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Selected Physical and Chemical Characteristics of Soils of the Middle Awash Irrigated Farm Lands, Ethiopia

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Abstract

The irrigation based cotton production system in the Middle Awash basin has got progressive productivity decline in the present times. A study was made to provide basic information with regard to the present fertility status and physical characteristics on the soils of the basin. Based on soil color, texture, and land use, 12 pedons were opened in Melka-Sedi farm and Werer Agricultural Research Center and studied for their physical and chemical characteristic. Results showed that the main soil types were Salic Fluvisos, Eutric Fluvisols and Eutric Vertisols. Among these soil types, Eutric Flvisoils occupies the largest portion of the cultivated land of the basin. Salic and Eutic Fluvisols show stratification with weak horizon differentiation with alternating silt and clay particle size dominance within profile depth, while the Eutric Vertisols have homogenous solum overlaying stratified subsoil. Eutric and Salic Fluvisols have 1.2 - 1.3 g cm^{-3} bulk density, pH values ranging from 7.0 - 8.4 and high ECe (37 dS m^{-1}). The bulk density, pH and the average ECe of the Eutric Vertisol ranges from 1.3-1.6 g cm^{-3} , 8.1- 8.4 and 0.5 dS m^{-1}, respectively. Total nitrogen in all soil types is low to medium, while available phosphorous and CEC is high. The fertility status of the irrigated soils of the middle Awash as observed from this work is medium to high except the toxic concentration of Mn and deficiency of Zn. Undesirable salt accumulation commonly aggravates salinity and sodicity in the area.

Key words: Alluvials, Horizon, Pedons, Salinity, Sodicity, and Vertisols

Introduction

The Awash River basin is one of the potential areas for irrigated agriculture located in North Eastern part of the Ethiopian rift valley. Based on physical and socio-economic factors the basin is divided into Upper Valley, (all lands above 1500m asl), Middle (area between 1500m and 1000m asl), Lower Valley (area between 1000m and 500m asl) and Eastern Catchment (closed sub -basin are between 2500m and 1000m asl), and the Upper, Middle and Lower Valley are part of the Great Rift Valleys systems. It covers an area of 120,000 square kilometers of which approximately 70,000 square kilometers are effectively drained by the Awash river and its 14 major tributaries (AVA, 1960). It is found between the southern and eastern side of the central plateau in the Ethiopian Rift Valley. Based on geographical position, climate, and land resource for agricultural development, the basin is divided into upper, middle, and lower basin.

A reconnaissance soil survey covering some two million hectares and semi detailed soil survey on selected areas totaling 500,000 ha indicated that the gross potentially irrigable land was approximately 206,000 ha of which around 83,000 ha are located in the middle Awash valley (AVA, 1960). At present, more than 9,500 ha of land are under irrigation farming in the middle Awash. Regarding the soil classification in the middle Awash basin, until now, only a few attempts have been done. According to the general reconnaissance soil survey of AVA (1960) three-soil groups were identified and broadly classified as: 1. saline alluvial/colluvial 2. Non saline medium and fine textured alluvial with stratified and laminated profiles and 3. Fine textured Vertisols overlaying stratified often coarse textured colluviums. Murphy (1968) reported from the surface soil analysis of the middle Awash basin that the soil texture varies from sandy loam-to-loam, silt to clay loam and clay. The pH of the soils ranges from 7.4 to 8.4. They have low organic matter and nitrogen content, and medium in phosphorus and high in potassium.

Few study reports made in this sub-valley confirmed that the steady increase of neutral salt accumulation and sodium concentration of the soils in the area is the one to be mentioned. On the other hand, several reports of WARC (Werer Agricultural Research Center) also testified that the N, P, K fertility status of the area remains low to medium. The same report showed that chemical fertilization for the last three decades on fluvisols and vertisols with different test crops did not give any positive response. The exhaustion trials with cotton and maize as monocrops executed in the early 70s and still in progress at the research center have shown no plant nutrient depletion and need no for fertilization till now. From five to eight years after the scheme development, about 33% of the total area became saline. At present some 40% of the total area is out of production due to salinity. The current soil salinity study was carried out on 4000 ha on banana and cotton fields of the Melka Sadi State Farm (MKSF).

Soils in general and irrigated agricultural soils in particular have temporal and spatial dynamic nature. Detailed and site-specific periodic assessments and explorations of the physicochemical status of soils will then be quite relevant to update and enrich the available information for sound soil management and technology transfer. In doing so, appropriate soil management techniques will be accounted for maximization of crop production to the potential limit. This study was therefore undertaken in order to provide basic information on the present physic-chemical characteristics of the soils that will contribute to maintain sustainable crop production in Middle Awash basin.

Materials and Methods

Description of the study area

Topography and geology

The middle Awash basin is predominantly low land with an altitude ranging from 500 to 752 masl and located at 9^0 16'N and 40^0 9'E. Topographically, it is flat to almost flat plain with exception of some isolated volcanic cones. Small hills, points of volcanic activity and rift tectonic mark the boundaries of the area. It is encircled by the southeast highlands and the central escarpments of Ethiopia.

The irrigated flat land is of fluvial origin caused by the fluviatle action of the Awash River along with its tributaries from the central and southeast highlands of the country. Different scholars stated that some of the major underlying sediments consist of nearly horizontal beds of basalt, pumice, tuff, gravel, sand, silt and clay. Although the middle Awash basin is situated on the floor of the Ethiopian Rift Valley system, active volcanoes are missing, whereas the volcanic activity in the basin at present is limited to fumarolas and hot springs that are commonly associated with recent volcanic phenomena.

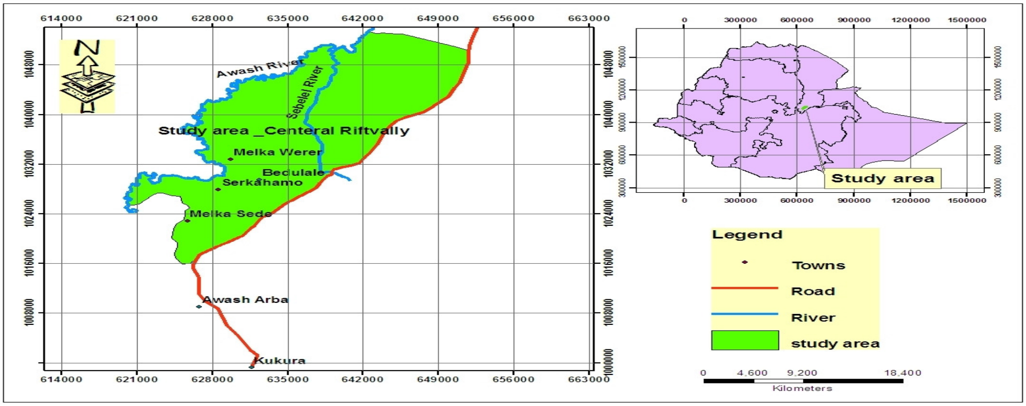

Figure 1. Geographical map of the study sites

Vegetation and climate

The pre-agricultural vegetation has been cleared during the land development in the basin in the early 1960s. The flood plain has served for the Afar herdsmen as a dry season grazing land for centuries. Along the flood plains of the Awash River the vegetation was dominated by deciduous Acacia bush land. Away from the river the vegetation varies from closed dry thicket to open shrub land, and further to grassy plains. Since the establishment of irrigation agriculture remnants of forest, mainly *Acacia neolithica,* are found along both sides of the Awash River bank. Nowadays-exotic tree species, *Prosopis juliflora* is invading the irrigated and grazing land. At present time, part of the flood plain is intensively cultivated with full irrigation. The major crop grown is cotton as a monocrop, while banana, onion, and tomato are only covering small areas.

The middle Awash basin is categorized as semi-arid to arid climate zone receiving a mean annual rainfall of 515 mm. The rainfall is bimodal and characterized by erratic, unpredictable, and uneven distribution throughout the year. Even though most of the rainfall occurs in the months of July and August, another lesser peak fall occurs during the months of February, March and April. The mean maximum and minimum are 34.6^0C and 19.3^0C respectively. The mean annual potential evaporation recorded from the same station is 2700 mm (WARC, 1998).

Soil sample collection

Few auger hole observations were made on each farm unit since the flood plain of the middle Awash basin has no remarkable differences of relief features. Differences in soil color, textural and land use served as selection indicators for profile pit opening. A total of 12 soil profiles were opened at MKSF and WARC which seemed to be representative for the soils types occurring in the Middle Awash cultivated land. The soil profiles were described following the guideline of FAO (1990) and samples were collected for laboratory analysis. Composite samples of each horizon were collected, mixed, air-dried and ground to pass through a 2 mm size sive (USDA, 1972). The soil color was described in moist and dry state using Munsell soil color chart (Munsell, 2000).

Laboratory analysis

Physical and chemical analyses were conducted following standard procedures after the soil samples had been air dried and ground to pass through 2 mm sieves. Particle size distribution was determined by hydrometer method (van Reeuwijk, 1993). The bulk density values were determined from undisturbed sample collected using core ring sampler. The soil pH was determined in saturation extract with standard glass electrodes as described van Reeuwijk (1993). To estimate the content of neutral salts in the soils, electrical conductivity of the saturation extract (ECe) was measured with an electrical conductivity meter following the method outlined by U.S. Salinity Laboratory Staff (1954). The soluble cations concentration (Ca^{++}, Mg^{++}, K^+, Na^+) obtained from saturated pastes using a suction filter were read from flame photometer (K^+, Na^+) and Ca^{++}, Mg^{++} by titration with EDTA. Bicarbonate was determined by titrating with sulfuric acid to phenolphthalein and methyl orange end points. From the same extract chloride was determined by titrating with silver nitrate using potassium chromate as indicator. Cation exchange capacity (CEC) and exchangeable bases (Ca^{++}, Mg^{++}, K^+, Na^+) were determined after the soils were leached with ammonium acetate at pH 7 (Jackson, 1970). Exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) were computed as follows.

$$ESP = \frac{Na^{+}}{CEC} \times 100 \qquad SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}, \text{ in meq/liter}$$

Organic carbon was determined following the procedure of Walkley and Black (1934) and the organic matter was calculated by multiplying the organic carbon using the factor 1.724. The total nitrogen was determined by the Kjeldal method as described in Jackson (1970), while the available phosphorus was determined according Olsen's method (Olsen *et al*. 1954). Selected micronutrient concentrations were also determined following by diethylenetriaminepentaacetic acid (DTPA) method (Tan, 1996) and the contents of available micronutrients in the extract were determined by AAS.

Results and Discussion

Physical properties

The bulk density in all profiles in both locations lies between 1.0 g to 1.5 g cm^{-3}. Volumetric samples were taken in the field in a swollen water saturated state. During drying in the stove shrinkage has occurred. The given data ranging between 1.5 and 1.0 g cm^{-3}represents low density of permanently cultivated and irrigated soils. If one takes a density for the shrink soil core in the cylinder of 1.6 equally, the given densities of the whole cylinder sample reflect the linear index or vice versa the linear extensibility (LE) of the soil. For example, a bulk density of 1.0 corresponds to about 20% and 1.5 to about 3%. Nevertheless, bulk density values showed inconsistent variations along the depth of some profiles.

The textural classes of all pedons of the fluvisols showed different textural classes within the profiles, which indicate stratification alluvial deposition taken place by the Awash River under varying rate of flow at different time. They are variable in depth and have heterogeneity in particle size distribution within the profile. The dominant particle size in these profiles is silt size particles to the extent of 62% on the upper horizons. The lower horizons were mostly dominated by clay size particles. Exceptions to this are the pedons 6/230, F3/3/35, F3/2/22 and 2D/8, which have got relatively high clay size particles in the upper horizons. The vertisols is dominated by clay size particles up to the depth of 133 cm attaining 58 % at WARC and 81 % MKSF. Below this depth the predominant particle size is silt. According to Young's (1976) rating of silt to clay ratio, this study showed generally high ratio (above 0.5) (data not shown) throughout the profiles, suggesting high degree of weathering stages.

Table 1. Selected soil physical characteristics of Middle Awash soils

Profile name	Depth (cm)	Color Munsel value		Particle size (%)				Bulk density (gm cm^{-3})	Total porosity (%)
		Moist	Dry	Sand	Silt	Clay	Class		
WARC 105/106	0-19	10YR 3/2	10YR 5/4	14	56	30	ZCL	1.4	47.17
Eutric Fluvisol	19-70	10YR 3/2	10YR 6/4	18.6	56.67	24.67	ZL	1.23	53.58
	70-95	10YR 3/4	10YR 4/4	11	56	33	ZCL	1.2	54.72
	95-115	10YR 3/2	10YR 5/3	14	51	35	ZCL	1.15	56.60
	130-168	10YR 3/2	10YR 3/4	10	28	61	C	1,2	54.72
	168-200	7.5YR 3/1	7.5YR 2/2	8	38	55	C	1,2	54.72
WARC 111/112	0-17	10YR 4/2	10YR 4/4	16	54	31	ZCL	1.1	58.49
Eutric Fluvisol	17-65	10YR 4/2	10YR 5/4	18	53.3	29.67	ZCL	1.01	61.89
	65-83	10YR 3/2	10YR 4/4	12	50	39	ZCL	1.2	54.72
	83-135	10YR 3/2	10YR 5/4	18	60	23	ZL	1.0	62.26
	135-157	10YR 4/2	10YR 3/4	10	36	55	C	1.0	62.26
	157-200	10YR 3/2	10YR 4/3	20	46	36	ZCL	1.2	54.72
WARC 129/130	0-26	10YR 4/2	10YR 5/4	16	46	39	ZCL	1.2	54.72
Salic Fluvisol	26-88	7.5YR 3/2	7.5YR 3/3	13.3	51.3	36.3	CL	1.2	54.72
	88-110	10YR 3/2	10YR 3/4	10	38	53	C	1.2	54.72
	110-135	7.5YR 3/2	7.5YR 3/4	8	38	54	C	1.3	50.94
	135-158	7.5YR 3/2	7.5YR 3/3	12	38	50	C	1.2	54.72
	158-200	7.5YR 3/2	7.5YR 3/3	10	38	25	C	1.2	54.72
WARC 202/203	0-25	7.5YR 4/2	7.5YR 4/3	9.00	39.00	52.00	C	1.35	49.06
Eutric Vertisol	25-70	7.5YR 3/2	7.5YR 3/3	8	35	57	C	1.45	45.28
	70-95	7.5YR 4/2	7.5YR 5/3	6	36	58	C	1.3	50.94
	95-123	7.5YR 3/2	7.5YR 4/3	4	40	56	C	1.3	50.94
	123-150	7.5YR 4/2	7.5YR 5/4	28	44	28	CL	1.3	50.94
	150-200	7.5YR 4/2	7.5YR 4/4	16	44	40	ZCL	1.2	54.72
WARC 213	0-20	7.5YR 3/2	7.5YR 3/2	12	38	50	C	1.2	54.72
Eutric Fluvisol	20-60	10YR 3/2	10YR 3/4	12	34	54	C	1.35	49.06
	60-100	5YR 3/2	5YR 5/2	18	52	30	CL	1.0	62.26
	100-120	5YR 4/2	5YR 5/2	17	63	20	ZL	1.1	58.49
	120-155	5YR 3/3	5YR 5/2	10	68	22	ZL	1.1	58.49
	155-180	5YR 3/2	5YR 3/2	5	49	46	ZC	1.0	62.26
WARC 229/230	0-25	5YR 3/2	5YR 2/2	7	47	47	ZC	1.1	58.49
Eutric Fluvisol	25-46	7.5YR 3/2	7.5YR 2/3	7	51	51	ZC	1.3	50.94
	46-78	5YR 3/2	5YR 2/2	13	43	43	ZC	1.3	50.94
	78-95	7.5YR 4/2	7.5YR 4/3	9	45	45	ZC	1.3	50.94
	95-160	7.5YR 4/2	7.5YR 6/3	7	51	51	ZC	1.3	50.94
	160-195	7.5YR 4/2	7.5YR 2/2	9	51	51	ZC	1.2	54.72
MKSF F3/3/35	0-20	10YR 3/1	10YR 3/1	8	39	53	C	1.4	47.17
Eutic fluvisol	20-65	10YR 3/1	10YR 3/2	9	42	49	ZCL	1.2	56.60
	65-90	10YR 3/1	10YR 3/1	6	35	59	C	1.0	62.26
	90-123	10YR 3/2	10YR 4/2	14	45	41	ZC	1.1	58.49
	123-152	10YR 3/2	10YR 4/3	32	51	17	ZL	1.1	58.49
	152-180	10YR 3/2	10YR 4/3	8	53	39	ZCL	1.1	58.49
	180-225	10YR 3/2	10YR 4/2	8	47	45	ZC	1.1	58.49
MKSF F3/4/50	0-20	10YR 3/2	10YR 2/1	8	21	71	C	1.5	43.40
Eutric Vertisol	20-90	10YR 3/1	10YR 2/1	6.00	14.33	79.67	C	1.43	46.04
	90-110	10YR 3/1	10YR 3/1	8	13	79	C	1.3	50.94
	110-133	10YR 3/1	10YR 3/1	8	21	71	C	1.3	50.94
	133-165	10YR 4/3	10YR 4/3	44	29	27	L	1.2	54.72
	165-200	10YR 4/3	10YR 4/3	54	31	15	ZL	1.2	54.72
MKSF F3/2/22	0-20	10YR 4/2	10YR 4/2	14	33	54	C	1.4	47.17
Salic Fluvisol	20-33	10YR 4/3	10YR 5/2	6	53	41	ZC	1.4	47.17
	33-49	10YR 4/3	10YR 5/3	26	49	25	L	1.3	50.94
	49-68	10YR 4/3	10YR 5/3	20	51	29	CL	1.3	50.94
	68-113	10YR 4/3	10YR 5/3	52	29	19	ZL	1.2	54.72
	113-166	10YR 4/3	10YR 5/3	54	29	17	ZL	1.2	54.72

Profile name	Depth (cm)	Color Munsel value		Particle size (%)				Bulk density (gm cm^{-3})	Total porosity (%)
		Moist	Dry	Sand	Silt	Clay	Class		
	166-200	10YR 4/2	10YR 5/2	84	5	11	LZ	1.2	54.72
MKSF F1/1/1 Eutric Fluvisol	0-16	10YR 3/2	10YR 4/2	8	43	49	ZC	1.3	50.94
	16-44	10YR 3/3	10YR 4/2	15	33	53	C	1.3	50.94
	44-65	10YR 4/2	10YR 5/2	6	47	47	ZC	1.2	54.72
	65-87	10YR 3/2	10YR 4/2	10	41	49	ZC	1.2	54.72
MKSF F1/28/49 Eutric Fluvisol	0-20	10YR 2/1	10YR 3/1	6	33	61	C	1.5	43.40
	20-45	10YR 2/1	10YR 3/1	6	31	63	C	1.5	43.40
	45-70	10YR 2/1	10YR 3/1	8	31	61	C	1.4	47.17
	70-105	10YR 2/1	10YR 3/1	8	27	65	C	1.4	47.17
	105-125	10YR 3/1	10YR 3/2	8	29	63	C	1.3	50.94
	125-151	10YR 3/1	10YR 3/2	4	39	58	C	1.2	54.72
	151-200	10YR 3/2	10YR 4/2	6	43	52	ZC	1.2	54.72
MKSF 2D/8 Eutric Fluvisol	0-19	10YR 3/2	10YR 4/2	22	37	42	C	1.4	47.17
	19-37	10YR 4/3	10YR 5/2	14	45	42	ZC	1.4	47.17
	37-60	10YR 3/2	10YR 4/2	12	53	36	ZCL	1.4	47.17
	60-90	10YR 4/3	10YR 5/3	22	53	26	ZL	1.3	50.94
	90-130	10YR 4/3	10YR 5/3	16	61	24	ZL	1.3	50.94
	130-200	10YR 4/3	10YR 5/3	32	31	38	CL	1.2	54.72

C= clay, ZC= silty clay and CL= clay loam, ZCL=silty clay loam, ZL=silty loam, L=loamy

Soil color of the identified horizons varied from 5YR through 7.5YR to 10YR hues. This could be related to the contents of organic matter, drainage class, clay-organic matter complexity and positions in the profile. Except profile 129/130, 202/203, 213 and 229/230, the rest had dark color with hues of 10YR. This suggests the presence of relatively high content of clay-organic matter complexity but not attributed to the organic matter content as it is in the range of low status except profile 10(F1/1/1) (Table 1). Consequently, the brown to dark colors (moist hues of 7.5YR) in surface horizons of profile 202/203 and 213 explained the degraded patterns of organic matter as the soil is under cultivation of cotton for more than three decades and the presence of well drainage conditions. In most of the identified horizons, the dry color had the same hues as the moist color with some units higher in values and /or chromas.

Chemical properties

The soil pH values ranged from7.0-8.7(Table 2). As per the ratings for Ethiopian soils (Murphy, 1968), these pH values can be rated to range from neutral to moderately alkaline. Moreover, pH values tend to decrease within profile depth. The pH of the vertisols lies between 7.7 and 8.5. The neutral to slightly alkaline pH values of profiles 105/106, 111/112 and 129/130 of WARC and profile F3 2/22 of MKSF indicate that there is high accumulation of neutral soluble cations in the soil.

The electrical conductivity values of saturation extract differs from profile to profile. Profiles of fluvisols of WARC and MKSF have EC_e value ranging from 0.4-16 and 0.4-26.0 dS m^{-1}, respectively. The higher values of EC_e were found in the upper surface and upper portion of the subsoil layers of the pedons. An exception to this were profile 1/105/106 and F3/2/22 and F3/4/50 of the WARC and profile MKSF, respectively, which have got slight increment of EC_e values in the lower depth. The accumulation of salt in the fluvisols profiles is limited to the depth that is frequently moistened by the ground water. The higher value of EC_e in the upper surface layers of the fluvisols indicates salt accumulation that might have been caused by shallow water depth, texture and structure of the soil that enhance the draw up of moisture to the surface by capillarity and bringing with it dissolved salts which will be left behind as the moisture evaporates. Accordingly profiles 111/112 and 129/130 from WARC and F32/22 from MKSF have ECe value > 8 dS m^{-1} and are severely affected by salt. These Profiles represent about 60 ha of WARC and 550 ha of MKSF.

In vertisols, higher concentrations of anions were determined in the lower layers. The reason might be that vertisols overlaying the deeper silty clay loam are heavily clay textured and very slowly permeable which prevents the transport of the electrolytes with the capillary rise of soil water. This might be an important factor that has saved the vertisols from becoming saline as compared to the fluvisols.

The organic matter content in all soil types is very low and ranges between 0.7% and 4%. Except profile F3 2/22 having a 2-4%, which was high according to Landon (1984), the rest profiles were in the range of 0.2-2% is laying from low to medium range. Generally, the value is similar to most of cultivated soils of Ethiopia, which have low organic matter content which is attributed to land use history such as complete removal of biomass from the field and rapid rate of mineralization (Abayneh Esayas, 2001). Besides that, the content of organic matter in all profiles, independent of the soil type, shows only a slight decrease downward the profile. The non-systematic variation in levels of organic matter in profile 2D/8 and F1/1/1 may reveal its stratification with in a profile and its genetic path of development (Shimelis Damene *et al*., 2007). There is a small increase in the humus content only in the upper 20 to 60 cm, and this might be attributed to post-sediment pedogenic humus accumulation. With a few exceptions, the C/N ratios show values that are characteristics for the humic substances precipitated on the clay particles. So it seems that the contents of organic matter down to a depth of 2 meters and more are mainly the result of sedimentation of soil born and eroded humiferous topsoil material with different original contents of organic matter. This interpretation gets some support by the fact that there is no correlation of organic matter and clay content despite the organic matter must be tightly bound to the clay minerals.

The total nitrogen content determined in all profiles based on the critical limit description of Landon (1984) and generally is in the range of low to medium (0.01-0.3 %) and tends to decrease with profile depth. Nitrogen is the most limiting plant nutrient in most of the Ethiopian cultivated soils. However low to medium amount of total nitrogen is found in these soil types. Even though the total nitrogen is merely an indicator of the soil potential for the element, but not the measure in which it becomes available to the plant, field observation and N fertilizer experiments with different test crops indicated that nitrogen is not as such a limiting element in the Middle Awash valley irrigated soils. (WARC, 1998). This controversy scenario is attributed to the absence of balanced supply of essential plant nutrients particularly the micronutrients. Similar to the organic matter content, the total N content of profile F1/1/1 was also superior to the rest profiles (Table 2).

The available soil phosphorous in both site profiles based on the critical limit description of Tekalign Mamo and I. Haque (1991) is very high and ranges from 17 ppm to 81.6 ppm. The high pH of these soils may have favored the availability phosphorous. Several scholars reported that the calcium bounded (Ca-P) is the major inorganic P fraction in saline and alkaline soils where its solubility increases with increased soil pH. Piccolo and Huluka (1986) found in their studies on phosphorus status of some Ethiopian soils that the most abundant form of phosphorus in WARC soils is Ca bounded phosphorus. It is also known that Olsen's $NaHCO_3$ extractable P increases with increasing pH particularly in sodic soils. Phosphorous in salic and sodic soil is generally high and crops are not likely to respond to phosphorous fertilizer. This was also reported from many years fertilizer trial with different test crops at WARC on the two different soil types (WARC, 1993). The other reason for high amount of available phosphorous in these soils with pH above 8.2 might be the presence of sodium that increases phosphate availability by formation of soluble sodium phosphate.

Table 2. Selected chemical properties of Middle Awash soils

Profile name	Depth (cm)	pH	ECe (dS m^{-1}	OM (%)	TN (%)	P (ppm)	Exchangable bases (meq /100g)				CEC	SAR	ESP (%)
							Na	K	Mg	Ca			
WARC	0-19	8.1	1.2	1.40	0.21	73	3.4	2.2	3	30.5	37	4.6	9.2
105/106 Eutric	19-70	7.9	2.47	1.37	0.12	81.6	3.3	1.2	3.66	31.5	37.33	4.8	8.83
Fluvisol	70-95	7.8	3.2	1.20	0.15	52.5	3.35	0.7	3.75	32.5	43.5	5.3	7.85
	95-115	7.5	5.2	1.20	0.02	46.5	4.1	0.9	3.5	32	45	6.0	9.2
	130-168	7.5	6.9	1.00	0.05	65	4.6	1.2	2	29.5	55	5.6	8.3
	168-200	7.4	8.6	0.90	0.03	75	4.6	1.4	1	29	56	5.4	8.1
WARC	0-17	7	13	2.34	0.22	20	4.3	1.8	1.5	32.5	40	5.3	11
111/112 Eutric	17-65	7.1	9.86	2.20	0.31	32.3	3.43	1.13	3	31.5	39.67	7.4	8.7
Fluvisol	65-83	7.3	6.8	2.00	0.01	52	4.1	1.3	4	29.5	51	6.1	7.9
	83-135	7.2	7.7	1.88	0.04	46	3.1	1	5	32.5	37	5.1	10
	135-157	7.3	7.3	1.70	0.02	61	6.5	1.5	5	60	53	0.7	12
	157-200	7.5	6.7	1.50	0.03	45	5.9	1.4	4	55	52	0.6	11
WARC	0-26	7	12	2.60	0.15	51	6.5	2.7	3	57	49	0.6	13
129/130 Salic	26-88	7.1	16	2.41	0.12	42.3	6.7	1.0	5.2	63.3	49.0	0.7	13.7
Fluvisol	88-110	7.3	13	1.01	0.10	51	8.1	1.2	5	55.5	53	0.9	15
	110-135	7.2	11	2.04	0.09	50	8.5	1.3	9.5	56.5	53	0.8	16
	135-158	7.5	10	1.81	0.04	51	8.7	1.3	5.5	57.5	48	1.5	18
	158-200	7.5	11	1.47	0.03	61	9	1.4	5	62.5	51	1.4	18
WARC 202/203 Eutric	0-25	8.4	0.60	3.02	0.21	56.50	5.05	2.00	3.40	51.0	44.00	1.2	11.50
Vertisol	25-70	8.5	0.5	2.20	0.19	56	5.1	1.65	2.25	54	47	1.0	11
	70-95	8.3	0.4	2.01	0.14	64	5.3	1.8	5	51	53	1.1	10
	95-123	8.3	0.5	1.66	0.06	61	5	1.7	2	50	53	1.3	9.5
	123-150	8.3	0.5	1.54	0.03	58	4.4	1.6	2.5	43.5	43	1.5	10
	150-200	8.3	0.4	0.49	0.01	66	4.6	1.7	2	55	46	1.5	10
WARC 213	0-20	8.4	0.6	3.08	0.16	60	5.3	2.4	3.5	48	42	1.5	11
Eutric Fluvisol	20-60	8.4	0.4	3.02	0.13	64	5.2	2.3	3.25	53.5	47.5	1.5	11
	60-100	8.2	0.5	2.81	0.15	60	4.4	2.2	8.5	66	40	4.2	11
	100-120	8.2	0.4	1.20	0.11	60	4	1.6	5	87.5	41	3.5	9.8
	120-155	8.3	0.45	1.02	0.09	60	4.25	1.55	3	75	42	4.2	10
	155-180	8.3	0.5	0.83	0.01	63	4.6	1.7	4	56.5	53	4.8	8.6
WARC	0-25	8.2	0.7	3.01	0.16	58	5.3	2.2	2.5	55	53	4.1	10
229/230 Eutric	25-46	8.3	0.5	2.34	0.14	60	5.5	2.2	3	55	51	4.8	11
Fluvisol	46-78	8.4	0.4	1.51	0.12	55	4.6	1.6	2	51	52	4.4	8.8
	78-95	8.5	0.5	1.80	0.06	64	5.3	1.4	3	45	50	4.1	11
	95-160	8.4	0.7	0.45	0.03	53	6.2	1.7	3.5	51.5	51	2.2	12
	160-195	8.1	0.4	0.34	0.02	63	7.2	1.7	4.5	62	51	2.1	14
MKSF F3/3/35	0-20	8.4	0.6	4.98	0.15	25	5.9	3.7	3.2	53.1	48	3.0	12

Profile name	Depth (cm)	pH	ECe (dS m^{-1})	OM (%)	TN (%)	P (ppm)	Exchangable bases (meq /100g)				CEC	SAR	ESP (%)
							Na	K	Mg	Ca			
Eutic fluvisol													
	20-65	8.4	0.55	3.65	0.12	29	5.45	3.15	4.65	69.75	64.5	2.2	12
	65-90	8.3	0.5	1.21	0.10	23	5.9	3.1	3.2	83.3	51	3.1	12
	90-123	8.3	0.5	1.09	0.09	22	7.4	2.5	4.1	86.4	44	4.0	17
	123-152	8.1	0.8	1.07	0.06	21	2.7	1.4	4.1	72	31	2.8	8.9
	152-180	8.4	0.7	1.30	0.05	21	5.3	1	4.1	97.2	44	4.0	12
	180-225	8.5	0.6	0.20	0.01	20	5.6	0.9	4.5	99	44	2.3	13
MKSF F3/4/50 Eutric Vertisol	0-20	8.5	1.2	4.30	0.19	27	5.5	2.7	5.4	62.5	63	2.5	8.7
	20-90	8.4	0.67	3.12	0.17	22.67	6.40	2.43	3.33	60.6	61.00	3.7	10.73
	90-110	8.1	3.1	2.18	0.16	26	6.5	2.1	4.1	64	64	5.1	10
	110-133	7.6	13	2.90	0.14	25	8.1	2	3.6	58.5	59	4.5	14
	133-165	7.8	14	1.50	0.05	22	5.9	1.3	3.6	36	36	6.6	16
	165-200	7.7	13	0.50	0.02	20	5	1	3.5	38	38	0.2	13
MKSF F3/2/22 Salic Fluvisol	0-20	8.1	26	4.95	0.18	23	13	3.2	3.5	73.5	34	0.2	38
	20-33	8	18	3.65	0.15	22	13	2	3.2	94.5	42	0.2	30
	33-49	7.9	14	3.56	0.07	17	11	1.2	3.1	80.1	36	0.3	30
	49-68	7.8	19	1.00	0.04	20	10	0.9	2.8	91.5	37	0.2	28
	68-113	7.9	14	1.09	0.02	17	7.1	1	3.2	38.3	28	0.2	25
	113-166	7.8	15	0.61	0.01	20	5.8	0.8	4.5	34.2	27	0.3	22
	166-200	7.9	3.8	0.31	0.01	18	4	0.6	1.4	29.3	18	0.2	22
MKSF F1/1/1 EutriFluvisol	0-16	8.7	1	6.21	0.30	38	5.2	4.2	2.7	54.9	53	0.2	9.9
	16-44	8.5	0.7	5.23	0.28	28	4.4	2.7	3.6	54	46	0.2	9.9
	44-65	8.4	1.1	5.12	0.22	24	4.8	2.1	1.8	54	50	0.3	9.6
	65-87	8.4	2.9	4.67	0.16	24	4.4	2.4	1.8	44.5	51	0.2	8.7
MKSF F1/28/49 Eutric Fluvisol	0-20	8.6	0.5	2.09	0.21	37	5	2.6	1.4	49.1	57	0.2	8.8
	20-45	8.5	0.5	2.02	0.11	36	4.4	2.3	3.2	48.6	56	0.2	7.9
	45-70	8.4	0.5	1.00	0.09	25	4.3	2	7.2	51.8	53	0.2	8.2
	70-105	8.4	0.6	0.40	0.09	13	4.6	1.9	8.1	51.8	48	0.2	9.7
	105-125	8.2	1.6	0.30	0.05	15	5.2	1.7	7.2	54	53	0.3	9.8
	125-151	8	4.6	0.20	0.03	22	5.6	1.6	7.7	51.8	51	0.5	11
	151-200	7.9	6.6	0.20	0.01	20	5.8	1.6	4.5	52.2	51	0.6	12
MKSF 2D/8 Eutric Fluvisol	0-19	8.6	0.8	2.8	0.19	12	4.6	3.2	1.8	52.2	77	0.2	6
	19-37	8.6	0.6	1.9	0.18	10	4.2	2.7	2.7	50.9	57	0.1	7.3
	37-60	8.4	0.5	2.07	0.16	15	4	2.1	4.5	47.3	4 5	0.2	8.8
	60-90	8.3	0.5	1.64	0.11	16	3.3	1.3	2.3	47.7	49	0.2	6.8
	90-130	8.2	0.5	1.09	0.10	19	2.9	1.4	4.1	46.4	45	0.2	6.5
	130-200	8.2	0.4	1.10	0.03	20	3.5	1.3	2.3	45	41	0.1	8.6

ECe- electrical conductivity;OM- organic matter; TN- total nitrogen;P-available phosphorus;Na-sodium;Ca-calcium;K-potassium,Mg-magnessium;CEC-cation exchange capacity;SAR-sodium adsorption ratio;ESP-exchangable sodium percentage

Determinations of ESP values have showed variations in the two locations (WARC & MKSF). In MKSF profiles it ranges between 6 and 38 with maximum value in profile 7, while in profiles from WARC it ranges between 8.1and 18 with maximum value in profile 3. The high value of ESP is as expected associated with high sodium concentration. The fields with ECe less than 4 dS m^{-1}, pH >8.5 and ESP > 15 are sodic due to high concentration of sodium. Due attention should be given to these fields because sodium will interfere with the growth of crops by its adverse effect on the soil physical properties. ESP greater than 15% enhances the dispersion of clay particles and their local displacement resulting in clogging of soil pores and formation of a high impedance crust appears to limit water transmission (FAO, 1988).

In all the profiles, the exchange complex is dominated by Ca^{++} followed by Na^{+}, Mg^{++} and K^{+}. This reveals the progress of development of soil sodicity. The large presence of Ca throughout the profiles was due to the nature of the parent material, high evapotranspiration and irrigation of Ca-rich water that has left high amounts of carbonet and bicarbonet of calcium in the surface and subsurface horizons. Such scenarios often cause the total exchangeable bases to exceed the exchange capacity of the soils. The cation exchange capacity is medium to high and ranges between 18 and 64 meq/100g indicating that the soils have adequate basic cation to support plant growth. The high value of CEC soils is mainly due to high clay content and the predominance of 2:1 layer clay minerals as observed from the CEC/Clay ratio (data not shown).

Soluble cations and anions

In profile 105/106, 202/203, 213, and 229/230 soluble sodium content in saline soils was higher than calcium plus magnesium in all the depths (Table 3). Calcium plus magnesium content in saline soils was higher than sodium content in the rest profiles. Excess calcium is usually associated with excess calcium chloride and sulphate in the soils of the Middle Awash Valley. Excess calcium was prevalent in saline soils; in which excessive amounts of gypsum ($CaSO_4.2H_2O$), calcium chloride ($CaCl_2.6H_2O$) or soluble calcium salt have accumulated through capillary rise from the ground water. Variation was observed with regard to the nature of anions present in these soils. In MKSF profiles the anionic preponderance is in the order $Cl^- > HCO_3^- > SO_4^=$. From this result it could be concluded that chloride and bicarbonate salts of sodium and calcium and magnesium could be the major soluble salts that contributes for saline condition of the soils. On the other hand, profiles of WARC (105/106, 111/112, and 129/130) have got anion predominance in the order $Cl^- > SO4^= > HCO3^-$.

In Saline soils although pH (<8.5) and ESP (<15%) are not high, EC >4 mmhos/cm and an excess of soluble salt in the subsoil restricts water uptake by crops. Chloride salts are the leading contributor of the available EC records in this study. Excessive chloride was accumulated in the shallower depths in both soils. Accumulation of chloride in these soils was the result of failure to use enough water to leach the root zone, lack of good soil permeability or drainage conditions which permit adequate leaching rates and high water table and capillary movement of chloride into the root zone. In addition to this, hydrological conditions and seasonal fluctuations of shallow saline ground water table enhanced chloride accumulation at plough layer.

As observed from ground and irrigation water analysis (data not shown here), the ground water contains higher concentration of electrolytes, while the irrigation water has very low amount, and it is safe to be used for irrigation. Hence, the major source of the anions in the soils should be the ground water which has received dissolved salts from the system. The depth of the ground water was reported to be more than 10 meters at the beginning of the middle Awash Valley development projects. At present pesiometer, monitoring of the ground water indicates that in salt affected fields the ground water depth has raised up to 3 meters (WARC, 1998).

Sodium adsorption ratio (SAR)

The replacement of exchangeable calcium and magnesium by sodium proceeds apace with salt accumulation under many circumstances. The degree to which this reaction takes place may depend on the properties of calcium and magnesium to sodium in the soil solution that comes in contact with the colloidal soil particles, as well as with the total concentration of these elements. SAR value tends to be higher at lower depths in saline and saline-sodic soils. The value of SAR in the overall profiles is between 0.1 and 6.00 (Table 3). This proves that sodium ion is not too dominant to cause its deleterious effect on soil and crop growth.

Table 3. Soluble ions and micronutrient status of Middle Awash soils

Profile name	Depth (cm)	Soluble cations (meq l^{-1})				Soluble anions(meq l^{-1})			Micronutrients(ppm)			
		Na	K	Mg	Ca	Cl	HCO_3	SO_4	Fe	Mn	Cu	Zn
WARC	0-19	6.5	0.5	2	2	7.6	1.8	1.9	17	98.5	0.75	0.365
105/106 Eutric	19-70	12.3	0.4	8.67	2	16.33	2.1	0.53	18	18.5	1.07	0.29
Fluvisol	70-95	15.5	0.35	10	6	19	5.4	0.95	20.75	16	0.77	0.315
	95-115	23.35	0.25	24	3	28.5	10.35	2.95	16	15	1.05	0.315
	115-168	27.4	0.4	26	14	36	16.2	1.1	16.75	15	1.3	0.54
	168-200	26.5	0.5	40	14	53	11.7	1.9	11	13	1.05	0.315
WARC	0-17	4.27	1.59	56	16	99	9	0.8	14.5	13	0.85	0.365
111/112 Eutric	17-65	3.44	0.83	42	16	74.3	6	0.8	16	45.8	0.9	0.35
Fluvisol	65-83	4.06	0.44	26	14	55	5.4	0.8	19	14.5	1.65	0.265
	83-135	3.7	0.61	28	16	49	9	4.4	14.5	14.5	1.1	0.315
	135-157	6.54	0.52	28	8	48	5.4	1.1	15.5	11	1.2	0.315
	157-200	5.93	0.52	26	8	46	8.1	1.1	19	19.5	1.2	0.415
WARC	0-26	6.5	2.7	57	3	105	7.2	0.8	12.5	28.5	1.2	0.415
129/130 Salic	26-88	6.7	1.0	63.7	5.7	134.3	7.5	0.7	13.75	25.25	1.45	0.39
Fluvisol	88-110	8.1	1.2	56	5	110	11.7	4.8	12.5	17.5	1.25	0.465
	110-135	8.5	1.3	57	10	84	8.1	1.3	16	15	0.8	0.465
	135-158	8.7	1.3	58	6	76	7.2	0.8	9.5	8	0.45	0.465
	158-200	9	1.4	63	5	78	9.2	2	11	12.5	1.3	0.465
WARC	0-25	3.85	0.20	1.00	1.0	3.00	1.00	1.35	11	14.75	1.15	0.27
202/203 Eutric	25-70	3.2	0.1	1	0	2	0.2	2.2	13.75	11	0.97	0.32
Vertisol	70-95	2.9	0.2	1	0	2	0.1	2	11.5	12.5	1.55	0.265
	95-123	3.4	0.1	1	0	4	0.5	0.3	11.5	13.5	1.3	0.265
	123-150	3.1	0.3	1	0	2	1	1.6	21	33.5	1.35	0.665
	150-200	2.9	0.2	1	0	1.6	0.4	2.4	17	25	1.25	0.565
WARC 213	0-20	2.7	0.3	2	1	2	0.6	3.3	10	25.5	0.75	0.315
Eutric Fluvisol	20-60	2.1	0.3	1	0.5	2	0.8	1.15	17.75	29.75	1.45	0.54
	60-100	2.2	0.2	1	1	2	0.8	2	21.5	28.5	1.45	0.465
	100-120	2.2	0.2	1	0	2.2	0.2	3.3	23.5	28.5	1.15	0.515
	120-155	2.8	0.1	1	1	3	0.6	1	30.25	22	1.53	0.365
	155-180	2.8	0.1	1	0	1.2	0.2	1	25	24.5	1.55	0.715
WARC	0-25	3.2	0.2	3	1	3	0.5	3.8	19	29	1.15	0.515
229/230 Eutric	25-46	2.5	0.2	2	0	1.8	0.2	2.9	15.5	29.5	1.5	0.465
Fluvisol	46-78	2.6	0.1	1	0	1.2	0.4	3.8	22	25.5	1.25	0.315
	78-95	3.6	0.1	1	0	1.6	0.3	2.9	24	28	1.25	0.315
	95-160	4.5	0.1	2	0	3.2	0.1	3.3	18.5	27	1	0.365
	160-195	9.4	0.2	4	0	8	1	4.7	15.5	25.5	1	0.415
MKSF F3/3/35	0-20	0.4	0.1	4	2	3.8	1	0.8	15.96	18.32	1.36	0.9
Eutic fluvisol	20-65	0.35	0.1	3.5	1.5	2.85	1	0.4	14.86	21.12	1.75	0.75
	65-90	0.4	0	3	1	1.9	1	1.4	13.44	10.8	1.06	0.54
	90-123	0.3	0.1	3	1	1.9	1	0.6	12.68	7.82	1.2	0.46
	123-152	0.4	0	4	2	3.8	2	0.8	6.64	7.84	0.09	0.46
	152-180	0.5	0	4	2	3.8	1	0.2	12.4	12.64	0.48	0.5

Profile name	Depth (cm)	Soluble cations (meq l^{-1})				Soluble anions(meq l^{-1})			Micronutrients(ppm)			
		Na	K	Mg	Ca	Cl	HCO_3	SO_4	Fe	Mn	Cu	Zn
	180-225	0.4	0	4	2	3.8	1	0.8	12.04	10.96	0.74	0.48
MKSF F3/4/50 Eutric Vertisol	0-20	0.5	0.1	8	3	5.7	3	0.2	21.6	25.46	1.16	0.78
	20-90	0.47	0.03	4.00	2.0	3.80	1.00	0.20	18.9	37.13	1.08	0.73
	90-110	1.9	0.1	11	10	19	4	0.2	17.24	22.46	1.04	0.78
	110-133	3.7	0.2	26.4.	28	62	5	0.2	13.92	16.8	1.16	0.5
	133-165	4.2	0.4	31	24	89	6	0.8	7.72	13.74	0.76	0.72
	165-200	3.9	0.3	24	26	80	5	0.9	12.96	48.2	0.62	0.58
MKSF F3/2/22 Salic Fluvisol	0-20	2.7	0.6	24	24	116	7	1.1	12.72	110.8	1.16	1.14
	20-33	9.2	0.3	24	24	97	6	2	13.96	170.8	1.78	0.8
	33-49	8.1	0.2	24	24	87	5	1.4	15.48	116	0.92	0.96
	49-68	9.6	0.4	16	16	114	5	0.2	14.32	193.8	2.14	1.14
	68-113	5.9	0.2	14	11	95	3	0.2	14.32	30.48	0.74	0.74
	113-166	5.9	0.2	15	12	99	4	0.2	13.92	21.98	0.64	0.72
	166-200	2.5	0.1	8	7	27	4	0.2	14.98	19.12	0.46	0.44
MKSF F1/1/1 EutriFluvisol	0-16	0.3	0.1	5	3	5.7	2	0.2	31.24	119.4	1.94	1.74
	16-44	0.3	0.2	5	2	3.8	2	0.2	26	68.8	2.34	1.38
	44-65	0.5	0.1	6	4	5.7	3	0.2	34.48	96.6	2.44	1.28
	65-87	1.2	0.1	13	7	9.5	4	0.4	30.28	48	1.08	0.72
MKSF F1/28/49 Eutric Fluvisol	0-20	0.3	0.1	2	1	1.9	1	0.2	27.6	39.6	1.64	1.1
	20-45	0.3	0.1	2	2	1.9	1	0.2	27.4	46.4	1.82	1
	45-70	0.3	0.1	2	2	3.8	1	1.1	27.48	187.4	0.62	0.82
	70-105	0.3	0	3	2	3.8	1	0.6	19.32	39	1.5	1.04
	105-125	0.8	0.1	10	4	9.5	4	0.2	18	173.4	1.3	0.82
	125-151	1.3	0.1	11	2	32	6	0.2	16.92	117.6	1.82	0.92
	151-200	1.7	0.1	10	5	48	6	0.9	16.68	114.72	1.88	0.82
MKSF 2D/8 Eutric Fluvisol	0-19	0.3	0.1	4	2	3.8	2	0.2	11.32	138.8	0.94	0.82
	19-37	0.2	0.1	3	2	1.9	2	0.2	13.72	143.2	0.84	0.64
	37-60	0.2	0.1	2	1	1.9	1	0.2	15.4	43.96	1	0.74
	60-90	0.2	0.1	2	1	1.9	1	0.2	15.8	35.2	0.68	0.4
	90-130	0.2	0.1	2	1	1.9	1	0.2	15.2	29.8	0.98	0.5
	130-200	0.1	0	2	1	1.9	1	0.4	11.32	138.8	0.94	0.82

Available Micronutrients

The available micronutrient content (Fe, Mn, Zn, and Cu) in all profiles depict inconsistent trend with increasing soil depth. In some of the profiles more micronutrient accumulations have been found in the lower horizons. The incidence of downward movement of the ions up on formation of variety of metallic and organic complexes may attribute to this effect. The concentration of available micronutrients were found to be Mn> Fe> Cu> Zn across all the profiles. Despite the unexplainablity of the reason, Mn concentrates more in MKSF (67.48 ppm) profiles than WARC (23.18 ppm) (Table 3). Its concentration has got a level of toxicity to most of the crop species (Jones, 2003). In fact, the micro nutrient content of soils is influenced by several factors among which soil organic matter content, soil reaction and clay content are the major ones (Fisseha, 1992).

The average amounts of Fe, Mn, Zn, and Cu in the profiles of WARC were 16, 23.8, 1.165 and 0.4, respectively while in MKSF the figures were 17.24, 67.48, 1.19 and 0.8, in the same order. In relative terms, MKSF is apparently has superior potentially available micronutrient accumulations than WARC. The average concentrations of Fe, Mn, Cu and Zn in WARC surface soil (A horizon) were 14.42, 49.13, 0.96 and 0.37

ppm, respectively. These values were 39.24, 53.48, 42.61 and 188.64% less from what has been found in MKSF.

According to critical values of available micronutrients set by (Jones, 2003) the amount of Fe and Cu in the surface soils were medium and high for WARC and MKSF, respectively. As cotton requires 2960 Fe and 120 Cu (g ha^{-1}) to yield 2500 kg ha^{-1}(Jones, 2003) the continuous production without replenishing these nutrients might hinder or reduce cotton production. The Mn level in both areas is found beyond the normal range. The poor availability of zinc (< 1.00) in both areas needs immediate intervention to sustain cotton production that requires 116 g of Zn to yield 2500 kg ha^{-1}. This finding is in agreement with various works that stated that Cu is most likely deficient, Zn contents are variable and, Fe and Mn contents usually at an adequate level in Ethiopian soils (Fisseha, 1992). Micronutrient status of the soils reveals that only available Zn is below the critical limit. The deficiency of Zn ion across the two locations in Middle Awash area is expected to arise from high soil alkalinity or ample phosphate availability (Jones, 2003). As can be observed in Table 1, the heavily abundant available phosphate inevitably may induce unavailability of Zn ion in the region.

Soil classification

The physical and the chemical properties of 12 profiles of the WARC and MKSF are shown on Table 2. Soils selected for the analytical characterization were fluvisols and vertisols softly affected by salts but- with an exception of 3 horizon samples not being enough for fullfuling the FAO/ UNESCO term"salic." There are intergrades existing between fluvisols and vertisols. Because the soils are under permanent irrigation, the vertisols do not show deep cracks and soil structures typical characteristics of this soil. In order to distinguish them from the fluvisols, the black colour with Munsell values less than 3 and chroma at 1 together with a clay content >50% were chosen as criterion for differentiation.

All the fluvisols profiles show stratification with a weak horizon differentiation whereas the vertisols form homogenous soil bodies overlying stratified subsoil. Therefore, according to FAO/UNESCO (1988/1997) classification the vertisols can be classified as eutric vertisols and the fluvisols as eutric fluvisols. Observations made at the two locations, WARC and MKSF indicate that in both sites fluvisols dominate the soil associations. They are also the basis for high potential productivity and for intensive agriculture in the area. Both soils show white salt residue and polygonal cracks on their surface after irrigation, which indicates the dispersion of clay by sodium. Beside this the fluvisols of profile 11 which represents farm numbers F1/1/5 to F1/1/10 of MKSF and profile 2 and 3 which represent farm numbers from 110 to 130 of WARC have oily dark brown colored patches and bare soil surfaces which might be caused by sodium dispersed humified organic matter. These soils could be classified as sodic soils FAO/UNESCO (1988/1997)

Conclusion and Recommendation

The fertility status of the irrigated soils of the middle Awash as observed from this work is medium to high except the toxic level concentration of Mn and deficiency of Zn. The major limitation in relation to soil physical and chemical properties is the undesirable salt accumulation, which commonly aggravates salinity and sodicity. The salt problem of the studied area is associated with poor drainage, rise of ground water table and moisture drawn to the surface by capillary movement bringing with it dissolved salts thereby leaving behind the salt as the moisture evaporates. Such conditions could have been removed through leaching. This approach is only satisfactory whenever there is appropriate subsurface drainage at the face of high water table. Since subsurface drainage outlay is very costly, caution should be exercised on the amount, method and frequency of irrigation water use. Selection of salt tolerant varieties of the major crops in the area should get due attention too. Studies should also be undertaken on the relation of sodium and major plant nutrients uptake by crops and on improving soil physical condition measures as well as on plant response to Zn fertilizer.

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