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RESEARCH ARTICLE

SPATIAL VARIATION OF SOIL pH AND SOIL PHOSPHOROUS AND THEIR INTERRELATIONSHIP IN THE PLATEAU AREA OF WEST BENGAL, INDIA

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ABSTRACT

The plateau of West Bengal is a part of Chhotanagpur plateau consisting of Puruliya district of West Bengal. Physiographically this region is undulating terrain composed of granite-gneiss rock. Primarily soil is lateritic in nature. Soil in this region is acidic in nature i.e. soil pH value below 7 and low available phosphorous content covering nearly 80% area. There is a close relation between acid soil and low phosphorous content. Availability of phosphorous content is decreased in both high acid and high alkaline soil. Uses of lime may be reduced the acidity of soil and increases phosphorous availability.

INTRODUCTION

Soil reaction means the degree of acidity or alkalinity caused by the relative concentration or activity of hydrogen (H+) or hydroxyl (OH-) ions present in it. Acidity is due to the excess of H ions over the OH^+ ions. On the other hand alkalinity is due to the excess OH-ion ions over H ions. The pH value of solution may be defined as the logarithm of the reciprocal of hydrogen ion activity or concentration and is expressed as:

pH = log 1/H+ = - log(H+) (Daji, J.A. 1996). In this scale pH ranges from 0 to 14 where pH 0 represents the highest limit of active acidity, pH 14 represents the highest degree of alkalinity where pH represents a neutral reaction. Soil reaction has great importance because crop growth both directly and indirectly depends on soil reaction. Plants growths are well in neutral soil but plants growths hampered both very acidic and alkaline soil. There is strong relationship between soil reaction and the availability of phosphorous. The availability of phosphorous is highest when pH of the soil is between 6 to7. When the soil reaction is below or above the range, the availability is reduced. The low availability of the phosphorous in the plateau area of West Bengal is due to acidic nature of soil.

The Study Area

Based on physiographic division of West Bengal, the plateau region of West Bengal consists of Puruliya district (Singh R.L. 1970). The western most district of West Bengal, Puruliya laying between latitude $22^0$42'35" N to $23^0$42'0" N and longitude 85049'25" E 86054'37" E, has hardly any natural boundary demarcated by streams or hills. Only about a hundred-kilometer of the district boundary follows the river Damodar in the north and the river Subarnarekha in the West **(Fig.1)**. The artificial boundary was made on linguistic basis and administrative convenience. It was bounded on the west, north and south by Jharkhand State while the north east and east of the district was bounded by Barddhaman, Bankura and Medinipur district of West Bengal. An ordinary village, Puruliya had grown gradually in importance and became the headquarters of the former Manbhum District in 1838 (District Gazetteers, Puruliya 1985). At the time of independence and partition of India in 1947, Puruliya town was a subdivision of Puruliya, except 3 police stations which was separated from Bihar and amalgamated to West Bengal in 1956 under Bihar and West Bengal through Transfer of Territories Act 1956. There are three subdivision in Puruliya district such as Raghunathpur, Puruliya Sadar (West), Puruliya Sadar (East) and 20 Community Development Blocks, Puruliya municipal town is the headquarters of Puruliya district **(Fig. 2)**. Puruliya municipal town is the headquarters of Puruliya district. The total population of the district is 29, 27,965 with a density of 468 persons per sq. km. The average literacy rate is 65.38% in 2011. The male literacy rate is 78.85% while female literacy is only 51.29 % (Census of India, 2011). The geology of the region is mainly characterized by granite-gneiss rocks of Achaean-Proterozoic periods except north eastern and southern part. The north-eastern part is covered by sedimentary rocks of

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Gondwana age while the volcanic rocks of Dalma group cover southern part. Topography is interesting because the area has a hilly upland tract in western and north-western part and extensive undulating land with river valley in the middle and eastern part while southern part have rugged topography with lateritic capping (Ghosh S, 2012). Soils of the region is primarily controlled by parent materials mainly granite-gneiss rocks, undulating topography, climate and vegetation. The area is mostly covered by residual soil, which is formed due to disintegration and decomposition of rocks by weathering process. Geologically, these soils are older but immature. Most of the soil is laterite, originated from granite-gneiss rocks. Based on parent materials, soils are classified into three broad group namely (a) gneissic soils (laterite soils) (b) Gondwana soils on sedmientary rocks (sandy soils) and (c) transition soils of sub metamorphic rocks (loamy soil). Soils in the region is primarily lateritic with acidic in nature and low phosphorous content.

Table 1 reveals that sandy to sandy loam texture soil is observed in *Tard* and *Baid* (highland) region. The depth of soil is shallow.

Water holding capacity in this category of soil is very low (25 to 35%) and moisture content is also low (3 to 5%). Sandy loam to loam texture soil is observed in *Kanali* land (medium land). Water holding capacity is moderate (35-45%) and moisture content is also moderate (5-8%) clay loam to clay soil is observed in *Bahal land* (low land). The depth of soil cover is relatively good. Water holding capacity is also relatively good (50-63%) and soil moisture content is also good (8-12%). Water resources are primarily enriched by surface water and lack of ground water resource due to hard crystalline basement. About 15% area is irrigated mainly through surface water irrigation. Climate of the region is characterized by hot summer and monsoon type climate with average annual rainfall is 1260 mm. for last 48 years average.

Table 1 Some physical properties of soils in study area

Soil texture	Type of land	Depth of soil	Water holding capacity	Soil moisture content	Leaching	Remarks
Sandy to sandy loam	Soil at or near the high land	Shallow	25-35%	3-5%	Excessive	Quartz, feldspar and iron contents hindrance to cultivation
Sandy loam to loam	Soil below the high land and above the valley field zone	Moderately deep	35-45%	5-8%	Moderate	Moderately suitable for cultivation
Clay loam to clay	Valley field zone	Deep soil	50-63%	8-12%	Low	Suitable for paddy cultivation

Source: Compilation of laboratory analyzed soil data

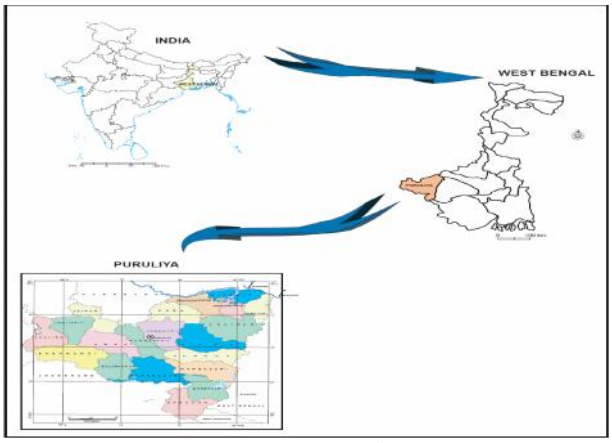

Fig 1 Location Map of the Study Area

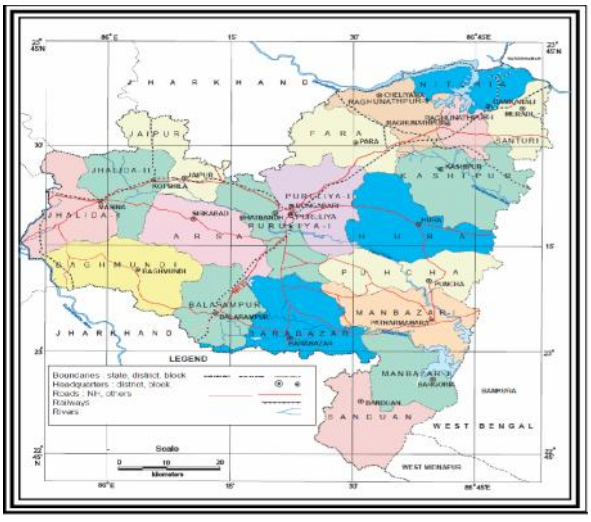

Fig 2 Administrative Map of the Study Area

Agriculture is the dominant land use (about 70% area) and rice is the dominant crop.

Objectives of the Study: The main objectives of the study are given below:

- To show and analyze the spatial variation of soil pH
- To show and analyze the spatial variation of soil phosphorous
- To find out the interrelationship between soil pH and soil Phosphorous
- To manage both soil pH and low soil phosphorous content

MATERIALS AND METHODS

Soil is the most important natural resources for agricultural activities as well as human habitation. Soil samples are collected from different physiographic units covering all C. D. Blocks of the district Different physiographic units are identified from Survey of India topographical map and satellite imageries. Soil sample are collected in the different places in the district (Fig.3). Soil pH and Soil phosphorous are collected are analyzed in laboratory. Soil pH and soil phosphorous data are plotted in the different sample point and isopleths are drawn and this study area is classified in different soil pH and soil phosphorous zone through GIS. Data are generated through GIS and it is analyzed through cartographic techniques.

RESULTS AND DISCUSSION

Since the soil is one of the important factors for determining the quality of land, soil samples have been collected from different physiographic zones during field sampling **(Fig 3)**.

Analytical results are plotted on maps and isopleths are drawn to obtain the information on spatial variability of the various chemical properties. These maps are digitized to generate a new set of data on chemical properties of the soil samples at micro level. The soil of the study region is mainly acidic in nature. In acid soils, most of the plant nutrients become unavailable and consequently plant growth affected. whish are of acid in nature such as granite and gneiss. These two rocks are predominantly found in this region. The data on soil pH is presented in **Fig 4& Fig 5**.

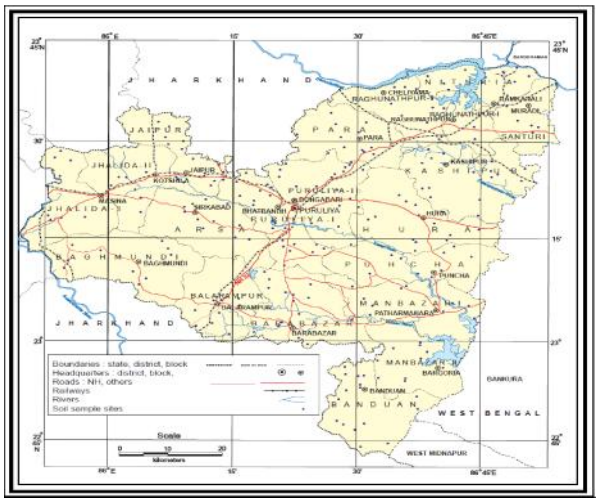

Fig 3 Soil Sample Sites

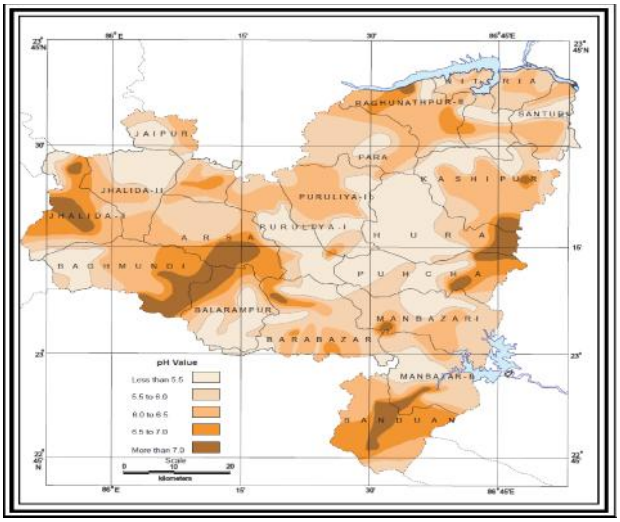

Fig 4 Soil pH Map

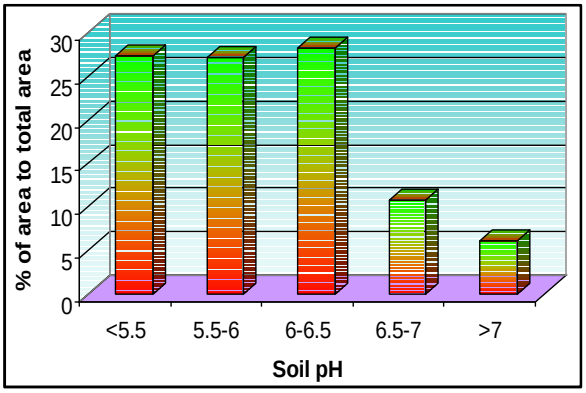

Fig 5 Histogram showing percentage area in different categories soil pH

Form the **Fig 4 and Fig 5** it is observed that > 27% of the total geographical area have very strong acidic soil with pH value < 5.5. This type of soil is mostly concentrated in the central part, northern and north-western part of the region and is a major constraint for plants grow as it affects the soil microbiological activities. Slightly alkaline soil (pH >7) is observed in the western hilly region with small patchy occurrences in the eastern and southern part of the region and covers 6.1% of the total geographical area. The histogram plot **(Fig 5)** of the soil pH also indicates that ≈ 39% of the total geographical area belongs to pH value between 6 to7 which indicates that only a part of the area is favourable for crop production as far as soil pH value is concerned.

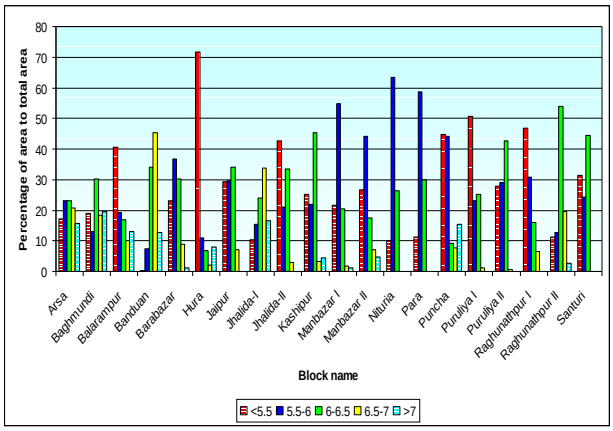

Fig 6 Histogram showing Block wise percentage area of soil pH

Fig 6 represents the micro-level pH value of the region. A detailed analysis of the table indicates that most of the blocks have soil below pH value 6. However Hura represents acidic soil with total geographical ≈72%, followed by Puruliya-I (50.63%) and Raghunathpur-I (46.84%).The soils are derived from laterisation process of the parent rock - granite-gneiss. Pedogenesis process is still going on. The soil is immature and rich in iron and aluminum content and thus it is acidic in nature.

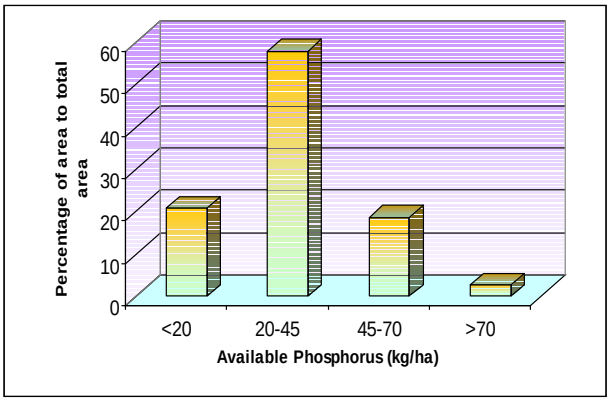

Fig6 Histogram showing percentage area in different categories of available soil phosphorus

The availability of phosphorus in the soil determines the nutrient availability to the plant growth. The lack of phosphorus in the soil leads to poor plant growth and subsequently poor yield. Determination of available phosphorus in the soil allows the farmers to take necessary measures for application of inorganic fertilizer to make agriculture sustainable in the region. Unscientific and random

application of inorganic fertilizer on the other hand creates environmental problems and necessitates proper management of land resources. The results of the chemical analysis of the available phosphorus (P_2O_5) in the soil represent a very gloomy picture **(Fig 6 and Fig 7**). About the 80% of the study region have very low to low Phosphorous content (<45 kg /ha.). It is occurred in central, eastern, southern, and northern parts were pH value below 6. Moderate and high phosphorous content are nearly 18% and 2% respectively. It has patchy and scatter occurrence in different places in the region.

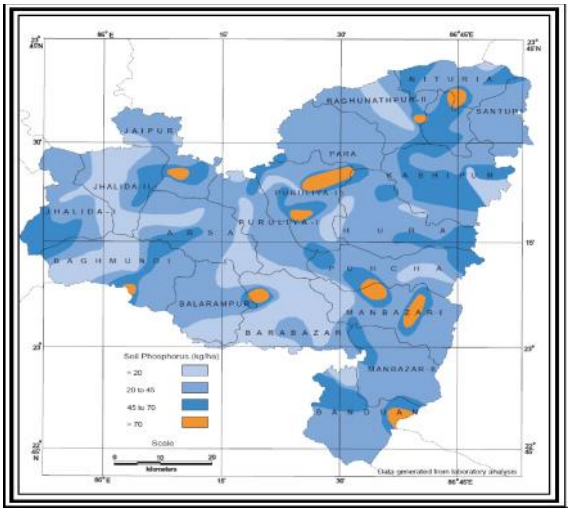

Fig 7 Available soil phosphorous map

The histogram plot (**Fig 6**) also reveals that ≈ 58% of the total geographical area have low phosphorus content (available phosphorus 20 – 45 kg/ha) in the soil which indicates the fertility level is low. According to (Daji 1996) the availability of phosphorus is highest in the neutral soil. However, the availability is reduced both in acidic and alkaline soil. Very low to low fertility level of the soil is mainly due to acidic nature of the soil.

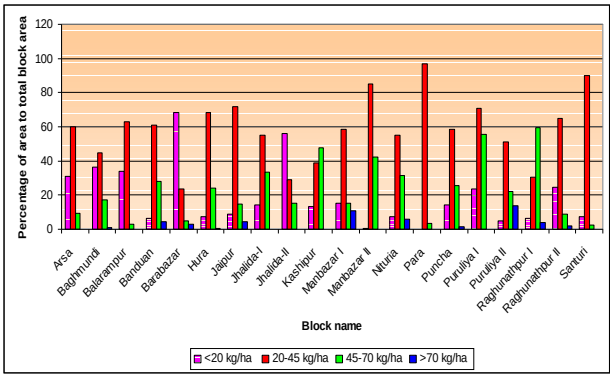

Fig 8 Histogram showing Blocks wise percentage area in different categories of available soil phosphorus

The detailed analysis of the spatial variability of the phosphorus content in the soil is presented in **Fig 8**. From the **Fig 8**, it is apparent that very low phosphorus content (<20 kg/ha) in the soil covers more than 68% area of Barabazar block followed by Jhalida - II (55.87) and Baghmundi (36.63%). In other blocks, the aerial coverage of the low phosphorus content soil is very limited. While phosphorus content of the soil (20 – 45kg/ha) covers .97% of the total area of Para block, followed by Santuri (89.84%), Manbazar – II (85.25%), Jaipur (71.84%), Puruliya – I (71%) and Hura (68.49%). In fact all the blocks of Puruliya districts have low phosphorus content.High phosphorus content in the soil (>70 kg/ha) covers .14% of the total area of Puruliya – II block, followed by Manbazar – I (10.90%). At least eight blocks of the study region do not have any area within the category of the high phosphorus content. The plausible explanation for low phosphorus content in the soil is due to the low pH content in the soil.

There is close relation between soil pH and soil phosphorous. The availability of the soil phosphorous depends on soil pH. The higher phosphorous availability is between 6.5 and 7.5. Phosphorous content falls in the soil above and below this limit. In the study region, relatively high concentration soil phosphorous and high pH value is observed in higher elevation and rugged topographic region where soil formation is not mature stage such as western hilly region, southern rugged topography region, parts of Raghunathpur and kashipur region. In acidic soil iron, aluminum, manganese and other bases are present in a soluble state and in more quantity. The phosphate ions react with these bases and insoluble phosphate of these elements are formed and become unavailable.

$$Al + H_2PO4 + 2H_2O = 2H + Al\,(OH)^{2}.\ H2PO^{4}$$
(Soluble) (Insoluble)

The phosphates react with hydrated oxides of iron and aluminum and form insoluble hydroxyl-phosphates of iron and aluminum. Unavailability of phosphorous called *phosphorus-fixation* (Sahai, 1990). The availability of phosphorous at different pH is linked with ionic in which it is present in soil solution. The monovalent H2PO4 ions predominate in highly acid solution (pH 4-5). With decreasing acidity, the divalent HPO4 ions begin to appear. In the pH range 6 to 7, phosphate-fixation is very slight. Consequently at the pH range phosphorous availability is highest.

CONCLUSION

It may be concluded that nearly 20% area of the district have good to moderately good quality soil in terms soil pH and phosphorous which is suitable for agricultural activities. The use of lime may control soil pH and increase the soil phosphorous content. When lime is added to moist soil, the soil solution becomes charged with calcium ions. Lime may be reduced hydrogen ions in the colloidal complex. It increases the availability of almost all the plants nutrients such as nitrogen, phosphorous, potassium, calcium, magnesium, boron, zinc, copper and molybdenum. It also reduces the toxicity caused by soluble iron, aluminum and manganese. Lime also encourages the microbial activity of the soil. Use of basic fertiliser such as sodium nitrate, basic slag etc. reduces the acidity of the soil. Proper soil and water management checks the leaching of bases and enhance decomposing of organic matter. Acid tolerant crops should be grown according to the soil pH. Rice, potato, oat, pulses etc. is grown in moderately high acid soil condition. Barley, wheat, maize, turnip, brinjal etc. is grown in the moderately acid soil condition while tomato, carrot, red clover is the slightly acidic soil. After augmenting the soil fertility,

this land may be used for oil seeds, vegetables, short growing paddy, forestry and others as there is increasing trend in oil seeds production. Forestry will be grown in high land and wasteland. in poor and fair quality land. Open scrub land will be rejuvenated through afforestation. Degraded agricultural land will be protected from erosion through terracing, criss-cross ploughing etc, though many agricultural lands have terracing pattern. The district is agriculturally drought and about 15% areas are irrigated mainly surface water irrigation. Surface water irrigation must be increased through digging new tanks, small reservoirs, *jhore bandhs* at suitable places mainly waste land for better agriculture purposes. So, Sustainable land management is urgently needed for better agriculture in this region.

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