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Available Macro and Micronutrient Status in the Soils of Garud Watershed in Bageshwar District of Uttarakhand (U.K) in Relation to Soil Characteristics

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ABSTRACT

Soils of Garud watershed in Bageshwar district of Uttarakhand state were assessed for distribution of macro and micronutrients viz. N, P, K, Ca, Mg, Na, Fe, Mn, Zn and Cu including soil texture, soil acidity and organic carbon content. The soil of the region was generally sandy-loam type with high organic matter content and acidic in nature. Soil was well drained with average thickness ranging from 0.1 to 0.5 m. The climate of the region is sub-tropical and humid with three distinct seasons. The average annual rainfall is about 1152 mm. The concentration of available primary nutrients nitrogen, phosphorus and potassium in the surface soil was found in the range of 310.14-400.03, 17.3-26.4 and 94.08-239.68 kg/ha, with the mean values of 330.37, 22.63 and 179.24 kg/ha, respectively, whereas in sub-surface soil it was in the range of 170.5-413.28, 13.2-23.2 and 78.4- 203.84 kg/ha with the mean values of 264.49, 18.47 and151.12 kg/ha, respectively. The concentration of available secondary nutrients calcium, magnesium and sodium in the surface soil was found in the range of 72.15-168.34, 53.64-92.66 and 21-59 mg/kg, with the mean values of 117.95, 78.02 and 35 mg/kg, respectively, whereas in sub-surface soil it was in the range of 88.18-192.38, 53.64-112.16 and 17 to 38 mg/kg, with the mean values of 146.95, 87.08 and 27.29 mg/kg, respectively. The concentration of available micronutrients Copper, Zinc, Manganese and Iron in the surface soil was found in the range of 0.11-0.35, 0.34-0.83, 1.58-2.82 and 30.3-82.6 mg/kg, with the mean values of 0.23, 0.56, 2.06 and 60.39 mg/kg, respectively, whereas in sub-surface soil it was found in the range of 0.20-0.34, 0.21-0.78, 0.15-2.10 and 22.3-73.8 mg/kg, with the mean values of 0.28, 0.51, 0.96 and 48.16 mg/kg, respectively. Soil EC showed positive and significant correlation with % silt, whereas, organic carbon showed positive and significant correlation with nitrogen, zinc and copper in surface soil. Available nitrogen showed the positive and significant correlation with the iron and copper, whereas, potassium and iron showed positive and significant correlation with zinc in surface soil. Organic carbon showed negative and significant correlation with the % sand but positive and significant correlation with the % clay, % silt + clay and available nitrogen in sub-surface soil. Per cent silt and % silt + clay showed positive and significant correlation with the available nitrogen, whereas, the potassium showed positive and significant correlation with the sodium and copper in sub-surface soil. Soil of the study area was deficient in DTPA extractable manganese (Mn) and zinc (Zn), whereas, nitrogen (N), phosphorus (P), potassium (K) and copper (Cu) content were in medium range. Iron (Fe) content of soil was very high in the soil of study area. Therefore, it could be recommended to enhance micronutrients availability in the study area soils. As carbon content of soil of the study area is high there is more scope for carbon sequestration in soil is net advantageous, improving the productivity and sustainability.

Introduction

At present the explosive agriculture with sustained efforts to increase crop yield has not only depleted our soils of their nutrient serve, but also resulted in the emergence of a number of new nutrients deficiencies due to salinization, hill topography etc. Soil is a diverse complex that can be defined as a mixture of minerals and organic materials, which are capable of supporting plant life (Ayoub *et al.,* 2007; Brady *et al.,* 1990). Soil contains 13 out of 16 different elements essential for plant growth (Raven *et al.,* 1995). However, only small amounts of nutrients are available for plants (McLean and Watson, 1985). According to Cope and Evans (1985), the term, "available" is defined as the amount of a nutrient that is directly proportional to the quantity taken up by growing plants in a growing crop season. Nutrients become available through mineral weathering and through decomposition of organic matter into inorganic mineral which are absorbed by plants in the form of ions. The physical properties of a soil largely determine the ways in which it can be used. Important physical properties center on the size and shape of the spaces between the particle arrangements, called the pore space, which has a direct effect on the movement of air and water, the ability of the soil to supply nutrients to plants, and the amount of water available to the plant. The proportions of the four major components of soils i.e. inorganic particles, organic materials, water and the air can vary greatly from place to place and with depth. The amount of water and air in a soil can also fluctuate widely from season to season. Chemical properties of soils are important in that, along with their physical and biological properties, they regulate the nutrient supplies to the plant. Without these nutrients, supplied by the soil or applied as inorganic fertilizers, organically by manures, and other vegetative materials, plant growth would cease. Good physical and chemical properties supply the right environment and sufficient nutrients to the organisms for optimal biological activity. This in turn improves the physical and chemical properties through improved soil structure and nutrient cycling.

Essential plant nutrients such as N, P, K, Ca, Mg and Na are called macronutrients, while Fe, Zn, Cu and Mn are called micronutrients. It is necessary to assess the capacity of a soil to supply nutrients in order to supply the remaining amounts of needed plant nutrients (total crop requirement - soil supply).

It is only phosphorus and nitrogen fertilizers that are being used in the country hence; attention is not given to micronutrients which are deficit in plain as well as hilly region of country. Soil nutrients are threatening agriculture potentials, because their availability depends on SOM content, soil pH, adsorptive surface, soil texture and nutrient interactions in the soil. Also the efforts to enhance soil macro and micronutrients are constrained by lack of up-to-date data Hence, such kinds of interventions depend on major national soil survey information dating back to the 1980s (FAO). Millions of hectares of land worldwide are low in available micronutrients, and many of these deficiencies were further aggravated by the increased demands of more rapidly growing crops for available forms of micronutrients (Rengel, 2007; Alloway, 2008). The solubility and availability of micronutrients is largely influenced by clay content, pH, SOM, CEC, phosphorus level in the soil and tillage practices (Fisseha, 1992).

Therefore, an ideal extractant must extract only that amount of nutrient from the soil which is proportional to the amount absorbed by a crop during the growing season. The Diethylene Triamine Penta acetic acid extractant of pH 7.3 (DTPA test) was developed by Lindsay and Norvell (1978) for near-neutral (i.e. pH = 6.2-7.3) and calcareous soils. The DTPA extractant (pH 7.3) was selected because it offered the most favorable combination of stability constants necessary to simultaneously extract all four micronutrient cations (Fe, Mn, Cu, and Zn).The estimation of the micronutrient bioavailability in acidic soils through a suitable soil extractant is an important issue for investigation.

Plants absorb nutrients differentially from various fractions and remove their varying quantities from soil. Since different fractions of the element have different solubility and the amount of each depends on various soil characteristics. It is also important to examine the relationships of the major physical and chemical properties of soils with their available form for a better understanding of their available pool in the soil. Such information is potentially valuable in predicting bioavailability, metal leaching rates, and transformations between chemical forms in agricultural and polluted soils. Optimum use of fertilizers contributes significantly in bringing about an increase in agricultural production. Amount of fertilizers required for the same crop varies from soil to soil and even from field to field. Maintenance of fertility of soils is of immense concern to obtain harness higher yields. Therefore, an attempt was made to study the fertility status and correlation with each other of irrigated soils of Garud watershed in Bageshwar district of Uttarakhand.

Materials and Methods

The following sections contain the details of materials, experimental procedures and techniques adopted for determination, and analysis of macro and micronutrient's content of the soils of the experimental site.

General description of study area

The study area (Garud watershed) is located at Garud (Baijnath), on Kausani-Baijnath-Bageshwar route, near Baijnath Temple in Bageshwar district of Uttarakhand state. The watershed drains into Gomti river at Garud (Baijnath) and lies between 29^{o}54'12" to 29^{o}89'78" N latitude and 79^{o}36'43" to 79^{o}61'68" E longitude with 604 ha (6.04 km^{2}) geographical area. The elevation varied from 1086 to 1700 m above mean sea level (msl). The soil of the region was generally sandy-loam type with high organic matter content and acidic in nature. Soil was well drained with average thickness ranging from 0.1 to 0.5 m. The color of soil was light to moderately dark. The average annual rainfall is about 1152 mm. The maximum and minimum humidity ranged are from 98 to 66 per cent and 67 to 25 per cent, respectively. The mean maximum and minimum temperatures were found to be 28.2 and -1.2 ^{o}C, respectively. In the study area major source of irrigation was canal (i.e. Talihat canal network) in the form of small *guls* in the valley region and another source of irrigation was natural water streams at high altitude.

Soil analysis

Soil is the main source of nutrients for crops. Soil also provides support for plant growth in various ways. Knowledge about soil health and its maintenance is critical for sustaining crop productivity. The health of soil can be assessed by the quality and stand of the crops grown on them. However, this is a general assessment made by the farmers. A scientific assessment is possible through detailed physical, chemical and biological analysis of the soils.

Essential plant nutrients such as N, P, K, Ca, Mg and Na are called macronutrients, while Fe, Zn, Cu and Mn are called micronutrients.

It is necessary to assess the capacity of a soil to supply nutrients in order to supply the remaining amounts of needed plant nutrients (total crop requirement - soil supply).

Collection and preparation of samples

Composite soil samples at 0-15 and 15-30 cm depths were collected from agriculture lands before starting of experiments for fertility status of soil and correlation among the soil properties and nutrients status. The collected soil samples were dried in shade, grounded and passed through 2 mm sieve and finally stored in polythene bags for analysis.

Analytical methods for soil samples

The soil samples were analyzed for pH, EC, OC, available N, P, K, available Ca, Mg, DTPA extractable Fe, Mn, Zn and Cu. The soil organic carbon was estimated by following Walkley and Black's method. Available N was estimated by alkaline permanganate method. Available P was extracted using Bray's reagent and estimated through spectrophotometer (Systronics PC based Double Beam Spectrophotometer 2202) after developing blue colour by ascorbic method. Available K and Na was extracted with neutral 1N ammonium acetate and estimated by flame photometer.

The available Ca and Mg were estimated by versenate titration method with EDTA. The DTPA extractable Fe, Mn, Zn and Cu were estimated by using atomic absorption spectrophotometer. The analytical procedures adopted and their references are given in Table 1 for soil.

Categorization of soil nutrient status and nutrient indices for agriculture soil of garud watershed

The soil nutrient status is classified as low, medium and high categories using standard soil nutrient rating values for each nutrient. Nutrient index value was calculated from the proportion of soils under low, medium and high available nutrient categories for each soil sample.

The following equation was used to calculate Nutrient Index Value:-

Nutrient Index (NI) = $(N_l \text{ X } 1) + (N_m \text{ X } 2) + (N_h \text{ X } 3) / N_t$ … (2.1)

Where N_t = Total number of samples analysed for a nutrient in any given area.

N_l = Number of samples falling in low category of nutrient status.

N_m = Number of samples falling in medium category of nutrient status.

N_h = Number of samples falling in high category of nutrient status.

Results and Discussion

Physico-chemical properties along with the status of primary, secondary and micro nutrients in the soils of watershed were determined by adopting suitable methods and correlation among them was observed. The concentration of physical properties of surface and sub-surface soils is elaborated in table 2 and 3, respectively.

Physical properties

Particle size analysis*:* of soil samples was carried out by Boyoucos hydrometer method, as per procedure given by Black (1965). The texture class of the surface soil was clay, sandy clay loam and sandy loam were found, whereas, in case of sub-surface soils it was clay loam, sandy clay loam and sandy loam. In general loamy soil was found in the Garud watershed.

pH: The surface soil was found more acidic in nature having pH values in the range of 6.1 to 6.7 with the mean value of 6.4 than the sub-surface soil having pH values in the range of 6.3 to 6.8 with the mean value of 6.61.

Electrical conductivity (EC): It was found that, the electrical conductivity of the surface soil was more (60 to 110 µs/cm) with the mean value of 95.7 µs/cm than the sub-surface soil (40 to 160 µs/cm) with the mean value of 74.28 µs/cm.

Organic matter content (OM %): Organic matter content in the soil was determined using modified Walkley and Black (1934) method. The per cent organic matter content in the surface soil was observed in the range of 3.98 to 8.57 per cent with the mean value of 5.9 per cent and in the range of 3.26 to 7.12 per cent with the mean value of 4.4 per cent in the sub-surface soil. It can be observed from the tables, that the organic matter content was higher at lower altitude in the agricultural land near the river bed than in the agricultural land at high altitude.

Status of available macro and micronutrients

The nutrient concentration, extracted by a specific extractant, is a function of both the chemical composition of the extractant and the properties of the soil being tested. The term, "available" is defined as the amount of a nutrient that is directly proportional to the quantity taken up by growing plants in a growing crop season. Therefore, an ideal extractant must extract only that amount of nutrient from the soil which is proportional to the amount absorbed by a crop during the growing season.

Primary soil nutrients status

Available N was estimated by alkaline permanganate method, which was proposed by Subbiah and Asija (1956). Available P was extracted using Bray reagent and estimated through spectrophotometer (Systronics PC based Double Beam Spectrophotometer 2202) after developing blue colour by stannous chloride reductant method (Black, 1965). Available K was extracted with neutral 1N ammonium acetate and estimated by flame photometer. The concentrations of above nutrients in the surface and sub-surface soil profiles are given in Tables 4 and 5, respectively.

Available nitrogen (N) content

The available (mineralizable) nitrogen in the surface soil was found in the range of 310.14 to 400.03 kg /ha with the mean value of 330.37 kg/ha, whereas, in sub-surface soil, it was in the range of 170.5 to 413.28 kg/ha with the mean value of 264.49 kg/ha. The concentration of available nitrogen was found more in surface soil than sub-surface soil. It was also found that, the available nitrogen was more in the soils at lower altitudes, near to river bed in the agricultural land.

Available phosphorus (P) content

The available phosphorus in the surface soil was found in the range of 17.3 to 26.4 kg/ha with the mean value of 22.63 kg/ha, whereas, in sub-surface soil, it was found in the range of 13.2 to 23.2 kg/ha with the mean value of 18.47 kg/ha. The concentration of available phosphorus was more in surface soil than sub-surface soil. It was also found that, the concentration of available phosphorus had no relationship with the altitude of the agricultural land.

Available potassium (K) content

The available potassium in the surface soil was found in the range of 94.08 to 239.68 kg/ha with the mean value of 179.24 kg/ha, whereas, in sub-surface soil, it was found in the range of 78.4 to 203.84 kg/ha with the mean value of 151.12 kg/ha. It was more in the surface soil than sub-surface soil. The concentration of available potassium in the agricultural land was more in the soils at lower altitude near the river bed than at the higher altitude .

Secondary soil nutrients' status

The calcium, magnesium and sodium concentration in the surface and sub-surface soils is shown in Tables 4 and 5, respectively.

Calcium (Ca) content

The concentration of available calcium in the surface soils was found in the range from 72.15 to 168.34 mg/kg with the mean value of 117.95 mg/kg, whereas, in sub-surface soils, it was found in the range of 88.18 to 192.38 mg/kg with the mean value of 146.95 mg/kg. In sub-surface soils it was more than in surface soils. It was also found that, the concentration was more in the soils of agricultural land at the higher altitude than the lower altitude.

Magnesium (Mg) content

The concentration of available magnesium in the surface soils was found in the range from 53.64 to 92.66 mg/kg with the mean value of 78.02 mg/kg, whereas, in the sub-surface soils, it was found in the range of 53.64 to 112.16 mg/kg with the mean value of 87.08 mg/kg. In sub-surface soils it was more than the surface soils. It was also found that, the average concentration of magnesium was more in the soils of agriculture land at high altitude.

Sodium (Na) content

The concentration of available sodium in the surface soils was found in the range from 21 to 59 mg/kg with the mean value of 35 mg/kg, whereas, in the sub-surface soils, it was found in the range of 17 to 38 mg/kg with the mean value of 27.29 mg/kg. In surface soils it was more than sub-surface soils. It was also found that, the concentration was more in the soils of agricultural land at low altitude, near the river bed than the soils of agriculture land at the high altitude.

Available micronutrients' status

The overall concentration of micronutrients in the soil is given in Table-6.

Copper (Cu) content

The concentration of available copper (Cu) in the surface soils was found in the range from 0.11 to 0.35 mg/kg with the mean value of 0.23 mg/kg, whereas, in the sub-surface soils, it was found in the range from 0.20 to 0.34 mg/kg with the mean value of 0.28 mg/kg. In the sub-surface soils it was more than the surface soils in the agricultural land of Garud watershed. It was also found that, the concentration of Cu increased as elevation decreased, which is more around the river bed.

Zinc (Zn) content

The concentration of Zinc (Zn) in the surface soils was found in the range of 0.34 to 0.83 mg/kg with the mean value of 0.56 mg/kg, whereas, in the sub-surface soils, it was found in the range of 0.21 to 0.78 mg/kg with the mean of 0.51 mg/kg. In the surface soils it was more than the sub-surface soils of agricultural field in Garud watershed. It was also found that, the concentration of Zn was high in the lower altitude, in the agriculture land nearby river bed.

Manganese (Mn) content

The concentration of manganese (Mn) in the surface soils was found in the range of 1.58 to2.82 mg/kg with the mean value of 2.06

mg/kg, whereas, in the sub-surface soils, it was found in the range of 0.15 to 2.10 mg/kg with the mean value of 0.96 mg/kg. It was very high in the surface soils than the sub-surface soils in agricultural field of Garud watershed.

Iron (Fe) content

The concentration of Iron (Fe) in the surface soils was found in the range of 30.3 to 82.6 mg/kg with the mean value of 60.39 mg/kg, whereas, in the sub-surface soils, it was found in the range of 22.3 to 73.8 mg/kg with the mean of 48.16 mg/kg. It was more in the surface soils than the sub-surface soils and more at lower altitude, near the river bed than the higher altitude in the agriculture land.

The ranges and mean of all above elements are given in Table-7.

Relationship among the soil properties and available nutrients

Analysis of correlation of soil properties with various nutrients in surface soils is shown in Table-8. Soil pH showed negative and significant correlation with soil EC (r = -0.958 **) and with % silt (r = -0.856*) in surface soils. Soil EC showed positive and significant correlation with % silt (r = 0.919**), whereas, organic carbon showed positive and significant correlation with nitrogen (r = 0.773*), zinc (r = 0.773*) and copper (r = 0.808*). The % sand showed negative and significant correlation with % clay (r = -0.97**) and % silt + clay (r = -1.00**), whereas, % clay showed positive and significant correlation with the % silt + clay (r = 0.969**).

Available nitrogen showed the positive and significant correlation with the iron (r = 0.894**) and copper (r = 0.762*), whereas, potassium and iron showed positive and significant correlation with zinc (r = 0.912**), zinc (0.767*), respectively. The calcium content showed positive and significant correlation with the magnesium content (r = 0.884**).

Analysis of correlation of soil properties with various nutrients in sub-surface soils are given in Table-9. Organic carbon showed the negative and significant correlation with the % sand (r = -0.896 **) but positive and significant correlation with the % clay (r = 0.801*), % silt + clay (r = 0.896**), available nitrogen (r = 0.992**). The % sand showed the same correlation with the % clay and % silt + clay and % clay also showed same correlation with the % silt as in the surface soil and sub-surface soil for agricultural land. Per cent silt and % silt + clay showed positive and significant correlation with the available nitrogen (r = 0.776*) and (r = 0.859*), respectively. The potassium showed positive and significant correlation with the sodium (r = 0.881*) and copper (r = 0.835*), whereas, the sodium showed positive and significant correlation with the copper (r = 0.949**). The calcium showed similar correlation with magnesium in surface and sub-surface soil.

Nutrient Index (NI)

Parker *et al.,* (1951) classified the nutrient index values less than 1.5 as the indicative of low nutrient status and between 1.5 to 2.5 as medium while higher than 2.5 as high nutrient status. The rating limits for available soil nutrients are given in Table-10 and nutrient indices are shown in Table-11. It is found that, the manganese (Mn) and zinc (Zn) had low nutrient index, whereas, nitrogen (N), phosphorus (P), potassium (K) and copper (Cu) had medium nutrient index. The iron (Fe) content of soil had high nutrient index.

Table.1 Details of the analytical methods followed in soil analysis

Sl. No	Soil characteristics	Method of estimation	Reference
1	pH (1: 2 soil : water)	pH meter	**Jackson (1973)**
2	Electrical conductivity	EC bridge	**Jackson (1973)**
3	Organic carbon	Walkley and Black wet oxidation method.	**Jackson (1973)**
4	Available N	Alkali permanganate method	**Subbiah and Asija (1956)**
5	Available P	Spectrophotometer method using Bray reagents.	**Black (1965)**
6	Available K and Na	Flame photometer method using neutral normal ammonium acetate as extractant	**Jackson (1973)**
7	Available Ca and Mg	Versenate titration method with EDTA	**Cheng and Bray (1951)**
8	**DTPA extractable Fe, Mn, Zn, Cu**	**Atomic absorption spectrophotometer method using DTPA as extractant**	**Lindsay and Norvell (1978)**

Table.2 Physical and chemical properties of surface soils

Soil sample	Elevation (m)	Surface soil (0-15 cm)				pH	EC	% OM
		Sand (%)	Silt (%)	Clay (%)	Texture			
G-1-A	1170	13.14	25.94	60.92	Clay	6.3	110	5.43
G-1-C	1150	61.86	21.06	17.08	Sandy Loam	6.6	60	4.88
G-2-A	1140	62.08	22.92	15.00	Sandy Loam	6.5	90	3.98
G-2-C	1133	54.56	31.86	13.78	Sandy Loam	6.3	110	5.93
G-3-A	1120	45.86	21.06	33.08	Sandy Clay Loam	6.6	70	3.62
G-3-C	1120	13.00	37.00	50.00	Clay	6.1	160	8.57
G-3-E	1130	13.00	25.00	62.00	Clay	6.7	70	6.20

Table.3 Physical and chemical properties of sub-surface soils

Soil sample	Elevation (m)	Surface soil (0-15 cm)				pH	EC	% OM
		Sand (%)	Silt (%)	Clay (%)	Texture			
G-1-B	1170	56.00	21.92	22.08	Sandy Clay Loam	6.8	40	3.26
G-1-D	1150	63.04	24.00	12.92	Sandy Loam	6.7	50	3.31
G-2-B	1140	61.92	24.08	14.00	Sandy Loam	6.3	160	4.40
G-2-D	1133	61.86	26.14	12.00	Sandy Loam	6.6	60	3.74
G-3-B	1120	61.28	21.58	17.14	Sandy Loam	6.5	70	6.48
G-3-D	1120	41.92	28.08	30.00	Clay Loam	6.7	70	7.12
G-3-F	1130	52.00	27.08	20.92	Sandy Clay Loam	6.7	70	5.14

Table.4 Primary and secondary nutrients' content in surface soils

Soil sample	primary and secondary nutrients in surface soils						
	N (Kg/ha)	P (Kg/ha)	K (kg/ha)	Na (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	% OC
G-1-A	278.25	26.4	132.16	27	152.31	82.88	3.15
G-1-C	331.50	17.3	94.08	21	144.29	92.65	2.83
G-2-A	310.14	22.7	150.34	30	168.34	92.64	2.31
G-2-C	306.51	24.6	230.72	38	72.15	53.64	3.44
G-3-A	356.20	26.4	239.68	36	72.15	68.29	3.76
G-3-C	400.03	21.3	232.96	34	128.26	92.66	4.79
G-3-E	329.95	19.7	174.72	59	88.18	63.4	3.60

Table.5 Primary and secondary nutrients' content in sub-surface soils

Soil sample	primary and secondary nutrients in sub-surface soils						
	N (Kg/ha)	P (Kg/ha)	K (kg/ha)	Na (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	% OC
G-1-B	170.50	21.2	89.60	18	144.29	107.29	1.89
G-1-D	200.00	15.4	78.40	17	192.38	102.39	1.92
G-2-B	270.15	19.3	130.54	25	168.34	92.64	2.55
G-2-D	248.19	13.2	203.84	31	88.18	53.64	2.17
G-3-B	233.50	19.5	179.20	38	152.31	82.88	2.34
G-3-D	413.28	17.5	201.60	30	176.35	112.16	4.13
G-3-F	315.83	23.2	174.72	32	128.26	58.59	2.98

Table.6 Micronutrients' content in the soil

Soil sample	Concentration in surface soils				Concentration in sub-surface soils			
	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Fe (mg/kg)
1-A-B	0.11	0.56	2.82	30.3	0.20	0.33	1.04	22.3
1-C-D	0.18	0.40	1.80	59.1	0.24	0.38	0.79	56.2
2-A-B	0.16	0.34	2.11	57.2	0.28	0.27	0.15	37.4
2-C-D	0.26	0.70	1.58	62.0	0.30	0.55	0.11	42.7
3-A-B	0.26	0.83	2.31	77.4	0.34	0.78	1.87	71.0
3-C-D	0.35	0.76	2.09	82.6	0.30	0.72	1.98	73.8
3-E-F	0.32	0.50	1.825	54.1	0.30	0.21	0.64	33.7

Table.7 Range and mean values of all parameters

Sr. No.	Element	Unit	Surface soil		Sub-surface soil	
			Range	Mean	Range	Mean
1	pH	-	6.1-6.7	6.40	6.3-6.8	6.61
2	EC	µs/cm	60-110	95.70	40-160	74.28
3	OM	%	3.98-8.75	5.90	3.26-7.12	4.40
4	N	kg/ha	310.14-400.03	330.37	170.5-413.28	264.49
5	pH	kg/ha	17.3-26.4	22.63	13.2-23.2	18.47
6	K	kg/ha	94.08-239.68	179.24	78.4-203.64	151.12
7	Ca	mg/kg	72.15-168.34	117.95	88.18-192.38	146.95
8	Mg	mg/kg	53.64-92.66	78.02	53.64-112.16	87.08
9	Na	mg/kg	21-59	35.00	17-38	27.29
10	Cu	mg/kg	0.11-0.35	0.23	0.20-0.34	0.28
11	Zn	mg/kg	0.39-0.83	0.56	0.21-0.78	0.51
12	Mn	mg/kg	1.58-2.82	2.06	0.15-2.10	0.96
13	Fe	mg/kg	30.3-82.6	60.39	22.3-73.8	48.16

Table.8 Simple correlation coefficient among the soil properties and available nutrients in surface soil

	EC	Silt (%)	Clay (%)	Silt + Clay (%)	N (kg/ha)	Mg (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
pH	**-0.958****	**-0.856***							
EC		**0.919****							
% OC					**0.773***			**0.773***	**0.808***
Sand (%)			**-0.97****	**-1.00****					
Clay (%)				**0.969****					
N (kg/ha)							**0.894****		**0.762***
K (kg/ha)								**0.912****	
Ca (mg/kg)						**0.884****			
Fe (mg/kg)								**0.767***	

Table.9 Simple correlation coefficient among the soil properties and available nutrients in sub-surface soil

	EC	Sand (%)	Clay (%)	Silt + Clay (%)	N (kg/ha)	Na (mg/kg)	Mg (mg/kg)	Cu (mg/kg)
pH	**-0.892****							
% OC		**- 0.896****	**0.801***	**0.896****	**0.992****			
Sand (%)			**-0.954****	**-1.00****	**-0.859***			
Silt (%)					**0.776***			
Clay (%)				**0.954****				
Silt + Clay (%)					**0.859***			
K (kg/ha)						**0.881***		**0.835***
Na (mg/kg)								**0.949***
Ca (mg/kg)							**0.825***	

Table.10 Rating limits for available soil nutrients

Nutrient	Low	Medium	High
N (kg/ha)	<280	280-560	> 560
P (kg/ha)	<10	10-25	>25
K (kg/ha)	<108	108-280	>280
Fe (mg/kg)	<4.8	4.8-8.0	> 8.0
Mn (mg/kg)	<2	2-4	> 4
Zn (mg/kg)	<0.6	0.6-1.2	> 1.2
Cu (mg/kg)	<0.2	0.2-0.4	> 0.4
Nutrient Indices (NI)	**<1.5**	**1.5-2.5**	**>2.5**

Table.11 Percent samples falling in low, medium and high categories of essential nutrients and nutrient indices (Number of samples = 14)

Nutrient	Low	Medium	High	Nutrient Indices (NI)
N	6 (43)	8 (57)	0	**1.60 (Medium)**
P	0	12 (86)	2 (14)	**2.10 (Medium)**
K	3 (21)	11 (79)	0	**1.80 (Medium)**
Fe	0	0	14 (100)	**3.00 (High)**
Mn	10 (71)	4 (29)	0	**1.30 (Low)**
Zn	9 (64)	5 (36)	0	**1.35 (Low)**
Cu	3 (21)	11 (79)	0	**1.78 (Medium)**

Note: Values in parenthesis are per cent soil samples.

In conclusions, as carbon content of soil of the study area is high there is more scope for carbon sequestration in soil is net advantageous, improving the productivity and sustainability. The more the organic content in soil is higher the better soil aggregation is. The soil without organic content is compact. This reduces its capacity to infiltrate water, nutrients solubility and productivity, and that way it reduces the soil capacity for carbon sequestration.

It becomes evident that soil acidity together with the moderate range of N, P, K and Cu status as well as deficient range of Zn and Mn certainly indicate the moderate fertility status of the zone and therefore requires attention regarding soil management practices for optimum agricultural production.

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