

ANALYSIS OF THE SUITABILITY OF DEVELOPING ECONOMICALLY VALUABLE AND SUSTAINABLE INTEGRATED AGRICULTURE IN THE RECLAMATION OF FORMER MINING LANDS

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Abstract

Intensive nickel mining activities in North Morowali Utara Regency have resulted in severe environmental degradation, including soil damage, biodiversity loss, and water pollution. This study aims to analyze the impact of sustainable integrated farming development as a reclamation strategy for former nickel mining land, and to evaluate the sustainability of this system from economic, ecological, and social perspectives. The research was conducted in Molores and Molino Villages using an exploratory qualitative approach, with data collected through interviews, field observations, focus group discussions (FGDs), and Multidimensional Scaling (MDS) analysis based on the Rappfish method. The findings indicate that the implementation of integrated farming combining agriculture, livestock, aquaculture, and organic waste processing can effectively restore soil fertility, increase household income, and enhance community resilience in food and energy. The sustainability index indicated a "moderately sustainable" status, with the highest score observed in the economic dimension. This system also reduces community dependency on the mining sector and promotes active participation in environmental conservation. Sustainable integrated farming has proven to be an effective, community-based reclamation solution and is highly replicable in other post-mining areas.

Keywords: Land Reclamation, Integrated Farming, Sustainability, Nickel Mining, North Morowali Utara

INTRODUCTION

The increase in nickel mining activities in North Morowali Regency, Central Sulawesi Province, has caused significant environmental damage, including deforestation, land degradation, water pollution, and loss of biodiversity. Although intensive nickel mining makes an important economic contribution, it has also resulted in adverse environmental impacts on ecosystems and local communities who depend on forests for their daily livelihoods (Brooks et al., 2019; Ministry of Environment and Forestry, 2022). Data indicate that around 30% of the total forest area in North Morowali Regency has been degraded due to these activities. This underscores the urgent need for forest restoration efforts to restore the ecological and social functions of damaged forests and ensure the sustainability of natural resources for future generations.

Reclaiming land in nickel mining areas requires a comprehensive and integrated approach. Restoration techniques such as reforestation, agroforestry, and hydrological function recovery can be effective in repairing degraded forest ecosystems, but their implementation in former nickel mining areas requires special adaptation to local conditions (Chazdon et al., 2016; Rodrigues et al., 2009). One promising approach is agroforestry, which combines tree planting with agricultural crops, providing dual benefits in ecosystem restoration and improving community welfare (Leakey, 2017). This approach aligns with Indonesian government policies emphasizing the importance of forest rehabilitation and reclamation in accordance with Government Regulation No. 76 of 2008 and Minister of Environment and Forestry Decree No. 70/MENLHK/SETJEN/KUM.1/12/2017.

However, challenges in implementing these policies often include a lack of coordination between central and regional governments, as well as funding issues that hinder effective forest restoration (CIFOR, 2020). On the ground, many restoration projects do not run optimally due to limited financial resources and a lack of active participation from local communities (Sudarmadi, 2020). Therefore, it is important to develop strategies that integrate various stakeholders including the government, mining companies, local communities, and non-governmental organizations to achieve sustainable restoration outcomes.

The nickel mining areas in North Morowali Regency hold significant potential for the utilization of abandoned post-mining land. Considering environmental carrying capacity, these lands can be reclaimed for sustainable integrated agriculture. Based on the spatial planning of North Morowali Regency, many mining areas have not yet been reclaimed and can be optimized into productive land with high economic value. The potential for developing agriculture, plantations, livestock, and agribusiness on these lands is considerable and could provide economic benefits to surrounding communities. The distribution map of mining land in North Morowali Regency is shown in Figure 1.

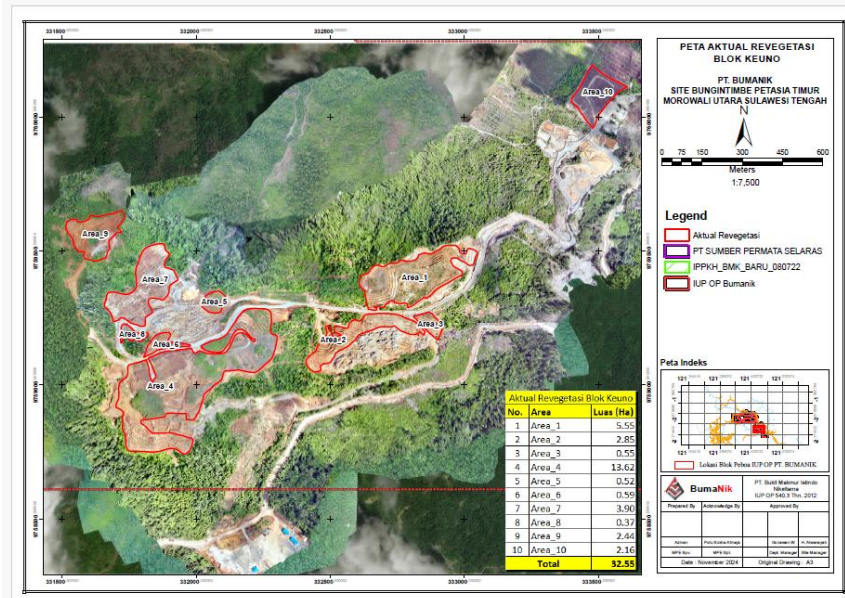


Figure 1.
Map of mining land distribution in North Morowali Regency

Rapid population growth and increasing food and energy needs in Indonesia also influence resource management. Population data show that the number of residents in North Morowali Regency has fluctuated from 2019 to 2024. In this context, integrated farming systems that combine agriculture, livestock, and fisheries with a zero-waste agriculture approach can be a solution to meet food needs while supporting environmental restoration (Minami, 1996; Russelle, 2007).

The average monthly per capita expenditure for various food groups in North Morowali Regency shows different trends between 2019 and 2021. For example, spending on grains decreased from IDR 83,900 in 2019 to IDR 77,370 in 2020, then increased again to IDR 81,336 in 2021. Meanwhile, spending on prepared food and beverages increased significantly from IDR 118,999 in 2019 to IDR 130,097 in 2021.

Table 1.
Average Monthly Per Capita Expenditure by Commodity

No	Food Groups	Average Expenditure (Rupiah)		
		2019	2020	2021
1	Grains	83900	77370	81336
2	Tubers	6803	6467	7717
3	Fish/Shrimp/Squid/Shellfish	73227	66730	74383
4	Meat	16059	15165	18792
5	Eggs and Milk	29410	27043	30261
6	Vegetables	41059	39369	48669
7	Nuts	10462	7918	8985
8	Fruits	28296	42189	44899
9	Coconut Oil	17070	13782	16080

No	Food Groups	Average Expenditure (Rupiah)		
		2019	2020	2021
10	Drink Ingredients	23748	18910	24385
11	Spices	12824	13617	13679
12	Other Consumables	10927	9867	10558
13	Prepared Foods and Beverages	118999	113874	130097
14	Cigarettes	71034	81315	97615
Total		543818	533616	607455

Source: North Morowali in Figures

The importance of integrated agriculture in the restoration of former nickel mining land is driven by the need to increase land productivity while reducing negative environmental impacts. This approach not only aims to restore ecosystem functions but also to increase economic value and improve local community welfare. Considering the ecological, social, and economic aspects of restoration, this study aims to analyze the impact of developing sustainable integrated agriculture in the reclamation of former nickel mining land in North Morowali Regency. This research will provide insights into the effectiveness of agroforestry and integrated farming systems in improving environmental quality and community welfare, as well as offer recommendations for better restoration policies and practices in the future

REVIEW OF LITERATURE

Impact of Nickel Mining on Forests

Nickel mining significantly impacts forest ecosystems in physical, ecological, and socio-economic aspects. These activities drastically alter landscapes and lead to various environmental consequences that affect the sustainability of forest ecosystem functions.

Reclamation of Former Mining Land

According to Barton et al. (2007), reclamation of former mining land involves actions to improve the physical, chemical, and biological conditions of soil degraded by mining activities. The main objective of reclamation is to return the land to a condition that allows it to be reused for productive activities such as agriculture, forestry, or settlements.

Integrated Farming Systems

Agriculture is the process of utilizing solar energy to produce plant and animal products with economic value. In Indonesia, the Green Revolution in the 1960s introduced the use of chemical fertilizers, high-yield varieties, and pesticides, which significantly increased food production. In this context, modern organic farming emerged as a solution using technology-based approaches and natural materials to reduce the negative impacts of synthetic chemicals (Nurhidayati et al., 2008).

Sustainable Development

The concept of sustainable development was first defined by the World Commission on Environment and Development (WCED) in the Brundtland Report (1987) as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development integrates economic, ecological, and social aspects in designing and implementing development strategies (Munasinghe, 1993).

Integrated Farming Systems in the Reclamation of Former Mining Land

In the context of reclaiming former nickel mining land in North Morowali Regency, implementing sustainable integrated farming systems can be an effective solution. Former mining land often experiences severe damage, such as reduced soil fertility and environmental pollution. Therefore, reclamation requires an approach that considers improving soil quality, increasing productivity, and ensuring sustainable environmental management (Wijayanto, 2018)

RESEARCH METHOD

This study employs an exploratory qualitative approach aimed at gathering in-depth information regarding the impact of integrated farming on former mining areas in North Morowali Regency. This approach was chosen because it provides flexibility in understanding complex and dynamic phenomena from the perspectives of stakeholders.

The research focused on several villages in North Morowali Regency, Central Sulawesi Province, Indonesia, that are directly affected by mining activities, in order to obtain a representative picture of the ecosystem conditions and the integrated farming efforts undertaken. The villages included in the research location are Molores and Molino in East Petasia District. The study was conducted over a period of six months, from January to June 2024. This timeframe covered preparation activities, data collection, data analysis, and the drafting of the research report.

The study population comprises all stakeholders involved in mining activities and sustainable integrated farming in North Morowali Regency. These stakeholders include local communities, mine workers, local government officials, and non-governmental organizations engaged in integrated farming programs. The research sample was selected using purposive sampling to identify key informants with knowledge and experience related to the research topic. The sample size was as follows:

1. Local households affected by mining activities, to obtain direct perspectives from impacted communities 50 households.
2. Mine workers, to understand their views on the environmental and social impacts of mining activities and their involvement in integrated farming efforts — 20 workers.
3. Local government officials, to obtain information on policies and regulations supporting sustainable integrated farming 5 officials.
4. Representatives from environmental non-governmental organizations, to gain insights into their initiatives and integrated farming programs 5 representatives.

RESULTS AND DISCUSSION

Respondent Profile

A total of 80 respondents were involved in the field study through interviews, observations, and focus group discussions. Respondent profiles were categorized as shown in Table 2.

Table 2.
Respondent Identity
Respondent Identity

Age	Percent (%)
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18–30 Years	32,5
31–45 Years	50,0
>45 Years	17,5
Work	Amount (%)
Farmers	38
Miners	25
Local Trades	15
Others (Teachers, Civil Servants)	22
Last Education	Percentage
Elementary–Middle School	35%
High School/Vocational School	45%
Bachelor's Degree or Above	20%

Most respondents in Table 2 were within the productive age range (31–45 years) and worked as farmers, mine laborers, and local traders, indicating their direct involvement in the agricultural sector and their exposure to land degradation impacts. The majority had low to medium levels of education (elementary to high school/vocational), indicating limited access to higher education and the need for practical, easy-to-understand technical training. Such training should cover simple agricultural technologies, harvest management, and environmentally based integrated farming techniques, using participatory approaches and local languages. These interventions are expected to improve community capacity, production efficiency, and independence in managing agricultural resources sustainably.

Impact of Sustainable Integrated Farming Development on the Reclamation of Former Nickel Mining Land in North Morowali Regency

Ecological Impacts of the Integrated Farming System

Ecologically, the implementation of the integrated farming system has shown significant effects in improving environmental quality, particularly in post-mining areas. One of the main issues in former mining lands is reduced water absorption capacity and loss of soil nutrients. The integrated system provides solutions through increasing soil organic matter, directly enhancing water-holding capacity and land fertility.

Improved availability of irrigation water became one of the most prominent ecological indicators. About 76% of farmers reported that integrated water management systems, including reservoirs, were able to meet agricultural water needs for more than eight months a year. This contrasts sharply with pre-program conditions, when irrigation was only available seasonally.

The use of agricultural and livestock waste as organic fertilizer and animal feed also contributed to reducing the use of pesticides and chemical fertilizers. Laboratory tests showed an increase in nitrogen (N) content and stabilization of soil pH toward neutral conditions, both indicators of fertile soil. In addition, practices such as providing probiotics and vitamins to livestock carried out by around 80% of farmers indicated growing awareness of animal health and livestock production efficiency in a sustainable system.

In this sense, integrated farming is not only a technical approach but also ecologically transformative, capable of restoring local ecosystems, increasing biodiversity, and reducing carbon footprints through low-emission farming systems.

Post-mining lands that were previously unproductive have begun to show signs of recovery. Observations indicated an increase in soil pH from acidic conditions (around 4.5)

to more neutral levels (around 6.1) within less than a year after the adoption of integrated farming systems. Organic matter content increased significantly through the use of manure, compost, and biourine from livestock waste. Tree planting and perennial crops also helped stabilize soil structure and reduce erosion.

Adoption of low-emission technologies such as biogas not only reduced waste but also provided alternative energy for communities that previously had limited access to clean energy sources. Organic waste from livestock and harvests was reused in a circular farming system, in line with the principles of zero-waste agriculture.

In short, sustainable integrated farming has become an efficient, inclusive, and long-term-oriented reclamation approach. It not only improves soil quality and increases the economic value of land but also builds social and environmental resilience for communities around mining areas. This approach is therefore highly replicable in other former mining areas in Indonesia, with contextual adjustments to local geographic and social conditions.

Social and Economic Impacts

From a socio-economic perspective, integrated farming systems have made a significant contribution to improving farmers' welfare. This approach creates household farming systems that are resilient and adaptive to local and global economic dynamics. Farm business diversification is key to achieving more stable and sustainable incomes.

Survey results showed that over 55% of farmers experienced income increases that placed them above the local minimum wage. This increase was largely due to additional activities such as catfish farming in tarpaulin ponds, oyster mushroom cultivation, and the production and sale of organic fertilizers and biourine. Besides serving as new income sources, these activities also created local job opportunities, including for women and young farmers.

The use of appropriate technology such as biogas installations from livestock waste also significantly reduced household energy expenses. Most households reported savings on LPG costs and time efficiency in cooking activities due to the availability of stable and low-cost alternative energy.

This demonstrates that integrated farming not only provides ecological benefits but also serves as an instrument for rural economic empowerment. In an inclusive development framework, the system opens opportunities for small farmers to independently and sustainably improve their livelihoods.

Economically, integrated farming systems have created new income sources for communities previously highly dependent on mining jobs. Farm diversification such as catfish farming, poultry and cattle rearing, oyster mushroom cultivation, and biogas production has increased the economic value of land and reduced dependency on external resources. Several households are now able to sell surplus production—such as eggs, catfish, and mushrooms both in local and inter-village markets.

Socially, sustainable integrated farming has encouraged active community participation in environmental restoration processes. Training programs, technical assistance, and the formation of farmer groups have strengthened local capacity in managing post-mining lands. These activities have also fostered collective awareness of the importance of environmental preservation and sustainable resource management.

Table 3.
Economic Impact of Integrated Farming on Households

No	Type of Business Activity	Before (IDR/month)	After (IDR/month)	Remarks
1	Livestock Income	IDR 0	IDR 1,200,000	From cattle and chickens
2	Catfish Farming Income	IDR 0	IDR 900,000	Harvest of 1–1.4 quintals/month
3	Oyster Mushroom Sales	IDR 0	IDR 800,000	Daily routine harvest
4	Energy Savings (Biogas)	IDR 0	IDR 190,000	LPG efficiency
5	Compost/Biourine Sales	IDR 0	IDR 121,000	Organic fertilizer from livestock waste

Source: Interview Results with Households & Business Estimates, 2024

This table illustrates the direct impact of implementing an integrated farming system on household income and cost savings for communities in Molores and Molino Villages.

- a. Before implementation, most households did not have a fixed income from the agricultural sector due to limited land productivity and dependence on mining
- b. After implementation, there was an increase in income from several business units:
 1. Cattle and poultry farming generated an average additional income of IDR 1,200,000/month.
 2. Catfish farming provided an additional income of around IDR 900,000/month per household, thanks to regular harvests and stable market demand.
 3. White oyster mushrooms, harvested daily, contributed up to IDR 800,000/month.
 4. Energy savings from household biogas replacing LPG reached about IDR 190,000/month.
 5. Sales of compost and biourine provided additional income of up to IDR 121,000/month.

Overall, this table shows that the integrated farming system can open new, stable, and sustainable sources of income, while also reducing household dependence on mining activities or non-agricultural jobs.

Daily Per Capita Food and Energy Needs of Each Family in Villages Around the Nickel Mining Area in North Morowali Regency

Reclamation activities on former nickel mining land through the development of sustainable integrated farming in Molores and Molino Villages are aimed not only at improving ecological conditions but also at supporting local food and energy security.

As part of the feasibility analysis of this system, calculations were made regarding household food consumption needs as well as the local production capacity per month to assess the level of community food and energy self-sufficiency.

Food needs were calculated based on the average household consumption of several staple commodities such as rice, eggs, fish (catfish/pangasius), meat, vegetables, fruits, and processed products such as cooking oil and local beverages. Meanwhile, harvest yields were

obtained from estimated average output of integrated farming activities already running in the area.

The Food Self-Sufficiency Level (KP) for each commodity was calculated by comparing the monthly harvest with the average monthly consumption of all households in each village cluster (TK) in the study area. The higher the KP value (≥ 1), the higher the level of self-sufficiency for that commodity.

Below is the table analyzing food self-sufficiency based on the main commodities consumed and produced in Molores and Molino Villages:

Table 4.
Food Self-Sufficiency of Commodities in Molores and Molino Villages

No	Commodity Description	Monthly Harvest (kg/liter/unit)	Monthly Consumption per TK (kg/liter/unit)	Commodity Food Self-Sufficiency (CFSS = Harvest/Consumption)	CFSS (%)
1	Rice	2,000 kg	2,500 kg	0.8	80%
2	Eggs	4,800 units	3,000 units	1.6	160%
3	Catfish/Pangasius	1,500 kg	1,000 kg	1.5	150%
4	Chili	200 kg	250 kg	0.8	80%
5	Vegetables (mixed)	3,000 kg	2,700 kg	1.11	111%
6	Fruits	1,000 kg	1,500 kg	0.67	67%
7	Cooking Oil	150 liters	200 liters	0.75	75%
8	Beef	250 kg	300 kg	0.83	83%
9	Chicken Meat	800 kg	700 kg	1.14	114%
10	Mushrooms (White Oyster)	600 kg	400 kg	1.5	150%
11	Beverages (local/processed)	1,000 liters	950 liters	1.05	105%

Source: Interview and field observation results in Molores and Molino Villages, 2024.

Notes:

- a. Monthly Harvest is the average yield from residents' integrated farming units per month.
- b. Monthly Consumption per TK is the total needs of all households (village cluster) in the study area.
- c. KP (Food Self-Sufficiency) = Harvest / Consumption.
 1. $KP > 1$ means surplus and self-sufficient.
 2. $KP < 1$ means not yet self-sufficient (requires external supply).

From Table 4, it can be seen that most of the food commodities needed by the people of Molores and Molino Villages can already be met independently, and some even show production surpluses. This can be seen from the KP values greater than 1, including:

- a. Eggs (KP: 1.60) and white oyster mushrooms (KP: 1.50) show that production far exceeds consumption, thus not only meeting local needs but also having the potential for sale outside the village.

- b. Catfish/pangasius (KP: 1.50) and chicken meat (KP: 1.14) are also surplus commodities, reflecting the success of integrating fish farming and poultry farming in the integrated farming system.
- c. Vegetables (KP: 1.11) and local beverages (KP: 1.05) also contribute positively to achieving local food security.

However, there are several strategic commodities that are still in deficit and not yet self-sufficient, such as:

- a. Rice (KP: 0.80) and chili (KP: 0.80), indicating that local production has not yet been able to fully meet community needs.
- b. Fruits (KP: 0.67) and cooking oil (KP: 0.75), which still rely on supplies from outside the village.
- c. Beef (KP: 0.83) also shows needs that have not been fully met, even though cattle farming has already begun.

This condition indicates that further intervention is needed to increase the production of several commodities, especially rice, fruits, and vegetable oil, either through expansion of planting areas, increased production capacity, or strengthening of farmer institutions and distribution of production inputs.

Considering that the average KP value is above 1 for most commodities, it can be concluded that Molores and Molino Villages are already on a positive path toward local-based food self-sufficiency. The integrated farming system has proven to be an appropriate approach to supporting food security while restoring the ecological function of former mining land.

Integrated Agricultural Sustainability Index

Table 5 shows that the average sustainability index value for the integrated agricultural development plan on post-mining land is 20.55, with a status category of unsustainable. The sustainability index values with low scores from the three assessed aspects are the ecological aspect (15.31), technology and infrastructure (16.33), and the economic aspect (30.50).

Table 5.
Sustainability Index

No	Aspects	Validation Status%
1	Ecology	15,31
2	Economic	32,50
3	Technology and infrastructure	16,63
average		20,65
Status: Unsustainable		

Random Iteration Data Validation

According to the random iteration values, all aspects show a very small error rate. This also indicates that the level of respondents' consistency in their answers is very good because it is still below 10% (Firmansyah, 2022). The values from the random iteration analysis are presented in Table 6.

Table 6.
Random Iteration Validation Values

No	Aspects	Validation Status%
1	Ecology	0,31
2	Economic	4,00
3	Technology and infrastructure	9,37
Validation Status		4,56

Leverage Factor

The leverage factor is a driving factor that describes the elements that have the most influence on changes in status, whether in individual aspects or in the overall status. The leverage factor values are taken from the highest values obtained from the sum of maximum sensitivity plus actual sensitivity. The following are the factors estimated to influence the integrated agricultural development plan on post-mining land. The results of the leverage factor analysis are presented below.

Ecological Dimension

Leverage analysis is carried out to identify sensitive attributes that contribute to the sustainability index value of integrated agricultural development in each dimension. It is known that out of 13 analyzed attributes, there are 8 dominant or sensitive attributes influencing agricultural development, namely:

1. Household food supply from integrated farming,
2. Soil fertility,
3. Use of organic materials and utilization of agricultural waste,
4. Types of livestock feed,
5. Quantity of livestock waste used for biogas,
6. Quantity of agricultural production,
7. Seed procurement,
8. Distance between livestock farming location and residential areas.

Economic Dimension

Based on the results of leverage analysis, from the analyzed attributes, there are 4 sensitive attributes influencing the sustainability index value of agricultural development in the economic dimension, namely:

1. Profit from horticultural farming,
2. Price fluctuations,
3. Market accessibility, and
4. Average farmers' income relative to the regional minimum wage (UMR).

Therefore, in order for the sustainability of agricultural development in the economic dimension to be achieved or further improved, the four attributes or variables above need to be given proper attention.

Technology and Infrastructure Dimension

The results of leverage analysis show that out of 8 analyzed attributes, there are 4 sensitive attributes influencing the sustainability index value of agricultural development in the social dimension, namely: (1) Feed technology, (2) Availability of agricultural facilities and infrastructure, (3) Standardization of agricultural production quality, and (4) Availability of waste processing institutions.

CONCLUSION

Performance expectancy, effort expectancy, and social influence significantly impact users' behavioral intention to adopt e-procurement; this suggests that users are more inclined to adopt the system when they perceive it as improving their performance, being user-friendly, and having support from their social surroundings. Performance expectancy and social influence also indirectly affect the use of e-procurement through behavioral intention. These findings highlight the role of behavioral intention as a critical bridge connecting users' beliefs in the system's benefits and social support to their final decision to adopt the technology. However, effort expectancy does not significantly affect the use of e-procurement through behavioral intention. This can be attributed to experienced users who are less influenced by ease-of-use factors. Additionally, facilitating conditions, such as infrastructure, technical support, and adequate resources, directly and significantly impact the use of e-procurement; this underscores that the availability of supportive conditions enhances users' comfort, confidence, and motivation in effectively adopting e-procurement. Finally, this study confirms that users' firm intention to utilize the system actively is an essential component driving the level of e-procurement usage in Ogan Ilir Regency. Positive behavioral intention reflects users' commitment to the system's benefits and ease of use, ultimately supporting the successful implementation of this technology. Based on these findings, e-procurement managers in Ogan Ilir Regency should focus on the following strategies: 1) enhancing perceptions of system benefits through promotional efforts that emphasize the efficiency and effectiveness achieved by e-procurement, 2) ensuring ease of use by providing a user-friendly interface and effective training programs, 3) building strong social support by engaging organizational leaders and fostering workplace socialization about the importance of e-procurement, and 4) strengthening infrastructure and ensuring adequate resources to support accessibility and ease of system use. Implementing these strategies can further improve the adoption rate and effectiveness of e-procurement in the Ogan Ilir Regency.

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