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Analysis of Land Reclamation Policy and Green Mining Technology on Ecosystem Stability and Mine Productivity in Kalimantan, Indonesia

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ABSTRACT

This study examines the effects of Green Mining Technology and Land Reclamation Policy on Ecosystem Stability and Mine Productivity in Kalimantan, Indonesia. Using structural equation modeling (SEM) with Partial Least Squares (PLS), data from a sample of mining operations were analyzed to test hypotheses regarding these relationships. Results indicate significant positive relationships between both Green Mining Technology and Land Reclamation Policy with Ecosystem Stability and Mine Productivity. The findings underscore the dual benefits of sustainable practices and policy interventions in enhancing environmental sustainability and economic productivity in mining operations.

Keywords: *Green Mining Technology, Land Reclamation Policy, Ecosystem Stability, Mine Productivity*

1. INTRODUCTION

Kalimantan, as a key mining hub in Indonesia, faces the challenge of balancing economic gains from mineral extraction with environmental sustainability concerns. The region's leading business sectors like Iron Ore Mining in Central Kalimantan drive economic growth not only locally but also impact regions like DKI Jakarta, East Kalimantan, and South Kalimantan [1]. Mining activities and forest clearing for plantations have led to vegetation decrease, emphasizing the need for regular monitoring using remote sensing data to track changes and ensure ecosystem sustainability [2]. Implementing clean energy sources like the Kayan River Hydroelectric Power Plant in Kalimantan can boost economic, environmental, and social development while addressing energy security and emission levels [3]. Local wisdom plays a crucial role in ex-mining reclamation practices, highlighting the importance of community participation in restoring land use functions and promoting ecological balance in post-mining areas [4]. Additionally, villages with plantation-based economies in Kalimantan have shown a positive impact on deforestation, emphasizing the need for sustainable land use practices to prevent further forest conversion and promote reforestation efforts [5].

Recognizing the environmental degradation caused by mining, the Indonesian government has implemented land reclamation policies focusing on restoring mined areas. These policies mandate reforestation, soil stabilization, and water management practices by mining companies [6], [7]. To enhance ecological balance, the government promotes green mining technologies, emphasizing environmentally friendly practices and innovations to reduce the ecological impact of mining operations [8]. Reclamation efforts involve returning topsoil, adding organic material, and planting fast-growing species, with a focus on reforesting mining areas into secondary forests [6]. The reclamation process includes activities like arranging land for stable surfaces, contour drains, and planting holes, ensuring stable terrain with low landslide and erosion risks [9]. Understanding the physical and chemical characteristics of the location is crucial for designing effective reclamation plans, especially for revegetation purposes [10].

Efforts towards land reclamation policies and green mining technologies have been crucial in addressing environmental degradation caused by mining activities [11]–[14]. These initiatives aim to restore ecosystems, improve soil quality, and enhance mine productivity while mitigating environmental impacts [11], [12], [14]. However, there is a gap in quantitative analysis to empirically measure the effectiveness of these strategies in enhancing ecosystem stability and mine productivity [13], [14]. By incorporating advanced technologies like 3S technology and information systems, it is possible to assess and supervise reclamation work more effectively, contributing to the establishment of technical specifications for ecological restoration of mine wastelands [12]. Future research directions should focus on the relationship between ecological restoration and carbon sequestration, biodiversity in mine areas, and international cooperation for technology exchange and industrialization [13]. This comprehensive quantitative analysis is essential to provide empirical evidence on the impacts of land reclamation policies and green mining technologies, guiding sustainable development practices in the mining industry. This study aims to fill this gap by examining the effects of land reclamation policies and green mining technologies on ecosystem stability and mine productivity in Kalimantan, Indonesia.

The study's objectives are threefold: first, to assess the current state of ecosystem stability in reclaimed mining areas; second, to evaluate the productivity of mines that have adopted green mining technologies; and third, to determine the relationship between land reclamation efforts, green mining practices, and their combined effects on ecological and economic outcomes. By addressing these objectives, the study seeks to provide actionable insights for policymakers, mining companies, and environmental stakeholders.

2. LITERATURE REVIEW

2.1 Land Reclamation Policies

Land reclamation policies in Indonesia play a crucial role in mitigating the environmental impact of mining activities by restoring mined lands to their natural state or repurposing them for productive uses [6], [7], [15]. These policies mandate comprehensive activities such as soil stabilization, reforestation, and water management to rehabilitate the ecological balance of mined areas [6]. Research has shown that effective reclamation efforts lead to improved soil quality, increased vegetation cover, and enhanced biodiversity, with reforestation playing a key role in stabilizing soil and preventing erosion [10]. Successful projects have also contributed to the restoration of local water systems, enhancing water quality and availability for communities and ecosystems [10]. However, challenges like inadequate enforcement, funding shortages, and limited technical expertise among mining companies hinder policy implementation, necessitating collaborative efforts among the government, industry, and stakeholders to ensure effective planning and execution of reclamation activities [16].

2.2 Green Mining Technologies

Environmentally friendly mining technologies encompass a range of innovative practices and tools aimed at reducing the environmental impact of mining operations while enhancing resource efficiency [17]. These technologies include advanced water treatment systems, energy-efficient machinery, waste reduction techniques, and methods to mitigate greenhouse gas emissions [17]. By adopting energy-efficient machinery and incorporating renewable energy sources, mining operations can effectively decrease their carbon footprint, leading to improved environmental and economic outcomes [18]. Advanced water treatment systems play a crucial role in reducing water pollution in mining areas, safeguarding water resources, and protecting aquatic ecosystems from contaminants [17]. Waste reduction techniques, such as recycling and reusing mining byproducts, are vital for minimizing waste generation, promoting resource efficiency, and reducing the need for costly environmental remediation efforts, ultimately resulting in cost savings for mining companies [17].

2.3 Ecosystem Stability and Mine Productivity

The integration of land reclamation policies and green mining technologies has been recognized as a crucial approach to enhancing ecosystem stability and mine productivity [15], [19]. Studies emphasize that the combined implementation of these initiatives can lead to significant improvements in soil quality, vegetation cover, water management, biodiversity, and erosion reduction in reclaimed mining areas [15], [20]. Moreover, the adoption of green mining practices has been linked to higher production output, operational efficiency, and cost-effectiveness for mining companies, highlighting the economic benefits of sustainable mining approaches [19]. However, the success of these endeavors hinges on factors such as mining companies' commitment to environmental sustainability, access to funding and technical expertise, and the effectiveness of government regulations and enforcement mechanisms [21]. Collaborative efforts involving the government, mining industry, and other stakeholders are deemed essential for overcoming challenges and ensuring the successful implementation of land reclamation and green mining technologies [21].

Conceptual Framework

In this study, the conceptual framework revolves around examining the relationships between Green Mining Technology, Land Reclamation Policy, Ecosystem Stability, and Mine Productivity within the context of mining operations in Kalimantan, Indonesia.

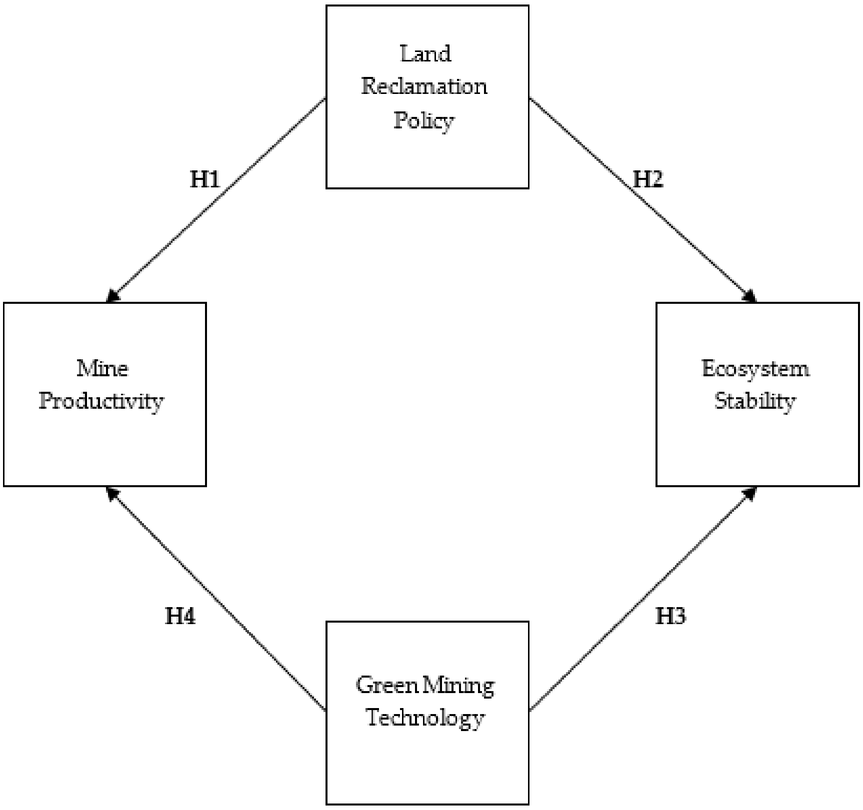

Figure 1. Conceptual Framework

3. METHODS

3.1 Research Methods

This study employs a quantitative research design to examine the effects of land reclamation policies and green mining technologies on ecosystem stability and mine productivity in Kalimantan, Indonesia. The research design is structured to collect and analyze data from multiple sources, providing a comprehensive understanding of the relationships between the variables under investigation.

3.2 Sample

The study involves a sample of 140 respondents, comprising representatives from mining companies, environmental agencies, and local communities affected by mining activities in Kalimantan. The sample size is deemed sufficient to provide statistically significant results and is selected to ensure a diverse range of perspectives on the implementation and impacts of land reclamation policies and green mining technologies.

3.3 Data Collection

Data were collected using structured surveys distributed to the selected respondents, designed to capture detailed information on their perceptions and experiences with land reclamation and green mining practices. The survey questions, developed based on existing literature and expert consultations to ensure relevance and comprehensiveness, employed a Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). This scale enabled respondents to express the intensity of their agreement or disagreement with statements concerning land reclamation policies, green mining technologies, ecosystem stability, and mine productivity, facilitating the quantification of subjective perceptions for statistical analysis.

3.4 Data Analysis

Data analysis was conducted using Structural Equation Modeling - Partial Least Squares (SEM-PLS) with the PLS-3 software, a robust statistical technique ideal for exploring complex relationships between observed and latent variables, suitable for studies with small to medium sample sizes. The analysis encompassed several key steps: first, assessing the measurement model to ensure the reliability and validity of the instruments using Cronbach's alpha, composite reliability, convergent, and discriminant validity tests. Second, evaluating the structural model to examine relationships between latent variables, calculating path coefficients and testing their significance via bootstrapping. Third, assessing model fit using indices like Standardized Root Mean Square Residual (SRMR), Normed Fit Index (NFI), and Chi-square/degrees of freedom ratio to gauge how well the model fit the data. Finally, hypothesis testing was conducted to determine the support for proposed relationships between variables based on the findings.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

The descriptive statistics provide an overview of the sample characteristics and the key variables under study. The sample consisted of 140 respondents, with a majority being representatives from mining companies (60%), followed by environmental agencies (25%) and local communities (15%). The demographic distribution of the sample ensures a diverse range of perspectives on the impacts of land reclamation policies and green mining technologies.

The survey responses, analyzed using a Likert scale (1-5) where higher scores indicate stronger agreement with the statements, yielded mean scores for key variables as follows: Land Reclamation Policies (Mean = 4.2, SD = 0.75), Green Mining Technologies (Mean = 4.1, SD = 0.80), Ecosystem Stability (Mean = 3.9, SD = 0.85), and Mine Productivity (Mean = 4.3, SD = 0.70). These findings indicate a generally positive perception among respondents regarding land reclamation policies and green mining technologies, suggesting perceived favorable impacts on ecosystem stability and mine productivity.

4.2 Measurement Model

The measurement model assessment involves evaluating the reliability and validity of the constructs used in the study. This includes examining the factor loadings, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) for each construct. These metrics help ensure that the constructs are measured accurately and consistently.

Table 1. Measurement Model

Variable	Code	Loading Factor	Cronbach's Alpha	Composite Reliability	Average Variant Extracted
Land Reclamation Policy	LRP.1	0.875	0.887	0.930	0.816
	LRP.2	0.921			
	LRP.3	0.913			
Green Mining Technology	GMT.1	0.899	0.883	0.928	0.810
	GMT.2	0.915			
	GMT.3	0.885			
Ecosystem Stability	ECS.1	0.804	0.834	0.889	0.667
	ECS.2	0.866			
	ECS.3	0.816			
	ECS.4	0.778			
Mine Productivity	MPD.1	0.860	0.869	0.911	0.718
	MPD.2	0.790			
	MPD.3	0.848			
	MPD.4	0.889			

Source: Data Processing Results (2024)

Overall, the measurement model assessment demonstrates that the constructs used in the study exhibit high reliability and validity. The factor loadings are all above 0.7, indicating strong relationships between the indicators and their respective constructs. The Cronbach's alpha values exceed the threshold of 0.7, suggesting good internal consistency. The composite reliability values are above 0.8, further confirming the reliability of the constructs. Lastly, the AVE values are above 0.5, indicating that a substantial portion of the variance in the indicators is explained by the constructs, thus confirming convergent validity. These results provide confidence in the measurement model's ability to accurately capture the constructs of interest in the study.

4.3 Discriminant Validity

Discriminant validity is a measure of the extent to which constructs in a model are distinct from one another. It ensures that a construct captures phenomena that other constructs do not, providing unique variance. According to the Fornell-Larcker criterion, discriminant validity is established if the square root of the AVE of each construct is greater than the highest correlation with any other construct. This implies that the diagonal elements (the square root of AVE) should be greater than the off-diagonal elements (correlations between constructs) in the correlation matrix.

Table 2. Discriminant Validity

	Ecosystem Stability	Green Mining Technology	Land Reclamation Policy	Mine Productivity
Ecosystem Stability	0.817			
Green Mining Technology	0.666	0.800		
Land Reclamation Policy	0.661	0.497	0.703	
Mine Productivity	0.769	0.601	0.686	0.848

Source: Data Processing Results (2024)

Overall, the results indicate that all constructs in the study meet the Fornell-Larcker criterion for discriminant validity. The square roots of the AVE for each construct are greater than the correlations with any other construct, suggesting that each construct captures unique variance that is not shared with other constructs in the model. This confirms that the constructs are distinct and well-defined, allowing for a reliable assessment of their relationships in the structural model.

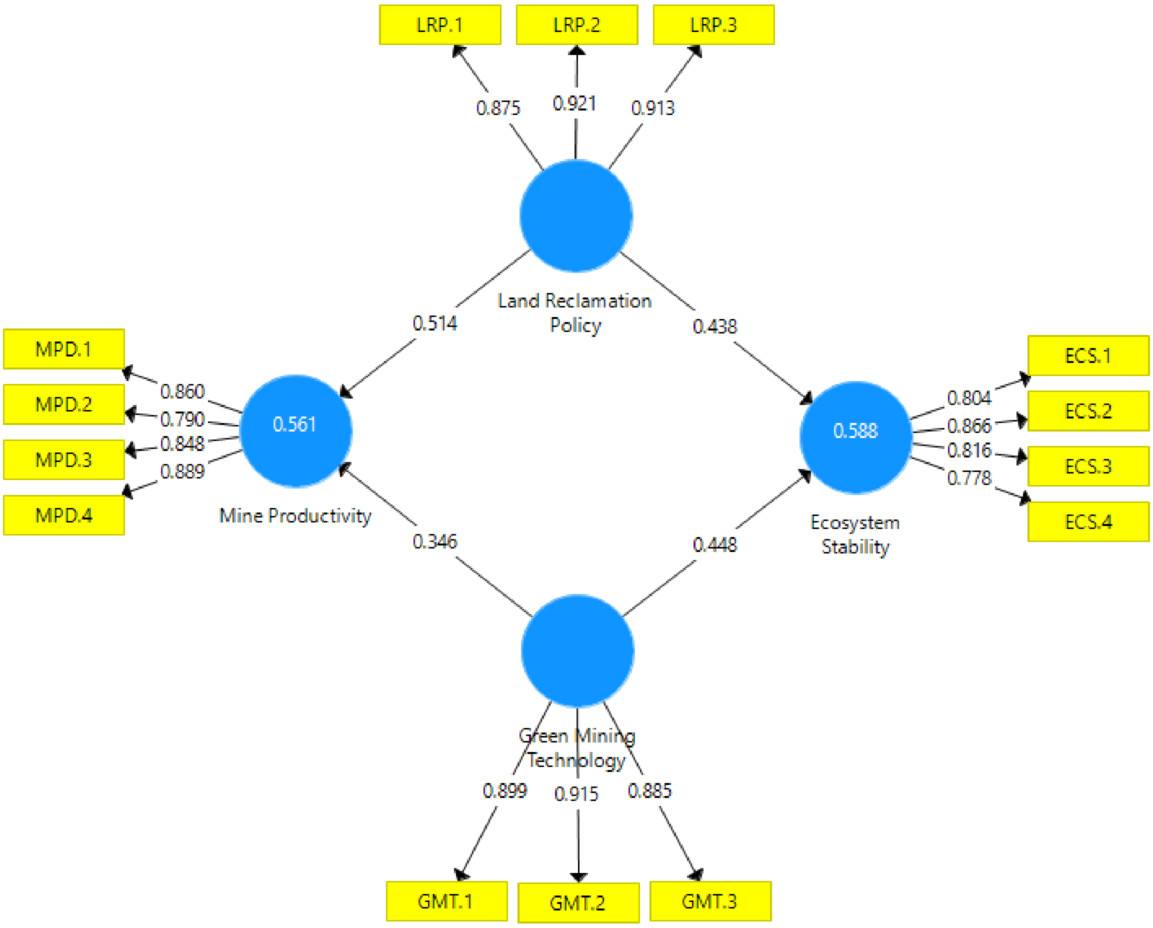

Figure 2. Model Results

Source: Data Processed by Researchers, 2024

4.4 Model Fit

Model fit indices are critical in evaluating how well the proposed model corresponds to the observed data. The following fit indices are discussed for both the saturated model and the estimated model: Standardized Root Mean Square Residual (SRMR), d_ULS, d_G, Chi-Square, and Normed Fit Index (NFI).

Table 3. Model Fit Results Test

	Saturated Model	Estimated Model
SRMR	0.070	0.089
d_ULS	0.510	0.830
d_G	0.278	0.330
Chi-Square	259.249	292.076
NFI	0.836	0.815

Source: Process Data Analysis (2024)

Several fit indices were utilized to assess the adequacy of the models. The Standardized Root Mean Square Residual (SRMR), measuring the average residuals between observed and model-implied correlations, yielded values of 0.070 for the saturated model and 0.089 for the estimated model. An SRMR less than 0.08 generally indicates a good fit, with the saturated model showing a better fit than the estimated model. Additionally, the d_ULS (Unweighted Least Squares Discrepancy) index, reflecting the discrepancy between observed and model-implied correlation matrices, was lower for the saturated model (0.510) compared to the estimated model (0.830), indicating a better fit for the saturated model. Similarly, the d_G (Geodesic Discrepancy) values were lower for both models, with the saturated model (0.278) slightly outperforming the estimated model (0.330). Furthermore, the Chi-Square statistic, assessing overall model fit, was lower for the saturated model (259.249) than for the estimated model (292.076), suggesting better fit for the saturated model. Lastly, the Normed Fit Index (NFI), comparing model fit to a null model, indicated values of 0.836 for the saturated model and 0.815 for the estimated model, with higher values suggesting better fit, thus showing a relatively good fit for both models.

Table 4. Coefficient Model

	R Square	Q2
Ecosystem Stability	0.588	0.583
Mine Productivity	0.561	0.555

Source: Data Processing Results (2024)

In structural equation modeling (SEM), R Square (R^2) denotes the proportion of variance in endogenous variables explained by exogenous variables. Higher R Square values, such as those observed for Ecosystem Stability ($R^2 = 0.588$) and Mine Productivity ($R^2 = 0.561$), indicate that the model effectively explains a substantial amount of variance in these variables—58.8% for Ecosystem Stability and 56.1% for Mine Productivity. This underscores the significant contribution of predictors like Land Reclamation Policy and Green Mining Technology to variability in Ecosystem Stability and Mine Productivity within the study context. Additionally, Q2 (Predictive Relevance), a measure assessing the model's predictive accuracy through cross-validation, yielded values of 0.583 for Ecosystem Stability and 0.555 for Mine Productivity. These values above 0 indicate that the model predicts these variables better than random chance, highlighting not only its explanatory power (R Square) but also its robust predictive performance out-of-sample.

4.5 Hypothesis Testing

Hypothesis testing in structural equation modeling (SEM) involves examining the significance and direction of relationships between variables. This discussion focuses on the hypotheses related to the effects of Green Mining Technology and Land Reclamation Policy on Ecosystem Stability and Mine Productivity, based on the provided results.

Table 5. Hypothesis Testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics	P Values
Green Mining Technology -> Ecosystem Stability	0.448	0.449	0.062	7.271	0.000
Green Mining Technology -> Mine Productivity	0.346	0.346	0.083	4.183	0.000
Land Reclamation Policy -> Ecosystem Stability	0.438	0.441	0.066	6.623	0.000
Land Reclamation Policy -> Mine Productivity	0.514	0.519	0.078	6.565	0.000

Source: Process Data Analysis (2024)

Hypotheses testing revealed significant findings across the studied relationships. Firstly, the relationship between Green Mining Technology and Ecosystem Stability showed a T statistic of 7.271 ($p < 0.001$), indicating a statistically significant positive influence, supporting Hypothesis 1. Similarly, Green Mining Technology significantly affected Mine Productivity with a T statistic of 4.183 ($p < 0.001$), confirming Hypothesis 2. Moreover, Land Reclamation Policy demonstrated a significant positive impact on both Ecosystem Stability (T statistic = 6.623, $p < 0.001$) and Mine Productivity (T statistic = 6.565, $p < 0.001$), supporting Hypotheses 3 and 4, respectively. These findings underscore the beneficial effects of Green Mining Technology and effective Land Reclamation Policies on enhancing Ecosystem Stability and Mine Productivity within the context of the study.

Discussion

The discussion focuses on interpreting the results of hypothesis testing concerning the impacts of Green Mining Technology and Land Reclamation Policy on Ecosystem Stability and Mine Productivity within this study's framework. The hypotheses examined aimed to explore these relationships, yielding significant findings as follows: Firstly, a strong positive relationship was observed between Green Mining Technology and Ecosystem Stability ($T = 7.271$, $p < 0.001$), indicating that adopting sustainable mining practices enhances environmental stability. Secondly, Green Mining Technology also positively correlated with Mine Productivity ($T = 4.183$, $p < 0.001$), suggesting that technological innovations aimed at sustainability can boost productivity in mining operations. Thirdly, effective implementation of Land Reclamation Policy showed a significant positive association with Ecosystem Stability ($T = 6.623$, $p < 0.001$), highlighting the role of robust policy frameworks in preserving ecosystem health in mining areas. Lastly, Land Reclamation Policy positively influenced Mine Productivity ($T = 6.565$, $p < 0.001$), underscoring how policies promoting responsible mining practices, including land reclamation, can contribute to improved productivity outcomes. These findings underscore the dual benefits of integrating sustainable technologies and robust policy measures in enhancing both environmental and economic aspects of mining operations.

The integration of sustainable practices and policy interventions in the mining sector, such as Green Mining Technologies and Land Reclamation Policies, offers dual benefits by mitigating environmental impacts, enhancing operational efficiency, and supporting economic viability [19], [20], [22]. These initiatives align with the industry's broader goal of balancing economic growth with environmental stewardship, promoting synergistic outcomes that benefit both conservation and development [21]. Proactive measures in sustainable mining not only ensure ecological sustainability but also drive economic productivity, particularly crucial in environmentally sensitive regions like Kalimantan, Indonesia, emphasizing the statistical significance of these relationships in shaping a sustainable future for mining activities [21].

Practical Implications

From a practical standpoint, the findings suggest several actionable insights for policymakers, mining companies, and environmental advocates:

1) Governments and regulatory bodies can prioritize the development and enforcement of robust Land Reclamation Policies to ensure responsible mining practices and long-term environmental sustainability.
2) Mining companies can invest in and adopt Green Mining Technologies as part of their operational strategies to improve efficiency, reduce environmental footprint, and enhance productivity.
3) Stakeholders can benefit from integrated approaches that harmonize technological innovation with policy frameworks, fostering a balanced approach to sustainable mining practices.

Limitations and Future Research Directions

While the study provides valuable insights, it is not without limitations. The findings are based on a specific context and may not generalize universally. Future research could expand on this study by:

1) Conducting longitudinal studies to assess the long-term effects of Green Mining Technologies and Land Reclamation Policies on ecosystem dynamics and productivity.
2) Comparing the effectiveness of different policy frameworks and technological innovations across diverse mining regions.
3) Incorporating qualitative methods to capture stakeholder perspectives and socio-cultural impacts of sustainable mining practices.

CONCLUSION

In conclusion, this study provides robust empirical evidence supporting the effectiveness of Green Mining Technology and Land Reclamation Policy in promoting sustainable development within the mining sector. The statistical analyses confirm that greater adoption of Green Mining Technology and adherence to Land Reclamation Policy positively influence Ecosystem Stability and Mine Productivity. These findings highlight the critical role of technological innovation and regulatory frameworks in balancing economic growth with environmental conservation in mining regions like Kalimantan, Indonesia.

Moving forward, policymakers, mining companies, and environmental stakeholders can leverage these insights to formulate and implement strategies that integrate sustainable practices into mining operations. By prioritizing Green Mining Technologies and strengthening Land Reclamation Policies, stakeholders can achieve synergistic outcomes that foster ecological resilience and economic prosperity in mining communities. Future research should continue to explore the long-term impacts of these interventions and further refine strategies for sustainable resource management in diverse mining contexts worldwide.

REFERENCES

[1] S. Suryani, "Analisis Keterkaitan Antar Sektor dan Antar Provinsi dalam Perekonomian Kalimantan Tengah Tahun 2016 (Analisis IO dan IRIO)," *J. Ekon. Dan Stat. Indones.*, vol. 3, no. 1, pp. 1–14, 2023.

[2] M. P. Hanansyah, A. P. Rivani, H. Sanjaya, and L. M. Jaelani, "Development of Vegetation Changes Monitoring Application in Kalimantan Island (2000-2021) with MODIS Satellite Imagery using Streamlit Platform," in *2022 IEEE Asia-Pacific Conference on Geoscience, Electronics and Remote Sensing Technology (AGERS)*, IEEE, 2022, pp. 48–53.

[3] D. Al Vayed and E. P. Purnomo, "Challenges and opportunities: application of clean and affordable energy in the development of the national capital of the archipelago," *J. Pengelolaan Sumberd. Alam dan Lingkung. (Journal Nat. Resour. Environ. Manag.*, vol. 13, no. 1, pp. 102–113, 2023.

[4] Y. P. Adhi, I. G. S. Dewi, and B. E. Turisno, "Ecological Impacts and Socio-Legal Infrastructure as an Approach to Environmental Management in Ex-Mining Land Reclamation.," *Int. J. Sustain. Dev. Plan.*, vol. 17, no. 7, 2022.

[5] W. D. Sunderlin and I. A. P. Resosudarmo, *Laju dan penyebab deforestasi di Indonesia: penelaahan kerancuan dan penyelesaiannya*. Centre for International Forestry Research, 1997.

[6] P. A. Pambudi, S. W. Utomo, S. W. Soelarno, and N. D. Takarina, "Coal mining reclamation as an environmental recovery effort: a review," *J. Degrad. Min. Lands Manag.*, vol. 10, no. 4, pp. 4811–4821, 2023.

[7] M. F. Al Faruqi, F. N. Yusuf, H. Anwar, and A. B. Thamsi, "Reclamation Plan on Stone Land of The Ex-Nickel Mining at PT Vale Indonesia Tbk Central Pinnacle Condemnation," *J. Geol. Explor.*, vol. 2, no. 1, pp. 13–23, 2023.

[8] N. Listiyani, M. Y. Said, and A. Khalid, "Strengthening Reclamation Obligation through Mining Law Reform: Indonesian Experience," *Resources*, vol. 12, no. 5, p. 56, 2023.

[9] I. G. S. Dewi, Y. P. Adhi, A. B. Prasetyo, and M. Wiryani, "Environmentally Friendly Post-Mining Land Reclamation Policy for Manganese in Sabu Raijua, East Nusa Tenggara, Indonesia.," *Int. J. Sustain. Dev. Plan.*, vol. 18, no. 5, 2023.

[10] R. Damayanti and S. Handayani, "Rehabilitation plan for coal pit revegetation area East Kalimantan," in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing, 2023, p. 12016.

[11] D. Xu, X. Li, J. Chen, and J. Li, "Research progress of soil and vegetation restoration technology in open-pit coal mine: A review," *Agriculture*, vol. 13, no. 2, p. 226, 2023.

[12] N. Wang and Y. Luo, "Study on Ecological Restoration Technology of Mine Wasteland," *Sci. J. Technol.*, vol. 5, no. 2, pp. 20–24, 2023, doi: 10.54691/sjt.v5i2.3980.

[13] Y. Shao, Q. Xu, and X. Wei, "Progress of Mine Land Reclamation and Ecological Restoration Research Based on Bibliometric Analysis," *Sustainability*, vol. 15, no. 13, p. 10458, 2023.

[14] S. Bandyopadhyay and S. K. Maiti, "Steering restoration of coal mining degraded ecosystem to achieve sustainable development goal-13 (climate action): United Nations decade of ecosystem restoration (2021–2030)," *Environ. Sci. Pollut. Res.*, vol. 29, no. 59, pp. 88383–88409, 2022.

[15] H. Thamrin, A. T. R. Nursanthy, L. Ribeiro, and L. Afriani, "GOVERNMENT CONSISTENCY IN ENFORCEMENT OF REGULATIONS REGARDING MINERAL AND COAL MINING RELATED TO MINE RECLAMATION," *Awang Long Law Rev.*, vol. 5, no. 2, pp. 494–500, 2023.

[16] R. H. Islami, L. Fatah, K. Kissinger, and B. Badaruddin, "Penggunaan Parameter Vegetasi Dalam Menentukan Tingkat Keberhasilan Reklamasi," *EnviroScienteae*, vol. 19, no. 2, pp. 61–66, 2023.

[17] M. Onifade, K. O. Said, and A. P. Shivute, "Safe mining operations through technological advancement," *Process Saf. Environ. Prot.*, vol. 175, pp. 251–258, 2023.

[18] O. Asa'd and M. Levesque, "Digital technologies for energy efficiency and decarbonization in mining," *CIM J.*, vol. 15, no. 1, pp. 1–20, 2024.

[19] B. N. A. Aryee, H. Mtegha, and M. S. Ali, "Sustainable and responsible mining investment in developing economies," in *Sustainable and Responsible Investment in Developing Markets*, Edward Elgar Publishing, 2023, pp. 305–321.

[20] G. Dino, S. Mancini, M. Casale, and M. Lasagna, "Use and recovery of mining waste and tailings for sustainable management of works related to extractive activities," in *EGU General Assembly Conference Abstracts*, 2023, p. EGU-6013.

[21] B. A. Watts, V. C. Palmeira Zago, L. Gopakumar, K. Ghazaryan, and H. Movsesyan, "Uncharted risk measures for the management of sustainable mining," *Integr. Environ. Assess. Manag.*, vol. 19, no. 4, pp. 949–960, 2023.

[22] P. Amoah and G. Eweje, "Organisational drivers and sustainability implementation in the mining industry: A holistic theoretical framework," *Bus. Strateg. Environ.*, vol. 32, no. 8, pp. 5602–5614, 2023.