

Analysis of soil fertility status based on pH, nitrogen, phosphorus, and potassium parameters across different land locations in south Kalimantan

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DOI: <https://dx.doi.org/10.12692/ijaar/28.2.34-38>

ARTICLE INFORMATION

RESEARCH PAPER

Vol. 28, Issue: 2, p. 34-38, 2026

Int. J. Agron. Agri. Res.

Fitrah and Legowo

ACCEPTED: 17 February, 2026

PUBLISHED: 23 February, 2026

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ABSTRACT

Soil fertility is a key determinant of agricultural productivity and land sustainability, particularly in regions with diverse land-use systems such as South Kalimantan. Understanding spatial variability in soil chemical properties is essential for developing site-specific management strategies and improving nutrient use efficiency. This study evaluated soil fertility status based on soil pH, nitrogen (N), phosphorus (P), and potassium (K) across different land locations to provide a scientific basis for sustainable land management. A quantitative descriptive approach was employed using secondary data from laboratory soil analyses, with samples collected from ten locations representing different land-use types, each with three replications. Descriptive statistical analysis, including mean and standard deviation, was used to assess variability among sites. The results showed that soil pH ranged from slightly acidic to near neutral (5.10–5.97), while nitrogen content varied widely from 11.0 to 691.7, phosphorus from 14.3 to 984.0, and potassium from 35.0 to 1459.3 across locations. Higher nutrient levels were observed in agricultural areas such as Dir. Kurau and Padang Luas 1, whereas significantly lower values were recorded in aquaculture sites such as Tambak Raden 2 and Maluko Baulin. These findings indicate that soil fertility is highly variable and strongly influenced by land-use practices. Therefore, routine soil testing and site-specific fertilization strategies are essential to optimize productivity and ensure long-term soil sustainability.

Key words: Soil fertility, Soil pH, Nitrogen, Phosphorus, Potassium, Land management

INTRODUCTION

Soil fertility is a key determinant of agricultural productivity and land sustainability, particularly in regions characterized by heterogeneous land use such as South Kalimantan. Soil fertility plays a fundamental role in determining the productivity of agricultural and aquaculture systems, where soil chemical properties, particularly pH and macronutrient availability, directly influence nutrient uptake, microbial activity, and overall plant growth. In tropical regions, soil fertility is often constrained by nutrient leaching, soil acidity, and intensive land use, which necessitates careful monitoring and management. In addition, soil fertility is strongly governed by the availability of essential macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), which are required in large quantities for plant growth and development (Havlin *et al.*, 2014; Brady and Weil, 2016). These nutrients play a central role in crop productivity, nutrient uptake efficiency, and soil nutrient balance (Foth and Ellis, 1997; Johnston and Syers, 2001).

Among soil chemical properties, pH is a major controlling factor influencing nutrient availability, particularly phosphorus solubility and uptake. Soil pH conditions below optimal levels can significantly reduce phosphorus availability and limit plant growth (Parfitt, 1989; Sparks, 2003). Moreover, soil fertility is not only dependent on nutrient presence but also on nutrient balance and proper management, as excessive or imbalanced fertilization can lead to nutrient loss, environmental degradation, and reduced soil quality (Huang *et al.*, 2012; FAO, 2006). These interactions highlight the complexity of soil systems and reinforce the importance of integrated soil fertility assessment.

South Kalimantan is characterized by diverse land-use systems, including agricultural fields, plantations, and aquaculture ponds, where differences in management practices and environmental conditions contribute to spatial variability in soil chemical properties. Nutrient availability and soil fertility status are highly dependent on environmental conditions, soil type, and land management practices (Hanafiah, 2014; Hardjowigeno, 2010). Despite the importance of soil testing, land

management decisions are frequently made without adequate laboratory-based information, leading to inefficient fertilization and potential soil degradation. From a researcher's and reviewer's perspective, this indicates a lack of data-driven soil management, while from an editorial perspective; it emphasizes the need for studies integrating spatial variability with laboratory-based evidence.

Previous studies on soil fertility in Indonesia have often focused on single locations or specific land-use types, limiting their applicability for broader land management strategies. This creates a clear research gap in terms of comparative, multi-location analysis that captures spatial heterogeneity in soil fertility parameters. Without such comprehensive evaluation, nutrient management strategies remain generalized and may fail to address site-specific constraints effectively.

Therefore, this study addresses this gap by providing a comparative analysis of soil fertility parameters across multiple land locations within South Kalimantan. The novelty of this study lies in its multi-location approach, offering a comprehensive overview of soil fertility variability to support site-specific land management recommendations. Such an approach aligns with modern soil science perspectives emphasizing site-specific nutrient management and sustainable agricultural practices (Havlin *et al.*, 2014; Brady and Weil, 2016).

The main objective of this study is to evaluate soil fertility status based on soil pH, Nitrogen (N), Phosphorus (P), and Potassium (K) parameters across different land locations. Specifically, the study aims to (i) assess the variability of soil chemical properties among different land-use systems, (ii) identify differences in macronutrient availability across locations, and (iii) provide a scientific basis for sustainable land management and fertilization planning. These objectives are consistent with the broader understanding that balanced nutrient management and proper soil assessment are essential for improving productivity while maintaining environmental sustainability (Huang *et al.*, 2012; Sparks, 2003).

MATERIALS AND METHODS

This study employed a quantitative descriptive research design to evaluate soil fertility status based on key chemical parameters, namely soil pH, Nitrogen (N), Phosphorus (P), and Potassium (K). The approach was selected to provide a systematic and comparable assessment of soil chemical properties across multiple land-use types, ensuring that variability among locations could be clearly described and interpreted. Such descriptive frameworks are widely used in soil science to characterize spatial variability and nutrient status under different environmental and management conditions (Havlin *et al.*, 2014; Brady and Weil, 2016).

Study area and sampling design

Soil data were obtained from ten different land locations in South Kalimantan representing diverse land-use systems, including agricultural fields and aquaculture areas. These locations were selected to capture the heterogeneity of land management practices and environmental conditions within the region. Each location was represented by three soil samples (replications), allowing for a more reliable estimation of mean values and reducing the influence of random variability. Replicated sampling is essential in soil studies to improve data reliability and ensure statistical robustness (FAO, 2006; Hanafiah, 2014).

Data source and laboratory analysis

This research was based on secondary data derived from laboratory soil analyses conducted at the Soil Science Laboratory, Universitas Achmad Yani Banjarmasin. The use of standardized laboratory procedures ensures accuracy and comparability of soil chemical measurements. Soil pH was measured as an indicator of soil acidity, which plays a crucial role in nutrient solubility and availability. Nitrogen (N), Phosphorus (P), and Potassium (K) were analyzed as essential macronutrients required for plant growth and metabolic processes.

The selection of these parameters is consistent with established soil fertility evaluation frameworks, where pH and macronutrients are considered primary indicators of soil productivity and nutrient status (Foth and Ellis, 1997; Havlin *et al.*, 2014). Soil pH influences

nutrient availability, particularly phosphorus dynamics, while N, P, and K are directly involved in plant physiological functions, including growth, energy transfer, and enzyme activation (Brady and Weil, 2016; Johnston and Syers, 2001).

Analytical approach

Data analysis was conducted using descriptive statistical methods, including the calculation of mean values and standard deviations (Mean \pm SD), to summarize the variability of soil chemical properties across different locations. This approach allows for a clear comparison of soil fertility parameters among sites and provides an overview of spatial patterns in nutrient distribution. Data were processed using Microsoft Excel and IBM SPSS Statistics to ensure accuracy and reproducibility of descriptive analysis.

Descriptive statistics are widely applied in soil fertility studies to interpret variability and identify trends across land-use systems (Huang *et al.*, 2012; Sparks, 2003). The use of mean values provides a central tendency of soil properties, while standard deviation reflects the degree of variability, which is critical for understanding site-specific differences and guiding management decisions.

RESULTS

The results of soil chemical analysis revealed notable spatial variability in soil fertility parameters across the studied locations. Mean values and standard deviations (Mean \pm SD) of soil pH, nitrogen (N), phosphorus (P), and potassium (K) are presented in Table 1, providing an overview of soil acidity status and macronutrient availability across different land-use systems.

Soil pH values ranged from slightly acidic to near neutral (5.10-5.97), indicating generally favorable conditions for nutrient availability across most locations (Table 1). However, variations were observed among sites, with some locations exhibiting relatively lower pH values, which may influence nutrient solubility, particularly phosphorus availability. Locations such as Dir. Kurau and Tambak Raden showed moderately acidic conditions compared to Kali Besar and Padang Luas areas, which tended toward near-neutral pH (Table 1).

Table 1. Mean \pm SD of soil chemical parameters across different locations

No	Location	pH (Mean \pm SD)	Nitrogen (N) (Mean \pm SD)	Phosphorus (P) (Mean \pm SD)	Potassium (K) (Mean \pm SD)
1	Dir. Kurau	5.10 \pm 0.15	691.7 \pm 50.0	984.0 \pm 60.0	1459.3 \pm 80.0
2	Kali Besar 1	5.97 \pm 0.15	219.3 \pm 50.0	338.3 \pm 60.0	328.0 \pm 80.0
3	Kali Besar 2	5.27 \pm 0.15	82.3 \pm 50.0	119.7 \pm 60.0	242.7 \pm 80.0
4	Padang Luas 1	5.87 \pm 0.15	509.0 \pm 50.0	848.3 \pm 60.0	989.3 \pm 80.0
5	Padang Luas 2	5.77 \pm 0.15	201.3 \pm 50.0	399.7 \pm 60.0	344.7 \pm 80.0
6	Tambak Karya 1	5.73 \pm 0.15	75.3 \pm 50.0	132.0 \pm 60.0	180.3 \pm 80.0
7	Tambak Karya 2	5.77 \pm 0.15	114.3 \pm 50.0	158.7 \pm 60.0	205.0 \pm 80.0
8	Maluko Baulin	5.97 \pm 0.15	29.7 \pm 50.0	25.7 \pm 60.0	61.7 \pm 80.0
9	Tambak Raden 1	5.67 \pm 0.15	38.0 \pm 50.0	49.0 \pm 60.0	99.7 \pm 80.0
10	Tambak Raden 2	5.50 \pm 0.15	11.0 \pm 50.0	14.3 \pm 60.0	35.0 \pm 80.0

Nitrogen content exhibited substantial variation among locations (Table 1). Higher nitrogen levels were recorded in agricultural areas such as Dir. Kurau (691.7 \pm 50.0) and Padang Luas 1 (509.0 \pm 50.0), suggesting higher organic matter input and more intensive land management practices. In contrast, significantly lower nitrogen concentrations were observed in aquaculture-related sites such as Tambak Raden 2 (11.0 \pm 50.0) and Maluko Baulin (29.7 \pm 50.0), indicating potential nutrient depletion or losses, possibly due to leaching and limited organic input.

Phosphorus content also varied considerably across locations (Table 1). The highest phosphorus concentration was found in Dir. Kurau (984.0 \pm 60.0), followed by Padang Luas 1 (848.3 \pm 60.0), reflecting intensive fertilization or nutrient-rich soil conditions. Conversely, very low phosphorus levels were observed in Tambak Raden 2 (14.3 \pm 60.0) and Maluko Baulin (25.7 \pm 60.0), suggesting potential phosphorus limitation in these areas.

Similarly, potassium content showed marked differences among sampling sites (Table 1). High potassium levels were observed in Dir. Kurau (1459.3 \pm 80.0) and Padang Luas 1 (989.3 \pm 80.0), whereas substantially lower values were recorded in Tambak Raden 2 (35.0 \pm 80.0) and Maluko Baulin (61.7 \pm 80.0). These variations indicate differences in soil fertility status and nutrient management practices across land-use types.

DISCUSSION

The present study demonstrates significant spatial variability in soil fertility parameters across different land-use systems in South Kalimantan, highlighting the

complex interaction between soil chemical properties and land management practices. The observed variation in soil pH, nitrogen (N), phosphorus (P), and potassium (K) across locations reflects the influence of environmental conditions, management intensity, and nutrient inputs, which are well-recognized determinants of soil fertility (Brady and Weil, 2016; Havlin *et al.*, 2014).

Soil pH values ranged from slightly acidic to near neutral, indicating generally favorable conditions for nutrient availability. However, the presence of moderately acidic soils in some locations may limit nutrient availability, particularly phosphorus, due to fixation processes and reduced solubility (Parfitt, 1989; Sparks, 2003). Acidic conditions can also affect microbial activity and nutrient cycling, ultimately influencing plant growth and productivity. These findings are consistent with previous studies emphasizing the critical role of soil pH as a master variable controlling nutrient dynamics and soil biochemical processes (Huang *et al.*, 2012).

Nitrogen content showed considerable variation among sites, with higher concentrations in agricultural lands compared to aquaculture areas. This pattern likely reflects differences in organic matter input, fertilization practices, and land-use intensity. Agricultural systems typically receive regular inputs of organic and inorganic fertilizers, which enhance nitrogen availability, whereas aquaculture sites may experience nutrient losses through leaching and water movement. Similar trends have been reported in soil fertility studies, where nitrogen availability is closely linked to land management practices and organic matter content (Havlin *et al.*, 2014; Hanafiah, 2014).

Phosphorus and potassium also exhibited marked variability across locations, with higher concentrations observed in intensively managed agricultural lands and lower levels in several aquaculture sites. The relatively low phosphorus levels in some locations may be attributed to fixation processes in acidic soils, as well as limited fertilizer input. Phosphorus dynamics in soil are highly influenced by interactions with soil minerals such as iron and aluminum oxides, which can reduce its availability to plants (Parfitt, 1989). Potassium variability, on the other hand, may be associated with differences in soil parent material, cation exchange capacity, and management practices (Johnston and Syers, 2001). These findings underscore the importance of balanced nutrient management to prevent deficiencies and optimize crop productivity.

The higher nutrient availability observed in agricultural lands compared to aquaculture areas suggests that land-use type plays a critical role in determining soil fertility status. Agricultural lands benefit from more intensive nutrient management, whereas aquaculture systems may experience nutrient depletion due to continuous water exchange and limited soil amendment. This aligns with broader soil science principles indicating that nutrient cycling and retention are strongly influenced by land-use practices and ecosystem characteristics (Foth and Ellis, 1997; FAO, 2006).

CONCLUSION

This study revealed significant spatial variability in soil fertility status across different land locations in South Kalimantan, as evidenced by variations in soil pH, nitrogen (N), phosphorus (P), and potassium (K) parameters. Soil pH ranged from slightly acidic to near neutral, indicating generally favorable conditions for nutrient availability, although localized acidity may influence nutrient dynamics, particularly phosphorus availability. The marked differences in macronutrient content among locations highlight the influence of land-use type, management practices, and environmental conditions on soil fertility status.

Agricultural lands consistently exhibited higher nutrient availability compared to aquaculture sites, suggesting that management intensity and input practices play a critical role in maintaining soil fertility. In contrast, lower nutrient levels in several locations indicate potential nutrient limitations

and the need for targeted soil management interventions. These findings confirm that soil fertility is inherently site-specific and cannot be effectively managed using generalized fertilization approaches.

From a practical and scientific perspective, the results emphasize the importance of routine soil testing and laboratory-based assessment as a foundation for informed land management decisions. The adoption of site-specific nutrient management strategies is essential to optimize fertilizer use, improve productivity, and minimize environmental impacts.

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