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PHYSICO-CHEMICAL ASSESSMENT AND FERTILITY EVALUATION OF AGRICULTURAL SOILS FOR SUSTAINABLE NUTRIENT MANAGEMENT IN TELANGANA

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ABSTRACT----------
Soil fertility is a critical factor influencing agricultural productivity, nutrient availability, and sustainable crop production. The present study was undertaken to evaluate the physicochemical properties and fertility status of selected agricultural soils and to assess their suitability for sustainable nutrient management. Surface soil samples were collected from representative agricultural fields and analyzed using standard laboratory procedures for soil pH, electrical conductivity, organic carbon, available nitrogen, available phosphorus, and available potassium. The obtained data were interpreted using established soil fertility classification criteria. The findings revealed that the soils were generally slightly alkaline in reaction and non-saline in nature. Organic carbon content ranged from low to medium, indicating moderate soil organic matter status. Nutrient analysis showed that available nitrogen levels were low across the sampled soils, whereas phosphorus status was categorized as medium and potassium availability was high. The results indicate that nitrogen constitutes the primary limiting nutrient affecting soil fertility. In contrast, phosphorus and potassium levels were generally adequate to support crop growth under normal management conditions. The study emphasizes the importance of regular soil fertility evaluation, balanced fertilizer application, and integrated nutrient management practices for maintaining long-term soil productivity. Incorporation of organic amendments and appropriate nutrient supplementation can improve soil health, enhance nutrient-use efficiency, and support sustainable agricultural production. The findings provide valuable baseline information for farmers, soil scientists, and agricultural planners seeking to develop site-specific nutrient management strategies and promote sustainable agriculture in Telangana.

KEYWORDS: *Soil Fertility; Physico-Chemical Properties; Nutrient Management; Soil Health; Organic Carbon; Nitrogen; Phosphorus; Potassium; Sustainable Agriculture; Telangana*----------

INTRODUCTION

Soil is one of the most valuable natural resources supporting agricultural productivity, environmental sustainability, and food security. It functions as the primary medium for plant growth by supplying essential nutrients, water, and physical support to crop plants. The productivity of agricultural systems largely depends upon soil fertility and the availability of essential nutrients required for plant development (FAO, 2023). Healthy soils contribute to sustainable crop production, improved nutrient utilization, and ecological stability, making soil assessment an important component of agricultural management (FAO, 2023; Lal, 2020). As global food demand continues to increase, maintaining soil health has become increasingly important for achieving agricultural sustainability and long-term productivity (Montanarella & Panagos, 2021; FAO, 2023).

The fertility status of soil is determined by a combination of physical, chemical, and biological characteristics (Brady & Weil, 2017). Parameters such as soil pH, electrical conductivity, organic carbon content, nitrogen availability, phosphorus concentration, and potassium status significantly influence crop growth and nutrient availability (Havlin et al., 2014; Tisdale et al., 2013). Any imbalance in these parameters can affect agricultural productivity and reduce the efficiency of nutrient utilization by plants (Bünemann et al., 2018). Therefore, periodic soil evaluation is necessary to understand nutrient dynamics and formulate appropriate management strategies (FAO, 2023).

Modern agricultural systems often face challenges associated with nutrient depletion, declining organic matter, soil erosion, excessive fertilizer application, and changes in land-use patterns (Lal, 2015; Bationo et al., 2018). These factors can negatively affect soil fertility and crop productivity if not managed properly. Consequently, soil testing has become an essential scientific tool for assessing soil quality and identifying nutrient limitations affecting agricultural performance (Kibblewhite et al., 2008; FAO, 2023).

Soil Fertility and Nutrient Management

Soil fertility refers to the capacity of soil to supply essential plant nutrients in adequate quantities and suitable proportions for optimum crop growth (Brady & Weil, 2017). Fertile soils support healthy plant development by providing macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), in addition to various micronutrients required for physiological functions (Havlin et al., 2014). Among these nutrients, nitrogen plays a crucial role in vegetative growth, phosphorus supports root development and reproductive processes, while potassium contributes to disease resistance and overall plant health (Tisdale et al., 2013).

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Balanced nutrient management is critical for maintaining soil fertility and ensuring sustainable agricultural production (FAO, 2023). The continuous cultivation of crops without adequate nutrient replenishment often results in nutrient mining, soil degradation, and declining fertility levels (Lal, 2015). Excessive dependence on chemical fertilizers without considering soil nutrient status may further contribute to nutrient imbalances and environmental concerns (Katherasala & Bheenaveni, 2025; Chojnacka, 2024). Therefore, scientific evaluation of nutrient availability is essential for developing effective fertilizer management programmes.

Soil testing enables the assessment of nutrient deficiencies and helps formulate location-specific fertilizer recommendations (Havlin et al., 2014). Through scientific analysis of soil properties, farmers and agricultural scientists can identify nutrient limitations and implement corrective measures. Such practices not only improve crop productivity but also enhance fertilizer use efficiency and reduce environmental impacts associated with indiscriminate fertilizer application (Bationo et al., 2018; FAO, 2023).

Physico-Chemical Properties of Soil

The physico-chemical characteristics of soil provide valuable information regarding its fertility status and suitability for agricultural production. Soil reaction (pH) is considered one of the most influential factors affecting nutrient availability and microbial activity (Brady & Weil, 2017). The pH level regulates nutrient solubility, root growth, and biological processes within the soil environment (Havlin et al., 2014). Similarly, electrical conductivity (EC) serves as an indicator of soluble salt concentration and helps assess salinity-related constraints affecting crop growth (Richards, 1954).

Organic carbon is another important parameter because it reflects soil organic matter content and contributes to nutrient cycling, soil structure improvement, moisture retention, and microbial activity (FAO, 2023). Soils with adequate organic carbon generally exhibit better fertility and greater resilience under intensive cultivation (Lal, 2020; FAO, 2023). In addition, the availability of nitrogen, phosphorus, and potassium serves as a direct indicator of nutrient-supplying capacity and agricultural productivity (Tisdale et al., 2013).

Assessment of these physico-chemical properties enables researchers to evaluate overall soil health and determine the need for nutrient management interventions (Bünemann et al., 2018). The interpretation of soil fertility parameters provides important guidance for maintaining balanced nutrient conditions and ensuring sustainable agricultural production (Montanarella & Panagos, 2021).

Soil Fertility Assessment and Sustainable Agriculture

Soil fertility assessment plays a crucial role in promoting sustainable agriculture by providing scientific information on soil nutrient status and fertility conditions (FAO, 2023). Sustainable agricultural development depends not only on increasing crop yields but also on maintaining soil productivity for future generations (Lal, 2015). The adoption of evidence-based nutrient management practices can help improve crop performance while conserving natural resources and minimizing environmental degradation (Katherasala, 2025; Katherasala & Bheenaveni, 2024).

In regions experiencing intensive agricultural activity, regular soil fertility evaluation becomes particularly important for identifying emerging nutrient deficiencies and developing corrective management strategies (Bationo et al., 2018). Scientific assessment of soil properties enables the implementation of integrated nutrient management approaches that combine organic and inorganic nutrient sources to optimize productivity and maintain soil health (FAO, 2023; Katherasala et al., 2025). Such approaches contribute to long-term agricultural sustainability by improving nutrient use efficiency and reducing unnecessary fertilizer inputs.

The present study was undertaken to assess the physico-chemical properties and fertility status of selected agricultural soils and to evaluate their potential for sustainable crop production. By examining key soil fertility indicators including pH, electrical conductivity, organic carbon, and available nutrient status, the study seeks to provide valuable information for improving nutrient management and supporting sustainable agricultural practices in Telangana.

OBJECTIVES AND IMPORTANCE OF THE STUDY

Soil fertility assessment is essential for achieving sustainable agricultural productivity because soil physicochemical properties directly influence nutrient availability, crop growth, and long-term soil health. Continuous cultivation, nutrient depletion, low organic matter content, and imbalanced fertilizer application often affect the productive capacity of agricultural soils. Therefore, periodic evaluation of soil fertility is necessary for developing appropriate nutrient management strategies and ensuring sustainable crop production (FAO, 2023; Lal, 2015).

The present study aims to assess the physicochemical properties and fertility status of selected agricultural soil samples. Specifically, the study seeks to evaluate soil reaction (pH), electrical conductivity (EC), organic carbon content, available nitrogen, phosphorus, and potassium levels, and to determine the fertility status of the selected soils. The study further aims to identify nutrient deficiencies and provide recommendations for sustainable nutrient management practices.

The importance of the study lies in its contribution to sustainable agriculture and efficient nutrient management. Understanding soil fertility conditions helps farmers, agricultural scientists, and policymakers develop site-specific fertilizer recommendations and

improve nutrient use efficiency. The findings provide baseline information that can support integrated nutrient management practices and contribute to the maintenance of long-term soil productivity and environmental sustainability (Montanarella & Panagos, 2021; Katherasala, 2024).

MATERIALS AND METHODS

The present study was conducted to assess the physicochemical properties and fertility status of selected agricultural soils. Surface soil samples (0–15 cm depth) were collected from three representative agricultural fields following standard soil sampling procedures. Composite samples were prepared by combining multiple subsamples collected from each field. The collected soils were air-dried, processed, and sieved through a 2-mm mesh before laboratory analysis (Brady & Weil, 2017).

The soil samples were analyzed using standard soil science laboratory methods. Soil pH was determined using a digital pH meter, and electrical conductivity was measured using a conductivity meter. Organic carbon was estimated by the Walkley and Black wet oxidation method. Available nitrogen was determined using the alkaline potassium permanganate method, available phosphorus was estimated by the Olsen extraction method, and available potassium was measured using a flame photometer following ammonium acetate extraction. The analytical results were interpreted using standard soil fertility rating criteria commonly recommended for Indian agricultural soils. Descriptive analysis was employed to compare the fertility status of the selected soil samples and identify major nutrient limitations (Havlin et al., 2014; Tisdale et al., 2013).

RESULTS AND DISCUSSION

The results of the study are presented in this section to evaluate the physicochemical properties and fertility status of selected agricultural soil samples. The analysis focuses on key soil parameters including soil pH, electrical conductivity, organic carbon content, and the availability of major macronutrients such as nitrogen, phosphorus, and potassium. These parameters were assessed to determine soil fertility conditions and their implications for sustainable crop production and nutrient management. The findings are organized into two major components: physicochemical characterization of soils and fertility evaluation based on nutrient status. Collectively, the results provide useful insights into soil health and support the development of appropriate nutrient management strategies for sustainable agricultural production.

Table 1: Physico-Chemical Characteristics of Soil Samples

Soil Parameters	Sample 1	Sample 2	Sample 3
pH	8.05	7.80	8.12
Electrical Conductivity (dS m^{-1})	0.022	0.079	0.032
Organic Carbon (%)	0.32	0.42	0.37
Available Nitrogen (kg ha^{-1})	88.2	94.5	119.7
Available Phosphorus (kg ha^{-1})	16.1	21.2	15.2
Available Potassium (kg ha^{-1})	240.75	280.14	262.23

The physicochemical properties of soil provide important information regarding nutrient availability, soil fertility, and agricultural productivity. The analysis of the soil samples revealed slight variations in pH, electrical conductivity, organic carbon content, and nutrient status. The soils were generally found to be slightly alkaline in reaction, with pH values ranging from 7.80 to 8.12. Electrical conductivity values were low across all samples, indicating the absence of salinity-related constraints and favourable conditions for crop cultivation. Organic carbon levels ranged from low to medium, suggesting the need for regular incorporation of organic matter to improve soil health and nutrient-retention capacity (Brady & Weil, 2017).

The nutrient analysis indicated variations in the availability of essential macronutrients. Nitrogen levels were relatively low across the sampled soils, suggesting a potential limitation for crop growth if adequate nutrient replenishment measures are not adopted. Available phosphorus was present at moderate levels, indicating a satisfactory nutrient status for supporting crop development. Potassium concentrations were comparatively high in all samples, reflecting favourable potassium availability for agricultural production. Similar observations regarding nutrient variability and soil fertility assessment have been reported in studies on Indian agricultural soils (Katherasala et al., 2024; Havlin et al., 2014). The findings demonstrate that while the soils possess generally acceptable fertility conditions, nitrogen supplementation remains important for maintaining balanced nutrient status and sustainable productivity.

Table 2: Soil Fertility Classification and Nutrient Status

Parameter	Sample 1	Sample 2	Sample 3	Fertility Rating
Soil pH	8.05	7.80	8.12	Slightly Alkaline
Electrical Conductivity (dS m^{-1})	0.022	0.079	0.032	Non-Saline
Organic Carbon (%)	0.32	0.42	0.37	Low–Medium
Available Nitrogen (kg ha^{-1})	88.2	94.5	119.7	Low
Available Phosphorus (kg ha^{-1})	16.1	21.2	15.2	Medium
Available Potassium (kg ha^{-1})	240.75	280.14	262.23	High

The soil fertility classification revealed important information regarding the nutrient-supplying capacity of the selected soils. All three soil samples exhibited slightly alkaline pH conditions and non-saline characteristics, suggesting favourable soil environments

for crop cultivation. Organic carbon content was categorized as low to medium, indicating the need for enhanced application of organic amendments to improve soil structure and biological activity.

Available nitrogen was classified as low in all soil samples, highlighting nitrogen deficiency as the most important fertility constraint. In contrast, phosphorus levels were found to be within the medium fertility category, indicating adequate nutrient availability for crop growth under normal management conditions. Potassium status was categorized as high, reflecting sufficient potassium reserves and favourable nutrient conditions for sustainable production. Similar fertility trends have been documented in studies assessing agricultural soil health and nutrient dynamics under intensive cultivation systems (FAO, 2023; Katherasala & Bheenaveni, 2025). The findings suggest that nutrient management strategies should focus primarily on improving nitrogen availability while maintaining balanced phosphorus and potassium levels. Integrated nutrient management approaches combining organic manures and balanced fertilizer applications would be beneficial for sustaining soil productivity and improving long-term fertility.

Implications for Sustainable Nutrient Management

The findings emphasize the importance of regular soil testing and balanced nutrient management for sustaining agricultural productivity. The low nitrogen status observed across the soil samples suggests the need for appropriate nitrogen fertilization and increased use of organic nutrient sources such as farmyard manure, compost, green manuring, and crop residue incorporation. These practices can improve soil organic matter levels and enhance nutrient availability over time (Lal, 2015; FAO, 2023).

The moderate phosphorus and high potassium levels indicate that fertilizer recommendations should be tailored according to actual nutrient status rather than relying on uniform fertilizer application practices. Site-specific nutrient management can improve fertilizer-use efficiency, reduce input costs, and minimize environmental impacts associated with excessive fertilizer use. Sustainable nutrient management strategies integrating organic and inorganic nutrient sources are essential for maintaining soil fertility, improving crop productivity, and ensuring long-term agricultural sustainability (Katherasala, 2024; Chojnacka, 2024).

CONCLUSION

The present study assessed the physicochemical properties and fertility status of selected agricultural soils with a view to understanding their suitability for sustainable agricultural production. The findings revealed that the soils were generally slightly alkaline in reaction and non-saline in nature, indicating favourable conditions for crop cultivation. Organic carbon levels ranged from low to medium, suggesting the need for continuous incorporation of organic matter to maintain soil health and improve nutrient availability. Analysis of macronutrients revealed that available nitrogen levels were comparatively low, while phosphorus was present at moderate levels and potassium was available in sufficient quantities.

The study demonstrates that nitrogen deficiency remains the most significant fertility constraint among the analyzed soil samples. Therefore, appropriate nitrogen management strategies are essential for sustaining crop productivity and maintaining balanced nutrient status. The findings also indicate that blanket fertilizer recommendations may not be suitable for all fields, and site-specific nutrient management should be encouraged to improve fertilizer-use efficiency and reduce unnecessary input costs.

From a sustainable agriculture perspective, the study highlights the importance of regular soil testing, integrated nutrient management, and the combined use of organic and inorganic nutrient sources. Application of farmyard manure, compost, green manures, and balanced fertilizers can enhance soil fertility while improving long-term agricultural productivity. Overall, the study provides useful information for developing appropriate nutrient management strategies and contributes to the promotion of sustainable soil health management and environmentally responsible agricultural practices in Telangana.

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