JPPIPA 10(6) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Soil Quality Index Analysis of Pine Forest Land Use Types on Dryland in Aceh Besar Regency

Umar Husein Abdullah[1*], Reza Salima[1], Mulyanti[1], Mukhlis[2], Sufardi[3]

[1] Plantation Management Study Program, Politeknik Indonesia Venezuela, Aceh Besar, Indonesia
[2] Department of Agriculture Business, Politeknik Pertanian Negeri Payakumbuh, Payakumbuh, Indonesia
[3] Department of Soil Science, Faculty of Agriculture, Universitas Syiah Kuala, Jalan Tgk. Hasan Krueng Kalee 3, Darussalam, Banda Aceh 23111, Indonesia

Received: February 14, 2024
Revised: April 25, 2024
Accepted: June 20, 2024
Published: June 30, 2024

Corresponding Author:
Umar Husein Abdullah
umarah_1977@yahoo.co.id

DOI: 10.29303/jppipa.v10i6.7228

Abstract: This study aims to determine the analysis of soil quality index in pine forest land use type on dry land in Aceh Besar Regency. This research focused on several field observation points in the pine forest land use type area on dry land in Aceh Besar Regency. The soil quality index in the pine forest land use type in Aceh Besar Regency is included in the medium category. This is due to soil sampling on the inceptisol soil type in Aceh Besar Regency, which has characteristics of less fertile soil. Soils that have a high percentage of dust have a higher risk of erosion, because dust has a relatively small size so that it is easily washed away by surface flow. low C-organic content, high volume weight, pH H_2O, K- exchangeable, P-available and low N-total. In the type of pine forest land use, special treatment is needed in the form of adding organic matter to the soil by fertilizing, reforesting pine plants and conducting drainage so as to reduce nutrient leaching in the top soil layer.

Keywords: Dryland; Pine forests; Soil quality index

Introduction

Dryland is an agroecosystem that has great potential for agricultural activities, including food crops, horticulture, annual crops, and livestock. Land that covers the largest area and has a strategic position in the implementation of agricultural development in Indonesia. The utilization of dry land is an important tool in the pursuit of equitable development activities. Based on the Indonesian Agricultural Spatial Planning Direction Map, Indonesia has a land area of around 188.20 million ha, consisting of 148 million ha of dry land (78%) and 40.20 million ha of wetland (22%) (Suwati et al., 2022; Guillaume et al., 2016).

Organic matter plays a very important role in soil fertility. Changes in the physical, biological, and chemical characteristics of the soil have a direct impact on the role of organic matter in the soil. Organic material added to the soil can increase soil porosity. Organic materials will undergo a process of decomposition and mineralization. The results of decomposition are organic acids (organic compounds) which can be ingredients that play a role in the formation of soil aggregates. Aggregate (structure) improvements will be followed by improvements in porosity, aeration, infiltration, water holding capacity available water, permeability, and other physical properties. Providing organic matter can improve the chemical properties of the soil. The organic acids resulting from decomposition increase cation exchange capacity. Decomposition and mineralization accompanied by the formation of nutrients can increase the amount and availability of nutrients in the soil (Wawan, 2017).

*Pinus merkusii Jungh et de Vriese*is a priority type of plant (60%) planted in the Forest, Soil and Water Conservation Program, especially reforestation and greening activities by the government through the Ministry of Forestry which has been implemented since

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

the 60s. The choice of this type of pine is due to several factors, namely: the availability of sufficient seeds, its growth rate is fast and it can play a role and grow on marginal land. Similar to trees in general, pine tree growth is highly impacted by a favorable and well-balanced mix of environmental factors. If one environmental factor is out of balance with other factors, this factor can suppress plant growth. These environmental factors are light, nutrients, air, and water (Sallata, 2013).

Tools that can give precise information on the state of soil quality are necessary for the management of sustainable agroecosystems. Changes in soil quality have an impact on biodiversity, weather patterns, biogeochemical cycles, agricultural productivity, food, energy, and water security, as well as human well-being and socioeconomic survival. Because soil serves so many purposes (such as producing biomass, regulating the climate, and reducing pollution), assessing one or more soil characteristics alone is insufficient to determine the quality of the soil. Unpredictability in soil quality data can lead to calamities like landslides and disease outbreaks from tainted water, as well as delayed detection. Measurements of soil quality that are precise, repeatable, methodical, and transparent can enhance interpretation and cross-location comparison (Amorim et al., 2021; Mukherjee & Lal, 2015; de Paul Obade & Lal, 2014).

The ability of a specific type of soil to sustain plant and animal survival within naturally occurring or controlled limits, without endangering the quality of the surrounding environment, is referred to as soil quality. Although it is impossible to measure the physical, chemical, and biological characteristics of soil directly, one can determine the quality of the soil (Tian et al., 2020; de Paul Obade & Lal, 2016); Nakajima et al., 2015).

Aside from the quality of the water and air, soil quality is one of the three elements of environmental quality. The primary criterion for defining the quality of water and air is the amount of pollution that directly affects the health and consumption of humans and animals, as well as natural ecosystems. On the other hand, soil quality is more broadly defined as "the capacity of soil to function within the boundaries of ecosystems and land uses to maintain biological productivity, maintain environmental quality, and improve plant and animal health" rather than being restricted to the amount of pollution in the soil (Bünemann et al., 2018; Rinot et al., 2019).

Assessing soil quality is done by looking at indicators. Physical, chemical, biological, or soil-specific features can all serve as indicators. Plant morphological or physiological traits can serve as indicators. Indicators are measured to observe changes in the soil brought about by soil management. Because they are connected to the characteristics of the soil and the quality of particular soils, indicators of soil quality are established. Because it can reveal details about a variety of characteristics, including soil fertility, soil structure, soil stability, and nutrient retention, soil organic matter is a commonly used indicator. Additional plant indicators that can reveal information about soil compaction include rooting depth (Bünemann et al., 2018).

Research on soil quality index in pine forest land use type needs to be done because pine forest is one of the land use types in Aceh Besar Regency that needs to be preserved to maintain biodiversity and protect land resources that are very beneficial for the people in Aceh Besar Regency. Sustainable and sustainable land management efforts can prevent land degradation and are able to store nutrients in pine forest land use types and can store carbon sequestration which can reduce global warming due to the large amount of CO_2 content in the air. Classification of a vegetation/land use type is necessary as a basic effort in assessing the diversity of biological resources (Dewi et al., 2022)

For all types of soil to remain fertile, the type of land use is crucial. Leaching of nutrients frequently occurs in the pine forest land use type, which is primarily planted in Aceh Besar Regency's highlands. As a result, very little organic material is returned to the soil, and the effects of intensive tillage exacerbate this problem. The amount of organic material in the soil varies depending on its properties and the way it is used. The amount of organic matter in the soil varies due to modifications in the vegetation, land use, and soil management practices (Lestari, 2023). Soil quality index analysis of pine forest land use types on dry land in Aceh Besar Regency is the focus of this study.

Method

This research was prioritized at several field observation points in the pine forest land use type area on dry land in Aceh Besar Regency. Apart from the field, this research was also carried out at Universitas Syiah Kuala.

The G.P.S. (Geographic Information System), soil drill, sample ring, pH-meter, tape measure, plastic, rubber, knife, hoe, and Abney level are among the tools used in the field. Meanwhile, the equipment used in the laboratory for soil analysis included analytical scales, pH meters, ovens, shakers, hot plates, colonizers, distillation units, burettes, beakers, spectrophotometers, and A.A.S (Atomic Absorption Spectrophotometer). The top layer of soil (0–20 cm) was used to assess the soil fertility status as one of the materials used in this study. Regional maps, Google maps, soil type maps, observation point maps, and different chemicals—such

as H_2O_2 10%, HCl 10 N, distilled water, and materials for laboratory analysis—will be utilized during field soil surveys.

Descriptive techniques based on survey data, field observations, and laboratory analysis were used to conduct this study. Field surveys are conducted to gather primary data, such as the overall biophysical conditions of the region, the physical and chemical properties of the soil gleaned from observations, and indicators of the quality of the soil through laboratory soil analysis.

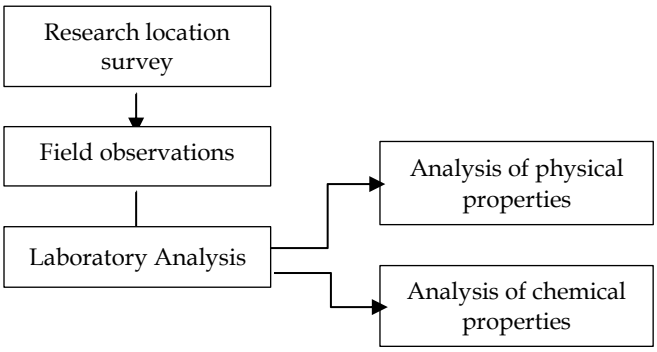

Figure 1. Flow diagram of the process of carrying out soil quality index research

Soil sampling points were determined using the purposive sampling method, namely points that had been determined in the pine forest area on dry land in Aceh Besar Regency. Each sampling point is taken as an average of five repetitions. Drilling is used to collect soil samples for chemical property analysis. The purpose of soil drilling is to ascertain the soil solum's thickness. Only the top 20 cm thick soil layer is the subject of sampling. Five or six sample points were collected for the pine forest land use type, and these were subsequently examined in a lab. The fertility status for each type of land use will then be ascertained using the data from the soil analysis. Every observation point (LUT) in Aceh Besar Regency is a pine forest that was the site of field observations and sampling. In order to represent the Entisol and Inceptisol soil types, soil samples were collected at slopes ranging from 0 to 15%, or from flat to slightly steep.

To learn more about the physical and chemical characteristics of the soil at the research site, a soil sample analysis was done in the lab. Analysis is done on the following variables: pH (H_2O), C-organic, N-Total, P-available, and K-exchangeable. In order to support soil classification, data on base saturation (BS) and cation exchange capacity (CEC) are used. In the meantime, fraction size (texture), volume weight, and porosity are analyzed from a single undisturbed soil sample. Table 1 describes the elements and procedures for analyzing the chemical, physical, and rooting depth characteristics of the soil.

Table 1. Soil Physical, Chemical, and Biological Properties analyzed in the Laboratory

Analysis Aspect	Analysis Method
Texture	Stokes' law pipette method
Reaction (pH) of soil: pH (H_2O) (%)	Electrometric
C-Organic (%)	Walkey and black
N-total (%)	Kjeldahl
P-available (ppm)	Bray and olsen
K-dd (cmol kg^{-1})	Extraction of 1 N NH_4COOH
Rooting dept (cm)	Drilling
Volume weight ($g.m^{-3}$)	Ring sample (core method)
Porosity (%)	Complete saturation

Source: Soil and Plant Laboratory and Biology Laboratory, Faculty of Agriculture, Universitas Syiah Kuala (Husni et al., 2016)

The method (Mausbach, 1998) for analyzing the soil quality index was modified by (Partoyo, 2005). The nine soil property criteria listed in Table 1 above are used to calculate the soil quality index changes made in a few instances in accordance with Partoyo (2005) and (Arifin, 2011) in response to the circumstances of the study area. The criteria for soil quality as stated by Partoyo are shown in Table 2.

Tabel 2. Soil quality criteria based on soil quality index (SQI) values

SQI Value Class	Soil Quality Criteria
0.80 – 1.00	Very good
0.60 – 0.79	Good
0.40 – 0.59	Mediun
0.20 – 0.39	Low
0.00 – 0.19	Very Low

Source: (Partoyo, 2005)

The research location map to determine the soil quality index for pine forest land use types in Aceh Besar Regency can be seen in Figure 2.

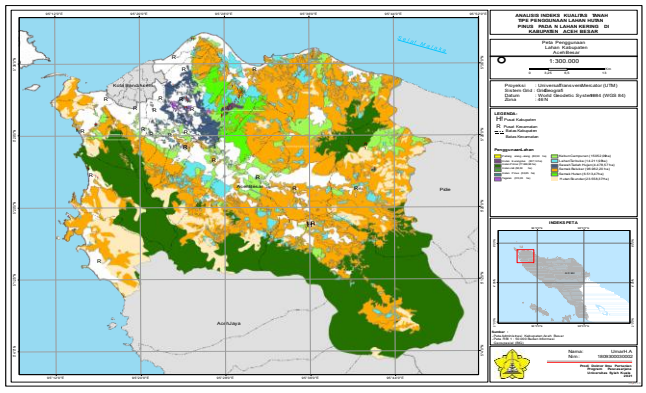

Figure 2. Map of research locations on pine forest land use types in Aceh Besar Regency

Result and Discussion

The outcomes of laboratory analysis and field observations can be used to inform soil quality indices. Surveys representing various types of pine forest land use on dryland in Aceh Besar Regency were conducted based on observations and descriptions of soil profiles at multiple locations.

Table 3. Physical, chemical characteristics and rooting depth of pine forest land use types on dryland in Aceh Besar Regency

	Pine forests 5				
Physical Chemical Properties	sample 1	sample 2	sample 3	sample 4	sample 5
Rooting depth (cm)	197	215	218	188	188
Volume weight	1.23	1.24	1.22	1.21	1.25
Porosity (%)	66.43	60.55	66.43	60.55	63.49
C-organic (%)	2.21	1.82	1.3	1.77	1.77
Dust-clay (%)	71	70	71	70	70.5
pH (H_2O)	5.58	5.66	5.58	5.66	5.62
P-available (ppm)	1.45	1.45	1.45	1.45	1.45
K-switched	0.37	0.24	0.37	0.24	0.31
N-Total (%)	0.14	0.12	0.14	0.12	0.13
Location	Lembah Seulawah 1	Lembah Seulawah 2	Lembah Seulawah 3	Lampuuk 1	Lampuuk 2
Sample point coordinates	95.697399 - 5.402485	95.703962 - 5.404807	95.701745 - 5.399843	95.235634 - 5.477866	95.235452 - 5.478222

One of the reasons for the moderate soil quality index criteria for the pine forest land use type is due to taking soil samples from the inceptisol soil type in the Aceh Besar Regency area, which has characteristics of less fertile soil. Inceptisol has low levels of essential nutrients such as nitrogen, phosphorus, and potassium. Damage to soil physics, chemistry, and biology may arise from intensive soil management. The process of acidification brought on by the frequent and extensive use of synthetic nitrogen fertilizer can harm the chemical composition of the soil (Rafika et al., 2022). Physical soil damage includes things like using improper agricultural machinery or applying chemical fertilizers on a regular basis, which can weaken the soil's structure and result in compaction. Population declines and decreased biodiversity of soil organisms are indicators of biological damage, which typically results from alterations to the physical or chemical properties of the organisms (Sahbudin et al., 2020; Akbar et al., 2022; Ma et al., 2022).

The percentage of dust (65.5%), as opposed to the percentages of sand (29.5%) and clay (5%), generally dominates the land use type of pine forests. Dusty clay is the soil type assigned to this land use type which is pine forests. Dusty soil is more susceptible to erosion because of its relatively small size, which makes it easy for surface flows to carry away. It is more prone to erosion because its erodibility value rises with dust fraction. Sand-dominated soils typically have low levels of erodibility due to their high infiltration capacity and relatively large sand grain size, which allows water to pass through more quickly (Emi, 2022; Palloan et al., 2023; Xiong et al., 2024).

The pine forest use type is soil quality index in Aceh Besar Regency is classified as medium due to the average C-organic content (1.77) being in the low classification and the average volume weight (1.23) in the pine forest land use type being extremely high. By increasing soil pore space and creating a crumbly soil structure, adding organic matter to the soil can lower the bulk density of the soil. The average bulk density of the soil at the study site is 1.24 $g.cm^{-3}$, which is marginally higher than the critical value of less than 1.2 $g.cm^{-3}$ for clayey soils, which is the critical value for healthy agricultural soil (Poukrel et al., 2022; Ashworth et al., 2020). A soil unit weight value of greater than 1.2 $g\ cm^3$ means that the soil has undergone a compaction process (Farrasati et al., 2019). The low C-organic content at the research location could be caused by a lack of public understanding of conservation efforts, especially efforts to replant pine plants. Adding organic fertilizer during the soil management process. By enriching the soil with organic matter, you can improve the soil's ability to exchange cations, give plants more nutrients, and produce rich soil that is ideal for plant growth (Raiesi & Salek-Gilani, 2020; Raiesi, 2017; Sheidai Karkaj et al., 2019). To maintain the condition of the pine forest land use type, it is necessary to carry out tree planting and maintenance programs, as well as efforts to improve the soil either by liming or by adding organic material (Lestari, 2023; Hakim et al., 2023).

Table 4. Average Soil Quality Index (SQI) for various types of dryland use in Aceh Besar Regency

Soil Quality Index (IKT)						Amount	Average	Standard deviation	Criteria
Land Use Type	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5				
Pine forests	0.6264	0.5906	0.5866	0.5884	0.5979	29,899	0.5980	0.015	Medium

According to Wasis, (2012) states that the primary source of soil organic matter is organic plant tissue, in the form of leaves, stems/branches, twigs, fruit, and roots. Meanwhile, the secondary source is the organic tissue of fauna including their feces and microflora. The presence of soil organic matter is very important in determining the fertility of soil because, in organic matter, nutrient elements such as total N, essential nutrients, soil minerals, and so on are stored. The pH value, C-organic content, and basic cations (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) are closely related to soil CEC. CEC is a chemical characteristic of soil that is similar to soil fertility in that it can both absorb and supply nutrients to plants. The effective CEC value is often referred to as base saturation (% BS). Opening of land due to forest encroachment causes basic cations or essential nutrients such as Ca and Mg to be washed away by rainwater and soil erosion. organic matter, stored nutrient elements such as total N, essential nutrients, soil minerals, and so on. The pH value, C-organic content, and basic cations (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) are very closely related to soil CEC. CEC is a chemical characteristic of soil that shares similarities with soil fertility in terms of its capacity to both absorb and supply plant nutrients. The effective CEC value is often referred to as base saturation (% BS). Opening of land due to forest encroachment causes basic cations or essential nutrients such as Ca and Mg to be washed away by rainwater and soil erosion (Zaman et al., 2023; Purnomo et al., 2022; Cotrufo et al., 2019).

The loss of land cover affects the reduction in total N content on land caused by the encroachment of pine forests. When it rains, the potential for surface runoff is greater, resulting in nitrogen in the form of NO_3 being very easily leached with flowing water. The amount of organic matter and soil microorganisms at that site is declining, which has an impact on the nitrogen content as well. Because the composition of the organic material network contains organic nitrogen elements which are decomposed by soil microorganisms into nitrogen available for plants (Wasis, 2012; Melya & Agus Setiawan, 2014). The reduction in organic matter following the encroachment of pine forests had a significant impact on the decrease in phosphorus levels in open land. One of the influences of organic matter on soil properties and its consequences on plant growth is as a source of nutrients N, P, S, microelements, etc. The potassium content after encroachment is higher than the potassium content in pine forests. This can be influenced by the process of washing mineral materials due to surface runoff (Wasis & Fikri, 2021). Similarly, the low pH values of H_2O, K-exchangeable, P-available, and N-total show that the pine forest's land use type falls into the medium category, making it somewhat less fertile. Improper land management can cause a decrease in soil and water quality and a decrease in plant growth (Hermon et al., 2023; Syamsu & Yusuf, 2019).

Conclusion

The Aceh Besar Regency is a pine forest land use type is soil quality index falls into the medium category. Low C-organic content, high volume weight, low pH H_2O, K-exchangeable, P-available, and N-total all indicate this. Special treatment is required for land used for pine forests. This treatment includes fertilizing, reforesting the area with pine plants, and performing drainage to minimize nutrient leaching from the topsoil layer.

Acknowledgments
We would like to express our gratitude to the Politeknik Indonesia Venezuela for its assistance in supporting this research activity until it was published in a journal. Likewise, to all respondents involved in helping to obtain data and the local government.

Author Contributions
Conceptualization: U.H.A., R.S., Y.A and M.Y.; methodology: U.H.A., RS., Y.A and M.K; validation: U.H.A., M.Y., L.M and MK; formal analysis: U.H.A., R.S., M.Y., LM; investigation, U.H.A., R.S., Y.A. and L.M.; resources: Y.A., M.Y. dan L.M.; data curation, U.H.A., Y.A. and L.M.; writing—original draft preparation, U.H.A., R.S., Y.A. and L.M.; writing—review and editing: M.Y., L.M. dan M.K.,; visualization, U.H.A., R.S., Y.A. and L.M.; supervision, U.H.A and R.S; project administration: M.Y. and M.K.

Funding
This research received no external funding

Conflicts of Interest
The authors declare no conflict of interest.

References

Akbar, Y., Endiyani, E., Agustina, S., Irhami, I., Rezvani, I., & Irmayanti, I. (2022). Analysis of Soil Quality Index of mixed garden land use type on dry land in Blang Bintang sub-district, Aceh Besar district. *Journal of Tropical Crop Agronomy (JUATIKA)*, 4(1), 155–165. https://doi.org/10.36378/juatika.v4i1.1794

Amorim, H. C. S., Ashworth, A. J., Brye, K. R., Wienhold, B. J., Savin, M. C., Owens, P. R., & Silva, S. H. G. (2021). Soil quality indices as affected by long-term burning, irrigation, tillage, and fertility management. *Soil Science Society of America Journal*, *85*(2), 379–395. https://doi.org/10.1002/saj2.20188

Arifin, Z. (2011). Analysis of entisol soil quality index values in different land uses. *J. Agroteksos*, 21(1), 47–54.

Ashworth, A. J., Owens, P. R., & Allen, F. L. (2020). Long-term cropping systems management influences soil strength and nutrient cycling. *Geoderma*, *361*, 114062. https://doi.org/10.1016/j.geoderma.2019.114062

Bünemann, E.K., Bongiorno, G., Bai, Z., Creamer, R.E., De Deyn, G., De Goede, R., Fleskens, L., Geissen, V., Kuyper, T.W., & Mäder, P. (2018). Soil quality–A critical review. *Soil Biology and Biochemistry*, 120, 105–125. https://doi.org/10.1016/j.soilbio.2018.01.030

Cotrufo, M. F., Ranalli, M. G., Haddix, M. L., Six, J., & Lugato, E. (2019). Soil carbon storage informed by particulate and mineral-associated organic matter. *Nature Geoscience*, *12*(12), 989–994. https://doi.org/10.1038/s41561-019-0484-6

De Paul Obade, V., & Lal, R. (2014). Soil quality evaluation under different land management practices. *Environmental Earth Sciences*, 72, 4531–4549. https://doi.org/10.1007/s12665-014-3353-z

De Paul Obade, V., & Lal, R. (2016). A standardized soil quality index for diverse field conditions. *Science of the Total Environment*, 541, 424–434. https://doi.org/10.1016/j.scitotenv.2015.09.096

Dewi, N. P. Y. A., Yustiningsih, M., & Saridewi, M. P. (2022). Orchid Exploration in the Forest of Saenam Village as Nuftah Plasma Conservation. *Jurnal Penelitian Pendidikan IPA*, *8*(3), 1148– 1150. https://doi.org/10.29303/jppipa.v8i3.1409

Emi, S. (2022). Fertility Status of Inceptisol Soil on Oil Palm Land Use in Pengadang Village, Sekayam District, Sanggau Regency. *Pedontropica: Journal of Soil Science and Land Resources*, 8(2), 25–35. https://doi.org/10.52045/jca.v3i1.277

Farrasati, R., Pradiko, I., Rahutomo, S., Sutarta, ES, Santoso, H., & Hidayat, F. (2019). Soil organic C in oil palm plantations in North Sumatra: status and relationship with some soil chemical properties. *Journal of Soils and Climate*, 43(2), 157–165. https://doi.org/10.51601/ijse.v3i4.85

Guillaume, T., Maranguit, D., Murtilaksono, K., & Kuzyakov, Y. (2016). Sensitivity and resistance of soil fertility indicators to land-use changes: New concept and examples from conversion of Indonesian rainforest to plantations. *Ecological Indicators*, *67*, 49–57. https://doi.org/10.1016/j.ecolind.2016.02.039

Hakim, L., Iemaaniah, ZM, & Rachmadi, A. (2023). Socialization of Forest and Land Rehabilitation Using Civil-Technical Conservation Methods in Land Control in Rembitan Village, Pujut District, Central Lombok. *Agricultural Scientist Broadcast Journal*, 4(1), 112–117. http://doi.org/10.17503/agrivita.v40i3.1605

Hermon, D., Barlian, E., Umar, I., & Efendi, N. (2023). Post-Coal Mining Reclamation Land Sustainability Study in Tebo Regency. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 10330–10337. http://doi.org/10.29303/jppipa.v9i11.5553

Husni, MR, Sufardi, S., & Khalil, M. (2016). Evaluation of fertility status on several types of soil in Dry Land, Pidie Regency, Aceh Province. *Agricultural Student Scientific Journa*l, 1(1), 147–154. https://doi.org/10.36378/juatika.v3i2.1380

Lestari, A. (2023). Physical and Chemical Properties of Soil in Various Types of Land Use in Lembanna Village, Tinggimoncong District, Gowa Regency. Hasanuddin University. https://doi.org/10.1088/1755-1315/715/1/012021

Ma, Y., Cheng, X., Kang, F., & Han, H. (2022). Dynamic characteristics of soil aggregate stability and related carbon and nitrogen pools at different developmental stages of plantations in northern China. *Journal of Environmental Management*, *316*, 115283. https://doi.org/10.1016/j.jenvman.2022.115283

Mausbach, M. J. (1998). Assessment of soil quality. Soil Quality and Agricultural Sustainability.

Melya, R., & Agus Setiawan, A. (2014). Soil fertility status in two land covers in the Batutegi Lampung Protected Forest Management Unit (KPHL). *Sylva Lestari Journal*, 2(2), 99–104. http://doi.org/10.23960/jsl2299-104

Mukherjee, A., & Lal, R. (2015). Tillage effects on quality of organic and mineral soils under on-farm conditions in Ohio. *Environmental Earth Sciences*, *74*,1815–1822. http://doi.org/10.1007/s12665-015-4189-x

Palloan, P., Ansar, N. A., & Susanto, A. (2023). Analysis of Soil Physical Parameters in Landslide Prone Areas in West Battang Village, Palopo City as Early Mitigation of Landslide Disasters. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 10230–10235. https://doi.org/10.29303/jppipa.v9i11.3031

Purnomo, J., Nurjaya, N., & Setyorini, D. (2022). The Effect of NPK 12-6-27 Fertilization on the Growth of Oil Palm Plants in the Main Nursery on Bogor Acid Dry Land. *Jurnal Penelitian Pendidikan IPA*, *8* (SpecialIssue), 129–136. https://doi.org/10.29303/jppipa.v8iSpecialIssue.2483

Partoyo, P. (2005). Analysis of the Soil Quality Index for Sand Dune Agriculture Land at Samas Yogyakarta. *Agricultural Science*, 12(2), 140–151.

Poukrel, S., Maguire, R.O., Thomason, W.E., & Stewart, R.D. (2022). Building Healthy Soil with Best Management Practices.

Rafika, A., Zuraida, Z., & Muyassir, M. (2022). Application of Compost on Soil Chemical Properties and Nutrient Content of Corn Plants on Inceptisol Dry Land in Krueng Raya, Aceh Besar. Agricultural Student Scientific Journal, 7(2), 665–671. e-ISSN: 2614-6053

Raiesi, F. (2017). A minimum data set and soil quality index to quantify the effect of land use conversion on soil quality and degradation in native rangelands of upland arid and semiarid regions. *Ecological Indicators*, *75*, 307–320. https://doi.org/10.1016/j.ecolind.2016.12.049

Raiesi, F., & Salek-Gilani, S. (2020). Development of a soil quality index for characterizing effects of land-use changes on degradation and ecological restoration of rangeland soils in a semi-arid ecosystem. *Land Degradation & Development*, 31(12), 1533–1544. https://doi.org/10.1002/ldr.3553

Rinot, O., Levy, G. J., Steinberger, Y., Svoray, T., & Eshel, G. (2019). Soil health assessment: A critical review of current methodologies and a proposed new approach. *Science of the Total Environment*, *648*, 1484–1491. https://doi.org/10.1016/j.scitotenv.2018.08.259

Sahbudin, S., Khairullah, K., & Sufardi, S. (2020). Soil Acidity and Cation Exchange Properties of Mollisols and Ultisols in Dry Land, Aceh Besar Regency. *Agricultural Student Scientific Journal*, 5(3), 25–34. https://doi.org/10.1088/1755-1315/922/1/012013

Sallata, M.K. (2013). Pine (Pinus merkusii Jungh et de Vriese) and its presence in Tana Toraja Regency, South Sulawesi. *Ebony Bulletin*, 10(2), 85–98. https://doi.org/10.20886/buleboni.5013

Sheidai Karkaj, E., Sepehry, A., Barani, H., Motamedi, J., & Shahbazi, F. (2019). Establishing a suitable soil quality index for semi-arid rangeland ecosystems in northwest of Iran. *Journal of Soil Science and Plant Nutrition*, *19*, 648–658. https://doi.org/10.1007/s42729-019-00065-4

Suwati, S., Muanah, M., Huda, AA, & Gunawan, A. (2022). Economic analysis of tomato cultivation on dryland with drip irrigation technique. *Ummat Agrotech Journal*, 9(3), 190–197. e-ISSN 2614-6541

Syamsu, J. A., & Yusuf, M. (2019). Sustainability status of pasture for cattle development area in Pinrang Regency, South Sulawesi. *IOP Conference Series: Earth and Environmental Science*, *247*(1), 12058. https://doi.org/10.1088/1755-1315/247/1/012058

Tian, K., Zhang, B., Zhang, H., Huang, B., Darilek, J. L., Zhao, Y., & Yang, J. (2020). Evaluation of soil quality in major grain-producing region of the North China Plain: Integrating minimum data set and established critical limits. *Ecological Indicators*, *117*, 106613. https://doi.org/10.1016/j.still.2014.10.001

Wasis, B. (2012). Impact of Reforestation Pine Forest Encroachment Activities on the Physical, Chemical, and Biological Properties of Soil in the Lake Toba Protected Area, North Sumatra. *Conservation Media*, 17(3).

Wasis, B., & Fikri, M. (2021). Growth of Mahogany Seedlings (Swietenia macrophylla) on Tailings Media with the Addition of Coconut Shell Charcoal and Compost Fertilizer. *Journal of Tropical Silviculture*, 12(3), 109–117. http://doi.org/10.1088/1755-1315/1271/1/012023

Wawan, W. (2017). Organic Material Management. Published. Accessed via Https://Mip. Faperta. Uni. Air conditioning. Id/File/Bahanajar/59899-BUKU-AJAR-PBO-PAK-WAWAN-. Pdf On Date, 10.

Xiong, J., Wu, H., Wang, X., Ma, R., & Lin, C. (2024). Response of soil fertility to soil erosion on a regional scale: A case study of Northeast China. *Journal of Cleaner Production*, *434*, 140360. https://doi.org/10.1016/j.jclepro.2023.140360

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

Zheng, X., Wei, L., Lv, W., Zhang, H., Zhang, Y., Zhang, H., Zhang, H., Zhu, Z., Ge, T., & Zhang, W. (2024). Long-term bioorganic and organic fertilization improved soil quality and multifunctionality under continuous cropping in watermelon. *Agriculture, Ecosystems & Environment*, *359*, 108721. https://doi.org/10.1016/j.agee.2023.108721