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Research Article

Pearson Correlation and Regression Analysis of Sahibganj Agricultural Soil of Eastern Barharwa (SASEB)

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Abstract

The objective of this research is to predict the soil quality of Sahibganj Agricultural Soil of Eastern Barharwa (SASEB) in the upcoming 2024 Pre-Monsoon season with precision, using correlation coefficients of various Soil Analysis Parameters (SAP). This study introduces new insights into SAP through Pearson Correlation coefficients, Mean, Standard Deviation, Skewness, Kurtosis, and Regression model analyses for different soils in SASEB.

Efforts have been made to develop linear regression models for predicting the concentrations in SASEB. Positive correlations were observed between Phosphorus (P) and Organic Carbon (OC) (0.8399), Sulphur (S) and Phosphorus (P) (0.8093), and Phosphorus (P) and pH (0.642). Regression analyses between these pairs showed coefficients of determination (R%) values of 70.5% for Phosphorus (P) and Organic Carbon (OC), 68.7% for Potassium (K) and Organic Carbon (OC), and 65.5% for Sulphur (S) and Phosphorus (P).

The regression equations serve as mathematical tools to calculate different characteristics of soil health quality (SHQ) in Eastern Barharwa by substituting values for independent parameters. Statistical data for Kurtosis revealed a high value of 2.98013 and a low value of -1.8758 for Phosphorus and Copper respectively, while Skewness analysis showed a high value of 1.37512 and a low value of -1.71108 for Potassium and Phosphorus.

The positive correlations indicate that these parameters may significantly influence soil quality. The application of linear regression equations offers new avenues for predicting soil quality that can be applied to the study area.

Keywords: Pearson Correlation, Regression, SASEB, SAP, Standard deviation.

Introduction:

Soil is an indispensable natural resource essential for sustaining life, socio-economic development, and ecosystem functions. It forms a thin layer of granular material, comprising a blend of minerals, weathered rocks, and organic substances, which covers the Earth's surface and interact in various ways, especially via the biogeochemical cycles [1]. The type of soil is determined by the minerals present in various landforms, and its fertility hinges on the composition of these minerals and organic matter.

The soil's pH level primarily affects plant growth indirectly by influencing the solubility of ions and the activity of microorganisms [2]. Additionally, various observable soil parameters such as texture, structure, colour, depth, and stoniness provide valuable insights into how specific soils affect plant growth [3]. Plant growth is dependent on both the physicochemical properties and the organic matter content of the soil [4]. Agricultural practices such as the application of fertilizers can directly influence soil micro biota and fauna, and also have indirect effects on animal-associated micro biota [5-7]. Furthermore, intense rainfall during the rainy season can contribute to soil degradation by eroding the fertile topsoil layer [8,9].

Soil chemistry examines the chemical properties of soil and their interaction with pollutants, nutrients, and microorganisms. It involves studying process with a nutrient cycling, ion exchange and the absorption and description of contamination. Soil chemistry plays crucial role in agriculture as it affects plant growth, soil fertility, and the uptake of Nutrients and pollutants by crop [10]. This research aims to accurately predict soil quality in the study areas of Bangalipara, Chandipur, Jhiktia, Chanda, Khairbani, Jhumarbad, and Baramasia (Map_1). It focuses on analysing Soil Analysis Parameters (SAP) using advanced statistical methods, including Pearson Correlation Coefficient, Skewness, Kurtosis, and Regression models, to evaluate the agricultural soils of Eastern Barharwa.

To achieve this goal, soil samples were systematically collected from the specified areas and subjected to rigorous analysis. The Pearson Correlation Coefficient was employed to discern relationships between various soil properties. Skewness and Kurtosis provided insights into the distribution and variability of these properties, while Regression models was used to predict soil quality based on the analysed parameters. This comprehensive methodological approach delivered précised and reliable data to enhance agricultural practices and soil management in the region.

Methodology:

Description of the Area of the Study:

Barharwa is a community development block that serves as an administrative division in the Rajmahal subdivision of Sahibganj district. It is located at the foothills of the Rajmahal Hills in the Santhal Pargana division of Jharkhand, India, and is drained by the River Ganges to the south. Barharwa CD block is bordered by Udhwa CD block to the north, Farakka and Samserganj CD blocks in Murshidabad district of West Bengal to the east, Pakur and Hiranpur CD blocks in Pakur district to the south, and Pathna CD block to the west [11] classified as a nagar panchayat [12], Barharwa is situated at coordinates 24.857778°N latitude and 87.777167°E longitude [13], encompassing an area of 1.57 sq. mi. According to the 2011 Census of India, Barharwa had a population of 12,617, with 6,550 males (52%) and 6,067 females (48%). The population of children aged 0–6 years was 1,694. The total number of literate persons in Barharwa was 8,570, accounting for 78.46% of the population over 6 years [14][15].

Barharwa is situated at an elevation of 0 meters (0 feet) above sea level. According to the Köppen climate classification, Barharwa has a humid subtropical, dry winter climate (Classification: Cwa). The average yearly temperature in Barharwa is 29.67°C (85.41°F), which is 3.7% higher than India's national average. The area receives an average annual precipitation of 35.72 millimeters (1.41 inches) and experiences an average of 37.72 rainy days per year, accounting for 10.33% of the total days in a year.

Map _1: Map of Barharwa

Soil Sampling Design:

The sampling method was done by standard methods [16-20]

The selection of study areas for soil analysis was conducted using a random sampling procedure [21]. A total of seven samples were collected from different locations within Eastern Barharwa, covering a range of 500-600 meters. The samples were obtained separately from the surface of various sites by digging V-shaped pits of 30 cm depth and placed in polythene bags. These were done during the winter season, specifically in January.

The soil aggregates were gently broken down using a pestle and mortar to ensure a thorough mix for better analysis, while avoiding the crushing of primary sand and gravel particles. The samples were then air-dried in the shade and passed through a 2mm steel sieve to remove any pebbles or concretions. The sieved samples were randomly collected using a coning method, labelled, bagged, and prepared for shipping [22-24].

Laboratory Analysis:

Soil sample were analysed in laboratory of Soil at Birsa Krishi Vigyan Kendra, Sahibganj (B.K.V.K., Sahibganj). Each sample was first dried [25] and analysis of soil for pH, electrical conductivity, organic carbon (O.C.), nitrogen, available phosphorus, potassium, sulphur, Iron, Boron, manganese & copper were conducted. All the samples were analysed by the standard method [26,27].

Results and Discussion:

In this study, soil samples collected from agricultural fields were primarily intended for agricultural use. The key physicochemical characteristics of the analysed soil samples, including Minimum, Maximum, Mean, Standard Deviation (S.D.) [28], Skewness, and Kurtosis, are presented in Table 1. The variation among the measured values from different locations in Eastern Barharwa is minimal, with a very narrow range. Various pairs of correlation coefficients (R) are shown in Table 2. The regression equation was employed as a mathematical tool to calculate different dependent characteristics of Soil Health Quality (SHQ) in Eastern Barharwa by substituting values for the independent parameters into the equation.

Table 1 depicts the mean, median and standard deviation of the different tested SAP.

PARAMETERS	Min^{m}.	Max^{m}.	Mean	Standard Deviation	Skewness	Kurtosis
pH	6	7.5	6.7142	0.566946	0.72513	-0.74321
EC (ms/cm)	0.11	0.41	0.2528	0.115139	0.37390	-1.47959
OC (%)	0.71	1.75	1.3471	0.323404509	-1.3064	2.80233
N(Kg/ha)	298.5	457.3	394.4286	61.322663	-0.3369	-1.21945
P (Kg/ha)	28.3	105.8	84.05	27.391428	-1.71108	2.98013
K (Kg/ha)	75.21	117.3	88.98143	14.706242	1.37512	1.67259
S (ppm)	13.6	82	57.21429	22.794109	-1.24527473	1.6710048
Zn (ppm)	1.12	8.3	5.592857	2.274369614	-1.29318467	2.6450633
Fe (ppm)	11.3	16.7	13.15714	2.024728083	0.938572016	-0.233511
B (ppm)	1.07	1.57	1.31	0.156737573	0.226878465	0.8549704
Mn (ppm)	1.62	3.69	2.76	0.816741493	-0.59086817	-1.268532
Cu (ppm)	0.17	1.27	0.795714	0.473985131	-0.56244981	-1.875892

Table 1: Minimum, Maximum, Mean, Standard Deviation, Skewness and Kurtosis value of Soil Quality Parameters of Eastern Barharwa.

Pearson Correlation:

The Pearson correlation coefficient, also referred to as an inferential statistic, serves to examine the statistical relationship between two variables. It quantifies the strength of this relationship on a scale from +1 to -1. A correlation coefficient near +1 indicates a strong positive association between the variables [29]. Statistical correlation analysis is highly effective in evaluating the relationships among various physicochemical parameters, marking a significant step in soil sample analysis. This investigation presents the findings derived from Pearson coefficient analysis.

The Pearson Coefficient can be calculated by using the formula

$$\mathbf{R} = \frac{n\sum xy - \sum(x)\sum(y)}{\sqrt{[n\sum x^2 - \sum(x^2)][n\sum y^2 - \sum(y)^2]}}$$

Where R = Pearson correlation coefficient,
n = No. of value in each data,
x & y = two variable
If,
R = 0.0 to 0.19 [Very Weak Correlation]
R = 0.20 to 0.39[Weak Correlation]
R = 0.40 to +0.59(Moderate Positive Correlation)
R = 0.60 to +0.79(Strong Positive Association)
R = 0.80 to+1.0(Very Strong Positive Association)
R = 1(Perfect Positive Association)

	pH	EC(ms/cm)	OC(%)	N(Kg/ha)	P(Kg/ha)	K(Kg/ha)	S(ppm)	Zn(ppm)	Fe(ppm)	B(ppm)	Mn(ppm)	Cu(ppm)
pH	1											
EC(ms/c	-0.088	1										
OC(%)	0.758	0.086193	1									
N(Kg/ha)	-0.092	0.474635	0.4326	1								
P(Kg/ha)	0.642	0.423748	0.8399	0.6201	1							
K(Kg/ha)	-0.291	-0.220168	-0.827	-0.693	-0.7501	1						
S(ppm)	0.465	0.029067	0.5841	0.5007	0.80933	-0.5645	1					
Zn(ppm)	0.313	-0.309477	0.691	0.5541	0.59289	-0.7775	0.7619	1				
Fe(ppm)	-0.492	0.370941	-0.546	0.2407	-0.253	0.37267	-0.2802	-0.444	1			
B(ppm)	-0.366	-0.0314	-0.399	0.2409	-0.001	0.14612	0.4234	0.15302	0.53253	1		
Mn(ppm)	-0.574	-0.604003	-0.542	-0.3318	-0.7183	0.39565	-0.3388	-0.0368	-0.2087	0.0333	1	
Cu(ppm)	-0.207	-0.039439	-0.217	-0.0332	-0.3874	0.18186	-0.5927	-0.3154	0.62689	-0.056	-0.1791	1

Table 2: Correlation Coefficient (R) among various Quality Parameters

Pairs of Parameters	Regression Equation	R%
pH - Organic Carbon (OC)	pH = 0.432 OC = -1.557	57.51%
Phosphorus(P) – Organic Carbon (OC)	P = 0.009 OC = 0.513	70.54%
Potassium(K) – Organic Carbon (OC)	K = -0.018 OC = 2.966	68.45%
Zinc (Zn) – Potassium(K)	Zn = -5.027 K = 117.1	60.45%
Sulphur(S) – Phosphorus(P)	S = 0.972 P = 28.40	65.50%

Table 3: Linear Correlation (R) and Regression Equation for Some Pairs of Soil Quality Parameters of Eastern Barharwa.

PARAMETERS	Bangalipara	Chandipur	Jhiktia	Chanda	Khairbani	Jhumarbad	Baramasia
pH	6.5	6.5	7.5	6.5	7.5	6.5	**6**
EC (ms/cm)	0.11	0.17	0.17	0.39	0.29	0.41	**0.23**
OC (%)	1.38	1.4	1.46	1.22	1.75	1.51	**0.71**
N(Kg/ha)	378.2	452.3	352.9	452.9	368.9	457.3	**298.5**
P(Kg/ha)	77.84	75.21	99.3	101.2	100.7	105.8	**28.3**
K(Kg/ha)	78.3	85.97	98.34	88.52	79.23	75.21	**117.3**

S(ppm)	70.3	50.9	82	72	46.7	65	**13.6**
Zn(ppm)	8.3	7.22	6.23	5.1	5.14	6.04	**1.12**
Fe(ppm)	11.3	14.2	11.5	16.7	12.1	11.8	**14.5**
B(ppm)	1.41	1.29	1.34	1.57	1.07	1.21	**1.28**
Mn(ppm)	3.44	3.28	2.77	1.71	1.62	2.81	**3.69**
Cu(ppm)	**0.59**	**1.27**	**0.19**	**1.06**	**1.21**	**0.17**	**1.08**

Table 4: Observation value of various parameters in different study area.

Tables 2 and 3 elucidate the distinct characteristics among various physicochemical parameters, emphasizing linearity as an assumption of straight-line relationships in variable analysis. Perfect positive associations are evident within the parameters themselves. A notably strong positive correlation is observed between Phosphorus (P) & Organic Carbon (OC), as well as between Sulphur (S) & Phosphorus (P). Similarly strong positive associations are noted between Phosphorus (P) & pH, Phosphorus (P) & Nitrogen (N), Zinc (Zn) & Organic Carbon (OC) and Copper (Cu) & Iron (Fe). Conversely, there is very weak negative correlation observed between Boron (B) & Phosphorus (P), Boron (B) & Electrical Conductivity (EC), Copper (Cu) & Nitrogen (N), Manganese (Mn) & Zinc (Zn), and Copper (Cu) & Electrical Conductivity (EC).

Moderate positive correlations are found between Zinc (Zn) & Phosphorus (P), Sulphur (S) & Organic Carbon (OC), Zinc (Zn) & Nitrogen (N), Sulphur (S) & Nitrogen (N), Nitrogen (N) & Electrical Conductivity (EC), and Sulphur (S) & pH.

Correlation between pH and Organic Carbon (OC):

A graph plotting pH against OC (Figure 1) was generated to establish the relationship between these two variables in the Soil Quality Parameters of Eastern Barharwa. The graph depicted a clear linear regression relationship between the variables. Linear regression analysis was conducted, revealing a regression coefficient (R) of 57.51% for this relationship. Table 3 and Figure 1 provide a comprehensive depiction of how the presence of organic carbon in the soil influences its pH value. The highest recorded OC value, observed at Khairbani is 1.75% and low value for Baramasia is 0.71%, and the highest value for pH is 7.5 for both Jhiktia and Khairbani and the lowest pH is for Baramasia(6) Figure 6 and Table 4, supports this finding. This relationship is likely influenced by the higher cation exchange capacity (CEC) and buffering capacities typically found in soils with higher levels of clay and/or organic matter, compared to soils with more silty or sandy compositions. This may be due to soil with higher Organic Carbon content usually has more Organic Matter which can release organic acid.

Furthermore, there exists a relationship among soil pH, total nitrogen, organic carbon, and water content [30]. Soil pH enhances the solubility of soil organic matter (carbon and nitrogen in this study) by promoting the dissociation of acid functional groups and weakening the bonds between organic constituents and clays [31]. This phenomenon elucidates the pronounced impact of alkaline soil pH conditions on the leaching of dissolved organic carbon and dissolved organic nitrogen [32]. Regarding water content, pH is regulated by the leaching of basic cations (Ca, Mg, K, and Na) well beyond their release from weathered minerals, thereby increasing the prevalence of H^+ ions as the dominant exchangeable ions. The dissolution of CO_2 in soil water generates acidic carbon, which dissociates and releases H^+ ions [33]. Additionally, H^+ ions result from the dissociation of high-density carboxyl and phenolic groups formed during the humification of soil organic matter [34]. Furthermore, H^+ ions can arise from the nitrification process where ammonium is converted to nitrate ions (NH_4^+ to NO_3^-) [35]. However, further studies are necessary to validate this assertion. In conclusion, soil pH, influenced by water presence, contributes to the regulation of nitrogen availability in plant and animal products [31]. Moreover, silty soils can retain moderate levels of soil water content [36] and essential soil nutrients [37] crucial for plant growth [38].

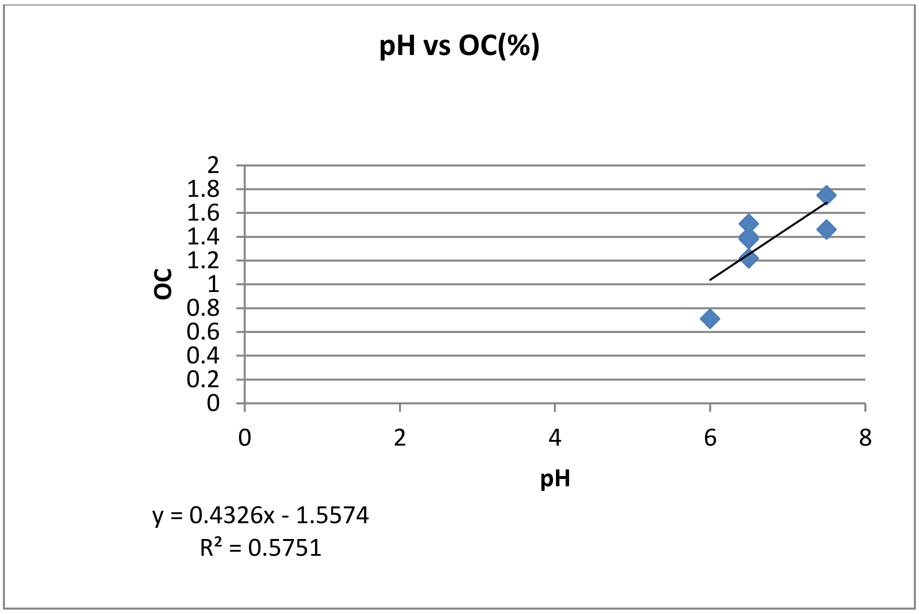

Figure 1: Correlation between pH and OC

Correlation between Phosphorus (P) and Organic Carbon (OC):

A graph plotting P against OC (Figure 2) was generated to establish the relationship between these variables in the Soil Quality Parameters of Eastern Barharwa. The graph revealed a clear linear regression relationship between the two variables. Linear regression analysis was conducted, revealing a regression coefficient (R) of 70.54% for this relationship. Figure 2 illustrates that the presence of organic carbon in the soil influences the phosphorus content. The highest OC value observed, is 1.75% in Khairbani (Figure 6), underscores this relationship. This phenomenon may be attributed to the addition of organic carbon, which increases phosphorus availability through the chelation of polyvalent cations by organic acids and other decay products. Among the different areas of E.B the highest value of P is 105.8 Kg/ha for Jhumarbad and the lowest value of P is 28.3 Kg/ha for Baramasia, Table 4 and Figure 6 support these findings. Mineralization of organic matter also contributes significantly to the phosphorus available for crop use.

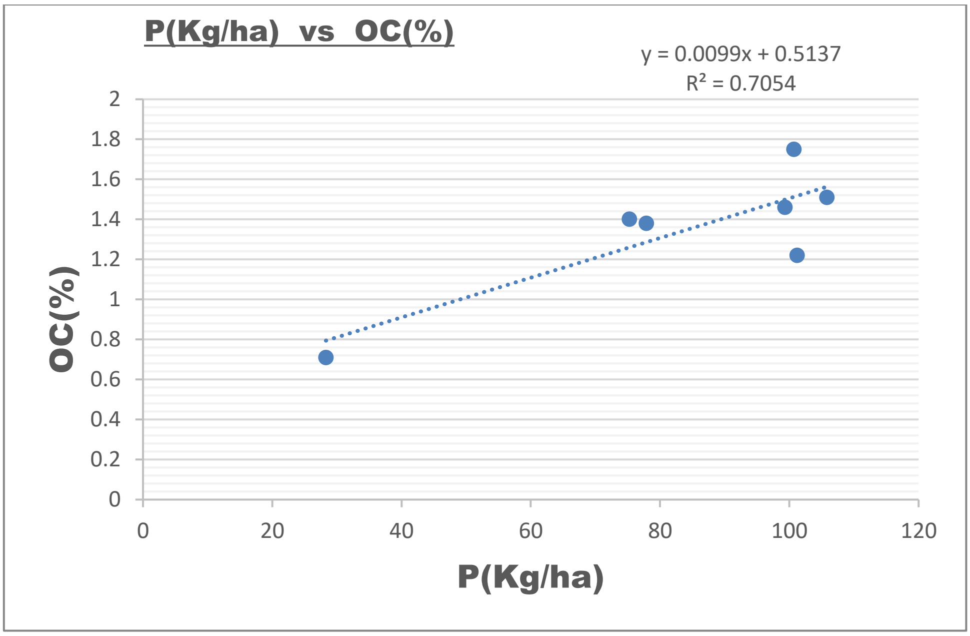

Figure 2: Correlation between P and OC

Correlation between Potassium (K) and Organic Carbon (OC):

A graph plotting K against OC (Figure 3) was created to establish the relationship between these variables in the Soil Quality Parameters of Eastern Barharwa. The graph demonstrated a direct linear regression relationship between the two variables. Linear regression analysis yielded a regression coefficient (R) of 68.45% for this relationship. Figure 3 illustrates that the presence of organic carbon in the soil affects potassium levels. The highest OC value observed, is 1.75% in Khairbani and the lowest value is 0.71% for Baramasia, Figure 6 highlights this relationship. This effect may be due to the complex interactions between potassium and organic carbon in soil, influencing potassium availability, adsorption, and exchange. Among the tested areas of E.B the high value of K is 117.3 Kg/ha for Baramasia and the low value of K is 75.21 Kg/ha for Jhumarbad, Table 4, Figure 6.

High gravel content in bare land can release water-soluble potassium from minerals within mounds in the presence of bacteria and various acids, thereby increasing organic carbon content through enhanced microbial activity.

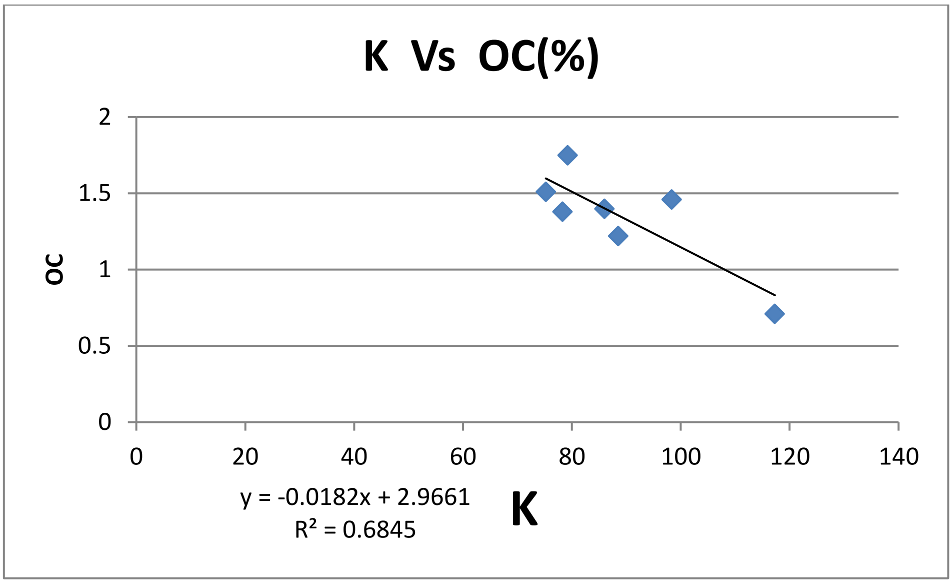

Figure 3: Correlation between K and OC

Correlation between Zinc (Zn) and Potassium (K):

A graph plotting Zn against K (Figure 4) was plotted to establish the relationship between these variables in the Soil Quality Parameters of Eastern Barharwa. The graph depicted a direct linear regression relationship between the two variables. Linear regression analysis revealed a regression coefficient (R) of 60.45% for this relationship. Figure 4 illustrates that the presence of potassium in the soil affects zinc levels. Among the tested parameters, the high value of Zn is 8.3 ppm for Bangalipara and low value of Zn is 1.12 ppm for Baramasia. Similarly, the highest K value observed is 117.3 Kg/ha in Baramasia and the lowest value observed for K is 75.21 Kg/ha for Jhumarbad, Figure 6 and Table 4 emphasizes this relationship. Increased potassium levels can significantly enhance zinc absorption. Higher potassium levels in soil reduce zinc deficiency in plants induced by phosphorus. Elevated zinc concentrations can lead to general yellowing and wilting of plants and various root damage. High zinc levels inhibit iron uptake, often resulting in severe iron deficiency symptoms caused by zinc toxicity. Thus, crop production yield is low.

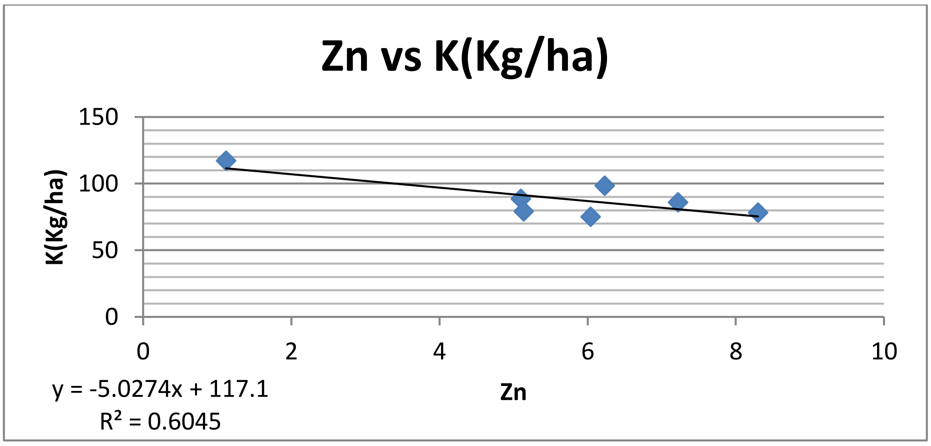

Figure 4: Correlation between Zn and K

Correlation between Sulphur (S) and Phosphorus (P):

A graph plotting S against P (Figure 5) was generated to establish the relationship between these variables in the Soil Quality Parameters of Eastern Barharwa. The graph demonstrated a direct linear regression relationship between the two variables. Linear regression analysis yielded a regression coefficient (R) of 65.50% for this relationship. Figure 5 illustrates that the presence of phosphorus in the soil affects sulphur levels. Among the tested parameters, the high value of S is 82 ppm and the low value of S is 13.6 ppm for Jhiktia and Baramasia respectively. Similarly, the highest P value observed is 105.8 Kg/ha in Jhumarbad and low value for Baramasia is 28.3 Kg/ha, Figure 6 and Table 4, illustrates this relationship.

Baramasia has low value of S (13.6 ppm) and Phosphorus (28.3 Kg/ha) it may be so because it is located in the foothills of Rajmahal hills due to which the soil of this area has high level of gravel and rock content. This place is sandwiched between the mining sites so this may also be the reason for its low phosphorus availability affected due to mining pollution. The crop production yield may be increased by the application of suitable fertilizers.

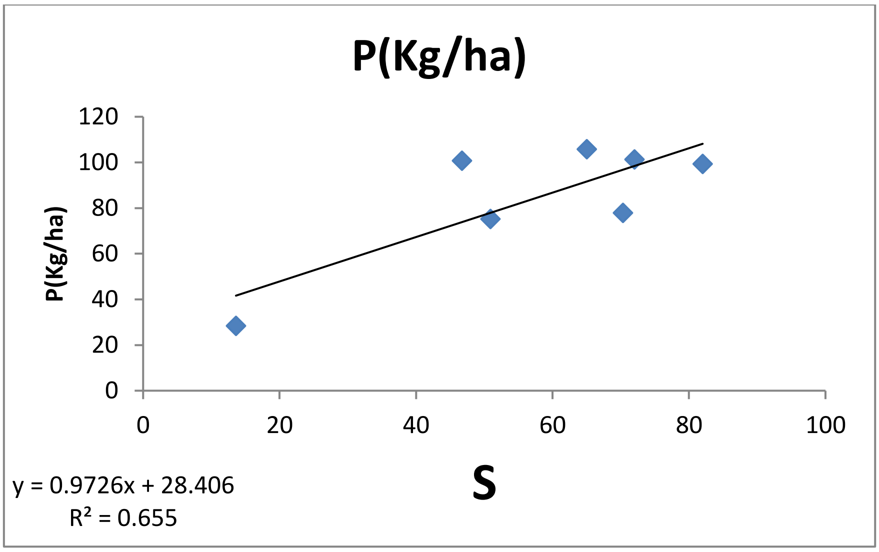

Figure 5: Correlation between S and P

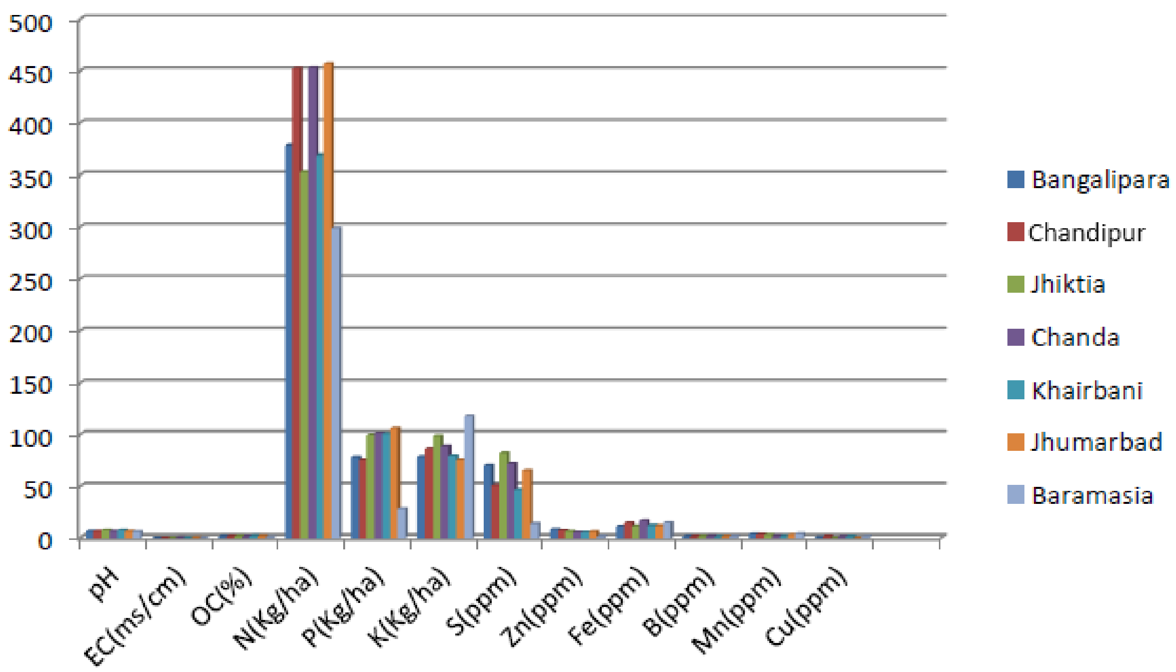

Figure 6: Correlation Graph among Various Parameters

Conclusion:

The statistical regression analysis, Skewness, Kurtosis, and Pearson correlation have proven to be invaluable techniques for establishing linear correlations among various physicochemical parameters in the Sahibganj soil area. Experimental studies have demonstrated that parameters such as Organic Carbon (OC), pH, Electrical Conductivity (EC), Nitrogen (N), Phosphorus (P), Potassium (K), Zinc (Zn), Iron (Fe), Boron (B), Manganese (Mn), and Copper (Cu) are interconnected. These findings offer new insights that can guide farmers, scientists, and researchers in this region.

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Conflict of Interests:

Author declares no conflict of interests.

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