 59%.

Mixed crop-livestock production system is the common farming system in the District.

Experimental materials, treatments and design

The experiment comprised of 5 treatments namely 0, 135.5 kg YaraMila cereal + 22.4 kg urea, 271.0 kg YaraMila cereal + 45 kg urea, 406.5 kg YaraMila cereal + 67.4 kg urea of YaraMila cereal fertilizer (16-17-17 N-P_2O_5-K_2O + 4.5 S + 0.25 B_2O_3 + 1 Zn) and combined recommended rates of N (64 kg N ha^{-1}) and P (46 kg P_2O_5 ha^{-1}) fertilizers. The field experiment was laid down in a randomized complete block design with three replications. Plot size was 4 m × 2.4 m (9.6 m^2). During the different growth stages of the crop, the necessary cultural and recommended agronomic management practices were all carried out.

Agronomic and yield data collection

Days to heading were recorded by counting the number of days required for the expression of the particular phonological stage. Similarly, days to physiological maturity were recorded as the number of days elapsed from planting until when 90% of the plants within a plot have physiologically matured; grain filling period was computed as the difference between the number of days to heading and number of days to maturity. Plant height was measured from 10 randomly taken plants at late flowering stage; number of fertile tillers was recorded at the late flowering stage from 0.5 m row length at two random spots in the sampling rows and then extrapolated for the total number of plants in the net plot area. The numbers of spikes per 6 m^2 was counted at maturity by taking the total number of spikes or ears from 0.5 m row length within the middle two rows of the net plot. The number of spikelets per spike and spike length were recorded as average values over 10 spikes taken randomly from the net plot.

At physiological maturity, the plants in the net plot area of each replication was harvested and left in open air for about 10 days until it attains a constant weight before threshing and then weighed for the determination of straw yield by subtracting the grain yield per plot. Grain yield was determined from the net harvested plot area after harvesting and threshing and after adjusting the grain moisture content to 12%.

Surface soil and profile sampling and sample preparation

Two soil profile pits (1 m width, 1.5 m length and 1.8 m depth) were opened at the experimental site for laboratory characterization of soil physical and chemical properties and before sowing, surface soil samples (0-15 cm depth) were collected for soil fertility evaluation.

Soil particle size distribution (texture) was analyzed by the Bouyoucos hydrometer method. Bulk density was determined from the undisturbed (core) soil samples collected using core samplers, weighed at field soil moisture content and then dried in an oven at 105°C to a constant weight (Baruah and Barthakur, 1997). Similarly, particle density was measured by the Pycnometer method. Finally, soil total porosity was estimated from the bulk density (BD) and particle density (PD) values as:

$$\text{Total porosity (\%)} = \left(1 - \frac{\text{BD}}{\text{PD}}\right) \times 100$$

Soil pH was measured in 1: 2.5 soil to water ratio. The Walkley and Black (1934) wet digestion method was used to determine soil organic carbon. Similarly, total N was analyzed using the Kjeldahl digestion and distillation method. Available P was carried out by the Olsen method. Available Zn was extracted with the DTP.

The exchangeable bases (Ca, Mg, K and Na) in the soil were determined from the leachate of 1 molar ammonium acetate (NH_4OAc) solution at pH 7.0. Cation Exchange Capacity (CEC) was measured after leaching the ammonium acetate extracted soil samples with 10% NaCl solution and determining the amount of ammonium ion in the percolate by the Kjeldahl procedure and reported as CEC (Hesse, 1972). The percent base saturation (PBS) was computed as the percentage of the sum of the exchangeable bases to the CEC of the soil: Finally, the fertility statuses of the soils of the experimental fields (study areas) were evaluated by comparing the values or concentrations of the respective parameter obtained from the laboratory analyses (both physical and chemical properties) with established ratings and/or critical levels for different classes of the respective soil parameter.

Statistical analysis

The yield and crop agronomic data were subjected to analysis of variance (ANOVA) appropriate to randomized complete block design using SAS software program (SAS Institute, 2000). The analysis result of the soil was interpreted using descriptive statistics. When significant differences were observed, comparisons of means were performed using the least significant difference (LSD).

RESULTS AND DISCUSSION

Characterization of the soils of study area at Aleltu

Soil physical properties

Soil texture: The data in Table 1 showed that the mean particle size distribution of the composite surface (0 to 15 cm) soil sample was clay loam although there were variations among the values of sand, silt and clay contents of the blocks. Moreover, the textural class for the profiles opened in both profiles and throughout their depths was clay (Table 1). This differentiation in the relative distribution of clay content with depth may be attributed to the variability in the degree of weathering, parent material and soil erosion and deposition of eroded sediments.

Bulk density, particle density and total porosity**:** The mean bulk density value of the composite surface (0-15 cm) soil samples was 1.18 g cm^{-3} (Table 1). However, the bulk density values of both soil profiles opened increased consistently with increasing soil depth. The relatively lower bulk density values at the surface composite soil samples and the surface layers of the profiles could be due to OM content (Table 1) which led to the relatively higher total porosity. While the highest bulk density at thebottom subsurface layers of both profiles could be due to compaction caused by the weight of the overlying soil material, reduced root penetration and relatively lower OM contents than the overlying layers (Brady and Weil, 2002). However, the bulk density values of the soils studied were within the ranges

Table 1. Selected physical properties of the soil profile and composite surface soil samples of the study area

Depth (cm)	Particle size (%)			Textural class	BD (g cm^{-3})	PD (g cm^{-3})	TP (%)
	Sand	Silt	Clay				
Profile 1							
0-35	19	17	64	Clay	1.33	2.27	41.40
35-80	13	19	68	Clay	1.34	2.41	44.81
80-180^{+}	23	37	40	Clay	1.47	2.51	41.40
Composite surface (0-15 cm) soil samples before planting							
Block 1	16	23	61	Clay	1.14	2.30	50.40
Block 2	40	37	23	Loam	1.21	2.31	47.60
Block 3	50	19	31	Sandy clay loam	1.20	2.32	48.30
Mean	35.3	26.3	38.3	Clay loam	1.18	2.31	48.90
Profile 2							
0-50	11	21	68	Clay	1.28	2.35	45.53
50-120	15	13	72	Clay	1.33	2.34	43.16
120-185	19	15	66	Clay	1.48	2.35	37.00

BD= Bulk density; PD = Particle density; TP = Total porosity.

reported by Brady and Weil (2002) for agricultural and/or mineral soils which is in the range of 1.0 to 1.65 g cm^{-3} and by Miller and Donahue (1995) who reported that for good plant growth, the bulk densities should be below 1.4 and 1.6 g cm^{-3} for clay and sandy soils, respectively.

The mean particle density value of the composite surface (0-15 cm) soil samples of the experimental site was 2.31 g cm^{-3} (Table 1). The values of particle density of the profile 1 increased consistently with depth. However, the particle density at profile 2 did not show consistent relationship with soil depth. Generally, the particle density values measured for the composite surface soils of experimental field and that of both soil profiles studied were lower than the commonly quoted standard average value (2.65 g cm^{-3}) for mineral soils worldwide.

The mean total porosity of the composite surface (0-15 cm) soil samples was 48.9%. However, the values of total porosity of the profile 1 did not show consistent relationship with soil depth however, at profile 2, it decreased consistently with increasing depth. The relatively lower (37.00%) and higher (48.9%) total porosity values were observed at the bottom (120-185 cm) subsoil layer of profile 2 and the mean composite surface soil samples of the experimental site, respectively. Thus, higher values of total porosity may be due to the relatively lower bulk density values and for the lower values could be the relative higher bulk density value observed at this layer. Hence, the value of total porosity lies almost in the usual range (30 and 70%).

Soil chemical properties

Soil pH: The pH of a soil is one of the most important properties influencing plant growth and production as it affects ion exchange capacity and nutrient availability. The mean pH value of the composite surface (0-15 cm) soil samples was neutral (pH = 7.00) for the experimental sites, as per the classification set by Tekalign (1991). On the other hand, the pH values of both profiles increased consistency with increasing depth ranging. Generally, increase in pH with increasing profile depth in both profiles could be increase in basic cations with depth and hence, percent base saturation. The increase in basic cations concentration with depth, in turn, may suggest the existence of downward movement of these constituents within the profile.

Organic matter: The mean soil organic matter (OM) content of the composite surface (0-15 cm) soil samples of experimental site was 1.13% (Table 2). On the other hand, the OM content of both profiles decreased consistently (Table 2). According to the OM content rating established by Tekalign (1991), the mean composite surface (0-15 cm) soil sample, surface layers of both profile with OM content of 1.6 and 2.12% and the upper subsoil layer with OM content of 1.58% at profile 2 could be rated as low while the remaining subsurface layers of both profiles and field experimental site fall under the very low soil OM content category.

The reasons for the very low content of organic matter (OM) could be intensive cultivation of the land and the total removal of crop residues for animal feed and source of energy. Moreover, there is no practice of organic fertilizers' addition, such as farmyard manure and green manure that would have contributed to the soil OM pool in the study area. Generally, the findings of the present study are in agreement with Yihenew (2002) who stated that most cultivated soils of Ethiopia are poor in their OM

Table 2. Selected soil chemical properties of the soil profiles and composite surface soils of the study areas.

Depth (cm)	pH (H_2O)	OM (%)	Total N (%)	AP (mg kg^{-1})	AK (mg kg^{-1})	Exchangeable bases and CEC (cmolc kg^{-1})					PBS	Ex. Zn (mg kg^{-1})
						Ca	Mg	K	Na	CEC		
Profile 1												
0-35	6.3	1.60	0.180	4.18	ND	50.03	10.61	0.61	0.00	57.42	106.7	1.740
35-80	8.0	0.62	0.080	1.92	ND	58.99	10.15	0.70	0.00	54.50	128.0	1.910
80-180^{+}	8.1	0.18	0.020	1.60	ND	59.04	9.26	0.64	0.00	46.66	147.8	0.640
Composite surface (0-15 cm) soil samples before planting												
Block 1	7.0	1.16	0.074	7.40	375.00	40.21	11.83	0.96	0.00	39.01	135.8	0.490
Block 2	7.1	1.13	0.073	6.72	371.45	41.64	10.81	0.95	0.35	40.72	132.0	0.410
Block 3	6.9	1.10	0.074	8.06	340.17	42.01	14.01	0.87	0.00	43.26	131.5	0.550
Mean	7.0	1.13	0.073	7.39	362.20	41.28	12.21	0.92	0.11	40.99	133.0	0.483
Profile 2												
0-50	6.6	2.12	0.180	4.64	ND	40.44	10.28	0.55	0.00	57.55	89.0	1.370
50-120	7.7	1.58	0.110	0.98	ND	46.64	10.18	0.59	0.00	61.51	93.0	1.490
120-185	7.9	0.57	0.040	0.06	ND	49.44	10.41	0.73	0.00	55.60	109.0	1.100

OM = Organic matter; AP = Available phosphorus; AK = Available potassium CEC = Cation exchange capacity; PBS = Percentage base saturation; Ex. Zn = Exchangeable Zinc; ND = Not determined.

contents due to low amount of organic materials applied to the soil and complete removal of biomass from the field for various purposes.

Total nitrogen: The mean total N content of the composite surface (0-15 cm) soil samples was 0.073% at the experimental sites (Table 2). The concentrations of total N in both profiles decreased consistently with increasing depth (Table 2). As per the classification of Tekalign (1991), the surface layers of both profiles with total N of 0.18% could be rated as medium while the subsurface layers of the soil of both profiles fall under the low total N category. Thus, the low total N contents indicate that the soils of the study area are deficient in nitrogen to support proper growth and development of crops, which confirms that the site must be fertilized with external nitrogen inputs. Furthermore, other research works (Tekalign et al., 1988; Mesfin, 1998; Eylachew, 1999, 2000; Engdawork, 2002; Mohammed, 2003) done in Ethiopia on Vertisols also indicated that N is the most deficient nutrient element than any other essential element in these soils and has called for the application of inorganic fertilizers and need for a sound management of soil OM through addition of organic fertilizers sources.

Available phosphorus: The mean soil available P content of the composite surface (0-15 cm) soil sample value was 7.39 mg kg^{-1} at the experimental site (Table 2). However, the available P content of both profiles displayed a decreasing pattern with depth. The relatively lower values of available P (0.98 and 0.06 mg kg^{-1}) contents were obtained at the upper subsoil layer and bottom subsurface layer at profile 2 while the highest (7.39 mg kg^{-1}) of available P was obtained at the mean composite surface soils. Tisdale et al. (2002) have indicated that for Olson extractable P below 3 mg kg^{-1} is considered as very low; between 4 and 7 mg kg^{-1} as low; between 8 and 11 mg kg^{-1} medium as and greater than 12 mg kg^{-1} as high. Thus, the available P content of the mean composite surface soil sample and the surface layers of both profiles could be rated as low. While the remaining subsurface layers of the soil of both profiles could be rated as very low soil available P.

In line with the available P contents of the profiles, observed in this study, Tekalign et al. (1988) reported that topsoil P is usually greater than that in subsoil due to sorption of the added P, greater biological activity and accumulation of organic material on the surface. Mulugeta (2000) also indicated decrease in P content with depth due to fixation by clay and Ca, which were found to increase with profile depth. Also the generally low and very low contents of available P contents in the soils at the study sites could be due to losses through crop harvest and erosion which are characteristic features of agricultural soils in the tropics.

Generally, the available P status of the soils of both the profiles and surface soil of the experimental plots at the experimental site, are very low, even below the critical level (8.5 mg kg^{-1}) indicating that soil P infertility is among the factors that are highly limiting the productivity of the

Table 3. Days to 50% heading, days to 90% maturity and grain filling period of wheat.

Treatment (kg ha^{-1})*	Days to 50% heading	Days to 90% maturity	Grain filling period
Blended 406.5 + 67.4 urea	68.00^{d}	121.00^{d}	53.00^{c}
Blended 271 + 45 urea	68.00^{d}	121.00^{d}	53.00^{c}
Blended 135.5 + 22.4 urea	74.00^{b}	132.00^{c}	58.00^{b}
Recommended urea + TSP	76.00^{b}	133.66^{b}	57.00^{b}
Control	83.00^{a}	143.66^{a}	61.00^{a}
LSD (0.05)	2.58	1.52	1.89
CV (%)	1.90	0.61	1.78

*Means within a column and the same site sharing common letter(s) are not significantly different at P > 0.01; LSD = Least Significant difference; CV = Coefficient of variation; TSP = Triple super phosphate.

soils. From this observation, it could even be said that available P was highly deficient and it is probably the first limiting nutrient in the study area. In agreement with this observation, many researchers (Harrison, 1987; Warren, 1992; Buehler et al., 2002) have also reported that soil P deficiency is a wide spread phenomenon and it is believed to be the second most important soil fertility problem throughout the world next to N and often the first limiting element in acid tropical soils.

Available potassium: The mean value of available K of the composite surface (0-15 cm) soil samples was (362.2 mg kg^{-1}) observed at the experimental site (Table 3). According to classification set by Jones (2003), the mean available K values of the surface composite soil samples (362.2 mg kg^{-1}) could be rated as very high. Generally, the available K contents measured for the soils studied indicated that the soils of the study sites are rich in available K. Thus, K could not be considered as a factor inducing low soil fertility and application of K containing fertilizer is not necessary at least for the time being in the soils of the study area. The result obtained for exchangeable K agrees with the common idea that Ethiopian soils are reach in K.

Cation exchange capacity (CEC): Cation exchange capacity (CEC) value of the mean composite surface (0-15 cm) soil samples was 40.99 cmolc kg^{-1}, (Table 2). On the other hand, the CEC values of the profile 1 decreased consistently with increasing soil depth while did not show consistent relationship with soil depth at profile 2. The relatively lower (40.99 cmol$_c$ kg^{-1}) and higher (61.51 cmol$_c$ kg^{-1}) CEC values were measured at the surface soils and the upper subsoil layer at the experimental sites and at the profile 2, respectively (Table 2).

According to the rating of CEC established by Hazelton and Murphy (2007), CEC values of the surface soils and throughout the profile depths could be classified as very high. The consistent decline of CEC with increasing profile depth at profile 1 may be due to the parallel consistent decline in organic matter content and due to the lower clay contents in the subsurface than in the surface soils.

In line with the findings of the current study, Eylachew (2000) reported that Vertisols identified at Wonji, Ginchi, Sheno and Alemaya areas were found to have high CEC values commonly ranging from 37 to 67 cmolc kg^{-1}. Moreover, Fisseha (1992) reported CEC values ranging from 50 to 73 cmolc kg^{-1} for the Vertisols at Shoa Robit areas. Although the OM content of the soil is low, the amount and type of clay might have been very important in contributing to the very high CEC observed in the soils of the study areas. Moreover, overestimation of Ca in the exchange site due to the dissolution of calcite ($CaCO_3$) as a result of the use of NH_4OAc (pH 7.0) as an electrolyte in CEC determination has also apparently contributed appreciably to the measured quantities of CEC in the soils. The high values of CEC offer high buffering capacity to the soil as described by Mohammed et al. (2005).

Exchangeable bases and percent base saturation: According to the classification of exchangeable bases set by FAO (2006), the mean exchangeable Ca and Mg contents of the composite surface soils as well as both profiles studied are classified as very high. Similarly, based the same rating, the exchangeable K contents of the surface and the upper subsoil layer of profile 2 could be rated as medium while the mean value of K of the composite surface soils and the subsurface layers of the soil profiles could be classified as high. In the current study, exchangeable Ca followed by Mg was the predominant cation in the exchange sites of the soil colloidal materials. In summary the concentrations of the basic cations in the exchange sites of the soils studied were in the order of Ca > Mg > K > Na based on their means in composites surface soil samples as well as in the profile of both sites. Mesfin (1998) and Yihenew (2002) also reported a similar order (Ca > Mg > Na > K) for Alfisols of Debre Markos and Bahir Dar area, and for different major soil groups of Adet Research Center and its testing sites, respectively.

According to the classification by Hazelton and Murphy (2007), the percent base saturation (PBS) content of all soils studied were very high and varied from 89.0 to 147.8% and considering the surface soil profiles depths (Table 3). This could be attributed to the very high contents of exchangeable Ca and Mg which apparently have been overestimated by including contents from Ca and/or Ca/Mg carbonates dissolved in the process of extraction.

Zinc (Zn): Micronutrients are required in trace amounts but they are as essential as the macronutrients in the soil and highly indispensable for the productivity of soils. The mean value of Zn in the composite surface (0-15 cm) soils was 0.483 mg kg^{-1} for the experimental site (Table 2). The available Zn contents of both profiles varied inconsistently with soil depth.

According, to the classification of Jones (2003), the available Zn contents of the mean composite surface soil samples of the experimental field could be rated as low while that of both profiles could be rated as high except for the bottom subsurface layer at profile 1 with 0.64 mg kg^{-1} which could be rated as medium soil available Zn. The reason for the low available Zn content could be continuous cultivation of the field which led to removal of zinc without external application.

Response of wheat to the applied fertilizers

Wheat phenology

The results of wheat phenological stages showed that the applied fertilizers had significant effect ($P \leq 0.01$) on days to 50% heading, days to 90% maturity and grain filling period (Table 6). As a result significant variation in number of days to heading was observed due to applied fertilizers at the experimental site. However, application of the higher (406.5 kg ha^{-1} blended + 67.4 urea kg ha^{-1}) and the recommended (271 kg ha^{-1} blended + 45 kg ha^{-1} urea) rates of blended (YaraMila cereal) fertilizer hastened days to heading as compared to the plots which received 135.5 kg ha^{-1} blended + 22.4 kg urea and recommended N + P rates and the control plots (Table 3).

Accordingly, application of the higher and recommended rates of blended fertilizer reduced days to heading by 15 days as compared with the control (Table 3). Thus, in the plots that received higher and recommended rates of blended fertilizer, the wheat crop took shorter period to reach days to heading. This may be due to the higher content of nutrients and presence of macro and micronutrients in the blended fertilizer.

The number of days to 90% physiological maturity also showed significant ($P \leq 0.01$) differences due to the applied treatments (Table 6). The maximum and minimum days to 90% physiological maturity were observed at the higher and recommended rate of blended fertilizer and the control plots, respectively (Table 3). Accordingly, application of the higher and the recommended rates of blended fertilizer decreased days to maturity by 22.7 days over the control (Table 3).

Similarly, the applied fertilizers resulted in significant ($P \leq 0.01$) differences on grain filling period (Table 6). Moreover, there was statistical difference in grain filling period between the means of the blended fertilizer rates and recommended N + P fertilizer. However, the wheat plants which received the highest and the recommended rate of the blended fertilizer reach grain filling period faster than with the lower rate of the blended, recommended N + P and the control plots (Table 3).

Wheat growth parameters

The effect of applied fertilizers on plant height was found significant at experimental site (Table 3). However, there was no statistical difference between the rates of blended and NP treatment means. Although the minimum (28.58 cm) and maximum (72.93 cm) plant height was obtained from the higher rate of blended fertilizer and the control plot, respectively. These maximum plant heights observed might be due to higher nutrient content of the fertilizer.

Number of fertile tiller per plant responded significantly ($P \leq 0.01$) to the applied fertilizers at the experimental site, application of the higher (406.5 blended + 67.4 urea kg ha^{-1}) rate of blended fertilizer and the recommended N + P fertilizers increased the number of fertile tillers per plant by 248 and 117%, respectively, over the control (Table 4).

Wheat yield and yield components

Number of spikes per meter square, spikelets per spike and spike length

The analysis of variance showed that the applied fertilizers had significant ($P \leq 0.01$) influence on the number of spikes per m^2 (Table 6). the highest and the-recommended rates of blended fertilizer resulted in the highest number of spikes (472 and 464 m^{-2}), respectively and the lowest number of spikes (240 m^{-2}) was obtained from the control plot indicating an increment of 97 and93% over the control plot (Table 5). Spike length and spikelets per spike were not significantly ($P > 0.05$) affected by the applied fertilizers at the experimental site (Table 5).

Table 4. Plant height and Number of fertile tillers per plant of wheat

Treatment (kg ha^{-1})*	Plant height (cm)	Number of fertile tillers per plant
Blended 406.5 + 67.4 urea	72.93^{a}	4.52^{a}
Blended 271 + 45 urea	70.78^{a}	3.78^{b}
Blended 135.5 + 22.4 urea	65.60^{a}	2.80^{c}
Recommended urea + TSP	66.02^{a}	3.00^{c}
Control	28.58^{b}	1.30^{d}
LSD (0.05)	9.01	0.35
CV (%)	7.88	6.05

*Means within a column and the same site sharing common letter(s) are not significantly different at P > 0.01; LSD = Least significant difference; CV = Coefficient of variation; TSP = Triple super phosphate.

Table 5. Number of spikes per m^2; spike length and spikelets per spike.

Treatment (kg ha^{-1})*	Number of spike per m^2	Spike length (cm)	Spikelets per spike
Blended 406.5 + 67.4 urea	472.00^{a}	6.70^{a}	13.00^{a}
Blended 271 + 45 urea	464.00^{a}	6.49^{a}	14.00^{a}
Blended 135.5 + 22.4 urea	400.00^{ab}	5.60^{a}	12.33^{a}
Recommended urea + TSP	384.00^{b}	5.96^{a}	13.66^{a}
Control	240.00^{c}	5.38^{a}	12.00^{a}
LSD (0.05)	77.40	ns	Ns
CV (%)	10.50	14.31	8.14

*Means within a column and the same site sharing common letter(s) are not significantly different at P > 0.01; LSD = Least significant difference; CV = Coefficient of variation; TSP = Triple super phosphate.

Table 6. Mean square estimates of crop phenology, growth, yield components and yield of wheat for randomized complete block design.

Parameter	Mean squares for source of variation†		
	Treatment (4)	Error (8)	Coefficient of variation (%)
Days to 50% heading	128.93**	1.88	1.90
Days to 90% maturity	274.40**	0.65	0.62
Grain filling period	36.27**	1.02	1.78
Plant height (cm)	1001.28**	22.94	7.88
Fertile tillers per plant	4.34**	0.03	6.05
Spikes per m^2	26112.00**	1690.00	10.50
Spike length (cm)	0.96ns	0.74	14.31
Spikelets per spike	1.73 ns	1.13	8.14
Grain yield (kg ha^{-1})	3950905.07**	304911.97	16.07
Straw yield (kg ha^{-1})	8086144.72**	536794.80	14.64
Total biomass (kg ha^{-1})	22816746.91**	95833009.00	11.59
Harvest index	0.0015ns	0.003	13.47

Grain yield and thousand grains weight

Grain yield responded significantly ($P \leq 0.01$) to the applied fertilizers at experimental sites (Table 6). However, no statistically difference between the means of blended fertilizer rates and recommended N + P fertilizers and the highest mean grain yield (4383.3 kg ha^{-1}) was obtained from the maximum (406.5 kg blended + 67.4 kg

Table 7. Grain yield, straw yield, biomass yield and harvest index of wheat.

Treatments (kg ha^{-1})*	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Bio mass (kg ha^{-1})
Blended 406.5 + 67.4 urea	4383.3^{a}	6166.6^{a}	10550.0^{a}
Blended 271 + 45 urea	4276.7^{a}	6055.5^{a}	10332.2^{a}
Blended 135.5 + 22.4 urea	3550.0^{a}	5972.2^{a}	9524.2^{ab}
Recommended urea + TSP	3444.3^{a}	4500.0^{b}	7944.3^{b}
Control	1525.3^{b}	2333.3^{c}	3860.8^{c}
LSD (0.05)	1039.7	1379.5	1843.2
CV (%)	16.07	14.31	11.59

*Means within a column and the same site sharing common letter(s) are not significantly different at P > 0.01; LSD = Least significant difference; CV = Coefficient of variation; TSP = Triple super phosphate.

urea) rate with an increment of 187% yield advantage over the control plot (Table 7).

Straw yield, total biomass yield and harvest index

The applied fertilizers were significant (P ≤ 0.01) at the experimental site (Table 6). As indicated in Table 7 the highest (6166.6 kg ha^{-1}) and lowest (2333.3 kg ha^{-1}) mean straw yield were revealed at the highest rate of blended fertilizer and the control plot, respectively. The increment in straw yield obtained with highest blended fertilizer rate over the control was 164.3%. In line with the grain and straw yields, total biomass yield was also significantly (P ≤ 0.01) affected by applied fertilizers at experimental site (Table 6). The relative highest (10550 kg ha^{-1}) mean total biomass yield was obtained from the maximum (406 kg blended + 67.4 kg urea) rate with an increment of 173% total biomass yield advantage over the control (Table 7).

Conclusion

The results of the current study provide basic information for further research and development efforts in soil fertility management for sustainable utilization of the soil resources as well as fertilizer recommendations in the area. Also the highest grain yield was obtained from the maximum application of blended rate but it is difficult to give concrete recommendation for the sites of the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Baruah TC, Barthakur HP (1997). A Textbook of Soils Analysis. Vikas Publishing House Private Limited, New Delhi.

Brady NC, Weil RR (2002). The Nature and Properties of Soils. 13th Edition. Macmillan Publishing Company, Inc. USA.

Buehler S, Obeson A, Rao IM, Friessen DK, Frossard E (2002). Sequential phosphorus extraction of a ^{33}P-labeled oxisol under contrasting agricultural systems. Soil Science Society of America Journal 66:868-877.

CSA (Central Statistical Authority) (2012) Agricultural Sample Survey 2011/2012. I.Report On Area and Production for Major Crops: Private Peasant Holding 'Meher' Season. Statistical. Bulletin CSA, Addis Ababa, Ethiopia.

Engdawork A (2002). Characteristics, classification and potentials of soils in Werkayia area, South Welo, Ethiopia. SINET: Ethiopian Journal of Science 25(1):45-70.

Eylachew Z (1999). Selected physical, chemical and mineralogical characteristics of major soils occurring in Chercher highlands, eastern Ethiopia. Ethiopian Journal of Natural Resources 1(2):173-185.

Eylachew Z (2000). Study on the physical, chemical and mineralogical characteristics of some Vertisols of Ethiopia. *In*: Wondimagegn Chekol and Engda Mersha. proceedings of the 5th Conference of the Ethiopian Society of Soil Science, March 30-31, 2000, Addis Ababa, Ethiopia.

Food and Agriculture Organization (FAO) (1998). Top Soil Characterization for Sustainable Land Management. Soil Resources, Management and Solutions Service. FAO, Rome.

Food and Agriculture Organization (FAO) (2006). Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16. FAO, Rome

Fisseha I (1992). Macro and micronutrients distributions in Ethiopian Vertisols landscapes. Ph.D. Dissertation Submitted to the Institute fur Bondenkunde und Standorslehre, University of Hohenheim, Germany 201 p.

Haileslassie A, Priess J, Veldkamp E, Teketay D, Lesschen P (2005). Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances. Agriculture, Ecosystems and Environment

108(1):1-16.
Hailu G (1991). Wheat production and research in Ethiopia. *In*: Hailu Gebremariam, D.G. Tanner, and Mengistu Hulluka. pp.1-16. Wheat Research in Ethiopia: Historical perspective. IAR/CIMMYT, Addis Ababa, Ethiopia.
Harrison AF (1987). Soil organic phosphorus-A review of World literature. CAB Intl, Wallingford, UK.
Hazelton P, Murphy B (2007). Interpreting soil test results: What do all the numbers mean? 2nd Edition. CSIRO Publishing 152 p.
Hesse P (1972). A textbook of soil chemical analysis. John Murry Limited, London, Great Britain.
Jones JB (2003). Agronomic Handbook: Management of Crops, Soils, and Their Fertility. CRC Press LLC, Boca Raton, Florida, USA.
Mesfin A (1998). Nature and management of Ethiopian soils. Alemaya University, Ethiopia.
Miller RW, Donahue RL (1995). Soils in Our Environment. 7th Edition. Prentice- Hall Inc. A Simon and Schuster Company Englewood Cliffs, New Jersey.
Mohammed A (2003). Land suitability evaluation in the Jelo Catchment, Chercher highlands, Ethiopia. PhD Dissertation, University of Free State.
Mohammed A, Leroux PAL, Barker CH, Heluf G (2005). Soils of Jel micro-catchment in the Chercher highlands of eastern Ethiopia: I. Morphological and physiochemical properties. Ethiopian Journal of Natural Resources 7(1):55-81.
Mulugeta S (2000). Uptake and Response of Rice (*Oryza Sativa* L.) to Nitrogen and Phosphorus fertilization under rain fed low land condition of the Fogera plain, northern Ethiopia. MSc Thesis Submitted to the School of Graduate Studies, Alemaya University, Ethiopia 93 p.
SAS Institute (2000). SAS User's Guide, Statistics version 8.2. SAS Inst., Cary, NC, USA.
Tamire H (1982). Summary of results of soil Science research program for Hararghie highlands of Eastern Ethiopia .vol. IV. Addis Ababa University College of Agriculture, Haramaya, Ethiopia 137 p.
Tekalign M, Haque I (1991). Phosphorus Status of Some Ethiopian Soils. III. Evaluation of soil test methods for available phosphorus. Tropical Agriculture (Trinidad) 68:51-56.
Tekalign M, Haque I, Kamara CS (1988). Phosphorus status of Ethiopian Vertisols: Management of Vertisols in Sub-Saharan Africa. pp. 232-252. *In*: Proceeding of the conference held at International Livestock Centre for Africa (ILCA), 31 August-4 September 1987.
Tilahun A, Takele B, Endrias G (2001). Reversing the degradation of arable land in the EthiopianHighlands. Managing African Soils No. 23. International Institute for Environment and Development.
Tisdale SL, Nelson WL, Beaton JD, Havlin JL (2002). Soil fertility and fertilizers. 7th Edition. Prentice-Hall of India, Newdelhi 633 p.
Walkley A, Black CA (1934). An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Science 63:251-264.
Warren G (1992). Fertiliser phosphorus sorption and residual value in tropical African soils. NRI bulletin 37. Natural resources institute, Chatham, England.
Yihenew G (2002). Selected chemical and physical characteristics of soils of Adet Research Center and its testing sites in northwestern Ethiopia. Ethiopian Journal of Natural Resources 4(2):45-70.

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