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Soil Fertility Characteristics Along A Chronosequence Of Paddy Field Development In East Kolaka, Indonesia

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Abstract

Sustainable rice production in tropical wetland systems depends heavily on maintaining adequate soil chemical fertility, making periodic evaluation of paddy field soils essential for identifying nutrient status and formulating appropriate fertilization recommendations. This study aimed to assess soil fertility levels and determine fertilization recommendations for paddy fields in Andowengga Village, Poli-Polia District, East Kolaka Regency, Southeast Sulawesi Province. Conducted in December 2025, the research used a purposive sampling survey method comparing new paddy fields (SB) and old paddy fields (SL). Five sampling points were established in each field type following a diagonal system, with soil collected in triplicate per point, yielding thirty subsamples composited for laboratory analysis of organic carbon (organic C), total phosphorus (P-total), total potassium (total K), cation exchange capacity (CEC), and base saturation (BS). Results showed organic C in SB was low (1.68–1.77%), while SL was predominantly medium (1.90–2.44%). P-total at all points was medium (26.96–34.76 mg/100g), K-total in SB was low (15.50–16.75 mg/100g), while SL was mostly medium (33.69–34.70 mg/100g), except SL.T2 was low (17.30 mg/100g). CEC in SB was medium (17.47–21.74 cmol(+)/kg), while SL was mostly high (27.03–34.21 cmol(+)/kg), except SL.T2, which was low (15.24 cmol(+)/kg). BS was predominantly low at most points, except SB.T3, SL.T2, and SL.T4, which were medium. Overall, soil fertility at the study site is categorized as low, indicating a need for balanced fertilization, particularly potassium and organic matter, to sustain paddy soil productivity.

Keywords: chronosequence; new rice field; old rice field; paddy field; soil fertility

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INTRODUCTION

Paddy soil is a strategic natural resource in supporting national food security, particularly as the primary growing medium for rice (*Oryza sativa* L.), the staple food commodity of the Indonesian population. Rice productivity is strongly influenced by the level of soil fertility, encompassing physical, chemical, and biological soil properties (Maro'ah et al., 2021). Periodic evaluation of soil fertility in paddy fields is necessary to identify nutrient status and to formulate appropriate fertilization recommendations, since a deficiency in even a single fertility parameter can act as a limiting factor for land productivity even when other parameters remain at an optimal level (Suleman et al., 2026).

Differences in the intensity and duration of paddy field management can significantly affect soil fertility status (Pan et al., 2024). Old paddy fields, which have undergone repeated cultivation and flooding over a long period, generally exhibit different nutrient dynamics compared to new paddy fields that have recently been opened or converted from dryland (Cai et al., 2025). Hermansyah et al., (2024) reported that cation exchange capacity (CEC) and organic carbon are the primary limiting factors of soil fertility in paddy fields undergoing land-use changes, with fertility status ranging from very low to medium depending on land-use history. The expansion of new paddy field areas is also one of the strategies continuously promoted to increase rice production in various regions, including Southeast Sulawesi Province, making the comparison of fertility status between old and new paddy fields important to examine in order to understand patterns of nutrient change over the course of land management.

Poli-Polia District, East Kolaka Regency, Southeast Sulawesi Province, is one of the areas contributing substantially to rice production in the province, with East Kolaka Regency recorded as the second-largest rice-producing regency in Southeast Sulawesi in 2024, supported partly by the expansion of planting areas and the opening of new land. However, scientific studies on the chemical fertility status of paddy soils in Southeast Sulawesi remain relatively limited and have largely focused on other areas such as South Konawe (Sumanta et al., 2023), Konawe Islands (Febriyansyah et al., 2024), and North Buton (Azza et al., 2025), so baseline data on paddy soil fertility specifically in Andowengga Village, Poli-Polia District, East Kolaka Regency, still needs to be established.

Soil fertility evaluation in this study focused on five key chemical parameters: organic carbon (organic-C), total phosphorus (total-P), total potassium (total-K), cation exchange capacity (CEC), and base saturation (BS), which are consistently used as standard indicators in various soil fertility evaluation studies of paddy fields across Indonesia, including in regions with comparable agroecosystem characteristics (Fang et al., 2026). These five parameters are

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interrelated in determining the soil's capacity to supply and retain nutrients for plants, making a comprehensive evaluation of soil chemical properties essential for formulating nutrient management strategies suited to actual field conditions (Wibowo & Kasno, 2021).

The comparison of soil chemical properties between paddy fields of different cultivation ages can be conceptually framed within a chronosequence approach, in which soils sharing similar parent material and climatic setting but differing in time since a specific pedogenic event in this case, the onset of paddy cultivation are treated as space for time substitutes to infer temporal trends in soil development (Pan et al., 2024). This approach has been widely applied to elucidate how prolonged rice cultivation and repeated flooding alter soil organic matter, nutrient stocks, and cation exchange properties over time, from decadal to centennial scales. In the present study, the contrast between new paddy fields and old paddy fields represents a localized, twopoint chronosequence of paddy field development, offering a practical basis for inferring how soil chemical fertility evolves as paddy fields transition from recently opened land to long-established wetland-rice systems under comparable agroecological conditions in Andowengga Village.

Based on the above, this study aims to evaluate the level of soil fertility in old and new paddy fields in Andowengga Village, Poli-Polia District, East Kolaka Regency, and to formulate appropriate fertilization recommendations for maintaining and improving soil fertility in both field types. The results of this study are expected to complement baseline soil fertility data for Southeast Sulawesi and provide useful scientific information for farmers and stakeholders in the sustainable management of paddy fields.

METHOD

Study Area and Time

This study was conducted from October to December 2025, on paddy fields located in Andowengga Village, Poli-Polia District, East Kolaka Regency, Southeast Sulawesi Province. Soil chemical analysis was carried out at the Soil Science Laboratory, Faculty of Agriculture, Halu Oleo University Kendari.

Materials and Equipment

The primary data source used in this study was a working map of the study area. The equipment used included a Global Positioning System (GPS) unit for determining sampling-point coordinates, a hoe and a field knife for soil excavation, a digital camera for field documentation, and standard stationery for recording field observations.

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Sampling Method

This study employed a free survey method with a purposive sampling technique, in which sampling locations were deliberately selected based on the length of time the paddy fields had been under cultivation (chronosequence), distinguishing between old paddy fields (SL) and new paddy fields (SB). Five sampling points were purposively established in each field type (SB and SL) following a diagonal sampling system. At each point, soil samples were collected in three replicates, yielding a total of thirty soil subsamples across both field types. The three replicate subsamples from each point were subsequently composited into a single representative sample per point, resulting in ten composite samples (five for SB and five for SL) submitted for laboratory analysis.

Laboratory Analysis

The composite soil samples were analyzed for five soil chemical fertility parameters: organic carbon (organic-C), total phosphorus (total-P), total potassium (total-K), cation exchange capacity (CEC), and base saturation (Sasongko et al., 2022). The analytical methods used for each parameter are presented in Table 1.

Table 1. Soil chemical parameters and analytical methods

Parameter	Unit	Extraction / Method
Organic-C	%	Walkley and Black (wet oxidation)
Total-P	mg/100 g	HCl 25% extraction
Total-K	mg/100 g	HCl 25% extraction
Cation Exchange Capacity (CEC)	cmol(+)/kg	1N NH_4OAc extraction, pH 7
Base Saturation	%	Basic Cations/CEC* 100%

Data Analysis

Laboratory results for each parameter were classified into fertility categories Low, Medium, and High, according to standard soil chemical property criteria (Balai Penelitian Tanah, 2023), consistent with the classification approach used in recent regional soil fertility evaluations. Data were analyzed descriptively, and the fertility status of the SB (new paddy field) and SL (old paddy field) groups was compared for each parameter to identify differences in nutrient status between the two field types and to formulate site-specific fertilization recommendations.

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RESULTS AND DISCUSSION

Soil Chemical Properties

Laboratory analysis of ten composite soil samples, collected from two paddy-field types (SB, n = 5, new paddy field; SL, n = 5, old paddy field) in Andowengga Village, Poli-Polia District, East Kolaka Regency, characterized five key fertility indicators: organic-C, total-P, total-K, CEC, and base saturation. Table 2 and Figures 1–2 summarize the results, with soil fertility classes (Low, Medium, High) assigned according to standard soil chemical property criteria.

Table 2. Chemical properties of paddy-field soils in Andowengga Village, Poli-Polia District, East Kolaka Regency

Unit	Organic-C (%)	Total-P (mg/100g)	Total-K (mg/100g)	CEC (cmol(+)/kg)	BS (%)
SB.T1	1.68 (L)	29.84 (M)	15.50 (L)	17.47 (M)	26.00 (L)
SB.T2	1.72 (L)	27.38 (M)	16.37 (L)	18.22 (M)	28.00 (L)
SB.T3	1.74 (L)	26.96 (M)	16.34 (L)	21.41 (M)	33.00 (M)
SB.T4	1.75 (L)	29.36 (M)	16.75 (L)	21.74 (M)	29.00 (L)
SB.T5	1.77 (L)	28.50 (M)	16.57 (L)	21.51 (M)	24.00 (L)
SL.T1	2.02 (M)	31.54 (M)	34.38 (M)	27.33 (H)	32.00 (L)
SL.T2	1.90 (L)	29.77 (M)	17.30 (L)	15.24 (L)	48.00 (M)
SL.T3	2.20 (M)	32.82 (M)	34.01 (M)	34.07 (H)	30.00 (L)
SL.T4	2.15 (M)	30.32 (M)	33.69 (M)	27.03 (H)	34.00 (M)
SL.T5	2.44 (M)	34.76 (M)	34.70 (M)	34.21 (H)	28.00 (L)

Note: L = Low; M = Medium; H = High; SB = new paddy field; SL = old paddy field unit.

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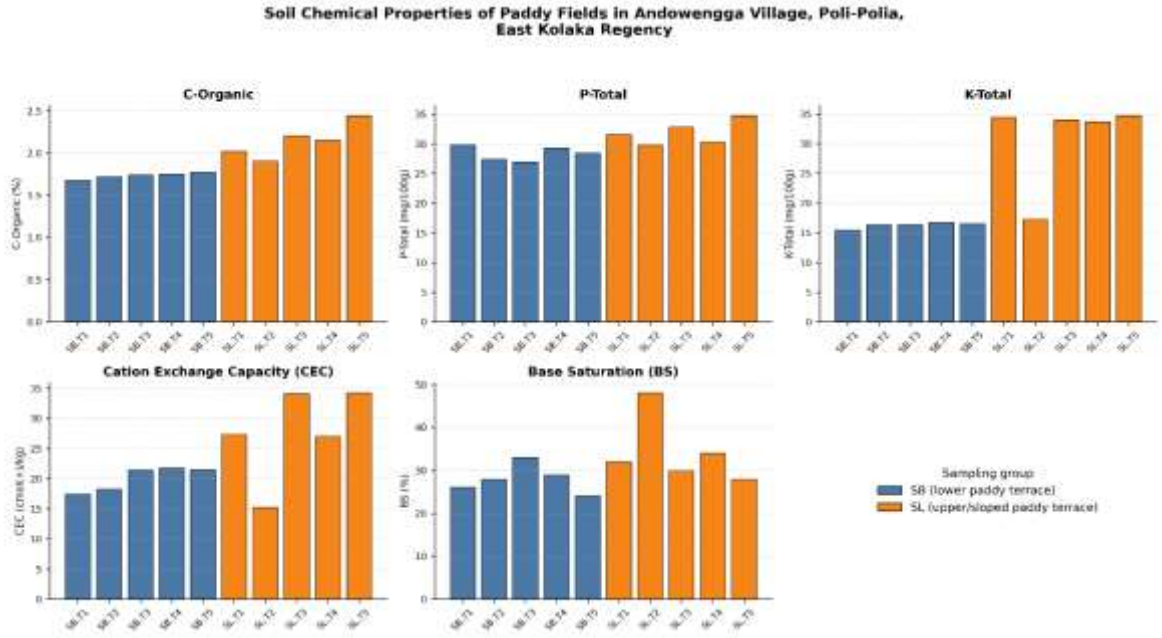


Figure 1. C-organic, P-total, K-total, CEC, and base saturation of individual sampling units (SB.T1–T5, SL.T1–T5), Andowengga Village, Poli-Polia District, East Kolaka Regency

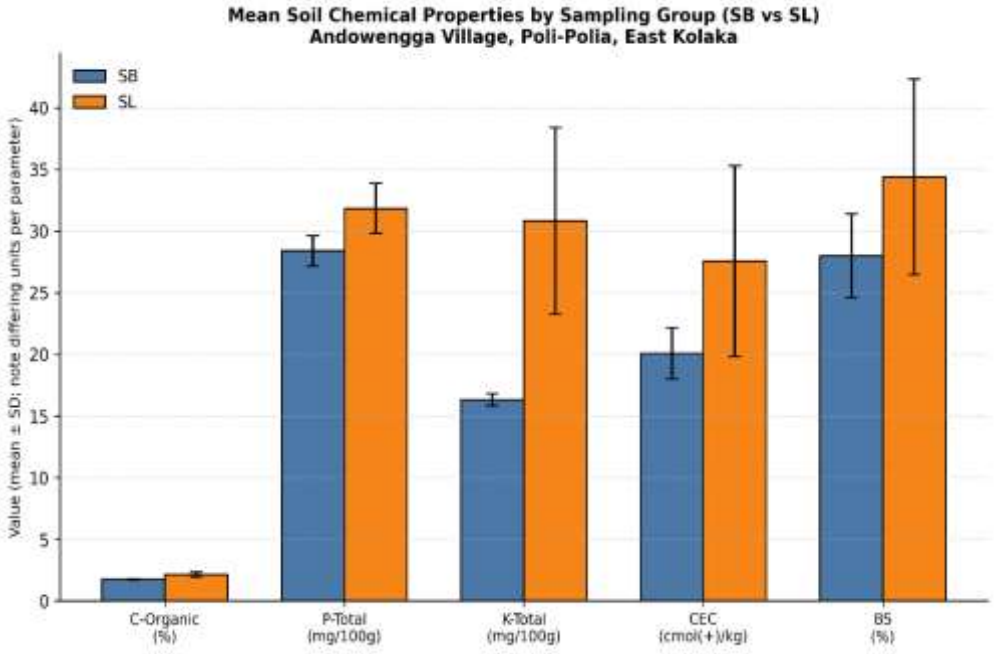


Figure 2. Mean (± SD) soil chemical properties compared between the SB (new paddy field) and SL (old paddy field) sampling groups.

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Organic Carbon and Macronutrient Status

Organic carbon content ranged from 1.68% to 2.44% across the ten sampling units, falling within the low-to-medium fertility class. Mean organic-C content was higher in the SL (old paddy field) group (2.14 ± 0.20%) than in the SB (new paddy field) group (1.73 ± 0.03%), with SL soils predominantly rated medium and SB soils uniformly rated low (Figure 1). This pattern suggests greater organic matter accumulation in long-cultivated SL fields, plausibly linked to prolonged organic residue incorporation and repeated flooding cycles, consistent with land-use history as a key determinant of soil organic matter status (Supriyadi et al., 2020).

Total phosphorus was rated medium at every sampling unit, ranging from 26.96 to 34.76 mg/100 g, with the SL group again showing a marginally higher mean (31.84 ± 2.01 mg/100 g) than the SB group (28.41 ± 1.24 mg/100 g). The uniformly medium total-P status across both field types indicates that phosphorus availability is not a major limiting factor at this site, although the values remain moderate rather than optimal for intensive rice cultivation (Hernández-jiménez et al., 2026).

Total potassium showed the most pronounced contrast between the two field types. SB soils were consistently rated low (15.50–16.75 mg/100 g; mean 16.31 ± 0.48 mg/100 g), whereas most SL soils were rated medium (mean 30.82 ± 7.57 mg/100 g), with the exception of unit SL.T2 (17.30 mg/100 g, low). The wide standard deviation within the SL group reflects this single low-lying outlier and points to spatial heterogeneity in potassium status even within the same field type, which may relate to localized differences in parent material or leaching (Hermiyanto et al., 2026).

Cation Exchange Capacity and Base Saturation

Cation exchange capacity (CEC) ranged from 15.24 to 34.21 cmol(+)/kg. All SB units were rated medium (17.47–21.74 cmol(+)/kg; mean 20.07 ± 2.05 cmol(+)/kg), while the SL group spanned a wider range from low to high, with three of five units (SL.T1, SL.T3, SL.T5) rated high (>27 cmol(+)/kg) and one (SL.T2) rated low (15.24 cmol(+)/kg). This variability suggests that clay mineralogy and/or organic matter content both major determinants of CEC differ more substantially within the SL (old paddy field) group than within the more homogeneous SB (new paddy field) group (Abshiba et al., 2025).

Base saturation (BS) was predominantly low (24.00–33.00%) across the SB units, while the SL units ranged from 28.00% to 48.00%, including two units rated medium (SL.T2 and SL.T4). The overall low-to-medium base saturation across the site indicates a moderate degree of base-cation depletion, consistent with the humid tropical setting and the intensive wetland-rice

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management typical of Southeast Sulawesi paddy systems (Mesele et al., 2026).

Comparison Between Old and New Paddy Fields

Taken together, the SL (old paddy field) units generally exhibited higher and more variable values than the SB (new paddy field) units for every parameter except C-organic variability, where SB was more uniform (Figure 2). This trend may be explained by the longer duration of organic matter incorporation, sediment deposition, and flooding-driven chemical transformations in the long-cultivated SL fields, though confirmation would require additional data on soil texture, drainage class, and fertilizer input history. The consistently low K-total in SB and low-to-medium BS across both field types point to potassium and base-cation management as priority targets for site-specific soil fertility improvement, for example through balanced potassium fertilization and organic amendment strategies suited to local rice-farming practices (Arunrat et al., 2020).

Interpreted within the chronosequence framework outlined earlier, the SB-to-SL contrast can be read as a proxy trajectory of soil chemical development along the timeline of paddy field establishment, rather than merely a categorical difference between two management groups. This interpretation is consistent with chronosequence-based studies elsewhere, which show that soil organic carbon, nutrient stocks, and cation exchange properties tend to increase progressively with cultivation duration before stabilizing once a pedogenic threshold specific to the local parent material and hydrological regime is reached (Pan et al., 2024). However, because the present dataset represents a two-point, space-for-time substitution rather than a true longitudinal record, the observed differences should be interpreted as indicative of a general developmental trend rather than a precise rate of change; the pronounced within-group variability at SL, particularly the anomalously low values at SL.T2, further illustrates that chronosequence-based inference can be confounded by localized site-specific factors that are not directly attributable to field age alone (Chen et al., 2011).

Overall, the results indicate that paddy-field soils in Andowengga Village are characterized by low organic carbon and potassium status in the new fields, medium phosphorus availability across both field types, and low-to-high but spatially variable CEC and base saturation, with the old paddy fields (SL) showing generally more favorable, but also more heterogeneous chemical fertility than the new paddy fields (SB). These findings are broadly consistent with regional studies showing that CEC and organic carbon are common limiting factors in paddy soils under varying land-use histories and that balanced fertilization directions specific to local conditions are needed to sustain soil productivity. Framed as a chronosequence,

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the pattern observed here also suggests that fertility gains from prolonged paddy cultivation in this area are likely to continue accruing over time for organic carbon and potassium in particular, underscoring the value of periodic re-evaluation as the SB fields themselves mature into longer-cultivated systems.

CONCLUSION

Soil fertility at the study site in Andowengga Village, Poli-Polia District, East Kolaka Regency is generally categorized as low. New paddy fields (SB) show low organic carbon and low potassium status, while old paddy fields (SL) show medium organic carbon and generally higher, but more heterogeneous, potassium, CEC, and base saturation. Phosphorus availability is uniformly medium across both field types. Balanced fertilization, particularly targeting potassium and organic matter inputs together with site-specific management adapted to field age, is recommended to sustain and improve paddy soil productivity at this location.

REFERENCE

Abshiba, K., Sharma, V. K., Kumar, P., Syam, S., Barnwal, P. P., & Kumar, S. (2025). A comprehensive review of soil quality indicators under diverse land uses in rainfed areas. Discover Soil, 2(91), 1–27. https://doi.org/10.1007/s44378-025-00109-5

Arunrat, N., Kongsurakan, P., Sereenonchai, S., & Hatano, R. (2020). Soil Organic Carbon in Sandy Paddy Fields of Northeast Thailand: A Review. Agronomy, 10(1061), 1–25. https://doi.org/10.3390/agronomy10081061

Azza, R. K., Ginting, S., Resman, R., Darwis, D., & Alam, S. (2025). Evaluasi Status Kesuburan Tanah pada Lahan Tanaman Nilam di Desa Karya Mulya Kecamatan Kulisusu Barat Kabupaten Buton Utara. Agronu:Jurnal Agroteknologi, 4(1), 22–32.

Balai Penelitian Tanah. (2023). Analisis Kimia Tanah, Tanaman, Air, dan Pupuk. In Petunjuk Teknis Edisi 3 Analisis Kimia Tanah, Tanaman,Air,dan Pupuk (3rd ed.). Balai Pengujian Standar Instrumen Tanah dan pupuk.

Cai, Y., Xiao, J., Liao, X., Dong, Y., Pan, B., Zhang, L., & Xie, G. (2025). Dryland-to-Paddy Conversions Lead to Short-Term Decreases in Soil Organic Carbon and Carbon Pool Management Index in Karst Soil of Guizhou Province , China. Agriculture, 15(396), 1–19. https://doi.org/10.3390/agriculture15040396

Fang, M., Shen, J., Liu, G., Zhang, C., & Tang, Z. (2026). Degradation and Regeneration of Soil Structure in Intensified Paddy Fields : Plant – Soil Interactions , Ecological Effects , and Restoration Pathways. Plants, 15(225), 1–30. https://doi.org/10.3390/plants15142225

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Febriyansyah, M. F., Suleman, D., Alam, S., Pasolan, Y. B., Leomo, S., & Rustam, L. O. (2024). Evaluasi Kesuburan Tanah Sawah pada Sentra Pertanaman Padi Sawah di Kecamatan Wawonii Utara. Agritechpedia: Journal of Agriculture and Technology, 2(02), 65–77.

Hermansyah, A. D., Partoyo, P., & Virgawati, S. (2024). Status Kesuburan Tanah Pada Lahan Sawah Dilindungi Yang Beralih Fungsi di Kapanewon Seyegan, Kabupaten Sleman, Daerah Istimewa Yogyakarta. Jurnal Tanah Dan Sumberdaya Lahan, 11(1), 205–214. https://doi.org/10.21776/ub.jtsl.2024.011.1.22

Hermiyanto, B., Budiman, S. A., Hafizh, M., Maharani, M., & Hadi, S. (2026). Analysis of soil quality in various land uses in the Central Rembangan micro-watershed , Indonesia. Journal of Degraded and Mining Lands Management, 13(3), 10333–10347. https://doi.org/10.15243/jdmlm.2026.133.10333

Hernández-jiménez, A. V., Ontiveros-garcía, L. A., Leyva-morales, J. B., Fuentes-valencia, M. A., Amillano-cisneros, J. M., Camacho-lópez, C., Acevedo-sandoval, O. A., Leyva-camacho, L., & Torre-espinosa, Z. Y. De. (2026). Mechanisms That Control Phosphorus Availability and Accumulation in Intensive Agricultural Soils : Implications for Environmental Sustainability. Environments, 13(353), 1–16. https://doi.org/10.3390/environments13060353

Maro'ah, S., Hendro, B., & Utami, S. N. H. H. (2021). Status Kesuburan Tanah sebagai Dasar Strategi Pengelolaan Lahan Sawah di Kabupaten Bantul, Indonesia. Agrihealth: Journal of Agri-Food, Nutrition and Public Health, 2(2), 78–87. https://doi.org/10.20961/agrihealth.v2i2.54957

Mesele, S. A., Babatunde, A. B., & Uponi, J. (2026). Soil macro- and micronutrient variability across contrasting land-use systems with differing no-till histories in humid tropical Ferric Luvisols. International Soil and Water Conservation Research, 100671. https://doi.org/10.1016/j.iswcr.2026.100671

Pan, J., Wang, J., & Zhuang, S. (2024). Soil biological fertility evolution in a chronosequence under long-term rice cultivation after land reclamation in China. European Journal of Soil Science, 75(4), e13539. https://doi.org/10.1111/ejss.13539

Sasongko, P. E., Purwanto, P., Dewi, W. S., & Hidayat, R. (2022). Assessment of soil fertility using the soil fertility index method on several land uses in Tutur District , Pasuruan Regency of East Java. Journal of Degraded and Mining Lands Management, 10(1), 3787–3794. https://doi.org/10.15243/jdmlm.2022.101.3787

Suleman, D., Alam, S., Suaib, S., & Yusuf, D. N. (2026). Pengaruh Topografi Terhadap Beberapa Karakteristik Tanah Sawah Tadah Hujan Di Desa Sindang Kasih Kabupaten Konawe

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Selatan. Jurnal Agrotek Tropika, 14(2), 635–643. https://doi.org/10.23960/jat.v14i2.8722

Sumanta, W. R., Ginting, S., Alam, S., Darwis, D., & Resman, R. (2023). Evaluasi Status Kesuburan Tanah Pada Lahan Sawah Tadah Hujan di Desa Jati Bali, Konawe Selatan. Jurnal Agroteknos, 13(3), 121–128.

Supriyadi, S., Pratiwi, M. K., Minardi, S., & Prastiyaningsih, N. L. (2020). Carbon Organic Content under Organic and Conventional Paddy Field and its Effect on Biological Activities (A Case Study in Pati Regency , Indonesia). Caraka Tani: Journal of Sustainable Agriculture, 35(1), 108–116. https://doi.org/10.20961/carakatani.v35i1.34630

Wibowo, H., & Kasno, A. (2021). Soil organic carbon and total nitrogen dynamics in paddy soils on the Java Island, Indonesia. IOP Conference Series: Earth and Environmental Science, 648(1). https://doi.org/10.1088/1755-1315/648/1/012192

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