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Biogeochemistry of Rainfed and Irrigated Agricultural Soil of Sidhi District, Central India

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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.*

1. INTRODUCTION

The Sidhi District is situated on the Northeastern 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.

2. MATERIALS AND METHODS

2.1 Study area

The Sidhi District is situated on the Northeastern boundary (between 22 47.5' and 24 42.10' North latitude and 81 18.40' and 82 48.30' East latitude) of the Madhya Pradesh State, India which lies over a transitional area between the

IndoGangetic 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 dicktite 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/km^2 . 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. 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 and lentil in Rabi season. The natural vegetation comprises tropical dry deciduous forests.

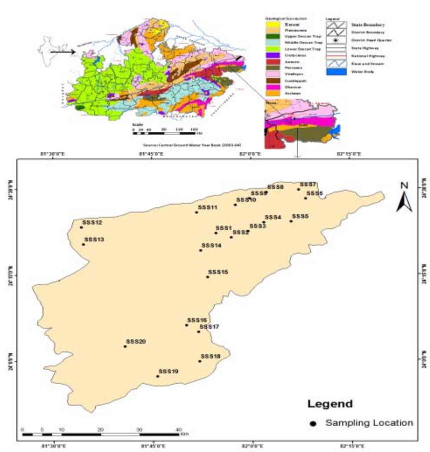


Fig. 1: The map of study area with sampling locations

2.2 Field survey and sample collection

Twenty soil samples (0-20 cm depth) were collected from agricultural lands 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.

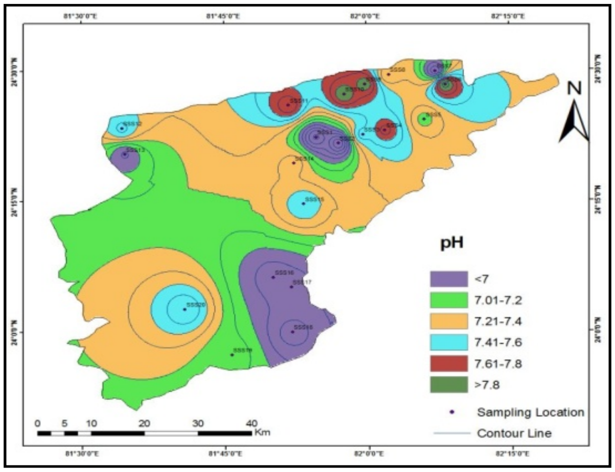
laboratory analysis The pH and electrical conductivity (EC) were measured on a 1:2.5 and 1:5 soil: water (w/v) ratio, respectively (Allison and Moodie, 1965); bulk density (BD) was analysed by Core method (Blake, 1965); water holding capacity (WHC) was determined by keeping fresh soil overnight with 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.

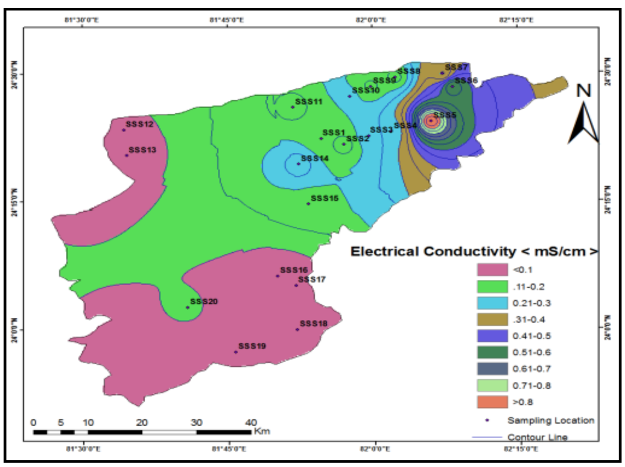
3. RESULTS AND DISCUSSION

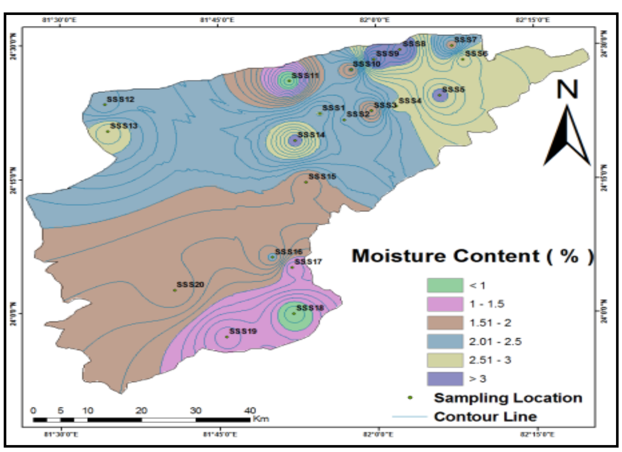
3.1 Physico-chemical properties of agricultural soils

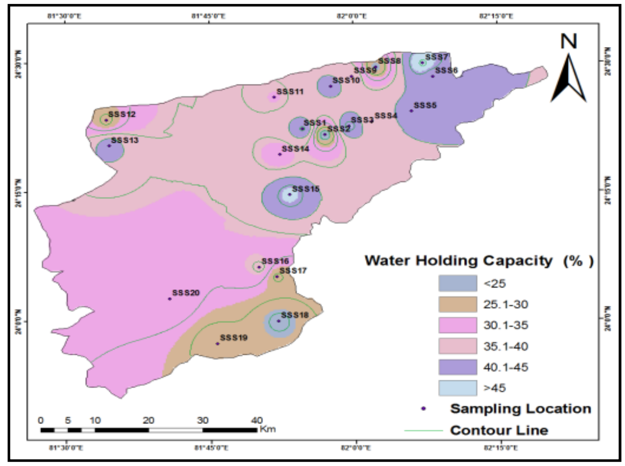
The spatial variability of physico-chemical parameters is given as Figure 1. Soil pH is considered a master variable in soils as it controls many chemical processes that take place. The pH values (6.52 - 7.95) of soils indicated that pH of the soil samples varied from slightly acidic to neural and neutral to moderately alkaline (Fig.1). The electrical conductivity (EC) is a measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electrical current through it. The significant spatial variation was observed in the soil samples collected from the catchment of Son River where double cropping pattern may be responsible sorption of ions in agricultural soils. The moisture content was high in agricultural soils near to catchment area of Son River and its tributaries (Gopad and Banas). In those samples in which percentage of sand was more than the percentage of clay particular sample showed poor WHC. BD was high in both clay dominating soil as well as silt dominating soil indicating agricultural practises after the soil profile and continuous irrigation led to erosion of fine particles from agricultural land constituents in rocky and agricultural land. It indicated poor physical condition of soil for plant growth because of its compact and low pore space. In cultivated soils physical process are major importance in decline soil invariably led to decrease in soil porosity and an increase in BD. The high CEC was associated with soil samples rich in silt and clay. Moreover the presence of silt and clay may responsible for spatial variation in CEC .This may be considered as a tropical deciduous nature of the study area.

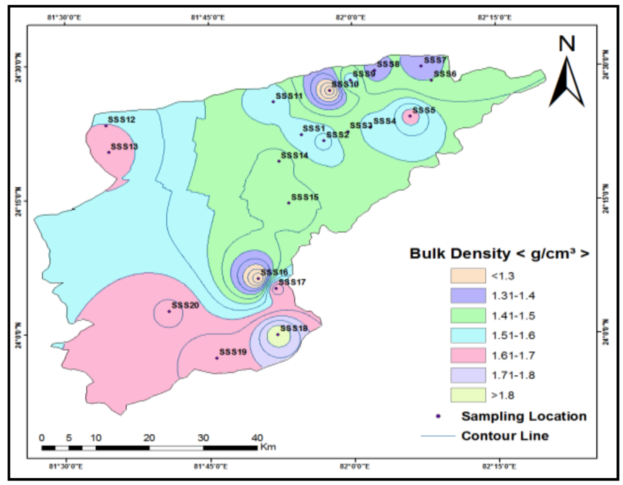
The high CEC was associated with soil profile which rich in silt and clay. The CEC in the study area showed their recent alluvium activities. Soils with CEC greater than 20cmol/gm may have high clay content, low leaching potential for cation, high WHC. The presence of high SOM in the agricultural soils reports poor mineralisation. A lower SOM signified by low LOI indicated greater proportion of Calcium carbonate in soils. The presence of high LOI values in agricultural soil manifest presence of carbonate minerals.











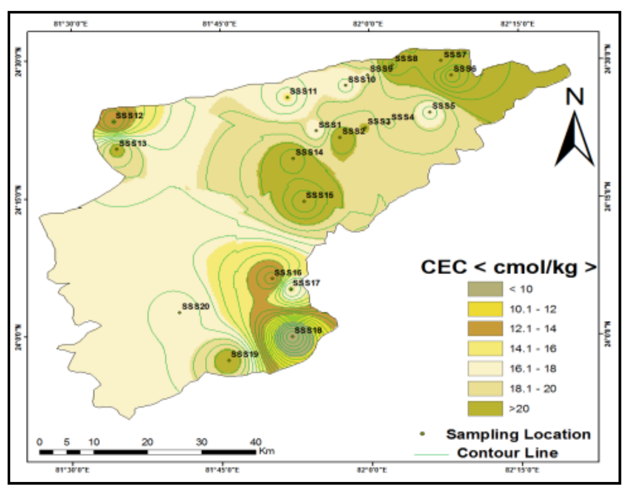
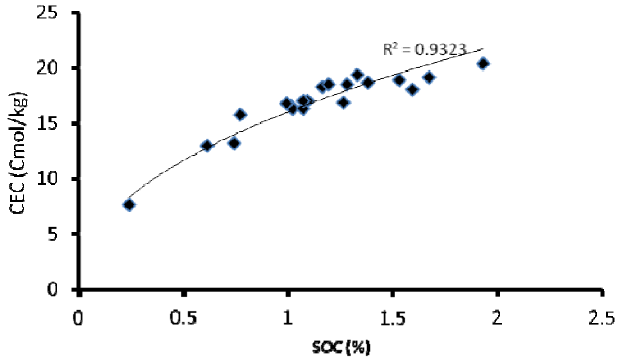


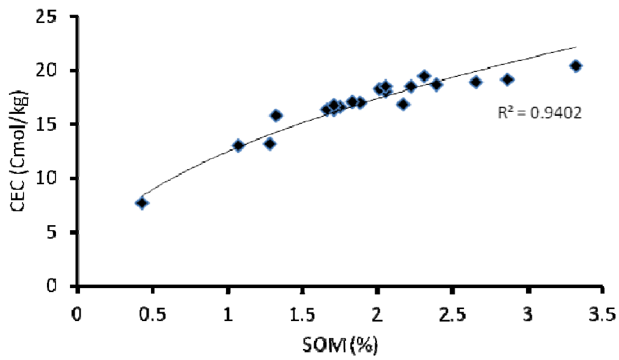
Fig. 2: Spatial variability in physico-chemical parameters in the study area

3.2 Biogeochemistry of Agricultural Soils

The CEC showed positive relationship with SOC and SOM an indication of stable physic-chemical conditions, microbial immobilization, insignificant leaching and translocation as dissolved or particulate organic carbon and poor chances of soil organic matter loss through soil erosion in the summer season (Fig. 3).



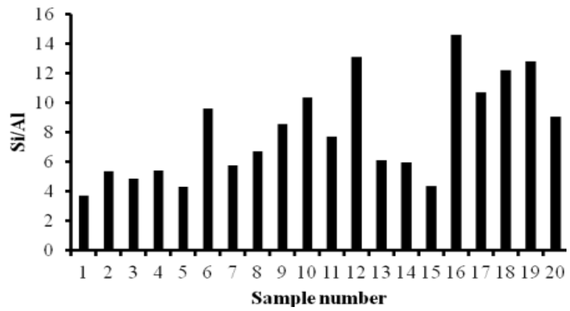
(a)



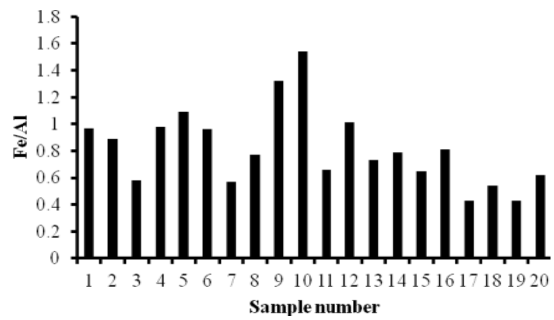
(b)

Fig. 3: The non-linear relatiosnhip between (a) SOC versus CEC, (b) SOM versus CEC

The high Si/Al ratio in rain fed soil samples shows dominance of siliceous materials mainly formed by quartz sands and silt which contain only silicon (Fig. 4a). Increase in Si/Al ratio may be related to enhanced input of quartz due to incongruent dissolution of silicate minerals and formation of new solid phases along mainly oxy-hydroxides of Al, Fe, Mn, (Tardy et al., 2004). As a whole, the relatively low Si/Al ratio may be used as indicators of non-silicate nature of agricultural soil in the Sidhi district. The high Fe/Al ratio indicates significant amounts of dissolved iron as a result of chemical weathering of soils in the northern Sidhi district (Fig.4b). The rain fed dependent cultivation shows relatively small Fe/Al ratio indicating low iron loss rate from primary silicates. The low Ca/Al ratios indicate Ca is a minor constituent of agricultural soils (Fig. 4c).



(a)



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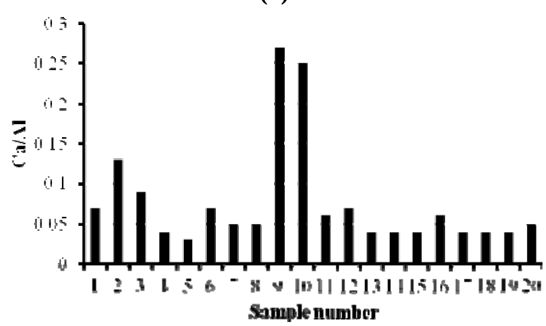
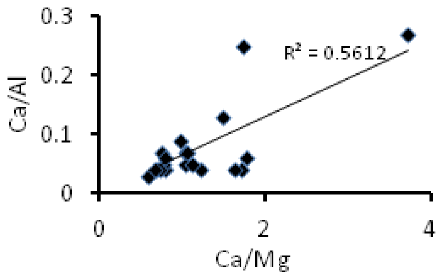


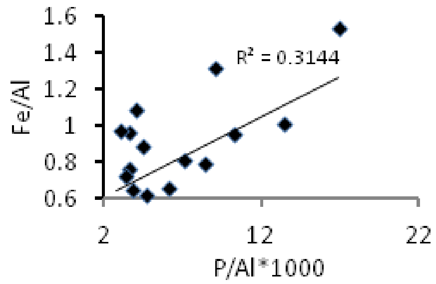
(c)

Fig. 4: Spatial variability in elemental ratio (a) Si/Al, (b) Fe/Al and (c) Ca/Al

The positive relationship between Ca/Mg and Ca/Al (Fig. 5a) suggests Mg is mainly associated with the aluminosilicates fraction (Lopez et al., 2006). The positive statistical relationship between P/Al and Fe/Al (Fig. 5b) indicate that the authigenic iron oxy-hydroxides have a high capacity to adsorbed phosphorus onto their surface (Likjlema, 1980; Lopez et al., 1996). 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 of Sidhi district. This reflects that the increase of phosphate concentration due to fertilizer application over the back ground composition is linked with the increase in iron across the same background material.



(a)



(b)

Fig. 5: Linear relationship between elemental ratios Ca/Mg versus Ca/Al, (b) P/Al*1000 versus Fe/Al.

4. 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 sawing and harvesting.

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