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Soil Fertility and Its' Impact on Agricultural Productivity: A Study in Sapar Mouza, Burdwan-I C.D. Block, West Bengal

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Abstract

Soil is the principal medium of plant growth for providing nutrients in adequate manner. At the dawn of the civilization, agriculture based sedentary civilizations have been grown up in fertile soil of the river. Over time, with the increase of population and food demand, methods of agriculture and stress on soil have been accelerated simultaneously because of mismanagement of soil fertility. Declining soil fertility has become a threat in agricultural productivity and agro-economic scenario.

In this study, soil fertility and factors of agricultural productivity have been studied in Sapar Mouza where double cropped paddy is cultivated for last 35 years using inorganic fertilizer. Declining soil fertility has created an adverse effect on productivity of paddy. Soil pH is an important factor for productivity followed by phosphate and nitrogen content in soil. Phosphate, organic carbon and potassium are the main three components of production system of paddy which has shown that not only chemical fertilizer but also organic manure can sustain the productivity of paddy. Hence, integrated management of chemical fertilizer and organic manure are essential for sustainability of agricultural productivity of the mouza.

Key Words: Soil fertility, Agricultural productivity, Soil pH, Declining soil fertility, Organic manure.

Introduction: Soil is one of the fundamental bases of agriculture because soil is a medium of plant growth. In *Atharva Veda* (1200-1000 B.C.), an ancient Indian philosophical text, soil has been considered like mother as providing foods for human society and the establishment, survival and disappearance of civilizations have been based on the performance of productivity of soil to provide food, fiber and further essential goods for humans (Mueller et. al., 2010). Soil productivity, the capability of a soil to produce plants and or crop (yield), is dependent on soil fertility (Basak, 2000; Hatfield, 2006). In ancient Indian literature, on the basis of fertility, soil was divided into two, *urvara* (fertile) and *anurvara* or *usara* (sterile) and on cropping practice, *urvara mritika* was divided into *tila* (sesamum), *vrihi* (rice) and *mandiena* (mung) etc. (Raychaudhuri, 1975). Soil fertility is the intrinsic capacity of soil to provide essential plant nutrients in adequate amounts to ensure optimum plant productivity including maximum economic benefit and minimum environmental degradation (Basak, 2000; Dalal and Rao, 2006; Biswas and Mukherjee, 1994; Singh, 2006; SSSA, 1996; Foth, 1990; Prasad and Power, 1997). Soil fertility can be measured by soil test, plant analysis and deficiency symptoms of plant (Dalal and Rao. 2006). Though soil test provides the chemical properties of soil fertility, the assessment of soil fertility takes place in context of individual farming system and agro-climatic region (Stockdale et al., 2013)

Decline of soil fertility, one of the most serious problems of the world, is a matter of concern from the development of sedentary agricultural system since 10000 years ago (Hartemink, 2003) and loss of soil fertility is a major problem in tropical crop land (Akinrinde, 2004) for overexploitation of land resources (Knudsen et al. 2006) as 95 per cent population is increasing in tropical countries (Hartemink, 2003). Traditionally, in most of the permanent agricultural system, soil fertility is managed through manure, fertilizer (organic and inorganic) and other organic material (Hartemink, 2003; Foth, 1990). Soil fertility is a result of long term application of manure and inorganic fertilizer (Akinrinde, 2004). Declining soil fertility is the main constrain in improving the yield of annual crops resulting into dwindling productivity (Fageria and Baligar, 2003; Buresh et al., 1997). Therefore, to maintain productivity of crop, management of soil fertility and soil health are the key to the development of sustainable agriculture (Prasad and Power, 1997) which is concerned with chemical reactions in soil, amount and availability or unavailability of essential plant nutrients, mechanism of nutrition depletion and replenishment in soil (Prasad and Power, 1995).

In Sapar mouza (J.L. No. 101) in Burdwan-I C.D. Block, 83 per cent of total land is used for double cropped paddy cultivation since 1980s using mainly chemical fertilizer, 4Q ha^{-1} on an average. 73 per cent farmer cultivate with only chemical fertilizer whereas 26 per cent use both organic and inorganic fertilizer while traditional techniques of soil management has been redundant from the agricultural scenario. Nutrient indices for nitrogen (N), phosphate (P) and potassium (K) of the mouza (2013) are 1.00, 1.65 and 1.60 respectively which represent low nutrient indices (<1.67 is low, as mentioned by Ramamoorthy and Bajaj, 1969). Due to declining fertility, productivity of paddy is highly unpredictable in nature and spatial variation is prevailing there. The uneven productivity and low fertility have created an unstable agro-economic scenario in the mouza. Therefore, factors of production of paddy have been studied for maintaining stable production of paddy and to revive agro-pedological as well as agro-economic system of the mouza.

Study Area: Total area of the Sapar Mouza is 165.2 hectare and total population is 1103 (2011). Population density of the mouza is 667 person/km^2 and agricultural density is 2 cultivator/ha though physiological density is 7 person/ha. Agriculture is the main economic activity in the mouza where 65 per cent of total population is engaged in agricultural sector (Census, 2011). Distance of the mouza from Burdwan town is 11 km. The latitudinal and longitudinal extension of the mouza are $23^0\ 16'\ 59''$ N to $23^0\ 17'\ 47''$ N and $87^0\ 55'\ 36''$ E to $87^0\ 56'\ 44''$ E respectively. Cropping intensity of the mouza is 200 and 83 per cent of the land of the mouza is cultivated for doubled cropped paddy with canal and submersible irrigation.

Objectives:

The objectives of this study are:

i) to assess chemical properties and macro nutrients of the soil,
ii) to find out major determining factor of productivity of paddy in the mouza and
iii) to analyse the influence level of the studied chemical properties and nutrient availability in productivity of paddy.

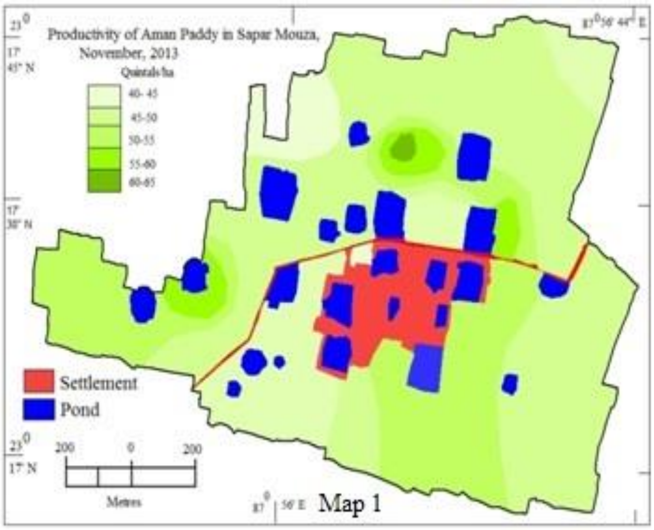
Database and Method: The empirical research work has been carried out fully based on primary data. Twenty soil samples have been collected randomly from the mouza along with detail interview with the corresponding farmers to know about cropping pattern, fertilizer application, production and problems as well as their suggestions regarding the concerned agricultural practice.

Selection of the issue and geographical area, literature survey, collection of mouza map and preparation of questionnaires have been done in prior to field visit. Field survey includes perception study with the farmers, collection of soil samples and use of GPS for collection of ground control point (GCP). After completion the field study, collected soil samples have been tested by pH metre, Electrical Conductivity metre, flame photometer and soil kit. The correlation values have been tested its level of significance at N-2 level (N=(20-2)=18). Principal component has been analyzed in statistical software, Past 3.0 and SPSS 22. Interpretation of the findings through maps and diagrams has been prepared with the help of GIS software, Map Info 9.0 and MS-excel, 2007 respectively.

Result and Discussions:

i. Productivity of *Aman* Paddy: Level of crop productivity is the prime factor in profit or loss of farmers in agriculture. It controls the total production of crops in any administrative area. In the earlier system of cultivation in Bengal, productivity was 27.17 Q/ha for summer rice and 9.386 Q/ha for autumn rice in 1972-73 (Bandyopadhyaya, 1975). But, after green revolution in 1970s, the productivity of crops has been increased more than five times as 49.75 Q/ha in the mouza due to HYV seed, chemical fertilizer, pesticide and irrigation facility.

Spatially, there is a variation in productivity in the mouza from 40 to 62 Q/ha. The lowest productivity (40-45 Q/ha) has been found in the north-western part of the mouza whereas the highest productivity (60-65 Q/ha) has been observed in northern middle part of the mouza, by using green manure (dhaincha) (Map No.1).



ii. Soil pH: Soil reaction is measured by pH, (puissance de Hydrogen) proportion of H^+ and OH^- ions in soil solution (Sahai, 2004; Foth, 1990). Mathematically, soil pH is defined as the negative logarithm of the concentration of hydrogen ion or pH = - log $[H^+]$ (Biswas and Mukherjee 1995; Foth, 1990; Sparks, 2003). Soil pH has appreciable influence of soil fertility, activity of organisms and nutrient availability and plant growth (Prasad and Power, 1997; Daji et al., 1996; Rengel, 2002; McBride, 1994; Chesworth, 2008). The principal adverse effects of acidity on soil fertility occur at soil pH values below 5.5 due to acid dissolution of aluminum (Al^{3+}) and the onset of Al and Fe_2^+ phytotoxicity to susceptible plants (Blamey et al., 1989; Lal, 2006).

The soil pH in Sapar Mouza ranges between pH 4.96 to 6.36. This range belongs to slightly acidic (5.5 to 6.5) and acidic (below 5.5) with respect to the classification of soil of West Bengal by Bhattacharyya (2000). The lowest pH value (4.96) is found in south-west part of the mouza while highest pH value is observed in middle-western part of the mouza using organic manure at 28 Q ha^{-1} $year^{-1}$ and chemical fertilizer. In the pH categories, 46.06 per cent and 50.41 per cent of agricultural land belong to 5.0 to 5.5 and 5.5 to 6.0 pH class respectively. Only 1.57 per cent of agricultural land is found out the pH 6.0 to 6.5. Hence, 51.98 per cent agricultural land belongs to slightly acidic class and 48.02 per cent land belongs to acidic state.

Suitable pH range for paddy cultivation is 5.5 to 6.5 (Daji et al., 1996). Accordingly, 48.02 per cent of agricultural land of the mouza is not suitable for paddy cultivation.

In Sapar, there is significant correlation between soil pH and agricultural productivity (0.54, 99 % confidence level). As total data set of soil pH belongs to below 7.0 (acidic condition), the correlation value may be best fitted in acidic soil, may not be in alkaline soil reaction (Fig. No.1).

Standard error of estimate is the lowest (5.04) in soil pH in respect of other variables and pH has explained the highest percentage of variance (29.16%) with productivity of paddy. Residual from regression of pH is varied from +21 to -21. The highest residuals is found out in northern middle part of the mouza and positive residuals is detected in the western part of the mouza showing higher productivity of paddy and higher pH value of the mouza. Negative residual value is noticed in southern middle part, eastern part, north eastern and north western part of the mouza revealing low

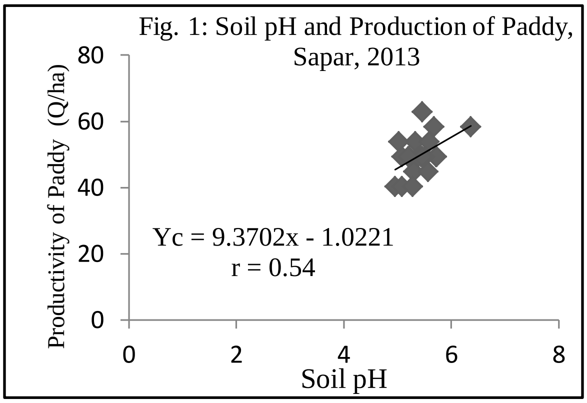
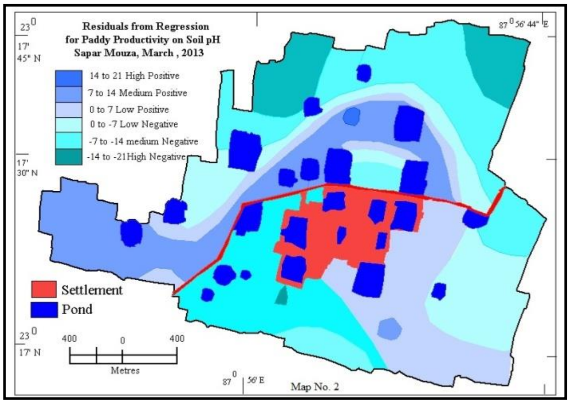


Fig. 1: Soil pH and Production of Paddy, Sapar, 2013



productivity of paddy. Highest negative residual value (-14 to -21) is observed in small part of the south and north western and north eastern part explaining low productivity of paddy as well as lower pH value of that part (Map No. 2).

iii. Oxidizable Organic carbon and Productivity of Paddy: Organic carbon is one of the components of the fertility of soil. Organic carbon is the main element in organic matter (58%) (Sarkar and Halder, 2005), composed largely of carbon and hydrogen (Brady, 1990). Clay-humus complex, mixture of organic matter and clay, is a store house of nitrogen, phosphate and sulfur in soil (Biswas and Mukherjee, 1994).

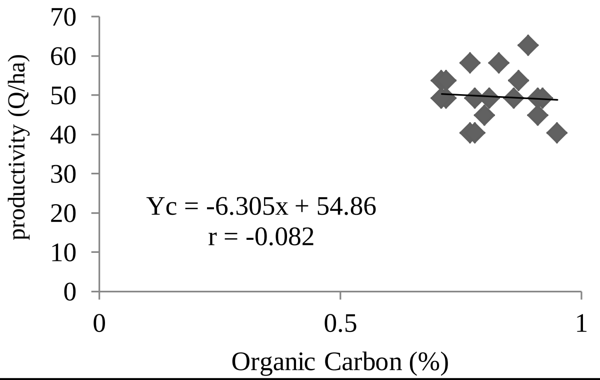
Since the early era of civilization, soil organic matter plays a vital role in soil fertility and productivity (Allison, 1973). In general, soil having a cover of grass or forest, contains more organic matter than arable soils (Daji et al., 1996). Soil regularly ploughed or harrowed, contain less organic matter than those not so cultivated. With greater aeration, decomposition of organic matter and depletion of humus have been increased with cultivation (Daji et al., 1996; Wolf & Synder, 2003). Generally, mineral soil contains 5 per cent of organic matter (Sahai, 2004).

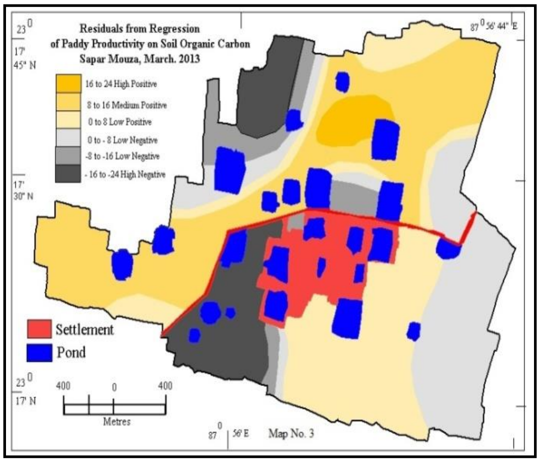
In the mouza, 21.47 per cent and 78.53 per cent of agricultural land contain 0.5 to 0.75 per cent and 0.75 to 0.95 per cent of oxidizable organic carbon, belong to medium fertility and high fertility class respectively.

The correlation value between organic carbon and productivity is -0.082. As the correlation value is very low, t-test value is not satisfactorily significant and standard error of estimate is 5.95. The correlation value is explained only 0.67 per cent of variance which is also negligible (Fig. No.2). As organic matter content in the soil is low, it may not be influential on productivity at significant level.

The range of residual value is between +24 to -24. Highest positive residual (16 to 24) is found out in northern middle part of the mouza depicting higher productivity of paddy and moderately

Fig. No. 2: Oxidizable Organic Carbon and Productivity of Paddy, Sapar, 2013





organic carbon content (0.85 to 0.90%). Negative residual is obtained in the north western part for low organic matter content and low productivity of paddy. Again, positive residuals are observed in western part and north eastern part of the mouza revealing higher productivity of paddy and higher organic matter content in soil (Map No. 3).

iv. Electrical Conductivity (EC) and Productivity of Paddy: Electrical conductivity is the common measurement of soil salinity and is indicative of the ability of an aqueous solution to carry an electric current. By agricultural standard, soil with an EC greater than 4 dS/m is considered as saline. Actually, salt sensitive plants may be affected by the increasing electrical conductivity on less than 4dS/m range. Soil's EC is related with soil pH, nutrient availability, water holding capacity, cation exchange capacity which affect crop yield (Chan et al., 2006; Aimrun et al., 2007).

The correlation value between electrical conductivity and productivity is -0.21 in the study area. The t-test value is signified at 50 per cent confidence level. So, this significance level can also be considered as insignificant relation between these two variables because the range and value of EC is not so higher to affect the growth of plants. The standard error of estimate value is 5.85 and the correlation value is explained only 4.27 per cent (Fig. No.3).

Residuals from regression of productivity of paddy has been calculated which ranges between +27 to -27. Positive residuals are found in middle of the northern part and western part of the mouza revealing high productivity of paddy. Southern part is showing positive residuals and moderately to high productivity (47-50 Q/ha). Western part of the mouza is characterized with positive residual explaining moderate productivity and higher EC. Negative residuals are observed in north-western and north-eastern part of the mouza showing low productivity of paddy and high EC value (Map No. 4).

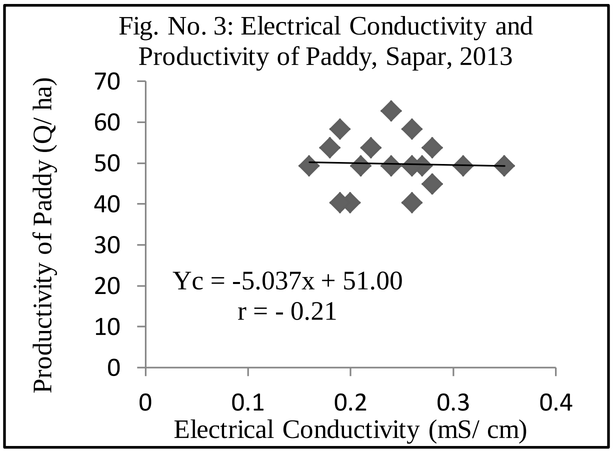
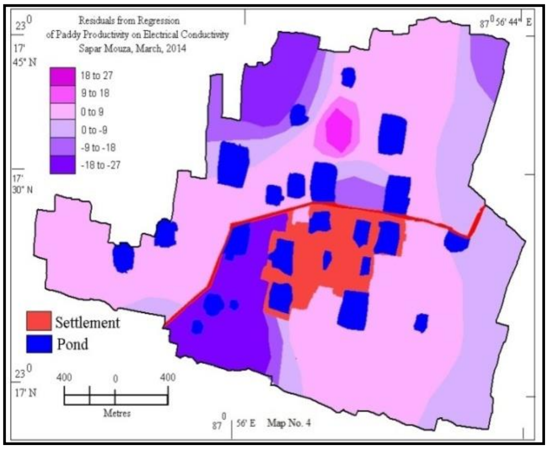


Fig. No. 3: Electrical Conductivity and Productivity of Paddy, Sapar, 2013



v. Total Nitrogen and Productivity of Paddy: Nitrogen is one of the macro nutrients for plant growth. Nitrogen is available to plant in the form of ammonium (NH_4^+) and nitrate (NO_3^-). In natural environment, nitrogen is synthesized from organic protein and organic compounds. In agro-pedological system, nitrogen is incorporated through chemical fertilizer, such as di-ammonium phosphate, $(NH_4)_2HPO_4$, urea, CO $(NH_2)_2$. Nitrifying bacteria normally convert ammonium rapidly to nitrate (Addiscott, 2005). These two ions are the source of nitrogen (N) to plant. Ammonium is unavailable to most of the plants due to nitrification in soil but paddy can utilize the ammonical nitrogen in soil (Sahai, 2004).

In the mouza, the range of total nitrogen content is 24.61 kg/ha - 123.22 kg/ha and the correlation value between total nitrogen and productivity is 0.38 which is signified at 90 per cent confidence level (Fig. No:4). The range of residuals of total nitrogen is +24 to -24. Northern middle part of the

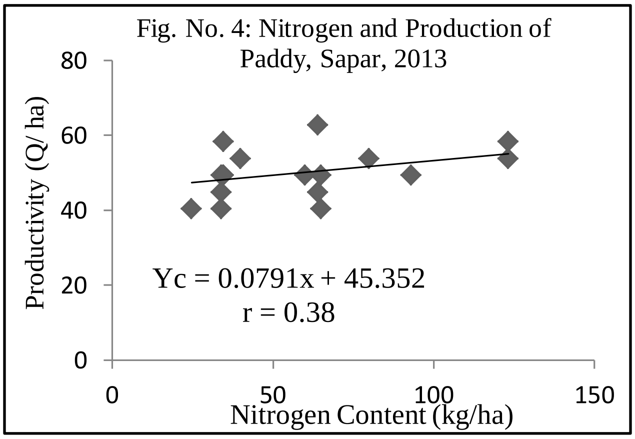
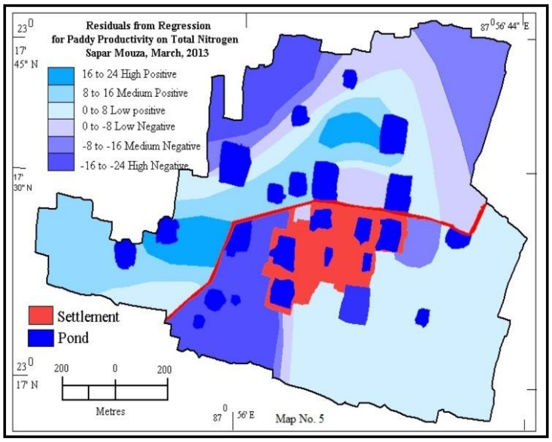


Fig. No. 4: Nitrogen and Production of Paddy, Sapar, 2013

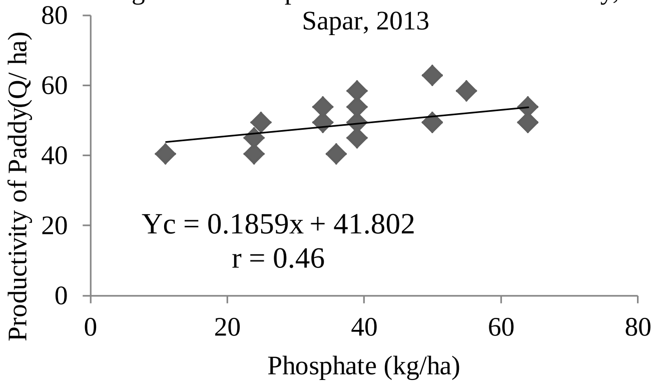


mouza is characterized with high positive residuals (16-24) showing higher productivity. Low and medium positive residuals are found out in western and middle part revealing low nitrogen content and with high productivity. Alternatively, high negative residuals (-16 to -24) are observed in the southern middle part and northern west part explaining low nitrogen content and medium productivity as 50 Q/ha. Positive residuals are obtained in southern part depicting high nitrogen content in the soil (Map No.5).

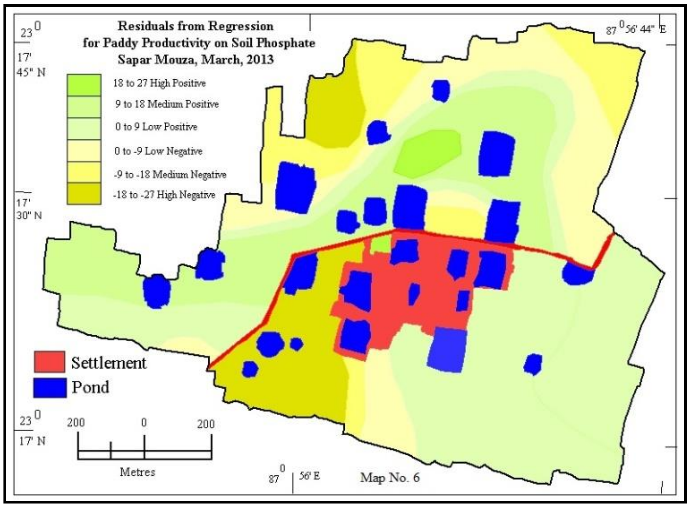
vi. Phosphate and Productivity of Paddy: Phosphate is another macro nutrient in growth of plant. Phosphorus is not fixed in soil by natural processes but it losses from agricultural land through leaching, crop removal and insoluble form of phosphorus. Phosphorous availability in soil is higher in pH range 6.0 to 6.5 (Prasad and Power, 1997). In acidic solution, applied phosphate reacts with Fe^{-2} and Al^{+3} and produce Al-phosphate. In solution of pH 7.0, both $H_2PO_4^-$ and HPO_4^{2-} ions are found because Ca-clay plays a dominant role in phosphate retention (Brady, 1990; Prasad and Power, 1997).

In the mouza, the range of phosphate content in soil is 22 kg/ha - 72 kg/ha belongs to medium and high fertility class of soil classification. The correlation value between phosphate content and paddy productivity is 0.46 which is signified at 95 per cent confidence level with the increase of phosphate in the soil, productivity of paddy increases (Fig. No.5).

Fig. No. 5: Phosphate and Production of Paddy, Sapar, 2013



The range of calculated residuals of phosphate is from +27 to -27. Middle of Northern part of the mouza is under high positive residual (18 to 27) showing higher productivity. In western part, positive residual is found explaining high productivity and medium to high phosphate content. Negative residuals is noticed in north western and north eastern part revealing low productivity and moderate to high content of phosphate. High negative residual (-18 to -27) is found out in the south western and north western part exhibiting low content of phosphate in the soil and low productivity of paddy (Map No.6).



vii. Potassium and Productivity of Paddy: Potassium is the third macro nutrient for plant growth. Potassium is available as K^+ and K_2O ion in soil. Potassium is also removed from soil through crop removal and leaching.

In the mouza, potassium content (K_2O) in soil is from 110 to 590 kg/ha. The correlation value between potassium and productivity of paddy is 0.16 which is signified at 50 per cent confidence level i.e. insignificant relation between these variables (Fig. No.6).

The range of residuals of potassium is +24 to -24. The positive residuals are found in northern-middle part and western part of the mouza showing moderate to high productivity of paddy (50-55Q/ha). Negative residuals is found out in north eastern and southern part indicating low productivity and moderate potassium content (Map No.7).

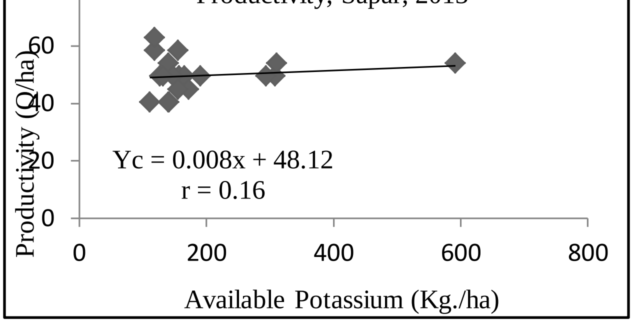


Fig. No. 6: Available Potassium and Productivity, Sapar, 2013

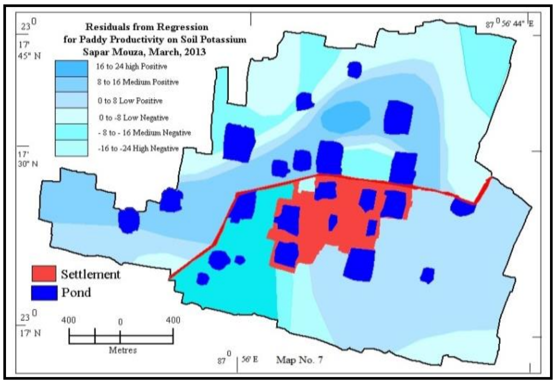


Table No. 1: Correlation of Variables with Productivity and their level of Significance

Variables	r value	t- test value	Significance level at N-2 degree of freedom	Remarks
pH	0.54	3.23	Signified at 99 % level	Causal relationship
Organic Carbon	-0.08	0.34	Insignificant	Insignificant relationship
Electrical Conductivity	-0.21	0.93	Signified at 50% level	Insignificant relationship
Total Nitrogen	0.38	0.1444	Significant 10% level	Significant relationship
Phosphate	0.46	0.2116	Significant 5% level	Significant relationship
Potassium	0.16	0.69	Signified at 50% level	Insignificant relationship

viii. Major Factors of Productivity of Paddy: First component of productivity of paddy is phosphate of the soil. The factor loading of first principle component is showing that it has a significant positive correlation with other variables in soil. Eigen value of first principle component is 1.682 which has explained 28.043 per cent of variance (Table No. 2&3). As different forms are available in soil for conversion between these forms and fate of P, quantity and quality of application of P fertilizer is very much essential for optimum production of paddy.

Table No. 2: Component Analysis of Agricultural Productivity, Sapar, 2013

Variables	Component		
	Component 1	Component 2	Component 3
PH (1:2.5) H_2O	.533	-.031	-.470
Organic Carbon (%)	-.023	**.832**	-.028
EC (1:2.5) H_2O	-.113	.804	.231
Total Nitrogen (Kg/ha)	.778	-.116	.360
Phosphate	**.836**	.179	.259
Potassium (Kg/ha)	-.285	-.234	**.775**

Second component of productivity is organic carbon. It has high positive correlation with other variables and it can be treated as subsidiary variable in the production system. The Eigen value organic carbon is 1.438 which has explained 23.981 per cent of variance.

Third principle component of the production system is potassium (K). The K has a positive relation with productivity of paddy. Eigen value of K is 1.0664 which has explained 17.876 per cent of variance (Table no. 3). This variable can be treated as tertiary variable in the production system.

Table No: 3: Eigen Value and Variance of Principle Components

Component	Eigen Values		
	Total	% of Variance	Cumulative % of Variance
Phosphate	1.682	28.043	28.043
Organic Carbon	1.438	23.981	52.024
Potassium	1.073	17.876	69.9
pH	0.848	14.143	84.043
Total Nitrogen	0.572	9.584	93.627
EC	0.382	6.372	100.000

From this study, it has explained that soil pH has a causal relationship with productivity of paddy. Though phosphate is become the first component of production system of paddy, the availability and forms of phosphate in soil are highly dependent on soil pH. The correlation value between pH and phosphate is 0.268, signified at 80 per cent confidence level. So, soil pH, phosphate, organic carbon and potassium are main factors in the productivity of paddy. As the whole mouza belongs to acidic condition, 4.374 to 8.505 ton ha^{-1} lime ($CaCO_3$) is required to raise soil pH at 6.0. with that, integrated management of fertilizer (inorganic, organic and green manure) can sustainable maintain productivity of paddy.

Conclusion: From this research work, it is comprehensible that growth and productivity of crop have been influenced by chemical properties and macro nutrients in soil. Among the studied six variables, 70 per cent of variance has been explained by P, OC and K in the productivity of paddy. Other physical and chemical properties of soil is also important for crop yield. As range of organic matter content and electrical conductivity in the soil is low, there is no such strong influence in productivity. But, soil pH is the most influential factor in the crop production. Agricultural methods of the mouza are solely responsible for negative consequences of soil pH, organic matter content and nutrient storage. As a result, productivity is being hampered, causing low nutrient index. In this situation, agricultural methods should be followed with organic agriculture for sustenance of soil quality as well as agricultural productivity in the mouza.

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