BUKTI KORESPONDENSI RESPONDENSI DAN SUBSTANSI ISI ARTIKEL JURNAL INTERNASIONAL BEREPUTASI

Judul : Nutrient dynamics in peat soil application under water management planning: A case study of Perigi, South Sumatra, Indonesia

Jurnal : Journal of Ecological Engineering, 2025, 26(6), 162–169

Scopus – Q2

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Kontribusi : Penulis Pertama dan Korespondensi

No.	Perihal	Tanggal
01	Submission	17 Februari 2025
02	New notification	24 Februari 2025
03	Peer Review	24 Februari 2025
04	Penyerahan Perbaikan	25 Februari 2025
05	Proofing	7 April 2025
06	Final Paper	15 April 2025

Submission

New manuscript received by Editorial Office (JEENG-07250-2025-01)

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Review 1:
(this review has file attachment)
This research is quite interesting and very useful, but it has not been written perfectly. Therefore, several improvements need to be made, including adding supporting

literature so that the discussion is even better. Pay attention to the typing which still has lots of typos and some sentence structures that need to be corrected. For more details, please read the comments I gave on the corrected file

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Nutrient Dynamics In Peat Soil Application Of Water Management Planning (A Case Study Of Perigi South Sumatra Indonesia)

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Abstract

The aim of this study was to systematically evaluate the effect of different seasons on dynamical of nutrients and the correlation between them in peat soil as a basic for water management plan. This study examines nutrient dynamics in peat soil facilitated by effective water management planning, focusing on a case study in Perigi, South Sumatra, Indonesia. Employing a combination of field observations and laboratory analyses, the research identifies key nutrient fluctuations in various hydrological conditions. The different sample in each season (wet and dry) was carried out based on the fluctuation of water table between 20cm-80cm to identified the dynamics of nutrients. Results showed the positive correlation between pH and others nutrients which are indicate the influence of ion H+ to enhance bond with other chemicals. The significant result of each nutrient between wet and dry seasons showed that increased rainfall can cause leaching of nutrients like nitrogen, phosphorus, and potassium. It will lead to optimize water management significantly enhances nutrient availability and soil fertility, leading to improved agricultural outcomes. The findings emphasize the importance of sustainable water practices in peatland areas to promote ecological health and agricultural productivity, providing valuable insights for policymakers and land managers.

Keywords: Peat soil, Nutrients, Water table

INTRODUCTION

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A form of soft soil known as peat is created when sedges, trees, mosses, and other flora that grows in marshes and wetland incompletely breaks down and disintegrates, leaving behind a high concentration of fibrous organic materials [1, 2]. Because of its highwater content, high compressibility, and low shear strength, this soil is frequently referred to as problematic [3, 4]. Unfortunately, the effects of burning on peat soils are sporadic because soil organic matter (SOM) can provide long-term fuel and prolong the fire process [5, 6, 7]. The research states that peat smoldering can reach maximum temperatures of 700°C, which gradually deteriorate SOM [8] even though it is lower than that of flame combustion (1,500–1,800°C, [9, 10]. Yet, these marginal lands must be stabilized in order to fulfill growing demand because of the scarcity of land resources. Nutrient dynamics in peat soil are shaped by the unique environmental conditions of peatlands, which include high water content, low oxygen levels, and acidic pH [11, 12]. These factors lead to a slow decomposition process, limited nutrient availability, and distinctive nutrient cycling patterns.

The water movement in the soil was significantly impacted by the high hydraulic conductivity of peat materials, which was an anisotropic and heterogeneous porous medium [13]. Peat exhibits both horizontal (Kh) and vertical (Kv) saturated hydraulic conductivities, with the Kh value being greater than the Kv value. Such conditions, as noted by [14], can hasten the leaching of nutrients into drainage channels, a process made worse by excessive rainfall in tropical regions, which also accelerates the leaching of nutrients. Fertilizers are carried out of the root zone by water, which prevents plants from absorbing their nutrients.

The dynamics of water table can directly influence soil nutrient status, such as ammonium-N, nitrate-N, and inorganic-N and organic C, available K and P concentrations [15, 16]. Research regarding the relationship between groundwater and the status of available soil nutrients in plant roots is still very rare, especially for peatlands. Peatlands with very porous soil characteristics with high hydraulic conductivity clearly have a big influence on fertilization efficiency [17]. Nutrient loss through air movement will be very fast towards water bodies. Therefore, appropriate water management must be found so that the environmental impacts of fertilizers and agricultural activities can be controlled [18].

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The availability of soil nutrients is greatly influenced by the dynamics of the water table, flooded and dry conditions have a real influence on the availability of soil nutrients, especially mobile nutrients such as nitrogen and potassium. The construction of drainage channels causes a decrease in the water level and soil moisture and accelerates the decomposition process. This condition causes the composition of nutrient status in the soil to change [19, 20]. Several factors that influence nutrient status in peat soil are the water

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dynamics which can easily change. Soil with high water conductivity will speed up the nutrient leaching process, thereby reducing fertilization efficiency [21]. Apart from that, soil microbial activity is also influenced by water level dynamics. There is a decrease in bacterial populations with increasing soil wetness, which ultimately also affects nutrient availability [22]. Efforts to control water levels are an important part of controlling the environmental impact of land that has already been reclaimed; interrupted wetting and maintaining a water level of 20-40 cm is the best option to maintain soil nutrient availability [23, 24]. In the future, it is very important for farmers to know the dynamics of soil nutrients, especially for fertilizer applications. Efforts to reduce the leaching of nutrients in peat soil are the most important part besides efforts to control the water level [25, 26, 27]. However only few research study have been conducted, regarding nutrient dynamics in tropical peat soils. Therefore, studies of nutrient dynamics in wet and dry conditions in peat soils was very useful for developing some recommendation how to maintaining the soil and water management for sustainable agriculture.

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MATERIALS AND METHODS

Field Sampling

The location of this research is located in a peat swamp land in Perigi Village, Pangkalan Lapam District, Ogan Komering Ilir Regency. Perigi is a village in Pangkalan Lapam District, Ogan Komering Ilir Regency, South Sumatra. Perigi Village has an area of 13,299 Ha. and has a swamp area of 7,000 Ha. The area of Perigi Village, Pangkalan Lapam District is in the lowlands of 6-7 MDPL (Meters Above Sea Level). Based on the study area, Perigi Village is included in the peat hydrological unit area.The method used in this study is a survey method with direct observation in the field. Sticking wood into the peat swamp water to find out the depth of the peat. Then, samples were taken which were then tested for peat soil fertility to carry out pH, N-total, P-available, K-available, and CEC analyses which were then linked to the condition of the peat land and water management planning [28].

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Treatments

The samples were taken in two period divided to wet samples and dry samples, the purpose is to get the fluctuation of nutrients in each seasons. Four treatments (T) of water table were established in this experiment during the wet season; (i) T1: water table fluctuated at 0-20 cm, (ii) T2: water table fluctuated at 21-40 cm, (iii) T3, water table fluctuated at 41-60 cm, (iv) water table fluctuated at 61-80cm. Each treatment found the water tale ranging from 40 to 45 cm below soil surface.

Data Analysis

Soil sample analysis was carried out at the Soil Science Department, Chemistry and Soil Fertility Laboratory, Universitas Sriwijaya. The effects of treatments on soil parameter were tested using Independent Sample T-Test SPSS. Then, the correlation was tested using Pearson correlation test. [29]

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RESULTS (*OR RESULTS AND DISCUSSION*)

Table 1 shows the descriptive data and Independent Sample T-test of soil chemical properties for each seasons and treatment whereas Table 2 demonstrates the correlation between variables.

The distribution and concentration of N, P, and K along the vertical peat profile were affected by the mixing of aerobic and anaerobic conditions through continual saturation, drying, and rewetting, in response to fluctuations in the water table in the peat profiles. In this study, soil samples of peat soil were identified acidic with a pH between 3.86 - 4.77. According to [30, 31], variations in peatland use have been reported to impact soil pH, a critical component determining the biogeochemistry of peatlands. Land use changes cause organic acids, carbonates, bicarbonates, and hydroxides to be released into the soil solution faster than peat breakdown occurs [32]. This procedure may lower the pH of the soil, affecting vegetation cover, microbiological activity, and nutritional availability of the ecosystems of peatlands. Due to the soil's high H+ ion content and the presence of additional organic acids like fulvic and humic acids, which are products of the decomposition process, the highly acidic characteristics of peat are entirely reasonable [33]. It is expected that the acidic environment in the peat profile (pH < 4) was the cause of the low concentration of key nutrients, particularly N, and exchangeable bases (K, Ca, Mg, and Na). It was widespread in lowland tropical forests [34].

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Prolonged water interruption caused water stress and altered the chemical characteristics of peat soil. Low soil water content made peat's hydrophobic qualities more likely to occur. If so, its capacity to store water—which is largely needed for metabolic processes and the translocation of nutrients—would be determined by this situation [35]. The kinetics and absorption of nutrients are limited by the pH and CEC. Previous studies usually indicated that COOH and OH groups were depleted and reduced the ability of peat soil to retain nutrients and drain them as pH and CEC decreased [36].

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The amount of N was ranged between 0.11%-1.48%, this value is in the range for oligotrophic peat (1%-4%) [37, 38]. The result showed that total nitrogen in dry season is lower compared to the rainy season, higher moisture content promotes the activity of microorganisms responsible for decomposing organic matter. This can lead to an increase in the release of nutrients, especially nitrogen, into the soil. During the dry season, the lack of moisture reduces microbial activity and slows down the decomposition of organic matter [39]. This results in less mineralization, which means fewer nutrients like nitrogen and phosphorus are available for plant uptake. The low concentration of K in this study is indicated to be caused by the dominance of acidic cations (H+ and Al3+), which is showed by the low pH of the soil, as well as the high mobility of K, which makes it easy to leach in soil solutions. While the latter was demonstrated by the large amount of K that leached from the column, the former was validated by the noteworthy correlation between pH and K.

The impact of water management on nutrient dynamics to soil fertility conditions during the rainy season (sample collection) indicate that soil pH is classified as acidic. There are no significant qualitative differences at various levels of water table inundation. The land drainage condition is very poor, with a natural decrease in water table of only 1 cm/ha in the absence of rain. The high inundation treatments T1-T4 show that pH under inundation conditions is better compared to dry soil conditions. Soil pH ranges from very acidic to acidic. This is consistent with the research by [40], which suggests that soil drying can reduce soil acidity. In wet soil conditions, the redox potential (Eh) decreases, which in turn increases the pH value. Furthermore, according to [41], soil drying can sharply increase exchangeable acidity, such as Al3+ or H+, compared to rewetting. This condition can decrease soil pH. Similarly, [42] found that soil moisture and pH decrease as groundwater depth increases. Therefore, amelioration efforts in peatland cultivation are still necessary.

Cereal crops other than rice require the groundwater level to be between 30-40 cm, as at this level the groundwater condition remains sufficiently moist and can meet the plant's evapotranspiration needs. Water retention in tertiary channels at a water level of 60-80 cm is adequate to create groundwater conditions in the root zone at a depth of -40 cm, in accordance with soil management requirements. No sulfuric acid layers were found up to a depth of 1.5 meters in the area due to the peat thickness being greater than 2 meters. This condition prevents a sharp decrease in pH during groundwater level declines to -50 cm (September) [43]. Once the rainy season begins, some toxic substances are leached out, and with increasing inundation, the soil pH rises again. This is consistent with [44] study, which found that soil in a reduced state (waterlogged soil) can raise soil pH, and the pH increases with the duration of waterlogging, although the increase is not very high. The reduction process involves the consumption of H+ ions equivalent to the amount of Fe2+ or H2S formed. The

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overall effect of waterlogging is to increase soil pH, particularly in acidic soils. The significant impact of waterlogging is similar to liming, achieving an optimal pH range that allows for the availability of most nutrients. Reduction is considered most important as it can raise pH, increase phosphorus availability, and replace cations in the exchange sites.

Research shows that under high groundwater conditions, nutrient leaching occurs, resulting in lower macro-nutrient values in soil samples taken from waterlogged conditions. This is consistent with [45], which states that in waterlogged conditions, there is a significant decrease in soil nutrients due to leaching. Conversely, when the groundwater level decreases to 40-80 cm, leaching decreases, leading to an increase in nutrient availability for plants [46].

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Managing water levels below 30-40 cm will also significantly affect the availability of several macro-nutrients in the soil. This is in line with the research by [47], which indicates that groundwater dynamics influence nutrient availability in the plant root zone. Figure 4 shows an increase in nitrogen and phosphorus as a result of the decrease in groundwater level. In conditions where the soil experiences air accumulation (anoxic) due to an increase in the ground water level, this will accelerate the accumulation of nitrogen in the soil. Next, nitrogen mineralization and nitrification occur in the soil oxidation layer at the groundwater interface under submerged conditions. Denitrification and ammonia evaporation are the main mechanisms resulting in the loss of nitrogen in the topsoil in an alkaline environment. In addition, tidal water cycles from river basins and surface runoff, will carry large amounts of suspended material as well as carry plant waste, which can affect nitrogen retention [48]. The availability of nitrogen macronutrients mostly hangs in the soil with a thickness of the top 20 cm. Accorcing to [49] maintaining ground water table under 50 cm is the optimum operation for providing nutrient availability, and crop growth environment. Consistent with the research by [50], experiments with oil palm seedlings show nutrient loss occurs at shallow groundwater levels (0-25 cm) and at levels greater than 75 cm. The optimal nutrient absorption value is found at a depth of 50 [51].

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Soil phosphorus content is also influenced by fluctuations in groundwater level (Figure 2). Analysis results show that phosphorus levels are low under wet conditions and moderate under dry conditions (groundwater level -40 cm). This is consistent with the research by [52], which states that phosphorus levels significantly increase at a groundwater depth of 40 cm below the soil surface. Similarly, [53] found that fluctuating groundwater levels during the dry-wet seasons lead to increased phosphorus flux from the Bh horizon, enhancing phosphorus availability in the plant root zone.

Analysis results show that cation exchange capacity (CEC) decreases with a lowering groundwater depth. The CEC value during sampling under wet conditions ranged from 58-62 me/100g, while in moist soil (groundwater depth 40-45 cm, representing the water table during the dry season) the CEC value ranged from 45-52 me/100g. Although qualitatively, peat soils in the Perigi area have very high CEC values. This is consistent with [54], exchange capacity. This is suspected to be due to moisture levels at varying groundwater heights affecting the organic carbon content, which shows an increase in organic carbon values. Organic carbon values indicate that organic matter in peat soils has already decomposed. According to [55], soil cation exchange capacity is greatly influenced by soil organic matter content. Decomposed organic matter has functional groups ($COOH^-$) that can contribute negative charges, thereby enhancing cation exchange in peat soils, making the CEC higher with greater organic carbon content. Therefore, controlling groundwater levels is crucial for agricultural practices in peatlands. Maintaining the water table at -40 cm is the best option for providing crop nutrients. Nitrogen and phosphorus are more available at a groundwater level of 40 cm [56].

The cation exchange capacity (CEC) of soil depends on soil texture, the type of clay minerals, and organic matter content. The higher the clay content or the finer the texture, the greater the CEC. Similarly, higher soil organic matter content results in a higher CEC [57]. In agricultural practice, measuring the actual CEC and pH of the soil can help farmers determine the appropriate type and dosage of fertilizers for their crops. By understanding the soil's CEC and pH, farmers can optimize plant growth and avoid damage from over-fertilization or under-fertilization. Measuring CEC and soil pH helps maintain the balance of soil chemical properties and ensures optimal plant growth [58]. CEC is crucial for plant productivity because it affects how many nutrients are retained and available in the soil. Soils with low CEC cannot retain and hold essential nutrients like ammonium (NH4+), Ca2+, Mg2+, K+, and Na+ effectively.

CONCLUSIONS

Soil nutrient dynamics show a decrease in pH values When the soil dries out, it means that the pH during the rainy season is higher than in the dry conditions. This is inversely proportional to the Nitrogen nutrient in the season dry season has higher levels than the rainy season. Likewise, it is followed by Phosphorus content. Only the CEC and K-dd values in the rainy season have value which is higher compared to the dry season.

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Data on nutrient dynamics and groundwater levels is important for farmers to understand when to apply fertilizer appropriately and plan land use in the future.

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ACKNOWLEDGMENTS

The research was funded by collaboration research between National Institute of Forest Science (NIFoS) Republic of Korea and Sriwijaya University Indonesia. The authors would like to acknowledge Deasy. M.Irfan support, and Sumantri and Agus Prihanto for the field assistance during the field survey

CONFLICT OF INTEREST

The authors declare no conflict of interest.

Author Contributions

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Bakri – Developing the Conceptualization, Data collection, Funding acquisition, Investigation, Methodology, Supervision, Field Survay, Monitoring Data,Validation, Writing – original draft. **Momon Sodik Imanudin** – Conceptualization, Data analysis, Investigation, Methodology, Supervision, Visualization, Writing – review & editing. and
All authors read and approved the final manuscript.

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Figure captions:

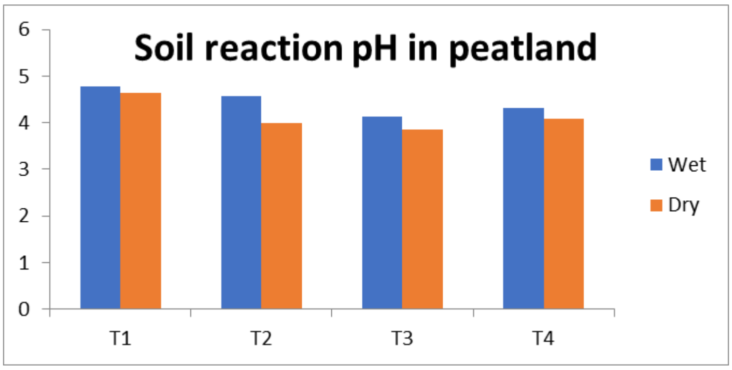

Figure 1. The soil reaction on peat soil at wet and dry soil sampling condition

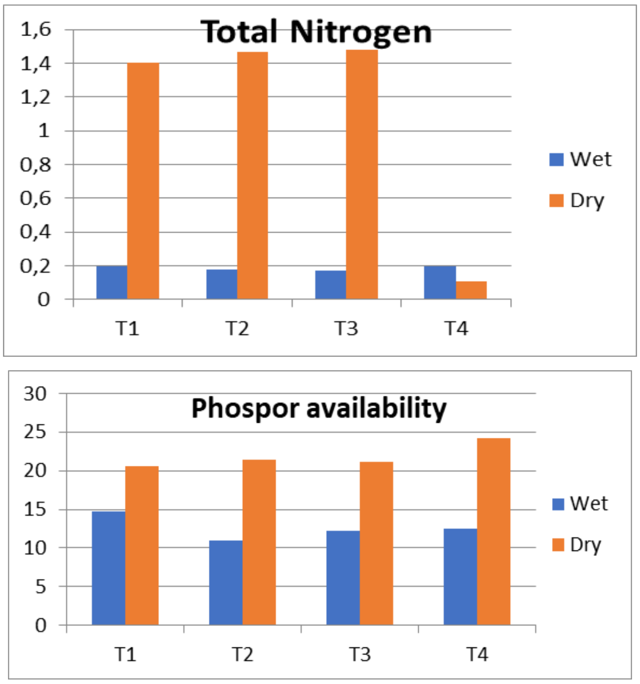

Figure 2. Dynamics of macro-nutrients Nitrogen and Phosphorus under wet and dry conditions.

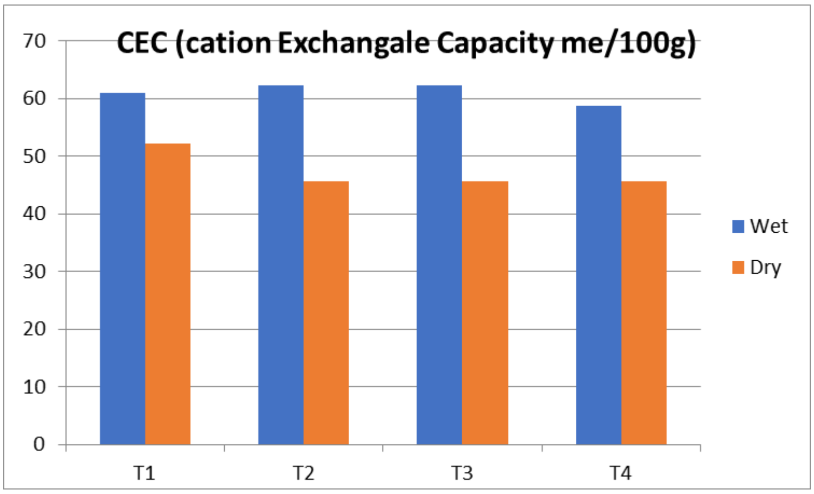

Figure 3. Dynamics of soil cation exchange capacity (CEC) under wet and dry conditions (groundwater level -45 cm)

Table 1. Descriptive Data and Independent Sample T-Test of Soil Chemical Properties

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Soil Properties	Treatment	Mean	Std Dev	Min	Max	F	Sig
pH	Wet	4,45	0,29	4,12	4,77	0,03	0,22
	Dry	4,14	0,35	3,86	4,64		
Total-Nitrogen	Wet	0,19	0,02	0,17	0,2	8,46	0,02
	Dry	1,12	0,67	0,11	1,48		
Phospor	Wet	12,56	1,57	10,95	14,7	0,02	0,00
	Dry	21,83	1,59	20,55	24,15		
Kalium	Wet	0,35	0,03	0,32	0,38	8,65	0,00
	Dry	0,23	0,04	0,19	0,26		
KTK	Wet	61,03	1,66	58,73	62,25	1,75	0,00
	Dry	47,31	3,26	45,68	52,2		

Table 2.Correlation between Variables

Soil Properties	Total Nitrogen	Phospor	Kalium	KTK
pH	0,33	0,457	0,231	0,642
Total Nitrogen		0,138	0,092	0,045
Phospor			0,853	0,95
Kalium				0.823

New revision received by Editorial Office (JEENG-07250-2025-02)

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Nutrient Dynamics In Peat Soil Application Under Water Management Planning (A Case Study Of Perigi South Sumatra Indonesia)

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Abstract

The aim of this study was to systematically evaluate the effect of different seasons on dynamical of nutrients and the correlation between them in peat soil as a basic for water management plan. This study examines nutrient dynamics in peat soil facilitated by effective water management planning, focusing on a case study in Perigi, South Sumatra, Indonesia. Employing a combination of field observations and laboratory analyses, the research identifies key nutrient fluctuations in various hydrological conditions. The different sample in each season (wet and dry) was carried out based on the fluctuation of water table between 20cm-80 cm to identified the dynamics of nutrients. Results showed the positive correlation between pH and others nutrients which are indicate the influence of ion H+ to enhance bond with other chemicals. The significant result of each nutrient between wet and dry seasons showed that increased rainfall can cause leaching of nutrients like nitrogen, phosphorus, and potassium. This will support the successful optimization of water management which can significantly increase the availability of nutrients and soil fertility, leading to improved agricultural outcomes. The findings emphasize the importance of sustainable water practices in peatland areas to promote ecological health and agricultural productivity, providing valuable insights for policymakers and land managers.

Keywords: peat soil, nutrients, water table

INTRODUCTION

A form of soft soil known as peat is created when sedges, trees, mosses, and other flora that grows in marshes and wetland incompletely breaks down and disintegrates, leaving behind a high concentration of fibrous organic materials (Andriesse, 1988; Das *et al.*, 2024). Because of its high-water content, high compressibility, and low shear strength, this soil is frequently referred to as problematic (Ashraf *et al.*, 2017; Van der Laan *et al.*, 2024). Unfortunately, the effects of burning on peat soils are sporadic because soil organic matter (SOM) can provide long-term fuel and prolong the fire process (Moreno et al., 2010; Apori *et al.*, 2023; Natali *et al.*, 2023). The research states that peat smouldering can reach maximum temperatures of 700°C, which gradually deteriorate SOM Kreye *et al.*, (2011) even though it is lower than that of flame combustion (1,500–1,800°C) (Rein, 2009; Rein *et al.*, 2008). Yet, these marginal lands must be stabilized in order to fulfil growing demand because of the scarcity of land resources. Nutrient dynamics in peat soil are shaped by the unique environmental conditions of peatlands, which include high water content, low oxygen levels, and acidic pH (Kunarso *et al.,* 2022; Li *et al.,* 2024). These factors lead to a slow decomposition process, limited nutrient availability, and distinctive nutrient cycling patterns.

The water movement in the soil was significantly impacted by the high hydraulic conductivity of peat materials, which was an anisotropic and heterogeneous porous medium Rupngam and Messiga, 2024). Peat exhibits both horizontal (Kh) and vertical (Kv) saturated hydraulic conductivities, with the Kh value being greater than the Kv value. Such conditions, as noted by Widiarso *et al.,* (2020) can hasten the leaching of nutrients into drainage channels, a process made worse by excessive rainfall in tropical regions, which also accelerates the leaching of nutrients. Fertilizers are carried out of the root zone by water, which prevents plants from absorbing their nutrients.

The dynamics of water table can directly influence soil nutrient status, such as ammonium-N, nitrate-N, and inorganic-N and organic C, available K and P concentrations (Bai *et al.,* 2020; Zhang *et al.,* 2022).Research regarding the relationship between water table and the status of available soil nutrients in plant roots is still very rare, especially for peatlands. Peatlands with very porous soil characteristics with high hydraulic conductivity clearly have a big influence on fertilization efficiency (Jurasinski *et al.,* 2020). Nutrient loss through air movement will be very fast towards water bodies. Therefore, appropriate water management must be found so that the environmental impacts of fertilizers and agricultural activities can be controlled (Imanudin *et al.,* 2024).

The availability of soil nutrients is greatly influenced by the dynamics of the water table, flooded and dry conditions have a real influence on the availability of soil nutrients, especially mobile nutrients such as nitrogen and potassium. The construction of drainage canal causes a decrease in the water level and soil moisture and accelerates the decomposition process. This condition causes the composition of nutrient status in the soil to change (Laine *et al.,* 2021; Anggat *et al.,* 2024). Several factors that influence nutrient status in peat soil are the water dynamics which can easily change. Soil with high water conductivity will speed up the nutrient leaching process, thereby reducing fertilization efficiency (Anggat *et al.*, 2024). Apart from that, soil microbial activity is also influenced by water level dynamics. There is a decrease in bacterial populations with increasing soil wetness, which ultimately also affects nutrient availability (Rupngam and Messiga, 2024; Basuki, 2024). Efforts to control water levels are an important part of controlling the environmental impact of land that has already been reclaimed; interrupted wetting and maintaining a water level of 20-40 cm is the best option to maintain soil nutrient availability (Van der Laan *et al.,* 2024; Azis *et al.,* 2022). In the future, it is very important for farmers to know the dynamics of soil nutrients, especially for fertilizer applications. Efforts to reduce the leaching of nutrients in peat soil are the most important part besides efforts to control the water level (Ngan *et al.,* 2023; Harpenslager *et al*., 2024; Das *et* al., 2024). Increasing the water table was followed by increasing nutrient losses (Hashin *et al.,* 2019). However, only a few research studies have been conducted, regarding nutrient dynamics in tropical peat soils. Therefore, studies of nutrient dynamics in wet and dry conditions in peat soils were very useful for developing some recommendations on how to be maintaining the soil and water management for sustainable agriculture.

MATERIALS AND METHODS

Field Sampling

The location of this research is located in a peat swamp land in Perigi Village, Pangkalan Lapam District, Ogan Komering Ilir Regency. Perigi is a village in Pangkalan Lapam District, Ogan Komering Ilir Regency, South Sumatra. Perigi Village has an area of 13,299 Ha. and has a swamp area of 7,000 Ha. The area of Perigi Village, Pangkalan Lapam District is in the lowlands of 6-7 MDPL (Meters Above Sea Level). Based on the study area, Perigi Village is included in the peat hydrological unit area. The method used in this study is a survey method with direct observation in the field. Sticking wood into the peat swamp water to find out the depth of the peat (Basuki, 2024). Then, samples were taken which were then tested for peat soil fertility to carry out pH, N-total, P-available, K-available, and CEC analyses which were then linked to the condition of the peat land and water management planning (Pulunggono *et al.,* 2023).

Treatments

The samples were taken in two period divided to wet samples and dry samples; the purpose is to get the fluctuation of nutrients in each seasons. Four treatments (T) of water table were established in this experiment during the wet season; (i) T1: water table fluctuated at 0-20 cm, (ii) T2: water table fluctuated at 21-40 cm, (iii) T3, water table fluctuated at 41-60 cm, (iv) water table fluctuated at 61-80cm. Each treatment found the water tale ranging from 40 to 45 cm below soil surface.

Data Analysis

Soil sample analysis was carried out at the Soil Science Department, Chemistry and Soil Fertility Laboratory, Universitas Sriwijaya. The effects of treatments on soil parameter were tested using Independent Sample T-Test SPSS. Then, the correlation was tested using Pearson correlation test (Bevans, 2020).

RESULTS (*OR RESULTS AND DISCUSSION*)

Table 1 shows the descriptive data and Independent Sample T-test of soil chemical properties for each season and treatment whereas Table 2 demonstrates the correlation between variables.

The distribution and concentration of N, P, and K along the vertical peat profile were affected by the mixing of aerobic and anaerobic conditions through continual saturation, drying, and rewetting, in response to fluctuations in the water table in the peat profiles. In this study, soil samples of peat soil were identified acidic with a pH between 3.86 - 4.77. According to Hikmatullah dan Sukarman (2014); Imanudin *et al.,* (2022), variations in peatland use have been reported to impact soil pH, a critical component determining the biogeochemistry of peatlands. Land use changes cause organic acids, carbonates, bicarbonates, and hydroxides to be released into the soil solution faster than peat breakdown occurs (Aziz *et al.,* 2022). This procedure may lower the pH of the soil, affecting vegetation cover, microbiological activity, and nutritional availability of the ecosystems of peatlands. Due to the soil's high H^+ ion content and the presence of additional organic acids like fulvic and humic acids, which are products of the decomposition process, the highly acidic characteristics of peat are entirely reasonable (Das *et al.,* 2024). It is expected that the acidic environment in the peat profile (pH < 4) was the cause of the low concentration of key nutrients, particularly N, and exchangeable bases (K, Ca, Mg, and Na). It was widespread in lowland tropical (Jarukas *et al.,* 2021).

Prolonged water interruption caused water stress and altered the chemical characteristics of peat soil. Low soil water content made peat's hydrophobic qualities more likely to occur. If so, its capacity to store water which is largely needed for metabolic processes and the translocation of nutrients would be determined by this situation (Ngan *et al.,* 2024). The kinetics and absorption of nutrients are limited by the pH and CEC. Previous studies usually indicated that COOH and OH groups were depleted and reduced the ability of peat soil to retain nutrients and drain them as pH and CEC decreased (Lucas dan Re, 1982).

The amount of N was ranged between 0.11%-1.48%, this value is in the range for oligotrophic peat (1%-4%) (Imanudin *et al.,* 2022; Jayasekara *et al.,* 2025). The result showed that total nitrogen in dry season is lower compared to the rainy season, higher moisture content promotes the activity of microorganisms responsible for decomposing organic matter. This can lead to an increase in the release of nutrients, especially nitrogen, into the soil. During the dry season, the lack of moisture reduces microbial activity and slows down the decomposition of organic matter (Dettmann *et al.,* 2021). This results in less mineralization, which means fewer nutrients like nitrogen and phosphorus are available for plant uptake. The low concentration of K in this study is indicated to be caused by the dominance of acidic cations (H^+ and $Al3^+$), which is showed by the low pH of the soil, as well as the high mobility of K, which makes it easy to leach in soil solutions. While the latter was demonstrated by the large amount of K that leached from the column, the former was validated by the noteworthy correlation between pH and K.

The impact of water management on nutrient dynamics to soil fertility conditions during the rainy season (sample collection) indicate that soil pH is classified as acidic. There are no significant qualitative differences at various levels of water table inundation. The land drainage condition is very poor, with a natural decrease in water table of only 1 cm/ha in the absence of rain. The high inundation treatments T1-T4 show that pH under inundation conditions is better compared to dry soil conditions. Soil pH ranges from very acidic to acidic. This is consistent with the research by Lee *et al.* (2021), which suggests that soil drying can reduce soil acidity. In wet soil conditions, the redox potential (Eh) decreases, which in turn increases the pH value. Furthermore, according to Imanudin *et al.* (2019), soil drying can sharply increase exchangeable acidity, such as $Al3^+$ or H^+, compared to rewetting. This condition can decrease soil pH. Similarly, [42] found that soil moisture and pH decrease as groundwater depth increases. Therefore, amelioration efforts in peatland cultivation are still necessary.

Cereal crops other than rice require the groundwater level to be between 30-40 cm, as at this level the groundwater condition remains sufficiently moist and can meet the plant's evapotranspiration needs. Water retention in tertiary channels at a water level of 60-80 cm is adequate to create groundwater conditions in the root zone at a depth of -40 cm, in accordance with soil management requirements. No sulfuric acid layers were found up to a depth of 1.5 meters in the area due to the peat thickness being greater than 2 meters. This condition prevents a sharp decrease in pH during groundwater level declines to -50 cm (September) (Zhang *et al.,* 2018). Once the rainy season begins, some toxic substances are leached out, and with increasing inundation, the soil pH rises again. This is consistent with Hashim *et al.* (2019) study, which found that soil in a reduced state (waterlogged soil) can raise soil pH, and the pH increases with the duration of waterlogging, although the increase is not very high. The reduction process involves the consumption of H+ ions equivalent to the amount of Fe^{2+} or H_2S formed. The overall effect of waterlogging is to increase soil pH, particularly in acidic soils. The significant impact of waterlogging is similar to liming, achieving an optimal pH range that allows for the availability of most nutrients. Reduction is considered most important as it can raise pH, increase phosphorus availability, and replace cations in the exchange sites.

Research shows that under high groundwater conditions, nutrient leaching occurs, resulting in lower macro-nutrient values in soil samples taken from waterlogged conditions. This is consistent with Imanudin *et al. (*2022), which states that in waterlogged conditions, there is a significant decrease in soil nutrients due to leaching. Conversely, when the groundwater level decreases to 40-80 cm, leaching decreases, leading to an increase in nutrient availability for plants (Damanik *et al.,* 2023).

Managing water levels below 30-40 cm will also significantly affect the availability of several macro-nutrients in the soil. This is in line with the research by Zhang *et al.* (2018), which indicates that groundwater dynamics influence nutrient availability in the plant root zone. Figure 4 shows an increase in nitrogen and phosphorus as a result of the decrease in groundwater level. In conditions where the soil experiences air accumulation (anoxic) due to an increase in the ground water level, this will accelerate the accumulation of nitrogen in the soil. Next, nitrogen mineralization and nitrification occur in the soil oxidation layer at the groundwater interface under submerged conditions. Denitrification and ammonia evaporation are the main mechanisms resulting in the loss of nitrogen in the topsoil in an alkaline environment. In addition, tidal water cycles from river basins and surface runoff, will carry large amounts of suspended material as well as carry plant waste, which can affect nitrogen retention (Hashim *et al.*, 2019). The availability of nitrogen macronutrients mostly hangs in the soil with a thickness of the top 20 cm. According to Striling *et al.* (2020); Imanudin *et al.* (2022), maintaining ground water table under 50 cm is the optimum operation for providing nutrient availability, and crop growth environment. Consistent with the research by Imanudin *et al.* (2022), experiments with oil palm seedlings show nutrient loss occurs at shallow groundwater levels (0-25 cm) and at levels greater than 75 cm. The optimal nutrient absorption value is found at a depth of 50 cm (Kassim and Yaacob, 2019)

Soil phosphorus content is also influenced by fluctuations in groundwater level (Figure 2). Analysis results show that phosphorus levels are low under wet conditions and moderate under dry conditions (groundwater level -40 cm). This is consistent with the research by Obour *et al.* (2011), which states that phosphorus levels significantly increase at a groundwater depth of 40 cm below the soil surface. Similarly, Rupngam and Messiga (2024), found that fluctuating groundwater levels during the dry-wet seasons lead to increased phosphorus flux from the Bh horizon, enhancing phosphorus availability in the plant root zone.

Analysis results show that cation exchange capacity (CEC) decreases with a lowering groundwater depth. The CEC value during sampling under wet conditions ranged from 58-62 me/100g, while in moist soil (groundwater depth 40-45 cm, representing the water table during the dry season) the CEC value ranged from 45-52 me/100g. Although qualitatively, peat soils in the Perigi area have very high CEC values. This is consistent with Becher *et al.* (2020), exchange capacity. This is suspected to be due to moisture levels at varying groundwater heights affecting the organic carbon content, which shows an increase in organic carbon values. Organic carbon values indicate that organic matter in peat soils has already decomposed. According to Kassim and Yaacob (2019), soil cation exchange capacity is greatly influenced by soil organic matter content. Decomposed organic matter has functional groups ($COOH^-$) that can contribute negative charges, thereby enhancing cation exchange in peat soils, making the CEC higher with greater organic carbon content. Therefore, controlling groundwater levels is crucial for agricultural practices in peatlands. Maintaining the water table at -40 cm is the best option for providing crop nutrients. Nitrogen and phosphorus are more available at a groundwater level of 40 cm (Suryani *et al.*, 2022).

The cation exchange capacity (CEC) of soil depends on soil texture, the type of clay minerals, and organic matter content. The higher the clay content or the finer the texture, the greater the CEC. Similarly, higher soil organic matter content results in a higher CEC Hannu *et al.* (2024), In agricultural practice, measuring the actual CEC and pH of the soil can help farmers determine the appropriate type and dosage of fertilizers for their crops. By understanding the soil's CEC and pH, farmers can optimize plant growth and avoid damage from over-fertilization or under-fertilization. Measuring CEC and soil pH helps maintain the balance of soil chemical properties and ensures optimal plant growth (Chen *et al.*, 2024). CEC is crucial for plant productivity because it affects how many nutrients are retained and available in the soil. Soils with low CEC cannot retain and hold essential nutrients like ammonium (NH_4^+), Ca^{2+}, Mg^{2+}, K^+, and Na^+ effectively.

CONCLUSIONS

Soil nutrient dynamics show a decrease in pH values when the soil dries out, it means that the pH during the rainy season is higher than in the dry conditions. This is inversely proportional to the Nitrogen nutrient in the season dry season has higher levels than the rainy season. Likewise, it is followed by Phosphorus content. Only the CEC and K-dd values in the rainy season have values which is higher compared to the dry season.

Data on nutrient dynamics and groundwater levels is important for farmers to understand when to apply fertilizer appropriately and plan land use in the future. Proper water management by maintaining a water level of 40-50 cm can increase fertilizer efficiency.

ACKNOWLEDGMENTS

The research was funded by collaboration research between National Institute of Forest Science (NIFoS) Republic of Korea and Sriwijaya University Indonesia. The authors would like to acknowledge Deasy. M.Irfan support, and Sumantri and Agus Prihanto for the field assistance during the field survey

CONFLICT OF INTEREST

The authors declare no conflict of interest.

Author Contributions

Bakri – Developing the Conceptualization, Data collection, Funding acquisition, Investigation, Methodology, Supervision, Field Survay, Monitoring Data,Validation, Writing – original draft. **Momon Sodik Imanudin** – Conceptualization, Data analysis, Investigation, Methodology, Supervision, Visualization, Writing – review & editing. And All authors read and approved the final manuscript.

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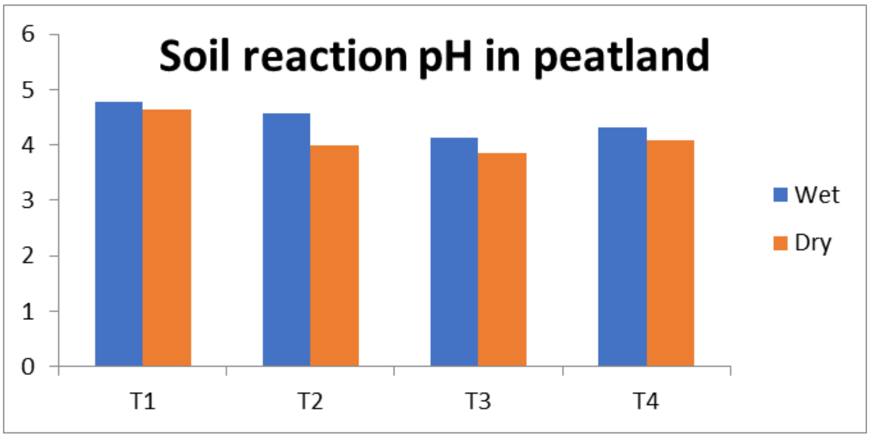

Figure 1. The soil reaction on peat soil at wet and dry soil sampling condition

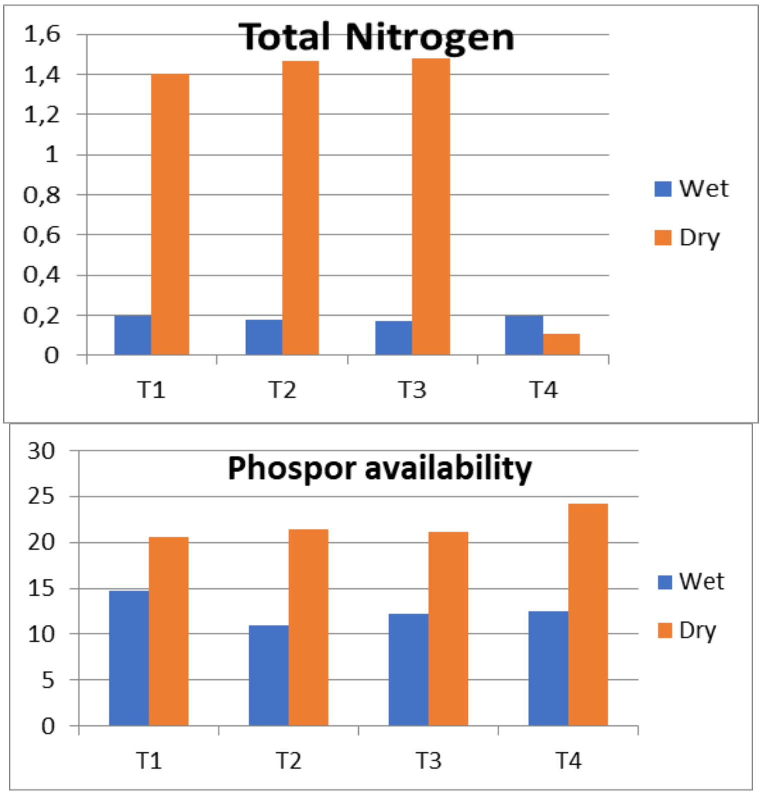

Figure 2. Dynamics of macro-nutrients Nitrogen and Phosphorus under wet and dry conditions.

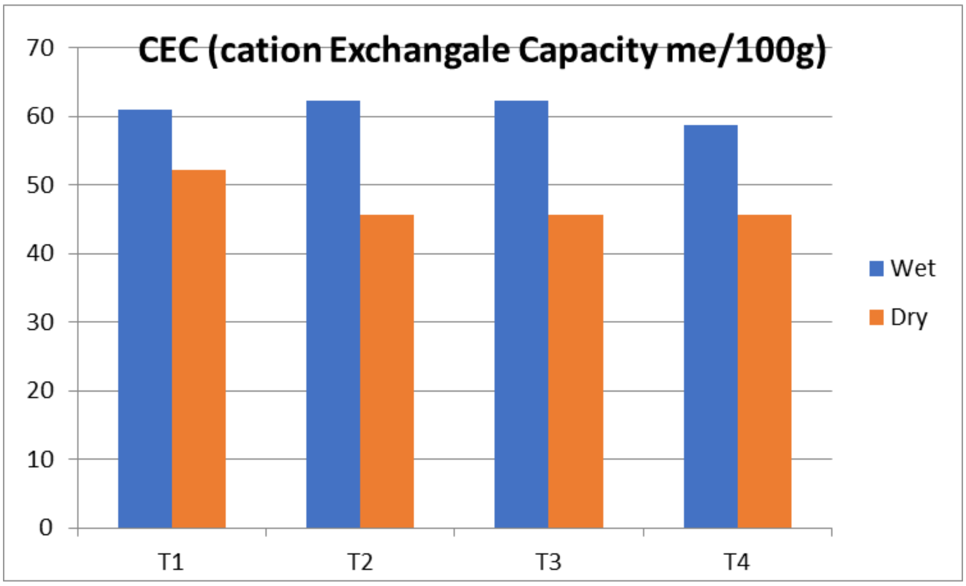

Figure 3. Dynamics of soil cation exchange capacity (CEC) under wet and dry conditions (groundwater level -45 cm)

Table 1. Descriptive data and independent sample t-test of soil chemical properties

Soil Properties	Treatment	Mean	Std Dev	Min	Max	F	Sig
pH	Wet	4,45	0,29	4,12	4,77	0,03	0,22
	Dry	4,14	0,35	3,86	4,64		
Total-Nitrogen	Wet	0,19	0,02	0,17	0,2	8,46	0,02
	Dry	1,12	0,67	0,11	1,48		
Phospor	Wet	12,56	1,57	10,95	14,7	0,02	0,00
	Dry	21,83	1,59	20,55	24,15		
Kalium	Wet	0,35	0,03	0,32	0,38	8,65	0,00
	Dry	0,23	0,04	0,19	0,26		
KTK	Wet	61,03	1,66	58,73	62,25	1,75	0,00
	Dry	47,31	3,26	45,68	52,2		

Table 2. Correlation between Variables

Soil Properties	Total Nitrogen	Phospor	Kalium	KTK
pH	0,33	0,457	0,231	0,642
Total Nitrogen		0,138	0,092	0,045
Phospor			0,853	0,95
Kalium				0.823

JEE 26(6), 2025

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Journal of Ecological Engineering, 2025, 26(6), 162–169
https://doi.org/10.12911/22998993/202347 ISSN
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Received: 2025.02.17
Accepted: 2025.04.07
Published: 2025.04.15

Nutrient dynamics in peat soil application under water management planning: A case study of Perigi, South Sumatra, Indonesia

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ABSTRACT

The aim of this study was to systematically evaluate the effect of different seasons on dynamical of nutrients and the correlation between them in peat soil as a basic for water management plan. This study examined nutrient dynamics in peat soil facilitated by effective water management planning, focusing on a case study in Perigi, South Sumatra, Indonesia. Employing a combination of field observations and laboratory analyses, the research identified key nutrient fluctuations in various hydrological conditions. The different samples in each season (wet and dry) were collected based on the fluctuation of water table between 20–80 cm to identify the dynamics of nutrients. Results showed the positive correlation between pH and other nutrients which indicates the influence of ion H+ on enhancing the bond with other chemicals. The significant results of each nutrient between wet and dry seasons showed that increased rainfall can cause leaching of nutrients like nitrogen, phosphorus, and potassium. This will support the successful optimization of water management which can significantly increase the availability of nutrients and soil fertility, leading to improved agricultural outcomes. The findings emphasize the importance of sustainable water practices in peatland areas to promote ecological health and agricultural productivity, providing valuable insights for policymakers and land managers.

Keywords: peat soil, nutrients, water table.

INTRODUCTION

A form of soft soil known as peat is created when sedges, trees, mosses, and other flora that grows in marshes and wetland incompletely breaks down and disintegrates, leaving behind a high concentration of fibrous organic materials (Andriesse, 1988; Das *et al.*, 2024). Because of its high-water content, high compressibility, and low shear strength, this soil is frequently referred to as problematic (Ashraf *et al.*, 2017; Van der Laan *et al.*, 2024). Unfortunately, the effects of burning on peat soils are sporadic because soil organic matter (SOM) can provide long-term fuel and prolong the fire process (Moreno et al., 2010; Apori *et al.*, 2023; Natali *et al.*, 2023). The research states that peat smouldering can reach maximum temperatures of 700 °C, which gradually deteriorate SOM Kreye *et al.*, (2011) even though it is lower than that of flame combustion (1.500–1.800 °C) (Rein, 2009; Rein *et al.*, 2008). Yet, these marginal lands must be stabilized in order to fulfil growing demand because of the scarcity of land resources. Nutrient dynamics in peat soil are shaped by the unique environmental conditions of peatlands, which include high water content, low oxygen levels, and acidic pH (Kunarso *et al.*, 2022; Li *et al.*, 2024). These factors lead to a slow decomposition process, limited nutrient availability, and distinctive nutrient cycling patterns.

The water movement in the soil was significantly impacted by the high hydraulic conductivity of peat materials, which was an anisotropic and heterogeneous porous medium Rupngam and Messiga, 2024). Peat exhibits both horizontal (Kh) and vertical (Kv) saturated hydraulic conductivities, with the Kh value being greater than the Kv value. Such conditions, as noted by Widiarso *et al.,* (2020) can hasten the leaching of nutrients into drainage channels, a process made worse by excessive rainfall in tropical regions, which also accelerates the leaching of nutrients. Fertilizers are carried out of the root zone by water, which prevents plants from absorbing their nutrients.

The dynamics of water table can directly influence soil nutrient status, such as ammonium-N, nitrate-N, and inorganic-N and organic C, as well as available K and P concentrations (Bai *et al.,* 2020; Zhang *et al.,* 2022). The research regarding the relationship between water table and the status of available soil nutrients in plant roots is still very rare, especially for peatlands. Peatlands with very porous soil characteristics characterized by high hydraulic conductivity clearly have a large influence on fertilization efficiency (Jurasinski *et al.,* 2020). Nutrient loss through air movement will be very fast towards water bodies. Therefore, appropriate water management must be developed so that the environmental impacts of fertilizers and agricultural activities can be controlled (Imanudin *et al.,* 2024).

The availability of soil nutrients is greatly influenced by the dynamics of the water table; flooded and dry conditions have a real influence on the availability of soil nutrients, especially mobile nutrients such as nitrogen and potassium. The construction of drainage canal causes a decrease in the water level and soil moisture and accelerates the decomposition process. This condition causes the composition of nutrient status in the soil to change (Laine *et al.,* 2021; Anggat *et al.,* 2024). the water dynamics, which can easily change, are a factor that influences the nutrient status in peat soil. Soil with high water conductivity will speed up the nutrient leaching process, thereby reducing fertilization efficiency (Anggat *et al.,* 2024). Apart from that, soil microbial activity is also influenced by water level dynamics. There is a decrease in bacterial populations with increasing soil wetness, which ultimately also affects nutrient availability (Rupngam and Messiga, 2024; Basuki, 2024). The efforts to control water levels are an important part of controlling the environmental impact of land that has already been reclaimed; interrupted wetting and maintaining a water level of 20-40 cm is the best option to maintain soil nutrient availability (Van der Laan *et al.,* 2024; Azis *et al.,* 2022). In the future, it is very important for farmers to know the dynamics of soil nutrients, especially for fertilizer applications. The efforts to reduce the leaching of nutrients in peat soil are the most important part besides the efforts to control the water level (Ngan *et al.*, 2023; Harpenslager *et al*., 2024; Das *et* al., 2024). Increasing the water table was followed by increasing nutrient losses (Hashin *et al.,* 2019). However, only a few research studies regarding nutrient dynamics in tropical peat soils have been conducted. Therefore, studies of nutrient dynamics in wet and dry conditions in peat soils were very useful for developing recommendations on how to be maintaining the soil and water management for sustainable agriculture.

MATERIALS AND METHODS

Field sampling

This research was carried out in a peat swamp land in Perigi Village, Pangkalan Lapam District, Ogan Komering Ilir Regency. Perigi is a village in Pangkalan Lapam District, Ogan Komering Ilir Regency, South Sumatra. Perigi Village has an area of 13.299 Ha. and has a swamp area of 7.000 Ha. The area of Perigi Village, Pangkalan Lapam District is in the lowlands of 6–7 MDPL (Meters Above Sea Level). On the basis of the study area, Perigi Village is included in the peat hydrological unit area. The method used in this study was a survey method with direct observation in the field. It involved sticking wood into the peat swamp water to determine the depth of the peat (Basuki, 2024). Then, samples were taken which were subsequently tested for peat soil fertility to carry out pH, N-total, P-available, K-available, and CEC analyses which were then linked to the condition of the peat land and water management planning (Pulunggono *et al.,* 2023).

Treatments

The samples were taken in two periods divided to wet samples and dry samples; the purpose was to obtain the fluctuation of nutrients in each seasons. Four treatments (T) of water table were established in this experiment during the wet season; (i) T1: water table fluctuated at 0–20 cm, (ii) T2: water table fluctuated at 21–40 cm, (iii) T3, water table fluctuated at 41–60 cm, (iv) water table fluctuated at 680 cm. Each treatment found the water tale ranging from 40 to 45 cm below soil surface.

Data analysis

Soil sample analysis was carried out at the Soil Science Department, Chemistry and Soil Fertility Laboratory, Universitas Sriwijaya. The effects of treatments on soil parameter were tested using Independent Sample T-Test SPSS. Then, the correlation was tested using Pearson correlation test (Bevans, 2020).

RESULTS AND DISCUSSION

Table 1 shows the descriptive data and Independent Sample T-test of soil chemical properties for each season and treatment whereas Table 2 demonstrates the correlation between variables.

The distribution and concentration of N, P, and K along the vertical peat profile were affected by the mixing of aerobic and anaerobic conditions through continual saturation, drying, and rewetting, in response to fluctuations in the water table in the peat profiles. In this study, soil samples of peat soil were identified as acidic with a pH between 3.86–4.77. According to Hikmatullah and Sukarman (2014); Imanudin *et al.*, (2022), variations in peatland use have been reported to impact soil pH, a critical component determining the biogeochemistry of peatlands. Land use changes cause organic acids, carbonates, bicarbonates, and hydroxides to be released into the soil solution faster than peat breakdown occurs (Aziz *et al.*, 2022). This procedure may lower the pH of the soil, affecting vegetation cover, microbiological activity, and nutritional availability of the ecosystems of peatlands. Due to the high H^+ ion content of soil and the presence of additional organic acids like fulvic and humic acids, which are products of the decomposition process, the highly acidic characteristics of peat are entirely reasonable (Das *et al.*, 2024). It is expected that the acidic environment in the peat profile ($pH < 4$) was the cause of the low concentration of key nutrients, particularly N, and exchangeable bases (K, Ca, Mg, and Na). It was widespread in lowland tropical environment (Jarukas *et al.*, 2021).

Prolonged water interruption caused water stress and altered the chemical characteristics of peat soil. Low soil water content made the hydrophobic qualities of peat more likely to occur. If so, its capacity to store water which is largely needed for metabolic processes and the translocation of nutrients would be determined by this situation

Table 1. Descriptive data and independent sample T-test of soil chemical properties

Soil properties	Treatment	Mean	Std Dev	Min	Max	F	Sig
pH	Wet	4.45	0.29	4.12	4.77	0.03	0.22
	Dry	4.14	0.35	3.86	4.64		
Total Nitrogen	Wet	0.19	0.02	0.17	0.2	8.46	0.02
	Dry	1.12	0.67	0.11	1.48		
Phospor	Wet	12.56	1.57	10.95	14.7	0.02	0.00
	Dry	21.83	1.59	20.55	24.15		
Kalium	Wet	0.35	0.03	0.32	0.38	8.65	0.00
	Dry	0.23	0.04	0.19	0.26		
CEC	Wet	61.03	1.66	58.73	62.25	1.75	0.00
	Dry	47.31	3.26	45.68	52.2		

Table 2. Correlation between variables

Soil properties	Total nitrogen	Phospor	Kalium	CEC
pH	0.33	0.457	0.231	0.642
Total Nitrogen		0.138	0.092	0.045
Phospor			0.853	0.95
Kalium				0.823

(Ngan *et al.*, 2024). The kinetics and absorption of nutrients are limited by the pH and CEC. Previous studies usually indicated that COOH and OH groups were depleted and reduced the ability of peat soil to retain nutrients and drain them as pH and CEC decreased (Lucas and Re, 1982).

The amount of N ranged between 0.11–1.48%, this value is in the range for oligotrophic peat (1–4%) (Imanudin *et al.*, 2022; Jayasekara *et al.*, 2025). The result showed that total nitrogen in dry season is lower compared to the rainy season, higher moisture content promotes the activity of microorganisms responsible for decomposing organic matter. This can lead to an increase in the release of nutrients, especially nitrogen, into the soil. During the dry season, the lack of moisture reduces microbial activity and slows down the decomposition of organic matter (Dettmann *et al.*, 2021). This results in less mineralization, which means fewer nutrients like nitrogen and phosphorus are available for plant uptake. The low concentration of K in this study is indicated to be caused by the dominance of acidic cations (H^+ and $Al3^+$), which is shown by the low pH of the soil, as well as the high mobility of K, making it easy to leach in soil solutions. While the latter was demonstrated by the large amount of K that leached from the column, the former was validated by the noteworthy correlation between pH and K.

The impact of water management on nutrient dynamics on soil fertility conditions during the rainy season (sample collection) indicates that soil pH is classified as acidic. There are no significant qualitative differences at various levels of water table inundation. The land drainage condition is very poor, with a natural decrease in water table of only 1 cm/ha in the absence of rain. The high inundation treatments T1-T4 show that the pH under inundation conditions is better compared to dry soil conditions. Soil pH ranges from very acidic to acidic. This is consistent with the research by Lee *et al.* (2021), which suggests that soil drying can reduce soil acidity. Under wet soil conditions, the redox potential (Eh) decreases, which in turn increases the pH value. Furthermore, according to Imanudin *et al.* (2019), soil drying can sharply increase exchangeable acidity, such as $Al3^+$ or H^+, compared to rewetting. This condition can decrease soil pH. Similarly, [42] found that soil moisture and pH decrease as groundwater depth increases. Therefore, amelioration efforts in peatland cultivation are still necessary.

Cereal crops other than rice require the groundwater level to be between 30–40 cm, as at this level the groundwater condition remains sufficiently moist and can meet the plant's evapotranspiration needs. Water retention in tertiary channels at a water level of 60–80 cm is adequate to create groundwater conditions in the root zone at a depth of -40 cm, in accordance with soil management requirements. No sulfuric acid layers were found up to a depth of 1.5 meters in the area due to the peat thickness being greater than 2 meters. This condition prevents a sharp decrease in pH during groundwater level declines to -50 cm (September) (Zhang *et al.*, 2018). Once the rainy season begins, some toxic substances are leached out, and with increasing inundation, the soil pH rises again. This is consistent with Hashim *et al.* (2019) study, which found that soil in a reduced state (waterlogged soil) can raise soil pH, and the pH increases with the duration of waterlogging, although the increase is not very high. The reduction process involves the consumption of H+ ions equivalent to the amount of Fe^{2+} or H_2S formed. The overall effect of waterlogging is to increase soil pH, particularly in acidic soils. The significant impact of waterlogging is similar to liming, achieving an optimal pH range that allows for the availability of most nutrients. Reduction is considered most important as it can raise pH, increase phosphorus availability, and replace cations in the exchange sites.

Research shows that under high groundwater conditions, nutrient leaching occurs, resulting in lower macro-nutrient values in the soil samples taken from waterlogged conditions. This is consistent with Imanudin *et al. (*2022), which states that under waterlogged conditions, there is a significant decrease in soil nutrients due to leaching. Conversely, when the groundwater level decreases to 40–80 cm, leaching decreases, leading to an increase in nutrient availability for plants (Damanik *et al.*, 2023).

Managing water levels below 30–40 cm will also significantly affect the availability of several macro-nutrients in the soil. This is in line with the research by Zhang *et al.* (2018), which indicates that groundwater dynamics influence nutrient availability in the plant root zone. Figure 1 shows an increase in nitrogen and phosphorus as a result of the decrease in groundwater level. Under the conditions where the soil experiences air accumulation (anoxic) due to an increase in the ground water level, this will accelerate the accumulation of nitrogen in the soil. Next, nitrogen

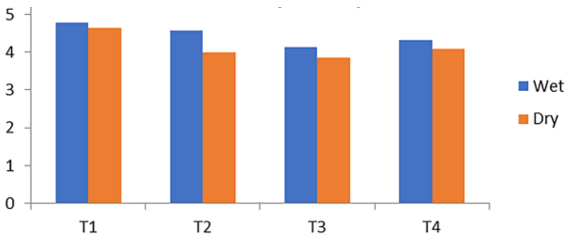

Figure 1. The soil reaction on peat soil at wet and dry soil sampling condition

mineralization and nitrification occur in the soil oxidation layer at the groundwater interface under submerged conditions. Denitrification and ammonia evaporation are the main mechanisms resulting in the loss of nitrogen in the topsoil in an alkaline environment. In addition, tidal water cycles from river basins and surface runoff, will carry large amounts of suspended material as well as carry plant waste, which can affect nitrogen retention (Hashim *et al.*, 2019). The availability of nitrogen macronutrients mostly hangs in the soil with a thickness of the top 20 cm. According to Striling *et al.* (2020); Imanudin *et al.* (2022), maintaining ground water table under 50 cm is the optimum operation for providing nutrient availability, and crop growth environment. Consistent with the research by Imanudin *et al.* (2022), experiments with oil palm seedlings show nutrient loss occurs at shallow groundwater levels (0–25 cm) and at levels greater than 75 cm. The optimal nutrient absorption value is found at a depth of 50 cm (Kassim and Yaacob, 2019).

Soil phosphorus content is also influenced by fluctuations in groundwater level (Figure 2). Analysis results show that phosphorus levels are low under wet conditions and moderate under dry conditions (groundwater level -40 cm). This is consistent with the research by Obour *et al.* (2011), which states that phosphorus levels significantly increase at a groundwater depth of 40 cm below the soil surface. Similarly, Rupngam and Messiga (2024), found that fluctuating groundwater levels during the dry-wet seasons lead to increased phosphorus flux from the Bh horizon, enhancing phosphorus availability in the plant root zone.

Analysis results show that cation exchange capacity (CEC) decreases with a lowering groundwater depth. The CEC value during sampling under wet conditions ranged from 58–62 me/100 g, while in moist soil (groundwater depth 40–45 cm, representing the water table during the dry season) the CEC value ranged from 45–52 me/100 g.

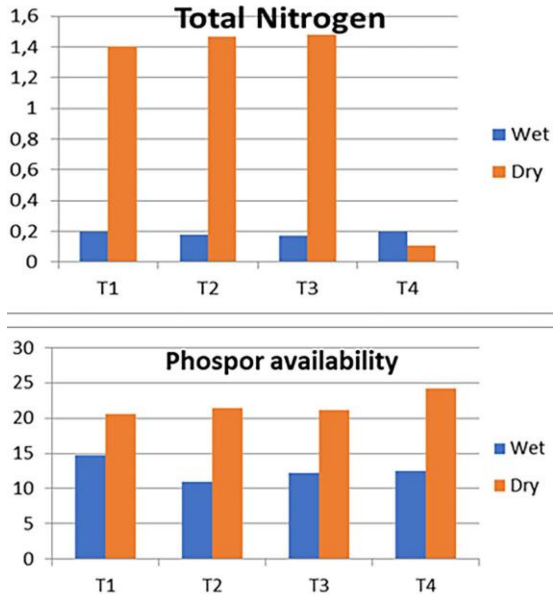

Figure 2. Dynamics of macro-nutrients nitrogen and phosphorus under wet and dry conditions

Although qualitatively, the peat soils in the Perigi area have very high CEC values. This is consistent with Becher *et al.* (2020), exchange capacity. This is suspected to be due to moisture levels at varying groundwater heights affecting the organic carbon content, which shows an increase in organic carbon values. Organic carbon values indicate that the organic matter in peat soils has already decomposed. According to Kassim and Yaacob (2019), soil cation exchange capacity is greatly influenced by soil organic matter content. Decomposed organic matter has functional groups ($COOH^-$) that can contribute negative charges, thereby enhancing cation exchange in peat soils, making the CEC higher with greater organic carbon content. Therefore, controlling groundwater levels is crucial for agricultural practices in peatlands. Maintaining the water table at -40 cm is the best option for providing crop nutrients. Nitrogen and phosphorus are more available at a groundwater level of 40 cm (Suryani *et al.*, 2022) (Figure 3).

The CEC of soil depends on soil texture, the type of clay minerals, and organic matter content. The higher the clay content or the finer the texture, the greater the CEC. Similarly, higher soil organic matter content results in a higher CEC Hannu *et al.* (2024), In agricultural practice, measuring the actual CEC and pH of the soil can help farmers determine the appropriate type and dosage of fertilizers for their crops. By understanding the soil's CEC and pH, farmers can optimize plant growth and avoid damage from over-fertilization or

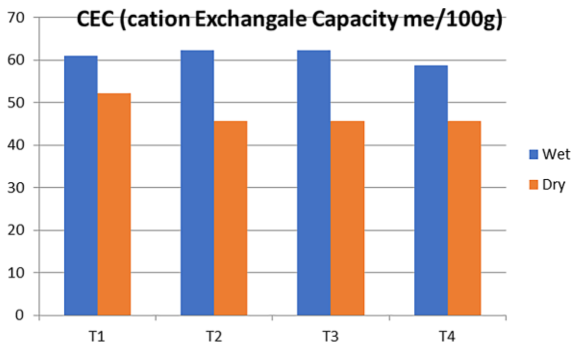

Figure 3. Dynamics of soil cation exchange capacity (CEC) under wet and dry conditions (groundwater level -45 cm)

under-fertilization. Measuring CEC and soil pH helps maintain the balance of soil chemical properties and ensures optimal plant growth (Chen *et al.*, 2024). CEC is crucial for plant productivity because it affects how many nutrients are retained and available in the soil. Soils with low CEC cannot retain and hold essential nutrients like ammonium (NH_4^+), Ca_2^+, Mg_2^+, K^+, and Na^+ effectively.

CONCLUSIONS

Soil nutrient dynamics show a decrease in pH values when the soil dries out, it means that the pH during the rainy season is higher than under the dry conditions. This is inversely proportional to the Nitrogen nutrient in the season dry season has higher levels than the rainy season. Likewise, it is followed by phosphorus content. Only the CEC and K-dd values in the rainy season have values which is higher compared to the dry season.

The data on nutrient dynamics and groundwater levels is important for farmers to understand when to apply fertilizer appropriately and plan land use in the future. Proper water management by maintaining a water level of 40–50 cm can increase fertilizer efficiency.

Acknowledgments

The research was funded by collaboration research between National Institute of Forest Science (NIFoS) Republic of Korea and Sriwijaya University Indonesia. The authors would like to acknowledge Deasy. M.Irfan support, and Sumantri and Agus Prihanto for the field assistance during the field survey

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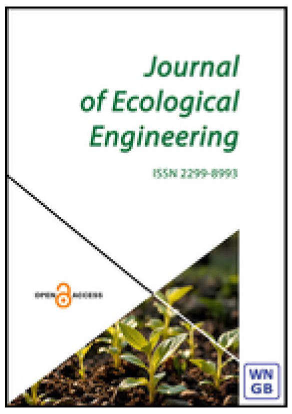

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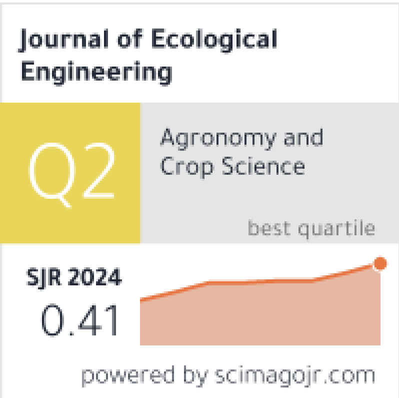

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Volume 26, Issue 10, 2025

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Anna Figas, Magdalena Tomaszewska-Sowa, Dorota Olszewska, Sara Michaś, Anetta Siwik-Ziomek

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Stats

Abstract

Circular bioeconomy strategy for livestock waste: Valorizing biogas slurry as a low-nutrient source for *Nannochloropsis* sp. cultivation

Dhomas Indiwara Prana Jhouhanggir, Ambar Pertiwiningrum, Nanung Agus Fitriyanto, Eko Agus Suyono

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Stats

Abstract

Groundwater quality in coal mines of Ukraine: Possibility of using as drinking water

Iryna Shvets, Yevgen Zbykovskyy, Olha Bohomaz

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Stats

Abstract

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pharmaceutical industry

Fatkhiyatus Sa'adah, Heri Sutanto, Hady Hadiyanto, Ali Khumaeni, Wahyu Zuli Pratiwi

J. Ecol. Eng. 2025; 26(10):42-57

Stats

Abstract

Tree risk assessment for enhancing urban green space resilience in Surakarta

Sovia Wijayanti, Sapta Suhardono, Sunarto Sunarto

J. Ecol. Eng. 2025; 26(10):58-69

Stats

Abstract

Indoor air quality parameters in a didactic room in central Poland

Katarzyna Gładyszewska-Fiedoruk, Józefa Wiater

J. Ecol. Eng. 2025; 26(10):70-77

Stats

Abstract

Agricultural runoff and relief factors as determinants of well water contamination in Kosovo's vineyard region

Ilir Mazreku, Donjeta Kukalaj, Kemajl Bislimi, Ylli Krasniqi, Valon Morina

J. Ecol. Eng. 2025; 26(10):78-86

Stats

Abstract

Sublethal effects of polyvinyl chloride microplastics on growth performance and survival of whiteleg shrimp (*Litopenaeus vannamei*)

Bagus Dwi Hari Setyono, Ramida Saharani, Yuliana Asri, Syawalina Fitria, Thoy Batun Citra Rahmadani, Awan Dermawan, Hanif Cahyo Wicaksono, Rangga Idris Affandi

J. Ecol. Eng. 2025; 26(10):87-102

Stats

Abstract

Potential agroforestry system on peat land to improve soil chemical properties in Palangkaraya, Central Borneo

Fitri Wijayanti, Anita Dwy Fitria, Adi Jaya Adi, Haidar Fari Aditya, Safira Rizka Lestari, Maroeto Maroeto

J. Ecol. Eng. 2025; 26(10):103-115

Stats

Abstract

Cochineal powder as an eco-friendly carotenoid supplement to enhance coloration in *Betta splendens*

R Adharyan Islamy, Rizky Trisna Putri, Nurul Mutmainnah, Fitri Sil Valen, Ahmad Syazni Kamarudin, Veryl Hasan

J. Ecol. Eng. 2025; 26(10):116-125

Stats

Abstract

Ecological insights into weed seed bank dynamics: Management strategies through tillage and mulching interventions in Maize (*Zea mays* l.) fields

Ijaz Ahmad, Rana Nadeem Abbas, Zubair Aslam, Muhammad Anwar -Ul-Haq

J. Ecol. Eng. 2025; 26(10):126-143

Stats

Abstract

Synthesis and characterization of magnetic nanoparticles coated with citric acid as a coagulant for the Tigris River treatment

Miqat Hasan Salih

Abstract

Varietal features and sowing dates of wheat winter as factors of increasing the sustainability of agroecosystems

Ihor Kovalenko, Olha Bakumenko, Yevheniia Butenko, Oksana Datsko, Mykola Zheldubovskyi, Danyil Naumov, Nelli Kozhushko, Ihor Masyk, Olena Osmachko, Olesia Danylchenko

J. Ecol. Eng. 2025; 26(10):156-165

Stats

Abstract

Synthesis of eco-friendly activated biochar using mix shells as an adsorbent for phenols from waste water

Sara Assif Alfyad, Nagam Obaid Kariem, Zainab A Naser

J. Ecol. Eng. 2025; 26(10):166-179

Stats

Abstract

Fertilizer changes soil bacteria community and soil quality on coffee agroforestry in the tropic

Rima Rahwani Matondang, Reni Ustiatik, Silvia Febiona, Syahrul Kurniawan

J. Ecol. Eng. 2025; 26(10):180-190

Stats

Abstract

Dynamics of nutrient release rate and pattern from pyroclastic material due to the influence of humic substances and potassium-solving bacteria

Kurniati Kurniati, Suwardi Suwardi, Budi Mulyanto, Budi Nugroho

J. Ecol. Eng. 2025; 26(10):191-199

Stats

Abstract

Assessment of waste cooking oil-based biodiesel blend: Properties, performance and optimal blend ratio

Kadumcanadka Srithejas, Vikram Athreya, Pathirimadam Santhamallappa Prajwal, Raghu Ram Achar, Kalya Tulasidas Vadiraj

J. Ecol. Eng. 2025; 26(10):200-210

Stats

Abstract

Ecological and health risks of microplastic contamination in edible fish from the Musi River Palembang, Indonesia

Khairil Anwar, Nurhayati Damiri, Yuanita Windusari, Mohammad Zulkarnain

J. Ecol. Eng. 2025; 26(10):211-226

Stats

Abstract

Analysis of tools supporting public transport travel in Lublin, taking into account a dedicated solution

Kamil Zieliński

J. Ecol. Eng. 2025; 26(10):227-237

Stats

Abstract

Optimizing aquaculture sustainability: Synergistic role of bio-silica fertilization and soil remediation in improving water quality and plankton productivity in acid sulfate soil

Nur Asia Umar, Muh Hatta, Agustin Rustam, Sutia Budi, Tarunamulia Tarunamulia, Kamariah Kamariah

J. Ecol. Eng. 2025; 26(10):238-251

Stats

Abstract

EN PL

and emerging applications (1955–2024)

Ilham Misbakudin Al Zamzami, Defri Yona, Abd Rahem Faqih, Andi Kurniawan

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Stats

Abstract

Study of the effect of bacterial bioactivator on the content of phenolic compounds in *Salvia sclarea* L.

Aidai Turatbekova, Dilbar Mirzarakhmetova, Nan Shang, Gulnara Dzumaniyazova, Yunus Kenjaev, Zamira Abdushukurova, Umida Kurbanova, Nusratillo Toshpulatov, Ismoiljon Rozikov, Makhbuba Khayitova

J. Ecol. Eng. 2025; 26(10):272-290

Stats

Abstract

Assessment of groundwater quality-case study, Suharekë Municipality, Kosovo

Hazir S. Çadraku, Agron Shala, Skender Bublaku

J. Ecol. Eng. 2025; 26(10):291-315

Stats

Abstract

Characteristics of bio-briquettes from candlenut shells as a renewable energy: Selection of adhesive type, adhesive concentration, and biochar particle size

Rosdanelli Hasibuan, Juliza Hidayati, Erni Misran, Rosma Natalia Samosir, Anggi Julia Sitohang, Viqry Pramananda, Risma Fazillah

J. Ecol. Eng. 2025; 26(10):316-327

Stats

Abstract

Optimization of culinary wastewater treatment using intermittent slow sand filter with bacterial augmentation to remove biochemical oxygen demand, chemical oxygen demand, and phosphate

Nurina Fitriani, Vindi Elsa Fatikasari, Ni'matuzahroh Ni'matuzahroh, Moch. Affandi, Eddy Setiadi Soedjono, M. Bagas Pramudya Pratama, Radin Maya Saphira Binti Radin Mohamed

J. Ecol. Eng. 2025; 26(10):328-339

Stats

Abstract

Green synthesis of reduced graphene oxide using *Indigofera tinctoria* leaf extract and its antibacterial activity against *Escherichia coli*

M. Yasser, Abd. Wahab, Abdul Karim, St. Fauziah

J. Ecol. Eng. 2025; 26(10):340-351

Stats

Abstract

Facile synthesis and catalytic evaluation of iron-doped ZnO nanocatalysts for biodiesel production

Jaffar Hussain, Zeenat Muhammad Ali, Farman Ali Shah, Abdul Qadeer, Abdul Nasir Laghari, Munazza Sohil

J. Ecol. Eng. 2025; 26(10):352-359

Stats

Abstract

Dispersion modelling of methane emissions from Indonesian landfills using air quality dispersion modeling

Nita Citrasari, Chita Melati Ghea Wasturani, Clarissa Dinda Ayu Zahra, Dwi Ratri Mitha Isnadina, Sucipto Hariyanto, Muhammad Abdus Salam Jawwad, Indriyani Rachman, Toru Matsumoto

J. Ecol. Eng. 2025; 26(10):360-373

Stats

Abstract

disintegration

Dalia Ahmed, Ahmed M. Aboulfotoh, Zaki Elsafty

J. Ecol. Eng. 2025; 26(10):374-388
Stats

Abstract

Groundwater quality assessment for the wells system in Zurbatiyah, Iraq, for civil and irrigation uses by two water quality index approaches

Marwan Arkan Hussein, Sadiq Salman Muhsun, Zaidun Naji Abudi

J. Ecol. Eng. 2025; 26(10):389-402
Stats

Abstract

Analysis of precipitation and runoff in Carpathian catchments using the soil and water assessment tool model

Stanisław K. Lach, Marek T. Kopacz, Agnieszka Kowalczyk, Beata Grabowska-Polanowska

J. Ecol. Eng. 2025; 26(10):403-415
Stats

Abstract

Impacts of railway transportation on the enrichment of heavy metals in hortisols of allotment gardens in the city of Zawadzkie

Izabella Pisarek, Kamila Śmieszkoł, Aleksandra Cichoń, Magdalena Śliwa, Dżoana Latała-Matysiak, Katarzyna Łuczak, Grzegorz Maciej Kusza

J. Ecol. Eng. 2025; 26(10):416-425
Stats

Abstract

Comparative evaluation of phytoplankton-based indices for water quality assessment in tropical lentic ecosystems of Thailand

Peangtawan Phonmat, Ratcha Chaichana, Chuti Rakasachat, Pawee Klongvessa, Wirong Chanthorn, Sitthisak Moukomla

J. Ecol. Eng. 2025; 26(10):426-438
Stats

Abstract

Seasonal variability of physicochemical parameters in stormwater sediments as indicators of urban environment

Edyta Wojtaś, Justyna Kujawska, Grzegorz Łagód

J. Ecol. Eng. 2025; 26(10):439-449
Stats

Abstract

Influence of soil characteristics on the distribution and evolution of Trollius dschungaricus Regel populations in the Northern Tien Shan, Kazakhstan

Dina Karabalayeva, Meruyert Kurmanbayeva, Kanat Kulymbet, Adil Kusmangazinov, Moldir Zhumagul, Raiymbek Anatoliy, Madina Saken, Meruyert Kuanyshbayeva, Bagdagul Alzhanova

J. Ecol. Eng. 2025; 26(10):450-459
Stats

Abstract

The impact of physical-geographical conditions on the sizing of rain gardens: A spatial case of Poland

Anita Białek, Grzegorz Łagód

J. Ecol. Eng. 2025; 26(10):460-476
Stats

Abstract

Instructions for Authors

All issues

Articles in press

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Month Year

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Indexes

Keywords index

Authors index

Journal of Ecological Engineering
ISSN 2299-8993

All issues

Volume 26, Issue 6, 2025

Presence of potentially toxigenic cyanobacteria and characterization of the aquatic environment in the irrigation system of the Arequipa countryside, Peru

Luis Fernando Del Carpio Ccapa, Piero Ayma Condo, Cesar Augusto Ranilla Falcon

J. Ecol. Eng. 2025; 26(6):1-11
DOI: https://doi.org/10.12911/22998993/200276
Stats

Abstract Article (PDF)

Effects of partial root-zone drying and deficit irrigation on yield, quality and water productivity of Washington Naval orange

Salah Belkher, Basma Iatrech, Mourad Rezig, Rym Bouhlal, Wifak Bekri, Felix Markwordt, Corentin Dupont, Mohamed Abdur Rahim, Hedi Daghari, Mohamed Ali Ben Abdallah

J. Ecol. Eng. 2025; 26(6):12-27
DOI: https://doi.org/10.12911/22998993/200478
Stats

Abstract Article (PDF)

Optimizing electric discharge cavitation processes as green solution for enviromental safety

Antonina Malyushevskaya, Olena Mitryasova, Justyna Zamorska, Andrii Mats

J. Ecol. Eng. 2025; 26(6):28-35
DOI: https://doi.org/10.12911/22998993/201436
Stats

Abstract Article (PDF)

Reduction of pollution of vegetable oil refinery effluents by flotation: Case of phenol, detergents, ammonium, nitrates, and total phosphorus

Amina Khalidi-Idrissi, Malika Kastali, Latifa Mouhir, Safaa Khattabi Rifi, Oussama Hartal, Abdelaziz Madinzi, Salah Souabi

J. Ecol. Eng. 2025; 26(6):36-47
DOI: https://doi.org/10.12911/22998993/201993
Stats

Abstract Article (PDF)

Controlled-release pesticide nanofibers for sustainable agriculture: Effects of processing parameters on fiber morphology and release kinetics

Vu Anh Doan, Le Thanh Hai Anh, Tuan Anh Phung, Duc Minh Vu, Vu Tran Khac, Liem Thanh Nguyen

J. Ecol. Eng. 2025; 26(6):48-61
DOI: https://doi.org/10.12911/22998993/201995
Stats

Abstract Article (PDF)

Adsorption kinetics and isotherm study of ammonium and phosphate removal using magnesium-activated biochar

I Made Wahyu Wijaya

J. Ecol. Eng. 2025; 26(6):62-75
DOI: https://doi.org/10.12911/22998993/201996

Enhancing wheat resistance to salinity: The role of gibberellic acid and β-Carotene in morphological, yielding and ionic adaptations

Mudassar Nadeem, Muhammad Shahbaz, Farooq Ahmad, Ejaz Ahmad Waraich

J. Ecol. Eng. 2025; 26(6):76-94
DOI: https://doi.org/10.12911/22998993/202091

Stats

Abstract Article (PDF)

Optimizing chemical oxygen demand and total nitrogen removal from tofu wastewater using a multi-rod helical electrocoagulation system in a tubular reactor

Rachmad Ardhianto, Afifah Yusrina, Mardiah Rangkuti

J. Ecol. Eng. 2025; 26(6):95-109
DOI: https://doi.org/10.12911/22998993/202092

Stats

Abstract Article (PDF)

Development of lightweight foamed concrete using surface-modified oil palm kernel shell

Abdullah Mahmud, Izarul Machdar, Sofyan Sofyan, Wahyu Rinaldi, Ernawati Ernawati, Riazhul Jannah, Giovani Giovani

J. Ecol. Eng. 2025; 26(6):110-119
DOI: https://doi.org/10.12911/22998993/202130

Stats

Abstract Article (PDF)

Sustainable valorization of marine dredged sediments from Jebha port as a partial sand replacement in eco-friendly concrete

Khadija Benhaddou, Ayoub Souileh, Achraf Mabrouk, Latifa Ouadif, Sabihi Abdelhak, Khadija Baba, Mustapha Rharouss

J. Ecol. Eng. 2025; 26(6):120-133
DOI: https://doi.org/10.12911/22998993/202133

Stats

Abstract Article (PDF)

Long-term effects of olive mill wastewater on the physicochemical properties of a wastewater treatment plant in central Morocco – Wastewater quality index approach

Maria El Ouazzani, Mustapha Afdali, Naaila Ouazzani, Abdelmajid Haddioui

J. Ecol. Eng. 2025; 26(6):134-149
DOI: https://doi.org/10.12911/22998993/202234

Stats

Abstract Article (PDF)

Fertigation with sprinklers: Food and water security on the Ukrainian steppe

Dmytro Onopriienko, Hennadii Hapich, Andrij Tkachuk, David Dent, Volodymyr Kovalenko, Tetiana Makarova, Hynek Roubík

J. Ecol. Eng. 2025; 26(6):150-161
DOI: https://doi.org/10.12911/22998993/202346

Stats

Abstract Article (PDF)

Nutrient dynamics in peat soil application under water management planning: A case study of Perigi, South Sumatra, Indonesia

Bakri Bakri, Momon Sodik Imanudin, Muh Bambang Prayitno, A. Hermawan, Assad Syazili, Leviana Leviana, Eunho Choi, Hyunyoung Yang

J. Ecol. Eng. 2025; 26(6):162-169
DOI: https://doi.org/10.12911/22998993/202347

Stats

Performing acute phytotoxicity of widely used drugs on germination and root elongation of *Lactuca sativa* L.

Kateryna Tsytlishvili

J. Ecol. Eng. 2025; 26(6):170-178
DOI: https://doi.org/10.12911/22998993/202348

Stats

Abstract Article (PDF)

Accelerated degradation of low-density polyethylene by bacteria isolates: Insights from Surabaya River, Indonesia

Atik Widiyanti, Eddy Setiadi Soedjono, Maya Shovitri, Adhi Yuniarto, Muchammad Tamyiz

J. Ecol. Eng. 2025; 26(6):179-188
DOI: https://doi.org/10.12911/22998993/202494

Stats

Abstract Article (PDF)

Sustainable synthesis of carbon nanomaterials from waste tire-derived char using microwave pyrolysis

Amani Hussein Sharaf Addin, Raihan Mahirah Ramli, Suriati Sufian, Najib Al-Mahbashi, Siti Shawalliah Idris, Abid Salam Farooqi, Shakimi Haikal Shamsu Bakri

J. Ecol. Eng. 2025; 26(6):189-201
DOI: https://doi.org/10.12911/22998993/201751

Stats

Abstract Article (PDF)

Sustainable management of coastal organic waste: A pilot study on beach wrack treatment in reed bed system

Alicja Kupczyk

J. Ecol. Eng. 2025; 26(6):202-218
DOI: https://doi.org/10.12911/22998993/201994

Stats

Abstract Article (PDF)

Environmental effects of coal power plant expansion on plankton and benthos in Tanjung Jati's marine ecosystem

Slamet Isworo, Poerna Sri Oetari, Handung Nuryadi

J. Ecol. Eng. 2025; 26(6):219-240
DOI: https://doi.org/10.12911/22998993/202495

Stats

Abstract Article (PDF)

Effects of oil palm bunches and coal fly ash on the cation exchange capacity of reclaimed mining soil

Akhmad Rizalli Saidy, Bambang Joko Priatmadi, Meldia Septiana, Abdul Haris, Ronny Mulyawan, Andin Muhammad Abduh, Aditya Dyah Utami

J. Ecol. Eng. 2025; 26(6):241-250
DOI: https://doi.org/10.12911/22998993/202657

Stats

Abstract Article (PDF)

Biosorption technique using water hyacinth plant as an effective and sustainable approach for treating oil refinery waste: Vanadium element as a case study

Suadat Mustafa Mohammed Al-Hermizy, Halah Abdulkhaliq Awadh, Mohammed Nsaif Abbas

J. Ecol. Eng. 2025; 26(6):251-272
DOI: https://doi.org/10.12911/22998993/202658

Stats

Abstract Article (PDF)

Manabi, Ecuador

Allison Skarlet Linzan Cedeño, Juan Horacio Alcivar Hidrovo, Carlos Alfredo Salas Macias, Anderson Javier Pazmiño Castro, Freddy Alain Mendoza Rivadeneira, Ramona Cecilia Párraga, Humboltd Octavio Moreira Menendez, Cesar Moreira Alcivar, Orestes La O León

J. Ecol. Eng. 2025; 26(6):273-281
DOI: https://doi.org/10.12911/22998993/202659

Stats

Abstract Article (PDF)

Wastewater treatment and biogas production from fish cracker (Krepoh) production process using anaerobic digestion system

Yakoh Karemdabeh, Niramon Juntarachat, Chokchai Mueanmas

J. Ecol. Eng. 2025; 26(6):282-297
DOI: https://doi.org/10.12911/22998993/202750

Stats

Abstract Article (PDF)

Comparative analysis of phosphorus removal efficiency from water on selected filter beds for use in the natural swimming pond filtration systems

Artur Serafin, Wojciech Walczak, Tadeusz Siwiec

J. Ecol. Eng. 2025; 26(6):298-314
DOI: https://doi.org/10.12911/22998993/201975

Stats

Abstract Article (PDF)

BIoindication characteristics of trees in solid protection forest strips depending on intensive agriculture

Ihor Didur, Oleksandr Tkachuk, Apantsyreva Hanna Pantsyreva, Yaroslav Chabanuk, Snizhana Pankova, Halyna Hutsol, Olha Mazur, Nataliia Kovka

J. Ecol. Eng. 2025; 26(6):315-328
DOI: https://doi.org/10.12911/22998993/202749

Stats

Abstract Article (PDF)

Environmental effects of coal mine closures in the Lower Silesian Coal Basin, Poland

Maria Hełdak, Joanna Lipsa, Ryszard Pokładek

J. Ecol. Eng. 2025; 26(6):329-341
DOI: https://doi.org/10.12911/22998993/202630

Stats

Abstract Article (PDF)

Green synthesis of ferrous sulfide and magnesium sulfide nanoparticles and evaluation of their applications in photocatalytic degradation and antimicrobial activity

Elizabeth M. Kezia, Randhi Uma Devi

J. Ecol. Eng. 2025; 26(6):342-351
DOI: https://doi.org/10.12911/22998993/202912

Stats

Abstract Article (PDF)

Effects of plant density and fertilisation on yield structure and yield elements of maize hybrids for biofuel production

Serhii Bogomaz, Kristina Zayka, Ihor Didur, Olena Mazur, Oleksandr Mazur, Viacheslav Tsyhanskyi

J. Ecol. Eng. 2025; 26(6):352-364
DOI: https://doi.org/10.12911/22998993/202943

Stats

Abstract Article (PDF)

Amino-functionalized dendritic mesoporous silica nanoparticles for removal of copper from aqueous solutions

EN PL

DOI: https://doi.org/10.12911/22998993/202979
Stats

Abstract Article (PDF)

Synthesis and characterization of slow release fertilizer nitrogen and slow release fertilizer potassium based on biochar with nanotechnology and alginate

Nia Herlina, Sri Nuryani Hidayah Utami, Makruf Nurudin, Eko Hanudin

J. Ecol. Eng. 2025; 26(6):378-390
DOI: https://doi.org/10.12911/22998993/202978
Stats

Abstract Article (PDF)

Enhancing phytoremediation of heavy metals: A comprehensive review of performance microorganism-assisted *Cyperus rotundus* L.

Novianti Adi Rohmanna, Lya Agustina, Riza Adrianoor Saputra, Noorkomala Sari, Ihsan Noor, Zuliyan Agus Nur Muchlis Majid

J. Ecol. Eng. 2025; 26(6):391-401
DOI: https://doi.org/10.12911/22998993/202998
Stats

Abstract Article (PDF)

The possibility of the neutralisation and precipitation of heavy metals in industrial wastewater from oil emulsion processing

Aleksandra Chrapczyńska, Magdalena Chandzlik, Aleksandra Kosior, Karolina Nikiel, Anna Puchalik, Dariusz Szufłat, Mariusz Jurzak, Łukasz Żoczek, Klaudiusz Grübel

J. Ecol. Eng. 2025; 26(6):402-409
DOI: https://doi.org/10.12911/22998993/202752
Stats

Abstract Article (PDF)

Development of a computational tool for stormwater management in small urban catchments

Anita Białek, Anna Musz-Pomorska

J. Ecol. Eng. 2025; 26(6):410-423
DOI: https://doi.org/10.12911/22998993/202322
Stats

Abstract Article (PDF)

Impact of beaver dams on watercourse hydrology and morphology change in the Roztocze National Park

Katarzyna Kuśmierz, Antoni Grzywna, Agata Basak

J. Ecol. Eng. 2025; 26(6):424-436
DOI: https://doi.org/10.12911/22998993/202623
Stats

Abstract Article (PDF)

The phytoremediation of manganese in Gumuskoy (Kutahya-Türkiye) mining soils by the native plants

Nevin Konakcı, Ahmet Sasmaz

J. Ecol. Eng. 2025; 26(6):437-446
DOI: https://doi.org/10.12911/22998993/203228
Stats

Abstract Article (PDF)

Impact of Faisalabad industrial and domestic wastewater on stress morphophysiological and biochemical responses of lettuce (*Lactuca sativa* L.)

Hafiza Iqra Almas, Fahd Rasul, Muhammad Shahbaz, Ghulam Mustafa

J. Ecol. Eng. 2025; 26(6):447-463
DOI: https://doi.org/10.12911/22998993/203266

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Indexes

Keywords index

Authors index

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Indexes

Keywords index

Authors index