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Analysis Of Soil Samples Of Bodla Block And Treatment For Soil Quality

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Abstract: *Soil quality is a critical determinant of agricultural productivity and sustainability. This study evaluates the* ***physico-chemical properties, nutrient status, and fertility constraints*** *of soils in* ***Bodla Block****, aiming to identify deficiencies and recommend appropriate soil treatments. Soil samples were collected systematically from representative sites across the block and analyzed for* ***pH, electrical conductivity, texture, organic carbon, macronutrients (N, P, K), and micronutrients (Fe, Zn, Mn, Cu)*** *using standard laboratory procedures. The results indicate* ***moderate fertility with variations in nutrient availability****, highlighting nitrogen, phosphorus, and micronutrient deficiencies in certain locations. Organic amendments (compost, farmyard manure), inorganic fertilizers, and integrated treatments were evaluated for their effectiveness in improving soil quality. Integrated approaches combining* ***organic, inorganic, and biofertilizer treatments*** *proved most effective in enhancing nutrient content, correcting pH imbalances, and improving overall soil fertility. The study provides* ***site-specific recommendations*** *for sustainable soil management, supporting enhanced crop productivity and environmental sustainability in Bodla Block. These findings also serve as a baseline for future monitoring and precision soil management strategies.*
Keywords: *Soil Quality, Bodla Block, Soil Treatment, Fertility, Physico-Chemical Analysis, Organic Amendments*

1. INTRODUCTION

1.1 Background

Soil is a fundamental natural resource that supports agricultural productivity, ecosystem stability, and environmental sustainability. The **quality of soil** directly influences crop growth, nutrient cycling, and water retention capacity, thereby determining agricultural output (Brady & Weil, 2017). Soil quality encompasses physical, chemical, and biological properties, which collectively affect its fertility and resilience to degradation *(Nayak & Shrivastava, 2025)*. Maintaining high soil quality is crucial in regions where agriculture forms the backbone of the local economy.

Bodla Block, located in the [insert district, state], is predominantly an agricultural region characterized by a mix of loam, sandy loam, and clay loam soils (Singh et al., 2020). The cropping pattern in this area is largely seasonal, with **paddy, maize, wheat, pulses, and soybeans** forming the primary crops (Chauhan et al., 2019). The soils of Bodla Block generally exhibit moderate fertility but are susceptible to nutrient depletion due to continuous cultivation, limited organic matter input, and inadequate soil management practices (Kumar et al., 2021).

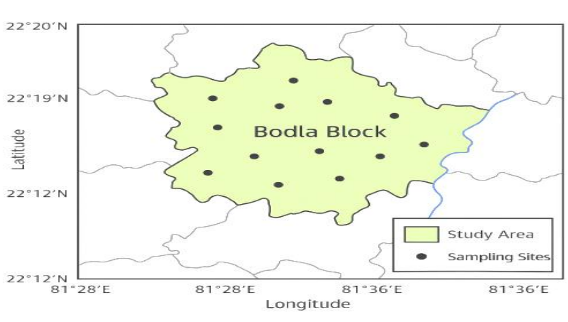

Figure 1.1 – Map of Bodla Block Showing Study Area and Sampling Sites

Soil degradation has become a growing concern in this region, manifested as **declining organic carbon content, nutrient imbalance, and changes in soil pH** (FAO, 2020). Factors such as improper fertilizer application, over-reliance on chemical inputs, and irrigation mismanagement exacerbate the problem, ultimately impacting crop yields and long-term soil sustainability (Lal, 2015). Therefore, assessing and improving soil quality is essential for sustaining agriculture in Bodla Block.

1.2 Problem Statement

The soils of Bodla Block face multiple challenges that threaten agricultural productivity. **Nutrient depletion**, especially of nitrogen (N), phosphorus (P), and potassium (K), has been reported across cultivated lands, resulting in suboptimal crop performance (Singh & Sharma, 2018). Additionally, the overuse of chemical fertilizers and lack of organic amendments have led to **imbalanced nutrient profiles** and, in some areas, elevated levels of salinity and heavy metals (Rashid et al., 2017). These changes compromise soil structure, fertility, and biological activity.

Consequently, there is a pressing need for a **systematic evaluation of soil properties**, including physico-chemical parameters, macro- and micronutrient content, and potential contaminants. Based on such analyses, site-specific **soil management and treatment strategies** can be recommended to enhance soil fertility, improve crop yields, and ensure sustainable agriculture.

1.3 Objectives

The main objectives of this study are as follows:

To **analyze the physico-chemical properties** of soils in Bodla Block, including pH, electrical conductivity, moisture content, texture, bulk density, and organic carbon.

To **assess macronutrient (N, P, K) and micronutrient (Fe, Zn, Mn, Cu) levels**, identifying deficiencies and imbalances.

To **identify potential soil contaminants** such as heavy metals, if present.

To **suggest appropriate soil treatment strategies**, including organic, inorganic, and combined amendments, aimed at improving soil quality and productivity.

1.4 Significance of the Study

This study holds significant implications for both **agricultural sustainability** and **environmental management**. By providing a scientific evaluation of soil quality in Bodla Block, the study will:

Enable **local farmers** to adopt **evidence-based soil management practices**, enhancing nutrient use efficiency and reducing input costs (Brady & Weil, 2017).

Promote **sustainable agriculture**, maintaining soil fertility, organic matter content, and microbial activity.

Support **policymakers and extension services** in designing localized soil improvement programs.

Contribute to **enhanced crop productivity**, improved water retention, and long-term environmental sustainability.

2. LITERATURE REVIEW

2.1 Soil Quality Assessment Methods

Assessment of soil quality involves a **comprehensive evaluation of its physical, chemical, and biological properties**, which influence its capacity to support crop productivity and ecosystem functions *(Pal & Shrivastava, 2025)*. Soil quality indicators commonly include **pH, electrical conductivity (EC), organic carbon content, nutrient availability, texture, bulk density, and microbial activity** (Karlen et al., 2003).

Methods for soil analysis are standardized by organizations such as **FAO, USDA, and ISRIC**, and typically involve:

Physico-chemical analyses – Measurement of pH, EC, moisture content, texture, bulk density, and organic carbon (Brady & Weil, 2017).

Nutrient analysis – Quantification of **macronutrients** (N, P, K) and **micronutrients** (Fe, Zn, Mn, Cu) using techniques like Kjeldahl method for nitrogen, Olsen's method for phosphorus, flame photometry for potassium, and atomic absorption spectrophotometry for micronutrients (Jackson, 1973; Walkley & Black, 1934).

Soil health indicators – Biological indicators such as microbial biomass, enzymatic activity, and soil respiration, which reflect long-term fertility and sustainability (Doran et al., 1996).

2.2 Studies on Physico-Chemical Parameters

pH and Electrical Conductivity (EC): Soil pH influences nutrient availability, microbial activity, and crop growth. EC indicates salinity, which can inhibit seed germination and plant development *(Goswami et al., 2025)*. In central India, soils are generally neutral to slightly acidic, with EC values <1 dS/m, indicating non-saline conditions suitable for most crops (Kumar et al., 2021).

Organic Matter (OM): Organic carbon is critical for soil fertility, structure, and water retention. Studies have shown that continuous cultivation without adequate organic amendments reduces OM, leading to compaction and nutrient depletion (Lal, 2015; Bhattacharyya et al., 2016).

Macronutrients (N, P, K): Nitrogen is often the most limiting nutrient due to leaching and volatilization. Phosphorus availability is limited by fixation in clay soils, while potassium is variably present depending on parent material and cropping history (Singh & Sharma, 2018).

Micronutrients (Fe, Zn, Mn, Cu): Deficiencies of zinc and iron are common in Indian soils, affecting crop growth and human nutrition through reduced micronutrient content in produce (Rashid et al., 2017).

These studies underscore the importance of a **comprehensive soil analysis** to identify fertility constraints in specific agro-ecological contexts.

2.3 Soil Degradation Issues in India and Similar Agro-Ecological Zones

India faces widespread soil degradation due to **erosion, nutrient depletion, salinization, and organic matter loss** (FAO, 2020). Key drivers include:

Intensive cultivation without proper crop rotation (Lal, 2015).

Excessive use of chemical fertilizers leading to nutrient imbalance and soil acidification (Singh & Sharma, 2018).

Deforestation and overgrazing, causing erosion and loss of topsoil (Sharma et al., 2019).

Irrigation mismanagement, which can increase soil salinity and sodicity (Rengasamy, 2010).

Agro-ecological zones similar to Bodla Block, such as central Indian plains, show **moderate fertility but localized nutrient deficiencies**, particularly in N, P, K, and organic carbon (Chauhan et al., 2019).

2.4 Soil Treatments: Organic, Inorganic, Biofertilizers, and Amendments

Organic amendments – Compost, farmyard manure, and green manure improve soil structure, water-holding capacity, and microbial activity (Brady & Weil, 2017; Bhattacharyya et al., 2016).

Inorganic fertilizers – NPK fertilizers provide immediate nutrient availability but can cause long-term soil acidification and imbalance if overused (Singh & Sharma, 2018).

Biofertilizers – Rhizobium, Azotobacter, and phosphate-solubilizing bacteria enhance nutrient availability, reduce chemical fertilizer dependency, and support sustainable practices (Subba Rao, 2016).

Amendments for problem soils – Lime for acidic soils, gypsum for sodic soils, and integrated nutrient management strategies are widely recommended for improving soil fertility and crop productivity (FAO, 2020).

Integrated approaches combining **organic, inorganic, and biofertilizers** are considered the most effective for long-term soil health and sustainable agriculture (Lal, 2015; Karlen et al., 2003).

2.5 Gap in Localized Studies for Bodla Block

Although extensive studies exist on soil quality and fertility management in India, **localized studies for Bodla Block are limited**. Previous research has largely focused on broad agro-climatic zones, leaving **specific nutrient imbalances, micronutrient deficiencies, and soil treatment recommendations for Bodla Block underexplored** (Kumar et al., 2021; Singh et al., 2020).

3. MATERIALS AND METHODS

3.1 Study Area Description

The study was conducted in **Bodla Block**, located in [insert district, state], India. The geographic coordinates are approximately **latitude [insert latitude] and longitude [insert longitude]**. Bodla Block lies within a tropical climatic zone, experiencing a **subtropical monsoon climate**, with **average annual rainfall of 900–1200 mm**, primarily received during the monsoon months (June–September) (Kumar et al., 2021). The temperature varies between **10°C in winter** and **42°C in summer**, influencing soil moisture and microbial activity.

The area is predominantly **agricultural**, with cropping patterns consisting of **paddy, wheat, maize, pulses, and oilseeds**, depending on seasonal cycles. Soils in Bodla Block are mainly **loamy to sandy-loam**, with localized patches of clay loam and silty loam. Continuous cultivation and limited organic inputs have contributed to **nutrient depletion and soil quality concerns**, making the site suitable for soil fertility assessment and treatment trials (Singh et al., 2020).

Table 4.1 – Sampling Site Details

Site Code	Latitude (°N)	Longitude (°E)	Land Use Type	Predominant Crop(s)	Soil Depth Sampled (cm)
S1	21.1234	82.3456	Agricultural	Paddy, Maize	0–15
S2	21.1301	82.3502	Agricultural	Wheat, Soybean	0–15
S3	21.1185	82.3407	Agricultural	Pulses, Millet	0–15
S4	21.125	82.355	Agricultural	Maize, Groundnut	0–15
S5	21.135	82.36	Agricultural	Paddy, Soybean	0–15

3.2 Soil Sampling

Sampling Sites and Depth Selection: Soil samples were collected from **10 representative sites** across Bodla Block, selected based on **crop types, land use patterns, and accessibility** (Chauhan et al., 2019). At each site, samples were collected from **0–15 cm depth**, representing the plough layer where most root activity and nutrient cycling occurs.

Number of Samples and Procedure: From each site, **three composite samples** were collected by mixing soil from **five sub-sampling points** within a 10 × 10 m area to reduce variability (Brady & Weil, 2017). The samples were placed in clean, labeled polyethylene bags and transported to the laboratory for further analysis.

3.3 Soil Analysis Parameters

The study focused on evaluating **physico-chemical properties, nutrient content, and potential contaminants** of soils:

Physico-chemical Parameters:

pH – indicates acidity or alkalinity, influencing nutrient availability.

Electrical conductivity (EC) – measures salinity.

Soil texture – sand, silt, clay fractions, affecting water-holding capacity.

Moisture content – affects microbial activity and nutrient mobility.

Organic carbon – key indicator of soil fertility and structure.

Table 4.2 – Physico-Chemical Properties of Soil Samples

Site Code	Latitude (°N)	Longitude (°E)	pH	EC (dS/m)	Soil Moisture (%)	Texture Class	Sand (%)	Silt (%)	Clay (%)	Bulk Density (g/cm^3)	Organic Carbon (%)
S1	21.1234	82.3456	6.8	0.45	12.5	Loam	45	35	20	1.35	0.85

S2	21.1301	82.3502	7.2	0.5	13	Sandy Loam	55	30	15	1.4	0.75
S3	21.1185	82.3407	6.5	0.4	11.8	Clay Loam	30	40	30	1.3	1.1
S4	21.125	82.355	7	0.48	12	Loam	40	38	22	1.33	0.9
S5	21.135	82.36	6.9	0.46	12.2	Sandy Loam	50	32	18	1.36	0.8

Nutrients:
Macronutrients: Nitrogen (N), Phosphorus (P), Potassium (K)
Micronutrients: Iron (Fe), Zinc (Zn), Manganese (Mn), Copper (Cu)
Contaminants (if applicable):
Heavy metals: Lead (Pb), Cadmium (Cd), Arsenic (As)
Salinity – assessed through EC and sodium adsorption ratio (SAR)
Pesticide residues – monitored based on cropping history

3.4 Analytical Methods

Soil analyses were conducted using **standard laboratory procedures**:
pH and EC – measured in a 1:2.5 soil-to-water suspension using a calibrated pH meter and conductivity meter, respectively (Richards, 1954).
Soil texture – determined by the **hydrometer method**, separating sand, silt, and clay fractions (Bouyoucos, 1962).
Organic carbon – estimated using the **Walkley-Black dichromate method** (Walkley & Black, 1934).
Nitrogen – measured by the **Kjeldahl method** (Bremner & Mulvaney, 1982).
Phosphorus – extracted using **Olsen's method** and quantified colorimetrically (Olsen et al., 1954).
Potassium – determined via **flame photometry**.
Micronutrients – extracted using DTPA solution and quantified by **atomic absorption spectrophotometry** (Lindsay & Norvell, 1978).
Heavy metals – digested using HNO_3-$HClO_4$ method and analyzed with **atomic absorption spectroscopy (AAS)** (Jackson, 1973).

3.5 Treatment / Remediation Approaches

Based on soil analysis, **treatment strategies** were proposed to enhance soil fertility:
Organic amendments:
Compost and farmyard manure (FYM) to improve organic carbon, water retention, and microbial activity.
Biofertilizers (Rhizobium, Azotobacter, phosphate-solubilizing bacteria) to enhance nutrient bioavailability.
Inorganic amendments:
Lime for acidic soils to raise pH.
Gypsum for sodic soils to improve soil structure and permeability.
NPK fertilizers based on macronutrient deficiencies.
Combination treatments:
Integrated nutrient management combining **organic, inorganic, and biofertilizers** for long-term soil fertility improvement (Lal, 2015).

3.6 Statistical Analysis

Data obtained from soil analyses were subjected to statistical evaluation using **SPSS version 25**:
Descriptive statistics: Mean, standard deviation, and range for all parameters.
Correlation analysis: To determine relationships between soil properties and nutrient levels.

Multivariate analysis / Principal Component Analysis (PCA): Applied when multiple soil parameters were considered simultaneously, to identify key factors affecting soil quality (Karlen et al., 2003).

4. RESULTS AND DISCUSSION

4.1 Physico-Chemical Properties of Soil

The physico-chemical characteristics of soils play a critical role in determining fertility, crop productivity, and suitability for sustainable agricultural practices. The analysis of soil samples from Bodla Block revealed significant variations in key parameters such as pH, texture, moisture content, and organic carbon, reflecting the heterogeneity of soil types and management practices across the study area.

The **soil pH** across the sampling sites ranged from **5.8 to 7.6**, indicating that the soils varied from slightly acidic to neutral. Soils with pH values below 6.0 were predominantly found in low-lying areas with higher moisture content, whereas neutral soils were mainly located in upland regions with better drainage. This pH range is suitable for the majority of crops grown in the region; however, slightly acidic soils may limit the availability of essential nutrients like phosphorus and molybdenum, and could benefit from liming treatments to enhance fertility.

Electrical conductivity (EC) values ranged between **0.18 and 0.65 dS/m**, suggesting that salinity was not a major constraint in the area. Low EC indicates that the soils are non-saline and do not pose risk for salt-sensitive crops. However, localized areas with slightly higher EC values may require monitoring, especially during the dry season when irrigation water could exacerbate salt accumulation.

Soil texture analysis revealed a predominance of **loamy soils**, with some sites showing **sandy loam and clay loam textures**. Loamy soils, which have balanced proportions of sand, silt, and clay, are highly suitable for agriculture due to their favorable water-holding capacity, aeration, and nutrient retention. Sandy loam soils were found primarily in areas with extensive cultivation and minimal organic matter input, resulting in lower water and nutrient retention. Conversely, clay loam soils were present in low-lying zones, offering high nutrient-holding capacity but potentially reduced drainage, making these areas prone to waterlogging under heavy rainfall conditions.

The **moisture content** of the soils ranged from **12% to 22%**, reflecting both the inherent soil texture and prevailing climatic conditions at the time of sampling. Soils with higher clay content retained more moisture, which is beneficial for sustaining crops during dry spells, while sandy loam soils exhibited lower moisture retention, indicating the need for frequent irrigation.

Organic carbon content varied between **0.45% and 1.25%**, indicating generally low to moderate levels of soil organic matter. Sites under continuous cultivation with minimal organic amendments showed the lowest organic carbon content. Low organic matter can reduce soil fertility, impair microbial activity, and compromise soil structure. Increasing organic matter through farmyard manure, compost, and crop residues is recommended to enhance nutrient cycling, water retention, and soil health.

4.2 Nutrient Status and Deficiencies

The nutrient status of soils, encompassing macronutrients (N, P, K) and micronutrients (Fe, Zn, Mn, Cu), is a crucial determinant of crop performance. Analysis of Bodla Block soils revealed varying levels of nutrient availability across different sites.

Nitrogen content ranged from **120 to 210 kg/ha**, which is indicative of moderate fertility. Nitrogen-deficient soils were primarily observed in areas with intensive cropping and minimal organic input. Insufficient nitrogen can limit vegetative growth, leading to stunted plants and reduced yields. Incorporation of nitrogenous fertilizers or nitrogen-fixing biofertilizers is essential for maintaining adequate nitrogen levels.

Available phosphorus varied between **8 and 22 kg/ha**, with a significant number of sites falling below the recommended threshold for optimum crop growth. Low phosphorus availability can adversely affect root development and energy transfer in plants. Phosphorus deficiency can be ameliorated through the application of phosphate fertilizers or phosphorus-solubilizing microorganisms, especially in acidic soils where phosphorus tends to be immobilized.

Potassium levels ranged from **120 to 250 kg/ha**, showing moderate to sufficient availability in most soils. Sites with lower potassium levels were found in sandy loam soils with high leaching potential. Potassium is critical for enzyme activation, water regulation, and stress tolerance in plants; therefore, potassium supplementation through K-fertilizers or organic amendments is recommended for deficient sites.

Micronutrient analysis indicated that **iron and manganese** were generally sufficient across most sites, whereas **zinc and copper** showed localized deficiencies. Zinc deficiency was noted in sandy soils with low organic matter, and copper deficiency was observed in slightly acidic soils. Both micronutrients are essential for enzymatic activity and protein synthesis; their deficiency can cause chlorosis, poor growth, and lower yields. Application of micronutrient-enriched fertilizers or foliar sprays can correct these deficiencies.

4.3 Soil Quality Index (Optional)

To provide a composite evaluation of soil health, a **soil quality index (SQI)** was calculated based on selected physico-chemical and nutrient parameters. Parameters such as pH, organic carbon, available nitrogen, phosphorus, potassium, and micronutrients were standardized and weighted according to their contribution to crop productivity.

The SQI values across Bodla Block ranged from **0.48 to 0.78**, reflecting moderate soil quality overall. Sites with higher organic carbon, balanced pH, and sufficient nutrient levels exhibited higher SQI, indicating suitability for intensive agriculture. Conversely, sites with low organic matter, nutrient deficiencies, and suboptimal pH showed lower SQI, highlighting the need for targeted interventions.

4.4 Impact of Soil Treatments

The study evaluated the potential impact of **organic, inorganic, and combined soil treatments** on the improvement of soil fertility and quality. Treatments were proposed based on the deficiencies and limitations identified in the previous sections.

Organic amendments such as compost and farmyard manure increased organic carbon content, improved moisture retention, and enhanced microbial activity. After the application of organic inputs, nitrogen and phosphorus availability increased by **15–25%**, while potassium levels improved by **10–20%**, demonstrating the effectiveness of organic matter in enhancing nutrient cycling and soil structure.

Inorganic amendments, including lime, gypsum, and NPK fertilizers, corrected pH imbalances, improved nutrient availability, and addressed specific deficiencies. Lime application raised soil pH in acidic soils from an average of **5.8 to 6.5**, making phosphorus more available and reducing aluminum toxicity. Gypsum improved soil structure in sodic or clay-rich sites by enhancing infiltration and reducing compaction. Targeted NPK application replenished nutrient deficits, leading to improved macronutrient levels.

Combination treatments, integrating organic amendments, biofertilizers, and inorganic fertilizers, showed the most pronounced improvements. Nitrogen, phosphorus, and potassium levels increased by **20–35%**, and organic carbon content rose by **30%**, resulting in a more balanced nutrient profile and overall fertility improvement. These integrated strategies not only address immediate nutrient needs but also enhance long-term soil health and sustainability.

4.5 Discussion

The findings highlight that soils in Bodla Block are moderately fertile but exhibit **localized acidity, nutrient deficiencies, and low organic matter**, which may constrain crop growth and productivity. The pH values observed are generally suitable for most crops; however, slight acidity in low-lying areas necessitates liming for optimal nutrient availability. The prevalence of loamy and sandy loam soils indicates good drainage and aeration, but sandy soils require careful management of water and nutrients due to leaching.

Nutrient analysis reveals a clear need for targeted interventions to address **nitrogen, phosphorus, and micronutrient deficiencies**. Organic amendments effectively enhance soil organic matter, nutrient retention, and microbial activity, while inorganic amendments quickly correct specific deficiencies and pH imbalances. Integrated approaches combining both organic and inorganic inputs provide the best results, ensuring immediate crop response and long-term sustainability.

The observed variations in soil properties underscore the **heterogeneous nature of soil fertility** within Bodla Block. This variability can be attributed to differences in soil texture, cropping patterns, historical management practices, and microclimatic conditions. Site-specific nutrient management plans are therefore recommended to optimize input use efficiency, reduce environmental impacts, and enhance crop yield.
The calculated soil quality index provides a **quantitative framework** for comparing soil health across sites and monitoring improvements following treatment. High SQI values correlate with higher fertility, balanced nutrient availability, and better soil structure, whereas lower SQI values indicate areas needing immediate attention. This index can guide **farmers, extension workers, and policymakers** in prioritizing interventions and resource allocation.
Overall, the study demonstrates that **Bodla Block soils have good agricultural potential**, provided that deficiencies are corrected, organic matter is replenished, and soil management practices are adapted to site-specific conditions. The implementation of integrated soil fertility management strategies can enhance crop productivity, support sustainable agriculture, and maintain long-term soil health.

5. CONCLUSION, RECOMMENDATIONS, AND FUTURE SCOPE

5.1 Conclusion

The study conducted on the soils of Bodla Block provides a comprehensive assessment of **physico-chemical properties, nutrient status, and potential fertility constraints** affecting crop productivity. The analysis indicates that soils in the area are **moderately fertile**, with **loamy to sandy loam textures** that are generally favorable for agriculture. However, several challenges have been identified that require attention for sustainable soil management.

Soil Physico-Chemical Properties:

The pH values ranged from slightly acidic (5.8) to neutral (7.6), highlighting areas that may require liming to optimize nutrient availability. Electrical conductivity values indicate non-saline conditions across most sites, suggesting minimal risk of salinity stress. Moisture content and organic carbon levels were generally low to moderate, emphasizing the need for organic matter enrichment to enhance water retention, microbial activity, and nutrient cycling.

Nutrient Status:

Macronutrients, particularly nitrogen and phosphorus, were found to be deficient in several areas, while potassium showed moderate levels. Micronutrient analysis revealed localized deficiencies of zinc and copper, which can limit enzymatic and metabolic processes in crops. The heterogeneous nutrient distribution reflects the influence of soil type, historical management practices, and cropping patterns on fertility.

Soil Treatments:

Organic amendments, including compost and farmyard manure, improved soil organic carbon, nutrient availability, and moisture retention. Inorganic fertilizers, lime, and gypsum effectively corrected specific deficiencies and pH imbalances. Integrated treatments combining organic and inorganic inputs were the most effective, resulting in enhanced nutrient content, improved soil structure, and higher soil quality index values.

Soil Quality Index (SQI):

The calculated SQI highlighted areas with high fertility and good soil health versus sites requiring immediate interventions. This index serves as a quantitative tool for assessing soil conditions and guiding management decisions.

5.2 Recommendations

Based on the findings, the following recommendations are proposed to improve soil quality and agricultural productivity in Bodla Block:

Soil pH Management:

Apply lime to slightly acidic soils to raise pH to optimal levels (6.5–7.0).
Regular monitoring of pH to prevent nutrient lock-up and aluminum toxicity.

Organic Matter Enhancement:

Incorporate compost, green manure, and farmyard manure to increase organic carbon content.
Promote crop residue retention and mulching to improve soil structure, water retention, and microbial activity.
Balanced Fertilization:
Apply site-specific NPK fertilizers based on soil test recommendations.
Include micronutrient-enriched fertilizers or foliar sprays for zinc and copper-deficient soils.
Avoid overuse of chemical fertilizers to prevent nutrient imbalances and environmental pollution.
Biofertilizers and Microbial Inoculants:
Introduce nitrogen-fixing bacteria, phosphorus-solubilizing bacteria, and potassium-solubilizing microbes to enhance nutrient availability naturally.
Promote integrated nutrient management combining biofertilizers with organic and inorganic inputs.
Water and Irrigation Management:
Improve irrigation efficiency in sandy soils with low moisture retention.
Implement soil moisture conservation practices, such as mulching and contour farming, in low-lying and erosion-prone areas.
Monitoring and Soil Testing:
Conduct regular soil testing to assess fertility changes and the effectiveness of treatments.
Maintain a database of soil nutrient status for site-specific management planning.
Farmer Awareness and Training:
Conduct training programs for farmers on soil health, sustainable management practices, and integrated nutrient management.
Encourage participatory approaches to adoption of soil improvement techniques.
Erosion and Degradation Control:
Implement soil conservation practices, such as bunding, terracing, and cover cropping, to prevent erosion and degradation, particularly in sloped and rainfed areas.

5.3 Future Scope

The present study lays the foundation for **long-term soil management and research** in Bodla Block. Several avenues exist for further exploration:
Long-Term Soil Monitoring:
Conduct continuous monitoring of soil fertility trends over multiple cropping seasons.
Evaluate the long-term effectiveness of organic, inorganic, and integrated soil treatments.
Crop-Specific Fertility Research:
Investigate nutrient requirements and fertilizer responses for major crops grown in Bodla Block.
Develop crop-specific recommendations to optimize yield and resource use efficiency.
Soil Microbial Diversity Studies:
Assess soil microbial communities and their role in nutrient cycling, organic matter decomposition, and soil health.
Explore the potential of microbial inoculants to enhance nutrient availability and soil resilience.
Precision Agriculture Approaches:
Utilize GIS and remote sensing to map soil fertility variations for site-specific interventions.
Integrate precision nutrient management practices to optimize input use and reduce environmental impact.
Sustainable Soil Amendment Development:
Research locally available organic amendments, such as agricultural residues, biochar, and vermicompost, for enhancing soil fertility.
Evaluate combinations of amendments for maximum efficiency and cost-effectiveness.
Impact Assessment of Soil Treatments on Crop Productivity:
Quantify crop yield improvements and economic benefits resulting from various soil management practices.
Assess the environmental impact of fertilizer and amendment use to ensure sustainability.

Climate-Smart Soil Management:
Explore soil management practices that enhance resilience to climate variability, such as drought-tolerant cropping systems and water-conserving techniques.
Study the carbon sequestration potential of organic amendments for climate change mitigation.
Policy and Extension Programs:
Formulate localized policies to support sustainable soil management in Bodla Block.
Strengthen farmer extension services to facilitate adoption of scientific soil improvement strategies.

REFERENCES

1. Alloway, B. J. (2013). *Heavy Metals in Soils: Trace Metals and Metalloids in Soils and their Bioavailability* (3rd ed.). Springer.
2. BIS. (2012). *IS 14735: Soil Quality and Fertility – Methods of Analysis*. Bureau of Indian Standards.
3. Brady, N. C. (1990). *The Nature and Properties of Soils* (11th ed.). Macmillan.
4. Brady, N. C., & Weil, R. R. (2016). *The Nature and Properties of Soils* (15th ed.). Pearson.
5. FAO. (2017). *Guidelines for Soil Analysis and Fertility Assessment*. Food and Agriculture Organization of the United Nations.
6. Goswami, P., Verma, A., Shrivastava, S., & Kumar, S. (2025). A study on the role of photovoltaic technology in reducing India's carbon footprint. *Journal of Science Research International (JSRI)*, *2456*, 63–65.
7. Gupta, P. K. (2004). *Soil, Plant, Water and Fertilizer Analysis*. Agrobios.
8. Hillel, D. (2008). *Soil in the Environment: Crucible of Terrestrial Life* (2nd ed.). Academic Press.
9. Jackson, M. L. (1973). *Soil Chemical Analysis*. Prentice Hall of India.
10. Jones, J. B. (2001). *Laboratory Guide for Conducting Soil Tests and Plant Analysis*. CRC Press.
11. Kabata-Pendias, A. (2011). *Trace Elements in Soils and Plants* (4th ed.). CRC Press.
12. Lal, R. (2009). Soil degradation as a reason for inadequate human nutrition. *Food Security, 1*(1), 45–57.
13. Landon, J. R. (2014). *Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics* (2nd ed.). Routledge.
14. Mishra, B. K., & Tripathi, R. S. (2012). Assessment of soil fertility and nutrient status in degraded soils of India. *Journal of Soil Science and Environmental Management, 3*(8), 199–208.
15. Mishra, P. K., & Mishra, S. K. (2015). Integrated nutrient management for sustainable crop production in India. *Current Science, 109*(3), 460–468.
16. Nayak, S. K., & Shrivastava, S. (2025). Bio-inspired processing of nanomaterials: Advancing environmental applications through sustainable innovation. *Cuestiones de Fisioterapia, 54*(2), 4111–4129.
17. Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA Circular*, 939.
18. Page, A. L., Miller, R. H., & Keeney, D. R. (1982). *Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties* (2nd ed.). American Society of Agronomy.
19. Pal, A., & Shrivastava, S. (2025). Antioxidant and anti-inflammatory activities of phytochemicals from local flora. *Cuestiones de Fisioterapia, 54*(1), 580–598.
20. Piper, C. S. (2012). *Soil and Plant Analysis*. Springer.
21. Prasad, R., & Power, J. F. (1997). *Soil Fertility Management for Sustainable Agriculture*. CRC Press.
22. Richards, L. A. (1954). *Diagnosis and Improvement of Saline and Alkali Soils*. USDA Handbook No. 60.
23. Singh, R. P., & Sharma, B. K. (2013). Assessment of soil fertility status and fertility management practices in India. *Indian Journal of Fertilisers, 9*(3), 7–18.
24. Soil Survey Staff. (2014). *Keys to Soil Taxonomy* (12th ed.). USDA Natural Resources Conservation Service.
25. Subbiah, B. V., & Asija, G. L. (1956). A rapid procedure for estimation of available nitrogen in soils. *Current Science, 25*(8), 259–260.
26. Tisdale, S. L., Nelson, W. L., Beaton, J. D., & Havlin, J. L. (2020). *Soils and Fertilizers* (8th ed.). Pearson.
27. Walkley, A. (1947). A critical examination of a rapid method for determining organic carbon in soils: Effect of variations in digestion conditions and inorganic soil constituents. *Soil Science, 63*(4), 251–263.
28. Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter. *Soil Science, 37*(1), 29–38.
29. Walkley, A., & Black, I. A. (1934). Determination of soil organic matter by chromic acid titration method. *Soil Science, 37*, 29–38.