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RESEARCH ARTICLE

INFLUENCE OF DIFFERENT SALT AFFECTED SOIL CLASSES ON TOTAL NITROGEN, AVAILABLE PHOSPHORUS AND POTASSIUM IN CENTRAL RIFT VALLEY OF ETHIOPIA

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ABSTRACT

The aim of this study was to scrutinize influence of different salt affected soil classes on TN, Av.P and Av.K in the study area. A total 400 soil samples were collected from two soil depth (0-20 and 20-40 cm) using systematic sampling technique. Then, salinity and sodicity parameters for all soils were analyzed. Based on analytical results, the study area was classified into 6 mapping units were indentified from both soil types. Standard procedures were employed for the analyses of soil parameters. The results of the study revealed that TN, Av.P and Av.K were significantly affected ($P \leq 0.05$ and/or $P \leq 0.01$) by salt affected soil class in both soil types, except TN were non-significant in Vertisols. TN and Av.P was showed decreasing pattern from non-saline non-sodic soil to salt affected soil classes in both soil types, although Av.P higher in Fluvisols of saline-sodic soil, whereas Av.K was higher in both soil types of saline soil. Pearson's correlation matrix analysis, soil total nitrogen were significantly ($p \leq 0.01$) and negatively correlated with SAR and HCO_3^- whereas positively correlated with OM. Besides, Av.P was positively and significantly correlated with pHe, SAR, Cl^-, HCO_3^- and CO_3^{2-}, whereas Av.K was negatively associated with SAR, HCO_3^- and CO_3^{2-}. TN, Av.P and Av.K were decreasing pattern from surface to sub-surface soil but higher Av.K at Fluvisols of sub-surface soil. Therefore, analytical result revealed of sufficiency in available K and P and deficient in TN. As recommendation appropriate management nitrogen fertilizer was sustaining agricultural productivity of in salt affected soils.

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INTRODUCTION

Global drive for sustainable agricultural systems involves optimizing agricultural resources to satisfy human needs and at the same time maintaining the quality of the environment and conserving natural resources (FAO, 1988). The establishment of irrigation agriculture is vital to enhance crop production to attain food sufficiency, especially in arid and semi arid regions. The major problem irrigation agricultural in arid and semi arid areas was salt affected soil and this adverse affect on soil chemical properties, fertility and sustainable productivity (Roy *et al.*, 2003; Deshmukh, 2012). Still, soil degradation is an outcome of depletive human activities and their interaction with natural environments. Salinization, alkalization, waterlogging etc. particularly in semi-arid regions are the output of such undesirable interactions (Deshmukh, 2012). Salt affected soil is a critical environmental problem in many countries around the world. This problem has deleteriousimpactonsoil fertility which in turns reduces the soil productivity (Farifteh *et al.,* 2006; Ashenafi, 2015). Nutritional disorders, that is, decreased or increased solubility and availabilities of essential nutrients caused by the presence of excessive accumulations of specific ions and/or salts such as Na^+, HCO_3^-, CO_3^{2-}, SiO_3^{2-}, or NaCl and Na_2SO_4 (Tester and Davenport, 2003; White, 2006). The edaphic (saline and alkaline) indicators that showed the greatest change from pristine conditions were organic C, N, P, Mg, K, B, Ca, and Zn contents and cation exchange capacity (Allotey *et al.,* 2008; Noredin *et al.,* 2013). The chemical properties of a soil give a strong indication of its fertility and productivity. Saline soils are characterized by high concentrations of soluble salts and also lower organic matter and nitrogen content (Lodhi *et al.,* 2009). Nitrogen losses from salt affected soil concluded that losses were likely to be highest under alternate aerobic and anaerobic conditions, a situation exactly met within saline soil and sodic soil, respectively (Al-Busaidi, 2014; Ashenafi 2015). In addition to this, it's induced biological stress to microbial assemblages that resulted in smaller and less efficient microbial communities for nitrogen mineralization (Lodhi *et al.,* 2009; Monaco *et al.,* 2010; Nacide *et al.,* 2013; Ashenafi 2015). The phosphorus deficiency frequently compounds the problems of saline soils of the tropics (Landon, 1991). The

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availability of P to plants for uptake and utilization is messed up in alkaline and calcareous soils due to formation of poorly soluble calcium phosphate raw materials and hence fixation and precipitation of applied P (Mahmood *et al.,* 2013). On moderately saline soils, the application of potassium fertilizers may increase the crop yields (Keshavarz *et al.,* 2004) either by directly supplying K or by improving its balance with respect to Na, Ca and Mg. However under high salinity conditions it is difficult to exclude Na effectively from the plant by use of K-fertilizers. Finding solutions to these problems require identifying the currently georeferenced soil fertility status, irrigation water management systems that induce the problem of salt affected soils. Conversely, knowledge of total nitrogen, available phosphorus and potassium plays a vital role in enhancing production and productivity of the agricultural sector on sustainable basis and little scientific information is available. Therefore, to scrutinize influence of different salt affected soil classes on nitrogen, available phosphorus and potassium in Amibara areas, central rift valley of Ethiopia.

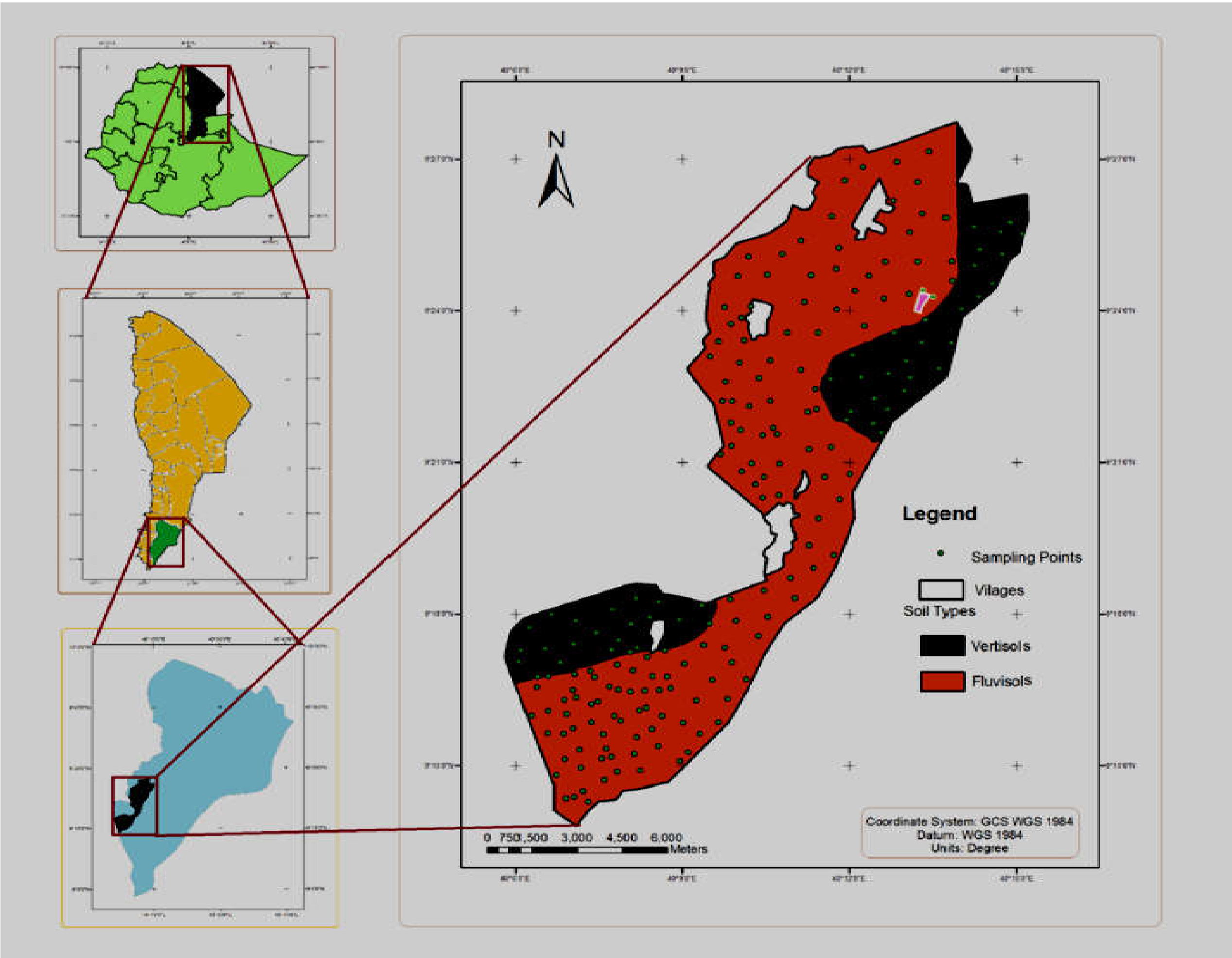


Figure 1. Location map of the study area

MATERIALS AND METHODS

Description of the study area

Amibara irrigation project area is located in at 9°12'8" to 9°27'46" N latitude and 40°5'41" to 40°15'21" E longitude in Gabiressu zone of Afar National Regional State Ethiopia (Figure 1). The area is at an average elevation of about 740 meters above sea level. The climate of the area is classified as semi-arid to arid. According to the data obtained from the meteorological station of WARC, Amibara irrigation project area is characterized by bimodal rainfall pattern. The mean annual rainfall, maximum and minimum temperature recorded are 571.3 mm, 34.3 and 19.1 ^{o}C, respectively (Figure 2). The major crop grown is Cotton, with minor crops including Maize, Wheat, Sesame, Banana and Vegetables in some areas of the research center (Ashenafi, 2015). Currently, the state farmland has been changed to sugarcane plantation. The soil of the study area is predominantly Eutric Fluvents; order Fluvisols followed by Vertisols occupying about 30 % of the total area (Italconsult, 1969; Halcrow and Partners 1982). There is wide-spread occurrence of salinity and sodicity problem in irrigated area of Amibara irrigation project area (Gedion, 2009; Frew, 2012, Ashenafi, 2015).

Sample Collection, Method of Sampling and Preparation Sampling units

Soil sample collection was conducted during the months of September and October 2014.

Sample collection was based on the information obtained from reconnaissance survey and topographic map (scale 1:50,000) of the study area, two hundred sampling spot areas were identified from topographic map (Halcrow and Partners, 1989). Accordingly, a total of 400 composite auger samples were collected at a soil depth of 0-20 and 20-40 cm using systematic sampling technique. All 400 soil samples were analyzed for critical salinity and sodicity parameters. Based on the analysis, the study area was classified into 6 mapping units: non-saline non-sodic and saline soils in Vertisols; whereas in Fluvisols, non-saline non-sodic, saline, saline-sodic and sodic soils

(Figure 3). From each mapping units, three representative soil sampling areas were selected to homogenize in preparation of composite soil sample from those collected soil samples. Then, with two depths, a total of 36 soil samples were used for the selected soil fertility parameter. In general, about 1 kg of each composite soil sample was bagged, properly labeled, and transported to the laboratory for analysis.

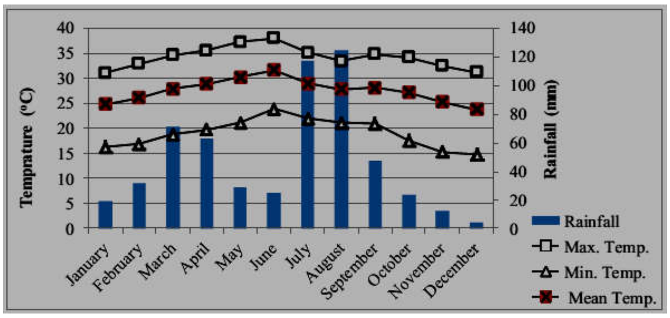


Figure 2. Mean monthly rainfall, and minimum, maximum and mean temperatures of the study area

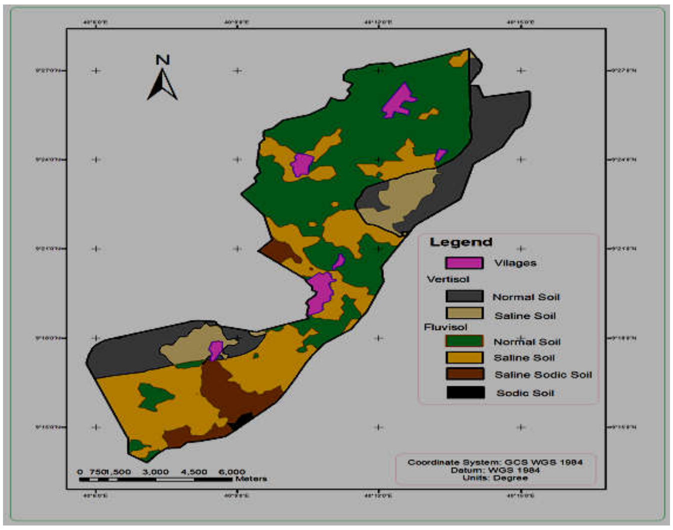


Figure 3. Map of spatial distribution of surface salt affected soils in AIP areas

Soil sample preparation and Lab. Analysis

The collected soils were air-dried on plastic trays, gently crushed using pestle and mortar and passed through a 2 mm sieve. Particle size distribution was determined by the hydrometer method (Bouyoucos, 1962). Once the sand, silt and clay separates were calculated in percent, the soil was assigned to a textural class based on the soil textural triangle using International Soil Science Society system. Soil reaction (pHe) and electrical conductivity (ECe) were determined from saturated paste extract following the methods described by (FAO, 1999). Organic carbon was analyzed by wet oxidation with potassium dichromate ($K_2Cr_2O_7$) in a sulfuric acid medium (Walkley and Black, 1934). Percent organic matter content of the soils was estimated by multiplying the value of percent organic carbon by the conversion factor of 1.724. Total Nitrogen was analyzed using the Kjeldahl digestion, distillation and titration method as described by Blake (1965) by oxidizing the organic matter in concentrated sulfuric acid solution (0.1N H_2SO_4). Available phosphorus was determined calorimetrically using spectrophotometer after the extraction of the soil samples with 0.5 M sodium bicarbonate ($NaHCO_3$) adjusted at pHe 8.2 following the Olsen extraction method as described by Olsen *et al.* (1954). Available potassium was measured by flame photometer from neutral normal ammonium acetate extraction (Kundsen *et al.,* 1982). The cation exchange capacity (CEC) of the soils was determined by the neutral normal ammonium acetate method according to the percolation tube procedure (Van Reeuwijk, 1992). Basic water soluble cations (Ca^{2+} and Mg^{2+}) were determined by atomic absorption spectrophotometry and Na^+ flame photometer, and expressed as mmolc l^{-1} of extract as described (Melese and Gemechu, 2010). SAR value was determined proportion of water soluble sodium to calcium plus magnesium in the soil and is expressed in an equation.

$$SAR = \frac{[Na^+]}{\sqrt{[Ca^{2+} + Mg^{2+}]/2}}$$

Basic water soluble anion (Cl^+, $CO_3^{2+}$and HCO_3^+) were determined by titration and SO_4^{2+} spectrophotometry, and expressed as mmolc l^{-1} of extract as described (Melese and Gemechu, 2010). Calcium Carbonate (CaCO3) was determined by acid neutralization method (Melese and Gemechu, 2010).

Statistical Analysis

An analysis of variance were used to test differences in total N, available P and available K across the different salt affected soil classes and soil depth. For statistically different parameters ($P \leq 0.05$), means were separated using the Least Significant Difference (LSD) comparison test. Correlation analyses were also carried out to detect functional relationships among key soil variables.

Mapping of Selected Soil Fertility Parameters

Salt affected soil map was developed by subjecting the GPS readings, salinity and sodicity parameters to the Arc View GIS 10.1 and the degree of salinity and sodicity extent which is expressed as a ECe and SAR value was categorized on the bases of the rating suggested by (USSLS, 1954). Based on this, the study area was demarcated and then categorized in to six mapping units. Finally, selected soil fertility parameters (total N, available P and available K) were mapped.

RESULT AND DISCUSSTION

Salt affected soil classes and Soil characteristics

The salt affected soil classes characterized form electrical conductivity and sodium absorption ratio of the saturated paste. According to USSLS (1954) classifications, significant parts of Fluvisols were characterized as non-saline non-sodic, saline, sodic and saline sodic soils. Around 27.51 % in Fluvisols and 8.76 % Vertisols of AIP area are saline soils with ECe greater than 4 dS m^{-1} and SAR less than 13. About 6.36 % in Fluvisols of the area is mapped as saline-sodic soils with ECe and SAR values greater than 4 dS m^{-1} and 13, respectively. Approximately 0.33 % of Fluvisols in AIP area are sodic soils with ECe less than 4 dS m^{-1} and SAR greater than 13. Among the two types of soils, significant area of farms under the light textured Fluvisols were affected by salinity and sodicity problem; where as in Vertisols, the extent of area affected by salinity was less severe. Moreover, soils with either of sodic or saline-sodic category have not been identified under Vertisols.

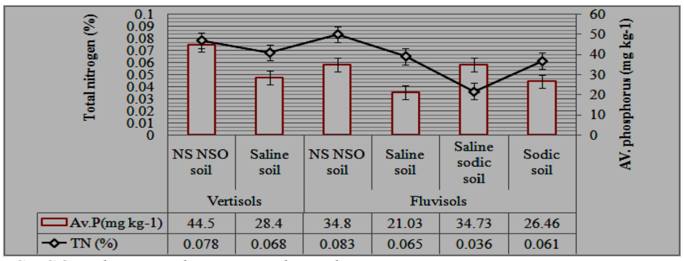
Table 1. Area coverages of salt affected soils class on Fluvisols and Vertisols of AIP area at depth of (0-20 cm)

No.	Salt affected soils class	Area (ha)	Area (%)
Fluvisols			
1	Non-saline non-sodic soils	6555.99	44.33
2	Saline soils	4068.26	27.51
3	Saline-sodic soils	940.38	6.36
4	Sodic soils	48.33	0.33
Vertisols			
5	Non-saline non-sodic soils	1879.78	12.71
6	Saline soils	1294.84	8.76
	Area	14787.58	100 %

The salt affected soil classes of the study area had textural classes ranging from clayey to silt clay loam. The overall range of sand, silt and clay was from 6.42 to14.98 %, 31.16 to 55.46 % and 35.92 to 60.72 %, respectively in the study area. The soil reactions were found to range from Neutral to strongly alkaline with a pHe ranging from 7.20 to 8.60 with a mean value of 7.90. The "ideal" soil pHe is within a range from a Neutral pHe of 6.6 to slightly alkaline pHe of 7.5. It has been established that most plant nutrients are moderately available to plants within this pHe range, plus this range of pHe is generally medium compatible to plant root growth (Tisdale, 2002). The electrical conductivity, organic matter and SAR were ranges 0.41 - 93.94 dS m^{-1}, 0.73 - 1.75 %, and 0.68 - 40.29, respectively in the study area.

The influence of salt affected soil on Total nitrogen

Nitrogen content lower under salt-affected soils are characterized by high concentrations of soluble salts (Lodhi *et al.,* 2009). The total nitrogen contents generally followed similar trends with the soil organic matter contents. The mean values of soil total nitrogen contents showed significant ($P \leq 0.05$) differences between the salt affected soil classes as well as the soil depths in both soil types, except in Vertisols where non-significant differences were observed between the salt affected soil classes. In both soil types, interaction effect was non-significant (Appendix Table 1). The result further indicates that the mean values of total N under non-saline non-sodic soil were significantly higher than other salt affected soils in Vertisols (0.078%) and Fluvisols (0.083%). On other hand, the lowest values were recorded in saline soil (0.068) for Vertisols and saline-sodic soil (0.036 %,) for Fluvisols (Figure 4). In general according Tekalign (1991), total nitrogen content of the studied areas was ranges from low to very low status in both soil types (Figure 4 and 5).



NS NSO soil; Non-saline non-sodic soil

Figure 4. Influence of salt affected soil class on Total nitrogen and Available phosphorus of Vertisols and Fluvisols in the study area

The main reasons for the low N status in the soils of the study areas could be due to volatilization loss of N in the form of ammonia which is likely to occur in alkaline soils (sodicity problem); generally low input of organic matter content in salt affected soils; high leaching losses of N in the form of NO_3 under saline soil; its induced biological stress to microbial assemblages that resulted in smaller and less efficient microbial communities for nitrogen mineralization. This finding is supported by different reports (Rao and Batra, 1983; Wichern *et al.,* 2006; Jackson and Vallaire, 2009; and Nacide *et al.,* 2013). This may result in total N limited for crops in salt affected soils.

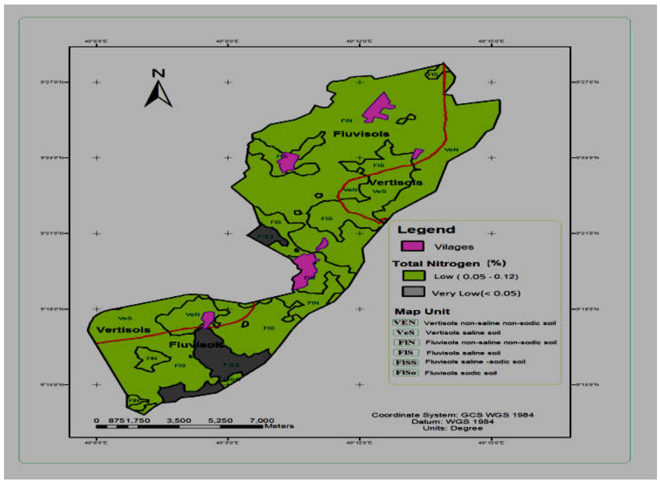


Figure 5. Spatial variability of Total Nitrogen on the surface soils of study area

The total nitrogen content significantly decreased from surface soil (0-20 cm) to the sub surface soil (20-40 cm) in both soil types. It decreased from 0.085% to 0.061 % in Vertisols and from 0.067 to 0.055 % in Fluvisols (Figure 6). The result presented in this study agreed with the report of Yacob (2015).

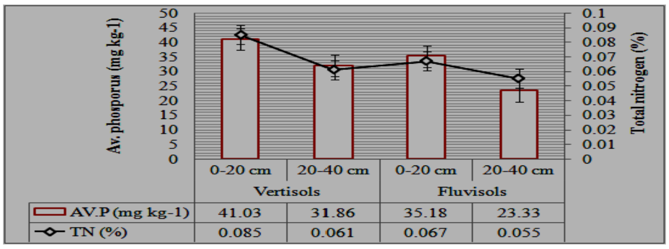


Figure 6. Influence of soil depth on Total nitrogen and Available phosphorus of Vertisols and Fluvisols in the study area

The influence of salt affected soil on Available phosphorus

Phosphorus has been called the "Master key to agriculture". Because low crop production more often due to lack of phosphorus than the deficiency of other elements except nitrogen (Tandon, 1997). The mean values of soil Available P contents showed significant ($P \leq 0.05$) differences between the salt affected soil classes, soil depths and their interactions in both soil types (Appendix Table 1). The mean values P content of non-saline non-sodic soil (44.50 mg kg^{-1}) was significantly higher than the P contents of saline soil (28.40 mg kg^{-1}). On the other hand in Fluvisols, the mean values of P content under non-saline non-sodic soil (34.80 mg kg^{-1}) and saline sodic soil (34.73 mg kg^{-1}) were statistical indifferent and higher than saline soil (21.03 mg kg^{-1}), and sodic soil (26.46 mg kg^{-1}) (Figure 4). According to the ratings of Cottenie (1980), the soil available P status of the study area could be rated as high to very high in both soil types. It was very high in all salt affected soil categories of both soil types except in saline soil of

Fluvisols. Commonly, the variations in available P contents in soils are related with the presence of free $CaCO_3$ in calcareous soils, the degree of P-fixation in Ca and continuous alluvial deposits as sources P fertilizer indicated by Iqbal *et al.* (2011). In addition to this is possibly attributable to strongly alkaline condition of the soil (pHe > 8.2) increase the available P (Deshmukh, 2012). soil. The result presented in this study agreed with the results reported by many authors Chhabra and Thakur (2000) and Mahmood *et al.* (2013). According to the rating of available P given by Cottenie (1980), spatial variability of surface soil layer in salt affected soil class qualify for very high range in both soil types, except for saline soil of Fluvisols which was rated as high available P status (Figure 4 and 7).

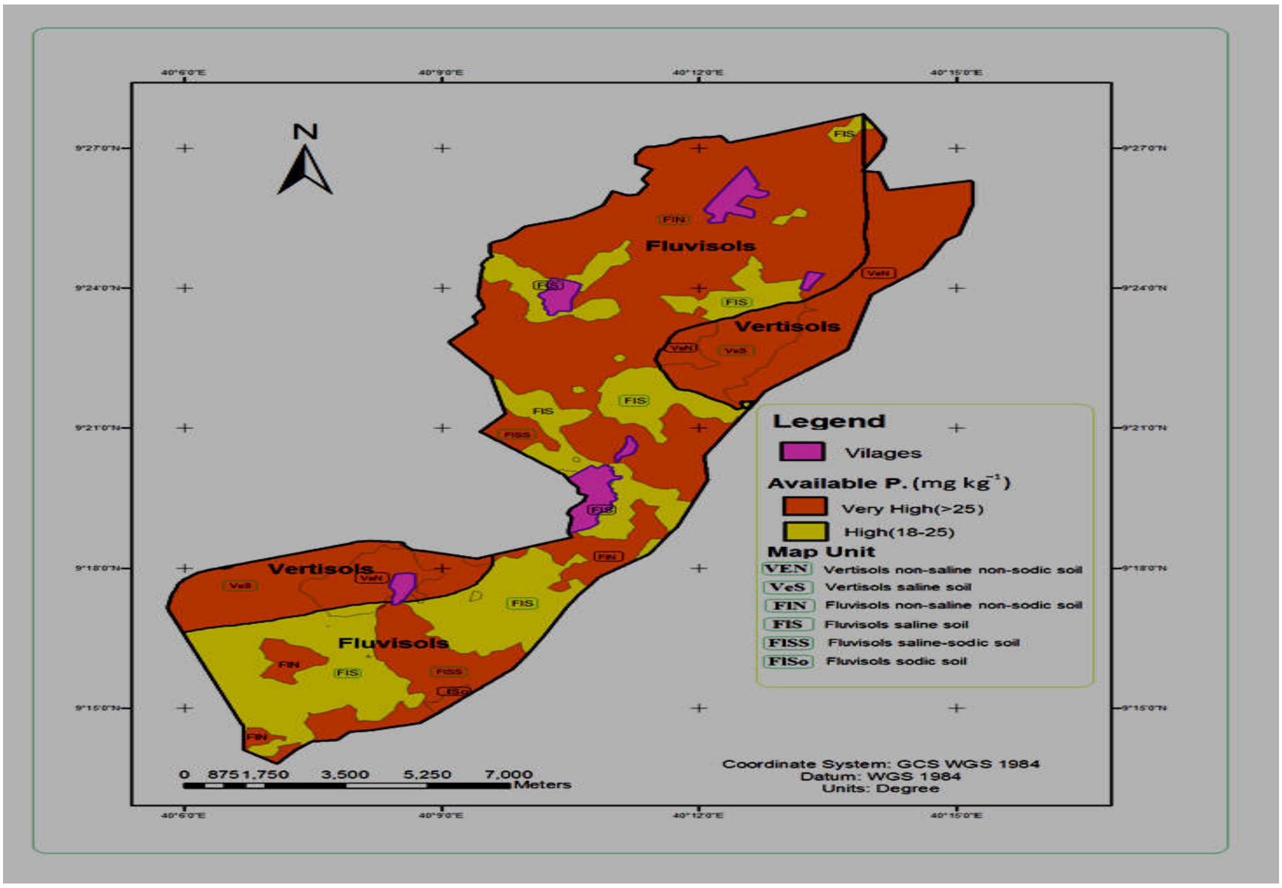


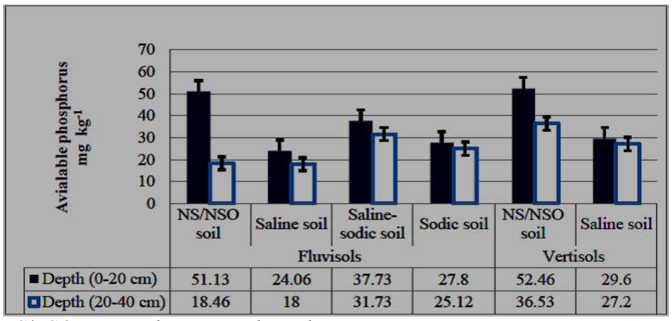
Figure 7. Spatial variability of available phosphorus surface soils on the study area

In most soil types, available P tends to decrease at the lower depth. The mean values of available P significantly ($P \leq 0.01$) decreased from 41.03 mg kg^{-1} and 35.18 mg kg^{-1}in the surface (0-20 cm) to 31.86 mg kg^{-1}and 23.33 mg kg^{-1} in the subsurface (20-40 cm) soil layers of Vertisols and Fluvisols, respectively (Figure 6). Available P showed redaction from surface to sub-surface soil layer in both soil types studied area. The decrease in available P at the lower soil depths may be related to the decrease in organic matter from surface soil to sub surface soil. In addition to this, under aerobic soil conditions, addition of organic matter at surface layer of soil has been reported to decrease P sorption and increase P desorption (Fageria, 2009). The interaction effect of salt affected soil class by soil depth showed that the highest values (51.13 mg kg^{-1}, 52.46 mg kg^{-1}) were recorded at the surface (0-20 cm) layer of non-saline non-sodic soils in Vertisols and Fluvisols, respectively. The lowest interaction values of available P sub-surface layer of saline soil 18.0 mg kg^{-1} and 27.2 mg kg^{-1}were recorded under Fluvisols and Vertisols respectively (Figure 8). This might be the relatively lower availability of P in saline soil may be due to the high concentration of calcium and magnesium in the soil which results in precipitation of insoluble calcium phosphate compounds and decreases available P. Furthermore, these may indicate lower addition of organic matter and temporally OM mineralization also under saline soil than non-saline non-sodic

The higher values of soil available P could also be attributed to the presence of seasonal additions of phosphoric rich sediments through Awash River deposition during the course of irrigation practices. This situation could be confirmed considering chemical fertilization like phosphorus and potassium for the last three decades on Fluvisols and Vertisols with different test crops did not give any positive response (Melese *et al.,* 2016). In general, the higher contents of available P observed in the soil of the studied area was in agreement with the results reported by many authors (Tekalign and Haque, 1991; Wondimagegne and Abere, 2012).

The influence of salt affected soil on Available potassium

Total K present in the soil, the largest portion (90-98%) is found in a relatively unavailable form to plants whereas only 1 to 2% of the soil K is readily available to plants (Tahir, 2009). Available potassium was significantly ($P \leq 0.01$) affected by salt affected soil class in both Vertisols and Fluvisols, whereas it was non-significantly ($P > 0.05$) affected by the soil depth and interaction of salt affected soil class by soil depth in both soil types (Appendix Table 1). The highest values (683.15 mg kg^{-1} and 707.20 mg kg^{-1}) were recorded under the saline soil in Vertisols and Fluvisols respectively, whereas the lowest values (475.60 mg kg^{-1} and 345.15 mg kg^{-1}) were recorded under non-saline non-sodic soil of Vertisols and sodic soil of in Fluvisols respectively (Figure 10).



NS/NSO= Non-saline non-sodic soil

Figure 8. Interaction effect of salt affected soil class and soil depth on amount of Available phosphorus in Vertisols and Fluvisols

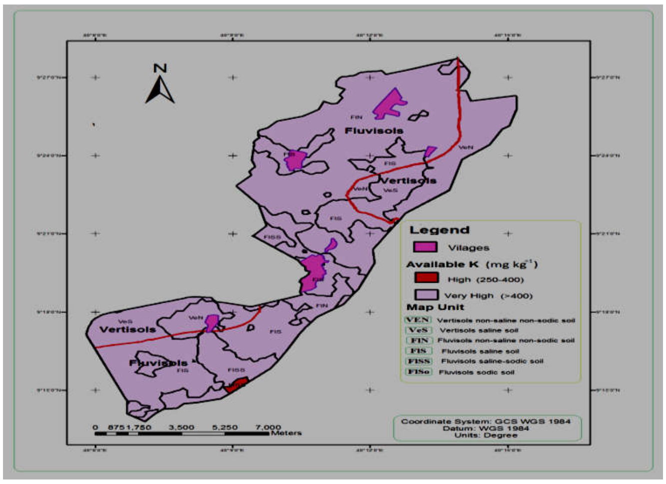
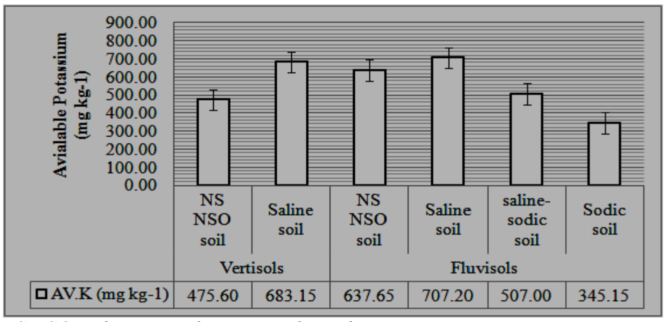


Figure 9. Spatial variability of available potassium on the surface soils of the study area



NS NSO soil = Non-saline non-sodic soil

Figure 10. Influence of salt affected soil class on Available potassium of Vertisols and Fluvisols in the study area

As the result shows, the relatively higher availability of K in saline soil could be due to the high concentration of water soluble potassium under saline soil than other salt affected soils as indicated by (Bar-Tal *et al.,* 1991). However, under saline and sodic conditions, K fertilization management may need to be modified because of K competition with other cations and especially Na in the plant, and to the effects of salinity on K reactions in soils (Bar-Tal *et al.,* 1991). According to the rating of Landon (1991), the available potassium on surface soils of the study are arranges from high to very high (Figure 9 and 10). Firstly, this could be due to the weathering of K and other cations rich igneous rocks and their primary minerals in rift valley system that is characterized by volcanic activities. These include granites, feldspars and aluminosilicates of potassium and sodium rich parent materials (Halcrow and Partners, 1989). Secondly, the higher values of soil available K could also be attributed to the presence of seasonal additions of potash rich sediments through Awash River deposition during the course of irrigation practices. On the other hand, there was no significant difference in K content with depth in both soil types. Numerically, available K values of 553.95 and 586.30 mg kg^{-1} were recorded in the surface layer Vertisols and Fluvisols respectively while it was 586.95 and 512.20 mg kg^{-1} in the sub-surface layers Vertisols and Fluvisols, respectively (Figure 11). The higher accumulation of soluble salts in the subsurface layer of Vertisols might have contributed to the higher available potassium at sub-surface layer of soil depth and also the reverse was true for Fluvisols. This is due to the smaller pore size of Vertisols than Fluvisols that contributed to the movement of water soluble potassium were reducing at surface of Vertisols. In general, the higher contents of available K observed in the soils of the study area is in agreement with the result reported by (Melese and Taye, 2012; Melese *et al.,* 2016).

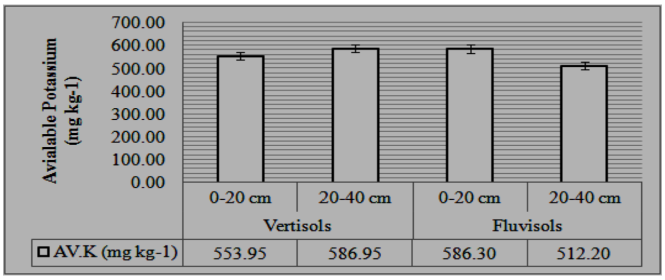


Figure 11. Influence of soil depth on Available potassium of Vertisols and Fluvisols in the study area

The correlation effects total nitrogen, available phosphorus and potassium with salt affected soil parameters

Simple correlation studies between total nitrogen, available phosphorus and available potassium were made with some soil parameters as shown in Table 2. Pearson's correlation matrix analysis, soil total nitrogen were significantly ($p \leq 0.01$) and negatively correlated with sodium adsorption ratio (SAR) with r values of -0.58** and HCO_3^- (r = -0.60**), whereas positively correlated with organic matter (r = 0.78**) (Table 2). This could reveal the existence of high sodium content, which is caused by the hydrosis reactions with OH^-, CO_3^{-2} and HCO_3^- into the soil solution and retained as sodium salt (Na_2CO_3 or $NaHCO_3$). These will affect the growth of plant and it results in low input of organic matter content in salt affected soils. In addition to this, it's induced biological stress to microbial assemblages that resulted in smaller and less efficient microbial communities for nitrogen mineralization. This result corroborates the reports of (Lodhi *et al.,* 2009; Monaco *et al.,* 2010). In general, salt-affected soils are characterised by high concentrations of soluble salts and low organic matter and nitrogen content (Lodhi *et al.,* 2009). Association of available P with basic anions (Cl^-, CO_3^{-2} and HCO_3^-) were positively correlated (r) value of 0.58**, 0.38* and 0.36* respectively, while negatively associated with $CaCO_3$ (r = -0.34*) (Table 2). The association result farther more, available P value (r) with pHe and SAR were 0.21 and 0.26 respectively; it means that available P was positively correlated with pHe, and SAR. The probably reason for positive correlation of available P and soil reaction (pHe), high amount of available phosphorous in these soils with pHe above

8.2 might be the presence of sodium that increases phosphate availability by formation of soluble sodium phosphate (Wondimagegne and Abere, 2012). In addition to this, high concentration of calcium carbonate in the soil which results in precipitation of insoluble calcium phosphate compounds and decreases available P. In general, the correlation results obtained from this study are in agreement with the findings reported by various authors (Tisdale *et al.,* 2002; Qadir *et al.,* 2003; Ghafoor *et al.,* 2004 Mahmood *et al.,* 2013).

Table 12. Pearson's correlation matrix between total nitrogen, available phosphorus, and available potassium made with some soil parameters

Soil parameters	Total nitrogen (TN)	Available phosphorus (Av.P)	Available potassium (Av.P)
Clay	0.18^{NS}	0.14^{NS}	0.32*
Silt	-0.36*	-0.27^{NS}	-0.30^{NS}
Sand	0.27^{NS}	0.20^{NS}	-0.10^{NS}
pHe	-0.07^{NS}	0.33*	0.58**
ECe	-0.29^{NS}	-0.11^{NS}	0.33*
SAR	-0.58**	0.32*	-0.49**
OM	0.78**	-0.29^{NS}	0.28^{NS}
Ca^{2+}	0.31^{NS}	-0.23^{NS}	0.52**
Mg^{2+}	0.36*	0.04^{NS}	0.26NS
Na^{+}	-0.52*	0.23^{NS}	-0.43*
CEC	0.15^{NS}	0.03^{NS}	0.34*
$CaCO_3$	-0.05^{NS}	-0.34*	-0.37*
Cl^{-}	0.25^{NS}	0.53**	0.16^{NS}
CO_3^{2-}	-0.08^{NS}	0.38*	-0.50**
HCO_3^{-}	-0.60**	0.36*	-0.34*
SO_4^{2-}	0.08^{NS}	-0.18^{NS}	0.39*

**significant at p = 0.05; **significant at p = 0.01 and NS, non-significant*

Pearson correlation matrix of available K with clay, soil reaction (pHe), ECe, CEC, water soluble Ca and SO_4^{2+} were significant and positively correlated (r) value of 0.32*, 0.58**, 0.33* 0.34*, 0.52** and 0.39*, respectively, while significant and negatively correlated with SAR (r = -0.49**), CO_3^{2-} (r = -0.50**) and HCO_3^{-} (r = -0.34*) (Table 2). The probably reason for positive correlation of available K and soil reaction (pHe), decreasing soil reaction (pHe) to around 7 may facilitate for the available of potassium in the soil solution. In general, the correlation results obtained from this study are in agreement with the findings reported by various authors (Bar-Tal *et al.,* 1991).

Conclusion

From the study, it was possible to conclude that total nitrogen, available phosphorus and available potassium soil parameters significantly vary among different salt affected soil classes and soil depths. It is apparent from this study that available phosphorus and available potassium appeared to be sufficiencies in all salt affected soil classes and soil depths. In addition to this, further research is required regarding the annual input/output balance of these nutrients to formulate sound P and K management strategies in long-term basis. Even though total nitrogen was ranged from low to very low soil test results, observed in the study area also exposes the available organic matter to moisture, aeration, high temperature and other decomposing agents, facilitating the fast degradation and mineralization of the available organic matter and low input of crop residue due to salinity and sodicity thereby reducing the TN. However, in order to predict nitrogen fertilizer requirements, the soil test for crop response in field trials for the major crops grown in the area and the optimum application rates, time and methods of fertilizers application, synergetic and antagonistic effects of excess ions and balanced fertilizer application on crop productivity need to be studied.

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APPENDIX

Table A1. Mean square (MS) and results of two-way analysis of variance of under total nitrogen, available phosphorus and available potassium salt affected soil Class and two soil depths in the AIP areas

Soil parameters	Mean squares for source of variation‡				
	SAS (3)	Soil depth (1)	SAS *depth (4)	Error (14)	CV (%)
Fluvisols					
Total nitrogen	0.00**	0.00*	0.0002 NS	0.008	25.24
Available phosphorus	272.29**	842.77**	292.60**	3.97	23.55
Available potassium	152409.30**	32944.80 NS	14349.3 NS	62.62	19.76
Vertisols					
	SAS (1)	Soil depth (1)	SAS *depth (1)	Error (6)	CV (%)
Total nitrogen	0.00 NS	0.00*	0.000 NS	0.01	19.15
Available phosphorus	777.63**	252.08**	137.36*	2.63	12.50
Available potassium	152618.4**	3296.7 NS	37062.9 NS	54.79	16.63

‡Figures in parenthesis = Degrees of freedom; * = Significant at P < 0.05; ** = Significant at P < 0.01; NS = Not significant at P > 0.05; CV = Coefficient of variation.

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