#7891 GEO-STATISTICAL PREDICTION OF SPATIAL DISTRIBUTION OF SALT-AFFECTED SOILS OF MEKI-ZEWAY FARM AREAS IN ETHIOPIA: BASELINE INFORMATION FOR PRACTICAL IMPLEMENTATION OF PRECISION AGRICULTURE SYSTEM

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ABSTRACT

Salinity and sodicity induced soil degradation are major soil property related environmental constraint with severe negative impacts on productivity and sustainability of both rainfed and irrigated agriculture in arid and semi-arid lowlands of Ethiopia. The spatial prediction, data bases creation and preparation of actionable digital soil salinization/sodiciation pattern maps has a special importance to enable site-specific management system leading to the establishment and execution of Digital Agriculture (DA) in general and Precision Agriculture in particular. Spatially high-resolved digital input layers are the fundamental requirements of space time conscious variable rate application devices in the Internet of Things (IOT)realm to address the with-in-farm-plot soil property variation. This study was conducted at Meki-Zeway farm areas during 2018-2019 with objective to investigate extent and spatial distribution of salt-affected soils and prepare the associated digital database and digital maps. A grid sampling scheme was designed and auger samples were collected at three depths (0-30, 30-60 and 60-90cm). Based on Geo-referenced soil attribute data related to salinity/sodicity was collected from the field and respective laboratory values generated. The spatial prediction and mapping of the unsampled surface from laboratory point values was carried out in opensource GIS environment following geo-statistical interpolation techniques. Statistical surfaces of the salinity/sodicity indicator preliminary layers including EC, ESP and pHe and the final salinity/sodicity distribution predicted raster was generated. The results revealed a widespread occurrence of salt-affected soils of the investigated farm areas being remarkably varied spatially in terms of extent and types of the problems both in vertical and horizontal modes. Larger proportion of the area contained pHe values greater than 7.8 with extreme value of 10.3 and overall range values of ECe and ESP between 0.20-15.30dS/m and 3-58, respectively for the upper 0-30cm soil depth. With increasing soil depth sodicity and alkalinity increased consistently whereas salinity followed the reverse depth-wise distribution. Extent of soils alkalinity and sodicity was more pronounced South-ward (Zeway farm area) than Meki farm area (North-ward). Chloride and bicarbonate salts of calcium and sodium predominate in the salt composition of the saline soils while carbonate and bicarbonate salt of sodium appeared dominant salts in sodic soils contributing to common alkaline reaction of sodic and saline sodic soils of the area. Diverse manifestations of spatial heterogeneity in terms of types and severity among different salt-affected soil classes is highly evident from present study and therefore site-specific, more precise pixel-by-pixel reclametive and ameliorative measures must be taken to account such scenarios- with precision agriculture. The study recommended a similar pathway of preparing the remaining other soil properties to be prepared and included to provide a more complete and unified soil fertility improvement guide and digitally actionable input to AI and IOT tools for effective deployment of precision agriculture and underlines the need for further research on investigation of salinity-sodicity casual factors and development of effective management options.

INTRODUCTION

Widespread occurrence of salt-affected soil in Ethiopia has been well documented (Hawando, 1995; Aredehey et al., 2018; Kidane et al., 2006; Fantaw A (2007).). In recent years salinity and sodicity-induced soil degradation is becoming a major environmental constraint with severe negative impacts on productivity and sustainability of irrigated agriculture in arid, semi-arid and lowlands of the country. Meki-Zeway located in the Central Rift valley zone of the Great Rift Valley system of Ethiopia where soils of the area are naturally salt-affected and prone to secondary salinization. According to Meron (2007) buildup and expansion of salinization and sodiciation in particular is becoming potential threat to sustainability of irrigated farms of the area. Soil salinity and sodicity are spatially variable and temporally highly dynamic. Soil heterogeneity particularly imposed by mosaic distribution of salinity and sodicity is an important management challenge. Such heterogeneity predetermines differences in rehabilitation and management practices. In this regard the spatial prediction, data bases creation and preparation of actionable digital soil salinization/sodiciation pattern maps has a special importance to enable site-specific management system leading to the establishment and execution of Digital Agriculture (DA) in general and precision agriculture in particular. In past only limited studies has been conducted in the area which generally focused on soil taxonomic classification and related aspect where detailed information on extent and spatial distribution of salt-affected soils in the area is lacking. This study, therefore, was executed with objective to investigate extent and spatial distribution of salt-affected soils and prepare the associated digital database and digital maps.

MATERIALS AND METHODS

The study site lies between 7˚ 57' 6.15" N to 8˚ 9' 4.43" N Latitude and 38˚ 42' 36.2" E to 38˚51' 1.17" E Longitude found at 160 km south of Addis Ababa, and at an average altitude of 1628m above sea level. Slope gradients are generally very low, and predominantly lying in the range between 1 and 2%. The area received average annual rainfall of 775 mm and has a mean annual temperature ranging from 12.33 to 26.18°C laying within warm semi-arid lowland agro-climatic zone classification of Ethiopian (MOARD, 2005). The dominant soil type of the study site is Haplic Andosols, Typic Haploxerands (Zewdie 2004) and it is of sandy loam texture. The agro-climatic conditions allow farmers to grow onion (*Allium cepa*), tomato (*Solanum lycopersicum*) and maize (*Zea mays*). A grid sampling scheme was designed and auger samples were collected at three soil depths (0-30, 30-60 and 60-90cm). Following standard analytical method, collected soil samples were analyzed for particle size distribution, pH, EC, CEC, exchangeable bases, water soluble cations and anions. ESP was computed as the percentage of exchangeable Na to the CEC of the soil. The soils were classified into different salt-affected soils according to the standard guidelines. The spatial prediction and mapping of the unsampled surface from laboratory point values was carried out in opensource GIS environment following geo-statistical interpolation techniques. Statistical surfaces of the salinity/sodicity indicator preliminary layers including EC, ESP and pHe and the final salinity/sodicity distribution predicted raster was generated. Data generated was subjected to descriptive statistics. Regression analysis was also used to examine the relationships between selected soil properties.

RESULTS AND DISCUSSION

Particle size analysis indicates that the soils of Meki-Zeway irrigated farm areas was sandy loam to loamy textured soils. The proportion of clay particle varied between 14 to 25%

while silt and sand varied from 13 to 42 and 31 to 70%, respectively. Result revealed that the sand content in the soils of studied area was very high and silt/clay ratios were greater than 0.76 indicating that the soils are relatively young with high degree of weathering potential (Meron, 2007). Soil pH values of saturation paste extract (pHe) for all soil samples analyzed varied between range values of 6.9 to 9.3, 7.2 to 9.7 and 7.9 to 10.3, respectively for the upper (0-30cm), middle (30-60cm) and lower (60-90cm) soil layers and could be rated to lie between neutral to very strongly alkaline in reaction(Table 1). From range values, existence of remarkable spatial variation is evident on both vertical and horizontal planes. Magnitude of alkalinity and extent of spatial coverage increased in the direction from North (Meki) to South-ward (Zeway). Close to 3,897ha (40.1%) of farm area exhibit soil with pHe value that could be rated as moderately alkaline in reaction whereas about 398ha (4.1%) of studied area had pHe value greater than 9.0 and regarded as strongly alkaline in reaction.

Distribution of salinity and extent of severity showed spatially heterogeneous pattern throughout studied area mostly dominated along irrigated farm areas adjacent to Lake Zeway. The overall range values of ECe, varied from 0.20 to 15.30, 0.19 to 12.98 and 0.21 to 7.56dS/m with mean value of 3.08, 2.30 and 1.93dS/m, respectively at a soil depth of 0-30, 30-60 and 60-90cm (Table 1). Depth-wise distribution of soil ECe didn't showed consistent trend of either increasing or decreasing. Nearly 82% (7,969ha) out of the total farmland studied, contained ECe values less than 4dS/m and generally categorized as free of excess salt having no adverse effect on growth and productivity of most crops. Close to 17% (1,652ha) had ECe values between 4 and 8dS/m for the upper 0-30cm soil layer which could be rated as moderately saline soil class whereas only about 84ha (1%) were regarded as highly saline soil class (ECe between 8 and15 dS/m).

Sodic soils; contains soluble carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions of Na^+. The concentrations of Na^+ were greater than the accompanying levels of chloride (Cl^-) and sulfate (SO_4^{2-}) that is CNa: (CCl$^-$ + CSO$_4^{2-}$) ratio greater than 1. Alternatively, the ratio (2CCO$_3^{2-}$ + CHCO$_3^-$) : (CCl$^-$ + 2CSO$_4^{2-}$) was more than 1 in soil solution phase, expressed as meq/lt which agrees with Chhabra (2005) observation as cited by Qadir et.al., (2007). The main cause of alkaline reaction of soils is the hydrolysis of either exchangeable cations or of salts such as Na_2CO_3 (FAO (1988). Result implies that $NaHCO_3$ and Na_2CO_3 were the dominant salts in sodic soils and could be presumed to be the major soluble salts predominantly contributing to common alkaline reaction of sodic and saline sodic soils of the area. The range values of ESP as a measure of soil sodicity varied between 3 and 58 with mean value of 13 for the upper 0-30cm soil layer (Table 1). The ESP consistently increased with increasing soil depth indicating lower soil layer had more sodic property. Assessment of soils of irrigated lands in Meki Zeway by Mengistu (2001) as cited by Kidane *et.al.* 2006 revealed that the soils of the area are sodic in the subsurface horizons. Spatial distribution of soil with sodic nature followed the same trend to that of soils with alkaline property.

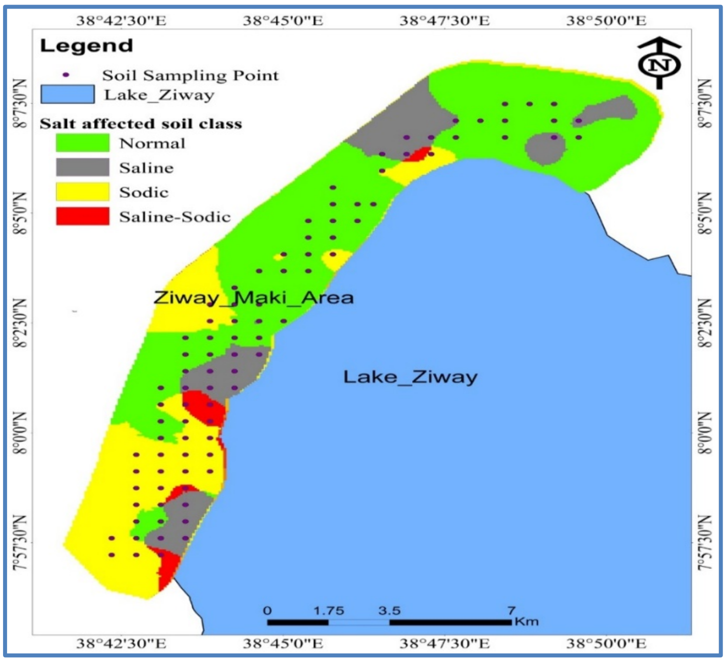

Figure 1. Spatial distribution of predicted salt-affected soil classes for Meki-Zeway.

Table 1. Mean and range values of soil pH, EC and ESP for Meki-Zeway irrigated farm areas.

Range and mean	pHe			ECe (dS/m)			ESP		
	0-30 cm	30-60 cm	60-90 cm	0-30 cm	30-60 cm	60-90 cm	0-30 cm	30-60 cm	60-90 cm
Min	6.9	7.2	7.9	0.20	0.19	0.21	3	5	7
Max	9.0	9.7	10.3	15.30	12.98	7.56	58	65	76
Mean	7.9	8.3	8.7	3.08	2.30	1.93	12	22	34

CONCLUSIONS

Some limited part of farms under investigation had shown to contain excess accumulation of free salt in which 15% out of the total area could be classified as saline affected soil. The soils lack appreciable quantities of neutral soluble salts but contain measurable to appreciable quantities of alts capable of alkaline hydrolysis, Substantial area of irrigated farms exhibit alkaline soil property that range from moderate to strongly alkaline reaction and tend to increase with increasing soil depth. The study also revealed that majority of farm areas contained soils with sodic character that increased with increasing soil depth and could be regarded as a major soil productivity constraint. Diverse manifestations of spatial heterogeneity in terms of types and severity among different salt-affected soil classes is highly evident from present study and therefore site-specific, more precise pixel-by-pixel reclaiming and ameliorative measures must be taken to account such scenarios- with precision agriculture. The study recommended a similar pathway of preparing the remaining other soil properties to be prepared and included to provide a more complete and unified soil fertility improvement guide and digitally actionable input to AI and IOT tools for effective deployment of precision agriculture. The study also underlines the need for further research on investigation of casual factors responsible for buildup of soils with saline and sodic property and development of effective management option.

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