International Journal of Plant & Soil Science

Volume 38, Issue 1, Page 36-42, 2026; Article no.IJPSS.150374
ISSN: 2320-7035

Effects of Oil Palm Empty Fruit Bunch and Coal Fly Ash on Soil pH and Nitrogen Status in Post-coal Mining Soil

Hidayatul Qamaliah [a], Fadly H. Yusran [a*], Bambang Joko Priatmadi [a] and Windi Bunga Devita [a]

[a] Soil Science Department, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru, 70714, Indonesia.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2026/v38i15923

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/150374

Short Research Article

Received: 29/09/2025
Published: 08/01/2026

Abstract

Aims: This research aims to determine the effect of applying oil palm empty fruit bunches (EFB) organic material and coal fly ash (CFA) application on soil pH, total N, and N availability in post-coal mining soil.
Study Design: The method used in this study was a completely randomized design (CRD) with two treatment factors in a greenhouse.
Place and Duration of Study: This research was conducted in the greenhouse and Soil Science Laboratory, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru, Indonesia 70714, from August 2024 to May 2025

**Corresponding author: E-mail: fhyusran@ulm.ac.id;*

Cite as: *Qamaliah, Hidayatul, Fadly H. Yusran, Bambang Joko Priatmadi, and Windi Bunga Devita. 2026. "Effects of Oil Palm Empty Fruit Bunch and Coal Fly Ash on Soil PH and Nitrogen Status in Post-Coal Mining Soil ". International Journal of Plant & Soil Science 38 (1):36-42. https://doi.org/10.9734/ijpss/2026/v38i15923.*

Methodology: The treatment factors were EFB (0, 4, 8 t ha^{-1}) and CFA (0, 5,10 t ha^{-1}) with three replicates for a total of 27 experimental units. The experimental units were 3.5 kg of soil sample in a plastic pot for two weeks of incubation. 400 mL of distilled water was added on the first day to make the soil reach the field capacity. In the following days, the field capacity was maintained by adding distilled water equal to the loss of weight. Distilled water and NPK fertilizer were added to guarantee any possible N mineralization.

Results: The results showed that the application of EFB significantly improved soil properties in post-mining soil by increasing pH. Among the treatments, the application of 8 t ha^{-1} EFB was the most effective dose for improving soil pH, while other treatments (CFA) did not show any effects, including the interaction.

Conclusion: The application of EFB increased the pH of post-mining soil, but it did not increase N availability, either $N\text{-}NH_4^-$ nor $N\text{-}NO_3^-$. Similarly, the total-N content of the soil was not affected. The application of 8 t ha^{-1} of EFB was the best dose for increasing the pH of post-coal mining soil. However, a higher dose may be needed to increase N status.

Keywords: EFB; coal fly ash; soil pH; N content.

1. Introduction

Indonesia is a country with abundant natural resources. One of these natural resources is non-renewable mining, namely coal mining. One region in Indonesia known for its coal production is South Kalimantan. According to data from the Geological Agency (Badan Geologi, 2023), coal mining production in South Kalimantan in 2023 reached 13,347.72 million tons. Coal mining causes changes in landforms and soil quality from post-mining stockpiles, destroying the topsoil, where the topsoil mixes with the subsoil. The topsoil is replaced by less fertile subsoil. Similarly, the biological population in the upper layers of the soil is submerged, causing damage and impaired function (Subowo, 2011).

Post-mining land is land that has changed from its original form, including the landscape, physical, chemical, and biological properties of the soil. Excavations cause the loss of topsoil due to mixing with the subsoil and parent material. Mining activities reduce soil fertility. Post-mining land generally has the potential to become agricultural land with proper management. One crop that can be planted on post-mining land is corn. Corn is an annual crop with a relatively short life cycle and is tolerant of extreme conditions such as nutrient-poor soil. However, corn cultivation on post-mining land requires soil fertility management, particularly nutrient management, such as through the application of ameliorants and fertilization (Ramayana et al., 2021). Materials that can be utilized to improve nutrient levels in post-mining soil include empty oil palm bunches (EFB) and CFA (Subagio et al., 2018).

Empty oil palm bunches are one of the main waste products generated by the palm oil processing industry (Radhitya, 2020). EFB, as a source of organic material, has the potential to be utilized due to its abundant availability and can be utilized as an organic fertilizer, which can improve the physical, chemical, and biological properties of the soil. Empty oil palm fruit bunches contain lignocellulose, the main components of which are cellulose (45.95%), hemicellulose (22.84%), lignin (1.23%), N (0.53%), and oil (2.41%) (Firmansyah, 2010). Furthermore, EFB not only improves soil properties but also has physiological effects on plant growth (Ariyanti et al., 2024; Hwong et al., 2022; Purwanto et al., 2025).

CFA is a solid residue from coal combustion that is carried along with exhaust gases and captured by air handling equipment. Generally, CFA contains various heavy metals. According to Government Regulation No. 85 of 1999, CFA is classified as hazardous and toxic waste (B3) due to its heavy metal content, including Cu, Pb, As, Cd, and others. These heavy metals are mobile and easily absorbed by plants, making them toxic. If CFA solid waste is not properly managed, it can cause environmental pollution, including water, air, and soil. However, optimizing the utilization of CFA waste can be developed and utilized in line with the issuance of Government Regulation of the Republic of Indonesia Number 22 of 2021, which classifies CFA as Non-B3 Waste. Moreover, CFA also contains limited amounts of nutrients which may be beneficial for plant growth (Basu et al., 2009; Saidy et al., 2021; Singh & Kaur, 2020). Therefore, treatment of EFB, CFA, and their interaction may affect soil characteristics.

2. Materials and Methods

This research was conducted from August 2024 to May 2025 in the Soil Department Greenhouse and the Soil Chemistry and Physics Laboratory, Faculty of Agriculture, Lambung Mangkurat University. Soil samples were taken from the mining area of PT Arutmin Indonesia, Satui District, Tanah Bumbu Regency.

This research was conducted in a greenhouse using a completely randomized design (CRD) with two factors using plastic buckets as soil containers. The first factor was EFB (0, 4, and 8 t ha^{-1}), and the second factor was CFA (0, 5, and 10 t ha^{-1}). Each treatment was replicated three times, resulting in 27 experimental units.

Soil samples were collected from the post-coal mining area of PT Arutmin Indonesia in Satui District, Tanah Bumbu Regency. Soil samples were taken at a depth of 0-20 cm. They were then air-dried, ground, sieved through a 2 mm sieve, and then composited. Next, 3.5 kg of soil was weighed and placed in a bucket, then incubated for two weeks. During the incubation process, the bucket was watered with 400 mL of water for each bucket on the first day. The second day, the bucket was weighed to determine field capacity. After the incubation process was complete, the soil was placed in a greenhouse. NPK fertilizer was applied at a dose of 0.2215 g $bucket^{-1}$ soil (3.5 kg) as a base fertilization (200 kg NPK ha^{-1}). The incubation process was held to make sure that all physical, chemical, and biological processes were established as in nature.

The experimental data were analyzed using Bartlett's homogeneity of variance test. If the data were homogeneous, analysis of variance (ANOVA) would be used. If not, data transformation was performed to achieve homogeneity. If a significant effect was found, as indicated by the calculated F value > F table, multiple comparisons were then performed using Duncan's Multiple Range Test (DMRT) at 95% confidence level or 5% alpha (Mahbub, 2025).

3. Results and Discussion

3.1. Soil Acidity (pH)

The results of the Bartlett homogeneity test indicated that the pH data were homogeneous. The analysis of variance results indicated that the application of EFB significantly affected the pH of post-mining soil. The increase in soil pH can be seen in Fig. 1, which shows that the application of 8 t ha^{-1} of EFB significantly increased soil pH and was the best treatment compared to the control and EFB 4.

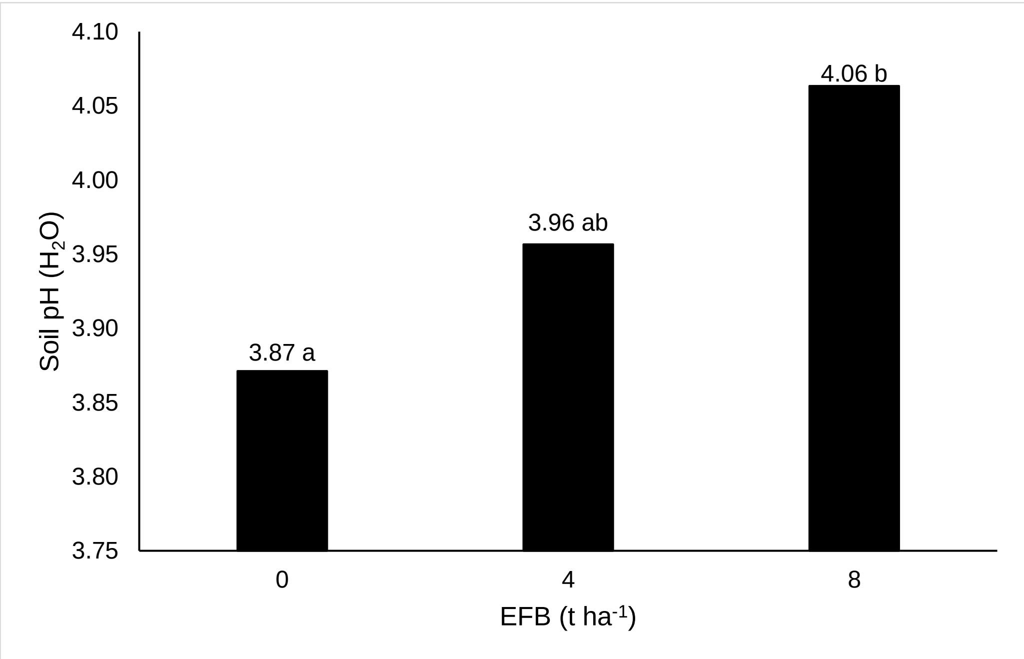

Fig. 1. The effect of oil palm empty fruit bunches application on soil pH

The results showed that the application of EFB increased pH in all treatments in line with the increasing dose. The 8 t ha^{-1} EFB treatment had the highest pH value with an average of 4.06. The control treatment had the lowest pH value with an average of 3.87. This is thought to be due to further decomposition, which releases base elements, which can raise the pH. The increasing trend in pH indicates that fresh EFB requires time to react, so prolonged application of EFB tends to increase the pH. This aligns with previous research by Hasibuan (2015), which stated that the decomposition process releases bases, thereby increasing soil pH.

3.2 Total-N

The results of the homogeneity of variance test for total-N data showed that the variance was homogeneous. However, the analysis of variance showed that CFA, EFB, and their interaction had no significant effect on total-N. Therefore, further tests such as the DMRT were not conducted because no significant effect was found between treatments. However, the results showed a slight increase compared to the initial soil analysis results. This was suspected to be due to soil N loss from several factors, including volatilization, immobilization by microorganisms, and leaching, in line with research (Setiawati et al., 2021). The analysis results showed that the overall total-N content in this study was classified as very low, at 0.09%. The low total-N content in post-mining soil is generally caused by low organic-C content, lost due to leaching and evaporation. The addition of organic matter can increase the soil total-N, although the increase is not significant. This increase in soil total-N comes from the mineralization of applied organic matter. According to (Afandi et al., 2015; Hardjowigeno, 2012; Salam, 2023), the process of N loss in the soil occurs because it is absorbed by plants, used by microorganisms, N is still in the form of NH_4^+ bound by clay minerals so it cannot be used by plants, N is also still in the form of NO_3^- which is easily washed away by rainwater and land conditions that are still flooded with poor drainage and poor air ventilation can also occur the process of denitrification and also volatilization in the form of NH_3.

3.3 Ammonium-N

The results of the homogeneity of variance test for N-NH_4^+ showed that the variance was homogeneous. The analysis of variance showed that the application of EFB affected the availability of N-NH_4^+, while CFA had no significant effect on N-NH_4^+. The results showed that the untreated control provided the highest N-NH_4^+ concentration with an average of 235 mg $kg^{-1.}$ Meanwhile, the 8 t ha^{-1} EFB treatment showed the lowest N-NH_4^+ availability with an average of 149 mg kg^{-1}, as can be seen in Fig. 2.

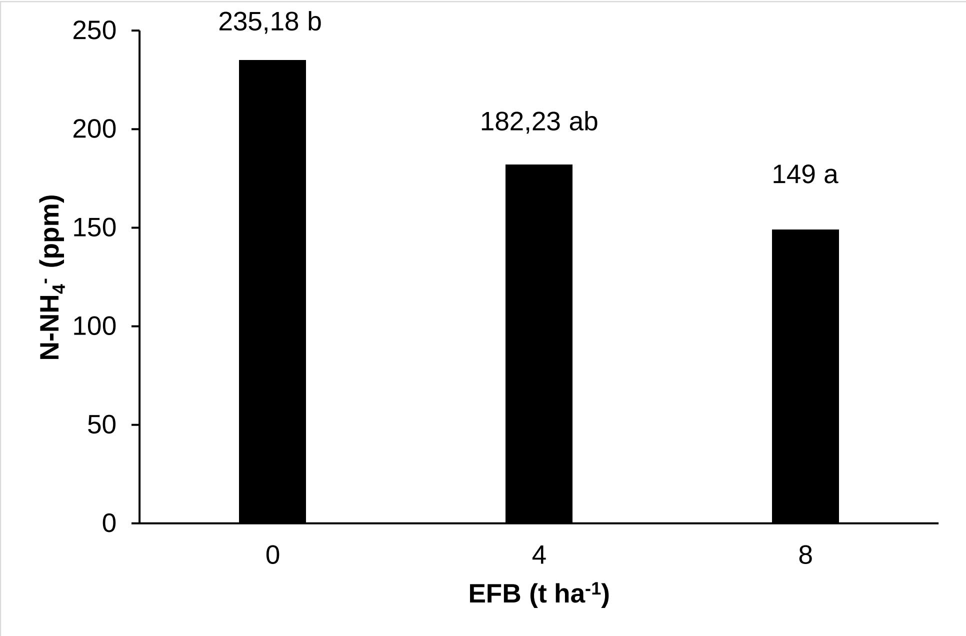

Fig. 2. The effect of oil palm empty fruit bunches on ammonium (N-NH_4^+)

The results showed that the application of EFB and CFA in post-mining soils had not been able to increase N availability in the soil. The control treatment showed the highest availability value. The control treatment showed the highest N-NH_4^+ availability in this study, with an average of 235 mg kg^{-1}, and the lowest was applied with 80 t ha^{-1} EFB, with an average of 148 mg kg^{-1}. In this phase, only EFB applications influenced N availability, although it did not increase it effectively. This is in line with previous research, which is suspected to be influenced by the rate of EFB decomposition. According to (Saidy et al., 2021) and (Ariyanti et al., 2024), the increase in N availability for plants (organic-N mineralization) or the decrease in N availability (immobilization) in soil supplemented with organic matter is determined by the C/N ratio of the added organic matter.

3.4. N-Nitrate

The results of the homogeneity test for N-NO_3^- showed that the variance was homogeneous. The analysis of variance results showed that the application of EFB affected the availability of N-NO_3^- and CFA had no significant effect on N-NO_3^- availability. The results showed that the control (without EFB and CFA) provided the highest N-NO_3^- availability, with an average of 372 mg kg^{-1}. Meanwhile, the treatment with 8 t ha^{-1} of EFB showed the lowest N-NO_3^- availability, with an average of 178 mg kg^{-1}, as can be seen in Fig. 3.

The results of the study indicate that the application of EFB and CFA could not increase N-availability in the soil. The control treatment showed the highest N-NO_3^- availability in this study, with an average of 372 mg kg^{-1}, and the lowest was applied with 80 t ha-1 of EFB, with an average of 178 mg kg^{-1}. Similarly, the application of EFB affected N-NO_3^- levels, although it was still not able to increase them effectively, as the control average value was still the highest.

This aligns with research indicating that EFB and CFA cannot effectively increase N levels in the soil, primarily due to slow biological and chemical processes in the soil and the nature of these materials. This is related to soil pH, which affects nutrient availability for plant uptake. This is also in line with Hardjowigeno (2012) and Salam (2023), who stated that plants will be productive in soil with a pH range of 5.50-8.30, depending on the crop type. However, in this study, the soil pH ranged from 3.87-4.06, which was considered very acidic. Low pH in the soil will be followed by low availability of nutrients, especially macronutrients such as N, K, Ca, Mg, and S.

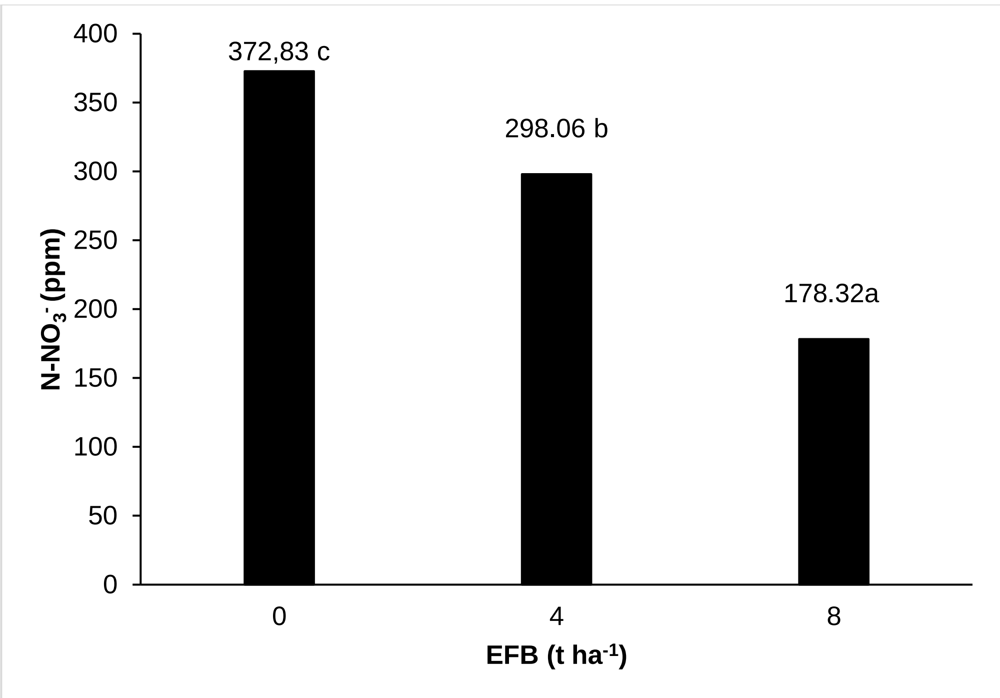

Fig. 3. The effect of oil palm empty bunch application on nitrate (N-NO_3^-)

4. Conclusion

The application of EFB can increase the pH of post-mining soil, but it does not increase N availability. Similarly, the total-N content of the soil was affected. The application of 8 t ha^{-1} of EFB was the best dose for increasing the pH of post-coal mining soil. However, higher doses may be needed to increase N status, either total-N or N-availability.

Disclaimer (Artificial Intelligence)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

References

Afandi, F. N., Siswanto, B., & Nuraini, Y. (2015). Pengaruh Pemberian Berbagai Jenis Bahan Organik terhadap Sifat Kimia Tanah pada Pertumbuhan dan Produksi Tanaman Ubi Jalar di Entisol Ngrangkah Pawon, Kediri. *Jurnal Tanah Dan Sumberdaya Lahan*, *2*(2), 237–244. https://jtsl.ub.ac.id/index.php/jtsl/article/view/134

Ariyanti, M., Rusmaputra, L., Anjarsari, I. R. D., & Hendriawaty, R. D. P. (2024). The Effect of Compost Application Dosage of Oil Palm Empty Fruit Bunches and Bacillus subtilis on the Growth of Oil Palm Seedlings. *Surjan: Journal of Sustainable Agriculture*, *1*, 62–69. https://ejournal.iaar.or.id/surjan/article/view/10

Badan Geologi. (2023). *Laporan Kinerja Badan Geologi 2023. Badan Geologi Kementerian Energi dan Sumber Daya Mineral*. https://geologi.esdm.go.id

Basu, M., Pande, M., Bhadoria, P. B. S., & Mahapatra, S. C. (2009). Potential fly-ash utilization in agriculture: A global review. *In Progress in Natural Science (Vol. 19*, Issue 10). https://doi.org/10.1016/j.pnsc.2008.12.006

Firmansyah, M. A. (2010). Teknik Pembuatan Kompos. In *Pelatihan Petani Plasma Kelapa Sawit di Kabupaten Sukamara, Kalimantan Tengah*. Balai Pengkajian Teknologi Pertanian (BPTP) Kalimantan Tengah.

Hardjowigeno, S. (2012). Ilmu Tanah. In *Akademika Pressindo*. Akademika Pressindo.

Hasibuan, A. S. (2015). Pemanfaatan Bahan Organik dalam Perbaikan Beberapa Sifat Tanah Pasir Pantai Selatan Kulon Progo. *Planta Tropika: Journal of Agro Science*, *3*(1), 31–40. https://doi.org/10.18196/pt.2015.037.31-40

Hwong, C. N., Sim, S. F., Kho, L. K., Teh, Y. A., Harrold, L. D., Chua, K. H., & Zainal, N. H. (2022). Effects of Biochar from Oil Palm Biomass on Soil Properties and Growth Performance of Oil Palm Seddlings. *Journal of Sustainability Science and Management*, *17*(4). https://doi.org/10.46754/jssm.2022.4.014

Mahbub, M. (2025). *M_maHbuB's activities in free for All*. https://mmahbub.wordpress.com/

Purwanto, B., Shalihy, W., & Indrawati. (2025). Effect of NPK Fertilizer and Trichoderma harzianum-Enriched Oil Palm Empty Fruit Bunch Compost on the Growth of Oil Palm Seedlings. *Agro Bali*, *8*(2). https://doi.org/10.37637/ab.v8i2.2356

Radhitya. (2020). Karakterisasi Bioetanol Tandan Kosong Kelapa Sawit dengan Metode Pemurnian Adsorpsi (Adsorpsi Menggunakan Adsorben Berupa Zeolit). *Jurnal Industri Pertanian*, *2*(2), 113–123.

Ramayana, S., Idris, S. D., Rusdiansyah, R., & Madjid, K. F. (2021). Pertumbuhan dan Hasil Tanaman Jagung (*Zea mays* L.) terhadap Pemberian Beberapa Komposisi Pupuk Majemuk pada Lahan Pasca Tambang Batubara. *AGRIFOR*, *20*(1), 35. https://doi.org/10.31293/agrifor.v20i1.4877

Saidy, A. R., Priatmadi, B. J., Septiana, M., & Mulyawan, R. (2021). Improvement of pH and Reduction of Heavy Metal Concentrations in Acid Mine. *Journal of Hunan University Natural Sciences*, *48*(10). https://www.jonuns.com/index.php/journal/article/view/807

Salam, A. K. (2023). Pengantar Ilmu Kimia Tanah. In *Badan Penelitian dan Pengembangan Pertanian*. Global Madani Press.

Setiawati, M. R., Utami, D. S., Hindersah, R., Herdiyantoro, D., & Suryatmana, P. (2021). Pemanfaatan Limbah Pertanian dalam

Menurunkan Dosis Pupuk Anorganik, Meningkatkan Populasi Azospirillum sp., Nitrogen Tanah, Serapan Nitrogen, dan Hasil Jagung pada Inceptisols Jatinangor. *Soilrens*, *19*(1), 9–19. https://doi.org/10.24198/soilrens.v19i1.35084

Singh, G., & Kaur, K. (2020). Influence of Fly Ash Incorporation on Soil Properties and Productivity of Crops: Review. *International Research Journal of Engineering and Technology*.

Subagio, A. A., Mansur, I., & Sari, R. K. (2018). Pemanfaatan Kompos Tandan Kosong Kelapa Sawit untuk Meningkatkan Pertumbuhan Tanaman Kayu Putih (Melaleuca cajuputi) di Lahan Pasca Tambang Batubara. *Journal of Tropical Silviculture*, *9*(3), 160–166. https://doi.org/10.29244/j-siltrop.9.3.160-166

Subowo, G. (2011). Environment Friendly Open Pit Mining Systems and Reclamation Post-Mining Efforts to Improve the Quality of Land Resources and Soil Biodiversity. *Jurnal Sumberdaya Lahan*, *5*(2). https://repository.pertanian.go.id/handle/123456789/2314

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/150374