IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Assessment Of Physico-Chemical Properties Of Soil In Five Villages Of Rajaborari Estate, Madhya Pradesh, India

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Abstract: This study was conducted in 2021 across five villages in the Rajaborari estate, involving 80 farmers' fields, to analyze the soil's physico-chemical properties. A total of 80 soil samples were collected from five villages: Rajaborari, Mara Podal, Mogra Dhana, Gorakhal, and Budhu Dhana. The physical properties of the soil, including texture, porosity, and permeability, were assessed using laboratory experiments and manual testing methods. The results indicated a predominance of clay, classifying the soil as silty-clay with low porosity and permeability, making it well-suited for paddy cultivation.Chemical properties such as soil pH, organic matter content, electrical conductivity (EC), and soil nutrients (nitrogen, phosphate, potassium, sulfur, iron, copper, zinc, and manganese) were determined using standard methods. The soil was found to be neutral to slightly acidic (pH 6.6-6.9) with low to medium organic carbon content (0.75-0.90%) and EC ranging from 0.29 dS m^{-1} to 0.45 dS m^{-1}. Post-crop production analysis showed low to moderate concentrations of key nutrients like nitrogen, phosphate, and potassium, influenced by agricultural practices and fertilizer application. Micronutrient analysis revealed varying levels of sulphur (12.17-34.0 ppm), iron (15.40-17.41 ppm), copper (3.25-4.20 ppm), zinc (1.22-2.32 ppm), and manganese (8.25-20.33 ppm). The study highlights the importance of regular soil testing and targeted fertilization to maintain optimal soil health and enhance crop productivity in agricultural areas

Index Terms: Soil pH, Organic Matter, Electrical Conductivity, Micronutrient, Rajaborari

1. INTRODUCTION

Soil plays a critical role in the physical environment, exhibiting regional variations in both its physical and chemical characteristics. It results from the complex interplay of climate, topography (including elevation, aspect, and slope), organisms, and parent materials evolving over time. Soil stands as a pivotal element within Earth's ecosystem. At the village level, soil variability arises from differential usage, while in agricultural regions, it stems from variations in agricultural techniques. Agriculture typically dominates the economic landscape of Indian villages, with the agricultural framework largely influenced by climate and soil conditions, both pivotal in determining crop yields. However, the modernization of technology, social dynamics, governmental policies, and regional development also wield significant influence over agricultural progress. Occupational structures and land utilization further underscore the reliance on and importance of agriculture. Over time, the agricultural patterns in many Indian villages have evolved due to advancements in agricultural technology and production methods. Presently, the agricultural sector in India faces challenges primarily due to economic conditions, prompting collaborative efforts among government authorities and agricultural scientists to identify necessary solutions [1]. While the concept of certain legumes being able to absorb nitrogen from the air and deposit it into the soil was recognized, it wasn't until the advancement of bacteriology in the late 19th century that a comprehensive understanding of the bacterial role in nitrogen fixation was achieved [2, 3]. In Harda District of Rajaborari estate (specifically in villages like Mara Padol, Mogra Dhana, Gorakhal, Budhu Dhana, and Rajaborari), various crops are cultivated including gram, pulses, jowar, bajra, rice, and wheat. Soil, as one of the most crucial environmental factors for agriculture, serves as the foundation for food production for both animals and humans. It plays a pivotal role in supporting crop growth, providing porosity that aids in water retention, heat regulation, nutrient absorption, and air circulation, while also lending mechanical support to plants. Despite being a reservoir of nutrients, the optimal levels for direct plant availability may not always be present. Therefore, soil analysis aims to assess the sufficiency, excess, or deficiency of available nutrients crucial for crop growth, and to monitor any alterations resulting from farming practices. The presence of macro and micronutrients significantly influences soil fertility, directly impacting plant growth. Nutrient deficiencies can limit the stability, sustainability, and productivity of soil, underscoring the necessity for regular soil quality assessments to ensure high yields of staple crops [4-6]. This paper presents a comprehensive evaluation of the physico-chemical properties of soils in the study area, offering valuable insights into the key factors that govern soil characteristics. Such a detailed assessment is essential for developing precise, crop-specific fertilizer recommendations that can enhance plant growth and improve agricultural productivity. Furthermore, the study evaluates the fertility status of the soil, providing a clear indication of nutrient availability and overall soil health. By integrating these aspects, the research contributes to a deeper understanding of soil dynamics and supports the formulation of more efficient, sustainable, and scientifically informed agricultural management practices.

2. STUDY AREA

The study area is located within the Rajaborari Estate in the southern part of Harda district (21^o 54’ N and 22^o 36’N latitude and 76^o 45’E and 77^o 30’E longitude; 302 masl : area of 3,334 Sq.km.) located in the south-western part of Madhya Pradesh lying in the Satpura hills. It comprises ten villages namely, Temrubahar, Mogra dhana, Gulardhana, Marapadol, Sahib Nagar, Rajaborari, Buddhudhana, Ratamati, Salai, and Mohagaon. It is a forest tract interspersed with scattered patches of cultivation. It is predominantly a tribal area where the Korku and the Gond tribal groups form two-thirds of the total population. It is a tropical dry deciduous forest with teak (Tectona grandis) as a dominant tree species and scattered Bamboo and Satkata trees. The total managed forest area of the division is 142,536 hectares of which 67 percent (98,318 hectares) is managed as Reserved Forest (RF) and the remaining 44,218 hectares as Protected Forest (PF) category.

The climate is generally healthy and very conducive. Cold season begins from December to February, hot season from March to the second week of June during which temperature goes up to 46^0 C. January is the coldest month in winter with maximum temperature 29^0 C and minimum temperature 10^0 C on an average. From mid- June to September is the rainy season. The district has recorded an average rainfall of 676.6 mm. The land is fertile for agriculture. Predominant crops are wheat, gram, soyabean, jowar, and maize. The non-timber products harvested from the forests and sold by tribals are Amla (Emblica officinalis), Tendu (Diospyros melanoxylon), Achar (Buchnanialanzan) and Mahua (Madhuca longifolia).

3. SAMPLE COLLECTION

For the present study, the soil sampleswere collectedfrom the well-cultivated fields of five different villages namely Rajaborari, Mara Padol, Mogra Dhana, Gorakhal and Budhu Dhana of the area during the year 2021 to assess the change in physicochemical properties of soil at different sites of Rajaborari (Figure 1). The selection of sites was done carefully, considering factors such as ground cover, micro relief, erosion levels, surface drainage, proximity to trees, and all other elements that could potentially impact the soil when compared to standard conditions. In the year 2021, eighty representative soil samples (0-15 cm depth) were gathered from five distinct villages within the Rajaborari estate using a spade. Prior to sampling, any grass, dead plants, or other debris were cleared away. To obtain a representative composite sample for each grid, soil was collected from five randomly selected points within a farmer’s field and thoroughly mixed. At each selected location, a ‘V’-shaped cut was made to a depth of 0–15 cm, from which the soil samples were collected. The samples were then placed in properly labeled polythene bags and transported for further analysis.

Following standard procedures, the samples were dried in the shade, ground, sieved through a 2-mm sieve, and stored at room temperature (27±1°C). The sieved samples were subsequently placed in polybags with care, to be assessed later for various physico-chemical parameters using standardized methods.

Precautions were diligently taken throughout this entire procedure. Table 1 provides a brief overview of the village, including the number of farmers.

Table 1: Farmer Information in the Chosen Villages of Rajaborari Estate

Village	Number of Farmers Field for Sample Collection
Rajaborari	40
Mara Padol	17
Mogra Dhana	15
Gorakhal	4
Budhu Dhana	4

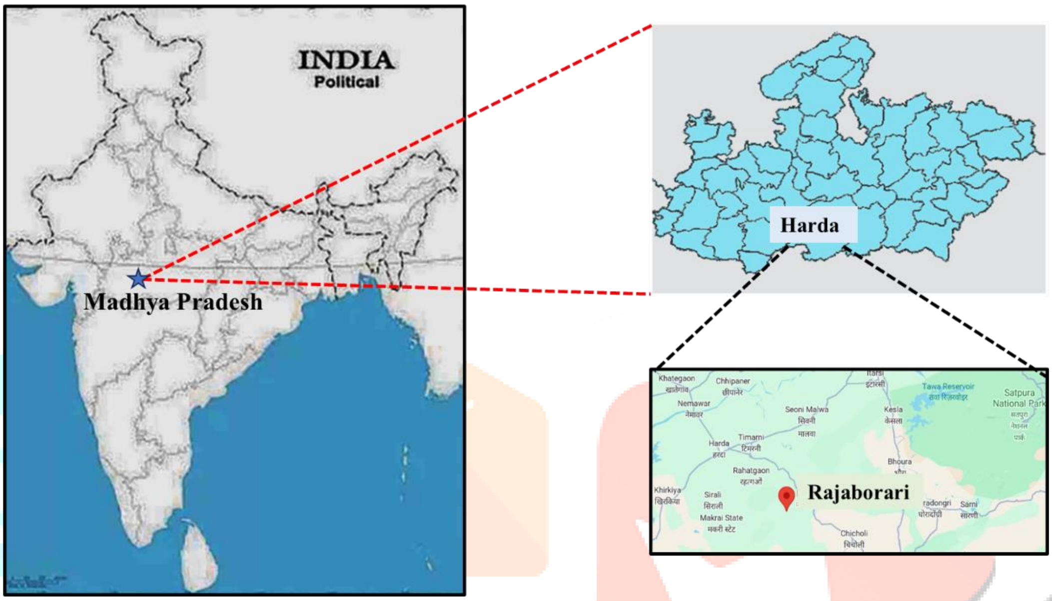

Figure 1. Soil Sampling Site Location

4. EXPERIMENTAL PROCEDURE

a) pH

For conducting the pH measurements, Systronics micron pH System 361 was utilized. The soil pH analysis involved creating a mixture of soil and water at a1:2 ratio. Specifically, 20 g of soil were combined with 40 ml of water in a 100 ml beaker. This mixture was stirred at regular intervals for 30 minutes, and the pH was subsequently measured using a pH meter. The pH meter was calibrated prior to soil sample testing to ensure accurate measurements. This involved using pH buffer solutions with known pH values (typically pH 4.01, 7.00, and 10.01). The electrode was rinsed with distilled water and then immersed in the pH 7 buffer solution to adjust the meter reading. Afterward, the electrode was removed from the pH 7 buffer solution, rinsed with distilled water, and the process was repeated with the pH 4.01 and pH 10.01 buffer solutions. Meter readings were adjusted accordingly to match the known pH values of the buffer solutions. Regular calibration is essential to maintain the accuracy of pH measurements**.** To prepare the pH meter for use, the electrode was washed with distilled water. Afterward, the contact switch was opened, and a 5-minute waiting period ensued before adjusting the temperature knob to room temperature. The electrode was then rinsed first with distilled water and subsequently with the soil suspension after stirring. Finally, the pH value of the soil suspension was read.

b) Electrical Conductivity (EC)

The electrical conductivity (EC) was determined using Systronics conductivity meter 306. To measure the electrical conductivity (EC) of soil, soil samples are first collected from the field and air-dried at room temperature. A 100-gram sample of the dried soil was weighed and mixed with 200 mL of distilled water in a beaker, maintaining a soil-to-water ratio of 1:2. The mixture was stirred thoroughly for 5 minutes to ensure complete interaction, then left to sit for 30 minutes to equilibrate. After equilibration, the mixture was stirred again briefly. The solution was filtered through filter paper to obtain a clear extract. The temperature of the soil extract was measured and recorded using a thermometer. For calibration, standard EC solutions, such as a 0.01 M KCl solution with a known EC value (e.g., 1413 µS/cm at 25°C), were used. The EC meter was turned on and allowed to stabilize according to the manufacturer's instructions, then rinsed and dried before being immersed in the calibration solution. The meter was adjusted to display the correct value of the standard solution, and the probe was rinsed and dried again before use. An EC meter probe was then inserted into the soil extract, ensuring the electrodes were fully immersed. The EC readings were recorded once the value stabilizes. Electrical conductivity serves as a means to measure the electrical resistance within a solution, providing insight into the total concentration of ionized constituents present. This measurement closely correlates with the combined levels of cations and anions in the suspension. As such, it serves as a useful indicator for assessing salinity levels in soil extracts.

c) Organic Carbon (OC)

1 to 2 g of dried soil (< 60 mesh) was weighed and transferred to a 500 ml Erlenmeyer flask.The sample was required to contain 10 to 25 mg of organic C (equivalent to 17 to 43 mg organic matter). For a 1 g sample, this amounted to 1.2 to 4.3% organic matter. Up to 2.0 g of sample were utilized for light-colored soils, while 0.1 g was used for organic soils. Next, 10 ml of 1 N $K_2Cr_2O_7$ was added by means of a pipette. This was followed by the addition of 200 ml of concentrated H_2SO_4 using a dispenser, and the mixture was gently swirled to mix. Afterward, the mixture was allowed to stand for 30 minutes, during which the flasks were placed on an asbestos sheet to prevent rapid heat loss. Subsequently, the suspension was diluted with about 200 ml of water to provide a clearer view of the endpoint. Then, 10 ml of 85% H_3PO_4 was added using a suitable dispenser, along with 0.2 g of NaF using a spatula. These additions served to complex Fe^{3+}, which could interfere with the titration endpoint. Additionally, 10 drops of ferroin indicator were added. The mixture was titrated with 0.5 N Fe^{2+} until reaching a burgundy endpoint. Initially, the color of the solution ranged from yellow-orange to dark green. A reagent blank was employed to standardize the Fe^{2+} solution on a daily basis [7]. Finally, the percentages of organic carbon (% C) were calculated using the equation given below -

$$\% C = \frac{(B-S) \times n \times Fe^{2+} \times 12}{\text{gm of soil}} \times \frac{100}{4000}$$

Where: B = ml of Fe^{2+} solution used to titrate blank,

S = ml of Fe^{2+} solution used to titrate sample, and 12/ 4000 = mill equivalent

d) Nitrogen

The alkaline potassium permanganate method was utilized for the analysis of available nitrogen [8]. 5 g of soil was taken in distillation tubes and distilled with potassium permanganate and sodium hydroxide. In a conical flask, boric acid mixed indicator was added for the absorption of ammonia. After absorption, the pink color turned green. 150 ml of distillate was collected and titrated with 0.02 N of sulfuric acid, which turned the green color to pink. A blank was also run in a similar way but without a soil sample.

e) Phosphorus

Available phosphorous of soil was extracted using $NaHCO_3$. The extracting solution was filtered withWhatman filter paper. In 5 ml of aliquot, H_2SO_4, water and ascorbic acid was added. The concentration of Phosphorus was measured using spectrophotometer at 660 nm. Standard curve was prepared using different concentration of Phosphorus solution i.e., 1, 2, 3, 4 and 5 ppm. Same steps were followed by adding $NaHCO_3$ [9].

f) Sulphur

To begin the soil analysis process, 10 grams of the soil sample was measured and placed onto a 100 ml plastic bottle. Next, 50 ml of a 0.15% calcium chloride solution was added into the bottle and the mixture was shaken vigorously for 30 minutes. Afterward, the solution was filtered through a Whatman No. 42 filter paper. 10 ml of the filtrate was transferred into a 25 ml volumetric flask, followed by addition of 1.0 gram of sieved barium chloride which was ensured to rinse the neck of the flask with distilled water. To stabilize the solution, 1 ml of gum acacia was included, and then the volume to the mark was adjusted with distilled water. Finally, for analysis, a calibrated calorimeter with a blue filter or a spectrophotometer set to a wavelength of 340 nm to obtain readings was utilized [10].

$$\text{Available S (mg/kg)} = \frac{\text{R} \times \text{Volume made at turbidity development} \times \text{Volume of Eluent}}{\text{Volume of Aliquot} \times \text{Sample Weight}}$$

g) Potassium, Iron, Copper, Zinc and Manganese

A quantity of 1 gram of the soil sample underwent microwave digestion utilizing 10 ml of Aqua Regia (a mixture of HCl and HNO_3 in a 3:1 ratio). The digested samples were subsequently filtered using Whatman filter paper and adjusted to a volume of 25 ml using 5 % HNO_3. Following this preparation, elemental analysis was conducted using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) with an Agilent 5110 instrument. Prior to analysis, the instrument was calibrated using a Standard solution containing a mixture of major and trace metals within the range of 1 to 50 ppm (parts per million).

5. RESULTS & DISCUSSION

A) Analysis of Physical properties of Soil

Physical properties refer to those characteristics of soil that can be assessed without the need for chemical analysis. These properties are typically observable through visual examination of soil particles under a microscope or through manual testing using methods such as the feel method. Key physical properties including texture, porosity, and permeability were examined in this study.

a) Texture

Laboratory experiments indicate that all soil samples exhibit a predominance of clay materials. Specifically, clay content surpasses 60% in major soil samples, while it ranges between 50% and 60% in thesome soil samples. Silt constitutes the second most abundant soil particle across all samples, with minimal presence of sand. Consequently, the region is typified by Silty-clay soil across its agricultural terrain.

b) Porosity

Porosity pertains to the volume of empty space within the soil. The primary determinant of soil porosity is its texture. In the study area, the abundance of clay material results in a notably low amount of void space within the soil.

c) Permeability, Infiltration Rate and Water Retention Capacity

The soil in the study area exhibits low permeability, leading to a slow infiltration rate and prolonged water retention. Consequently, the region is primarily utilized for paddy cultivation.

B) Chemical Properties of Soil

Chemical properties pertain to the factors influencing the chemical makeup of soil. These properties are assessed through various laboratory analyses of soil samples. The primary chemical characteristics of the study area's soil were determined through laboratory experiments conducted on collected samples, and their results are detailed in the accompanying table [Table 1].

a) Soil pH

Soil pH is a measure indicating whether soil is acidic or alkaline. It's rated on a scale from 0 to 14, with 7 being neutral, below 7 acidic, and above 7 alkaline. The soil pH analysis findings are presented in Table 2. reflecting the cumulative impact of acid-base reactions within the soil environment. Across the study area of different villages, soil pH ranged from 6.6 to 6.9, averaging at 6.7. Consequently, study of soil samples suggests that the bulk of the area has soil that is neutral to slightly acidic [Table 2.]. The acidity level of the soil (pH) is additionally modulated by the quantity of organic matter present. Variations in organic content across different soil depths contribute to divergent pH levels at each depth.

b) Organic Matter or Organic Carbon

Organic matter, comprising only 2-10% of the total soil mass, significantly impacts the physical, chemical, and biological functions of soil. In Rajaborari village, the level of soil organic matter is generally low, although certain areas exhibit medium concentrations ranging from 0.75-0.90% [Table 2]. Variations in organic matter content within the village are attributed to differing crop harvesting techniques. Machinery harvesting, for instance, leaves some crop residues on the land, leading to a slight increase in soil organic matter.Among the five villages surveyed, Rajaborari exhibited the lowest organic carbon (OC) content at 0.75%, whereas the majority of samples fell within the medium organic carbon range, ranging from 0.81% to 0.90%. The content of soil organic carbon (OC) correlates with the presence of soil organic matter [11].

c) Electrical Conductivity (EC)

Electrical conductivity is a standard method for gauging the electrical resistance in a solution, reflecting the overall concentration of ionized components. It correlates closely with the combined presence of cations and anions in the solution and thus serves as an indicator of soil extract salinity [Table 2]. Hence, ECserves as a measure of the total dissolved solids and ionized species in water, offering insights into the extent of inorganic contamination. From the survey, it was observed that the mean EC values across different villages within the Rajaborari estate ranged from 0.28dS m^{-1} to 0.45 dS m^{-1} in Rajaborari, Mara Padol, Mogra Dhana, Gorakhal, and Budhu Dhana, respectively. This range (0.28-0.45 dS m^{-1}) typically suggests a moderate to moderately high level of soil salinity. While it may not be excessively saline, it still signifies the presence of soluble salts, which could impact soil fertility and plant growth depending on the specific crops being cultivated. The lowest EC was recorded at 0.28 dS m^{-1} in Mogra Dhana, while the highest was observed at 0.45 dS m^{-1} in Budhu Dhana. This variation might be attributed to the increased presence of soluble salts in the soil due to the application of highly saline water in the fields.Hence, it is essential to monitor and manage soil salinity within this range to maintain optimal soil health and crop productivity.

Table 2. Chemical Properties of Soil Samples from Five Different Villages of Rajaborari Estate

d) Soil Nutrients

Village	pH value	Organic carbon (%)	Electrical conductivity (Deci Siemens/m)	Phosphorous (Kg/Hectare)	Potash (Kg/Hectare)
Rajaborari	6.8	0.75±0.17	0.29±0.07	30.97±16.60	273.45±216.26
Mara Padol	6.6	0.81±0.17	0.30±0.06	29.64±23.22	353.88±273.69
Mogra Dhana	6.8	0.78±0.16	0.28±0.08	34.93±23.08	443.53±283.66
Gorakhal	6.6	0.86±0.05	0.40±0.01	31.66±4.05	599.66±335.75
Budhu Dhana	6.9	0.90±0.00	0.45±0.50	89.50±88.31	580.25±382.96

Soil nutrients are essential minerals that play a vital role in determining soil fertility and productivity. These minerals serve as the primary source of nourishment for vegetation or crops growing in the soil. Key soil nutrients include Nitrogen, Phosphorus, and Potassium (NPK), which have a substantial impact on soil fertility and productivityfor certain crops like wheat and gram [Table 3. Figure 2. & 3.]. In this study, NPK levels were evaluated following crop production (specifically, wheat and gram) to gauge the soil's nutrient status after the crops have absorbed these nutrients. This evaluation offers valuable insights into the soil's fertility and its potential to sustain future crops. Overall, conducting NPK analysis after crop production is crucial for sustainable agriculture, enabling farmers to optimize nutrient management practices, maintain soil fertility, and enhance crop productivity while minimizing environmental risks.

1. Nitrogen(N)

Nitrogen serves as a crucial protein source for both plants and animals. Only a limited number of bacteria and plants have the capability to absorb nitrogen from the air and enrich the soil with it. In the majority of the village area, the soil contains a moderate concentration of nitrogen, with a moderate level of variability.Examination of the data in Table 3. reveals a predominance of low available nitrogen across the surveyed areas. Nitrogen content in the soil samples ranged from 8.0 to 9.20 ppm for gram crop production and 15.0 to 19.75 ppm for wheat crop production, with mean values of 8.59 ppm and 17.3 ppm respectively. In the case of gram crop, the lowest range (8.0 ppm) was observed in villages Gorakhal and Budhu Dhana, while the highest (9.20 ppm) was noted in village Rajaborari. Similarly, for wheat crop, the lowest range (15.0 ppm) was found in villages Gorakhal and Budhu Dhana, while the highest (19.75

ppm) was observed in village Rajaborari. According to suggested thresholds [12], 69% of the soil samples exhibited low nitrogen levels, while 31% showed medium nitrogen levels.

2. Phosphorus (P)

The presence of phosphorus in the soil significantly impacts plant growth as it is a key macronutrient essential for regulating photosynthesis. Within this village, the distribution of phosphate in the soil varies considerably, primarily due to differences in fertilizer application. The majority of the soil contains medium to high levels of phosphates, although a small portion has a minimal amount of phosphorous. The soil samples exhibited a range of available phosphorus levels, with values spanning from 20.0 to 29.0 ppm for gram crop production and 12.5 to 19.25 ppm for wheat crop production. The mean phosphorus content was calculated to be 26.52 ppm for gram and 17.96 ppm for wheat crops. In the case of gram crop production, the lowest phosphorus value (20.0 ppm) was recorded in Budhu Dhana village, while the highest (30.29 ppm) was observed in Mara Padol. Similarly, for wheat crop production, the lowest phosphorus value (12.5 ppm) was found in Budhu Dhana village, whereas the highest (19.41 ppm) was detected in Mara Padol [Table 3]. Analysis revealed that approximately 75.5% of the samples exhibited high phosphorus content, while the remaining samples were categorized as medium phosphorus, accounting for 24.5% of the total.

3. Potassium (K)

Potassium plays a crucial role in facilitating enzyme formation, CO_2 uptake, and ATP production in plants. Soil pH is a major determinant of potassium levels. However, in this village, there is minimal variation in soil pH but significant variability in potassium levels. This suggests that agricultural practices, particularly the use of fertilizers, primarily regulate potassium concentration rather than soil pH. Generally, this region has low potassium levels, although there are instances of extreme concentration in some areas. Hence, in the study area, potassium content was observed to be low, with values ranging from a maximum of 3.25 ppm to 4.5 ppm and a minimum of 1.33 ppm to 2.0 ppm, yielding mean values of 1.88 ppm and 2.5 ppm for gram and wheat production respectively. Across various villages within the Rajaborari estate, namely Rajaborari, Mara Padol, Mogra Dhana, and Budhu Dhana, potassium concentrations ranged from 1.33 ppm to 3.25 ppm for gram crop cultivation and from 2.0 ppm to 4.5 ppm for wheat crop growth [Table 3.]. Notably, potassium content was fully utilized for crop production in Gorakhal village.

Table 3: Availability of Major Soil Nutrients [Nitrogen (N), Phosphorus (P), Potassium (K)] after Gram and Wheat Crop Production

Village	N (ppm)	P (ppm)	K (ppm)	N (ppm)	P (ppm)	K (ppm)
	Gram			Wheat		
Rajaborari	9.20±2.0	29.0±5.3	3.25±4.7	19.75±6.9	19.25±5.8	4.5±5.1
Mara padol	8.82±1.9	30.29±5.7	2.35±4.3	17.94±6.6	19.41±6.8	3.52±5.5
Mogra Dhana	8.93±1.4	26.66±8.9	1.33±3.5	19.0±5.7	18.66±7.1	2.0±4.5
Gorakhal	8.0±0.1	26.66±2.8	0	15.0±0.1	20.0±0.1	0
Budhu Dhana	8.0±0.1	20.0±14.1	2.5±5.0	15.0±0.1	12.5±9.5	2.5±5.0

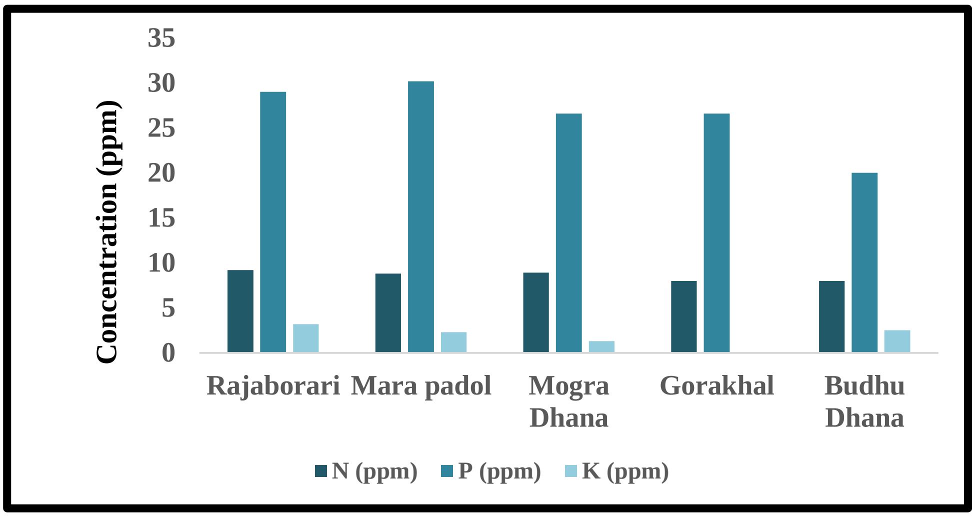

Figure 2. N, P, K Availability after Gram Crop Production in Rajaborari Estate

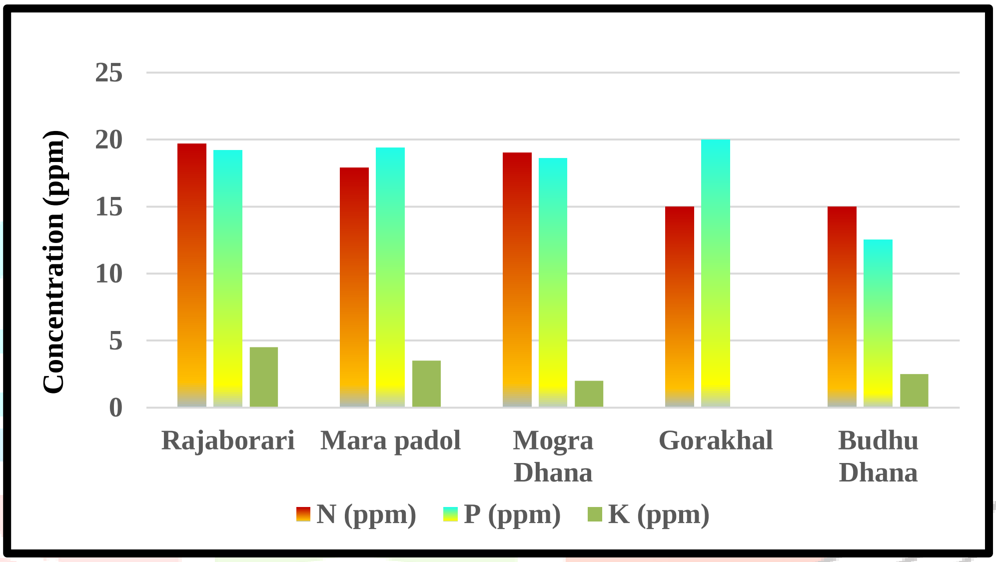

Figure 3. N, P, K Availability after Wheat Crop Production in Rajaborari Estate

4. Micronutrients (Sulphur, Iron, Copper, Zinc and Manganese)

A concise analysis of soil micronutrients within a village agricultural setting is provided in Table 4. Sulphur (S), while not categorized strictly as a micronutrient, is vital for protein synthesis and overall plant vigor. Its deficiency manifests through yellowing of younger leaves and diminished growth, influenced by soil organic matter content and microbial activity. The recorded sulphur levels across these agricultural sites span from 12.1 ppm to 34.0 ppm, with the highest concentration (34.0 ppm) observed in Gorakhal village and the lowest (12.17 ppm) in Mara Padol village. Iron (Fe), essential for chlorophyll synthesis and plant growth, varies in availability based on soil pH levels, with alkaline soils potentially inducing deficiency symptoms like interveinal chlorosis. Iron levels within the sites range from 15.4 ppm to 17.4 ppm, with the highest (17.41 ppm) in Mara Padol and the lowest (15.5 ppm) in Budhu Dhana. Zinc (Zn) is crucial for plant metabolic processes, and its deficiency manifests through stunted growth and chlorosis in younger leaves. Soil pH and organic matter content influence zinc availability, with levels observed between 1.2 ppm and 2.3 ppm, highest (2.32 ppm) in Budhu Dhana and lowest (1.22 ppm) in Mara Padol. Copper (Cu), vital for enzyme activation and photosynthesis, exhibits deficiency symptoms such as stunted growth and poor reproductive development. Copper levels range from 3.2 ppm to 4.2 ppm across the sites, highest (4.20 ppm) in Mogra Dhana and lowest (3.25 ppm) in Budhu Dhana. Manganese (Mn) is involved in various plant functions, and its deficiency leads to chlorosis between leaf veins. Soil pH affects manganese availability, with levels observed between 8.2 ppm and 20.33 ppm, highest (20.33 ppm) in Gorakhal and lowest (8.25 ppm) in Budhu Dhana [Table 4].

Regular soil testing and observation of plant health can help monitor micronutrient levels and address deficiencies through targeted fertilization practices. Additionally, maintaining optimal soil pH and organic matter content is vital for ensuring micronutrient availability to plants in agricultural settings.

Table 4: Availability of Soil Micronutrients [(Sulphur (S), Iron (Fe), Zinc (Zn), Copper (Cu) and Manganese (Mn)]

Village	S (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)
Rajaborari	15.16±10.8	15.40± 3.3	1.78± 0.9	3.7 ± 0.9	12.55± 5.4
Mara padol	12.171±12.6	17.41± 6.8	1.22 ± 0.8	3.42± 1.2	17.82 ±4.5
Mogra Dhana	14.33±10.8	16.26 ±2.9	1.76± 1.2	4.20 ± 1.2	15.06 ±7.2
Gorakhal	20.66±6.3	16.33 ±3.1	1.66 ± 0.6	4.0 ±0.1	20.33 ±3.2
Budhu Dhana	34.0±22.1	15.5 ± 3.5	2.32 ± 0.9	3.25± 0.9	8.25± 4.6

Conclusions

The findings of this study indicate that the soil pH ranged from neutral to slightly acidic, while the electrical conductivity (EC) values were within the normal range. Soil organic carbon content ranged from low to high. The available nitrogen (N), phosphorus (P), and potassium (K) content in the soil after crop production varied from low to medium levels. Micronutrients (like S, Fe, Zn, Cu and Mn) were found to be in sufficient range. These results offer valuable insights for assessing soil fertility, guiding nutrient management practices, preventing and diagnosing nutrient depletion, and promoting environmental sustainability.Such soil testing aids in assessing soil health through the issuance of soil health cards, facilitating tailored solutions for both soil and crop needs. These cards will serve to pinpoint problematic soil conditions, detailing nutritional status, texture, and structure. Utilizing this information, farmers receive guidance on optimizing soil fertility management strategies, which may include judicious application of manure, fertilizers, and amendments, thereby enhancing agricultural productivity and sustainability.

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