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Full Length Research Paper

Description, characterization and classification of the major soils in Jinka Agricultural Research Center, South Western Ethiopia

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The soils of Jinka in Southern Ethiopia were studied based on the detail works on soil pit description, characterizing and classification following the FAO and USDA guidelines. For this, along with the topo-sequence and landscape, six soil profiles were opened on an area of 100 ha of research field to make them suit for sustainable soil management practices. The soils were generally described as dark reddish brown to very dark brown and deep. These soils were characterized as slightly (4.87) to moderately acidic (6.18). The OC and available phosphorus were found to range from low to medium. All micronutrients were found to be highly associated with lower soil reaction. These soils group can be classified as Cambisols. Therefore, amending the soil with lime based on exchangeable acidity, essential and deficient nutrients will be vital for supplying food and feed crops in the region. However, continuous assessment of the nutrient status at every five to seven years is necessary to make sure that the soil quality is maintained.

Key words: Blocky, consistency, friable, granular, sub-angular, structure.

INTRODUCTION

In most developing countries where population grows very swift like Ethiopia, focusing only on the potential areas for agricultural use would not help to feed these mounting human and livestock populations. Therefore, exploiting the potential of marginal areas could be the best option to address agricultural product needs for local consumptions as well as export market through boosting agricultural production and productivity and hence economic development, too. In line with this fact that the Jinka Agricultural Research Center (JARC) was established in 2011 in order to address agricultural production constraints in marginal areas so as to fight poverty and exploit the potential of these areas thereby increasing the economic development of Ethiopia. Accordingly, it was intended to represents the humid lowlands of Ethiopia and to address the agricultural production related problems in the eight weredas. Six of them (Male, Salamago, Bena-Tsemay, Hamer, Gnangatom and Dasenech) are highly dominated by people who make their mainstay in agro-pastoral way of

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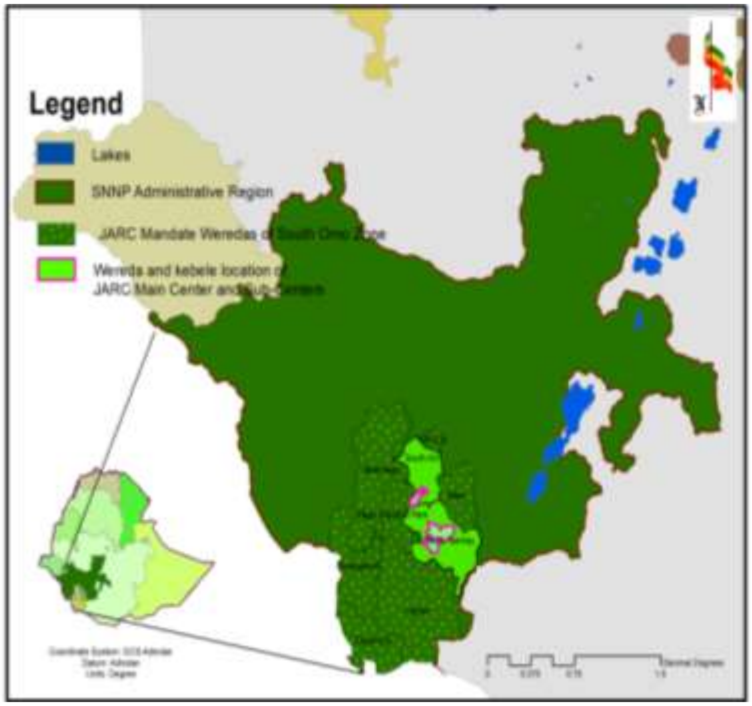

Figure 1. Location of JARC.

living while the rest two (Debub Ari and Semen Ari-Gelila) are known for crop production in the South Omo Zones of the South Nations, Nationalities and Peoples Regional state (SNNPR).

Generally, crop production involves a complex interaction among the environment, soil and nutrient dynamics. Because of this fact, the soil must be studied in terms of its dynamics and environment in order to make it more productive via proper management. Accordingly, failure to understand these complexities along with lack of proper management has resulted in poor crop production potential and hence agricultural production used to be very low (Bashour and Sayegh, 2007).

Management and exploitation of soil potential is strictly dependent on the critical and detail study on description, characterization and classification of the major soil types in the given area. However, there is no baseline information on the nutrient status and the overall characteristics of soils of the experimental site at JARC. The objective of this study is, therefore, to describe the major landforms, characterize and finally to classify the soils of Jinka.

MATERIALS AND METHODS

Description of the experimental site

JARC, is one of the research center of SARI, located 729 kms South West of the capital Addis Ababa at E 36° 33' 02.7" Longitude and N 05° 46' 52.0" Latitude and at an altitude of 1383 masl (Figure 1). Long term weather data revealed that the maximum and minimum monthly average temperature is 27.55 and 16.55°C, respectively while the mean annual rainfall of the area is 1274.67 mm. It is characterized by gentle to flat land features. The slope of the research field ranges from 0 to 5%.

Soil description and sampling

Based on unevenness of vegetation and land use system, six representative soil profile pits (Figure 2) were opened and described in situ according to the guidelines of FAO (2006). Besides, twenty four horizon samples (Table 1) from six profiles were collected from 72 auger points, recorded with GPS and analyzed for physico-chemical properties. Soil color notation was described according to Munsell Color Chart (KIC, 2000).

Laboratory analysis

Texture was determined by hydrometer method (Bouyoucos, 1962). The soil pH was potentio-metrically measured in the supernatant suspension of a 1:2.5 while the electrical conductivity was measured in 1:5 soil to water ratio (Rayment and Higginson, 1992). Organic carbon was determined using Walkley-Black oxidation method (Allison, 1965). Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method, and available P was determined using the standard Olsen extraction method (Olsen et al., 1954). Total exchangeable bases were determined after leaching the soils with ammonium acetate (Reeuwijk, 2002). Amounts of K^+, Na^+, Ca^{2+} and Mg^{2+} in the leachate were analyzed by AAS. Cation exchange capacity was determined at soil pH level of 7 after displacement by using 1N ammonium acetate method in which it was, thereafter, estimated titrimetrically by distillation of

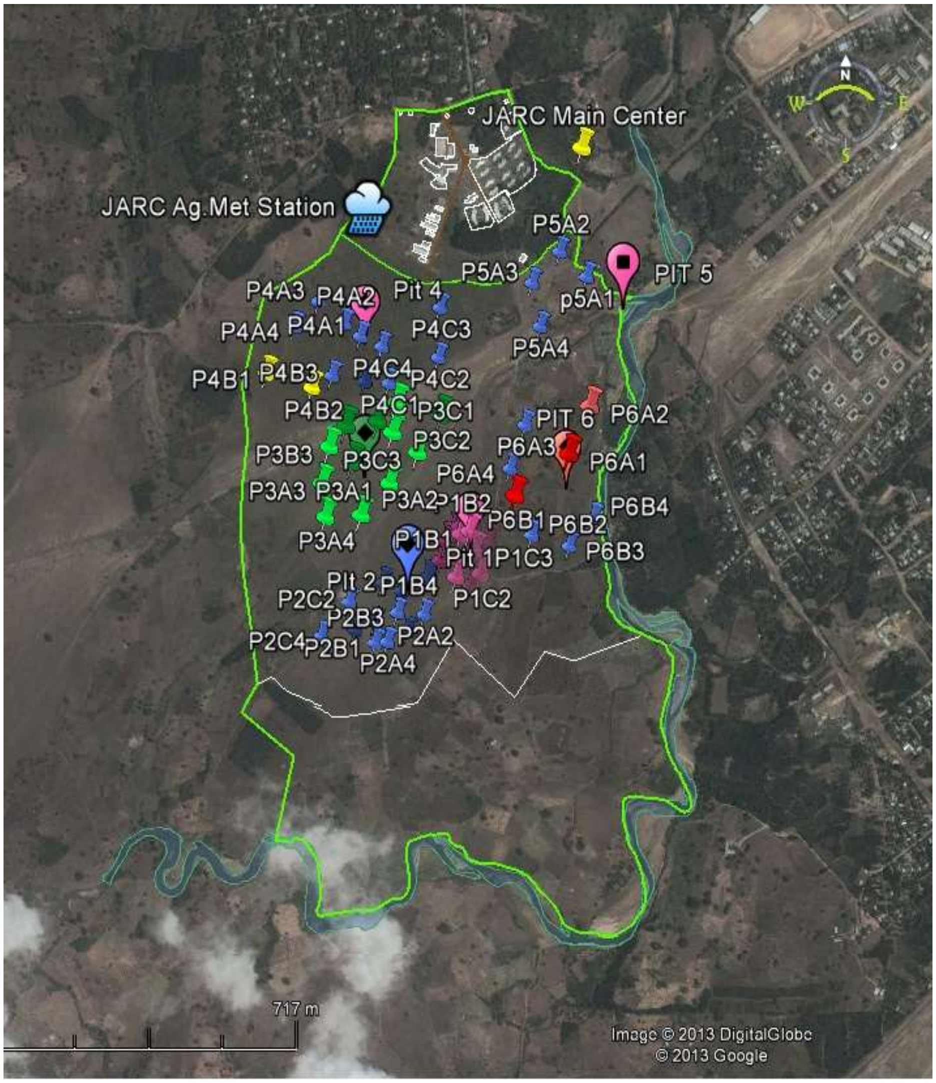

Figure 2. Soil profile distribution at JARC.

Table 1. Surface and profile samples at Jinka Research Center.

Labels	Coordinates	Altitude	Total number of horizon samples	Remark
JK1	05°46'30.4"N036°33'10.9"E	1366	4	12 Auger points
JK2	05°46'30.4"N036°33'10.9"E	1366	4	12
JK3	05°46'35.6"N036°33'02.7"E	1375	5	15
JK4	05°46'44.9"N036°33'02.7"E	1369	4	12
JK5	05°46'47.8"N036°33'20.4"E	1370	4	12
JK6	05°46'34.8"N036°33'18.3"E	1376	3	9
Total			24	72 Auger points

*Three sub-samples were taken to make composite horizon samples.

ammonium that was displaced by sodium (Chapman, 1965). Available micronutrient contents of the soil were extracted by diethylenetriaminepentaacetic acid (DTPA) method (Tan, 1996) and concentrations were determined by AAS.

Table 2. Selected physical characteristics of Jinka Research Center.

Horizon	Depth (cm)	Texture (%)			Textural class
		Sand	Clay	Silt	
1A	0-20	34	41	25	Clay
1AB	20-60	30	51	19	Clay
1BA	60-105	24	49	27	Clay
1B	105+	28	45	27	Clay
2A	0-25	20	47	33	Clay
2AB	25-50	18	39	43	Silty Clay Loam
2BA	50-85	28	42	30	Clay
2B	85+	38	40	22	Clay
3A	0-12	36	52	12	Clay
3AB	12-50	28	68	4	Heavy clay
3BA	50-80	22	70	8	Heavy clay
3BA	80-100	20	74	6	Heavy clay
3B	100+	22	68	10	Heavy clay
4O	0-22	22	66	12	Heavy clay
4A	22-80	26	48	26	Clay
4AB	80-130	14	70	16	Heavy clay
4B	130+	22	50	28	Clay
5A	0-40	26	58	16	Clay
5AB	40-90	24	68	8	Heavy clay
5BA	90-160	28	38	34	Clay Loam
5C	160-205	24	48	28	Clay
6A	0-20	32	64	4	Heavy clay
6E	20-60	32	60	8	Clay
6AB	60+	28	64	8	Heavy clay

RESULT AND DISCUSSION

Physical characteristics of the site

The main experimental site is quite flat and targeted to representing crop research. However, some wetlands have been formed at the heart of the experimental fields and at the peripheries, there is a river called Neri. It is used to be a common grazing land and has been partly cropped with maize (Zea maize) and Sorghum (Sorghum bicolor) by the surrounding farmers and those residing at the outskirt of Jinka town.

Morphological properties of the soils

The soil depth has been identified as very deep (> 150 cm). Pedons in JK1, JK2, JK3, JK4, JK5 and JK6 were characterized by Ap-AB-BA-Bt, Ap-AB-BA-Bt, Ap-AB-BA-BA-Bt, O-A-BA-Bt, O-A-Bt-C and Ap-E-A/AB, respectively. The thickness of the A horizon, which is a ploughed layer, varied from 12 to 58 cm while E was observed in only a pedon by having 20 cm. It does also contain a well established AB, BA, B and C horizons. Significant amount of clay translocation was observed in the middle and lower horizons, as evidenced considerable increase in the clay content of the B horizon (Table 2). Generally, the distinctness of the boundaries between horizons was clear with abrupt and diffuse changes.

A Munsell color chart reveals that the soil color varies from very Dark Grey (7.5 YR 3/1) to Dark Brown (7.5 YR 3/2) and Dark Grey (7.5 YR 4/1) to Black (7.5 YR 2.5/1) for dry and moist conditions, respectively (Table 2). With increasing soil depth, Value keeps increasing with the same Hue and sometime chroma implying that the organic matter distribution in the soil profile declines as the soil textural class mainly dominated by clay. According to Foth (1990), reddish color is due to the presence of iron compounds in various states of oxidation. Abayneh (2005) found that wet soil profiles have darker hues in the B horizons compared to those with relatively dry horizons.

All surface horizons of the studied soils had moderate fine granular structure while the sub-surface horizons had moderately strong to strong fine to very fine granular to

Table 3. Some morphological properties of soils at Jinka Research Center.

Horizon[a]	Depth (cm)	Color		Texture	Structure (Grade, Size, Shape)	Consistency (Moist)	Horizon boundary
		Dry	Moist				
				JK 1			
A	0 - 20	7.5YR4/2	7.5YR3/2	C	MO, FI, GR	VFR	Abrupt
AB	20 - 60	7.5YR4/2	7.5YR3/2	C	MO, FI, GR	VFR	Diffuse
BA	60 - 105	7.5YR4/1	7.5YR3/1	C	MS, FI, GR	VFR	Diffuse
B	105+	7.5YR6/1	7.5YR5/1	C	ST, VF, WE	FR	Diffuse
				JK 2			
A	0 - 25	7.5YR4/1	7.5YR3/1	SCL	MO, FI, GR	SO	difuse
AB	25 - 50	5YR4/1	5YR3/1	C	MO, FI, GR	SO	Diffuse
BA	50 - 85	7.5YR5/1	7.5YR4/1	C	MO, FI, GR	SHA	Abrupt
B	85+	7.5YR6/1	7.5YR5/1	C	MS, VF, WE	HA	Abrupt
				JK 3			
A	0 - 12	7.5YR4/1	7.5YR3/2	HC	MO, VF, GR	SO	Diffuse
AB	12 - 50	7.5YR5/3	7.5YR4/3	HC	MO, FI, GR	SO	Diffuse
BA	50 - 80	7.5YR5/1	7.5YR4/1	HC	MS, FI, GR	SO	Diffuse
BA	80 - 100	7.5YR6/1	7.5YR5/1	HC	ST, VF, BL	SHA	Abrupt
B	100+	7.5YR6/1	7.5YR5/1	HC	ST,FI, BL	HA	
				JK 4			
O	0 - 22	7.5YR3/1	7.5YR2.5/1	C	MO, VF, GR	SO	Diffuse
A	22 - 80	7.5YR5/2	7.5YR4/2	HC	MS, FI, GR	SO	Diffuse
BA	80 - 130	7.5YR5/1	7.5YR4/1	HC	ST, VF, GR	SHA	Abrupt
B	130+	7.5YR6/1	7.5YR5/1	HC	ST, FI, BL	HA	
				JK 5			
A	0-40	7.5YR4/4	7.5YR3/4	C	MS, FI, GR	SO	Diffuse
BA	40-90	7.5YR4/4	7.5YR4/4	C	MS, VF, GR	SHA	Diffuse
B	90-160	7.5YR4/4	7.5YR4/4	C	ST, FI, SAB	HA	Diffuse
C	160-205	7.5YR4/4	7.5YR4/4	C			
				JK 6			
A	0 - 20	7.5YR4/2	7.5YR3/2	C	MO, VF, GR	SO	Diffuse
E	20-60	7.5YR3/3	7.5YR2.5/3	C	MS, FI, GR	SHA	Diffuse
AB	60+	7.5YR4/3	2.5YR3/3	C	MS, FI, G	HA	Diffuse

*****[a] represent the number of soil profiles opened at Jinka while C, HC and SCL meant to clay, heavy clay and silt clay loam, respectively.

wedge structure (Table 3). Well developed structure of the subsurface soils could be due to the relatively higher clay content of the subsurface horizons than that of the surface horizons (Ahn, 1993). The moist consistencies of the surface layers ranges from soft to very friable while the sub-surfaces from friable to hard due to overburden effect of the overlay soils (Table 2)

Physico-chemical properties

The results of the particle size analysis indicate that the soils within the Jinka are fine to very fine textured soils. Generally, the soil textural classes of each of the six pedons were clayey to heavy clay. The proportion of clays in these textural classes ranges from 38 to 74 while sand and silt varies 14 to 42 and 4 to 43%, respectively (Table 2). The soil pH-H2O in all the study profiles ranges from 4.87 to 6.18 and had shown a general tendency of increasing with soil depth (Table 4). According to Murphy (1968) and Tekalign (1991) classification, it has been rated as very strongly acidic to slightly acidic, which is preferred range for most crops with some management.

The organic matter contents were classified to ranges from low to very medium by having a range of values between 2.07 to 3.37% (Murphy, 1968; Berhanu, 1980; Tekalign, 1991). All the three authors, generally, agreed that these soils have low OM contents (Table 4). The total

Table 4. Soil pH, EC, % OM, available P (ppm) and % TN of Jinka Research Center.

Horizon	Depth (cm)	pH	EC (ds m^{-1})	% OM	% TN	Av. P (ppm)
1A	0-20	5.09	0.04	3.059	0.2392	5.10
1AB	20-60	5.10	0.05	3.026	0.4855	6.08
1BA	60-105	5.24	0.04	3.021	0.1856	6.14
1B	105+	6.10	0.04	2.980	0.2856	5.12
2A	0-25	5.16	0.03	3.372	0.2892	5.09
2AB	25-50	5.52	0.04	3.103	0.3392	4.08
2BA	50-85	5.76	0.04	3.016	0.2356	5.11
2B	85+	5.89	0.03	3.044	0.3534	7.02
3A	0-12	5.36	0.06	4.955	0.1714	4.14
3AB	12-50	5.67	0.05	2.431	0.0500	3.30
3BA	50-80	5.70	0.04	3.076	0.1464	7.10
3BA	80-100	5.93	0.02	2.861	0.6747	5.08
3B	100+	6.11	0.02	2.491	0.0393	5.14
4O	0-22	5.80	0.02	5.957	0.0928	3.12
4A	22-80	5.83	0.04	2.420	0.2249	3.09
4AB	80-130	5.83	0.04	3.641	0.1607	2.10
4B	130+	6.18	0.02	2.703	0.1000	2.08
5A	0-40	5.52	0.01	2.592	0.0536	5.14
5AB	40-90	5.54	0.01	2.444	0.0464	2.12
5BA	90-160	6.17	0.04	6.650	0.2820	7.09
5C	160-205	6.18	0.04	6.192	0.2927	6.08
6A	0-20	5.49	0.02	4.770	0.1214	5.10
6E	20-60	4.90	0.06	2.212	0.0678	4.08
6AB	60+	5.20	0.01	2.461	0.1000	5.14

nitrogen contents of the soils of the sites ranges from 0.00.393 to 0.4855% and ranged from low to high according to the same authors. The high level of TN in the soil profile has probability been attributed to the effect of current cultivation and fertilization of the field with research experiments. These soils contains low to medium levels of available P, which was found to be little deficient to maintain annual crops (Olsen et al., 1954; Cottenie, 1980).

The cation exchange capacity (CEC) ranged from 18.16 to 25 Cmol (+) kg-1 (Table 5) and classified as a moderate which ranges from 12 to 25 Cmol (+) kg-1 soils for all profiles (Hazelton and Murphy, 2007; Landon, 1991). In general, there was an increase in CEC with depth which could be due to the strong association between clay contents and CEC. The exchange complex of the soils is dominated by Ca followed by Mg, K and Na (Table 5). According to Havlin et al. (1999), the prevalence of Ca followed by the rest in the exchange site of soils is favorable for crop production. Generally, the exchangeable cations increase with increasing soil depth. The increment was attributed to the leaching of exchangeable cations (Wakene and Heluf, 2003).

The range of critical values for optimum crop production for K, Ca and Mg are from 0.28 - 0.51, 1.25 - 2.5, and 0.25 - 0.5 cmol (+) kg-1 soil, respectively (Sims, 2000). Accordingly, the exchangeable K, Ca and Mg content of the soils are mostly within and sometimes little above the critical values. However, this does not prove a balanced proportion of the exchangeable bases. The ratio of exchangeable Ca/Mg should not exceed 10/1 to 15/1 to prevent Mg deficiency and also the recommended K/Mg are < 5/1 for field crops, 3/1 for vegetables and sugar beets and 2/1 for fruit and greenhouse crops. The Ca/Mg ratio of the studied soils was in the range of 2 - 7 indicating that the response of crops to Mg is not likely. The K/Mg ratio of the studied soils varied from 0.2 to 0.9 and hence it is within the acceptable range for crop production (Havlin et al., 1999). The base saturation (BS), calculated as the sum of exchangeable bases divided by the CEC and multiplied by 100, for all profiles ranges from very low-to-low (20.61 to 35.07%). Low BS is usually associated with low soil pH and the results of this project confirm this fact.

Generally, the concentration of available micronutrients were found to be Fe>Mn>Zn>Cu order. The micro nutrient content of soils is influenced by several factors among which soil organic matter content, soil reaction

Table 5. Soil exchangeable cations, CEC, BS and ESP of Jinka Research Center.

Horizon	Depth (cm)	Exchangeable Cations ($Cmol^+ kg^{-1}$ soil)				CEC	BS (%)	ESP	Ca:Mg	K:Mg
		Na	K	Ca	Mg					
1A	0-20	0.3	1.61	2.39	0.74	18.67	27.00	1.61	3.23	1.88
1AB	20-60	0.33	1.39	3.44	0.73	23.66	24.89	1.39	4.71	2.38
1BA	60-105	0.41	1.74	3.3	0.79	23.56	26.49	1.74	4.18	2.44
1B	105+	0.39	1.93	2.52	0.57	20.2	26.78	1.93	4.42	1.81
2A	0-25	0.22	1.03	3.02	0.97	21.32	24.58	1.03	3.11	1.25
2AB	25-50	0.27	1.21	3.37	0.99	22.24	26.26	1.21	3.40	2.14
2BA	50-85	0.43	2.12	3.82	1.32	20.26	37.96	2.12	2.89	1.51
2B	85+	0.46	1.99	4.3	1.57	23.17	35.91	1.99	2.74	0.87
3A	0-12	0.32	1.37	2.53	0.68	23.31	21.02	1.37	3.72	4.24
3AB	12-50	0.65	2.88	3.26	0.75	22.58	33.39	2.88	4.35	3.33
3BA	50-80	0.6	2.5	3.06	0.85	23.97	29.24	2.50	3.60	3.04
3BA	80-100	0.65	2.58	3.63	1.67	25.23	33.81	2.58	2.17	1.78
3B	100+	0.68	2.98	3.28	1.48	22.85	36.85	2.98	2.22	0.85
4O	0-22	0.26	1.26	2.56	0.34	20.66	21.39	1.26	7.53	3.56
4A	22-80	0.28	1.21	2.82	0.39	23.19	20.27	1.21	7.23	3.31
4AB	80-130	0.3	1.29	2.87	0.82	23.26	22.70	1.29	3.50	1.56
4B	130+	0.32	1.28	3.03	1.49	24.94	24.54	1.28	2.03	1.07
5A	0-40	0.32	1.6	2.32	0.62	19.99	24.31	1.60	3.74	2.39
5AB	40-90	0.38	1.48	2.91	0.67	25.7	21.17	1.48	4.34	2.28
5BA	90-160	0.38	1.53	3.29	0.72	24.79	23.88	1.53	4.57	2.29
5C	160-205	0.4	1.65	3.65	0.79	24.28	26.73	1.65	4.62	1.77
6A	0-20	0.31	1.4	2.07	0.3	22.12	18.44	1.40	6.90	7.60
6E	20-60	0.53	2.28	3.19	0.69	23.23	28.80	2.28	4.62	3.39
6AB	60+	0.58	2.34	3.96	1.28	24.82	32.88	2.34	3.09	2.23

and clay content are the major ones (Fisseha, 1992). The soils at Jinka are classified as medium (2.21-5.47) for Cu, (75.78-138.73) for Fe, (14.49-48.76) for Mn and (0.58-2.37) for Zn (Table 6). Although they fell into medium classes, most of the figures are found close to the lower margins of the medium class. Therefore, care has to be made and monitoring their status at every five to seven years is vital to keep these soils productive.

CONCLUSION AND RECOMMENDATION

The majority of the fields of the main research field have a very deep (> 150 cm) soil depth. Very dark grey (7.5 YR 3/1) to Dark Brown (7.5 YR 3/2) and dark grey (7.5 YR 4/1) to Black (7.5 YR 2.5/1) for dry and moist conditions represent the color of Jinka soils for both in dry and moist conditions.

Generally, the soil reaction varies from strongly acidic to slightly acidic and further increases with soil depth as the root and all biological activities ceases as the soil depth increases. The soil OM and the associated total nitrogen contents found to be low for all but it varies upto medium. Available P follows similar trends with TN and OM and found to be generally low for all. Exchangeable bases ranges from low to medium. However, the exchangeable Calcium were found to be Medium as the soil reaction rose but for the rest two even goes upto very low. Consequently, the base Saturation found to vary from very low to low as the soil reaction is low that can be accompanied by low levels of exchangeable bases. At Jinka, the micronutrients found to fall in medium.

The dominant soils of JARC are classified based on the criteria of World Reference Base (2006) of FAO/UNESCO and Soil Taxonomy (2010) of USDA. Accordingly, these soils were found to have a clayey B horizon, brown in color, increasing clay content and low base saturation. Besides, they are having low soil pH (mostly less than 6), leached soils from humid areas of the tropics and having a base saturation of less than 50% in most soil profiles. Therefore, these types of soils can be classified as CAMBISOLS according to Soil Taxonomy (2010) and FAO/UNESCO (WRB, 2006). Cambisols generally make good agricultural land and are used intensively. More acid Cambisols, although less fertile, are used for mixed arable farming and as grazing and

Table 6. Soil micronutrients of Jinka Research Center.

Horizon	Depth (cm)	Micronutrients (ppm)			
		Cu	Fe	Mn	Zn
1A	0-20	2.75	75.78	14.49	1.25
1AB	20-60	3.80	76.90	15.80	1.47
1BA	60-105	4.91	78.31	22.24	1.65
1B	105+	5.09	103.55	32.64	1.80
2A	0-25	2.74	75.26	22.88	0.89
2AB	25-50	3.74	78.48	33.54	1.39
2BA	50-85	4.34	93.83	42.58	1.83
2B	85+	4.88	109.94	48.76	2.37
3A	0-12	2.21	76.86	16.48	0.87
3AB	12-50	2.32	77.39	16.71	0.97
3BA	50-80	2.43	79.52	17.87	1.03
3BA	80-100	3.35	83.73	18.11	1.06
3B	100+	3.91	101.53	19.05	1.19
4O	0-22	2.49	82.38	17.84	0.85
4A	22-80	2.51	87.81	18.62	0.91
4AB	80-130	5.26	98.17	18.66	1.29
4B	130+	5.42	100.39	26.35	2.02
5A	0-40	2.62	78.90	18.39	0.95
5AB	40-90	2.70	86.29	19.85	1.68
5BA	90-160	3.36	99.26	32.69	1.98
5C	160-205	5.26	108.01	48.70	2.01
6A	0-20	2.05	83.38	18.35	0.85
6E	20-60	3.48	94.08	20.70	0.58
6AB	60-160	4.40	112.04	25.67	0.69

forest land. In the humid tropics are typically poor in nutrients but are still richer than associated Acrisols or Ferralsols and they have a greater CEC. Therefore, amending the soil with lime, essential and deficient nutrients will be vital for supplying food and feed crops in the region. However, continuous assessment of the nutrient status at every five to seven years is necessary to make sure that the soil quality is maintained.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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