

Physico-Chemical Characterization in Irrigated and Rainfed Agricultural Soils of Sidhi District, M.P

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ABSTRACT

The Sidhi District is situated on the North-eastern boundary of the Madhya Pradesh State, India which lies over a transitional area between the Indo-Gangetic plain in the north and the Deccan plateau in the south and the remotest district of Madhya Pradesh. The systemic and comprehensive analysis of twenty composite samples of rainfed and irrigated agricultural soil around Sidhi district. The pH of soil samples varied from 6.6 to 8 especially and recorded higher values in the irrigated soils. The EC and CEC showed large spatial variation in the irrigated soils. The results showed alterations in the biogeochemical relationships between physico-chemical parameters. In rain fed areas, the high Si/Al and low Fe/Al ratios showed silicate nature of agricultural soils along with low iron loss from primary silicates.

Key words: Agricultural, Soil texture, Irrigation, Rainfed.

INTRODUCTION

The Sidhi District is situated on the North-eastern boundary of the Madhya Pradesh State, India which lies over a transitional area between the Indo-Gangetic plain in the north and the Deccan plateau in the south and the remotest district of Madhya Pradesh. Soil is one of the important and valuable resources of the nature. All living things are directly and indirectly dependent on soil for day to day needs and 95 % of the human food is derived from the earth. Making plan for having healthy and productive soil is essential to human survival. Soil is a natural body consisting of layers (soil horizons) of mineral constituents of variable thicknesses, which differ from the parent materials in their morphological, physical, chemical and mineralogical characteristics. Soil is composed of particles of broken rock that have been altered by chemical and mechanical processes that include weathering and erosion. Soil has complex function which is beneficial to human and other living organism. It acts as a filter, buffer storage, transformation system and thus protects

the global ecosystem against the adverse effects of environmental pollutants. Environmental neglect by society, since the dawn of the industrial revolution has resulted in severe contamination of soil and water resources (Ramaswamy et al., 2007). Soil formation is a constructive as well as destructive process (Pujaret.al., 2012) the predominant destructive process are physical and chemical breaking down of materials, plants and animal structures which result in the partial loss of more soluble and volatile products. Soil types are a major factor in determining what types of plants will grow. The nature of soil primarily depend upon its continued change under the effect of physical factors like the parent material, time, the climate, the organic activity in it etc. (Solanki and Chavda, 2012). Although all physico-chemical properties are involved in soil functioning, bio chemical properties tend to react most rapidly to get change in the external environment (Nannipieriet al, 1990; Trasar-Cepeda et al, 2008). The soils of the study area comprised of Mollisol, Alfisols, Entisols, Inceptisols and Vertisol with alluvial, red and black soil types. The quality of parent material prevents

the transformation of smectite to kaolin, helps in the retention of adequate amount of smectite and provides a continuous supply of bases (Ca^{2+} ions) required for the formation of Mollisols. In the irrigated regions, soils were deep to medium deep black soils; while rainfed soils were characterized by red loamy soils. Crop yields everywhere in the developing world are consistently higher in irrigated areas than in rainfed areas (Hussain and Hanjra, 2004). About 17% of global agricultural land is irrigated contributing about 40% to the world's production of cereal crops (WCD, 2000). In India, approximately 48.3% of cultivated area is under proper irrigation which gives rise to 234.4 million-tons of total agricultural production whereas about 60% of the total net sown area comes under rain-fed lands and its crop accounts for 48% under food crops. Irrigation and modern agricultural practices secure crop production at the cost of alterations in the soil characteristics, mainly in arid and semi-arid regions (Assis *et al.*, 2010). The purpose of present study is to provide systematic and comprehensive analysis of rainfed and irrigated soils. This type of study is not previously done in the study area so this study may be useful for farmers. Information regarding some element in the agricultural soil may also be useful.

MATERIALS AND METHODS

Study area

The Sidhi District is situated on the North-eastern boundary (between 22 47.5' and 24 42.10' North latitude and 81 18.40' and 82 48.30' East

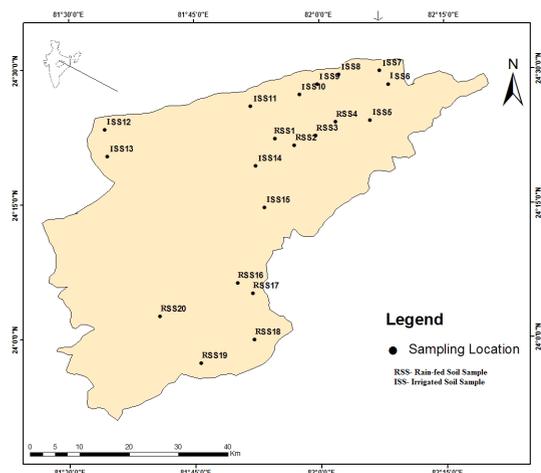


Fig. 1: Map of study area showing sampling locations

latitude) of the Madhya Pradesh State, India which lies over a transitional area between the Indo-Gangetic plain in the north and the Deccan plateau in the south (Fig. 1). The physiography is characterized by low hill, extensive plateaus and Son river valley which is a depository of the Gondwana rocks. Topographically the district can be divided into three zones, Vindhyan hills or Kaimour range, Gondwana zone and Archean zone. Clay minerals like kaolinite, halloysite, diaspore, gibbsite, nacrite, and dickite etc. are derived by the localized weathering of arkosic metasediments (Mehrotra *et al.*, 1979). The average elevation of the area is 311 m above MSL. The climate of the area is tropical monsoon type with three distinct seasons as hot and dry summer (March-June), monsoon (July-September), and winter (November - February). The average annual rainfall varies from 1000-1200 mm, peaks in the months of July and August. The total population of the area is 1.12 million spread with a density of 110/km² (Census, 2011). The total land covered in the Sidhi district is 10,536 km² in which the forest area covers 40%. The portion of the land used for agricultural purpose is 47% but only 17% (66,800 ha) of the land used for agricultural purpose has assured supply of irrigation and the rest of the agricultural land (413500 ha) is dependent on rainfed irrigation and produces only one crop a year (NRAA, 2012). The major irrigation sources are tube wells (26,500 ha), canals (12,800 ha) and wells (11000 ha), and other sources (16,500 ha). The land is largely undulating terrain, which often has steep gradients not ideal for cultivation; the valleys along the major rivers like the Son and the Gopad have fertile soils. The crops grown are rice, maize, barley, pigeon pea and jute in Kharif season, and wheat, mustard

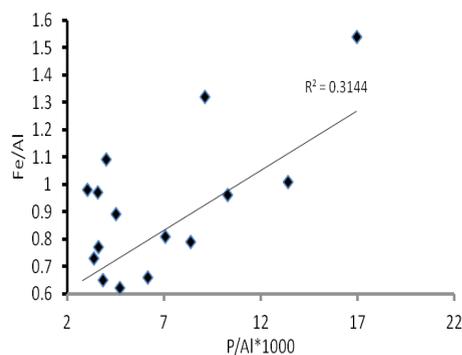


Fig. 2: Linear relationship between P/Al*1000 versus Fe/Al

Table 1: Physico-chemical parameters of agricultural soils

Sample ID	pH	CEC Cmol/kg	EC mS/cm	BD g/cc	WHC	Porosity	Sand	Silt	Clay	SOC	SOM %	TC	TN	AI	P	Mn	Ca	Mg	Fe	Si
SSS1	6.6	16.54	0.16	1.54	44.37	41.88	3.96	80.22	15.82	1.01	1.75	1.24	0.11	8.38	0.03	0.15	0.62	0.82	8.11	30.91
SSS2	6.6	18.50	0.11	1.58	21.69	40.37	3.92	76.66	19.42	1.28	2.22	1.46	0.14	6.63	0.03	0.12	0.88	0.59	5.90	35.63
SSS3	7.6	18.00	0.22	1.45	45.26	45.28	3.14	81.04	15.82	1.59	2.05	1.09	0.10	7.38	0.05	0.10	0.67	0.69	4.28	35.93
SSS4	7.8	17.00	0.26	1.54	37.71	41.88	4.01	76.44	19.55	1.09	1.88	1.06	0.98	6.56	0.02	0.11	0.26	0.33	6.41	35.46
SSS5	7.1	16.30	0.90	1.63	42.2	38.49	1.72	53.31	44.97	1.02	1.71	1.24	0.10	7.45	0.03	0.11	0.19	0.32	8.10	32.26
SSS6	8.0	20.38	0.60	1.4	42.22	47.16	1.52	77.87	20.61	1.93	3.32	2.80	0.26	3.89	0.04	0.05	0.27	0.26	3.72	37.33
SSS7	6.8	18.64	0.30	1.36	48.45	48.67	2.46	80.06	17.48	1.38	2.39	1.27	0.20	6.18	0.05	0.06	0.32	0.41	3.53	35.74
SSS8	7.2	19.10	0.13	1.36	23.97	48.67	1.87	84.41	13.72	1.67	2.86	1.18	0.12	5.53	0.02	0.04	0.26	0.25	4.27	37.20
SSS9	7.9	16.82	0.13	1.54	38.18	41.88	2.02	83.89	14.09	1.26	2.17	1.00	0.09	4.39	0.04	0.07	1.19	0.32	5.81	37.57
SSS10	7.9	16.32	0.21	1.17	42.11	55.84	2.20	77.45	20.35	1.07	1.66	1.88	0.13	3.54	0.06	0.06	0.88	0.51	5.45	36.61
SSS11	7.8	15.74	0.12	1.54	34.77	41.88	2.65	70.10	27.25	0.77	1.32	0.61	0.13	4.87	0.03	0.06	0.28	0.35	3.22	37.57
SSS12	7.6	12.96	0.08	1.6	27.36	39.62	32.79	56.10	11.11	0.61	1.07	0.71	0.12	2.98	0.04	0.05	0.20	0.19	3.02	39.01
SSS13	6.9	18.25	0.07	1.63	42.28	38.49	1.65	70.25	28.10	1.16	2.01	0.84	0.14	5.90	0.02	0.11	0.21	0.31	4.31	35.92
SSS14	7.3	18.86	0.29	1.42	32.87	46.41	7.20	76.53	16.27	1.53	2.65	1.84	0.19	5.96	0.05	0.07	0.24	0.33	4.71	35.61
SSS15	7.5	19.39	0.18	1.41	46.1	46.79	3.07	78.93	18.00	1.33	2.31	1.50	0.14	7.82	0.03	0.07	0.32	0.48	5.07	34.26
SSS16	6.9	13.17	0.07	1.16	36.65	56.22	43.66	45.91	10.43	0.74	1.28	2.58	0.20	2.83	0.02	0.02	0.16	0.09	2.30	41.28
SSS17	6.9	17.04	0.08	1.68	27.57	36.6	6.45	77.06	16.49	1.07	1.83	0.49	0.09	3.59	0.01	0.03	0.16	0.13	1.53	38.40
SSS18	6.8	7.65	0.06	1.84	23.17	30.56	34.34	51.03	14.63	0.24	0.43	0.34	0.10	3.22	0.02	0.02	0.12	0.07	1.73	39.23
SSS19	7.1	18.49	0.06	1.69	25.66	36.22	41.34	47.10	11.56	1.19	2.05	1.11	0.14	3.14	0.02	0.03	0.13	0.08	1.34	40.25
SSS20	7.6	16.76	0.10	1.66	34.83	37.35	3.02	74.77	22.21	0.99	1.71	0.83	0.09	4.25	0.02	0.04	0.20	0.18	2.64	38.55
Mean	7.3	16.75	0.210	1.51	35.87	43.01	10.15	70.96	18.89	1.14	1.97	1.25	0.18	5.22	0.03	0.06	0.37	0.33	4.27	36.73

and lentil in Rabi season. The natural vegetation comprises tropical dry deciduous forests.

Field survey and sample collection

Twenty soil samples (0-20 cm depth) were collected from agricultural lands (Table 1) cultivated by modern tools and techniques in the catchment of Son and Gopad rivers, and traditional techniques in the rainfed, hilly and forest areas (Fig. 1). In each field, a plot of one hectare was selected and five soil cores (5 cm inner diameter each) of 0-20 cm depth were randomly sampled from five points (north, south, east, west and central) and mixed to obtain a composite sample. The sampling was carried out in the dry summer season (June 2013). The all soil samples were stored in acid-cleaned HDPE bottles in frozen state using portable ice box to minimize the biogeochemical alterations and transported to the laboratory for analytical processing. All soil samples were air-dried, crushed by wooden stick and the gravel and relict bodies were picked out.

Laboratory analysis

The pH and electrical conductivity (EC) were measured on a 1:2.5 and 1:5 soil: water (w/v) ratio, respectively (Allison and Moodie, 1965); bulk density (BD) was analysed by Core method (Blake, 1965); water holding capacity (WHC) was determined by keeping fresh soil overnight with water at a 1:2 ratio (Harding and Ross (1964); soil organic carbon and organic matter content was determined by the Walkley and Black dichromate oxidation method (Nelson and Sommers, 1982); the cation exchange capacity (CEC) by ammonium acetate method. The total carbon (TC) and total nitrogen (TN) by Elemental Analyser (Thermo Flash 2000) The elements (Al, Fe, Ca, Mg, Mn, and P) were analysed by the ICP-OES (Leeman Profile Plus) at NMDC, Donimalai, Karnataka. The particle size analysis was carried out by Microtrac S3500 analyzer in Jawaharlal Nehru University, New Delhi. To evaluate the potential relationship between various physiochemical parameters, factor analysis were carried out by using "Statistical Package for Social Sciences (SPSS), version-10.0". "Principal component analysis" and "Varimax Rotation" was used for extraction and deriving factors, respectively

RESULTS AND DISCUSSION

Table-1 presents the results of physico-chemical parameters of agricultural soils of the Sidhi district. The pH of soil samples varied from 6.6 to 8 especially and recorded higher values in the irrigated soils. The EC and CEC showed large spatial variation in the irrigated soils. The SOC and SOM showed significant spatial variations. The elemental concentrations were found below the average earth crust values. Particle size analysis of soil samples showed a diversified range of sand, silt and clay with silt as the most dominating fraction. The bulk density did not show any trend and recorded high in both, irrigated and rain-fed agricultural soils. In the irrigated system, the greater soil bulk density might be due to the combined influence of greater wheel traffic (Carter *et al.*, 1998) and decrease in soil total organic carbon and soil aggregation (Celik, 2005) as a result of repeated events of sawing and harvesting (Li *et al.*, 2007). The mean value of TC and TN were 1.25% and 0.18% respectively. The C:N ratio varied from 1.08-14.46.

The Pearson correlation analysis reveals positive correlation of CEC with silt, SOC and SOM, and silt showed positive correlation with Si, SOC, SOM, Ca and Mg. This infers that the CEC is determined by inorganic and organic constituents of soils (Table 2). The positive relationship between Al and Fe, Al and Mg, Al and Mn, Fe and Mg, Fe and Mn indicate their similar sources and cation exchange reactions in highly weathered soils is regulated by dominance of oxy-hydroxides of Al, Fe and Mn.

The positive statistical relationship between P/Al and Fe/Al (Fig.2) indicates that the authigenic iron oxy-hydroxides have a high capacity to adsorb phosphorus onto their surface (Lijklema, 1980). Thus, precipitation and accumulation of authigenic iron-oxides causes a corresponding increase in P/Al and Fe/Al and seem to be the main process explaining the global variability observed in the agricultural soils. This reflects that the increase of phosphate concentration over the background composition is linked with the increase in iron across the same background material.

Table. 2: Pearson correlation analysis of physico-chemical parameters

	pH	CEC	EC	WHC	BD	Porosity	Sand	Silt	Clay	SOC	SOM	TC	TN	AI	P	Mn	Ca	Mg	Fe	Si
pH	1																			
CEC	0.18	1.00																		
EC	0.18	0.27	1																	
WHC	0.25	0.34	0.43	1																
BD	-0.25	-0.32	-0.11	-0.44	1															
Porosity	0.25	0.32	0.11	0.44	-1	1														
Sand	-0.26	-0.61	-0.37	-0.46	0.13	-0.13	1													
Silt	0.27	0.61	-0.01	0.33	-0.27	0.27	-0.85	1												
Clay	0.05	0.14	0.70	0.33	0.19	-0.19	-0.49	-0.05	1											
SOC	0.24	0.90	0.35	0.31	-0.40	0.40	-0.56	0.64	0.00	1										
SOM	0.19	0.91	0.34	0.24	-0.37	0.37	-0.54	0.61	0.01	0.97	1									
TC	0.16	0.36	0.38	0.33	-0.75	0.75	0.01	0.04	-0.08	0.49	0.51	1								
TN	0.26	0.09	0.12	0.11	-0.08	0.08	-0.08	0.10	-0.01	0.07	0.10	0.11	1							
AI	-0.20	0.45	0.35	0.49	-0.04	0.04	-0.62	0.47	0.39	0.37	0.33	-0.02	0.15	1						
P	0.39	0.21	0.29	0.46	-0.52	0.52	-0.28	0.34	-0.02	0.34	0.25	0.36	-0.13	0.15	1					
Mn	-0.15	0.32	0.29	0.41	0.06	-0.06	-0.54	0.37	0.42	0.21	0.17	-0.02	0.22	0.83	0.19	1				
Ca	0.21	0.18	-0.08	0.19	-0.25	0.25	-0.39	0.52	-0.11	0.23	0.16	0.11	-0.14	0.22	0.51	0.42	1			
Mg	-0.04	0.37	0.13	0.51	-0.27	0.27	-0.58	0.59	0.12	0.33	0.23	0.12	-0.03	0.77	0.50	0.80	0.62	1		
Fe	0.03	0.28	0.50	0.44	-0.17	0.17	-0.58	0.38	0.46	0.23	0.23	0.17	0.22	0.75	0.30	0.85	0.50	0.71	1	
Si	0.15	-0.38	-0.50	-0.53	0.03	-0.03	0.67	-0.46	-0.51	-0.29	-0.28	-0.02	-0.09	-0.90	-0.26	-0.85	-0.27	-0.77	-0.87	1

CONCLUSIONS

The physico-chemical parameters show spatial variation in cropping pattern, mode of irrigation, mechanical farming, soil texture etc. The silty loam texture and geochemical ratios show the dominance of clay minerals in the irrigated soils. The low Si/Al ratio and high Fe/Al ratio show high mobility or non-silicate nature of agricultural soils cultivated under double cropping system. The elemental concentrations were found below the average earth crust values. In the irrigated system, the greater soil bulk density might be due to the combined influence of greater wheel traffic. The decreasing trend of soil total organic carbon and soil aggregation as a result of repeated events of sowing and harvesting

The Pearson correlation analysis reveals positive correlation of CEC with silt, SOC and SOM, and silt showed positive correlation with Si, SOC, SOM, Ca and Mg. This infers that the CEC is determined by inorganic and organic constituents of soils.

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