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Assessment of Soil Respiration Under Different Land Use in East Kutai, Indonesia

Liris Lis Komara♥, Eka Sulastri, Veronika Murtinah[1], and Nanang Sasmita
Forestry Study Program, East Kutai Agricultural College School, North Sangatta, Indonesia
♥Corresponding author email: lirisliskomara@gmail.com

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Abstract. Forest areas are where the most advanced water and air cycles occur and cannot be replaced by any man-made products. For this reason, Indonesians' lives and forest lands are inextricably linked as economic resources. Deforestation also occurs at a considerable rate in East Kutai Regency. Changes in the area of forest land, which is continuously decreasing, followed by a growth in land area for other uses, including mining and plantations, serve as examples of this circumstance. To determine whether the conversion of this area is genuinely balanced between measures to protect the environment and the health of the soil and its economic value, more research must be done. One way to find out is to examine soil respiration in several locations. The purpose of the research was to compare soil respiration levels in three types of land cover in East Kutai Regency. The data collection method involves taking 0 – 30 cm depth of soil sample at three points in three locations, namely Rubber plantation, Teak plantation and Botanical Gardens. The total soil microorganism count is determined by soil organic carbon. The overall number of soil microorganisms increases with soil organic matter. Next, the soil samples are tested in the laboratory for colony total number. The study's findings indicated that the teak plantation had the lowest soil respiration, at21.37±0.9, and the Botanical Garden location had the highest, at29.87±1.91. The high total number of soil microorganisms makes respiration high because it produces high CO_2, which is caused by the high activity of the microorganisms in the soil.

Keywords: land use; microorganisms; organic carbon; soil respiration

INTRODUCTION

Forests provide life on Earth and sustain the living things in their habitat. Environmentalists say that forests are the world's lungs, while water is said to be the lifeblood of humanity. Tree roots that grow in the forest function to absorb water (Rahardjo et al., 2009) and send it to the earth. Forest areas are engines of environmental ecosystem circulation. Forest areas are the most advanced water and air cycles and cannot be replaced by any man-made products. Therefore, forest areas are an economic resource that cannot be separated from the lives of Indonesian people (Hidayat et al., 2021), because forests are a source of life for mankind. Forests play many roles in helping human life. These functions include: (a) Forests act as a carbon dioxide (CO_2) absorber (Witno et al., 2024) and enhance quality air (Has et al., 2024); (b) Forests play a role in controlling water (Shah et al., 2022); (c) Forests play a role in preventing landslides and preventing erosion (Grima et al., 2020); (d) Forests act as water catchment areas and providers of water resources (Springgay et al., 2021); and (e) Forests play a role in providing various kinds of human life needs (Hendrati, 2019).

The rate of deforestation in Indonesia is high, including in Kalimantan (Wegscheider et al., 2019). Deforestation is also occurring in East Kutai Regency, one of the regions that make up 17% (357474.50 Km^2) of East Kalimantan's total area. This state is demonstrated by changes in forest land, which is continuously decreasing, and then a growth in land area used for various uses, including plantations and mining. This land conversion needs to be studied to see whether the use of its economic value is truly balanced with efforts to preserve the environment and the health of the land. One way to find out is to examine soil respiration in several locations.

Soil respiration commonly refers to the natural release of CO_2 from the soil surface into the atmosphere (Irving et al., 2024; Barranco et al., 2025), primarily through either biological or mineralogical processes

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(Irving et al., 2024). The organic matter contained in the soil can be decomposed and mineralized by microbes, which will contribute to the nutrients needed by plants and improve the condition of the soil (Swaminathan et al., 2021). Soil respiration were count from the Microbial activity and its an important factor that influences plant growth and soil health (Vincze et al., 2024). In addition to biological (vegetation, microbes) and environmental (temperature, humidity, pH) influences, man-made factors have a greater impact on soil respiration (Tong et al., 2021). Microbial activity in the soil can be monitored from soil respiration (Widati, 2007). Because high soil respiration indicates the presence of sufficient organic matter, appropriate temperature, sufficient water availability, and supportive soil ecological conditions, knowing the microbial activity in the soil can help determine its fertility. Conversely, low respiration provides information on how to improve the ecological conditions on the land further (Widati, 2007).

Land use affects soil respiration (Vikram et al., 2022) and soil respiration studies are important to carry out so that land productivity is optimal. Based on this background, researchers are interested in conducting soil respiration research on three land uses in East Kutai Regency. The study's objective was to compare soil respiration levels in three types of land use in East Kutai Regency to find out how its microbial activity processes and how to improve soil conditions

METHOD

The research was carried out in 2023 at East Kutai, which has a land elevation of 07 to 1,000 meters above sea level (asl), is the location of the research. East Kutai Regency experiences 26°C average air temperature in a humid tropical forest climate. There is a 5°–7°C range or variation between the lowest and highest temperatures. The average annual rainfall is between 2,000 and 4,000 mm, and there are 130 to 150 days with rain on average. (East Kutai data portal). This research was carried out in three administrative locations, namely the North Sangatta District (teak plantation and botanical gardens which have mixed vegetation), and South Sangatta District (rubber plantations), the coordinates for the rubber plantation were at coordinates 0°18'39”– 0°29'44” N and 117°28'44 – 117°36'43 E, the teak plantation is at coordinates 00°32'18.4”N and 117°34'58.7” E, and the Botanical Garden is at coordinates 00°31'41”00 Nand117°36'15.3”E. Three different use location in were choosen, they are Rubber plantation, Teak plantation and Botanical Gardens.

Soil chemical sample analysis was conducted at the Soil Science Laboratory, Mulawarman University, Samarinda. Analysis of respiratory and microbial samples was done at the Laboratory of Biotechnology in Indonesian Education University of Bandung. Descriptive quantitative observation is the research approach used, namely direct field observation. Then determine the sampling point. One kg of soil sample was taken for chemical parameters (pH and Organic Carbon) which were then analyzed at the laboratory. A total of 300 g of soil was taken for microbial analysis (bacteria and fungi). The soil respiration measurement method is based on measuring sample incubation with 0.05 M NaOH solution and evaluated by titration using HCl solution (Husen et al., 2014).

The data collection method involves 0-30 cm depth of soil (Fu et al., 2024), at three points in three locations. Soil samples are tested in a laboratory. Orientation and observation activities are carried out to collect information and research location data which includes topography, geography, vegetation, climate and other supporting data. Supporting data as the first step in the work is equipped with research location maps, a global position system (GPS), stationery, and a documentation camera. Determining the location for taking soil sample points was carried out using systematic random sampling which was divided proportionally.

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The process of determining the sample is based on the diversity of a homogeneous population (Widati, 2007). There are three soil sampling locations, namely teak plantation, rubber plantation, and botanical gardens. Using a hoe, the top soil was excavated to a maximum depth of 30 cm, from which soil samples were gathered. On each land, several sample points will be taken at a distance of 50 meters.

The data and soil sample method were collected as below:

a. Soil moisture and temperature This activity was done in the field location; it is carried out by inserting a soil tester at each sub-sample point and then measuring soil moisture and temperature using a soil tester and a thermometer to record the results.
b. Analyze pH and soil organic carbon sampling for soil pH, and Organic Carbon analysis is carried out by taking 1kg of soil and then analyzing it in the laboratory.
c. Analysis of Microbial Abundance (Bacteria and Fungi) At each location, soil samples were taken with a scoop of 100 g of soil in a plastic clip and put in a black plastic bag so that it was not exposed to sunlight. The soil is stored in a cooler box to keep the temperature below 4 until it is time to identify and analyze it in the laboratory

In the laboratory, the soil organic carbon analysis was carried out using the Walkley and Black method (Abdullah et al., 2022). The microbial abundance was analyzed, to isolate microbes from samples in the form of soil around the research location and plant rhizosphere using the spread plate method with serial dilution techniques (Kannan et al., 2018).

1. Colony

Total Plate Count (TPC) is a method for determining the total amount of microorganisms (mold, yeast, and bacteria) in an ingredient. Plate Count Agar (PCA) is used as a medium for TPC analysis, with one gram of diluted material planted in a Petri plate and incubated. TPC computation results are expressed as colonies (cfu) per millilitre (Arifan et al., 2019). Colonies are counted using a colony counter, which meets the requirements to be counted in a colony number of 30-300. If the number of colonies >300 colonies, it is declared as Too Numerous To Count (TNTC) (Howen et al., 2022).

2. Soil Respiration

a. Molarity

This is done in the laboratory by preparing the chemical solution to be used. A 0.05 M HCl solution by diluting 4.14 ml of HCl with 1000 ml of distilled water is put into a agent bottle. $BaCl_2$ $2H_2O$ 0.5 M solution by diluting 30.5 grams of $BaCl_2.2H_2O$ with 250 ml of distilled water and put into a bottle. Phenolphthalein Indicator Solution 0.05% by diluting 0.05 g pp, adding 50 ml of ethanol and dissolving in 50 ml of distilled water. A 0.05M NaOH solution by diluting 2 grams of NaOH with 1000 ml of distilled water is put into a reagent bottle and closed tightly.

b. Incubation

Incubation is the process of capturing CO_2 in a jar using NaOH solution. Prepare as many jars as the samples are being analyzed. Next, prepare a paralon measuring 7 cm in the same diameter. Prepare 50 grams of dried soil samples. The next day's incubation treatment is to restore the soil water content to its original state. Next, prepare a 7 x 7cm wire as a support for the morin bottle, then prepare 10 ml of distilled water as a balancing indicator. Put the soil sample in, place 25 ml of NaOH solution right next to the sample

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container using a wire as a support so that the released CO_2 is immediately captured by the NaOH solution. After all the ingredients have been added, close it tightly and record the closing time. Cover with a dark cloth at room temperature and incubation can begin for approximately 20 hours.

After the data was collected, the data were evaluated using analysis of variance (ANOVA); then, the Least significant difference (LSD) test was used for means separation. Differences were considered statistically significant at $p < 0.05$, and the Pearson correlation test using Microsoft Excel software and presented in the form of tables and graphs

RESULTS AND DISCUSSION

1. pH and Soil Organic Carbon

Soil reaction indicates the soil acidity or soil alkalinity, which is expressed by the value of pH, which is used to express the concentration of hydrogen ions (H^+) in the soil. The degree of acidity in soil increases with the concentration of H^+ ions. In acidic soils, the H+ ions are more predominant than OH- ions, while in alkaline (basic) soils, the OH^- content is more than H^+. If the H^+ content is the same as OH^- then the soil reacts neutrally (Uchida & Nguyen Hue, 2020).

Table 1. Soil pH and Organic Carbon Content

No	Field Code	pH H_2O	C organic (%)
1.	Rubber Plantation	5.81± 0.03	1.09±0.36
2.	Teak Plantation	5.91± 0.08	0.34±0.29
3.	Botanical Garden	5.38± 0.40	2.13± 0.78

According to the research findings, the pH of the water in the three land covers varied, with the hepatic garden having the greatest pH (5.91 ± 0.08) and the botanical field having the lowest pH (5.38 ± 0.40) (Table 1). The acidity level of botanical gardens is acidic, while in rubber plantations and teak plantations, it is moderate. Soil organic matter is a material of soil (Solekhah et al., 2024) as the source of soil carbon. Soil organic carbon, is a carbon that comes from various organic materials, namely plants, animals and including microbes. The physical and chemical composition and the microbial community's metabolism of the soil all affect how much carbon is stored in the soil matrix (Campbell et al., 2022). The accessibility of soil carbon is affected by the physical surface area accessible for interaction and the chemical absorption of carbon molecules into minerals, which are both influenced by the physical structure of the soil and the chemical compounds present in it (Newcomb et al., 2017).

The accessibility of soil carbon is affected by the physical surface area accessible for interactions and the chemical absorption of carbon molecules into minerals, which are both influenced by the physical structure of the soil and the types of chemical compounds present in it. The results showed that the highest percentage of soil organic carbon content was in the Botanical Garden, namely 2.13 ± 0.78%, and the small least was 0.34 ± 0.29%, while the average was in the rubber plantation, namely 1.09 ± 0.36 %. For teak plantations, the organic carbon content is classified as below 1%, meaning it is very low; for rubber plantations, it is between 1% and 2%, meaning it is low; while soil organic carbon in botanical gardens is between 2%-3%, meaning moderate.

Botanical gardens contain a relatively high density of trees, canopy cover, understory vegetation, litter intake, and root systems. Previous studies have shown that forest conversion increases land density and reduces soil porosity in teak and rubber

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plantations. Different land uses have a direct impact on soil carbon, fertility, and physical qualities, leading to increased leaching and erosion. This is not consistent with the findings of a study conducted by Saputra et al., (2018) which looked at the relationship between bulk density, porosity, and infiltration rate in plantations and found that higher soil organic matter content positively impacted these three parameters. soil constant, this is most likely since each location's soil contains a unique combination of components and the inflow of organic material has minimal impact on the soil.

2. Soil Microbial Abundance

The abundance of soil microorganisms measured includes the total bacteria and fungi in the soil sample. The number of microbes in each group showed different results at each soil research location. The results of the research show that the average bacteria in the Botanical Gardens is the highest, namely 150.33×10^5 with a standard deviation of ±7.37.15x 10^5, and the lowest was in teak plantations, namely an average of 61 x 10^5 with a standard deviation of ± 9.54×10^5 (Table 2).

Table 2. Total Bacteria and Fungi at three research locations

No	Field Code	Bakteri (10^5)	Jamur (10^4)
1.	Rubber Plantation	124±10,15	92,67± 5,51
2.	Teak Plantation	61±9,54	83±10,44
3.	Botanical Garden	150,33± 7,37	102,33± 4,04

The results of the research show that the average fungus in the Botanical Gardens is the highest, namely 102.33 x 10^4 with a standard deviation of ± 4,04 x 10^4, the second was Rubber plantation 92,67 x 10^4 with a standard deviation of ± 5,51 x 10^4 and the lowest was in teak plantations, namely an average of 83 x 10^4 with a standard deviation of ± 10.44 x 10^4 (Table 2).

Soil microbial diversity is influenced by various environmental factors, including abiotic factors such as pH, seasonal changes, and soil nutrients. In the results of this research, botanical gardens which have many types of vegetation have high numbers of bacteria, which is different from research in China which states that the soil bacterial community was higher in monoculture than in mixtures due to the higher soil pH in monoculture, confirming that soil pH is the main driver for microbes (Jatoi et al., 2019).

3. Soil Respiration

Soil respiration, which is CO_2 produced by the biological activity of soil organisms, is in a major flux in the global carbon cycle, emitting approximately 10 times more CO_2 into the atmosphere annually than the burning of fossil fuels (Jiang et al., 2020; Fekete et al., 2021; Kotroczó et al., 2023)

Table 3. Soil respiration at three research locations

No	Field Code	Soil Respiration
1.	Rubber Plantation	21.37± 0.9
2.	Teak Plantation	11.29± 0.51
3.	Botanical Garden	29.87± 1.91

Soil respiration in the research area was highest in the botanical garden, namely 29.87 kg CO_2-C ha^{-1} day^{-1} with a standard deviation of ± 1.91 kg CO_2-C ha^{-1} day^{-1} followed by rubber plantation with respiration 21.37 kg CO_2-C ha^{-1} day^{-1} with standard deviation of ± 0.9kg CO_2-C ha^{-1} day^{-1} and the smallest is teak plantation 11,29 kg CO_2-C ha^{-1} day^{-1} with a standard deviation ±0.51 kg CO_2-C ha^{-1} day^{-1} (Table 3). Respiration in the Botanical Garden and Rubber plantation is between 16-32 kg CO_2-C ha^{-1} day^{-1} which means that the activities occur in medium soil, meaning that activities occur in the soil is medium, while in teak

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plantation, respiration is between 9.6–16, it means that the activity in the soil is low. Soil respiration in botanical gardens is higher due to various possibilities, including that in botanical gardens, more litter decomposes compared to rubber plantations or rubber plantations. besides, it may be due to temperature and humidity; in the botanical garden, the temperature is lower, and the humidity is higher. This is in accordance with Vikram's statement in 2022, which stated that soil respiration rate varies spatially and temporally. It is also heavily impacted by abiotic parameters such as soil water content and soil temperature in the specified land use system. Positive soil respiration rates increase with soil water content. Furthermore, on a temporal scale, specifically a monthly or seasonal basis, soil temperature has a greater influence on soil respiration than soil water content in the specified land use system (Vikram et al., 2022).

4. Correlation between Soil Respiration and its influence factor

The correlation between soil respiration and pH at the research location is R^2 = 0.528, which means there is a relation between soil respiration and pH as an influence factor (**Figure 1**). The findings of this investigation are consistent with those of a study conducted by Li et al. (2019), which demonstrated a substantial positive correlation between the cumulative respiration rate and soil pH, fine root biomass, urease activity, and sucrose activity.

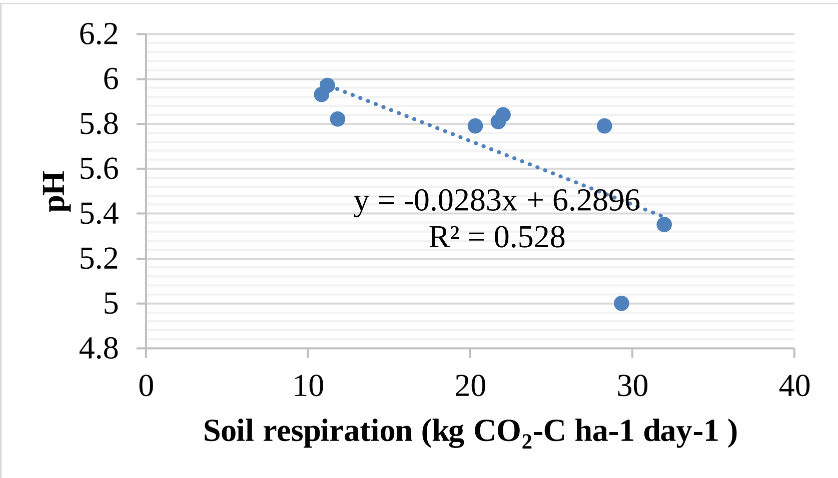

Figure 1. Correlation of soil respiration and pH

Soil respiration may be affected by the interaction of other elements with temperature and humidity (Yusnaini et al., 2021). In Mengcheng County, soil microbial properties were measured in conjunction with soil physicochemical characteristics and climatic factors to investigate the mechanism by which soil pH mediates the temperature sensitivity of soil respiration, and the results showed that soil acidification caused by long-term mineral fertilization reduced the temperature sensitivity of soil respiration. Under warming conditions, soil respiration's temperature sensitivity was intricately connected to the microbial community composition, alpha diversity, and soil ammonium nitrogen levels. The combination of pH and temperature influenced soil respiration; warming exacerbated the detrimental impact of soil pH on soil respiration. Furthermore, the mechanism by which soil pH impacts temperature sensitivity included not only microbial community composition, alpha diversity, and biomass but

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also soil phosphorus availability. To our knowledge, this is the first study to describe the microbiological mechanism underpinning soil acidification's effect on the temperature sensitivity of soil respiration in field settings (Jin et al., 2024)

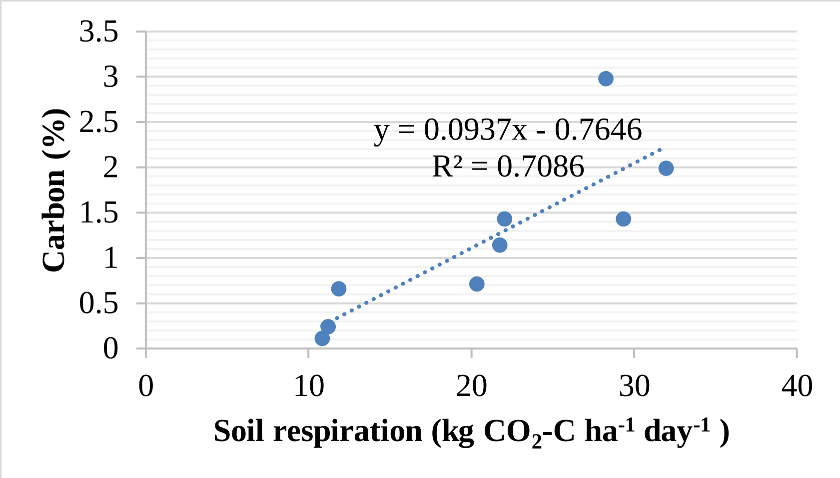

Figure 2. Correlation of soil respiration and carbon

The Correlation between soil respiration and Carbon at the research location is $R^2 = 0.7086$, which means there is the relation between soil respiration and carbon as an influence factor (**Figure 2**). The findings of this study closely resemble those of a study conducted by Rodtassana et al. (2021), which examined the temporal and spatial variations of soil respiration and the factors that drive it, such as soil temperature, soil moisture, and organic matter content. Their findings indicated that increased soil organic matter as a carbon source increases soil respiration significantly in most forest stages.

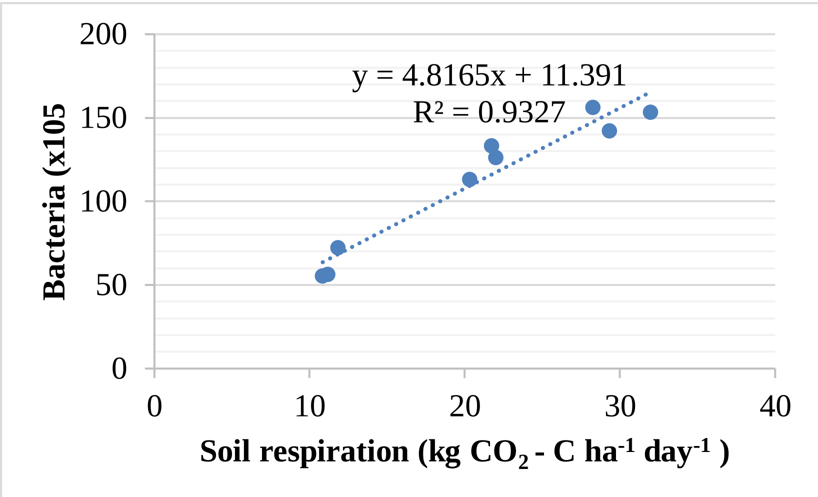

Figure 3. Correlation of soil respiration and Bacteria

The Correlation between soil respiration and bacteria at the research location is $R^2 = 0.9327$, which means there is a relation between soil respiration and carbon as an influence factor (**Figure 3**). Soil respiration is influenced by many factors, and responds strongly to factors that hinder the most, such as physiological and other

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microbial processes. High temperatures have a stronger impact on soil respiration than low temperatures. However, because high temperatures and high humidity have a bigger impact on respiration, a high temperature will have no meaningful effect. (Xiao et al., 2014). Soil temperature, microbial biomass and enzyme activity are important factors that influence soil respiration (Qu et al., 2023). A number of factors contribute to the low pH of the soil at the study site, including the high amount of organic matter in the soil, which encourages microorganisms to break down organic material and release organic acids, and leaching from erosion, which keeps Al and H^+ cations as the main cations and causes sourer actions in the soil (Khaidem & Thounaojam, 2018). As previously mentioned before, aluminium will be very soluble under extremely acidic soil conditions and can be found as $Al3^+$ and Al hydroxide (Gunasekera & Silva, 2020). Soil reaction (pH) influences the development of soil microorganisms that live in it, and the microorganisms that most live at this pH are bacteria and fungi (Gondal et al., 2021). According to Jufri (2020), in general, bacteria can grow well at a pH of around 7(neutral), although they can grow in the pH range of 5-8, while fungi can live in a wide pH range. Followed by Wang et al., (2019) that soil pH influences the development of soil microorganisms in different soil conditions.

CONCLUSION

The study's findings demonstrated that the largest soil respiration was at the Botanical Garden location at 29.87 ± 1.91 and the smallest at the teak plantation at 21.37 ± 0.9. The high total number of soil microorganisms makes respiration high because it produces high CO_2, which is caused by the high activity carried out by the microorganisms in the soil. The total soil microorganism number is defined by soil organic carbon. The total amount of soil microorganisms increases with soil organic matter. As a suggestion for further research, to be able to find out the relationship between the amount of respiration and the rate of decomposition by microorganisms, data is needed regarding the constituents of organic materials at that location in the form of lignin, cellulose and hemicellulose.

REFERENCES

Abdullah, U. H., Sufardi, S., Syafruddin, S., & Arabia, T. (2022). Soil organic carbon of grassland and bush forest on dry land in Aceh Besar District, Indonesia. *Biodiversitas*, *23*(5), 2594–2600. https://doi.org/10.13057/biodiv/d230541

Arifan, F., Winarni, S., Wahyuningsih, W., Pudjihastuti, I., & Broto, R. W. (2019). *Total Plate Count (TPC) Analysis of Processed Ginger on Tlogowungu Village*. *167*(ICoMA 2018), 377–379. https://doi.org/10.2991/icoma-18.2019.80

Barranco, S. A., Ortiz, P. S., Kowalski, A. S., & Sánchez-, E. P. (2025). Spatial and temporal heterogeneity of soil respiration in a bare-soil Mediterranean olive grove. *SOIL*, *11*(February), 1–30. https://doi.org/https://doi.org/10.5194/soil-11-213-2025

Campbell, T. P., Ulrich, D. E. M., Toyoda, J., Thompson, J., Munsky, B., Albright, M. B. N., Bailey, V. L., Tfaily, M. M., & Dunbar, J. (2022). Microbial Communities Influence Soil Dissolved Organic Carbon Concentration by Altering Metabolite Composition. *Frontiers in Microbiology*, *12*(January), 1–12. https://doi.org/10.3389/fmicb.2021.799014

Fekete, I., Berki, I., Lajtha, K., Trumbore, S., Francioso, O., Gioacchini, P., Montecchio, D., Várbíró, G., Béni, Á., Makádi, M., Demeter, I., Madarász, B., Juhos, K., & Kotroczó, Z. (2021). How will a drier climate change carbon sequestration in soils of the deciduous forests of Central Europe?

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.2022

Biogeochemistry, *152*(1), 13–32. https://doi.org/10.1007/s10533-020-00728-w

Fu, P., Clanton, C., Demuth, K. M., Goodman, V., Griffith, L., Khim-Young, M., Maddalena, J., Lamarca, K., Wright, L. A., Schurman, D., & Kellner, J. R. (2024). Accurate quantification of full-column soil organic carbon in CONUS using machine learning. *Remote Sensing*, *16*, 2217. https://doi.org/https://doi.org/10.3390/rs16122217

Gondal, A. H., Farooq, Q., Sohail, S., Shasang Kumar, S., Danish Toor, M., Zafar, A., & Rehman, B. (2021). Adaptability of Soil pH through Innovative Microbial Approach. *Current Research in Agricultural Sciences*, *8*(2), 71–79. https://doi.org/10.18488/journal.68.2021.82.71.79

Grima, N., Edwards, D., Edwards, F., Petley, D., & Fisher, B. (2020). Landslides in the Andes: Forests can provide cost-effective landslide regulation services. *Science of the Total Environment*, *745*(July), 18. https://doi.org/10.1016/j.scitotenv.2020.141128

Gunasekera, H. A. D. D. T., & Silva, R. C. L. De. (2020). Study of the Effects of Soil Acidity and Salinity on Aluminium Mobility in Selected Soil Samples in Sri Lanka. *Asian Journal of Environment & Ecology*, *February*, 58–67. https://doi.org/10.9734/ajee/2020/v13i430191

Has, D. H., Marpaung, S. S. M., Lubis, D. A., & Marpaung, J. U. (2024). Identification of the Role of Stakeholders in Sustainable City Forests, Case Study of Beringin Medan City Forest, North Sumatra, Indonesia. *Agro Bali : Agricultural Journal*, *7*(2), 410–422. https://doi.org/10.37637/ab.v7i2.1797

Hendrati, R. L. (2019). Environmental and Social Sustainability: The role of Forest as the most influential ecosystem. *IOP Conference Series: Earth and Environmental Science*, *256*(1). https://doi.org/10.1088/1755-1315/256/1/012052

Hidayat, Y., Alfitri, Purnama, D. H., & Riswani. (2021). The Shape of Forest , Social and Economic Conditions of Community Living Around Production Forest with Industrial Plantation Forest Permit (Case Study : Forest Management Unit of KPH Meranti) The Shape of Forest , Social and Economic Conditions of Commu. *IOP Conference Series: Earth and Environmental Science*, *810 012022*, 1–7. https://doi.org/10.1088/1755-1315/810/1/012022

Howen, M., Balatif, R., Lubis, N. D. A., Amelia, S., & Yusrani, E. (2022). The Number of Bacteria Colonies in Carp Fish (Cyprinus carpio) After Administration of Lime (Citrus aurantifolia) and Orange Extract (Citrus jambhiri Lush.). *Journal of Saintech Transfer*, *5*(1), 29–33. https://doi.org/10.32734/jst.v5i1.8694

Husen, E., Salma, S., & Agus, F. (2014). Peat emission control by groundwater management and soil amendments: Evidence from laboratory experiments. *Mitigation and Adaptation Strategies for Global Change*, *19*(6), 821–829. https://doi.org/10.1007/s11027-013-9526-3

Irving, D., Bakhshandeh, S., Tran, T. K. A., & McBratney, A. B. (2024). A cost-effective method for quantifying soil respiration. *Soil Security*, *16*(July), 100162. https://doi.org/10.1016/j.soisec.2024.100162

Jatoi, Tahir, M., Lan, G., Wu, Z., Sun, R., Yang, C., & Tan, Z. (2019). Comparison of Soil Microbial Composition and Diversity Between Mixed and Monoculture Rubber Plantations in Hainan Province, China. *Tropical Conservation Science*, *12*, 9. https://doi.org/10.1177/1940082919876

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.2022

072

Jiang, D., Chen, L., Xia, N., Norgbey, E., Koomson, D. A., & Darkwah, W. K. (2020). Elevated atmospheric CO2 impact on carbon and nitrogen transformations and microbial community in replicated wetland. *Ecological Processes*, *9*(1). https://doi.org/https://doi.org/10.1186/s13717-020-00267-0

Jin, L., Hua, K., Zhan, L., He, C., Wang, D., Nagano, H., Cheng, W., Inubushi, K., & Guo, Z. (2024). Effect of Soil Acidification on Temperature Sensitivity of Soil Respiration. *Agronomy*, *14*(5). https://doi.org/10.3390/agronomy14051056

Jufri, R. F. (2020). Journal la lifesci Microbial Isolation. *Journal La Lifesci*, *01*(01), 18–23. https://newinera.com/index.php/JournalLaLifesci/article/view/32/21

Kannan, M. N., Badoni, A., Chamoli, V., Chandra Bahuguna, N., & Sethi, S. (2018). Advances in Agriculture and Natural Sciences for Sustainable Agriculture (October 12 & 13, 2018) Isolation and characterization of bacterial isolates from agriculture field soil of Roorkee region. ~ *108 ~ Journal of Pharmacognosy and Phytochemistry*, *5*(2013), 108–110. www.statlab.iastate.edu/survey/SQI/

Khaidem, J., & Thounaojam, T. (2018). Influence of soil pH on nutrient availability: A review. *Journal of Emerging Technologies and Innovative Research*, *5*(August), 707. https://www.researchgate.net/publication/343555930

Kotroczó, Z., Makádi, M., Kocsis, T., Béni, Á., Várbíró, G., & Fekete, I. (2023). Long-Term Changes in Organic Matter Content and Soil Moisture Determine the Degree of Root and Soil Respiration. *Plants*, *12*(2), 1–13. https://doi.org/10.3390/plants12020251

Li, Y., Wang, Y., Wang, Y., & Wang, B. (2019). Effects of simulated acid rain on soil respiration and its component in a mixed coniferous-broadleaved forest of the three gorges reservoir area in Southwest China. *Forest Ecosystems*, *6*(1). https://doi.org/10.1186/s40663-019-0192-0

Newcomb, C. J., Qafoku, N. P., Grate, J. W., Bailey, V. L., & De Yoreo, J. J. (2017). Developing a molecular picture of soil organic matter-mineral interactions by quantifying organo-mineral binding. *Nature Communications*, *8*(1). https://doi.org/10.1038/s41467-017-00407-9

Qu, R., Liu, G., Yue, M., Wang, G., Peng, C., Wang, K., & Gao, X. (2023). Soil temperature, microbial biomass and enzyme activity are the critical factors affecting soil respiration in different soil layers in Ziwuling Mountains, China. *Frontiers in Microbiology*, *14*(February), 1–12. https://doi.org/10.3389/fmicb.2023.1105723

Rahardjo, H., Harnas, F. R., Leong, E. C., Tan, P. Y., Fong, Y. K., & Sim, E. K. (2009). Tree stability in an improved soil to withstand wind loading. *Urban Forestry and Urban Greening*, *8*(4), 237–247. https://doi.org/10.1016/j.ufug.2009.07.001

Rodtassana, C., Unawong, W., Yaemphum, S., Chanthorn, W., Chawchai, S., Nathalang, A., Brockelman, W. Y., & Tor-ngern, P. (2021). Different responses of soil respiration to environmental factors across forest stages in a Southeast Asian forest. *Ecology and Evolution*, *11*(21), 15430–15443. https://doi.org/10.1002/ece3.8248

Saputra, D. D., Rakhim Putrantyo, A., & Kusuma, Z. (2018). Hubungan Kandungan Bahan Organik Tanah dengan Bulk Density, Porositas, dan Laju Infiltrasi Pada Perkebunan Salak Kecamatan Purwosari Kabupaten

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.2022

Pasuruan. *Jurnal Tanah Dan Sumberdaya Lahan*, *5*(1), 2549–9793. http://jtsl.ub.ac.id

Shah, N. W., Baillie, B. R., Bishop, K., Ferraz, S., Högbom, L., & Nettles, J. (2022). The effects of forest management on water quality. *Forest Ecology and Management*, *522*(February), 1–23. https://doi.org/10.1016/j.foreco.2022.120397

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

Springgay, E., Mcnulty, S. G., Dannunzio, R., & Steel, E. A. (2021). A guide to forest–water management. In *A guide to forest–water management* (Issue August). Publisher: FAO, IUFRO and USDA. https://doi.org/10.4060/cb6473en

Swaminathan, C., Devi, N., & Pandian, K. (2021). Latest Trends in Soil Science (Volume - 1). In *Latest Trends in Soil Science (Volume - 1)* (Issue January). Integrated Publications. https://doi.org/10.22271/int.book.33

Tong, D., Li, Z., Xiao, H., Nie, X., Liu, C., & Zhou, M. (2021). How do soil microbes exert impact on soil respiration and its temperature sensitivity? *Environmental Microbiology*, *23*(6), 3048–3058. https://doi.org/10.1111/1462-2920.15520

Uchida, R., & Nguyen Hue. (2020). Soil Acidity and Liming. In J. A. Silva & R. S. Uchida (Eds.), *Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture Plant Nutrient Management in Hawai* (Issue February 2000, pp. 1–380). College of Tropical Agriculture and Human Resources (CTAHR). https://doi.org/10.2134/agronmonogr12.2ed

Vikram, K., Chaudhary, H., Notup, T., J, D., & Rao, K. S. (2022). Soil Respiration Under Different Land Use Systems in the Kumaon Region of Central Himalaya, India. *International Journal of Ecology and Environmental Sciences*, *48*(5). https://doi.org/10.55863/ijees.2022.0649

Vincze, É. B., Becze, A., Laslo, É., & Mara, G. (2024). Beneficial Soil Microbiomes and Their Potential Role in Plant Growth and Soil Fertility. *Agriculture (Switzerland)*, *14*(1), 1–23. https://doi.org/10.3390/agriculture14010152

Wang, C. yu, Zhou, X., Guo, D., Zhao, J. hua, Yan, L., Feng, G. zhong, Gao, Q., Yu, H., & Zhao, L. po. (2019). Soil pH is the primary factor driving the distribution and function of microorganisms in farmland soils in northeastern China. *Annals of Microbiology*, *69*(13), 1461–1473. https://doi.org/10.1007/s13213-019-01529-9

Wegscheider, S., Purwanto, J., Margono, B. A., Nugroho, S., Budiharto, Buchholz, G., & Sugardiman, R. A. (2019). Current achievements to reduce deforestation in Kalimantan. *Indonesian Journal of Geography*, *50*(2), 109–120. https://doi.org/10.22146/ijg.23680

Widati, sri. (2007). *Soil Biological Analysis Methods* (Rasti Saraswati, E. Husen, & R. D. M. Simanungkalit (eds.)). Balai Besar Penelitian dan Pengembangan Sumber Daya Lahan Pertanian. https://repository.pertanian.go.id/server/api/core/bitstreams/63eecc44-8bb1-4b39-b71f-d24523bf0635/content

Witno, W., Maria, M., Liana, L., & Wardi, W. (2024). Assessing Carbon Dioxide (CO2) Absorption Potential of Forests Around Landslides Along the Trans Palopo-Toraja Highways. *Jurnal Ilmu Kehutanan*, *18*(1), 59–70. https://doi.org/10.22146/jik.v18i1.9782

Xiao, W., Ge, X., Zeng, L., Huang, Z., Lei, J., Zhou, B., & Li, M. (2014). Rates of litter

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.2022

decomposition and soil respiration in relation to soil temperature and water in different-aged Pinus massoniana forests in the three gorges reservoir area, China. *PLoS ONE*, *9*(7), 1–11. https://doi.org/10.1371/journal.pone.0101890

Yusnaini, S., Niswati, A., Aini, S. N., Arif, M. A. S., Dewi, R. P., & Rivaie, A. A. (2021). Changes in soil respiration after application of in situ soil amendment and phosphate fertilizer under soybean cultivation at Ultisol South Lampung, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *724*(1). https://doi.org/10.1088/1755-1315/724/1/012002