Characterization and Classification of Salt Affected Soils of Amibara Irrigation Project at Middle Awash, Afar

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Introduction

Salt affected soils are common in most parts of the dry (arid and semi-arid) regions where evapotranspiration exceeds precipitation either permanently or during parts of the year (FAO, 1988). Over 6 million ha of the lands of our planet are estimated to be lost each year to salinity, sodicity and drainage problems (Gupta and Abrol, 1990). Salinity is an abiotic stress that severely limits crop growth and development, productivity, and causes the continuous loss of arable land, which results in desertification in arid and semi-arid regions of the world (Shirokova *et al*., 2000; Qadir *et al*., 2007; Pons *et al*., 2011; Shahbaz and Ashraf, 2013). Ethiopia has immense potential for expanding irrigated agriculture (Negash and Seleshi, 2004) in which most of the irrigation developed today is located in the Awash River basin where the irrigation water management is under problem (FAO, 2003; 2012), accordingly large area is affected by salinity (FAO, 1988). Moreover, primary and secondary salinization are being occurred in the Amibara irrigation project (AIP) and the problem is through time become increasing (Zeleke *et al*., 2014; Frew *et al*., 2015; Ashenafi and Bobe, 2016; Melese *et al*., 2016). As a result, good irrigation water management is required (Mohamed and Tessema, 2013).

According to Mohammad *et al*. (2015), irrigated lands now produce 40% of the food supply but due to inappropriate irrigation practices and the development of salt affected soils, production has been declining. Many other authors reported effect of soil salinity on plant growth, on socioeconomic and live hood of farmers (Sileshi *et al*., 2015, Sileshi 2016; Asad *et al*., 2019; Bethel *et al*., 2019; Birhane *et al*., 2019). Furthermore, the productivity of some farm plots has reduced and extent of abandoned lands is increasing with time, particularly, where irrigation has been practiced for long periods of time. The causes of salinity/sodicity, which vary between countries and regions, need to be identified, assessed and monitored carefully so that they can be managed and controlled (FAO, 2009). The overall objective this study was to investigate the current status of soil salinity of Amibara irrigation project.

Material and Methods

Description of the study area

Amibara irrigation project is located at Amibara District, Gebiresu zone of Afar National Regional State, covering a long broad alluvial plain along the right bank of the Awash river. The study area lies on a long broad alluvial plain along the right bank of the Awash River, which includes Melka Sedi, Melka Werer and Ambash Sheleko irrigated farms with a gross command area of more than 15,772.7 ha. The area has an elevation ranging from 724 to 745 m with average of about 734.5 meters above sea level. It is located at 9° 14’ 1.2" to 9°27’12.1" N latitude and 40° 6’ 19.2" to 40°14’26.1" E longitude in the Middle Awash Valley. The climate is semi-arid with a bimodal rainfall of 533 millimeters annually. The mean minimum temperature is 15.2^{O}C in December and 23^{O}C in June, while the mean maximum temperature is 32.5^{O}C in December and 38^{O}C in June for cool and main season, respectively.

The soils of the study area are predominantly Eutric Fluvents, order Fluvisols followed by Vertisols occupying about 30% of the total area (Halcrow, 1983; Wondimagegne and Abere, 2012). There is deficiency of micronutrient Fe, Zn and Mn in the micronutrient which needs neutralizing soil reaction (pH) but also minimizing toxicity effect of B and Mo (Ashenafi *et al*., 2016). Most parts of the soils of the area is affected by salinity (Heluf, 1985; Tena, 2002; Gedion, 2009; Wondimagegne and Abere, 2012; Frew *et al*., 2015; Ashenafi and Bobe, 2016; Melese *et al*., 2016) and ground water is shallow (Frew, 2015; Lemma 2018). The main problem of the area is the invasion of a thorny shrub named as *Prosopis julifora*, where most salinity and sodicity/alkalinity impacted abandoned areas are covered by *Prosopis julifora* (Zeraye, 2015).

Soil Sample Collection and Preparation

At the beginning, a general visual field reconnaissance survey was carried out and secondary information of the area were gathered: physical nature of the soil, farming system, surface soil color, drainage condition, land use system, vegetation cover, slope and cropping history, etc. Soil samples were collected at different depths (0 – 30, 30 – 60 and 60-90cm), using auger disturbed soil sampler. Each sampling points were geo-referenced. Then, the soil samples were bagged, properly labeled, and transported to the laboratory for analysis. The collected soil samples were dried in shade, powdered with wooden mallet, passed through 2 mm sieve and stored in clean sample box for analysis (Jackson, 1973). Following standard test procedures, soil samples were analyzed for selected physico-chemical properties at Werer Agricultural Research laboratory.

Soil laboratory Analysis

Soil paste extract of ECe and pHe was measured potentiometrically using a digital electrical-conductivity and pH-meter (Richards, 1954). Cation exchange capacity (CEC) of the soil was determined by 1M ammonium acetate (NH_4OAc) saturated samples at pH 7 (Van Reewijk, 1992). Samples were also analyzed for exchangeable sodium, potassium, calcium and magnesium extracted in 1M ammonium acetate pH 7 (Watanabe and Olsen 1965). Derived parameters such as percentage base saturation (PBS) and Exchangeable sodium percentage (ESP) were computed as the percentage of the sum of exchangeable bases and Na^+ divided to the CEC of the soil, respectively, as follows:

$$\text{PBS}\ (\%) = \frac{\text{Exchangeble bases}\ (\text{Ca}^{2+}, \text{Mg}^{2+},\ \text{K}^{+}, \text{Na}^{+})}{\text{CEC}} * \ 100$$

$$\text{ESP}\ (\%) = \frac{\text{Exchangeable bases}\ (\ \text{Na}^{+})}{\text{CEC}} * \ 100$$

Where, concentrations were in cmol (+)/kg of soil.

The other soil sodicity parameter computed was sodium adsorption ratio (SAR), from the relative concentrations of sodium, magnesium, and calcium (Richards, 1954).

Classification and Mapping Method

The soils were classified into the different salt affected soil classes based on the criteria established by Richards (1954) as presented in the Table 2. The spatial mapping of the soil salinity and sodicity parameters was carried out in GIS (ArcGIS 9.2) following Geostatistical analysis that employs the use of simple point kriging and simulations (ESRI, 2010).

Table 1. Guideline for Classification of salt affected soils

Salt affected Soil type	ECe dS/m)	ESP	Reaction (pHe value)
Saline	> 4	< 15	<8.2
Saline sodic	> 4	> 15	<8.2
Sodic (Alkali)	< 4	> 15	8.2-10
Non-saline non-sodic	< 4	< 15	About neutral

Result and Discussion

Electrical Conductivity (ECe)

Soil electrical conductivity of Amibara irrigated farm area varied between 0.22 to 93.44; 0.16 to 90.16 and 0.29 to 64.58 dS/m, respectively at a soil depth of 0-30, 30-60 cm and 60-90 (Table 2). As it can be seen from Table 3 and Figure 1 significant proportion of irrigated land exhibited saline soil property with varying degree of severity. Out of the total surveyed area saline soil in irrigated land constitute 62.31 % of surface soil has been affected by soil salinity and the distribution of salinity decreased with increasing depth, in the order of 58.36 % and 52.86 %, at 30-60 and 60-90 cm soil depths, respectively (Table 4). Saline sodic also cover from the total of irrigated land 10.23, 9.71 and 9.67 % in decreasing trend with depth for 0-30, 30-60 and 60-90 cm, respectively (Table 3).

Table 2. Maximum and minimum value of Amibara irrigation project soil analysis result

Depth (cm)	Range	pHe	ECe (dS/m)	Exchangeable cations (cmol/kg)			ESP (%)
				Ca + Mg	Na	K	
0-30	Max	8.9	93.94	79.20	57.47	7.64	61.23
	Min	7.15	0.22	27.20	0.42	0.32	0.84
30-60	Max	8.64	90.16	85.60	47.84	5.29	68.00
	Min	7.05	0.16	13.72	0.46	0.36	0.96
60-90	Max	8.65	64.58	76.00	63.61	5.49	60.1
	Min	7.20	0.29	29.64	0.51	0.41	1.00

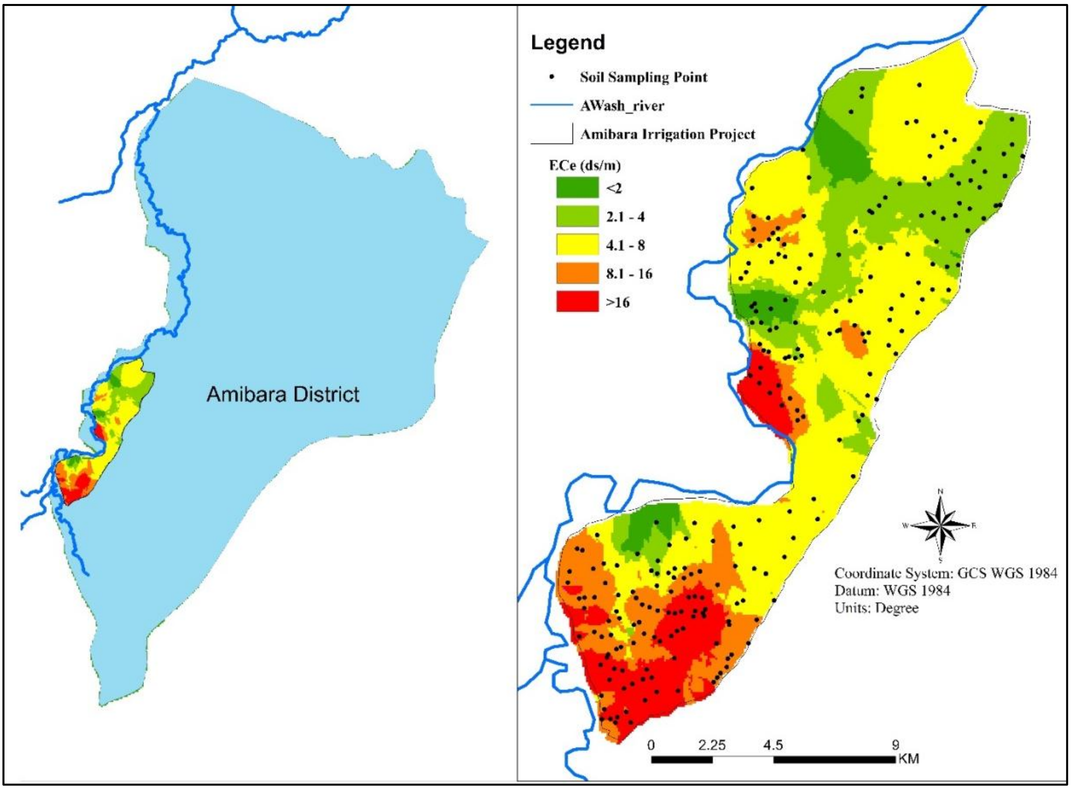

Figure 1: Amibara irrigation project soil electrical conductivity geo-spatial analysis.

Salt distribution

Considering depth-wise distribution soil salinity (ECe) values in irrigated land tend to decrease with increasing soil depth which is typical feature of ground water induced salinization. The result implies that irrigation practice had adversely affected soil property resulting in accumulation of excessive free salts that had led to buildup of sever salinity problem. It is obvious that introduction of irrigated agriculture to virgin lands or its intensification to already cultivated land usually leads to change, often deleterious, affecting the soil quality and ecological balance particularly when poor water management system is practiced. As the case recently that seen in Amibara irrigated farms. Melese *et al*. (2016) reported soils of the AIP are potentially salt affected unless accurate irrigation management implemented secondary salinization and sodiciation buildup. Many authors also reported the cause of salinity in Amibara irrigation project is miss management of irrigation water that raise up ground water (Gedion 2009; Frew, 2015; Lemma, 2018).

Table 3: Class, extent and distribution of salt affected soil of Amibara irrigation Project.

	Amibara irrigation project (15,772.7 ha)		
SAS Class	0-30	30-60	60-90
Normal	27.46	31.93	37.47
Saline	62.31	58.36	52.86
Sodic	0.00	0.00	0.00
Saline sodic	10.23	9.71	9.67
Total	100.00	100.00	100.00

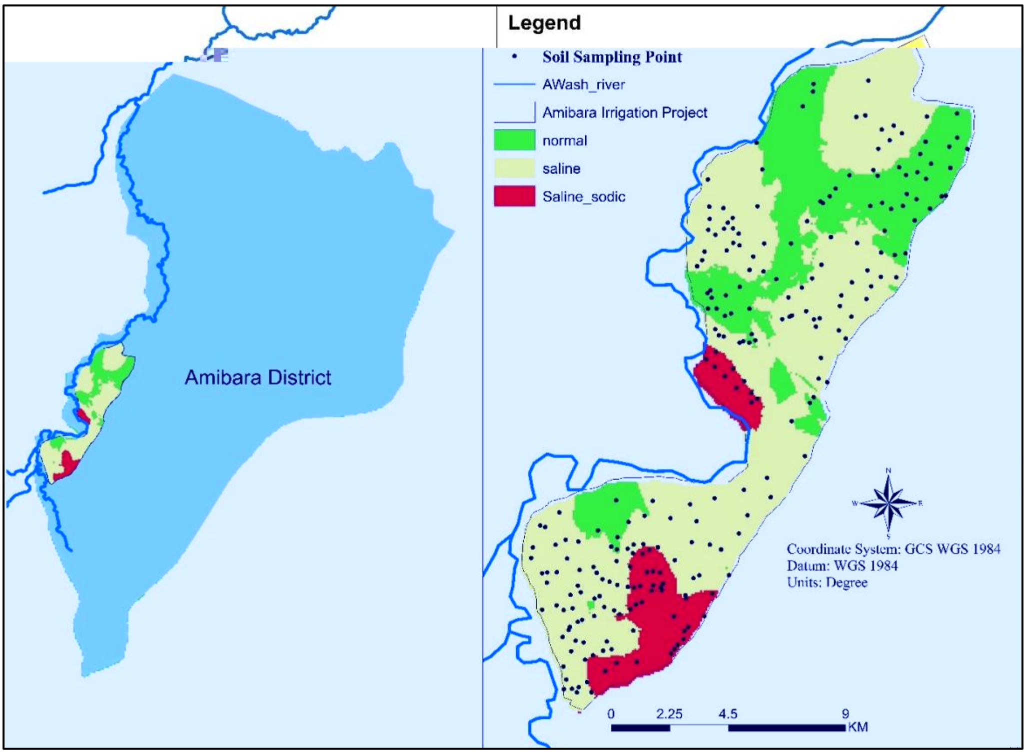

Figure 2: Amibara Irrigation project salt affected soil class geo-spatial analysis. This will be at the end of the parameters

Although irrigation has greatly increased the agricultural production potential, recharge brought by excess application of irrigation water over and above crop and leaching requirements, seepage losses from the irrigation net-work and deep percolation from farm irrigation has accumulated into the underlying groundwater.

Table 4: Extent and distribution of soluble salt/electrical conductivity of Amibara irrigation project

ECe (dS/m)	AIP (15,772.7 ha) salinity distribution (%) at different depth		
Range	0-30 (cm)	30-60 (cm)	60-90 (cm)
<2	5.18	6.40	6.80
2.01-4	22.28	25.53	30.67
4.01-8	47.05	46.72	45.83
8.1-16	13.88	13.82	13.79
>16	11.61	7.53	2.91
Total	100.00	100.00	100.00

Depth to groundwater in most of the irrigated farms of the Middle Awash valley, Amibara area were reported to have been well over 10m below surface during early period of the development (Halcrow, 1983). An investigation by AIP clearly indicated that a minimum of 60cm of excess water was applied annually contributing on the average a 40-50cm depth increment to the groundwater (Source). Rising water table has subsequently led to twin problems of water-logging and associated salinity problems. This has happened because drainage development has not kept pace with irrigation development. Soil salinity is also a serious problem in areas where groundwater of high salt content is used for irrigation (Zeleke *et al*., 2014; Zewdu *et al*., 2017; lemma, 2018).

Soil reaction /pH

Soil pH was found to be varied between slight to moderate alkaline classification. Soil pH of Amibara irrigation project ranged from 7.15 to 8.90 ; 7.05 to 8.64 and 7.20 to 8.65 for soil depth 0-30, 30-60 and 60-90 cm, respectively. As shown in Table 5, surface soil of Amibara Irrigation project constitutes 0.02 % neutral, 13.1 % slightly alkaline, 84.95 %, moderately alkaline, 1.93 % strongly alkaline (Murphy, 1968). Many authors reported the study area had high pH value (Frew *et al*, 2015; Ashenafi and Bobe, 2016). In general, probable reason for the high pHe value of the study area could be attributed to relative abundance of alkaline forming cations and salts of carbonates. In addition to this, the areas have higher evapotranspiration than rainfall, the reason for accumulation of basic cation at surface soil and it result for higher soil reaction.

Table 5: Extent and distribution of soil pH of Amibara irrigation project

Soil pH range	AIP (15,772.7 ha) soil pH distribution (%) at different depth 0-30 (cm)	30-60 (cm)	60-90 (cm)
6.6-7.48	0.02	0.02	0.01
7.49-7.8	13.1	12.54	11.67
7.81-8.4	84.95	82.63	81.72
8.41-9.0	1.93	2.48	3.79
>9.01	0.00	2.33	2.81
Total	100	100	100

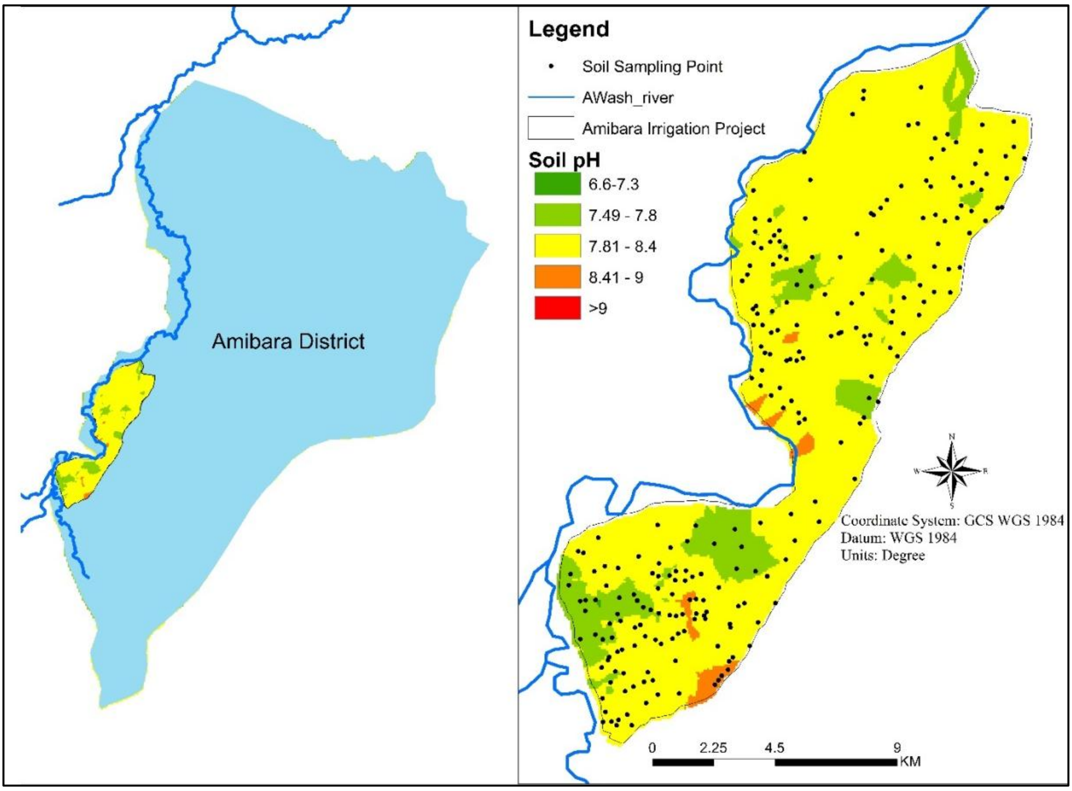

Figure 3: Amibara Irrigation project soil pH geo-spatial analysis.

Exchangeable sodium percentage (ESP)

The value of exchangeable sodium percentage of Amibara Irrigated farm ranged from 0.84% to 61.23%, 0.96% to 68.00% and 1.00% to 60.10% for soil sampled collected at the depth of 0-30cm, 30-60 cm and 60-90 cm, respectively. Geo spatial analysis result show in the Irrigated land sodisity problem could not found separately, however, saline sodic soil cover 10.23% (0-30 cm), 9.71% (30-60 cm) and 9.67 % (60-90 cm) from the total area of Amibara Irrigation Project. Saline sodic problem decrease with increasing depth. Previously presence of sodic soil in the area reported by different researchers (Frew *et al*, 2015; Ashenafi and Bobe, 2016), however this study showed extent and severity of sodisity in the area rapidly expanding. This implies, even if it is of a good quality, would ultimately contribute an appreciable amount of salt to the soil since it contains dissolved materials. Hence, depending on water management practices substantial quantities of salt could accumulate either from the irrigation water or rising ground water table. The total quantity of salt deposited by these two could be quite variable depending on quality as well as on management efficiencies. If salt inputs from such sources are not removed by proper water management practices salinization would become inevitable.

Table 5: Extent and distribution of exchangeable sodium percentage of Amibara irrigation Project

ESP Range (%)	AIP (15,772.7 ha) ESP distribution (%) at different depth			
	0-30 (cm)	30-60 (cm)	60-90 (cm)	Average
<10	84.73	82.10	81.98	82.94
10.01-15	5.03	8.19	8.35	7.19
15.01-20	2.91	3.19	3.81	3.30
20.01-25	2.77	2.61	2.22	2.53
>25	4.56	3.91	3.64	4.04
Total	100.00	100.00	100.00	

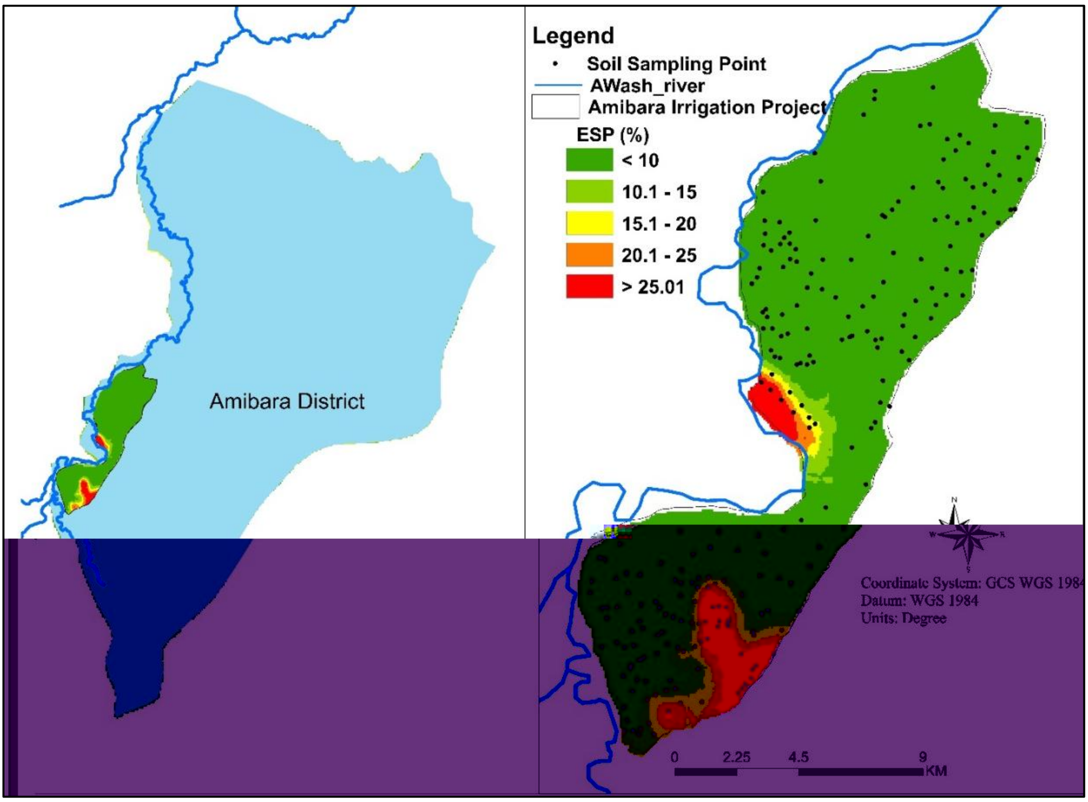

Figure 4: Amibara Irrigation project exchangeable sodium percentage geo-spatial analysis.

Conclusion and Recommendation

At Amibara Irrigation project out of the total irrigated farm area investigated, soils with saline and saline-sodic properties accounts for 62.31 and 10.23 %, respectively. Whereas, only 27.46 % was found to be classified as normal soil condition. The large-scale irrigated farm of Amibara was established without much consideration for proper land development work, land leveling, installation of proper structures for the delivery of irrigation water and provision of drainage facilities for safe disposal of excess water and this leads to raising up water table and salinization. Currently a number of productive fields have already abounded by salinity due to miss-management of irrigation practice and the process is spreading at a faster pace to newly developed land. As a result, there is a need for introduction and adoption of improved irrigation practice to halt buildup and further expansion of irrigation induced salinization problem to achieve more sustainability of the project farms. In line with this focus should also be given to awareness creation among all actors to foster the task of prevention strategy.

References

Asad SQ, Mulugeta M, Ashenafi W, Birhane H, Getnet B, Abeba T and Tesfaye, E. 2019. Improving agricultural productivity on salt affected soils in Ethiopia: Farmers' perceptions and proposals. African Journal of Agricultural Research, 14(21) 897-906, 23

Ashenafi Worku and Bobe Bedadi. 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 Worku, Bobe Bedadi and Muktar Mohammed. 2016. Assessment on the Status of Some Micronutrients of Salt Affected Soils in Amibara Area, Central Rift Valley of Ethiopia. *Academia Journal of Agricultural Research,* 4(8): 534-542.

Bethel Nekir, Lemma Mamo, Ashenafi Worku and Teshome Bekele. 2019. Evaluation of Wheat Varieties/Lines for Salt Tolerance at Different Growth Stages. Greener Journal of Soil Science and Plant Nutrition, Vol. 6(1), pp. 1-7, 201.

Birhane Hailu, Hagos Mahari and Abeba Tesfay. 2019. Screening of some selected Teff Varieties/lines for their salt stress tolerance. Journal of natural science research, 9(3): 53-59.

ESRI. 2010. The Principles of Geostatistical Analysis (3). Retrieved January 20, 2015, from http://maps.unomaha.edu/Peterson/gisII/ESRImanuals/Ch3_Principles.pdf

FAO (Food and Agricultural Organization). 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.

FAO (Food and Agricultural Organization). 2003.The State of Food Insecurity in the World, monitoring progress towards the World Food Summit and Millennium Development Goals

FAO (Food and Agriculture Organization). 2009. Advances in the assessment and monitoring of salinization and status of bio saline agriculture Report of an expert consultation held in Dubai, United Arab Emirates.

FAO (Food and Agriculture Organization). 2012. The State of Food Insecurity in the World, economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition

Frew Abebe, Tena Alamirew and Fentaw Abegaz. 2015. Appraisal and mapping of soil salinity problem in amibara irrigation Farms, middle awash basin, Ethiopia. *International Journal of Innovation and Scientific Research,* 13(1): 298-314.

Gedion Tsegaye. 2009. Surface water-Groundwater Interactions and Effects of Irrigation on Water and Soil Resources in the Awash Valley. MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Gupta RK and Abrol RP. 1990. Salt Affected Soils: Their reclamation and management for crop production. pp. 223-288. In: Lal, R. and Stewart, B.A. Soil Degradation: Advances in Soil Science. Springer-Verlag, New York.

Halcrow. 1983. Water Management Manual. Amibara irrigation project. Water Resources Development Authority, Ethiopia.

Heluf Gebrekidan. 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.

Hurni H, Solomon A, Amare B, Berhanu D, Ludi E, Portner B, Birru Y and Gete Z. 2010. Land degradation and sustainable land management in the highlands of Ethiopia. In: Hurni, H, Wiesmann, U. (eds.), with an international group of co-editors. Global change and sustainable development: A synthesis of regional experiences from research partnerships. Georaphica Bernensia, 5:187-201.

Lemma Mamo Haile. 2018. Impact of water table depth and groundwater quality on occurrence of salt affected soils in Amibara, Middle Awash, Ethiopia Msc Thesis, Haramaya University, Haramaya

Melese Menaleshoa, Ashenafi Worku Wondimagegne Chekol and Girma Tadesse. 2016. Effect of Long-Term Continuous Cotton Mono-Croppingon Depletion of Soil NPK and Changes in Some Selected Soil Chemical Characters on Vertisols and Fluvisols. *Agriculture, Forestry and Fisheries,* 5(5): 163-169.

Mohamed Seid and Tessema Genenew. 2013. Evaluation of soil and water salinity for irrigation in North-eastern Ethiopia: Case study of Fursa small scale irrigation system in Awash River Basin. *African Journal of Environmental Science*, 7(5):167-174.

Murphy HF. 1968. A report on fertility status and other data on some soils of Ethiopia. Collage of Agriculture HSIU. ExperimentalStation Bulletin No. 44, Collage of Agriculture: 551.

Negash W and Seleshi B. 2004. GIS based irrigation suitability analysis. Journal of Water Science and Technology, 8: 55-61.

Pons R, Cornejo MJ and Sanz A. 2011. Differential salinity-induced variations in the activity of H^+-pumps and Na^+/H^+ antiporters that are involved in cytoplasm ion homeostasis as a function of genotype and tolerance level in rice cell lines. *Plant Physiology and Biochemistry,* 49:1399–1409.

Qadir M, Oster J, Schubert S, Noble A. and Sahrawat K. 2007. Phytoremediation of sodic and saline-sodic soils. *Advances in Agronomy,* 96: 197-247.

Richards L. 1954. *Diagnosis and Improvement of Saline and Alkali Soils.* Agriculture handbook. United States Salinity Laboratory, Washington, USA.

Shahbaz M and Ashraf M. 2013. Improving salinity tolerance in cereals. *Critical Reviews in Plant Sciences,* 32: 237–249.

Shirokova YI, Forkutsa and Sharafutdinova N. 2000. Use of electrical conductivity instead of soluble salts for soil salinity monitoring in central Asia. *Irrigation and Drainage Systems,* 14(3): 199-206.

Sileshi Abbi Assefa. 2016. Status of salt affected soils, irrigation water quality and land suitability of Dubti/Tendaho area, north eastern Ethiopia, PhD dissertation, Haramaya University, Haramaya.

Sileshi A, Kibebew K and Amanuel Z. 2015. Temporal and spatial variations of salt affected soils using GIS and Remote Rensing at Dubti/Tendaho state farm, North Eastern Ethiopia, PhD dissertation thesis, Haramaya University, Haramaya, Ethiopia

Tena Alamirew. 2002. Spatial and Temporal Variability of Awash River Water Salinity and the Contribution of Irrigation Water Management on the Development of Soil Salinization in the Awash River Valley of Ethiopia. PhD thesis, University of Agricultural Sciences, Vienna.

Van Reewijk LP. 1992. *Procedures for soil analysis 3rd Edition.* International Soil Reference Center, Wageningen, Netherlands.

Watanabe FS and Olsen SR. 1965. Test of an ascorbic acid method for determining phosphorus in water and sodium bicarbonate extract from soils. *Soil Science Society of America Program,* 29: 405-410.

WMO (World Meteorological Organization). 2005. Climate and land degradation. http://www.wmo.int/web/wcp/agm/agmp.

Wondimagegne Chekol and Abere Mnalku. 2012. Selected Physical Chemical Characteristics of Soils the Middle Awash Irrigated Farm. *Ethiopia Journal of Agriculture Science,* 22:127-142.

Zeleke Teshome, Yusuf Kedir, Girma Abejehu and Ademe Ad inew. 2014. Re- evaluation of some Fields' Land Suitab ility at Kesem Sugar Project. African Journal of Agricultural Science and Technology (AJAST), 2(10): 196-200.

Zeraye Mehari. 2015. The invasion of Prosopis juliflora and Afar pastoral livelihoods in the Middle Awash area of Ethiopia. *Ecological Processes,* 4(13):1-9.

Zewdu, S, Suryabhagavan, KV and Balakrishnan M. 2017. Geo-spatial approach for soil salinity mapping in Sego Irrigation Farm, South Ethiopia. Journal of the Saudi Society of Agricultural Sciences, 16: 16–24.