JPPIPA 11(10) (2025)

Jurnal Penelitian Pendidikan IPA

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Physicochemical Characterization of Soils in Different Land Uses: A Case Study in Jatiroke Village, Sumedang, West Java

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Received: July 15, 2025
Revised: September 16, 2025
Accepted: October 25, 2025
Published: October 31, 2025

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DOI: 10.29303/jppipa.v11i10.12863

Abstract: This study aimed to analyze the physicochemical characteristics of soils across different land uses in Jatiroke Village, West Java. Twenty-four surface soil samples were collected from rice fields, plantations, residential areas, and a temporary waste disposal site (TPS) using a stratified random sampling design. Parameters measured included soil color, texture, temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS) through field and laboratory analyses. Principal Component Analysis (PCA) was applied to evaluate parameter relationships and identify dominant drivers of variability. Results showed that rice fields exhibited the highest salinity, primarily linked to the application of nitrogen- and potassium-based fertilizers, while TPS soils were affected by leachate containing organic and inorganic contaminants. Residential areas maintained near-neutral pH and low salinity, and plantations displayed intermediate variability. Descriptive traits such as color and texture varied across land uses but did not strongly differentiate soil conditions. PCA confirmed EC and TDS as the dominant differentiating factors, with pH and temperature contributing secondary variation. These findings demonstrate that fertilizer use and waste leachate are the main causes of elevated soil salinity, emphasizing the importance of monitoring EC and TDS for sustainable land management.

Keywords: Jatiroke Village; Land uses; Multivariate analysis; Soil physicochemical; Soil quality

Introduction

Soil physicochemical properties are fundamental indicators of land productivity and environmental sustainability. These properties determine nutrient availability, salinity tolerance, water retention, and biological activity, thereby directly influencing agricultural yields and ecosystem services (Cleophas et al., 2022; Mansyur et al., 2023; Mutlag & Hatimi, 2022). Land use change, particularly the conversion of agricultural land into residential, industrial, or waste disposal areas, often leads to degradation of these properties, with consequences ranging from reduced crop productivity to groundwater contamination and increased flooding risks (Suciati et al., 2025; Ye et al., 2024). Supporting this, Sanny et al. (2023) reported that land-use conversion generally has significant impacts on both the physical and chemical quality of soils, while Noriko et al. (2024) further highlighted how excessive fertilizer input and poor conservation practices can reduce soil fertility and exacerbate land degradation.

Previous research conducted by Mutlag & Hatimi (2022), Sirisathitkul & Sirisathitkul (2025), and Ye et al. (2024) have examined soil characteristics such as pH,

How to Cite:
Khanri, N. K., Asri, N. P. N., Hendra, H. A., Susantya, S., Susetyo, D. H., Kirana, K. H., … Agustine, E. (2025). Physicochemical Characterization of Soils in Different Land Uses: A Case Study in Jatiroke Village, Sumedang, West Java. *Jurnal Penelitian Pendidikan IPA*, *11*(10), 1116–1130. https://doi.org/10.29303/jppipa.v11i10.12863

electrical conductivity (EC), total dissolved solids (TDS), organic matter (OM), cation exchange capacity (CEC), soil texture, and temperature. These parameters vary with land use and influence soil's capacity to support plant growth and ecosystem functions. For instance, rice fields typically have high moisture and organic matter but are prone to acidification and salinity due to continuous fertilization (Ye et al., 2024). Residential soils often exhibit compaction, higher bulk density, and reduced porosity (Yondra & Wawan, 2017). Plantation soils may retain relatively balanced properties depending on vegetation cover, while temporary waste disposal sites (TPS) are commonly characterized by low pH, high EC and TDS, and leachate-induced contamination (Naveen et al., 2017; Suciati et al., 2025). Such variability, as also evidenced by Nasution & Fitria (2023), highlights how land use and management practices reshape soil conditions, with direct implications for agricultural productivity and environmental quality. Similarly, Murnita et al. (2024) demonstrated that the application of organic amendments, including pH, organic carbon, and macro-nutrient availability, reinforcing the sensitivity of soil physicochemical attributes to management interventions.

Each parameter of soil physicochemical provides specific insights, soil color reflects mineral content and organic matter (Mansyur et al., 2023), texture determines water retention and permeability (Cleophas et al., 2022), and temperature regulates biological and chemical processes essential for plant growth (Mahardika et al., 2023; Padusung et al., 2018). Meanwhile, pH influences nutrient availability, EC indicates salinity, and TDS represents soluble load, all of which directly affect soil fertility and degradation (Khaled & Sayed, 2023; Mutlag & Hatimi, 2022). The use of basic parameters such as soil color, texture, pH, and temperature are a common approach in soil studies in Indonesia (Latupeirissa & Latupeirissa, 2022; Mulyati et al., 2022), making it relevant to apply in this research for characterizing baseline soil conditions prior to further analysis. However, analyzing these variables individually is insufficient, as soil quality arises from their complex interrelationships. To address this, multivariate statistical approaches such as Principal Component Analysis (PCA) have been increasingly applied to simplify numerically based on multidimensional data and identify dominant drivers of soil variability (Firdous et al., 2016; Onoyima & Okibe, 2021). Such approaches are particularly relevant in peri-urban areas of Indonesia, where land conversion is rapid yet poorly quantified.

Jatiroke Village, located in Jatinangor District, Sumedang Regency, West Java, represents a rapidly transforming peri-urban landscape. The area has undergone dynamic land-use changes, with rice fields, plantations, residential developments, and temporary waste disposal sites coexisting in close proximity. Such conversion not only threatens agricultural productivity but also increases the risks of groundwater pollution, soil compaction, and local flooding, directly affecting community resilience (Zuhdy & Tjhen, 2024). Previous studies have also emphasized the importance of soil characterization in supporting both scientific research and sustainable land management practices in similar contexts (Mulyati et al., 2022; Zaman et al., 2023). Although many studies have examined soil physicochemical properties under different land uses, most remain descriptive and provide limited insight into the dominant drivers of variability. This study introduces novelty by integrating conventional soil characterization with Principal Component Analysis (PCA) to quantitatively identify key differentiating parameters. Such an approach is particularly relevant in peri-urban areas like Jatiroke, where rapid land conversion poses direct risks to soil resources.

To address these challenges, this study combines field-based soil measurements with Principal Component Analysis (PCA) to evaluate soil variability across different land uses in Jatiroke. Unlike descriptive characterizations, this integrative approach identifies which physicochemical parameters most strongly differentiate soils, thereby providing both methodological innovation and location-specific evidence to support sustainable land management. Accordingly, the objective of this research is to characterize the physicochemical properties of soils under various land uses in Jatiroke Village and to determine the key parameters driving their differentiation.

Method

The research was conducted by stratified random sampling approach, where land use types (rice fields, plantations, residential areas, and temporary disposal sites/TPS) were treated as strata. Within each stratum, sampling points were randomly selected to capture spatial variability and heterogeneity (Li & Vereecken, 2018). To facilitate point allocation, the study area was overlaid with a grid using QGIS version 3.32.3, which served as a visualization tool rather than the sampling design itself (Figure 1). A preliminary field survey was conducted to delineate land use boundaries and estimate their areal extent before determining sampling grids.

The grid spacing was adjusted according to both the areal extent and heterogeneity of each land use type.

Plantations, which covered the largest and relatively continuous area, were assigned a wider grid spacing (250 m) with 9 points distributed across the site. Rice fields, though smaller in extent, were sampled using a 200 m spacing with 6 points to capture local variation in soil properties. Residential areas, characterized by smaller parcels and higher heterogeneity, required denser spacing (150 m) with 8 points. The temporary waste disposal site (TPS) was represented by a single sampling point because Jatiroke Village has only one official temporary disposal site of significant size. Other waste deposits in the village consist of small household bins within residential areas, which were already captured under the residential stratum. Therefore, one point was considered sufficient to represent the temporary waste disposal site (TPS) land use type.

In total, 24 sampling points were collected. This number is consistent with practical field constraints and methodological recommendations that stratified sampling does not require equal allocation, but rather allocation proportional to both areal extent and within-stratum heterogeneity (Li & Vereecken, 2018; Thompson, 2012). Thus, the sample size is considered adequate to capture soil variability across the study area while maintaining feasibility of fieldwork.

Soil sampling was conducted manually using a shovel to collect topsoil (0–10 cm) samples, corresponding to the surface horizon (Ap). This depth was selected to specifically capture potential surface contamination and the direct influence of human activities, in line with recommendations by the International Atomic Energy Agency (2004) and Nordgaard & Correll (2018). After collection, soil samples were air-dried at room temperature, passed through a 10-mesh (2 mm) sieve to remove coarse fragments (stones, roots, plant debris), and stored in labeled ziplock plastic bags prior to laboratory analysis.

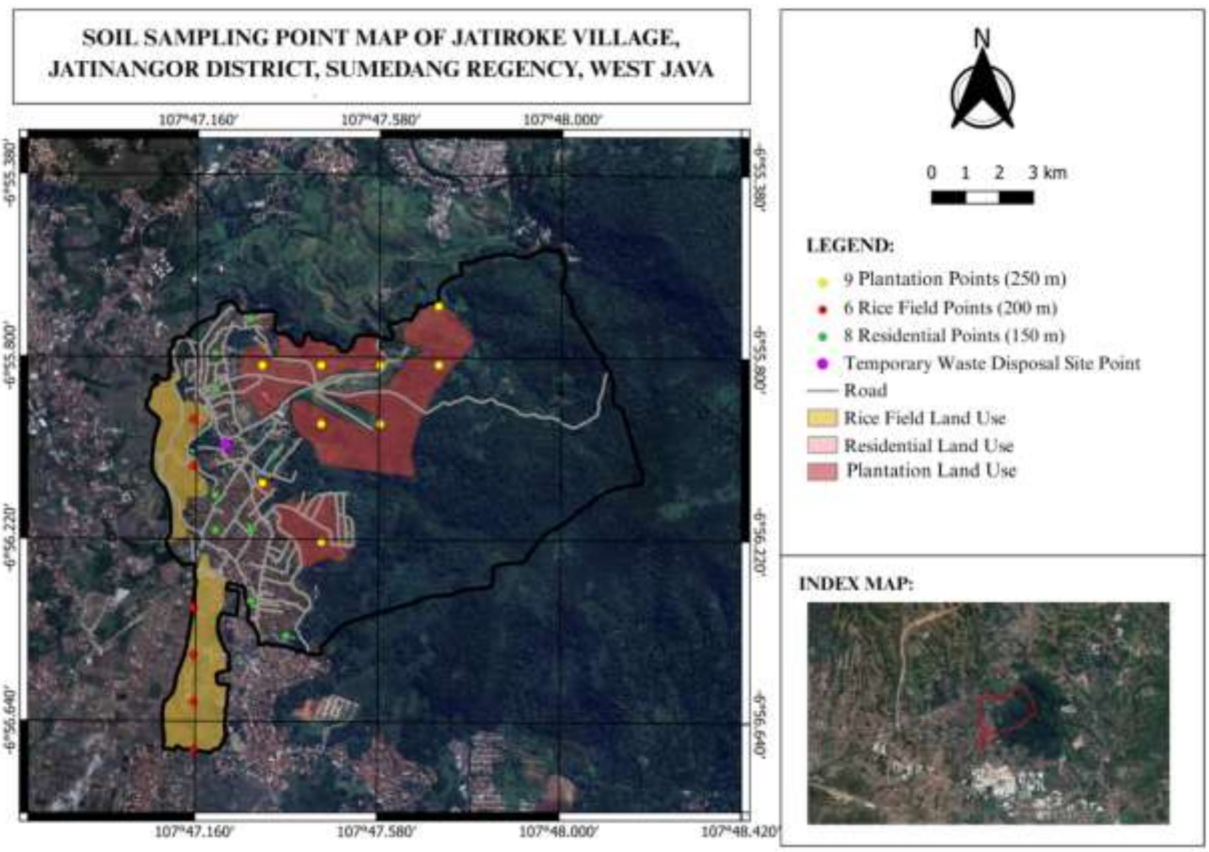

Figure 1. Soil sampling point map of study area

Soil temperature and pH were measured in situ using soil tester instrument. The instrument was operated by switching to the relevant parameter mode (temperature or pH) and inserting the probe directly into the soil at each sampling point. Between measurements when moving to the next sampling point, the probe was cleaned with a moist tissue followed by a dry tissue to avoid cross-contamination. After all measurements were completed, the device was switched off.

Soil color was identified using the Munsell Soil Color Chart, with hue, value, and chroma recorded directly for each sample (Rossel et al., 2016). Soil texture was classified using the USDA (United States Department of Agriculture) soil texture triangle approaches follow national protocols and comparable studies in Indonesia (Candra, 2019). The hydrometer method was applied, whereby soil suspensions were allowed to settle for 1–2 weeks to separate sand, silt, and clay fractions (Nisak et al., 2023; Zalwa et al., 2025). Meanwhile, EC and TDS were measured using a Hanna Combometer type HI9813-6. Soil samples were mixed with distilled water at a 1:2 volume/volume ratio, following the procedure described by Kirana et al. (2024). Specifically, 20 mL of soil was combined with 40 mL of distilled water in a graduated cylinder, thoroughly stirred until well dispersed, and then left to settle for 15 minutes before measurement. The sensor was subsequently immersed in the suspension to obtain the values (Hanna Instruments, 2018). This combination of in situ and laboratory analyses provided a comprehensive assessment of surface soil properties relevant to contamination, fertility, and land use conditions.

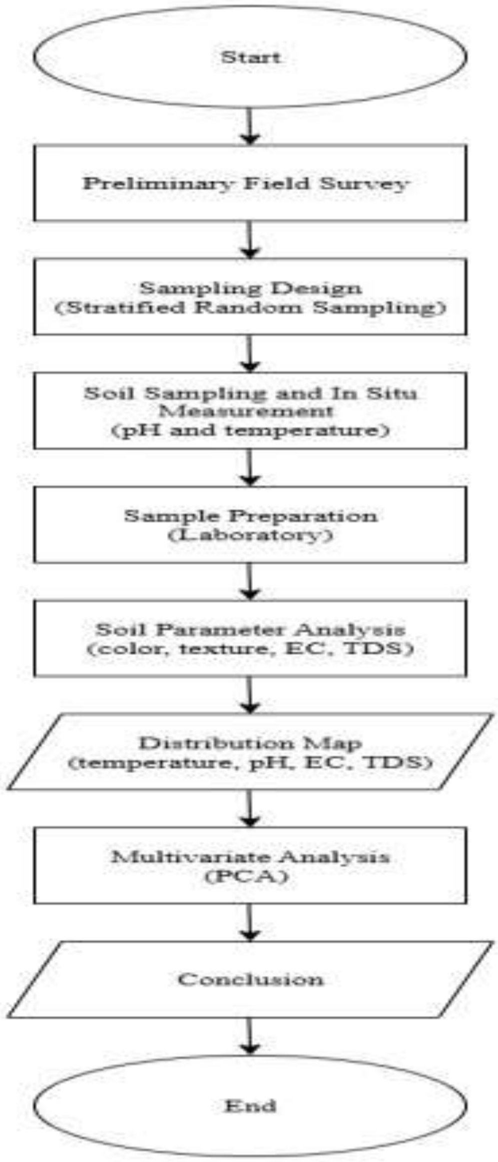

Figure 2. The flowchart of this research

Furthermore, to explore statistical relationships and patterns among the measured parameters, a multivariate statistical analysis was conducted using RStudio version 2025.05.0-496. First, a correlation matrix was generated to examine linear relationships between physicochemical variables, particularly the association between EC, TDS, pH, and temperature. Subsequently, Principal Component Analysis (PCA) was performed to reduce data dimensionality and identify the dominant variables contributing to soil variability. Soil color and texture were excluded from the Principal Component Analysis (PCA) because this method mathematically requires continuous numerical variables to construct covariance or correlation matrices (Jolliffe & Cadima, 2016). Since soil color and texture are categorical or semi-quantitative, they were analyzed descriptively rather than incorporated into the PCA. This multivariate approach provides a comprehensive interpretation of soil characteristics across different land use types, revealing key drivers of variability and supporting spatial decision-making for sustainable land management. The sequence of methods applied in this research is summarized in the flowchart shown in Figure 2.

Result and Discussion

Physicochemical Analysis

The results of the analysis of physicochemical parameters were classified in the form of tables and maps. The analysis of soil color and texture was classified into tables. Meanwhile, soil temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS), were mapped using interpolation via the Inverse Distance Weighting (IDW) method. This spatial interpolation method assumes that each input point has a localized influence that decreases with distance. The method is generally influenced by the inverse distance derived from mathematical equations and can adjust the relative influence of sample points (Yudanegara et al., 2021).

Based on the characteristic analysis of soil color using the Munsell Soil Color Chart, as shown in Table 1, land use in Jatiroke Village is dominated by the dark yellowish-brown color, found in rice fields, plantations, and residential areas. Specifically, rice fields are dominated by dark yellowish-brown, plantations by dark reddish brown and red, residential areas by dark brown, dusky red, and dark reddish brown. Soil in the TPS area is dusky red. In line with the findings of Sirisathitkul & Sirisathitkul (2025), the browner the soil color, the higher the content of goethite, while the redder the soil color, the higher the hematite content. Soils enriched with organic matter tend to have darker or blackish colors, which indicate fertile soil; the higher the organic matter content, the darker the soil color (Yang et al., 2024). This indicates that land use in Jatiroke Village has relatively high organic matter content in rice fields and plantations. Residential and TPS areas are assumed to have moderate organic matter content due to human activities that affect soil conditions, as well as accumulation of organic waste or leachate.

The results of soil texture characteristics analysis using the USDA (United States Department of Agriculture) soil texture triangle, as presented in Table 2, show that land use in Jatiroke Village is predominantly composed of sandy loam texture found in rice fields, plantations, and residential areas. Rice field soils are dominated by sand fractions with a small amount of clay, classified as loamy sand. This indicates that the soil has a good ability to retain water, although it tends to become hard when dry (Solekhah et al., 2024). Soils with sandy textures are generally easier to manage and dry quickly after rainfall, although they have lower capacities for water and nutrient retention compared to clay soils (Suleman et al., 2016). Plantation and residential lands are mostly composed of sandy loam texture, indicating that sand is the dominant fraction. Sandy soils offer better drainage compared to other soil textures, but water management in sandy soils requires attention due to their limited water-holding capacity (Alghamdi et al., 2023). The soil texture at the TPS is classified as silt loam, meaning the dominant fraction is silt. This soil type feels smooth, slightly sticky, and can be molded with a shiny surface (Ye et al., 2024).

Another parameter, soil temperature, measured using soil tester instruments, is presented in the form of a spatial distribution map as follows. Based on Figure 3, the range of soil temperature values in Jatiroke Village is between 24°C and 35°C, with an average soil temperature of 28.75°C. The standard deviation of the soil temperature values is 3.28°C. The highest recorded temperature is 35°C, while the lowest is 24°C. The highest soil temperature is found in the northeastern plantation area (P6), whereas the lowest is located in the northwestern temporary waste disposal site (TPS). This indicates that the plantation (P area) receives more solar exposure due to its open vegetation and soil surface, which increases soil temperature through enhanced absorption of solar radiation (Lozano-Parra et al., 2018). Soil temperature is significantly influenced by the amount of solar radiation received. The quantity of heat gained by the earth's surface through conduction, as well as from minor chemical and biological processes, also contributes to soil temperature. This corresponds with the conditions at the TPS area, where lower soil temperatures are influenced by the presence of solid or organic waste that reduces solar radiation penetration, together with high soil moisture that limits thermal input. Such interactions between land cover, moisture content, and surface properties have been shown to significantly affect soil temperature variation across different land uses, particularly in areas exposed to anthropogenic activities; however, soil temperature in this study showed only minor variation across land uses and is considered a secondary factor compared to salinity-related parameters (EC and TDS), as it is more strongly governed by environmental and temporal influences rather than land-use differences (Tang et al., 2022).

Table 1. Analysis results of soil color parameters

Sample Code	Hue	Value	Chroma	Color Description
F1	7.5 YR	2.50	2.00	7.5 YR 2.5/2 (very dark brown)
F2	10 YR	4.00	6.00	10 YR 4/6 (dark yellowish brown)
F3	10 YR	3.00	6.00	10 YR 3/6 (dark yellowish brown)
F4	10 YR	3.00	6.00	10 YR 3/6 (dark yellowish brown)
F5	7.5 YR	4.00	4.00	7.5 YR 4/4 (brown)
F6	10 YR	3.00	6.00	10 YR 3/6 (dark yellowish brown)
P1	2.5 YR	3.00	4.00	2.5 YR 3/4 (dark reddish brown)
P2	2.5 YR	3.00	6.00	2.5 YR 3/6 (dark red)
P3	2.5 YR	4.00	4.00	2.5 YR 4/4 (reddish brown)
P4	2.5 YR	4.00	6.00	2.5 YR 4/6 (red)
P5	2.5 YR	3.00	4.00	2.5 YR 3/4 (dark reddish brown)
P6	2.5 YR	2.50	3.00	2.5 YR 2.5/3 (dark reddish brown)
P7	2.5 YR	4.00	6.00	2.5 YR 4/6 (red)
P8	10 R	3.00	6.00	10 R 3/6 (dark yellowish brown)
P9	2.5 YR	4.00	6.00	2.5 YR 4/6 (red)
R1	2.5 YR	4.00	6.00	2.5 YR 4/6 (red)
R2	7.5 YR	3.00	3.00	7.5 YR 3/3 (dark brown)
R3	5 YR	3.00	4.00	5 YR 3/4 (dark reddish brown)
R4	10 R	3.00	2.00	10 R 3/2 (dusky red)
R5	2.5 YR	3.00	3.00	2.5 YR 3/3 (dark reddish brown)
R6	10 R	3.00	3.00	10 R 3/3 (dusky red)
R7	10 YR	3.00	6.00	10 YR 3/6 (dark yellowish brown)
R8	7.5 YR	3.00	4.00	7.5 YR 3/4 (dark brown)
Temporary Waste Disposal Site (TPS)	10 R	3.00	4.00	10 R 3/4 (dusky red)

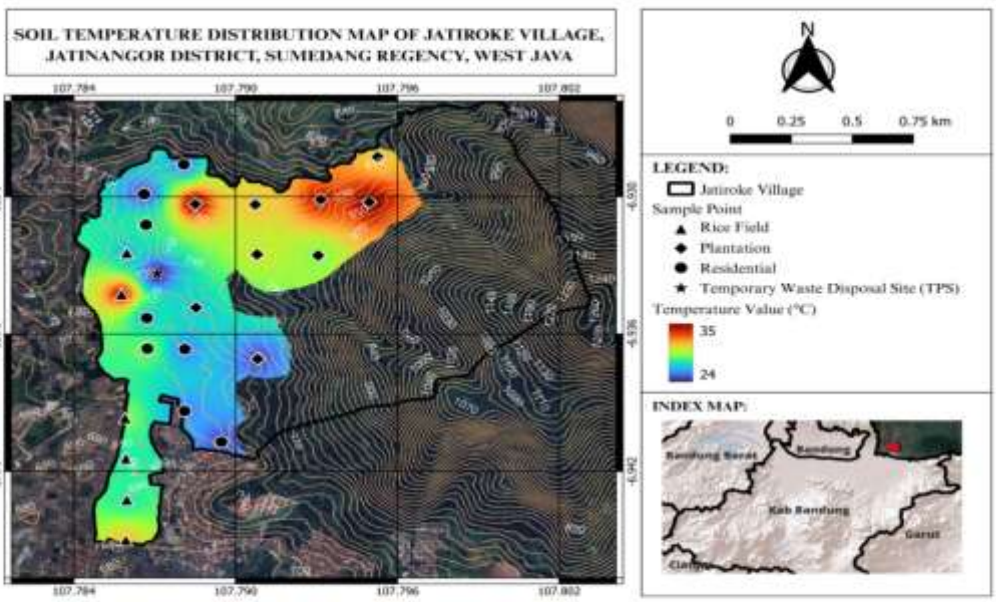

Figure 3. Soil temperature distribution map of Jatiroke Village

Table 2. Analysis results of soil texture parameters

Sample Code	Texture Composition (%)			Texture Description
	Sand	Silt	Clay	
F1	73.00	17.00	10.00	sandy loam
F2	0.00	97.30	2.70	silt
F3	80.00	16.00	4.00	loamy sand
F4	51.00	43.00	6.00	sandy loam
F5	78.00	15.00	7.00	loamy sand
F6	65.00	28.00	7.00	sandy loam
P1	80.00	12.00	8.00	loamy sand
P2	67.50	13.50	19.00	sandy loam
P3	59.00	13.00	28.00	sandy clay loam
P4	53.10	34.40	12.50	sandy loam
P5	82.90	14.60	2.50	loamy sand
P6	63.00	31.00	6.00	sandy loam
P7	72.00	24.00	4.00	sandy loam
P8	78.12	15.60	6.28	loamy sand
P9	68.00	27.00	5.00	sandy loam
R1	60.00	36.70	3.30	sandy loam
R2	71.00	16.00	13.00	sandy loam
R3	60.00	23.00	17.00	sandy loam
R4	77.00	14.00	9.00	sandy loam
R5	70.00	22.00	8.00	sandy loam
R6	68.00	16.00	16.00	sandy loam
R7	49.00	42.00	9.00	loam
R8	70.00	23.00	7.00	sandy loam
Temporary Waste Disposal Site (TPS)	18.64	69.40	11.96	silt loam

Based on the analysis of soil pH, Figure 4 shows that the pH values in Jatiroke Village range from 5.5 to 6.5, with an average of 6.3. The standard deviation of the soil pH data is 0.32. The highest pH value, 6.5, is found in almost all land use types throughout the village. Conversely, the lowest pH value of 5.5 is observed in the southwestern rice field (F5) and northern plantation areas (P3). A pH of 6.0 is recorded in the northeastern plantation (P5) and southern residential areas (R2).

The majority of Indonesia's agricultural soils are acidic, commonly registering pH values below 5 (Sumiahadi, 2019). Soils in Indonesia have an acidic pH with a value range of 4.0–5.5; hence, soils with a pH value of 6.0–6.5 can be said to be normal soils in pH, and those with a pH > 6.5 can be said to be alkaline soils. Referring to these pH values, the rice field (F5 area) and plantation (P3 area) is classified as acidic soils, while other areas with an average pH value 6.0–6.5 can be identified as normal soils. The lowest pH value (5.5) found in the rice field (F5) and plantation (P3) is likely due to the intensive use of inorganic fertilizers, which increases the accumulation of organic acids and biological reduction processes that lower the soil pH (Ayiti & Babalola, 2022). Similar effects have been reported in national peatland studies, where land-use conversion altered soil acidity and nutrient status (Yondra & Wawan, 2017).

Further corroborating this, Eddiwan & Hendrizal (2024) reported that a near-neutral pH (around 6.1–6.8) promotes and hastens the growth of plants. The study of Guo et al. (2023) also found relatively neutral pH values (6.0–6.5) in residential and TPS areas indicate more stable soil management practices, such as vegetative cover and balanced microbial activity, which help maintain chemical soil equilibrium. In this study, pH values of 5.5–6.5 were observed in several land-use categories, indicating the potential for greater nutrient availability (Abdullah et al., 2024).

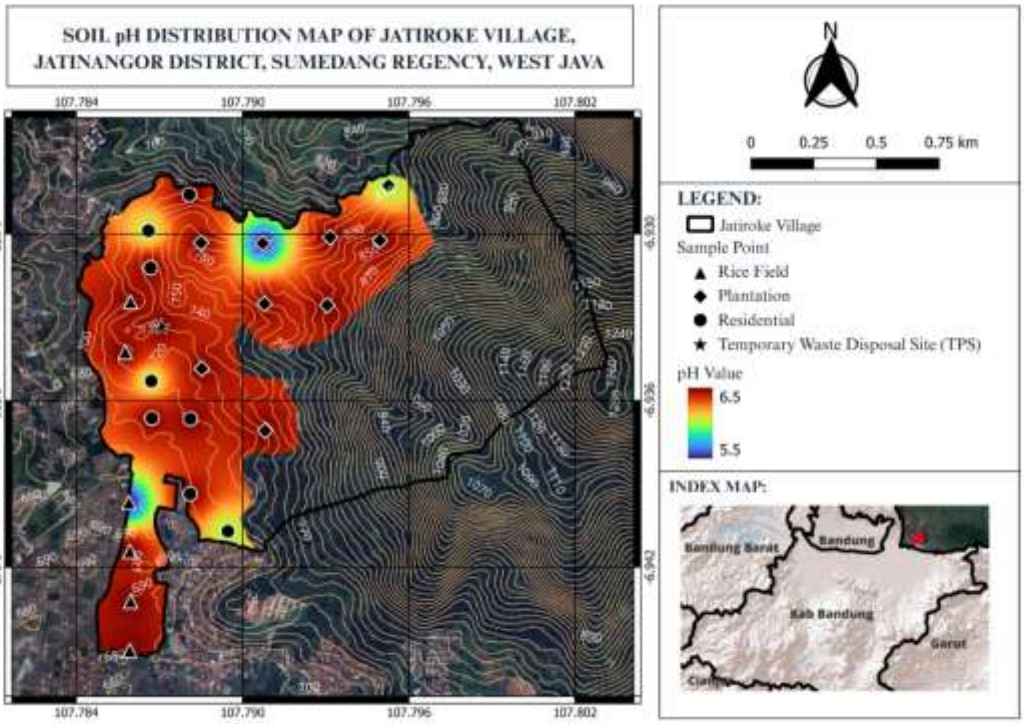

Figure 4. Soil pH distribution map of Jatiroke Village

Figure 5 presents the spatial distribution of soil electrical conductivity (EC) values in Jatiroke Village. The measured EC values range from 10 to 360 µS/cm, with an average of 70.42 µS/cm. The standard deviation of EC values is 88.34 µS/cm. The highest EC value, 360 µS/cm, is found in the western rice field area (F3), while the lowest value, 10 µS/cm, is observed across most land uses in the village. The TPS (temporary disposal site) also exhibits a relatively high EC value of 290 µS/cm.

According to the soil salinity classification by the Food and Agriculture Organization of the United Nations (FAO), all EC values recorded in Jatiroke Village fall within the non-saline category (EC < 400 µS/cm). Zaman et al. (2018) state that EC values within the non-saline range generally do not affect land productivity. However, relatively elevated EC levels, such as those found in rice fields and the TPS indicate salt accumulation, which may increase if not managed with proper soil and water practices.

The high EC values in the rice fields (F3 area) are likely due to the intensive use of fertilizers and pesticides, coupled with surface evaporation that contributes to the accumulation of salts in the upper soil layers (Devkota et al., 2022; Shokri et al., 2024). Specifically, nitrogen-based fertilizers such as urea and ammonium sulfate, along with potassium chloride (KCl) and phosphate fertilizers (e.g., SP-36), release ions (NH_4^+, NO_3^-, K^+, Cl^-, and PO_4^{3-}) that increase soil solution conductivity (Frattini et al., 2023). Similar findings were reported in West Java, where volcanic soils in agricultural fields exposed to fertilizer application showed significantly higher EC values compared to non-agricultural soils (Agustine et al., 2025). This pattern is also consistent with broader studies on fertilizer-induced salinity by Tian et al. (2024), and Putri et al. (2024), who reported that elevated EC levels in surface water are associated with agricultural runoff and domestic waste, introducing high concentrations of dissolved ions into the environment.

Meanwhile, the elevated EC in the temporary disposal site (TPS) area is presumably caused by leachate contamination from mixed organic and inorganic waste. Leachate typically contains organic acids, ammonium, chloride, sulfate, and occasionally heavy metals, all of which contribute to increased dissolved ion content in soil water (Naveen et al., 2017; Rashid et al., 2022). This is supported by recent evidence that landfill leachate may exhibit very high EC values (1304–1477 µS/cm), reflecting its high ionic load (Przydatek et al., 2025). This mechanism is consistent with Ansyar & Herdiana (2023) and Hanifah et al. (2024), who reported that waste-related leachate significantly elevates soil EC and TDS in landfill-affected areas.

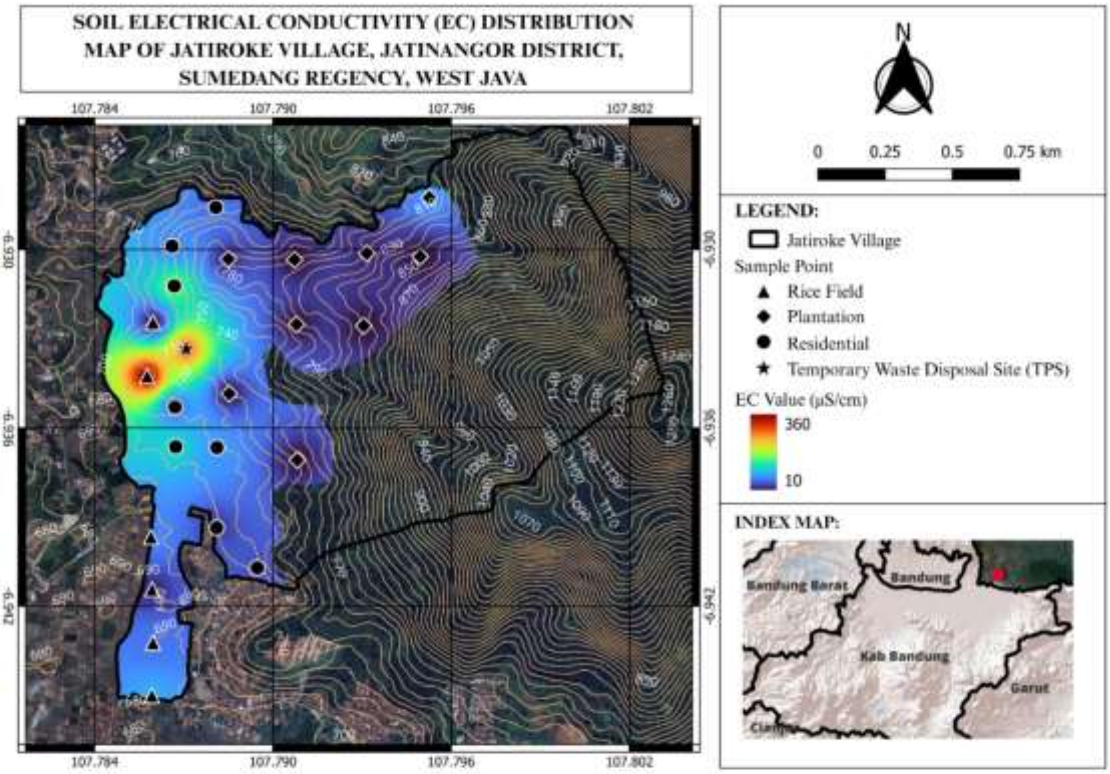

Figure 5. Soil EC distribution map of Jatiroke Village

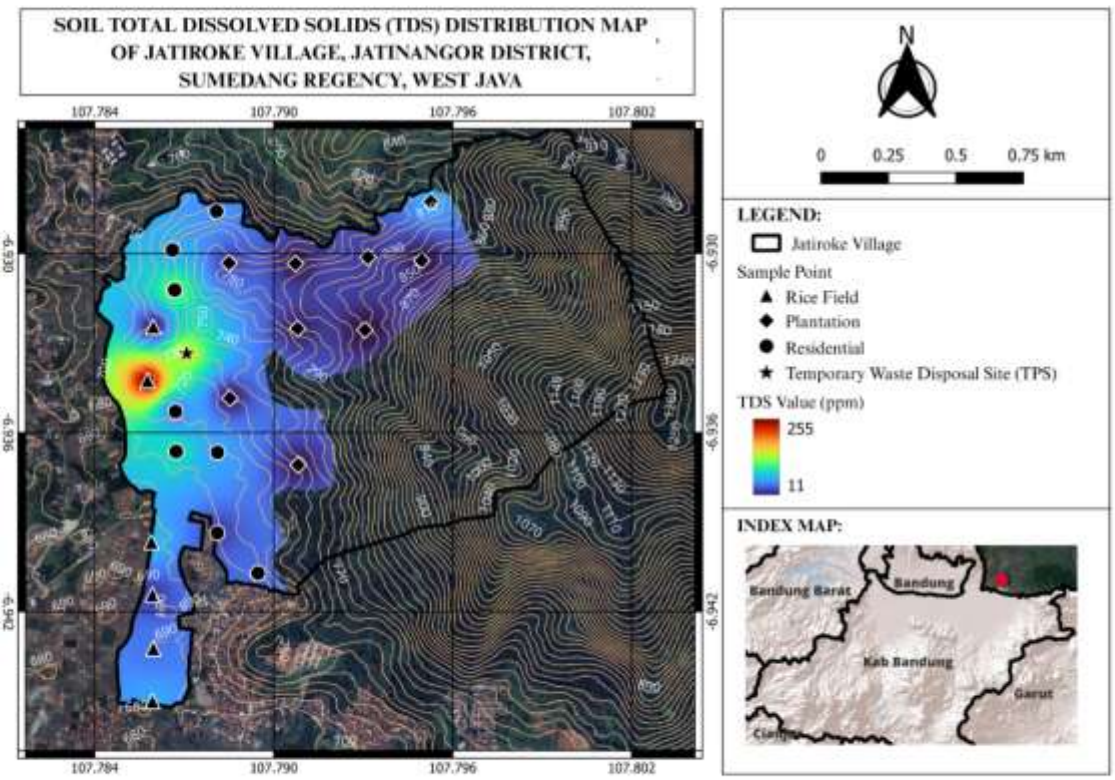

Figure 6. Soil TDS distribution map of Jatiroke Village

Figure 6 illustrates the spatial distribution of soil Total Dissolved Solids (TDS) measurements in Jatiroke Village, where values range from 11 ppm to 255 ppm, with an average of 55.42 ppm and a standard deviation of 55.33 ppm. The maximum value of 255 ppm was recorded in the western rice field area (F3), while the minimum value of 11 ppm appeared across most land use types. The TPS (temporary disposal site) showed the second-highest TDS concentration at 144 ppm. TDS is an important parameter for evaluating groundwater quality because elevated concentrations may indicate contamination from fertilizers, pesticides, wastewater, or leachate from waste sources (Al-Gburi et al., 2024). However, based on the Indonesian Minister of Health Regulation (2017), which sets the maximum permissible TDS limit in water at 1000 ppm, and the (World Health Organization, 2011), which considers groundwater with TDS levels below 500 ppm as generally acceptable for consumption and agricultural use, all values recorded in Jatiroke Village remain within a relatively safe range.

As the amount of dissolved solids increases, the ion concentration in the solution also increases, leading to higher EC values (Arlindia & Afdal, 2024). In other words, EC is also an indirect measurement of TDS (Rusydi, 2017). This is consistent with the results observed, where both the maximum and minimum values of TDS and EC occur in the same areas. High TDS and EC values in the western rice fields (F3 area) and the TPS area are assumed to be caused by anthropogenic activities, such as intensive use of fertilizers and pesticides or improper waste disposal. On the other hand, the low EC and TDS values found across most of the village are likely due to sandy soil textures or high porosity, allowing water carrying salts or dissolved substances to infiltrate easily without remaining in the topsoil. As a result, soil solution concentrations remain low despite external inputs.

Multivariate Analysis

Multivariate analysis is a statistical approach that evaluates relationships among multiple variables simultaneously to uncover shared patterns, group separation, and key determinants; one such method is Principal Component Analysis (PCA). The Principal Component Analysis (PCA) provides an overview of the multivariate structure of the measured soil physicochemical parameters across land uses. Dimension 1 (PC1) explains 49.9% of the total variance and is primarily influenced by EC and TDS, while Dimension 2 (PC2), accounting for 25.6%, reflects contributions from pH and temperature (Figure 7). Although PC1 alone accounts for less than half of the total variance, it represents the strongest axis of differentiation among samples. The vectors of EC and TDS are long and aligned, confirming their strong positive correlation and dominant role in soil differentiation. By contrast, pH and temperature show shorter vectors and contribute more modestly along Dimension 2, highlighting the multivariate nature of soil differentiation (Malik & Ubaidillah, 2021). Together, PC1 and PC2 capture 75.5% of the total variance, indicating that differentiation is shaped by multiple complementary factors.

The grouping patterns reveal that rice field soils (red cluster) are more strongly associated with EC/TDS, plantation soils (green cluster) show relatively greater alignment with Dimension 2 variables (pH and temperature), residential soils (blue cluster) cluster near the center, reflecting more homogeneous conditions, and TPS samples (purple cluster) display moderate association with EC and TDS, but their contribution along Dimension 2 is limited, as indicated by the shorter vectors of pH and temperature in the PCA biplot (Figure 7). Therefore, while PC2 contributes to overall multivariate differentiation, the TPS samples are primarily differentiated along the PC1 axis, consistent with the measured correlations.

The strong association between EC and TDS, also reflected in the correlation matrix ($r = 0.97$) on Figure 8, reinforces their role as primary drivers of soil differentiation across land uses (Arlindia & Afdal, 2024; Rusydi, 2017). By contrast, pH and temperature show weak correlations (< 0.13), consistent with their limited but spatially relevant influence in PCA. Correlation analysis shows a moderate negative correlation between pH and EC ($r = 0.13$) and between pH and TDS ($r = 0.06$), indicating that increased salinity is associated with a decrease in soil pH in some types of land use, such as rice fields and plantations. Overall, this emphasizes EC and TDS as dominant differentiating factors, while pH and temperature act as secondary modifiers—an interpretation supported by recent studies highlighting the effectiveness of PCA for soil multivariate analysis (Kaur & Godara, 2025).

As noted in the methodological framework, PCA requires continuous numerical variables; therefore, soil color and texture were not included in the multivariate model. This exclusion is consistent with standard practices in soil science, where categorical descriptors such as color and texture are analyzed descriptively rather than statistically integrated into PCA. Assigning arbitrary numerical codes would risk misrepresenting the relationships between categories (Pratama et al., 2020). In line with previous national studies by Neswati et al. (2019) and Suryani et al. (2022), soil color and texture in this study were thus discussed descriptively, complementing the PCA findings on EC, TDS, pH, and temperature. This approach ensures statistical validity of the PCA while still acknowledging the broader role of non-numerical soil properties in understanding land use impacts.

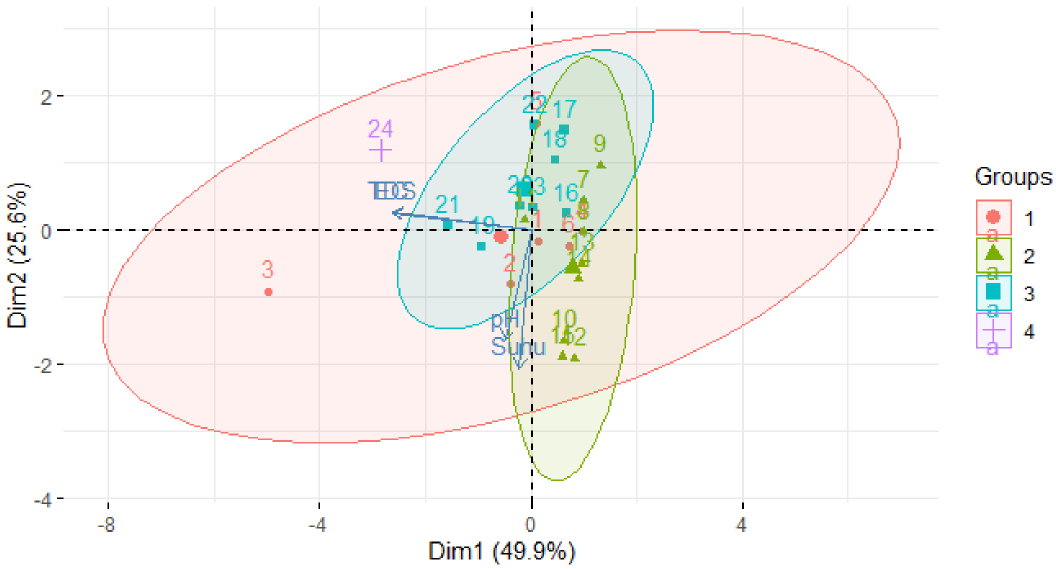

Figure 7. Principal component analysis of the measured parameters (pH, EC, TDS, temperature)

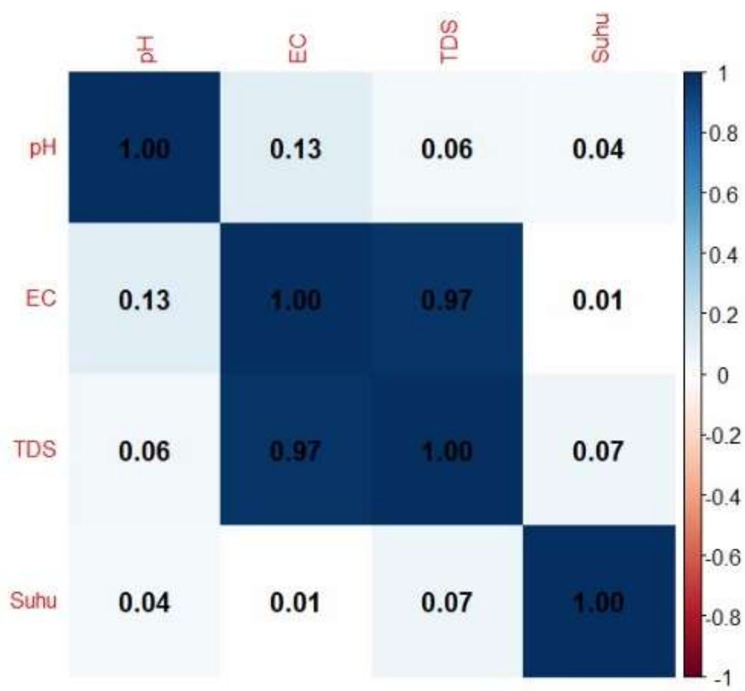

Figure 8. Correlation coefficient between soil parameters. The blue scale indicates positive correlations, while the red scale indicates negative correlations

Conclusion

This study demonstrates that land use strongly shapes soil physicochemical conditions in Jatiroke Village. Rice fields and the temporary waste disposal site (TPS) area exert the greatest influence through elevated salinity and altered soil chemistry, while residential zones remain the most stable and plantations show intermediate effects. Although soil color and texture varied across land uses, they were not the main differentiators, confirming that physicochemical parameters, particularly electrical conductivity (EC) and total dissolved solids (TDS), provide a stronger basis for distinguishing soil conditions. Principal Component Analysis (PCA) highlights EC and TDS as the dominant factors driving soil variability, with pH and temperature contributing secondary variations. These findings confirm the research objective by identifying key parameters differentiating soils across land uses and demonstrating that multivariate analysis offers clearer insights than descriptive characterization alone. Recommendations for future research include prioritizing EC and TDS monitoring as early indicators of soil degradation, particularly in rice fields and waste-affected areas, while also incorporating seasonal monitoring, expanding spatial coverage, and adding parameters such as heavy metals or organic matter to strengthen land management strategies and policy development.

Acknowledgments
The authors are grateful to the local government and community of Jatiroke Village for granting access and support during fieldwork.

Author Contributions
Conceptualization, writing—review and editing, N.K.K., K.H.K., D.F., and E.A.; methodology, investigation, N.K.K., N.P.N.A., H.A.H., S.S., and D.H.S.; software, visualization, H.A.H.; validation, K.H.K.; formal analysis, resources, data curation, writing—original draft preparation, project administration, N.K.K.; supervision, K.H.K., D.F., and E.A. All authors have read and agreed to the published version of the manuscript.

Funding
This research was funded by Ministry of Higher Education, Science, and Technology through Fundamental Research - Regular (PFR) with contract number 1595/UN6.3.1/PT.00/2025.

Conflicts of Interest
The authors declare no conflict of interest.

References

Abdullah, U. H., Salima, R., Mulyanti, M., Mukhlis, M., & Sufardi, S. (2024). Soil Quality Index Analysis of Pine Forest Land Use Types on Dryland in Aceh Besar Regency. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 2971–2977. https://doi.org/10.29303/jppipa.v10i6.7228

Agustine, E., Rosdiyanti, T., Fitriani, D., Kirana, K. H., Nurbaity, A., Solihin, M. A., Noviyanti, A. R., Susilawati, A., Hasanah, M., Putri, U. A., Nurfaradila, F., Fajar, S. J., & Srigutomo, W. (2025). Identification of Electrical Conductivity of The Volcanic Soil on Fertilizer-Exposed Agricultural Field (Case Study on Agricultural Field Parompong, West Java). *Malaysian Journal of Applied Sciences*, *10*(1), 22–28. https://doi.org/10.37231/myjas.2025.10.1.437

Al-Gburi, H. F., Al-Ali, I. A., Dar, F. A., & Al-Sheikh, O. N. (2024). Groundwater Quality Assessment and Pollution Sources Identification Using Statistical Analyses at Missan Governorate, Southeast Iraq. *Discover Sustainability*, *5*(1), 2–14. https://doi.org/10.1007/s43621-024-00578-8

Alghamdi, A. G., Majrashi, M. A., & Ibrahim, H. M. (2023). Improving the Physical Properties and Water Retention of Sandy Soils by the Synergistic Utilization of Natural Clay Deposits and Wheat Straw. *Sustainability*, *16*(1), 1–5. https://doi.org/10.3390/su16010046

Ansyar, M., & Herdiana, H. (2023). Analysis of the Factors Causing a Decline in Soil Quality and Their Solutions as an Effort to Increase Agricultural Productivity in Dry Areas. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 3875–3882. https://doi.org/10.29303/jppipa.v9i5.3226

Arlindia, I., & Afdal, A. (2024). Analisis Pencemaran Danau Maninjau dari Nilai TDS dan Konduktivitas Listrik. *Jurnal Fisika Unand*, *4*(4). https://doi.org/10.25077/jfu.4.4.%p.2015

Ayiti, O. E., & Babalola, O. O. (2022). Factors Influencing Soil Nitrification Process and the Effect on Environment and Health. *Frontiers in Sustainable Food Systems*, *6*, 1–8. https://doi.org/10.3389/fsufs.2022.821994

Candra, B. W. I. U. L. (2019). Studi Sifat Fisika Tanah pada Beberapa Tipe Luapan Lahan Pasang Surut di Kecamatan Sabawi Kabupaten Sambas. *Jurnal Sains Pertanian Equator*, *8*(2). https://doi.org/10.26418/jspe.v8i4.35586

Cleophas, F., Isidore, F., Musta, B., Ali, B. N. M., Mahali, M., Zahari, N. Z., & Bidin, K. (2022). Effect of Soil Physical Properties on Soil Infiltration Rates. *Journal of Physics: Conference Series*, *2314*(1), 1–5. https://doi.org/10.1088/1742-6596/2314/1/012020

Devkota, K. P., Devkota, M., Rezaei, M., & Oosterbaan, R. (2022). Managing Salinity for Sustainable Agricultural Production in Salt-Affected Soils of Irrigated Drylands. *Agricultural Systems*, *198*, 3–10. https://doi.org/10.1016/j.agsy.2022.103390

Eddiwan, K., & Hendrizal, A. (2024). The Effect of Soil Environmental Parameters on Mangrove Tree Growth in Lingga District. *Jurnal Penelitian Pendidikan IPA*, *10*(12), 10403–10409. https://doi.org/10.29303/jppipa.v10i12.9313

Firdous, S., Begum, S., & Yasmin, A. (2016). Assessment of Soil Quality Parameters Using Multivariate Analysis in the Rawal Lake Watershed. *Environmental Monitoring and Assessment*, *188*(9), 3–10. https://doi.org/10.1007/s10661-016-5527-5

Frattini, N., Carrasquero, A. P., Pronsato, L., Milanesi, L., & Vasconsuelo, A. (2023). Effects of Common Fertilizers on the Soil Ecosystem. *Bulletin of the National Research Centre*, *47*(1), 1–7. https://doi.org/10.1186/s42269-023-01051-8

Guo, L., Tóth, T., Yang, F., & Wang, Z. (2023). Effects of Different Types of Vegetation Cover on Soil Microorganisms and Humus Characteristics of Soda-Saline Land in the Songnen Plain. *Frontiers in Microbiology*, *14*, 2–9. https://doi.org/10.3389/fmicb.2023.1163444

Hanifah, S. D., Hendrayani, R., Carrisa, R., Rizki, M. I., Rohman, M. A., Hutabalian, M. A., Rahman, J. S., Sihombing, F. R., Ramadhan, F., Ramadan, A. Z., Nugraha, A., Kirana, K. H., & Fitriani, D. (2024). Mapping of pH, EC, and TDS Parameters to Identify Water Quality in Situ Cisanti. *Jurnal Phi Jurnal Pendidikan Fisika dan Fisika Terapan*, *10*(1), 91–97. https://doi.org/10.22373/p-jpft.v10i1.22175

Hanna Instruments. (2018). *Instruction manual HI9813-5 and HI9813-6 portable pH/EC/TDS/°C meters*. Retrieved from https://www.forestry-suppliers.com/Documents/2202_msds.pdf?srsltid=AfmBOoqLQGqXN4uZ4nKlENyr9UkqsW0ohzUMALtaU5vP9XSNHzKU3BsX

International Atomic Energy Agency. (2004). *Soil Sampling for Environmental Contaminants, Industrial Applications and Chemistry*. IAEA-TECDOC-1415

Jolliffe, I. T., & Cadima, J. (2016). Principal Component Analysis: A Review and Recent Developments. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *374*(2065), 2–14. https://doi.org/10.1098/rsta.2015.0202

Kaur, L., & Godara, P. (2025). Application of Principal Component Analysis (PCA) in Groundwater Quality Evaluation: A Case Study of Arid Region. *Energy & Environment Management*, *1*(2), 1–12. https://doi.org/10.63333/eem.v1n21

Khaled, F., & Sayed, A. (2023). Soil pH and Its Influence on Nutrient Availability and Plant Health. *International Journal of Advanced Chemistry Research*, *5*(2), 68–70. https://doi.org/10.33545/26646781.2023.v5.i2a.204

Kirana, K. H., Shalsabila, M. T., Putri, S. U., Fitriani, D., Agustine, E., Hamdan, A. M., Tamuntuan, G. H., Rosandi, Y., & Chaparro, M. A. E. (2024). Topsoil's Magnetic and Electrical Properties in a Volcanic and Tropical Region. *Environmental Monitoring and Assessment*, *196*(2), 4–5. https://doi.org/10.1007/s10661-024-12332-8

Latupeirissa, A. N., & Latupeirissa, J. (2022). Analysis of Physical and Chemical Quality of PDAM Water in Teluk Ambon Baguala Sub-District. *Jurnal Penelitian Pendidikan IPA*, *8*(3), 1314–1319. https://doi.org/10.29303/jppipa.v8i3.1535

Li, X., & Vereecken, H. (Eds.). (2018). *Observation and Measurement*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-47871-4

Lozano-Parra, J., Pulido, M., Lozano-Fondón, C., & Schnabel, S. (2018). How Do Soil Moisture and Vegetation Covers Influence Soil Temperature in Drylands of Mediterranean Regions? *Water*, *10*(12), 2–14. https://doi.org/10.3390/w10121747

Mahardika, I. K., Bektiarso, S., Santoso, R. A., Novit, A., Saiylendra, R. B., & Dewi, R. K. (2023). Analisis Peran Suhu pada Pertumbuhan dan Perkembangan Tanaman Stroberi. *PHYDAGOGIC: Jurnal Fisika dan Pembelajarannya*, *5*(2), 86–91. https://doi.org/10.31605/phy.v5i2.2197

Malik, A., & Ubaidillah, M. (2021). Multiple Skill Laboratory Activities: How to Improve Students' Scientific Communication and Collaboration Skills. *Jurnal Pendidikan IPA Indonesia*, *10*(4), 585–595. https://doi.org/10.15294/jpii.v10i4.31442

Mansyur, N. I., Antonius, A., & Titing, D. (2023). Karakteristik Fisika Tanah pada Beberapa Lahan Budidaya Tanaman Hortikultura Lahan Marginal. *Jurnal Ilmiah Respati*, *14*(2), 190–200. https://doi.org/10.52643/jir.v14i2.3779

Mulyati, M., Sania, A. L., Priyono, J., Baharuddin, A. B., & Tejowulani, R. S. (2022). Use of Soil Ameliorant and Inorganic Fertilizer to Increase Soil Fertility Phosphorous Concentrations in Plant Tissue, Growth and Yield of Shallot in Dry Land. *Jurnal Penelitian Pendidikan IPA*, *8*(SpecialIssue), 22–29. https://doi.org/10.29303/jppipa.v8iSpecialIssue.2498

Murnita, M., Desi, Y., & Meriati, M. (2024). Changes in Soil Chemical Properties and Growth of Palm Oil (Elaeis guineensis Jacq) with Comparative Composition of Plant Media. *Jurnal Penelitian Pendidikan IPA*, *10*(4), 1633–1639. https://doi.org/10.29303/jppipa.v10i4.7161

Mutlag, N. H., & Hatimi, I. A. R. A. (2022). Evaluation of Some of Chemical and Physical Properties and Some Nutrients in the Soils and Water of Bahr Al-Najaf Depression-Iraq. *International Journal of Health Sciences*, 5533–5547. https://doi.org/10.53730/ijhs.v6nS4.9387

Nasution, Y., & Fitria, F. (2023). Changes of Soil Density and Water Content at the Treatment of Compost Media and Husk Charcoal on Lettuce Plants in the Land Degradation. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4353–4360. https://doi.org/10.29303/jppipa.v9i6.3571

Naveen, B. P., Mahapatra, D. M., Sitharam, T. G., Sivapullaiah, P. V., & Ramachandra, T. V. (2017). Physico-Chemical and Biological Characterization of Urban Municipal Landfill Leachate. *Environmental Pollution*, *220*, 1–12. https://doi.org/10.1016/j.envpol.2016.09.002

Neswati, R., Lopulisa, C., & Adzima, A. F. (2019). Characterization and Classification of Soils from Different Topographic Positions under Sugarcane Plantation in South Sulawesi, Indonesia. *Journal of Tropical Soils*, *24*(2), 93–100. https://doi.org/10.5400/jts.2019.v24i2.93-100

Nisak, F. H., Royoga, P. R., Mahendra, M., Permitasari, I., Mandarani, S., & Sari, N. (2023). Penentuan Tekstur Tanah di Kawasan Hutan dengan Tujuan Khusus (KHDTK) Kemampo Kabupaten Banyuasin Provinsi Sumatera Selatan. *Prosiding Seminar Nasional Biologi*, *3*(2), 207–214. https://doi.org/10.24036/prosemnasbio/vol3/718

Nordgaard, A., & Correll, R. (2018). Sampling Strategies. In *Integrated Analytical Approaches for Pesticide Management* (pp. 31–46). Elsevier. https://doi.org/10.1016/B978-0-12-816155-5.00003-8

Noriko, N., Agustono, R., Wijihastuti, R. S., Novani, E., Choirunnisa, N. I., & Pambudi, A. (2024). Soil Conservation in Brassica rapa chinensis L (Pakcoy) Growth. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2621–2631. https://doi.org/10.29303/jppipa.v10i5.6989

Onoyima, C. C., & Okibe, F. G. (2021). Multivariate Analysis of the Physico-Chemical Properties of Soils in Selected Locations of the Floodplain of River Kaduna in Niger State, Nigeria. *Global Journal of Pure and Applied Sciences*, *27*(3), 279–288. https://doi.org/10.4314/gjpas.v27i3.3

Padusung, P., Mahrup, M., Kusnarta, I. G. M., & Fahrudin, F. (2018). P Soil Temperature Response of Exposure to Winter of Australia and Impact on Legume Plant in Soil of Vertisol Lombok. *Crop Agro, Scientific Journal of Agronomy*, *11*(2), 127–136. https://doi.org/10.29303/caj.v11i2.202

Pratama, M. A., Immanuel, Y. D., & Marthanty, D. R. (2020). A Multivariate and Spatiotemporal Analysis of Water Quality in Code River, Indonesia. *The Scientific World Journal*, *2020*, 1–11. https://doi.org/10.1155/2020/8897029

Przydatek, G., Ciuła, J., Barsan, N., Mirila, D., & Mosnegutu, E. (2025). Groundwater Quality Analysis: Assessing the Impact of a Closed Landfill—A Case Study on Physico-Chemical and Microplastic Contaminants. *Applied Sciences*, *15*(15), 1–14. https://doi.org/10.3390/app15158223

Putri, B. A., Putri, A. S. N., Prameswary, C. A., Ekklesia, E., Donita, F. T., Rahmawati, N., Agustine, E., & Susilawati, A. (2024). Identification of Pesticide-Saturated Soil Using Near-Surface Geophysics Method. *Jurnal Phi Jurnal Pendidikan Fisika dan Fisika Terapan*, *10*(1), 28–34. https://doi.org/10.22373/p-jpft.v10i1.22364

Rashid, S. W., Shwan, D. M. S., & Rashid, K. A. (2022). Physicochemical Characterization and Evaluation of Seasonal Variations of Landfill Leachate and Groundwater Quality around Tanjaro Open Dump Area of Sulaymaniyah City, Kurdistan, Iraq. *Journal of Chemistry*, *2022*, 1–12. https://doi.org/10.1155/2022/8574935

Rossel, R. A. V., Behrens, T., Ben-Dor, E., Brown, D. J., Demattê, J. A. M., Shepherd, K. D., Shi, Z., Stenberg, B., Stevens, A., Adamchuk, V., Aïchi, H., Barthès, B. G., Bartholomeus, H. M., Bayer, A. D., Bernoux, M., Böttcher, K., Brodský, L., Du, C. W., Chappell, A., …, & Ji, W. (2016). A Global Spectral Library to Characterize the World's Soil. *Earth-Science Reviews*, *155*, 198–230. https://doi.org/10.1016/j.earscirev.2016.01.012

Rusydi, A. F. (2017). Correlation between Conductivity and Total Dissolved Solid in Various Type of Water: A Review. *IOP Conference Series: Earth and Environmental Science*, *118*, 1–6. https://doi.org/10.1088/1755-1315/118/1/012019

Sanny, T. A., Asrib, M. L., & Insani, A. Z. M. (2023). Karakterisasi Tanah Menggunakan Pendekatan Electrical Resistivity Tomography (ERT) pada Lahan Non Tipikal Ipomoea Batatas "Cilembu." *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6128–6135. https://doi.org/10.29303/jppipa.v9i8.4653

Shokri, N., Hassani, A., & Sahimi, M. (2024). Multi-Scale Soil Salinization Dynamics From Global to Pore Scale: A Review. *Reviews of Geophysics*, *62*(4), 1–6. https://doi.org/10.1029/2023RG000804

Sirisathitkul, Y., & Sirisathitkul, C. (2025). Decoding Soil Color: Origins, Influences, and Methods of Analysis. *AgriEngineering*, *7*(3), 1–16. https://doi.org/10.3390/agriengineering7030058

Solekhah, B. A., Priyadarshini, R., & Maroeto, M. (2024). Kajian Pola Distribusi Tekstur Terhadap Bahan Organik pada Berbagai Penggunaan Lahan. *Agro Bali: Agricultural Journal*, *7*(1), 256–265. https://doi.org/10.37637/ab.v7i1.1571

Suciati, S. T., Zurhalena, Z., & Fuadi, N. A. (2025). Studi Beberapa Sifat Fisik Tanah Akibat Alih Fungsi Lahan Sawah Pasang Surut di Desa Karya Bhakti Kabupaten Tanjung Jabung Timur. *Jurnal Agroecotania: Publikasi Nasional Ilmu Budidaya Pertanian*, *8*(1). https://doi.org/10.22437/agroecotania.v8i1.45711

Suleman, S., Rajamuddin, U., & Isrun, I. (2016). Penilaian Kualitas Tanah pada Beberapa Tipe Penggunaan Lahan di Kecamatan Sigi Biromaru Kabupaten Sigi. *AGROTEKBIS: Jurnal Ilmu Pertanian (e-Journal)*, *4*(6), 712-718. Retrieved from http://jurnal.faperta.untad.ac.id/index.php/agrotekbis/article/view/80

Sumiahadi, A. (2019). Forage Crops in Acid Soils of Indonesia. *Proceedings of the International Symposium for Environmental Science and Engineering Research (ISESER)*, 529–536. Retrieved from https://www.academia.edu/40925472/FORAGE_CROPS_IN_ACID_SOILS_OF_INDONESIA

Suryani, S., Astuti, J., & Muchlisah, N. (2022). Kajian Sifat Fisika Kimia Tanah Inceptisol di Berbagai Kelerengan dan Kedalaman Tanah pada Areal Pertanaman Kakao. *Jurnal Galung Tropika*, *11*(3), 275–282. https://doi.org/10.31850/jgt.v11i3.1014

Tang, M., Li, W., Gao, X., Wu, P., Li, H., Ling, Q., & Zhang, C. (2022). Land Use Affects the Response of Soil Moisture and Soil Temperature to Environmental Factors in the Loess Hilly Region of China. *PeerJ*, *10*, 1–14. https://doi.org/10.7717/peerj.13736

Thompson, S. K. (2012). *Sampling* (Vol. 755). John Wiley & Sons.

Tian, X., Zhang, X., Yang, G., Wang, Y., Liu, Q., & Song, J. (2024). Effects of Microbial Fertilizer Application on Soil Ecology in Saline–Alkali Fields. *Agronomy*, *15*(1), 1–17. https://doi.org/10.3390/agronomy15010014

World Health Organization. (2011). *Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum*. WHO.

Yang, J., Wang, T., Que, S., Li, Z., Liang, Y., Wei, Y., Li, N., & Xu, Z. (2024). Effect of Colour Calibration on the Prediction of Soil Organic Matter Content Based on Original Soil Images Obtained from Smartphones under Different Lighting Conditions. *Soil and Tillage Research*, *238*, 106018. https://doi.org/10.1016/j.still.2024.106018

Ye, C., Zheng, G., Tao, Y., Xu, Y., Chu, G., Xu, C., Chen, S., Liu, Y., Zhang, X., & Wang, D. (2024). Effect of Soil Texture on Soil Nutrient Status and Rice Nutrient Absorption in Paddy Soils. *Agronomy*, *14*(6), 1–17. https://doi.org/10.3390/agronomy14061339

Yondra, Y., & Wawan, N. (2017). Chemical Properties Studys of Peatlandon Various Landuse. *Agric*, *29*(2), 103–112. https://doi.org/10.24246/agric.2017.v29.i2.p103-112

Yudanegara, R. A., Astutik, D., Hernandi, A., Soedarmodjo, T. P., & Alexander, E. (2021). Penggunaan Metode Inverse Distance Weighted (IDW) untuk Pemetaan Zona Nilai Tanah (Studi Kasus: Kelurahan Gedong Meneng, Bandar Lampung). *Elipsoida : Jurnal Geodesi dan Geomatika*, *4*(2), 85–90. https://doi.org/10.14710/elipsoida.2021.12534

Zalwa, C. A., Bukhori, D., Pratama, F. P., Nasution, A. R., Ginting, J. I., & Pastika, M. A. (2025). Analisis Penetapan Tekstur Tanah dengan Metode Hidrometer pada Tanah di Kecamatan Galang. *PUCUK: Jurnal Ilmu Tanaman*, *5*(1), 1-4. https://doi.org/10.58222/pucuk.v5i1.433

Zaman, B., Sarminingsih, A., & Pratiwi, L. C. (2023). Review of Potential Biochar Utilization on Soil Quality in Agricultural Environments. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 172–183. https://doi.org/10.29303/jppipa.v9iSpecialIssue.6201

Zaman, M., Shahid, S. A., & Heng, L. (2018). *Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques*. Springer International Publishing. https://doi.org/10.1007/978-3-319-96190-3

Zuhdy, A., & Tjhen, W. (2024). Design of Arboretum and Ecotourism Complex on Kahatex Green Open Space in Jatiroke Village. *IOP Conference Series: Earth and Environmental Science*, *1315*(1), 1–9. https://doi.org/10.1088/1755-1315/1315/1/012048