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Strengthen farmers' fertilizer self-sufficiency in the tourist area with a reduce-reuse-recycle system

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ABSTRACT

Mining activities at Tebing Breksi are a vital source of income for the community in Sambirejo village, Sleman Regency, Yogyakarta. However, these activities have caused several environmental issues, such as lowered pH levels, reduced soil fertility, shallow soil profiles, and water scarcity. Additionally, mining has led to biodiversity loss and land degradation, making post-mining reclamation essential to restore the area's environmental and social functions. This project aimed to enhance the community's skills in soil analysis and the production of liquid organic fertilizer using effective methods. The activities took place in the Tebing Breksi tourist area, located in Nglengkong, Sambirejo Village, Prambanan District, Sleman Regency. The project included a Focus Group Discussion (FGD), soil fertility analysis using test kits, and the creation of liquid organic fertilizer from household waste. During the FGD, it was discovered that the local community had not received prior training on producing fertilizer from household and organic waste. Until then, they relied on expensive commercial fertilizers to quickly stabilize soil pH. Through this training, the community learned how to perform rapid soil chemical analysis and produce liquid organic fertilizer independently. As a result, they can now apply the fertilizer locally, improving soil conditions and reducing their reliance on costly commercial products.

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1. INTRODUCTION

The Special Region of Yogyakarta (DIY) has diverse and hilly landscapes that contain valuable mineral resources. Especially in Sambirejo Village, Sleman District, breccia and limestone dominate the area, providing a source of livelihood for the local community through small-scale mining (Britannica, 2024; Indonesia Tourism, 2019). Breccia rocks are classified similarly to conglomerates as clastic sedimentary rocks. They form through the weathering of igneous rocks (Nugroho et al., 2019). Both conglomerates and breccias have fragment grains larger than 2 mm. The sedimentary rocks' structure comprises fragments of varying diameters, including clay (less than 2 mm) and sand or gravel (larger than 2 mm). Breccia rocks typically form in areas that have experienced an outcropping event (Prastowo et al., 2021). During this process, remnants of weathering igneous rocks accumulate. The flow carries

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fragments of igneous rock resulting from weathering and deposits them around the outcrop area, such as in alluvial fans. The remnants of igneous rock degrade into fragments bound with other minerals during the decomposition process, forming breccia rock (Pribadi, 2021). Moreover, according to Nugroho et al. (2019), *Tebing Breksi* (Breccia Clift) in Sambirejo Village contains a rock site that provides information about the formation of Java Island, particularly the process of volcano formation in the southern part of the island. This process took place during the Oligocene-Middle Miocene period, about 36-10.2 million years ago, and resulted in the formation of the Old Andesite Formation (OAF) period. This period can be considered the peak of volcanism on Java Island. The Semilir Formation includes the site where the Semilir volcano had a super eruption. Tebing Breksi is associated with the Nglanggran volcanic site in Gunung Kidul. After the super-eruption of Semilir Volcano, a new volcano called Nglanggran Volcano emerged in the center of its caldera (Hana Tour & Travel, 2019; Prastowo et al., 2021).

The history and environmental value of the area make its preservation critical. However, the socio-economic and environmental problem that exists in this area is small-scale mining, which extracts valuable materials from the earth, mainly breccia. According to government data, 25 percent of Sambirejo villagers work as small-scale miners of breccia and limestone. Although according to the Mining Business of Excavated Materials in Regional Regulation No. 11 of 2003 (Article 1 No. 8) in Gunung Kidul Regency, small-scale community mining is only a business carried out by local people in a limited area (Harjiyatni et al., 2024). Even in a limited area, mining can have a negative impact on the environment (Kurniati et al., 2023) due to changes in soil structure as a result of excavation, disruption of natural watercourses, and lowering of groundwater levels (Misbahuddin, 2021), accumulation of mine waste, depletion of soil fertility (due to soil acidification, low cation exchange capacity and base saturation), degradation of forest land, and negative impacts on aquatic biodiversity and public health (Sinukaban et al., 2024).

The impact of mining on soil fertility is very important to be addressed immediately to improve the ecosystem for a sustainable life. A previous study found that post-mining soils without treatment (reclamation measures) have a decreased pH of 2.2-3.5 (Nadalia & Pulunggono, 2020). Acidic soils have a low ability to support plant growth because the availability of most macronutrients decreases when the soil pH becomes acidic. Macronutrients, such as nitrogen, phosphate, potassium, calcium, magnesium, and sulfur, are not available under acidic pH (Zama et al., 2022). Micronutrients, except for molybdenum, are usually more available at low pH. When dealing with acidic soils, it is important to consider the solubility of micronutrients. Nutrients that are required by plants in small amounts can become available in large amounts, increasing the risk of toxicity, such as iron or aluminum toxicity in plants (Dhaliwal et al., 2019). Also, the problem that occurs at the mining site in the research area is the mining process that undermines environmental sustainability. The impact is the loss of several springs, which causes agricultural land to dry up, resulting in crop failure or reduced productivity. Ironically, these problems are seen as unrelated, and society sees them as the effects of global climate change. For this reason, a holistic approach is needed that is not limited to environmental approaches, but also includes social and economic aspects.

Former mining land must be reclaimed to restore environmental and social functions, based on local conditions (Rosa et al., 2022). In Sambirejo Village, Sleman District, Yogyakarta, the area has been transformed into a tourist destination, with a total of 61,065 visitors in 2022. Local visitors accounted for 99.04 percent of the total tourists, while the remaining 0.96 percent were foreign tourists (Britannica, 2024; Indonesia Tourism, 2019). However, the environmental function has not yet been fully restored due to several unresolved environmental problems. Mining activities have caused acidic soil pH, which remains a major obstacle in reclaiming ex-mining land for agricultural purposes. Farmers still using traditional farming methods often face difficulties with the solubility of these essential nutrients in agriculture as soil pH declines. One of many approaches that are used to increase soil pH is organic matter application that increases soil pH by adding cations (K^+, Na^+, Mg^{2+}, and Ca^{2+}) from fertilizer. These

cations displace protons and aluminum from exchange sites. This increases the base saturation of the soil, which in turn raises the soil pH (Food and Agriculture Organization, 2024). Additionally, NH_3 release from organic nitrogen decomposition can also cause an increase in pH (Zhang et al., 2015).

One effective and environmentally friendly reclamation method is the application of organic matter, which increases soil pH (Rosa et al., 2022). However, the quality and quantity of organic matter applied in the form of fertilizer is not adequate and increases farmers' dependence on fertilizer products imported from outside the area. Therefore, an increase in the quality and quantity of organic amendment or fertilizer from domestic production to increase soil pH is required. Consequently, increasing farmers' independence and resilience in agriculture is crucial to prevent the community from shifting from agriculture to mining. In order to realize the self-reliance of the community around the former mining area as part of land reclamation efforts, it is necessary to conduct training in soil analysis using rapid test kits so that farmers can decide on the necessary measures. Training the community in the production of organic fertilizer from household waste and how to apply the correct dosage of fertilizer is urgently needed to support the self-reliance of the area, which is currently being developed as an eco-friendly tourist area with the reduce-reuse-recycle mechanism. Reduce, reuse, recycle (3Rs) is a concept used to recycle waste into materials that can be reused to reduce the use of natural resources, reduce the amount of waste generated, and reduce negative impacts on the environment. Therefore, the activity aims to increase the knowledge of the surrounding community about soil fertility through soil chemical testing using rapid testing techniques and provide knowledge related to the process of making liquid organic fertilizer from household waste to realize sustainable living. This is expected to increase the productivity and sustainability of agricultural enterprises in the area.

2. METHODS

Location of Community Service Area

The community service was conducted in the Tebing Breksi tourist area located in Nglengkong, Sambirejo Village, Prambanan District, Sleman Regency, DIY, Central Java Province. The area covers 274,422.18 m^2 and is situated at 7°46'53.96" S and 110°30'18.73" E (Figure 1). The area originated from rock outcrops of ancient volcanic ash deposits. The community mined these deposits from 1980s to 2013. Mining was stopped due to environmental damage (Kurniawati et al., 2020). It is crucial to manage ex-mining land with proper measures to get both environmental and economic benefits. Proper management of ex-mining land is crucial in reducing environmental damage resulting from the loss of vegetation, flora, fauna, and soil layers (Radnawati et al., 2023).

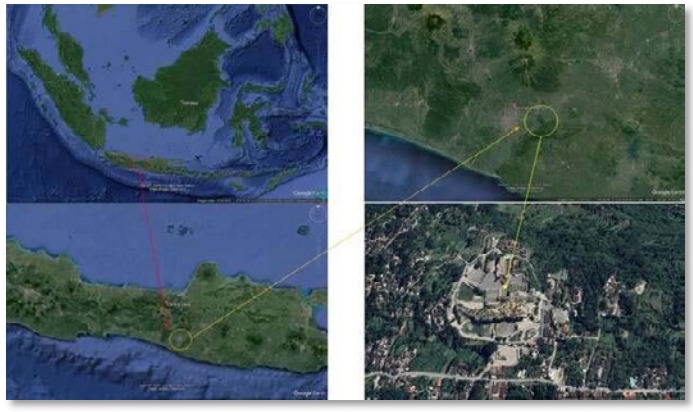

Figure 1. The location of community service

Focus Group Discussion

The first Focus Group Discussions (FGDs) were conducted with the Tebing Breksi Managers, the Tlatar Seneng Tourism Awareness Community Group (POKDARWIS) and the local village officials (Figure 2A). This approach was intended to diversify the information obtained regarding the discussion topics, which included socio-economic problems, environmental problems, revegetation constraints due to soil pH and soil fertility for crop production, community needs, and solutions to these problems. Figure 2B shows the problem-solving mechanism for waste management in the post breccia mine area that has been reclaimed into a tourist site in Sambirejo Village. The problem-solving mechanism was developed after the FGD. The first FGD was attended by 4 people from Tebing Breksi tourism managers and the local village officials. The topic related to socio-economic and environmental problems was delivered by the head of POKDARWIS Tlatar Seneng, however, the topic related to revegetation constraints for crop production and community needs was delivered by the head of farmers community group (GAPOKTAN) in Sambirejo Village. The second FGD on 23 December 2023, consisted of 50 people including Tebing Breksi tourism managers, village officials, farmers, former miners and villagers whose land was affected by drought due to mining activities. The topics discussed were related to understanding environmental sustainability and how to utilize ex-mining land to restore its environmental and economic function. This FGD provides an opportunity for participants to convey the problems faced by local residents, share experiences, and solutions that have been done in improving the chemical properties of local soil. The expected outcomes of this FGD will help guide future initiatives and interventions to address local needs and challenges.

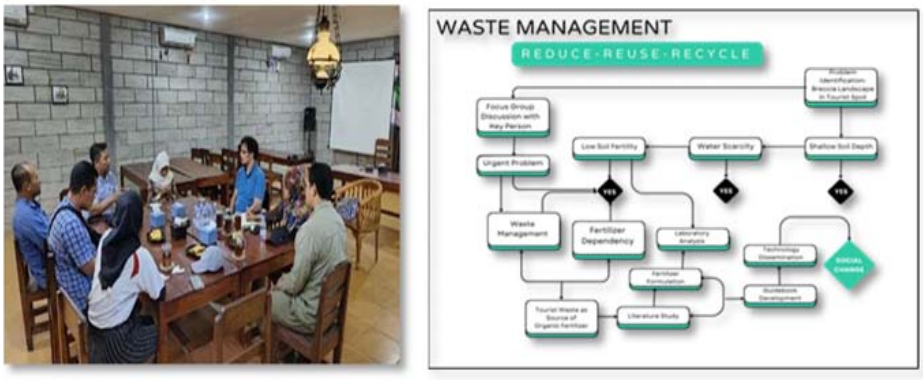

Figure 2. (A) Discussion with POKDARWIS Tlatar Seneng at Tebing Breksi, Sleman, Yogyakarta; (B) Problem-solving mechanism for waste management in the post-breccia mining area

Using Booklets for Work Instructions

The use of booklets in learning is an effective strategy for improving participants' understanding of the material presented. Booklets can serve as practical guides that provide complete and illustrated information. In the context of teaching aids, the booklet can be used as a guide for conducting soil fertility analysis using a test kit and for making liquid organic fertilizer from household waste. Both booklets aim to provide objective and understandable information to the readers. The purpose of the organic fertilizer booklet is to provide participants with clear and concise instructions on how to use liquid organic fertilizer made from household waste. The booklet includes tools, materials, work instructions and application dosages. Similarly, the soil fertility analysis booklet includes tools, materials, work procedures, and interpretation of soil fertility analysis results (Figure 3).

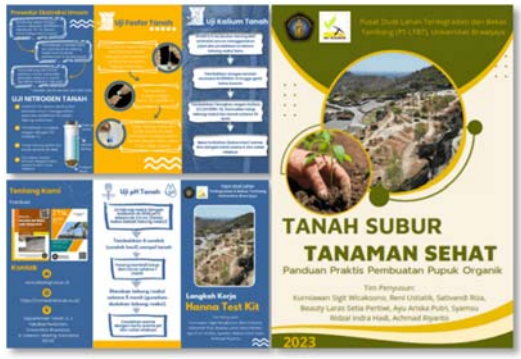

Figure 3. Booklets for work instruction problem-solving mechanism for waste management in the post-breccia mining area

Soil Fertility Testing Using a Test Kit

Soil fertility testing using test kit training was conducted for local farmers, members of local Family Welfare and Empowerment Organization (Indonesian: *Pemberdayaan Kesejahteraan Keluarga/PKK*) and managers of Tebing Breksi tourism area. The test was conducted in Tebing Breksi tourism area located in Pendhapa of Nglengkong, Sambirejo Village, Prambanan District, Sleman Regency, Yogyakarta, Central Java Province on December 22, 2023. The purpose of this activity is to increase the knowledge and skills of farmers and communities around Tebing Breksi related to soil fertility characteristics, especially soil chemical properties (soil pH, nitrogen, phosphorus and potassium content) analysis using Hanna Kit rapid test. Usually, soil analysis is done in a laboratory with advanced and complete laboratory equipment. This activity was carried out because there are soil fertility problems, especially related to soil pH on the former mining land, which affect the availability of soil nutrients and plant production in the surrounding community. This activity is carried out to improve the skills and awareness of the community on soil analysis as a basis for decision making in applying fertilizer to improve plant growth and production.

The materials and tools used for the training were Hanna test kit, soil samples and distilled water. The instructions of these tools were simplified and translated into Indonesian with flow chart and pictures so that the participants can easily understand. The test kit is equipped with a color chart for interpreting the results, classified as low, medium and high for NPK and acidic to alkaline for pH classification. Figure 4A shows a demonstration of how to use the soil fertility test kit. This demonstration was carried out with farmers. The use of these tools for soil fertility testing is expected to provide valuable insights and recommendations to the participants, which will ultimately contribute to improved agricultural practices and the overall productivity and sustainability of the local farming community.

Figure 4. (A) Soil fertility test kit demonstration;
(B) Preparation of liquid organic fertilizer from domestic waste with farmer

Liquid Organic Fertilizer from Domestic Waste

Figure 4B shows farmers engaged in the production of liquid organic fertilizer from household waste. Liquid organic fertilizer is a solution resulting from the decomposition of organic materials derived from plant residues, animal and human wastes that contain more than one plant nutrient. The process of producing liquid organic fertilizer from household waste is shown in Figure 5. The criteria for a ready-to-use fertilizer were as follows: the color of the liquid organic fertilizer solution turned brownish, there were no maggots, and it smelled like fermented drink. In addition, white spots on the surface indicated the activity of microorganisms that decompose organic waste.

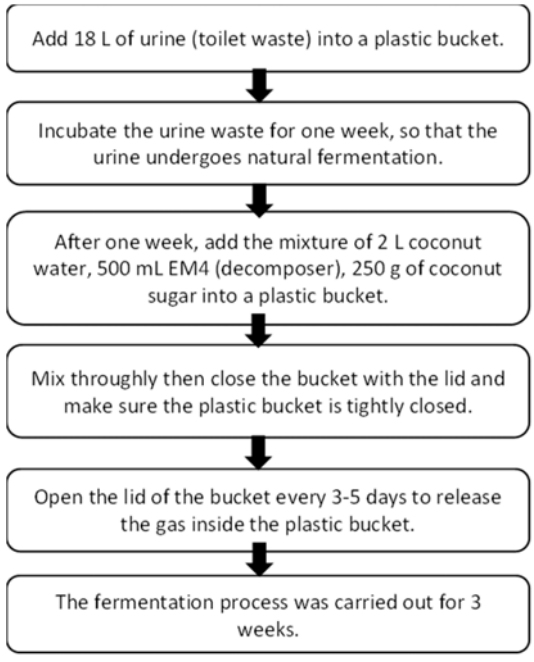

Figure 5. Procedure for making liquid organic fertilizer from domestic waste

3. RESULTS AND DISCUSSION

Environmental Conditions

Reclamation in a post-mining area is essentially required to restore the ecosystem (Masrurun & Ulfa, 2022). Post-mining activities are regulated, planned, and systematic actions that occur after mining activities have partially or completely ended. The goal of post-mining activities is to restore natural environmental and social functions in accordance with local conditions throughout the mining area (Huda, 2015). Post-mining activities involve reclamation, which includes designing, restoring, and improving the environment and ecosystems during different stages of mining to ensure they return to their intended function (ABM Investama, 2021; Agincourt Resource, 2024). Regulations ensure that the quality of the environment is improved after mining activities have ceased. The management of mined land is regulated by Law of the Republic of Indonesia No. 3 of 2020 on Mineral and Coal Mining, Indonesian Government Regulation No. 22/2010 on Mining Areas, and Indonesian Government Regulation No. 78/2010 on Reclamation and Post-Mining. Mined land can be restored to a condition similar to its original state through reclamation efforts, although it may not fully restore its biodiversity (Fauziyah & Afifa, 2023). Reclamation also helps reduce the risk of landslides and other disasters that can

result from ecosystem damage. Reclamation is required to be completed no later than one month after the cessation of mining activities on the land. In addition, the governor must receive an annual report on the implementation of reclamation (Karyono & Santiago, 2018).

As indicated by Geopark Jogja (2024) website, Tebing Breksi offers considerable tourism potential, given the presence of a steep mining cliff (high wall) and a magnificent view of Yogyakarta that can be appreciated from the summit of the cliff. This factor is one of the key motivations for the development of Tebing Breksi as a tourist destination. The cessation of mining activities was mandated by the Decree of the Head of the Geological Agency of the Ministry of Energy and Mineral Resources No. 1157 K/40/BGL/2014, dated October 2, 2014, which designated the area as a Geological Nature Reserve under the jurisdiction of the Government of the Special Region of Yogyakarta (Islami, 2021).

Socio-Economic Conditions

The area is designated as Dewi Sambi (Sambirejo Tourism Village) by POKDARWIS. The organizational structure of POKDARWIS is headed by a President Director of the Village-Owned Enterprise (BUMDES) Business division, Mr. Sugiyanto. Additionally, the organizational structure includes a Business Development Coordinator (Head of Breksi Management), Mr. Kholiq. He elucidated the general description and history of the Tebing Breksi tourism area, which was originally a mining area with a very low income for the village. Activities that occur in the Tebing Breksi geoheritage area include performances at the amphitheater, photo spot around the breccia cliffs, adventures with dirt bikes, and economic activities of the local community such as mining, plantations, and trade.

In the Tebing Breksi area, approximately 20 homestays are owned by residents. The Tebing Breksi tourist area has not yet developed a specialty food. This tourist area has an attraction that has attracted the attention of the World Bank, which has provided assistance to this tourist area in order to make it a gateway to international tourism. However, in order to meet the criteria, set forth by the World Bank, numerous requirements must be met. One such requirement is the implementation of environmentally friendly practices in the management of tourism areas. This can be achieved through the implementation of the Reduce, Reuse, and Recycle (3R) methodology.

The economic situation and income of the community are not only affected by the damage to road access, but also by changes in soil structure. This transformation has an impact on the condition of community plantations. This perspective is consistent with the view of Nadalia & Pulunggono (2020), who reported that damaging soil construction refers to the introduction of substances into the soil, which can damage its structure and impede plant adaptation. Furthermore, soil damage can be caused by mineral exploitation, such as mining activities, which also contribute to soil damage (Rosa et al., 2022).

Socio-economic issues in the Tebing Breksi mining area are further compounded by the low soil fertility, which prevents the local community from cultivating crops to meet their daily nutritional needs. Mr. Sugiyanto elucidated that the soil solum in the breccia area is a mere 40 cm in depth, with a layer of solid rock 400 m thick situated beneath it. The pH of the soil in this area is 3, with a range of 2.5 to 3. The area is not subject to erosion or landslides. He further elaborated that water is a scarce resource, noting that while it is readily available, the operational costs are considerable, amounting to approximately 50 million rupiah per month. During the dry season, the operation of 25 tank trucks in 24 hours is necessary. This amount is necessary to irrigate the plants in the Tebing Breksi area. The 2016 case study, as elucidated by the manager, elucidates the necessity of maintaining the plants in the Tebing Breksi area. One tank is worth 100 thousand rupiah, and the water required to water 400 trees is 10,000 liters (equivalent to one tank truck). Consequently, the requisite expenditure for one month is 3 million rupiah.

To fulfill this need, the management of Tebing Breksi has initiated a program called "tree adoption." One advantage of this approach is that it facilitates the creation of bio-pores at a distance of 2.5 meters.

Manager's Needs

The first FGD was held on September 26, 2023, in Tebing Breksi tourism area located in Nglengkong, Sambirejo Village, Prambanan District, Sleman Regency, Yogyakarta, Central Java Province. The FGD event was attended by 4 people from Tebing Breksi tourism manager and local village government (Figure 2A), resulted in the formulation of new performance targets to support this activity (Figure 2A) resulted in the formulation of new achievement targets to support this activity. The local community indicated that there had never been any training on the production of fertilizer from domestic and organic waste generated from the local tourist areas. Up to this point, the target market for fertilizer products believed to stabilize soil pH quickly at a high cost has been the local community. However, there is no laboratory evidence proving that these products can indeed stabilize soil pH. The managers of the Tebing Breksi area have reported that the liquid fertilizer processed from waste (liquid vapor) purchased from a specific company can lower the pH in alkaline soils and increase the pH in acidic soils. This assertion was corroborated by evidence provided by the company that supplies the liquid fertilizer. The capacity of this liquid fertilizer to regulate soil pH has prompted further inquiry into the specific chemical compounds it contains. This led to the formulation of new targets for this activity, which were adjusted to align with the local community's demands. The revised targets sought to fulfill both ecological and economic functions, thereby addressing the needs of the community.

The second FGDs on December 23, 2023 with POKDARWIS led to the formulation of new achievement targets. These targets were designed to address the needs of local residents in terms of fertilizer independence and the ability to conduct testing quickly and independently. This was done in order to prevent the community from becoming the target of fertilizer producers who charge high prices and whose products may not be of guaranteed quality or effectiveness. The formulated problems from the FGD results are as follows: (1) Problems: The primary challenge faced by residents in the Tebing Breksi area is the scarcity of water due to the depth of the rocks below the ground; (2) Need: The community requires a pioneering or pilot initiative in the form of a sustainable demonstration plot to attract the public. The reasons why the activities outlined in the proposal could not be implemented in Tebing Breksi, especially the creation of mini dams, are as follows: (a) Rainwater was once collected in the dams, but the water could not be used because tourists who used it experienced skin problems. As a result, this method was discontinued; (b) The manager of Tebing Breksi then recycled wastewater from the bathrooms to irrigate fruit trees planted in the Tebing Breksi area, including mango, guava, longan, and soursop. In the Tebing Breksi area, not all plants are able to survive. Only those that are tolerant of the conditions can flourish, such as the acacia.

The community proposed training activities that they believed to be more pressing in order to enhance community skills in waste management in tourist areas, with the objective of promoting more environmentally friendly tourism in accordance with the Sustainable Development Goals (SDGs) framework. Furthermore, the community aspires to have their tourist area designated as an environmentally friendly area. This would entail the management of domestic waste in the tourist area into fertilizer, with the objective of increasing soil fertility in areas with shallow solum and a high risk of drought. New target outcomes have been proposed to support the needs of the local community. The local community indicated that there has never been any training in the production of fertilizer from domestic waste and organic waste generated in the local tourism area.

Soil Chemistry Analysis

The managers of Tebing Breksi have indicated that the liquid waste fertilizer (liquid vapor) purchased from one of the companies has the capacity to stabilize soil pH. The potential of the liquid fertilizer to stabilize soil pH has prompted further investigation into the chemical composition of the fertilizer. However, it is first necessary to ascertain the veracity of this claim. A rapid test method was employed to analyze the soil pH. The results of the test indicated that the addition of liquid fertilizer at a 1:1 dilution ratio to the tested soil resulted in a reduction of the soil pH by one unit, thereby transforming the soil from neutral to acidic (Figures 6a and 6b). The test results appear to contradict the assertion made by the Tebing Breksi manager, who claimed that the liquid fertilizer can reduce the pH of alkaline soil and increase the pH of acidic soil. Given the conflicting results, it is necessary to conduct further tests to determine the pH level of the liquid fertilizer. The results of the conducted tests indicate that the pH of the liquid fertilizer is classified as very acidic, with a value of 4 (Figure 6c). The acidic pH of the liquid fertilizer is the primary factor responsible for the reduction in pH observed in the soil following its application. Following the test, it was demonstrated that the claim was false and that the local community was the target of deceptive marketing practices. Consequently, training the local community in the production of fertilizers and the utilization of rapid soil fertility tests can facilitate the attainment of fertilizer independence and the enhancement of local awareness regarding novel products and the quality control of such products independently.

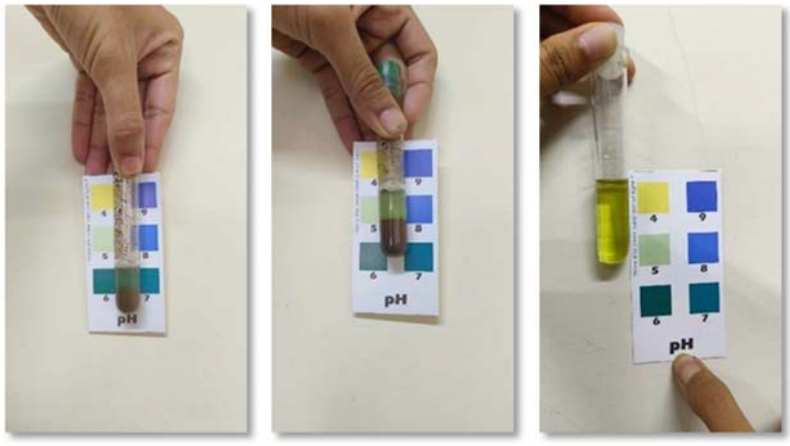

Figure 6. Rapid test for soil and liquid fertilizer sample; (1) Soil pH before added with liquid fertilizer; (2) Soil pH after added with liquid fertilizer; (3) pH of liquid fertilizer

4. CONCLUSION AND RECOMMENDATION

A comprehensive analysis conducted in the Tebing Breksi Tourism Area, Special Region of Yogyakarta (DIY), specifically in the village of Sambirejo, revealed that small-scale breccia and limestone mining impacts soil acidification and biodiversity loss, water scarcity (drought), which reduces soil fertility and ecosystem health. The proposed community training in waste management and organic fertilizer production from household and organic waste is a sustainable approach to address these challenges. The goal is to improve the ecological and economic functioning of the community. This initiative, in line with the Sustainable Development Goals, aims not only to restore the environmental integrity of the former mine site, but also to empower the local community towards self-reliance and sustainable tourism development. The achievement of the objectives of this activity can be seen in the increasing

ability of local farmers and tourism managers to reduce soil acidity through the use of household waste that has been independently processed into liquid organic fertilizer.

Training the local community in new skills can facilitate the attainment of community independence and the enhancement of local awareness regarding the quality control of products independently. Consequently, it may facilitate community awareness in other areas, such as economics, education, and tolerance.

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