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Technical and Environmental Feasibility Analysis in Revitalizing Former Coal Mines as a Green Economy Pillar for Sustainable Development

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ABSTRACTS

Introduction : Coal mining plays an important role in the national economy, but after exploitation, mining land is often left in a damaged and unproductive condition. Therefore, revitalizing former coal mines is a strategic step to utilize degraded land into a new economic area that is oriented towards sustainability. **Objective**: The technical and environmental feasibility study aims to ensure that the revitalization of ex-mining land can be carried out safely, efficiently and in accordance with sustainability principles. This research also aims to explore the potential of former coal mining land as a basis for a sustainable green economy found at PT XYZ, as well as providing solutions to environmental challenges in a post-mining context. **Method**: Method: This community service integrates quantitative and qualitative methods to comprehensively understand the technical feasibility, environment, and green economic potential in ex-coal mining areas. **Conclusion** : Revitalization of ex-mining land can bring great potential in improving technical and environmental quality, utilizing renewable energy, and introducing more sustainable land use. Through improving soil quality, efficient management of natural resources, and utilizing renewable energy potential, ex-mining land can be converted into productive land that supports the green economy and sustainable development. Test data also shows that the revitalization of ex-mining land has a positive impact on soil pH quality, which can support more environmentally friendly and sustainable land management.

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1. INTRODUCTION

Monitoring in the last few decades, the use of natural resources, especially coal mining, has become the main pillar of global economic growth. However, this activity also leaves negative impacts on the environment, such as ecosystem damage, soil and water pollution, and health threats to local communities. As awareness of climate change and the need for sustainable development increases, the world is starting to shift to a green economy, which focuses on resource efficiency, reduced carbon emissions, and social welfare. Coal has been widely used in various sectors, including industry and power plants as an energy source (Yodi Kurniawan et al., 2023). In Indonesia, the coal mining sector has an important role in the national economy, especially in generating foreign exchange (Arief et al., 2020). But post-exploitation, mining land is often left in a damaged and unproductive condition. Mining activities, especially at the end of their activities, often leave behind mined land in the form of voids and non-voids (Ibrahim et al., 2020). Therefore, revitalizing former coal mines is a strategic step to utilize degraded land into a new economic area that is oriented towards sustainability. This transformation not only improves environmental conditions, but also opens up opportunities for a green economy through activities such as ecotourism, sustainable agriculture, or the development of renewable energy.

Globally, many countries have implemented green economic principles to overcome challenges such as climate change, the energy crisis and environmental degradation. This happens because the mining sector is one of the most dangerous jobs, involving the use of chemicals that are dangerous to human health (Stevianingrum & Erwandi, 2022). Modernization is key in this transformation, including through the use of clean technology, the transition to renewable energy, and the development of a circular economy. In addition, digital technologies such as artificial intelligence and the Internet of Things (IoT) are increasingly accelerating the change towards a green economy by enabling more efficient and data-based resource management. In Indonesia, steps towards a green economy have become a priority in the development agenda, including in the management of areas degraded due to traditional economic activities. This economic growth makes coal mining one of the main industrial sectors in the country's economic structure (Helmiyyah et al., 2019). One example is the development of ex-mining land which has great potential to be transformed into a center of sustainable economic activity. By adopting modern approaches, such as innovative waste management, renewable energy, and the integration of digital technology, these lands can be optimized as new sources of growth in line with low-carbon development principles. Management of coal, which is a sedimentary rock that is dense, flammable, comes from plants, and is brown to black in color, involves physical and chemical processes that enrich its carbon content since deposition (Yulmansyah, 2021)

The technical and environmental feasibility study aims to ensure that the revitalization of ex-mining land can be carried out safely, efficiently and in accordance with sustainability principles. This effort is made to support environmental conservation, considering that 45% of the water in rivers such as in South Kalimantan has been polluted by coal mining waste (Habibi, 2022). The increase in the number of mining companies in East Kalimantan also has an impact on reducing water quality, because mining waste contains dissolved heavy metals with high levels of acidity (Suryani et al., 2022). This research also aims to explore the potential of former coal mining land as a basis for a sustainable green economy found at PT XYZ, as well as providing solutions to environmental challenges in a post-mining context. Mine management continues to pay attention to aspects of community empowerment, infrastructure development, natural and environmental disaster mitigation, as well as sustainable operations (E. Oktarinasari, M. Yusuf, 2021). This study is expected to make a significant contribution to better management of ex-mining land, support the national agenda for the transition to a low-carbon economy, and be in line with the targets of the Paris Agreement and the Sustainable Development Goals (SDGs).

1. METHODS

This community service integrates quantitative and qualitative methods to comprehensively understand the technical feasibility, environment, and green economic potential in ex-coal mining areas. The main stages of this community services include:

A. Quantitative Approach

   a. Technical and Environmental Feasibility Evaluation

      Quantitative data collection is carried out through testing and analysis of various parameters, including the physical condition of the land such as soil stability, erosion levels and the geomorphological structure of the area.

b. Environmental quality

Measurement of water, air and soil quality in former mining areas. Renewable energy potential, modeling of energy sources such as solar power, wind, or biomass.

c. Use of GIS and Remote Sensing

Geospatial data is used for regional mapping, environmental damage analysis, and identification of areas with the highest revitalization potential.

B. Qualitative Approach

a. In-depth Interviews and Focus Group Discussions (FGD)

Involvement of stakeholders, such as local government, local communities, environmental experts and academics, was carried out to obtain information about perceptions of green economic development in the area, as well as challenges and opportunities in implementing revitalization.

b. Documentation Review

Analyze policies, regulations and best practices from similar revitalization projects at both national and international levels.

c. Development of a Green Economic Model

Based on the quantitative and qualitative results, a conceptual model was created which includes an area management strategy based on green economic principles. Simulation of long-term impacts on the economy, social and environment.

d. Data analysis

The research uses quantitative analysis using descriptive statistics to evaluate technical and environmental data. Qualitative analysis was carried out through thematic analysis to identify patterns and trends from the results of interviews and FGDs. Followed by data integration, combining the results of quantitative and qualitative analysis to produce holistic and data-based recommendations. With this method, research is expected to be able to provide relevant results and can be implemented to support the implementation of a modern green economy in former coal mining areas.

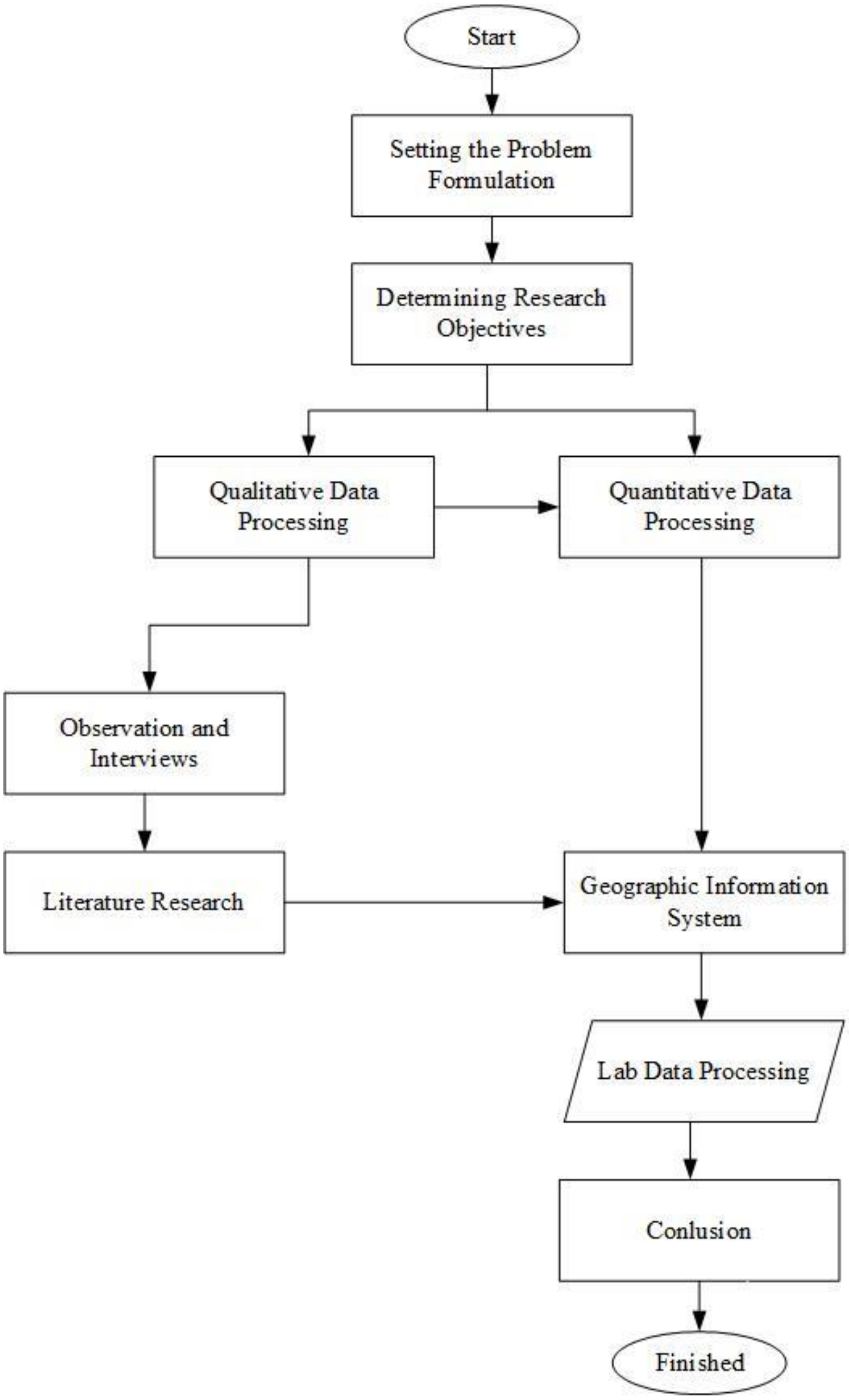

Figure 1. Community Services Process

2. RESULTS AND DISCUSSION

This research focuses on assessing the safety of water in former coal mine excavations if used in the plantation industry sector. This test can be categorized as a field clinical trial, especially if the local community or company wants to use the water for crop irrigation on a large production scale. In addition, the purpose of this testing is to minimize the risk of failure in developing plantation and livestock plans, so that potential undesirable events can be avoided. The sampling location for chemical analysis of soil and water was carried out around the edge of a former mine owned by the XYZ company, whose mining activities had been stopped for 13 months. Soil samples are focused on the topsoil around the edge of the mine, while water samples include groundwater from the former mine hole to the waste landfill area, as well as surface water from channels connected to the mine site.

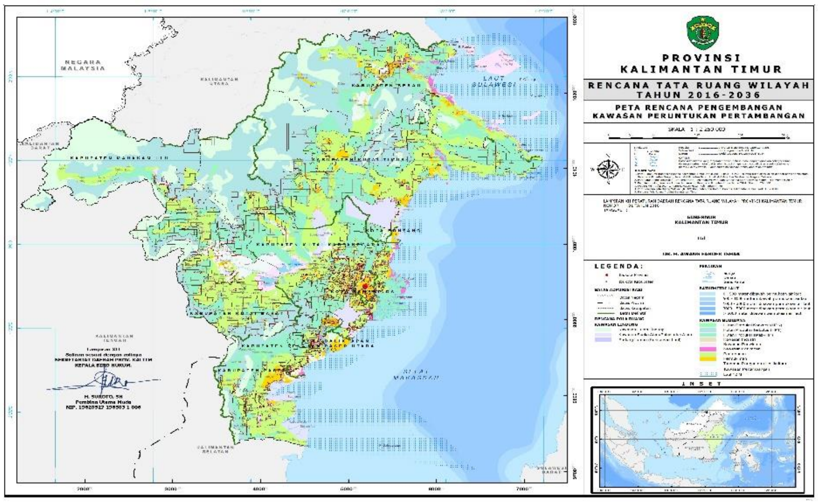

Figure 2 Mining Designated Area Plan Map

The results of research in the field produced technical data, environmental quality, energy potential and land use which can be seen as follows:

Data Technology

Table 1. Results of Technical Data Monitoring

Parameter	Mark	Information
Soil Stability	Safety factor: 1.2	Medium stability; slope reinforcement is required.
Erosion Rate	15 tons/hectare/year	Entered the high erosion category; requires erosion control.
15 tons/ha/year	20 meter	Potential for developing ecotourism or

Parameter	Mark	Information
		aquaculture.
Water Storage Capacity	50.000 m³	Large enough to be managed as a micro reservoir.
Geomorphological Structure	Clay is dominant	Limits use to direct agriculture.

Source : Data processed by the Author (2024)

Rock samples were taken through geotechnical drilling to obtain data regarding the physical and mechanical properties of the rock (Cahyono, 2022). The results of technical data monitoring of this figure show the level of soil erosion that occurs in one year on this land, namely 15 tonnes per hectare per year. This indicates a high level of erosion, which can lead to the loss of fertile soil layers. Erosion control is very necessary to prevent further damage, such as using ground cover plants, terracing, or drainage systems that can reduce the rate of erosion. The disused mining pool is 20 meters deep, which is deep enough to hold water. This provides the potential for further use, such as in the development of ecotourism (for example, as a lake or water tourist attraction) or aquaculture (cultivating fish or other aquatic organisms). With proper management, these deep ponds can become economically and ecologically beneficial assets. The water storage capacity of 50,000 m³ shows that this former mine has the potential to store large volumes of water. This capacity can be utilized for purposes such as micro reservoirs for irrigation, providing clean water, or even as a water reserve in emergency situations. Good management will ensure that this capacity can be used optimally for these purposes. Soil that is predominantly clay means that this soil tends to be dense, hard, and less permeable, which can inhibit water infiltration and worsen erosion problems. Clay soil is also not ideal for direct farming because it is heavy and easily waterlogged. Therefore, land use for agriculture must be done carefully, by implementing more suitable agricultural systems or tilling the land to increase its fertility.

Environmental Quality Evaluation

Table 2 Environmental Quality Evaluation Monitoring Results

Parameter	Measurement results	Quality Standards
Soil pH	4,5 – 4,7	5,5–7,5
Heavy Metal Rate (Pb)	0,03 mg/L	Maks. 0,01 mg/L
Water Quality	2 mg/L	Min. 5 mg/L
Air Particle Concentration	150 µg/m³	Maks. 120 µg/m³
Soil Organic Content	1,2%	Min. 3%

Source : Data processed by the Author (2024)

The measurement results show that environmental conditions in the area require improvement in several important aspects, such as acidic soil pH requiring treatment to increase its fertility. Heavy metal levels and poor water quality require treatment measures to reduce pollution levels and improve water quality. High concentrations of air particles need to be controlled with reforestation or other solutions to improve air quality. Low soil organic content requires the addition of organic material to increase soil fertility and capacity to support agriculture or other vegetation. Appropriate remediation steps will improve environmental quality and support sustainable use of post-mining land.

Renewable Energy Potential

Table 3 Renewable Energy Potential Monitoring Results

Energy Type	Potential	Information
Solar	5 kWh/m²/Day	Very potential for solar panels.
Biomass	200 tons/Years	Suitable for utilization of local organic waste.
Wind Energy	Speed: 2,5 m/s	Low speed; not suitable for wind turbines.
Microhydro	Water Discharge: 0,5 m³/s	Limited potential for small installations.

Source : Data processed by the Author (2024)

This potential data illustrates the various renewable energy potentials that can be utilized, with several types of energy having greater potential, such as solar power which is the main choice because of its high potential. Biomass can also be utilized efficiently by utilizing local organic waste. Wind power is less efficient in this area due to low wind speeds, although it can still be used for small turbines. Microhydro has limited potential, but can be optimized with small-scale energy generation in the right locations. Management and utilization of this energy potential can contribute to the development of sustainable and environmentally friendly renewable energy in the area. This potential is in line with previous research, where the company worked with the government to increase community resilience to drought by building communal drilled wells that could be accessed by more than 30 families around the clock (Pambudi et al., 2023)

Land Use

Table 4. Land Use Monitoring Results

Area	Land (Ha)	Potential Utilization
Former Mining Pool	10	Aquaculture, water ecotourism.
Open Land	20	Planting fast growing trees or biomass energy.
Areas of Damaged Vegetation	15	Rehabilitation with cover crops.

Source : Data processed by the Author (2024)

Ex-mining land and the surrounding area have the potential to be used sustainably for various purposes such as ex-mining ponds can be used for aquaculture and ecotourism, which not only manages natural resources but also opens up new economic opportunities. Open land is suitable for planting fast-growing and biomass trees, which supports efficient and sustainable natural resource management. Areas of damaged vegetation need to be rehabilitated with cover crops, which help improve soil quality and prevent further damage. This land use can support environmental conservation while providing natural resources that are beneficial to the community (Suciadi et al., 2020)

Descriptive Statistical Test

This test is carried out by monitoring pH before and after revitalization. The process of revitalizing soil pH on ex-mining land aims to restore soil pH to better support plant life and microorganisms. The use of lime, organic materials, and ground cover plants are the methods used to treat one area. Additionally, ongoing monitoring and adjustments are essential to maintaining successful soil revitalization. The comparison results can be seen as follows:

Table 5. Sample Test

Sampel	pH Before Revitalization	pH After Revitalization	Difference (Before-After)	(Difference – average difference)^2
1	4,5	6,0	1,5	0,0784
2	4,5	5,7	1,2	0,0004
3	4,7	5,8	1,1	0,0144
4	4,6	5,7	1,1	0,0144
5	4,7	5,9	1,2	0,0004
Amount			6,1	0,108
Average Difference			1,22	
Standard Deviation			0,164	
t-statistik			16,61	
Degrees of Freedom			4	
P-value			< 0,001	

Source : Data processed by the Author (2024)

a. Average Difference

The average change in pH after revitalization was 1,22.

b. Standard Deviation Difference

The standard deviation of the pH difference before and after revitalization is 0.164.

c. t-statistics

The calculated t-statistic value is 16,61.

d. P-value

The p-value is very small (less than,.001), indicating that the change in soil pH between before and after revitalization is very statistically significant.

With these results, we can conclude that the difference between soil pH before and after revitalization is very significant, and revitalization succeeded in increasing soil pH.

3. CONCLUSION

Revitalization of ex-mining land can bring great potential in improving technical and environmental quality, utilizing renewable energy, and introducing more sustainable land use. Through improving soil quality, efficient management of natural resources, and utilizing renewable energy potential, ex-mining land can be converted into productive land that supports the green economy and sustainable development. Test data also shows that the revitalization of ex-mining land has a positive impact on soil pH quality, which can support more environmentally friendly and sustainable land management.

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